THE BELL TOLLS FOR HYDROCARBONS: WHAT'S NEXT?

Hon. Richard D. Cudahy[*]

Synposis: There are two major threats to the dominant, hydrocarbon-fueled energy regime in the world. First, there is the arguable peak in production and subsequent depletion of oil, the leading hydrocarbon and the world's leading fuel. Second, there is global warming, which is significantly furthered by the combustion of oil and other hydrocarbons. These developments give rise to the same problem – a severe limitation on oil and other fossil fuels as a source of energy.

Many geologists are persuaded that oil production is currently at its peak and will soon sharply decline, but others, particularly economists, disagree. However, Peak Oil dictates the more urgent course and prudence requires that we pay heed. On the other hand, there is little scientific controversy about the anthropogenic sources of global warming and its restrictive impact on hydrocarbon use.

Responses to severe limitations on hydrocarbon use as fuel involve efforts to expand supply through development of substitute fuels and suppression of demand through demand response mechanisms, and otherwise, and through modifications to society and the economy. The supply approach would seek to maintain the existing energy base of civilization and its progressive development. Demand modifications might involve changes in society – even, in fanciful speculation, a slowing of "progress" or regression to a simpler era. Again and even more fancifully, history, based on the availability of energy, might tend to become cyclical rather than progressive in terms of development. There would be some differences between a decline in hydrocarbon availability based on the depletion of oil in contrast to one based on concern about global warming. Depletion of oil leaves other hydrocarbons available while global warming demands action on all fronts.

*Senior Circuit Judge, United States Court of Appeals for the Seventh Circuit. Judge Cudahy has taught Energy Law at George Washington University Law School and DePaul University College of Law and has written extensively on the subject. Judge Cudahy wishes to express his appreciation to John Roberts, Jr. and David Finkelstein, his law clerks, for all their assistance in preparing this Article.

I. INTRODUCTION

The most crucial issue of our age is the future of energy in the economy and in society. There are two major branches to this question: (1) Is the supply of oil (the most widely used form of fossil fuels – hydrocarbons) peaking and headed for exhaustion at such a rate that radical and immediate conservation and substitution of alternative fuels is required, and (2) is global warming, a severely harmful environmental result of the combustion of fossil fuels, so much of a threat to the world as we know it, that other sources of energy are urgently required? The first of these problems, the peaking of the oil supply, is predicted by geologists following the thinking of M. King Hubbert, a Shell scientist, who correctly forecast the peaking of oil production in the lower forty-eight states in 1970. Using the same methodology (fundamentally rooted in the concept that the largest pools of oil are the first discovered), geologists and geophysicists (or at least those who have rushed into print) have predicted a peaking of world oil production now or in the immediate future.[1] A peak of production, of course, does not mean that production will be immediately exhausted but at that point production will start to decline and will never again exceed the rate reached at its peak. Economists and other experts are far from unanimous in support of this view of the geologists.[2] Global warming similarly puts a ceiling on the use of fossil fuels, but, of course, this limitation applies to all hydrocarbons (including coal)[3] while the threat of imminent exhaustion affects only oil. In neither case is there necessarily a total cessation of hydrocarbon use, but in both cases in somewhat different ways the limitations of use is severe, if not drastic.

II. THE ROLE OF HYDROCARBONS AS A SOURCE OF ENERGY

A. Differing Opinion About Depletion and Global Warming

The imminent peaking of oil production in the world is, as indicated, an event not anticipated by all the experts, but seems to be primarily proclaimed by geologists and geophysicists following in the tradition of M. King Hubbert.[4] Many economists, and others (including Cambridge Energy Research Associates (CERA) and its Chairman, Daniel Yergin), take a more hopeful view of the

1. *See, e.g.*, RICHARD HEINBERG, POWERDOWN: OPTIONS AND ACTIONS FOR A POST-CARBON WORLD 23-24 (2004); MARK JACCARD, SUSTAINABLE FOSSIL FUELS: THE UNUSUAL SUSPECT IN THE QUEST FOR CLEAN AND ENDURING ENERGY 154-159 (2005); PAUL ROBERTS, THE END OF OIL: ON THE EDGE OF A PERILOUS WORLD 44-67 (2004).

2. JACCARD, *supra* note 1, at 155; ROBERTS, *supra* note 1, at 56.

3. JEFF GOODELL, BIG COAL: THE DIRTY SECRET BEHIND AMERICA'S ENERGY FUTURE 119-146 (2006).

4. *See, e.g.*, KENNETH S. DEFFEYES, BEYOND OIL: THE VIEW FROM HUBBERT'S PEAK 3-4, 35-51 (2005); JACCARD, *supra* note 1, at 154-156. MERRIAM-WEBSTER'S COLLEGIATE DICTIONARY 412 (11th ed. 2006).

adequacy of petroleum resources. But certainly, this is a crucial issue. For it is fundamental that the development of civilization rests upon the availability of energy to perform physical and mental tasks. Energy is defined as the ability to do work and it vastly enhances the capability of human beings to accomplish physical and mental tasks.[5] Energy is, of course, employed in huge quantities in manufacturing, transportation, construction, and a vast congeries of other human activities. Without the ability to harness major sources of energy, an industrial economy could not exist. It is significant that the invention of the steam engine is frequently taken as the opening event of the Industrial Revolution.[6] Current technology may have moved us from an "industrial" phase to a "post-industrial" one – a phase characterized by services, rather than goods, as the principal subjects of commerce and by information as the major concern of technology, exemplified by the computer. But computers require energy in the form of electricity, and energy is crucial whether the era is called "industrial" or "post-industrial."[7] A major source of energy in the modern economy is hydrocarbon fuels, such as coal, oil, and natural gas, and, at present, the most important of these is oil.[8]

The focus of this Article will be primarily on the depletion of crude oil and other hydrocarbon supplies, and, as indicated, on global warming, which acts as a limitation on the combustion of hydrocarbon fuels. The combustion of hydrocarbons produces unacceptable climate change and, hence, combustion of these fuels to produce energy must be eliminated or severely reduced, resulting in very much the same problems that follow from an exhaustion of the oil supply.[9] The subject of depletion and eventual exhaustion of the oil supply is a fundamental question that has recurred often, in some form, throughout the industrial era amid concern, for example, that crude oil supplies were running out with, of course, profound anticipated effects on the economy. It is a simpler, and more easily, understood phenomenon than the complexities of global warming even though, in the end, the two developments may affect the economy with equal severity and in very much the same way.[10] But, the simple question – are we running out of oil – is easily understood and has from time to time filled humanity with dread.

As I have indicated, the question, "Are we running out of oil?" has been asked many times in history and usually has led to the conclusion that there was enough oil yet to be discovered to provide for the needs of the world for the indefinite future. Thus, there has been a cycle of doubt and reassurance going

5. MERRIAM-WEBSTER'S COLLEGIATE DICTIONARY 412 (11th ed. 2006).

6. DAVID GOODSTEIN, OUT OF GAS: THE END OF THE AGE OF OIL 79-98 (2004); ROBERTS, *supra* note 1, at 21-31.

7. Electricity is predominantly derived from coal, water power, natural gas, and nuclear power. ROBERTS, *supra* note 1, at 175-177, 221, 266.

8. Of course, oil is generally required for most transportation uses but natural gas, apparently in more abundant supply, may be substituted and coal liquefied for these purposes. Gas and oil are also necessary for plastics manufacture and for other petrochemicals. ROBERTS, *supra* note 1, at 35-36, 169, 180; GOODELL, *supra* note 3, at 205.

9. JEREMY LEGGETT, THE EMPTY TANK: OIL, GAS, HOT AIR, AND THE COMING GLOBAL FINANCIAL CATASTROPHE 91 (2005).

10. *Id*.

back for many decades as one oil scare succeeded another, but in the end there was confidence that we were not running out of oil after all.[11] But today may be different. There is reason to believe – both at the micro and macro level – that this time we can really see the end of petroleum as we have known it and political unrest in several top oil-producing centers adds a dimension to the concern.[12]

B. Geologists Fear Oil Depletion

It is particularly interesting that the oil depletion question has elicited a different answer from the geologists than it has from the economists. The geologists have been much more prone than the economists to foresee in the relatively short term exhaustion of oil as a resource and a need to turn to substitutes. The leading figure among the geologists and geophysicists who have explored the sufficiency of the oil supply was the late M. King Hubbert, who worked at the Shell Research Laboratory in Houston. In the 1950s Hubbert, after making elaborate calculations, forecast that in about 1970 there would be a peak in oil production in the lower forty-eight states of the United States and that, thereafter, the production of oil there would decline rapidly.[13] Thus, oil production graphed against time would take the shape of a bell-shaped curve. This prediction was greeted with skepticism, but doubts dissipated when 1970 rolled around and, lo and behold, oil production peaked as forecast. Not surprisingly, Hubbert's methods have now been applied on a global basis, leading to predictions of a world peak in oil production for the first or second decade of the twenty-first century.[14] Of course, amid these calculations of a peak in oil production, the rate of usage of oil has continued to escalate due to rising consumption in the developing world – primarily in China and India.[15] This escalating usage contributes to the exhaustion of supply, and these trends may account for the present sharp rise in price.

The Hubbert-based calculations of a global oil production peak find apparent micro support in observations and speculation involving the fantastically abundant oilfields of Saudi Arabia. These fields, including the huge Ghawar field, were discovered in the 1950s and 1960s and have been immensely fruitful ever since, but are now producing only with the stimulus of extraordinary amounts of water injection. These fields have always been looked to as the ultimate global reserves, but there is now suspicion that they may not be up to

11. JACCARD, *supra* note 1, at 154-159.

12. *See, e.g.*, Michael Klare, *End of the Petroleum Age?*, FOREIGN POLICY IN FOCUS (2008), http://www.fpif.org/fpiftxt/5326.

13. KENNETH S. DEFFEYES, HUBBERT'S PEAK: THE IMPENDING WORLD OIL SHORTAGE 133-33-149 (Princeton University Press) (2003).

14. DEFFEYES, BEYOND OIL , *supra* note 4, at 35-51. *Cf.* JACCARD, *supra* note 1, at 155. A similar peaking of natural gas production is forecast later. *See, e.g.*, JULIAN DARLEY, HIGH NOON FOR NATURAL GAS: THE NEW ENERGY CRISIS 83 (Chelsea Green) (2004); VACLAV SMIL, ENERGY AT THE CROSSROADS: GLOBAL PERSPECTIVES AND UNCERTAINTIES 217-18 (MIT Press) (2005).

15. Jad Mouwad & Michael M. Grynbaum, *Economic Fears Slice Oil Prices For Second Day*, N.Y. TIMES, July 17, 2008, at A1.

the task of meeting world demand, which, of course, continues to grow.[16] The tendencies toward depletion may also be affecting some other large oil producers of last resort, including Russia (and former Soviet states, particularly those surrounding the Caspian Sea)[17] and Iran. Again, however, these intimations of inadequacy of the classic reserve fields are distinctly contrary to conventional thinking on the subject. Specifically, the supposed inadequacies of the Saudi fields are based in part on the analysis of Matthew R. Simmons, an investment banker, in his book, *Twilight in the Desert*, published in 2005.[18] Simmons's conclusions, however, may be inconsistent with the recent decision of the Saudi government to increase production by 500,000 barrels per day.[19] According to news reports, the Saudis are completing a huge investment program to bring their total production capacity to 12.5 million barrels per day.[20] This goal may be incompatible with Simmons's analysis, which essentially expresses skepticism about their capacity to maintain indefinitely their present claimed capacity of 11,000,000 barrels per day.

The Saudis have also recently convened a meeting devoted to energy supply and demand, bringing together a large number of producing and consuming nations, including the United States, Russia, Britain, China, India, and Japan. The objective was to achieve stable oil prices that the consuming nations can live with.[21] The Saudis, of course, fear that higher and higher oil prices will drive consuming nations to develop oil substitutes and to abandon an oil economy. These indications and counter-indications about the adequacy of Saudi and other reserves of last resort are difficult to resolve although in one light they seem to lend some support to the Hubbert approach.

C. Views of Economists and Prospects of Technology

Hubbert's calculations, and the analysis of geologists since, have been for the most part confined to what has been described as "conventional" oil: that is, oil capable of being recovered with normal methods and without extraordinary expense. It is to be contrasted with "heavy oil" found in the Athabasca region of Northern Alberta and the tar sands of the Orinoco Basin in Venezuela. These sources of oil must be processed at heavy expense in money and in energy to be converted to fuels suitable for use.[22] However, the relatively narrow specification of oil used by geologists in forecasting its limited longevity is to be

16. *See, e.g.*, MATTHEW R. SIMMONS, TWILIGHT IN THE DESERT: THE COMING SAUDI OIL SHOCK AND THE WORLD ECONOMY 151-230 (John Wiley & Sons Canada) (2006).

17. STEVE LEVINE, THE OIL AND THE GLORY: THE PURSUIT OF EMPIRE AND FORTUNE ON THE CASPIAN SEA 324-26 (Random House) (2007); SIMMONS, *supra* note 16, at 304-307.

18. SIMMONS, *supra* note 16, at 151-230.

19. *Id*.

20. Robert F. Worth, *Saudi Oil Project Brings Skepticism to the Surface*, N.Y. TIMES, July 1, 2008, at A8; Michael Klare, *supra* note 12.

21. Worth, *supra* note 20, at A8.

22. *See, e.g.*, C.J. CAMPBELL, OIL CRISIS 217-225 (Multi-Science Publishing) (2005); Jaccard, *supra* note 1, at 154-55; JEREMY RIFKIN, THE HYDROGEN ECONOMY: THE CREATION OF THE WORLDWIDE ENERGY WEB AND THE REDISTRIBUTION OF POWER ON EARTH 26-31 (J.P. Tarcher/Putnam) (2002); Government of Alberta, Canada, Prepared Testimony Before the Subcommittee on Energy and Air Quality, U.S. House of Representatives, 12/7/2005.

contrasted with the approach followed by many economists. In estimating the longevity of the oil supply, economists would be inclined to follow a much broader and more functional approach than their geological fellows.

The analysis of the economists would also be inclined to rely more heavily on price as a factor affecting supply and demand. As oil reserves declined, the price of oil would tend to rise making it more economic to recover oil by expensive methods and in more costly locales – for example, in the Arctic and in the deep ocean. It would also become more economic to find substitutes (like hydrogen) for oil. In addition, a higher price would tend to suppress demand. Economic analysis would tend to rely on the proposition that as demand for substitutes became more urgent, technology could be counted on to provide adequate substitutes. All that is needed for technology to meet the need for a substitute is the expenditure of enough money and the dedication of enough time – as in the development of the atomic bomb.[23] This assumption about technology is one that has been confirmed time and again since the early days of the Industrial Revolution, but it is an act of faith nonetheless. There is no logical imperative that guarantees that technology can be counted on to fill a need whenever one is created. It seems somehow irreverent to examine critically this article of faith in the modern scheme of things. Technology is the modern analog of God's grace–always available to answer from its overflowing bounty every demand of suffering humanity. One cannot question the depth of God's grace; so how can one question the adequacy of technology to meet every need? And, this is the sort of faith that assumes that there are completely adequate substitutes for oil, that has served us so well for centuries.

It is interesting that Hubbert-oriented petroleum geologists are skeptical of economic analysis as applied to the longevity of the oil supply. Colin Campbell, a leader in the geological community and a firm believer in a limited future for oil resources, has a chapter entitled, "Economists Never Get It Right" in his book, *Oil Crisis*.[24] Campbell describes what he regards as the mistaken approach of economists as follows:

> Hotelling in 1930 wrote a classic paper on the economics of depleting a resource. He concluded that there was no real charge attributable to the resource itself, suggesting that it should be essentially priced at the discount rate. He recognized that it was a finite resource, but thought it would be subject to a natural substitution if it began to fall into short supply. Thus, firewood was naturally superseded by coal, coal by oil, and oil by gas in a well-ordered progression under understood economic principles. It was not really a finite resource, but simply finite at a certain price.[25]

Campbell rejects this thinking as apparently do most petroleum geologists.

However, Congressional hearings have disclosed a variety of views of the Hubbert-related oil production peak by prestigious oil scholars. Thus, the Cambridge Energy Research Associates (CERA) (headed by Daniel Yergin) rejects the peak theory in favor of an extended "undulating plateau" in oil

23. JACCARD, *supra* note 1, at 155.

24. CAMPBELL, *supra* note 22, at ch.10.

25. *Id*. at 229.

production based in part on a recalculation of reserves,[26] while Robert Hirsch, whose research group conducted a study of the impacts of oil production peaking recommended a "mitigation crash program" to cushion the effects of peaking.[27] The analysis of the Yergin group defines "crude oil" much more broadly (including, not only conventional oil, but natural gas liquids, heavy oils, and other unconventionals) than the Hubbert approach and is really not entirely comparable in several respects. The methodology of the CERA is different in that it examines prospects field by field rather than adopting a more cumulative approach. The CERA, although it firmly rejects the "crisis" outlook of the "peakers," does seem to expect something resembling a peak a number of decades hence.[28] The National Petroleum Council (NPC), an advisory group to the Secretary of Energy, sees conventional oil production cresting around 2015 (with some forecasters predicting as late as 2030).[29] But, the NPC, weighted toward the industry and the government, may be suspected of Panglossian leanings. In view of the potentially dire consequences of failing to anticipate a supply downturn, one must accept Peak Oil as a working hypothesis while respecting the competing analyses that have been espoused by others. These alternative views do seem to rely ultimately upon the substitution for oil described by Campbell as the mechanism for mitigating the decline of oil.

The reality is that most of the fuel substitution accomplished during the Industrial era has been of one hydrocarbon for another – like the successors to coal mentioned by Campbell.[30] Whether non-hydrocarbon substitution, necessitated by the complete loss of the fossil fuel resource base, can be as adequate is a key question in evaluating the energy future. Writers are wrestling with this issue now. For example, Jeremy Rifkin in his visionary work, *The Hydrogen Economy*, sees, a more or less, seamless transition from hydrocarbon combustion as a universal energy source to a new hydrogen economy based on the fuel cell.[31] Mark Jaccard, on the other hand, in his book, *Sustainable Fossil Fuels*, sees a much more extended role for properly managed hydrocarbons' fulfilling a transitional function in energy development. Jaccard seems to be of the opinion that, as a practical matter, it will be difficult to replace fossil fuels – to find completely adequate substitutes for them.[32]

26. *See generally*, Robert Esser, CERA Senior Consultant and Director, Global Oil and Gas Resources, Prepared Testimony Before the Subcommittee on Energy and Air Quality, U.S. House of Representatives, 12/7/2005. Esser, incidentally, is a geologist but not of the Hubbert school. For a discussion of the need to modernize reserve calculations, s*ee generally*, Daniel Yergin, *How Much Oil is Really Down There?*, WALL ST. J., at A18 (Apr. 27, 2006).

27. *See generally*, Dr. Robert L. Hirsch, Senior Energy Program Advisor for SAIC, Prepared Testimony Before the Subcommittee on Energy and Air Quality, U.S. House of Representatives, 12/7/2005.

28. Esser, *supra* note 26.

29. NAT'L PETROLEUM COUNCIL, HARD TRUTHS: FACING THE HARD TRUTHS ABOUT ENERGY 105 (2007), http://downloadcenter.connectlive.com/events/npc071807/pdf-downloads/NPC_Facing_Hard_Truths.pdf.

30. CAMPBELL, *supra* note 22, at 229.

31. RIFKIN, *supra* note 22 *passim*; *cf.* JOSEPH J. ROMM, THE HYPE ABOUT HYDROGEN: FACT AND FICTION IN THE RACE TO SAVE THE CLIMATE *passim* (2005).

32. JACCARD, *supra* note 1, at 351-356.

D. The Difficulty of Transitions

In attempting to discern the outline of the post-hydrocarbon world it seems to me we should adopt the cautious view that it will not be easy to abandon fossil fuels entirely even though, quite apart from the prospect of oil depletion, their use is largely precluded by their contribution to global warming. However, hydrocarbon fuels have represented concentrated and stored solar energy accumulated over millions of years and relatively accessible for release by combustion. The thermal energy represented by these deposits is in a concentrated form and may by released more or less at the convenience of the user. Although there are renewable and nonrenewable substitutes for hydrocarbon fuels – like wind farms, and all with their advantages and disadvantages (and power densities) – there are no guarantees of seamless transitions to substitutes that will sustain an industrial infrastructure without losses and costs. Windmills have been around for centuries; yet only recently have they been thought to be adequate substitutes for gasoline engines.[33]

This, in fact, is the principal focus of this discussion. It is normal and natural for us to conceive of the Industrial Era as a progressive movement of civilization relying upon continuous technological development, including energy development, to provide a constantly improving standard of living. But one may speculate that there is no guarantee of industrial progress: that industrial society might be a mere phase, supported in large measure by hydrocarbon energy and destined to decline rapidly with exhaustion of fossil fuel supplies. The critical question is one that we have touched on: are there substitutes for hydrocarbon fuels, which can continue to support industrial progress and evolution without disabling interruption? The answer to this question is obviously important, and there are subsidiary questions involving the transition from hydrocarbon energy to substitute methods of energy production.

E. Supply Side and Demand Side

First of all, the issues can be viewed from the supply side, from the demand side, or from both. A supply-side analysis focuses on whether substitute fuels can be found which can maintain the economy in its then current state, more or less, without a gap or interruption. A demand side analysis first considers simple conservation of energy (including efficiency improvements), and, for example, demand response techniques[34] for electricity, where the system reduces flow when grid instability is detected or high wholesale prices are encountered. This analysis also looks at society and tries to determine how much the society and the economy would have to be modified to be sustained without the energy derived from fossil fuels. In other words, supply-side analysis is concerned with developing sources of energy that can successfully, and hopefully without interruption, take the place of hydrocarbons, the availability of which has been exhausted. The demand side looks to the modification of usage and of the existing economy, culture and society to make them compatible with the energy

33. SMIL, *supra* note 14, at 272-283.

34. KRISTIN BRIEF, MARKET DEV. MANAGER, ENERNOC, INC., ENERNOC DEMAND RESPONSE NETWORK (2007), http://www.enernoc.com/resources/EnerNOC_Demand_Response_Network.pdf.

supplies that are in fact available. Most prescriptions for the future of energy look to changes both in supply and in demand, but most also tend to emphasize one side or the other.

Popular discussions of the energy future tend to focus on the supply side since it is assumed (correctly, I think) that people would prefer to continue their existing way of doing things and of life rather than having to modify it in deference to a changed energy regime. The only group that seems to take a markedly different view I would designate as the "radical environmentalists," who have for years been of the view that humankind (or, at least, industrial humankind) were living beyond their ecological means and needed to simplify their way of life and lighten the burden they were placing on the natural world. Depletion and eventual exhaustion of fossil fuel supplies may put the speculation of environmental social critics to the test. Have we been living beyond our ecological means, and to save ourselves must we revert to a simpler era?[35]

III. LOSS OF HYDROCARBONS AND THE FUTURE OF SOCIETY

A. Significance of Population

As an example of how everyone, including the environmentalists, is reticent even about some crucial aspects of our way of life, I would suggest how no one wants to talk much about stabilization, let alone reduction, of population. This is a sensitive topic – not to be aired at the dinner table – but population is a key factor in measuring burdens on the environment and in calculating the demand for energy. The sensitivity of population as an aspect of the energy puzzle is a symptom of why people are not anxious to examine the means of modifying the demand for energy in fundamental ways. People have no objection to urging energy conservation in conventional ways, but to alter their way of life in a "radical" manner is something most people would rather not think about.[36] Even such measures as abandoning artificial fertilizer and insisting on organic food would be a wrenching adjustment for most people. The same probably goes for restricting one's diet to fruits and vegetables grown locally, thus saving the energy consumed in the long-distance delivery of food.

But, these sorts of things are far from the truly fundamental alterations of a way of life that might be suggested in bringing the demand for energy into balance with the supply. Such fundamental changes might involve the sort of population policy that would actually lower the number of people on the face of the earth. Fundamental changes might also involve abandonment of the kind of private conveyances represented by the automobile. The automobile is certainly a child of the industrial era and a major contributor to carbon dioxide emissions. Although its use might be curtailed, I know of no recommendations that the automobile be eliminated from our society, but this is certainly not unthinkable if

35. HEINBERG, *supra* note 1, at 87-115, 139-161; *see also* DONELLA H. MEADOWS, DENNIS L. MEADOWS, JORGEN RANDERS & WILLIAM W. BEHRENS III, THE LIMITS TO GROWTH (1972); DONELLA H. MEADOWS, DENNIS L. MEADOWS & JORGEN RANDERS, BEYOND THE LIMITS (1992); DONELLA H. MEADOWS, DENNIS L. MEADOWS & JORGEN RANDERS, THE LIMITS TO GROWTH: THE 30-YEAR UPDATE (2004).

36. HEINBERG, *supra* note 1, at 174-176.

we are strategizing about how to get by with far less energy.[37] Fundamental and drastic shifts of this sort might in theory take society back to pre-industrial times, with all the loss of convenience and comfort that might entail. I mention such things not because I necessarily think they are going to happen but because they illustrate why people prefer the supply side and the possibility of inventing new sources of energy to the demand side and the prospect of radical changes in society.

But, people's reluctance to talk about it does not remove the demand side from the reality of what may change with an exhaustion of the fossil fuel supply or the actual advent of global warming. The demand side – the very structure of our society and our way of life – may not be completely spared if fossil fuels disappear from the scene. It may be extreme to view the Industrial Era as a temporary cultural and economic phenomenon, floating upon a sea of hydrocarbon fuel and destined to be drastically modified by the exhaustion of that fuel, instead of part of an enduring historic movement to be sustained by energy supplies yet to be identified. But, extreme or not, the possibility of industrialization's being gravely impaired, if not actually halted, is one of the nightmares invoked by the environmental hawks.[38] Perhaps I am too conservative in derogating the possibility of the Industrial Age's disappearing when deprived of its customary fuel, but I am not an alarmist and I do not totally depreciate the ability of humanity to ferret out technological solutions to fundamental quandaries.

B. The Decline of Progress

Certainly, a number of environmental thinkers have not been restrained about making forecasts of the grave consequences of running out of fossil fuel. I have read speculation about a possible reprise of the decline of the Roman Empire brought on by a growing urban population and a consequent over-cultivation of soil and deforestation leading to soil erosion and consequent decline in food production. The same sort of analysis can lead to fears of a repetition of the "Dark Ages" with loss of knowledge and skills associated with the evolution of civilization to that point.[39]

It seems to me that speculation about the consequences of an exhaustion of fossil fuels turns essentially on one's estimate of the capability of technology to provide adequate substitutes for energy supplies. If one believes fervently that, given the time and resources, there will be a full technological solution, there is no danger of the Dark Ages' returning. But, if one believes there is no guarantee that the Industrial Era can survive without its hydrocarbon base, then speculation about the possibility of dire historical consequences may be justified, however unlikely. One reason that this is an interesting question is that there are so many gradations of opinion about the potential of technology to develop adequate sources of energy as substitutes for fossil fuels, as well as a plethora of views

37. Elimination is, of course, unlikely, since steam, electric power or now fuel cells are available for locomotion.

38. *See, e.g.*, HEINBERG, *supra* note 1, at 141-161.

39. RIFKIN, *supra* note 22, at 59-63; HEINBERG, *supra* note 1, at 154-161.

about the sensitivity of social and economic institutions to changes in energy availability.[40]

Of course, the fundamental factor in adjusting society and the economy to a decline in the fossil fuel supply is simple conservation of energy, which can in theory, at least, be achieved without a radical change in our way of life, as, for example, by demand response mechanisms. Present efforts to prepare for depletion of energy supplies suggest that few observers are deeply moved by the need for drastic change. Thus, the United States, the premier industrial power, is still playing catch-up in efforts to soften the blow of global warming or to cushion the shock of depletion of the crude oil reserves. At the moment, due to the persuasive efforts of Al Gore and other influences, the threat of global warming may seem more pressing than the peaking of oil production, but there is little sense of urgency on either score. Although activity has quickened recently, there is still no adequate response to global warming or to any prospect of the running out of the crude oil supply. And all authorities – both on global warming and exhaustion of oil – send the same message: the more adequate the warnings of catastrophe to come and the more thorough the preparations for it, the less devastating the impact on society's way of life.[41]

On the other hand, there may be a wide gap between expectations and realities as they relate to the impact on society of deficiencies in energy. The absence of urgency in preparing for the energy crisis may not actually increase the severity of the crisis when it finally comes upon us. But, I think the mere fact that at least some people are willing to speculate about the possibility of a new Dark Age should be enough to cause us to devote some analysis to the possibility of a harrowing outcome. Our speculation should involve both the theory of history that we find most congenial and others that seems less comfortable. I have referred earlier to various ways of explaining history and suggested that in modern times most people are willing to cast their vote for technology as the ultimate savior. Consistent with that, the historical expectation is for a continuous improvement in standards of living and in "progress." However, there is nothing intrinsically irrational about a cyclical theory of history – the idea that events and trends tend to repeat themselves periodically without moving progressively toward betterment.[42]

C. Historical Cycles

In accordance with a cyclical approach, it seems plausible to find a link between the level of development and the availability of fuel for the production of energy. Eras of development, like the Industrial Era, might from this perspective, be regarded as essentially transitory and thought to parallel the availability of fuels easily exploited for the production of energy. Consistent with this way of thinking, there might be a concern, probably without calculable basis, that the unavailability of these fuels would lead to the decline of an

40. HEINBERG, *supra* note 1, at 117-137, 157-161, 182-186; ROBERTS, *supra* note 1, at 188-212.

41. Campbell, *supra* note 22, at 194-199; Goodstein, *supra* note 6, at 37; Rifkin, *supra* note 22, at 174-175; Roberts, *supra* note 1, at 307-332; *cf.* Peter W. Huber & Mark P. Mills, The Bottomless Well: The Twilight of Fuel, The Virtue of Waste, and Why We Will Never Run Out of Energy 172-188 (2005).

42. HEINBERG, *supra* note 1, at 93-108.

industrial age and its possible reversion to some sort of pre-industrial state. If this sounds like a voyage into fantasyland, we might imagine the return of a way of life approximating that of the Amish or Mennonites (which are modern-day examples of the pre-industrial). At the least, a reversion to the pre-industrial implies greater access to the "natural" – to unprocessed food, to transportation based on domestic animals or on the bicycle,[43] to hand-made clothing and the like. Speaking in more general terms, to the extent that developmental steps rising above these "primitive" levels are made possible by the availability of relatively cheap energy, the disappearance of these energy supplies may signal a significant but unspecified decline in the standard of living.[44]

Many of these speculations, as has been indicated, employ a cyclical perspective. This would contemplate that events would repeat themselves at intervals of months or years or eons, time and time again. There would be little continuing "progress" – only historical cycles and repetition of history as time unfolded. This process would not necessarily unfold in an automatic and precise fashion. Events in one cycle would not necessarily exactly duplicate events in the preceding cycle; but there would be enough similarity in the cycles that people would sense that history was repeating itself although the pattern would be modified by the fact that the availability of energy is not the only historical variable. A world-view like the one presently in force, based on a universal belief in "progress," is rooted in confidence that technology will continue to bring change for the better in standards of living. But, as a practical matter based on the historical record, technological change can bring about improvement in the broader standard of living only to the extent that plentiful energy is available.[45] Thus, progress from horseback to automobile travel involves a great deal of automotive invention, but it also requires fuel transformable into energy.[46]

It may well be, of course, that any major interruptions in the supply of energy will not lead back to the energy levels characteristic of a pre-industrial age and that we can feel assured of enough energy, with or without hydrocarbons, to provide at least a limited, if parsimonious, supply of energy, sufficient to support a reasonable industrial development – if not the existing one. This outcome seems far more likely than a complete collapse of development in the event of a drastic impairment of energy. All of this is, of course, unpredictable except as a Jules Verne-like exercise. All we know is that the technological progress of civilization is securely linked to the supply of energy, which is always at risk but now seems to be particularly so for reasons that defy precise analysis.[47]

Of course, in meeting the decline in availability of hydrocarbon energy, the effort in applying energy alternatives will be to limit demand-side changes and

43. *See, e.g.*, Thomas L. Friedman, *Flush with Energy*, Op-Ed, N.Y. TIMES, Aug. 10, 2008, at 11.

44. HEINBERG, *supra* note 1, at 151-153.

45. Although historically energy use is linked to "progress," since 1995 European usage of energy was essentially flat but its standard of living rose to the same level as the United States. ENERGY INFORMATION ADMIN., INT'L ENERGY ANNUAL 2005, www.eia.doe.gov/iea/overview.html (last visited September 15, 2008); HEINBERG, *supra* note 1, at 37-39.

46. GOODSTEIN, *supra* note 6, at 37-40.

47. *Id*.

to alter the supply side to support existing social arrangements. In fact, the emphasis in the literature overwhelmingly assumes this outcome, and only that favoring a radical environmental outlook looks with much anticipation to changing the shape of civilization to accommodate a decline in available energy. The most probable approach is to assume that whatever energy can be salvaged will be applied to support existing arrangements, and social changes will be limited to what energy deficiencies make absolutely necessary. This outlook assumes, of course, that in general there can be a successful transition from a hydrocarbon-based energy system to one based on renewable resources. This is an assumption now widely made, but whether it is unassailable remains to be seen. Certainly, there are valid questions based on cost and other factors.[48]

D. Prospects for Renewables

The factor that may pose the most critical question about whether renewables can seamlessly replace hydrocarbons as a principal source of energy is the history of energy supply over the whole history of humankind from life in caves to date. The fuels used started with wood (biomass), and proceeded from there to a series of hydrocarbons – coal, oil, and natural gas – all of which, starting with wood, were burned to release their energy. These processes were remarkably similar and did not present transitions comparable with that offered by the move from gasoline to hydrogen or even by that from coal to wind. So there may be a basis for raising questions about whether the energy transitions of the future will be as smooth as those of the past. We have been misled as in some recent energy transitions, such as the one to nuclear power, which was originally thought to be cost-free and turned out to be anything but.[49] And there are visionary technologies out there, like fusion power, possibly promising but surely elusive, the transition to which is a complete mystery.[50]

Already, the process of planning for the energy future has been afflicted, given the general accuracy of our gross perception of the changes ahead, by doubt and caution about the specifics of how these changes will affect the human environment and human life. This doubt and caution is even perceptible in the matter of climate change. There seems to be agreement that accumulations of carbon dioxide and other greenhouse gases will lead to rising temperatures in the human environment. But, the specific impacts of rising temperatures, in the form of floods, of worsening storms, and of other bad weather phenomena, and the timing of these impacts are matters about which there is a great deal of controversy. Will global warming essentially transform the temperate zone into the tropics and improve growing conditions in far-northern and southern latitudes? Will such changes take place relatively abruptly, gradually, or even imperceptibly? These are apparently valid questions that are being asked when

48. "The best hope for our civilization lies in technologies that have not yet arisen – possibly based on scientific discoveries that have not been made." GOODSTEIN, *supra* note 6, at 115. *See also* HEINBERG, *supra* note 1, at 17-54; JULIAN DARLEY, HIGH NOON FOR NATURAL GAS: THE NEW ENERGY CRISIS 165-206 (2004).

49. LEGGETT, *supra* note 9, at 158-163.

50. *See generally* U.S. Gov't Accountability Office, Report to Congressional Committees: Fusion Energy: Definitive Cost Estimates for U.S. Contributions to an International Experimental Reactor and Better Coordinated DOE Research Are Needed, GAO-08-30 (Oct. 2007).

specific measures to address global warming are proposed. They are being asked in the context of: "Yes, forecasts of global warming are scientifically supportable, but this need not lead to panic. Do we really have a basis for knowing what the effects will be? Perhaps, they will be as much good as bad."[51]

One can attempt to refute the case for good effects as well as bad by relying on the universal tendency of environmental thinking to assume that what exists in nature is generally preferable to a state of affairs that is brought about by human manipulations.[52] Thus, there is inherent resistance in environmental thinking to the prospect of the earth's being made more liveable or more productive by artificial alteration of its climate (although I understand that the latter kind of thinking is now being pursued in some circles.) My own instincts would be resistive to this type of analysis as being risky, especially since the environmental changes involving rising temperatures were not planned but occurred as unplanned byproducts of human activity. Therefore, the odds against their being beneficial would appear to be high. However, can we merely assume that any change in climate brought about by artificial means must necessarily be undesirable? Perhaps, the question becomes, is nature some sort of seamless web, such that any alteration destroys natural perfection and is ipso facto undesirable? I think that could be characterized as a purely environmental point of view. In any event, the possibility that climate change might not be unqualifiedly damaging to humankind is not a good reason for refusing to limit it by reducing emissions of greenhouse gases.[53] The appalling risk of such a basic assault on nature should remain the key consideration.

E. Different Outcomes for Depletion and Warming

The question remains whether there will be a substantial difference between the kind of changes required by the imminent depletion of the worldwide supply of oil in contrast to the sort of changes occasioned by an accumulation of carbon dioxide from the combustion of fossil fuel that raises atmospheric temperatures. There is the further question whether measures indicated to meet one of these crises will be permissible in view of the demands of the other crisis. First, what specifically has to be done in the face of a terminal depletion of world oil supplies? The answer to this question seems fairly straightforward. Presumably, one must conserve remaining oil supplies and develop substitutes for oil. But it may not be obvious how a peaking of global oil production poses an immediate threat of unavailability of oil.[54] No doubt the price of the commodity will rise (or perhaps has risen), and it will be more costly and difficult to produce, but there will be no question of its immediate disappearance. On the other hand, the decline in production may be sharp and the aftermath of the peak alarming. Remember, however, that we are talking about oil, not about hydrocarbons in general; so, in theory, coal (if liquefied) might be an adequate substitute for oil

51. "As greenhouse contrarians will be quick to tell you there are many uncertainties." LEGGETT, *supra* note 9, at 74; *see also* ROBERTS, *supra* note 1, at 120-140.

52. Andres R. Edwards, The Sustainability Revolution: Portrait of a Paradigm Shift 11-27 (2005); *see also* Craig Morris, Energy Switch: Proven Solutions for a Renewable Future 74-76 (2006).

53. JACCARD, *supra* note 1, at 320-323.

54. Hirsch, *supra* note 27.

were it not for other considerations, like the greenhouse gas problem.[55] Of course, oil, when burned, emits carbon dioxide, so the option to extend the use of oil while its production declines is not an unmixed blessing. But the ability to use fossil energy in a less polluting form, like natural gas, which is more abundant than oil, is an option to help meet the oil depletion crisis.[56]

The threat of global climate change based on the accumulation of greenhouse gases calls for limiting the combustion of fossil fuels, which yields carbon dioxide. This is, therefore, a somewhat more all-encompassing problem than oil depletion because it affects the use of all fossil fuels, not merely oil. In fact, the threat of climate change may call for ameliorative measures more drastic than does depletion. Certainly, there is urgency about coming to grips with the accumulation of greenhouse gases because this development necessarily anticipates the rising temperatures which follow. But, urgency here may be no more pressing than appropriate action in the face of a terminal decline in the production of oil. Both of these phenomena call for prompt and determined action. But, even more importantly, it should be wise and fully considered action. What precise paths to follow in moving from a long and successful attachment to hydrocarbon fuels to as-yet-undetermined substitutes is by no means a simple matter and the costs, although inescapable, may be high. It is important that the costs be held to a minimum and the economic disruption mitigated. These considerations must be fully served while at the same time heeding the requirement of urgency. On the face of things, the requirement to move on from hydrocarbons as the primary fuels in our economy would appear unpredictably burdensome, but hopefully not devastating. However, despite the obvious burdens of the change, we do not know its undisclosed benefits. Perhaps, in the end these will prove a pleasant surprise.

IV. CONCLUSION

We have focused on two major threats to the existing energy regime in the world. The first of these is the presumed depletion and declining production of oil – now the world's leading hydrocarbon fuel. The second is global warming, brought on in significant part at least, by release of carbon dioxide into the atmosphere by the combustion of oil and other hydrocarbons. Both of these phenomena give rise to the same problem – a severe limitation on oil and other hydrocarbon fuels as sources of energy. In the case of depletion, oil will not be used because there isn't enough to go round. In the case of global warming caused by carbon dioxide emissions generated by the burning of fossil fuels or hydrocarbons, these fuels will be banned, or drastically limited, because of the threat of rising temperatures, devastating climatic shifts and untoward weather events. Of these threatening prospects, global warming may be the more menacing because it results from the use of all hydrocarbon fuels while the depletion phenomenon affects only oil (and potentially natural gas). Of course, also, global warming is perhaps better established scientifically than the peaking of oil production, the existence or extent of which is controversial.

55. DEFFEYES, BEYOND OIL, *supra* note 4, at 82; SMIL, *supra* note 14, at 207.

56. JACCARD, *supra* note 1, at 317.

The pattern of impact of unavailability for one reason or another of hydrocarbon fuel, or simply of oil, is difficult to predict with precision. Measures will certainly be in order to promote conservation and to suppress demand for the depleting or polluting fuel or to increase the supply of acceptable substitutes, and probably both kinds of measures will be pursued. Of these sorts of measures, the suppression and control of demand might have the most radical impact on our way of life. If civilization must be maintained on a smaller energy budget than the one it is accustomed to, industrial progress may be more difficult to pursue. To the extent that the very core of industrialization may be affected, changes attributable to regulating the demand for hydrocarbon fuel resources could be quite far-reaching and even, speculatively, resurrect earlier times and their ways. It seems to defy common sense that the Industrial Revolution could be repealed, even in part, but for whatever it may be worth, some observers would remind us that in the history of the world there have been long periods (Dark Ages) when progress ceased and most of the efforts of humankind were directed to clinging tenuously to the achievements of the past. So, it may or may not be that the economy can move seamlessly from a hydrocarbon base to some other base while continuing its forward motion in technology, science and in other important dimensions.

Only time will tell whether the leap from hydrocarbons to some other energy future will interrupt "progress," or in some way turn back the clock, or surprise us with unanticipated benefits, or none of the above.