ABUNDANT US ENERGY-SUPPLY OPTIONS FOR THE VERY LONG TERM[1]

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<u>Oil Facts</u>
(based on a lecture by James D. Hamilton, Dept. of Economics, UCSD, May 2008)

1. In current (inflation-adjusted) dollars, oil reached a price of about $105/bbl around 1980. The 1998 price was about $15/bbl (i.e. about the same as the 1949 price).
2. Iraq + Kuwait oil was 8.8% of world-wide production in 1990; that of Iran, 10% in 1978.
3. Oil-supply disruptions ranged from 7.2% in October 1980 during the Iran-Iraq war, to 7.8% in November 1973 (Arab-Israeli war), to 8.8 to 8.9% in August 1990 (Persian Gulf War) and November 1978(Iranian Revolution), to 10.1% in November 1956 (Suez Crisis). These supply disruptions caused GDP changes with oil-price changes showing variable income elasticities in different countries at different times.
4. In the US, the dollar share of oil in the GDP has generally decreased with time although this decrease is obviously reduced as oil becomes more costly. The dollar value of oil used in the US as a percentage of GDP has ranged from close to 2% during 1970 to 1975 and 1985 to 2003, it peaked above 8% in 1980, and reached about 4% in 2007 while rising.
5. Since most of the oil is used in the private transportation sector, rising oil costs have a profound effect on consumer choices of automobiles.
6. Large oil-price increases have generally reduced subsequent GDP growth, have impacted consumer confidence, and especially increased sales of vehicles with high miles per gallon.

1. Introduction

I had my first serious encounter with energy issues during 1946 as a Research Engineer of what was then called the Esso (now Exxon) Research Laboratory in Linden, NJ, where I was mostly involved in ship-board testing of lubricants but inevitably became exposed informally to oil exploration, recovery and refining issues during numerous informal encounters with experts from these vital areas of research employed by the company.

During 1972-73, I had a sabbatical leave with a Guggenheim fellowship. During this leave, I traveled around the world in search of advice from the large number of experts whom I

[1] Invited lecture prepared for the July 2008 meeting of Doctors for Disaster Preparedness (DDP) in Phoenix, AZ.

arranged to visit in order to gain a perspective on what an engineer or applied scientist needed to work on for the common good. Our travels took us first to London (with side trips to Oxford and Cambridge), then to Aachen to visit the renowned School of Aeronautical Engineering which Th. von Kármán had founded before moving to Caltech in 1930. A brief skiing holiday was followed by visits to Milano, Rome and Naples, a four-week stint at the Technion in Haifa (Israel), a few weeks each in Teheran (Iran) followed by the Tata Institute in Bombay now Mumbai (India), Hong Kong, Tokyo and a number of top-rank Japanese Universities, then the University of Western Australia in Perth where we lived on campus and I lectured and studied in the Department of Mechanical Engineering for about 4 months, then to the University of Sydney in Australia and finally to Auckland, New Zealand. When I flew home from Auckland via American Samoa, I reflected on what I had learned in the innumerable discussions with many intelligent people about what was the most important topic for research to meet human needs for the future, it became almost obsessively clear to me that I had to work on assuring the adequacy of energy supplies for all people everywhere if I wanted to contribute to the well being of future generations. No other single topic was even remotely competitive with this firm conclusion.

I was fortunate to have a three-way discussion on the second day after y return to La Jolla with then UCSD Chancellor William McElroy and Vice Chancellor for Academic Affairs Paul Saltman. Our nearly immediate conclusion was that we needed to establish an Energy Center at UCSD and that as Director of this newly organized research unit, I needed to work on adequacy of supplies, costs and economic issues, trade and security issues, that reducing the levels of energy use in affluent societies without impacting income and economic growth was as important as finding new supplies, that I had the obligation to develop classes at various levels of sophistication to train professional experts who would guide future developments in the US of appropriate and private sources would be mine. This decision was made in June 1973 and although formal approval from the UC hierarchy was more than a year away, the UCSD Energy Center began to function in some manner on the day after we three enthusiasts had decided to launch the UCSD Energy Center. I taught the first UCSD energy course at the sophomore level in the fall of 1973, ably assisted by graduate student Larry Icerman who became my co-author on the first two of our 3-volume series of introductory textbooks dealing with energy issues. The complete sequence as originally published is listed in

Table 1.
Books published by Addison-Wesley Publishing Co, Inc., Advanced Book Program, on the texts developed by the UCSD Energy Center (1974-76)

Volume I by S.S. Penner and L. Icerman	Demands, Resources, Impact, Technology, and Policy, 1974 (2nd printing, corrected, 1976)
Volume II by S.S. Penner and L. Icerman	Non-nuclear Energy Technologies, 1975 (2nd printing, revised and updated, 1977)
Volume III by S.S. Penner et al.	Nuclear Energy and Energy Policies, 1976

Because of the imminence of the Arab oil embargo, student interest in energy issues was very high. I remember presenting my initial lectures to about 250 sophomores and juniors in a hall designed for occupancy by about 180 students.

I will now turn to the topical areas that remain as important in 2008 as they were in 1973 when our energy-supply assessments began.

2. The Political Environment

In a TV interview, two evenings before the Indiana and North Carolina presidential primaries, Senator Obama provided measured replies to important energy-related questions, which reflect especially the political biases of his advisors. On the issue of biomass diversion for alcohol production, he provided unequivocal support for food production above transportation-fuel production but then muffled his laudable preference to feed people by the addition of a statement on available non-food crops for fuel production. Regrettably, his advisors had apparently not provided quantitative data on these mostly non-existent resources. On the issue of resurgence of nuclear power production, he expressed general support for this program if we can safely dispose of the (radioactive) waste. He did not mention repeated studies performed through the National Research Council by highly competent scientists and engineers who had concluded with the assertion that safe long-term storage could be accomplished in stable geological strata at identified locations in many parts of the US and abroad. His opponent, Senator Hillary Clinton, on the other hand, assured her supporters that the liquid supply deficiencies reflected shortcomings in the activities of the major oil companies which should therefore be held responsible for their misdeeds and made to pay the sales taxes for all liquid fuels purchased during the 2008 summer months. An especially benign comment was made by Senator McCain speaking more about global warming than about energy-supply deficiencies when he asserted that even if we are wrong about these ideas, we will leave a better world for our heirs.

The composite impact of the noted statements by our political leaders provides some indication of the sources of our problems and the frustration which any reasonably well informed energy specialist must feel on listening to statements about technical issues relating to the US "energy-supply crisis".

3. Energy Conservation

We learnt during the Carter administration that there were many opportunities for implementing energy-conservation measures without undesirable side effects. Accomplishing missions more efficiently is what engineers like to do. In fact, they work as a bridge between technology based of scientific knowledge and society, as eloquently proclaimed by the publication entitled "The Bridge" of the National Academy of Engineering.

My very first programs in the energy arena dealt especially with energy conservation for the simple reason that the local electric utility was constrained by California law to make financial awards for research on energy conservation to universities. Thanks to Otto Hirr of the San Diego Gas and Electric Company, I started the UCSD Energy Center (now called Center for Energy Research and primarily occupied with transferring fusion reactors into operating electric power-supply systems) with generous funds dedicated to increasing efficiencies in any and all types of technical processes.

It is, of course, very easy to tell when a technological system operates more efficiently after modifications than before. But, it is not so easy to see if a change was effective when humans are involved because human reactions may impact system efficiencies in unpredictable ways.

We had programs designed to reduce both electricity use and home-heating requirements. For these purposes, proper design and use of window coverings (fenestration devices) is of special importance, including the use of shade trees at preferred locations. We performed numerous theoretical and experimental studies before we were ready to implement field experiments. Our initial field experiments involved examinations of air flows into and out of homes in poorer neighborhoods of East San Diego County. The field measurements were performed by enthusiastic undergraduates who were among the first enrolled students in what became the succession of classes for whose uses we wrote a 3-volume series of books on energy supplies, uses, conservation, and economics. Our group of 15 to 20 undergraduates worked under the direct supervision of graduate students who had enrolled in one of our engineering areas of specialization such as mechanical or aerospace engineering since we did not offer graduate-degree programs in energy technologies. Our students carefully identified leaks, opportunities for clever uses of shade trees during the hot seasons, and spent many hours improving home air flows to reduce energy use during both the cooling and heating seasons. After about 3 years of education, field study and remediation, we were satisfied that we could prove the value of our activities by demonstrations of reduced energy use.

The efforts to demonstrate success in the field provided us with important insight concerning the futility of working on energy technologies in isolation as preferred vehicles for conserving energy. Our students working on field data to demonstrate reduced energy use in houses with clearly reduced leakages examined the utility-sales records and found that during the cold season, energy use had increased rather than decreased and that during the hot season, electricity use for air conditioning had increased rather than decreased. How could we explain these unexpected changes?

The answers turned out to be consistent with what homeowners told us. During the heating season with substantial reductions in cold-air inflows, thermostats had been set to higher temperatures in order to increase interior comfort levels whereas, during the cooling season, room temperatures had been set to lower temperatures than before our studies again for the purpose of raising comfort levels.

In summary, our early efforts had increased home comfort levels as the result of small increases in energy uses for heating or cooling but had not led initially to a substantial reduction in fuel utilization! Needless to say, during subsequent years, decreased energy use was achieved together with improved comfort levels when the levels of energy use were carefully tailored to reduce energy consumption.

During the next four decades until the present date, energy conservation, as reflected by improved technologies, has been a major success story in all areas of activity beginning with improved home designs, followed by energy-efficient utilities, energy-efficient light bulbs and electronic devices, energy-efficient automobiles (I bought my first hybrid Prius in 2002 which was the second year of production for these vehicles because, as a conservative engineer, I like to see radically new designs tested in the field before committing myself to their purchase and use), greatly improved and more efficient aircraft engines, more energy-efficient electronic devices of all types, etc, etc. This technology-driven increase in energy efficiencies is very far from complete and a great deal more can be and should be done to improve efficiencies in all segments of our societies from crop-growth efficiencies to improvements of every kind of device used. Some of the anticipated improvements may be small, some may be significant but the overall effect will surely be savings that will surprise even the optimists among us.

4. Biomass Conversion to Fuel Use

The idea to use biomass as a source of transportation fuel figured prominently in the efforts during the Carter administration to reduce US dependence on oil imports from foreign countries. Good ideas came from many inventors but realization of useful results failed when practical implementations in the real world were attempted. As an example, Melvin Calvin (who was awarded the Nobel Prize in Chemistry in 1961 for his contributions to understanding how carbon dioxide is assimilated by plants during photosynthesis) had found a desert plant which produced during its life cycle organic molecules that were suitable precursors for the production of gasoline-like mixtures. During many discussions with Calvin, the inevitable question of price in the market place for these products was repeatedly raised. Calvin was right that with zero cost for land use, a competitive product could be produced. Unfortunately, further estimations showed that all of the usable land was owned by someone who wanted a fair rental or sales price for the use of property. When this requirement was factored into the evaluations, gasoline substitutes extracted from Calvin's preferred plants turned out to be prohibitively costly.

During my many years in the energy-supply area, the question of using biomass for the production of fuel substitutes recurred repeatedly. About 10 years ago, while I served as Section Editor on fossil-fuel supplies for the Encyclopedia of Physical Science and Technology, I became acquainted with the work of David Pimentel (now Professor Emeritus of Entomology and Environmental Quality at Cornell University) who showed eloquently that the competition for land used to grow food supplies or energy crops would inevitably lead to unacceptable food shortages. After publication of the Encyclopedia,[2] I received irate phone calls for accepting Pimentel's carefully constructed analysis (one call was from as far away as Italy) objecting to the inclusion in a scholarly paper the idea that available arable land, growing world populations, and limiting land use for food production would soon lead to price escalation and aggravate world-wide hunger. We all have current knowledge that Pimentel's concern about interfering with land-use for crop production was very much on the mark in view of recent escalation of food prices and threatening famines in many parts of the world while the biomass-to-transportation programs remain at the research levels and the real impacts of land-use diversions for energy production have not even begun to be felt on a significant scale. We can only hope that Senator Barak Obama's science advisors can find in abundance the promised special biomass sources that will not adversely affect the world's food supplies before the biomass-to-fuel efforts are again condemned to the ash-heap of history as they were during the 20th century.

Fortunately, there has been progress on the scientific research front that may deter significant diversion of land-use for fuel production. There is an interesting research conference dealing with energy issues in Europe (under the leadership of Sergio Ulgiati who is now at a University in Naples), which I have been privileged to attend a number of times. In preparation for the 2008 conference at the University of Graz, Austria, I was asked to review the abstract of a paper dealing with production sustainability of biodiesel from soybeans in Brazil. The authors are O. Cavaletti and E. Ortega from the State University of Campinas, Brazil. The authors' conclusions are that "biodiesel production from soybean as proposed and implemented until now is not a sustainable alternative… and ... large-scale production puts high stress on the environment and biosphere. Furthermore, the renewable fuel fraction is only about 30% of the input level fraction."

I worked for many years on waste-to-energy systems, especially while serving on the Board of Directors of Ogden Corporation when this company was the world's dominant constructor of waste-to-energy systems (for details, see my article "Waste to Energy Systems" in the Encyclopedia of Physical Science and Technology, third Edition, Volume 17, pp. 631-638, Academic Press (2002)). Use of this technology in the US was terminated because of what may well have been unsupportable limitations placed on toxic dioxin emissions, unsupportable at least when the toxic emission levels were below the ambient toxic dioxin levels. The waste-to-energy systems deserve a renewed look for applications in the US while active research and development is occurring in many less developed countries. Waste-to-energy implementation is not a total solution but a potentially useful contribution at the 5 to 10% level for the total usable energy supplies.

7. Coals and Unconventional Fossil Fuels

Because of the abundance of coals, oil-carrying shales, and tar sands among US-based resources of fossil fuels, these were identified as preferred options to supply US needs during and after the Carter presidency. As chair of the DOE Fossil-Energy Research Working Group

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[2] The Encyclopedia of Physical Science and Technologies, Third Edition, Volume 17, Academic Press (2002).

(FERWG) for nearly 10 years, I was privileged to learn about the resource base and study the available recovery methods in the US and abroad on the basis of resource-availability and understood resource-recovery technologies. In view of major programmatic developments, these activities should have solved the US energy-supply requirements for about the next 500 years. That this did not happen must be attributed to a number of negative factors which we will now enumerate.

(i) The first impediment was the obvious economic fact that energy-recovery costs with adequate environmental controls were necessarily far above those for oil and natural gas supplies from world-wide sources. When using these identified rich sources for comparison, unconventional fossil fuels could only enter the market with imposition of a high cost structure through selective taxation of conventional fossil fuels. This requirement did not receive either consumer or industry support.

(ii) What was called the synthetic fossil-fuel industry was under constant but unfounded attack by environmental zealots. Among the opposition arguments were distortions such as the following: (a) The net usable energy derived from shale-oil recovery is negative. This particular issue ultimately became the subject for a dedicated sponsored workshop under my direction at which the error of the suggested negative net energy for shale-oil recovery was clearly demonstrated but with no ascertainable impact on government or company programs. There were influential opponents to unconventional fossil-fuel use for many reasons ranging from the fallacious idea of net energy loss to irreversible land degradation to objections on the grounds that these programs would lead to unsustainable world-population growth because minimal food and water requirements might not be met with water diversions to preferred locations for fossil-fuel plants. The recovery programs from the Athabasca tar sands in Alberta, Canada, were cited as technologies with irreversible and disastrous environmental impacts although these programs remain in progress and continue to yield large returns on the investments made to this day.

In the US, large fossil-fuel resources (enough for more than 500 years of likely requirements) remain unused while we subsidize oil-rich nations with huge price hikes over which we have no control.

New brands of biomass are being sought now for exploitation. These were talked about but not adequately described or evaluated during the last century. Examples are utilization of algae, plants grown in canals, mid-ocean plantations, etc. University-based pundits play with such doomed ideas and government research administrators supply the needed funds because no better approaches have been identified for the large-scale utilization of solar energy for making fossil-fuel substitutes.

The U.S. coal-science development programs received a significant boost from an exchange visit to Beijing, China, where a US delegation held extended discussions with Chinese coal-science experts during several days of meetings followed by brief exchanges of views in other Chinese cities. I served as a chair of this US delegation which arrived in China not long after President Nixon and Secretary Kissinger had re-established relations between our two countries.

Coal is the fossil fuel of choice for electric power generation and its use, together with nuclear energy, provides most of the world-wide supply of electricity. Furthermore, coal is an important raw material for syntheses of chemicals and fuels. Clean-coal technologies have been under active development for decades but the costs involved are high and remain under current evaluation and assessment. A major study dealing with the issues involved is described in Section 18.01 on "Energy Resources and Reserves" in the Encyclopedia of Physical Science and Technology, where the author's views on resources and reserves are summarized. Many of the entries in Table 18.01 – 1 of this Encyclopedia are based on studies performed during the 15 year period when I served as chair of the DOE Fossil Energy Research Working Group and auxiliary government studies. The data in this table represent consensus results derived from studies performed by expert groups of specialists over a period of about 15 years. Without regard to costs, there is an evident abundance of riches and there are many options for supplying the world's ever growing appetite for energy supplies of all types.

The recovery of energy supplies in usable form is an ever-present technical challenge and may yield greatly different preferred options depending on imposed preferences dictated by environmental, health, financial, and political considerations. These numerous alternatives may yield greatly different preferred market designs which are likely to change with time. Examples which have been preferred at different times are the following:

(i) Low-cost domestic coals for electricity generation from easily recoverable domestic medium-grade and high-grade supplies with little consideration for environmental degradations caused by the use of these systems.

(ii) Total reliance on solar, wind, biomass and other renewable supplies.

(iii) Total reliance on long-lasting nuclear energy supplies in the form of fission reactors with safe storage of radioactive wastes for unlimited millennia.

(iv) Future use of Generation IV nuclear reactors with secure waste storage.

(v) Future use of nuclear breeder reactors.

(vi) Future use of fusion reactors.

In actual fact, no ideal long-term solution has ever been identified. Since lowest-cost supplies must always be preferred if their availability is assured, we must necessarily converge on a mixed cocktail of energy supplies, varying with location and time, subject to different security requirements which are themselves subject to change as the levels of technological optimization change with time and social or health or political or other estimates may impact our current and long-term goals.

It is this multiplicity of possible options with doubtful costs and often variable or at least difficult-to-assess social and environmental implications that is the root-cause of uncertainty in the energy-supply markets. The allowable options are further multiplied by new findings when any particular approach is changed from the status of a minor contributor to a major supply source.

8. The Nuclear Option

In view of the rapid escalation of prices for fossil fuels and also of food products, it is appropriate to examine the status of energy supplies for the world as a whole since the countries of the world have become so interlinked that it is no longer useful to consider a single country in isolation. We have noted that the US responses to escalating costs have been similar to those that occurred during the oil embargo of the Carter presidency with similarly dismal results except for the penetration of energy-conservation measures which have proved to be useful and desirable in both cases. By contrast, the heavily subsidized measures designed to replace the use of fossil fuels by utilizing "energy crops" are failing as dismally during the present time as they did during the nineteen seventies and eighties while substantial growth of nuclear power generation in the US remains mired by inaction which continues to be motivated by presumed storage difficulties of nuclear wastes and flaws in nuclear power-plant designs that are more strongly related to technical errors made in the past than to the technological designs that have evolved in recent times. Thus, the illusions persist that were publicized after the accidents at Three-Mile Island (no fatalities) and Chernobyl (many casualties at the facility but far fewer cancer deaths than originally estimated for this faulty design without containment vessel which has always been used in Western plants). Administrative failures to demonstrate long ago that we have technologies for the long-term safe underground disposal of radioactive wastes, as proposed by successive expert reviews in National Research Council studies, has allowed the legend to persist that safe underground disposal is a continuing technical problem beyond our engineering competence. Equally wrong is the persistent construction delay of Generation IV nuclear reactors. These systems cannot contribute to nuclear weapons proliferation because the spent fuel contains less plutonium than ambient uranium ore. Instead of firm administrative leadership to proceed with reactor construction at the known bounds of our understood technologies, the US has slipped into the lower world ranks of nuclear reactor constructors by procrastinating to support the required technologies for demonstrating that improved designs have become available with passively safe features (i.e., these reactors are safe because utilization of known laws of physics allows reactor operations and shut-downs without human interference in case something goes wrong). Other flawed arguments that are popularly fed to the public involve "shortages" of raw materials for nuclear reactors without new discoveries made by "experts" who like to forget about the potential development of breeder reactors, with known supplies actually lasting for a sufficiently long period of time of the order of 3 to 5 billion years which approaches estimates for the length of human habitability in our solar system before the planets are engulfed and disappear under a solar embrace as the sun cools and expands.

A preliminary description of nuclear energy opportunities and design for Generation IV nuclear reactors was presented at a DDP meeting a couple of years ago and has since become available in final form on the Internet and has also been published in an archival journal (see Science Direct or Progress in Energy and Combustion Science (2008) for "Steps toward passively safe, proliferation-resistant nuclear power" by S.S.-Penner, R. Seiser and K.R. Schultz).

The weekly publication of the American Chemical Society is "Chemical and Engineering News (C&EN)." The May 5, 2008 issue contains a summary of the views of a number of authors by J. Johnson of C&EN entitled "The Forever Waste (A Long View of High-Level Radioactive Waste Raises Ethical Questions of Intergenerational Responsibilities") and supports the text with photos of the presumed originators of these ideas, namely, A. Makhijani (Director of a non-profit "Institute for Energy and Environmental Research"), Richard A. Meserve (Carnegie Institution and Former Chairman of the Nuclear Regulatory Commission), Milton Russel (Economics Professor Emeritus and former EPA Assistant Administrator), and Robert W. Fri (Vice Chair, Resources for the Future). There is no mention of the next Generation 4 types of nuclear reactors which are expected to be passively safe and do not produce plutonium levels in the spent wastes that are greater than those in naturally occurring uranium. As the result, we learn that one or more of the cited experts remain(s) worried about "mining"of the spent wastes for weapons-grade materials while they remain opposed to " nukes" by whatever means they can imagine a calamity to occur.

9. Breeder Nuclear Reactors and Fusion Energy

Very long-term energy-supply resources that can supply all of the world energy needs for as long as our planet has been estimated to provide a habitat for humans and other species (about 3 billion years) are available from both nuclear breeder or fusion reactors.

Breeder nuclear reactors have been tested successfully at full scale in France but near-term commercialization of breeder reactors was terminated in most countries because the price for uranium ore dropped greatly and thereby made breeder reactors non-competitive with conventional nuclear reactors. A multi-author summary of the status of breeder reactors was compiled with contributions from experts in the US, UK, Germany, France, Russia, and India (see "Advanced Nuclear Reactors, Current Developments and Future Prospects, edited by E.L. Zebrosksi, C.-P. Zaleski, M. Simnad, C.C. Baker, and S.S. Penner, Elsevier, Oxford 1998, Part I).

The development of functioning fusion reactors continues especially under the international cooperative ITER program. With guidance provided by the distinguished theoretical physicist Marshall Rosenbluth during his lifetime, experts from many countries continue the challenging work to build an operating prototype in France (although more than 40 years of previous work has not yet led to a functioning system). Fusion energy unlike nuclear energy from breeders will not lead to radioactive waste materials with very long active lives which are costly to isolate and dispose off before natural decay of high levels of radioactivity makes these systems relatively safe for

Management. Fusion energy is discussed in Part II of the above cited reference by C. C. Baker, R. W. Conn, F. Najmabadi, and M. S. Tillack. Unfortunately, a very recent examination of the proposed ITER entry system to assure operational safety led to the conclusion that there are many remaining opportunities for improvements (see Science, week of June 13, 2008). In response to the question asked, there are always at almost any stage for of development of a new technology "opportunities for improvements," which if followed carefully may delay a promising new technology indefinitely and cause cost escalations which may even lead to support cancellations by one or more sponsors. Since fusion reactors are one of only two long-term solutions for indefinite adequate supplies of clean energy with adequate care and some luck, possible deferral of this technology to make improvements is not a happy development.

10. Small and Possibly Dominant Contributions to Future Energy Supplies

Our summary of energy-supply options is incomplete because many currently minor contributing technologies and also possibly major new supply sources have not been mentioned.

Among currently used minor supply sources are geothermal energy, tidal and wave-energy electricity generators, wind-energy sources, photovoltaic power-conversion devices, etc. all of which have a long history of utilization but have shown only minor growth in the real world because of high costs, undesirable environmental impacts, resource limitations, etc. Much larger near-term supply sources are fossil fuels in the forms of methane hydrates, shale oil, tar sands, etc. These fossil-fuel variants have either not been developed to the point of low-cost trials (e.g., methane hydrates) or have been used in select locations with good success (shale oil, tar sands, etc.) but could not be commercialized world-wide because conventional fossil fuels (oil and natural gas, coals, etc.) were cheaper and easier to manage in most locations. Resource assessments for these fossil fuels suggest collectively supply possibilities for more than 500 years.

I did not include biomass conversion among the hopeful list because the more we learn about the impacts of these commercialization efforts, the less likely they seem suitable for large-scale developments because of interference with needed affordable food supplies and unanticipated environmental upsets. As an example, I cite a recently shown film on "Deutsche Welle (DW TV)" dealing with the triumph of making the German city of Uelzen self-sufficient by using no conventional fossil fuels such as coal or oil or natural gas but only renewable biomass in the form of palm oil imported from Indonesia. The darker side of this enterprise shows extensive rain-forest destruction in Indonesia with the associated large decrease in carbon-storing capacity, grim pictures of the threatening extermination of the native orangutan with efforts to help the species by relocating the young in Malasia, the decline of human native tribes who are threatened with failure to survive, and, of course, the inevitable cost escalation of food and other products for which palm oil is an essential ingredient and including also such a vital cosmetic commodity as lipsticks for ladies.

11.Addenda

Some expertise and useful background information relating to the entire previous discussion may be obtained by studying the tutorial entitled "What you need to know about ENERGY" prepared by the National Academies (see www.national-academies.org), 2008.

Some of the views on biomass conversion by experts remain more optimistic than those expressed in this presentation as is exemplified by a series of recently published letters in SCIENCE (see pp. 1419 to 1422, in the June 13, 2008 issue of the magazine).