Journal of Energy Resources Technology

Discussion

The Myth of Sustainable Development: Personal Reflections on Energy, its Relation to Neoclassical Economics, and Stanley Jevons

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As a card-carrying ecologist I would like to commend Lyn Arscott's recent discussion ("Sustainable development in the oil and gas industry" ASME J. Energy Resour. Technol. **126** (1) pp. 1–4) that appeared in this journal. Certainly given the past notorious history of the oil and gas industry in these areas and the legacy of destruction (e.g. Wall Street Journal October 22–25, 1984, Page 1, on the industry's legacy in Southern Louisiana) it is reassuring to see environmental and social concerns given as much weight as profitability. But there is also something strange about this article, an elephant in the living room, that is something that is overwhelmingly large but that no one will talk about. How can an industry, one whose principal products are critical to contemporary civilization but which by most accounts is facing imminent or at least incipient decline, be talking about sustainability?

I base that latter statement on my own experience with energy and the oil industry that spans over 35 years and many publications, and on what seems to me to be the consistency of the situation. I think the best way to make my point is to do so from the perspective of my own personal intellectual history as I have tried to sift through and interpret the information and propaganda. My PhD is in ecology and environmental sciences, and I did my dissertation on the energetics of fish migration. My interests, fueled by the ideas and interests of my remarkable doctoral advisor Howard Odum, has always been energy in all its forms and its relation to how natural and human-dominated ecosystems function.

I showed up in September 1970 at my new job at Brookhaven National Laboratory ready to go to work. But the first day was unexpected for the naive, idealistic young hippie that was me because it was filled with a bewildering array of bureaucratic affairs that I realized only later was the entrée to a really wonderful suite of benefits that comes with a real government job. So I got my first free medical examination, opened a new bank account at the laboratory bank, learned how to make myself safe from the various sources of radiation that were scattered about the laboratory, received an eye exam, free safety glasses, and two pairs of steel toed safety shoes! Finally they said go to such and such an office and arrange for your retirement account! I was astonished! This was my first day on a real job and they were talking about retirement! But I did as I was told, and the guy behind the counter asked whether I wanted CREF or TIAA or, as he recommended, half and half. I had no idea what these were so I asked him to tell me what they meant. He said "One gives you a higher rate of return but it is not guaranteed, the other gives you a lower rate of return but it is guaranteed." I asked him "when will I retire?" and he said (based on the more or less mandatory age of 65 in effect then) "about 2008." I remember thinking about M. King Hubbert's global oil use curve that I had studied intensively as a graduate student and thinking "Geez, that will be just after we go over the global oil peak." So I said "Put it all in the guaranteed one." At this moment I am glad that I did. I know it will be there when I retire. So even in 1970 I knew what was coming in the oil industry, although not exactly when, and I understood that the economic and other impacts were likely to be enormous for our society.

But even though I knew that eventually there would come a time when oil production would peak and fall, I was blindsided by the so called "energy crisis" of the 1970s. I was teaching energy courses to undergraduates by then and was actually quite surprised that as early as 1973 there was such a large impact of what eventually was blamed on a bulldozer piercing a pipeline. Of course I knew that Hubbert had predicted in 1955 that US oil production would peak by the year 1970, and that in fact it had done so, even after his predictions had been disparaged by all kinds of oil men. But global oil, which I figured we would be using ad libidum for many additional years, was another thing.

Projections of Gloom and Doom

Soon the scientific and even popular media was full of issues of energy and societal unsustainability. Gasoline and heating oil prices kept going up and up. In 1972 the first "Club of Rome" "Limits to growth" report [1] had come out predicting large growth and then larger crashes for the world economy, followed subsequently by the human population. I found myself and most of my friends and neighbors in upstate New York buying wood stoves, and it hardly seemed that I could go to a social event where a dominant topic of conversation was not heating with wood. Although "sustainability," energy or otherwise, was not in the popular lexicon we all thought about it. In addition at that time I undertook a series of analyses with colleagues that seemed to cement, at least in my mind, the critical importance of energy to just about everything that we did in our economy (e.g. Cleveland et al. [2], Hall et al. [3,4]), and also the increasing energy intensity of procuring our own fuels (e.g. Hall and Cleveland [4], Davis [5]). I even had my "Andy Warhol 5 minutes of fame" when the results of that paper were reported on the first page of the Wall Street Journal. However the popular and business media essentially has been silent on the oil depletion issue since then.

Most economists completely ignored our oil analyses and they did not like the Club of Rome report at all, saying for example that "Our objection was not to the idea of simulation but to the twin assumptions that underlay every computer run in the *limits* model. The bad things in the model . . . . pollution, population growth and so on—are all assumed to be growing exponentially. On the other hand, the things that could be relieving the stresses, the good things, ---technological innovation of the right sort, are not assumed to be growing exponentially . . . Once you make that (The authors of the Limits to growth) assumption the collapse of the world system . . . is a mathematical fact.'' (Ross and Passell [6]). These authors go on to argue that although indeed pollution and resource depletion were real, important and difficult issues, that leaving out the possibility of technical improvements, for example the possible development of fusion power, was completely wrong. Nordhaus writes in the same vein in the same publication ''A close look at the model has led a number of competent independent analysts to conclude that the underlying assumptions are founded in pure fantasy'' . . . and that the authors ''did not refer to empirical studies that have been done in different fields.'' In general these and other authors believed that market forces and technological advance would lead over time to solutions of the problems considered in the Limits to growth. Given that the world did not crash and burn, and that global oil supplies again flowed freely, the ''Limits'' study has been dismissed by almost all economists and even most scientists.

Yet how many readers who are aware of the Club of Rome study are also aware that as of 2004, and assuming that the model's ''resources'' is oil plus gas and ''pollution'' is carbon dioxide, all five predictions of this model are almost exactly on target? It also works for most other global resources and pollutants. Whether the club of Rome model is a reasonable representation of reality or not (I would prefer some more specificity) one must admit that 30 years later it has a proven track record! Of course the bumpy road predicted ahead is a different issue–we shall see.

The Victory of the Neoliberal Model

Before long oil prices came back down and public concern about energy scarcity, and scarcity in general, evaporated. Perhaps the most fundamental factor in the public's perception, and that of many of our political leaders, that energy and other resources issues have been largely resolved, and are hence no longer of interest, has been the ascendancy, indeed intellectual dominance, of neoclassical economics (NCE). This collection of economic ideas is also known, more or less according to its variants, as free market economics, moneterism or neoliberalism. The basic idea as applied to, for example oil, is that with increased prices there would be more incentives to develop new resources, and, through innovations, derive substitutes or more efficient ways to use the resources that we are using. Clearly this must have worked, for gasoline prices again dropped, oil use declined as electric utilities shifted to coal, and energy left the public consciousness. We even had the luxury of substituting cleaner natural gas for coal for electricity production, making acid rain and greenhouse gas production less, although at the rarely mentioned expense of our future ability to use this premium fuel and feedstock where there are no substitutes as there are for electricity production.

Increasingly free marketism and, more generally, neoclassical economics has become the dominant economic guideline for all aspects of the developed and the developing world, and increasingly the former functions of governments are being deliberately and sometimes disastrously turned over to market forces. In many cases its economic premises are presented both as unquestionable truths and as national political goals, and, for example, Presidents Clinton and Bush (both George the first and George the second) of the United States have spent considerable time unabashedly selling their perceptions of the virtues of neoclassical economics to the rest of the world.

There are a number of reasons for this ascendancy besides the enthusiasm and sometimes self interest of its adherents: 1) the unresolved economic problems associated with other, government-centered, approaches to economics, including, or exacerbated by, the enormous increase in debt in the third world, 2) the ''fall'' of communism, the only perceived real alternative to free market capitalism that was available to most of the world, 3) the role model, encouragement and apparent economic success of the United States which claimed, and appeared to many to be, the successful embodiment of the neoclassical model and 4) the intervention of the International Monetary Fund, the World Bank, US-AID and other powerful economic actors who were extremely strong advocates of NCE (often for their own ends), and who gained strong bargaining power for intervention in e.g. Latin American economies because of the increasing foreign debts of many nations. In effect the options given for many countries were either to go into default, with extremely serious repercussion on their economies and trade, or accept the neoliberal policies that were often thrust upon them. This was most generally put forth in a package called by the IMF (and others) ''structural adjustment,'' which included reducing government spending, decreasing trade barriers and enhancing export crops for the supposed benefit of the country upon which it was thrust. The arrogance and hubris of the powerful banks of the developed world requiring small powerless countries to stop subsidizing their own agriculture and open their domestic markets to the rest of the world in the name of ''free market efficiency,'' while the large industrial nations such as the U.S. and France continued to subsidize their own agriculture heavily rarely has been remarked upon by those who advocate the free market.

The rationale used almost universally to advocate NCE is ''efficiency,'' the concept that unrestricted market forces would seek lowest prices at each juncture and the net effect would be the lowest possible prices and also that all productive forces would be optimally deployed. It is rather amazing to see this argument trotted out again and again with so little understanding and with the definition of efficiency constantly transmogrified into whatever suits the writer's preconceptions or politics. Anyone who believes that free markets leads to any real efficiency needs to read Bromley's [7] remarkably insightful 1990 article on the subject, in which he found the definitions used for efficiency were so fluid and poorly defined as to be useless. Our own work (e.g. Tharakan [8], Ko et al. [9], others in press) has found that when efficiency is measured by commonly accepted scientific and engineering formulas (e.g. physical output over physical input, with output sometimes measured with a monetary proxy) that for most countries examined efficiency is declining in agriculture and static for economies in general [10]. Likewise the solution of most NCE-guided development schemes for, essentially more growth to solve all problems, has rarely worked in the past (Easterly [11]; Stiglitz [12]). If cheap oil, upon which all countries of the world are becoming ever more dependant, ceases being cheap, the possibility of successful development in the future seems even lower (e.g. Hall [13]).

Sustainable Development

Another supposed solution to the earlier predictions of resource scarcity has been the evolution of the term ''sustainable development.'' Whether this term is an oxymoron or not I leave up to the discretion of the reader but it is clear that the concept allows the fusion of two formerly contradicting concepts, as it is clear to almost anyone who bothers to look that most development is based upon either non renewable resources, such as oil, or on making formerly sustainable ecosystems, such as natural forests, unsustainable in the long run by converting it to e.g. most agriculture, which is either self degrading through erosion or salinization or requires subsidies from non renewable energy to maintain production. Virtually all developing economies that have grown in the past 50 years have done so with a very nearly one for one increase in the use of energy (e.g. Cleveland et al. [2], Ko et al. [9], Tharakan et al. [8]).

An important thing I learned early on about sustainability is that although the term sustainable development is often used in a promotional sense (e.g. for Costa Rica) the term has almost no utility since it normally is not carefully defined. In particular we found, in agreement with Goodland and Daly [14], that ''sustainable development'' in the existing literature means (at least) three different things to three different groups of users: a) sustainability of social structures (i.e. maintenance of certain communities or life style of groups of people, b) economic sustainability, that is a continuation of income flow, c) ecological or resource sustainability, which can mean many things from maintenance of biodiversity to ensuring the continuation of the resource base for future economic activity or even growth. Very often gaining sustainability by one of these definitions has to be at the expense of sustainability by one of the other definitions, so there is no wonder there is confusion.

Are We Becoming More or Less Sustainable Today?

For those who think about energy today with any degree of depth, and they are not many, the majority appear to believe that free markets, general neoclassical economic principles and perhaps something (exactly what is rarely heard) from sustainable development have resolved whatever physical limitations to supply exist. I wish to examine that question from the perspective of two very different societies: the United States and Costa Rica.

My first point is that the market has done little or nothing to help the long-range outlook for oil and gas in the United States. Despite unprecedented economic incentives as the price of oil increased dramatically from the 1970s through the early 1980s, the production of oil for the Unites States declined year by year from 1970 through the present, almost exactly as Hubbert had predicted, so that today we are producing each year only about half of the oil that we did in 1970. Most people are unaware of that fact. I talked to a group of about 50 citizens in Binghamton, New York recently and I asked how many knew that U.S. oil production declined each year and had been doing so for three decades. Not one person new either fact! I asked the same questions to about 100 environmental scientists at a recent meeting in Syracuse and found a far better response–about 20 percent knew these facts.

We have been buffered from the consequences of that oil production decline because global oil production has continued to increase so that the United States has been able to increase oil imports greatly. A downside is that this has been done at the expense of international debt, so that the United States changed from the world's largest creditor country to the world's largest debtor country. A number of analyses indicate that we may soon be approaching a peak for that oil too (e.g. Campbell, Leherrere [15]). Hubbert had predicted that global oil production would peak between 1990 and 2000 depending upon the ultimate amount of oil that would be found, which he estimated as between 1.35 and 2.1 trillion barrels. Scrutiny of the oil production figure in Campbell and Leherrere [15], which assumes a total quantity similar to the latter value, indicates that the large reduction in global oil use following the price increases of the late 1970s (mostly due to a sustained cessation of economic growth but also substitution) may have saved us–at least so far–from having to deal with the beginning of ''going over Hubbert's global peak.'' But we may not be far from that, and two important questions are whether even large increases in the price of oil, and hence economic incentives, can change the eventual downward trend and how the 'end of cheap oil' will effect the sustainability of the economy of the United States and the other roughly 180 oil import-dependant nations.

At least two reports in early 2004 confirm that there may be considerable reason to believe that ''Hubbert's peak may be soon upon us.'' The first, by Skrebowski [16], examines the present and projected output of the largest oil fields that supply some 80 percent of the world's oil. Most of the largest oil fields are 40 to 60 years old, and the output is declining for about one third of the global production at about 4 percent per year. In order for global production to be maintained new fields need to be coming on as fast as the old ones decline. The authors find that while there are enough large oil fields about to come on line in the next three years, there are none in the works for subsequent years. Since it takes at least 6 years physically to prepare an oil field for production one can conclude that the downturn will begin about 2007 or 2008. An even more sobering report was in The New York Times Business section February 25th 2004. Nearly all analysts put their faith in Saudi Arabia as a large ''swing producer'' that will be able to ramp up production more or less as needed to meet any world shortage. But this analysis indicates that the Ghawar field, overwhelmingly the most important field in Saudi Arabia and indeed the world, has been declining at about 8 percent a year. This study also considers past attempts to increase short term production of other smaller Saudi fields, which had resulted in catastrophic loss of the ability of the field to generate oil over the long run because the oil bearing strata compressed when the oil was withdrawn too rapidly. Our own research Hallock et al. [17] has found that progressively the domestic oil use of oil-exporting countries is catching up with oil production, which in turn inevitably will peak and then decline if it has not already. The net result is that the number of oil exporting countries will go from some 38 today to 20 in a decade or two to seven at most by the middle of the century, almost all concentrated in the middle East or adjacent areas. While one can also find more optimistic reports none of it sounds like sustainability to me.

And it may not be just oil. My email has been full of various ''unofficial energy news suppliers'' that said that due to harsh winters and declining domestic production there was likely to be a severe natural gas shortage this year or at least soon. This was followed by reports from our University physical plant to please make large efforts to save electricity (which in our case comes from natural gas) because the price of gas had doubled in the last year. Natural gas production in the United States peaked in about 1973, then declined until 1983, but increased again to a second peak in 2001 which may or may not be declining again despite large economic incentives. It is not clear to me that market economies are going to save us from the physical limitations of declining energy resources, and given that about two thirds of our energy comes from oil and gas, if both were to decline simultaneously the impact could be severe.

Energy Cost of Substitutability

In general economists are not especially worried about depletion, even should it happen, because they believe that if and as scarcity of one resource occurs other resources will be brought on line to compensate for the scarcity. Thus, they would argue, if and as copper becomes scarcer abundant aluminum and new fiber optics will be developed to take its place. In fact the average grade of copper ore in the United States has declined from about 4 percent copper by weight in 1900 to about 0.4 percent today. This has caused the energy cost of producing copper to increase despite increases in technology. We still use about the same quantity of copper in the United States as decades ago, but in fact we now use in addition much more (energy-intensive) aluminum to carry electricity and much more fiber optics and satellites (of unknown but probably much less energy intensity) to carry information.

There is a problem with finding substitutes for oil and gas though—most are of high and increasing energy intensive (coal is an exception) (Hall et al. [3]). There was great enthusiasm and government support for determining the energy-intensity of just about everything in the 1970s and early 1980s but very little of either since then. Nevertheless, based on these old studies, it does appear that essentially all possible large-scale substitutes for oil and gas are themselves considerably and increasingly more energy intensive (again with the exception of coal, which of course has other problems, and maybe windmills) (Cleveland et al. [2] Figure 6).

Economic Incentives and EROI

While it is clear that increased oil prices will generate increased incentives to drill more looking for oil, and that increased technology also may have a lot to say about how much oil we find in the short term, it is not clear that either will bail us out of what may be an impending crisis. The price of oil increased dramatically in the late 1970s, and drilling activity increased greatly in the 1980s, but the actual quantity of oil found in the United States was considerably less in the latter decade compared to the former (Hall and Cleveland [4]). It is possible that increased drilling activities may simply find about the same quantity of oil but less efficiently, something also noted in earlier decades (Davis [5]). Likewise the marvelous new lateral drilling techniques and 3-D imaging may mostly find oil that we would have anyway, but do so earlier. Oil technology has always been advancing, but the question is, is it advancing more rapidly now than in the past. In general there is a race between technological advance and depletion. In the long run nature appears to hold the cards, for we found in the U.S. some hundred or more barrels of oil per foot drilled in the 1930's compared to less than ten now (e.g. Hall et al. [3]).

We recently reviewed the status of oil reserves and their predictions of use (Hall et al. [18]). Nearly all assessments that have been done in recent decades, including by the U.S. Geological Survey (USGS), concluded that there were roughly 2 trillion barrels of ''Ultimately recoverable oil.'' This can be compared to the roughly one trillion barrels that we have already extracted and used. However one recent and apparently highly competent analysis by the USGS gave a best estimate of approximately 3 trillion barrels, and a five percent probability of as much as 4 trillion barrels. About half of their increased estimate compared to their own earlier values is due to the assumption that the more sophisticated technology derived in the United States could be applied worldwide and with similar good results. Squaring these new estimates with the 2 trillion barrels of virtually all other assessments is an extremely important issue. In any event oil production *per capita*, which may be the important value, peaked in about 1978 and is only about 80 percent of that now.

Clearly whatever oil that we find in the future will be coming increasingly from offshore, deep water and other difficult environments. Everyone in the industry knows that these are monetarily very expensive to exploit. What is less discussed is that they are also very expensive in terms of energy. Overall the production of oil in the United States has fallen from an energy return on energy invested (EROI) of roughly 100 to one in the 1930s to roughly 17 to one today (or half or two thirds that if we exclude the gas extracted) and much less than that for finding new oil. I am unaware of any such calculations for oil resources globally, but they need to be made, and made comprehensively. A further problem is that we do not know what the minimum value would be for EROI to run a modern society for we would need to include the energy required to make the machines that use the oil, feed and house the workers, deal with degradation of essential environmental services and so on. A guess is five to one. This eliminates many new technologies, including alcohol from corn (gasahol) and photovoltaics in many situations.

In concluding this section on economics, it is my belief that in the short run one can believe in the ability of markets to solve our energy and sustainability problems, but in the long run Mother Nature holds the cards. Most technology carries an energy cost, and we have barely begun to analyze what they may be. More fundamentally I believe that we need to generate a new ''biophysical economics'' that is based on the energy and material realities that readers of this journal deal with every day (Hall et al. [10]). This needs to be compared with the neoclassical economists' speculative and even hopeful assumptions about new technologies when most of our older technologies (agricultural for example, offshore platforms) have been based on cheap petroleum.

Jevon's Paradox

But, you might ask, what about an increase in the efficiency with which we do use fuel. Cannot this compensate for any possible future supply problems? For an answer to this I turn to a wonderful book published by Stanley Jevons, paradoxically one of the creators of the ''marginal revolution'' that led to neoclassical economics, for which we shall have to excuse him at least for the moment.

Stanley Jevon was asked by the British Government in about 1860 to assess the ''situation with regard to coal'' for the British Isles. His results are published in ''The coal question'' (Jevons [19]). In that book he first asked about the relation of coal to economic activity in England and, after a rather exhaustive analysis concluded that ''all economic activity led back to coal.'' Next he asked how long the reserves of England would last. He took all known coalfields in England and determined their extent. With the area in acres and the depth in feet, some heroic calculations were required to generate total volumes. He then divided this large number by current use and concluded that all of England's coal would be exhausted in 200 years, or less if the rate of use increased.

Jevons initially concluded that it would be necessary to increase the efficiency of coal powered engines in order that England did not run out of ''this most important resource.'' Before he made his final report, however, he undertook a thorough review of the earlier literature on coal, and found a number of authors who had concluded just the same thing: coal was limited and that it was critical for England to improve the efficiency of coal-powered engines. Jevon's found that indeed, spurred on by this perspective, a series of new, more efficient steam engines had been developed with a or the principal purpose of being more efficient, the most important of which was James Watt's. Jevons then examined whether these more efficient engines had reduced the use of coal and found quite the opposite: the more efficient engines were cheaper to operate and hence people found more uses for them. This is the paradox, engines designed to be more efficient to save coal in fact ended up using more coal, more than negating the efficiency improvements. The same has happened to greater or lesser degrees with more recent efficiency improvements, including automobile fuel efficiency, refrigerators, light bulbs and so on. As cars became more efficient people drove them more miles, as refrigerators have become more efficient people purchased larger ones and so on. While certainly efficiency can bring us greater social utility per unit energy used they do not by themselves save energy!

Assessing Sustainability in Costa Rica

In order to see the consequences of these actual and projected changes on an actual economy I turn to my own recent analysis of the small Central American country of Costa Rica. About a decade ago I decided to take a good hard look at the possibilities for developing some kind of real sustainability. I chose the country of Costa Rica for this as within conservation circles the country had a strong reputation for sustainability, their President had announced that they would make their country a ''laboratory for sustainability,'' and the sophisticated state of Costa Rican science meant that there was a great data base. In addition Costa Rica, a thriving democracy with health and literacy standards greater than, for example, the United States, was generally regarded as a rich agricultural country as well as possessing many other natural resources, including especially very high biodiversity. Thus I felt that if any place could be sustainable it would be Costa Rica.

What we found, rather to my surprise, was that Costa Rica was very far removed from sustainable. The principal reasons are given in Hall et al. [13], as summarized in chapter 26. They can be summarized as simply that Costa Rica has far more people now than can even be fed sustainably, let alone supported more generally, from the limited resources of the country. This has resulted in the necessary import of food (about one third of needs), enormous quantities of agrochemicals to increase yields on the limited good land, fuel for everyday life and the tourist industry, and so on. This in turn requires that up to half of their foreign exchange earnings are required to pay for the industrial inputs, without which much of the population would starve. In addition about 80 percent of their original forests have been cut down. Since Costa Rica cannot afford all of these industrial inputs much has been paid for with debt, which is another dimension of sustainability. Costa Rica is a wonderful place, and the birds may or may not be sustainable, but the economy and its people are not.

In conclusion, my own assessment, and that of my colleagues, suggests that if we look at the increasing dependence of these two nations, the United States and Costa Rica, on non-renewable resources, and the likelihood of possibly severe supply disruptions in the future, the possibility of anything resembling sustainability of present infrastructure, let alone ''sustainable growth'' appears rather small. A further conclusion is that growth, both of populations and of economies, undermines future sustainability because new technologies have not in fact decreased per capita dependence upon finite resources. We have had a wonderful ride on cheap oil. Sustaining anything like that for the future in a world where the population still grows, and the environmental problems that effect the resources that people are dependant upon mount, will be an enormous challenge, one not aided by systems of economics that hide from biophysical realities. And we should eliminate the word ''sustainable'' from our lexicon, at least for human-dominated systems, until if and when we have found a substitute for cheap oil and have figured out how to mobilize the energy capital required for its implementation or have figured out how to live decent lives on enormously less cheap energy.

Acknowledgments

I thank Laura Schmitt, Myrna Hall and Jae Young Ko for discussions about these issues.

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