The Energy Wars: Some Lessons Learned

The nation's energy crisis gets quite a bit of attention. Consider the headlines:

- Petroleum prices are skyrocketing, rising several fold in the past few years.
- Petroleum reserves and refinery capacities have dwindled causing gasoline shortages and lineups at the pumps.
- The federal government has launched major new R&D programs to develop alternative energy technologies such as solar, wind, biofuel, and geothermal power while increasing emphasis on nuclear power development.
- Congress has passed a several hundred million initiative to conduct the R&D necessary to put electric vehicles on the road in a few years.
- The automotive industry is researching non-petroleum options, including all-electric vehicles. (General Motors has announced a bold program to put an all-electric car in every showroom across the country.)

Actually, one of our faculty members, Jerry Mader, pulled these headlines from newspapers of 30 years ago…in the wake of the OPEC Oil Embargo and other energy shocks of the 1970s.

This brought back many of my own memories from the 1970s

- During a visit to the GM Technical Center, I recall its director boasting that "as long as the American automobile industry can put a car on the showroom floor for fewer dollars per pound than anyone else in the world, we'll be dominant" (Unfortunately, we were to learn in the 1980s that folks don't buy cars by the pound…and in the 1990s…that most don't buy them by the horsepower rating either…)

- I remember the GE Carousel of Progress at the 1964 New York's World's Fair…(and today still a relic at Walt Disney World)…portraying "a great big wonderful tomorrow", powered by limitless, cheap electricity.

- A conversation with Harold Shapiro on energy, where he reassured me "not to worry", that economics would cure all our energy problems, since energy shortages would drive up energy prices, enabling further investment to increase supply…

- Back in those days the nuclear power industry was projecting that the nation would be building over 1,000 nuclear plants in the United States before 2000. In fact, Michigan had five in operation, three more under construction, and four more in the advanced planning stage (which would have provided over 50% of our electricity). Bechtel was the largest employer in Ann Arbor, with over 1,000 engineers designing nuclear power plants through the Midwest.

- I had just finished "starring" in a television series on nuclear power, scheduled in 1979, but unfortunately it was scheduled to first appear the week of Three Mile Island! (We had to retape the program on nuclear reactor safety…)

But with OPEC, long lines at the gas pump, and finally Three Mile Island, it was also increasingly clear that while every aspect of contemporary society is dependent upon the availability of clean and affordable energy resources, these were at considerable risk.

Both Presidents Ford and Carter conveyed a sense of extreme urgency for the energy challenge ("we must deal with energy on a war footing") and proposed major new programs to develop new energy sources.

So where do we stand 30 years later?

At the National Level

1) The urgency of the 1970s soon disappeared as OPEC opened its pipelines and oil began to flow once again…and the efforts to develop new technologies faded away. In fact, over the past 30 years, the federal government has actually reduced energy R&D by 75%, the electrical utility industry down by 50% (EPRI), and shareholder pressure for short term earnings has eroded the capacity of great industrial research laboratories such as the Ford Scientific Laboratory and General Motors Research Laboratories.

- As one of my colleagues put it, when the OPEC crisis receded, the leaders of industry and government put their concerns and plans in their drawers, forgot about the crisis, and went out and started playing golf again.

2) Just as M. King Hubbert predicted, domestic U.S. petroleum production peaked in the mid 1970s, while demand continued to rise by 40% over the next two decades.

- As a consequence, today over 60% of our petroleum is now imported, with over 90% of it controlled by governments in politically unstable regions such as the Middle East.

- Rapid increases in gasoline prices have brought the American automobile industry to its knees, as a combination of burdensome labor costs and corporate myopia have inhibited their capacity to compete with the high fuel efficiency products of foreign companies.

3) Nuclear power has also been in a state of suspended animation, with no new plant orders after the late 1970s, even though the 103 plants currently in operation not only provide 20% of the nation's electricity but do so at costs considerably below those of any other energy source including coal.

(And Michigan today has only four nuclear plants, all approaching the end of their initial 40 year operating licenses.)

- EXAMPLE: JJD Textbook
  - 30 years ago I wrote a popular textbook on the subject of nuclear reactors.
  - This summer I got a recall from the publisher that since the book was still selling well, and nuclear power was about to take off again, would I be interested in doing a new edition!
  - I continue to get inquiries about the problems in the text from places like Japan, India, Korea, and…Tehran!

4) And despite what Big Oil tells you, global warming is real and it is likely here to stay. To quote the recent Intergovernmental Panel on Climate Change report:

- "Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values The global increases in carbon dioxide concentration are due primarily to fossil fuel use and land-use change."

- As John Holdren, president of the AAAS puts it, "We are not talking any more about what climate models say might happen in the future. We are experiencing dangerous human disruption of the global climate, and we are going to experience more. Yet we are not starting to address climate change with the technology we have in hand, and we are not accelerating our investment in energy technology R&D."

5) And, throughout it all, our political and corporate leaders continue to back into the future, blind to the degree that our American addiction to increasingly expensive foreign petroleum is not only obliterating our national competitiveness in key industries such as automobile and airlines, but driving us into international conflict (Iraq), while putting future generations at great risk of global climate change.

Closer to Home in Michigan

Unfortunately, we see the consequences of the past three decades of neglect in our state. Welcome to the poster child for the “flat world”…

- In the latest index of economic momentum (quarterly changes in personal income, employment, and production), Michigan ranks dead last among the states.
- Michigan unemployment leads the nation. The state has weathered six consecutive years of net job losses, the longest strength since the great Depression of the 1930s.
- Michigan has lost 246,000 or 25% of its manufacturing jobs since 2000.
- The Big Three’s share of domestic auto sales plummeted from 74% in 1993 to 54% in 2005. By 2011 the domestic share is predicted to drop to 45%.
- Michigan’s per capita income is now 5% below the national average and the lowest point it has been since 1933.
- Detroit has become the nation’s poorest city.
- Michigan leads the nation in the out-migration of young adults seeking better opportunities elsewhere.

Michigan’s economy, just as the national economy, has been based on the availability of cheap energy. Furthermore, every aspect of life in our state is dependent upon the availability of clean, affordable, flexible, and sustainable energy resources.

- Michigan currently spends over $20 billion each year on imported energy (oil, gas, coal, uranium).

- More specifically, our current transportation industry is heavily dependent on the availability of petroleum, over 60% of which is imported, predominantly from unstable regions such as the Middle East.
- The unsustainable nature of current energy technologies (fossil fuels) puts at great risk Michigan's existing industry and future economic prosperity.
- Over 500,000 Michigan jobs, directly or as a multiplier, are dependent upon energy and related industries (e.g., transportation and electrical power generation).
- Spiking of gasoline prices to Asian and European levels (currently $6 per gallon and above) would likely obliterate what remains of the American automobile industry, since it is unlikely that domestic companies would be able to shift rapidly enough to the small, fuel-efficient cars produced by Asian manufacturers or adept enough to exploit hybrid, electric, or hydrogen fuel technologies.

The situation is almost as serious throughout the Great Lakes region,

- From Pennsylvania to Minnesota, Cleveland to Detroit to Chicago, the question is the same: In an increasingly knowledge-driven global economy, what will replace factory-based manufacturing as the economic engine of future prosperity in the industrial Midwest?

- While this region benefited greatly during the 20th century in being the manufacturing center of the world, today's global phenomena such as outsourcing and off-shoring have destroyed the viability of low-skill, high-wage manufacturing jobs–and even threaten to displace many high-skill service activities–as a source of prosperity and social well-being.

- As characterized in a Brookings Institution study of the region, "Today the economic giant of the Great Lakes region stands with one foot planted in a waning industrial era and its other foot striding toward the emerging global knowledge economy"

Again, energy is a key factor, since the 20th century prosperity of this region was based on high energy industries such as manufacturing and high energy products such as cars and trucks.

- Today, manufacturing industries of the Great Lakes currently utilize 38% of the nation's electricity, produced primarily from coal-fired plants. Should electrical power generation from fossil fuels be sharply curtailed or should prices skyrocket through regulatory requirements for carbon sequestration, there is little likelihood that our remaining industrial capacity would remain competitive in the global economy.

- (By the way, I should also note that it provides roughly 30% of the electoral votes necessary to elect a new president…a feature that should not go unnoticed after the close elections of 2000 and 2004…)

So why did this happen? Why is the energy crisis even more serious today, some 30 years after the nation and its leaders claimed to recognize and address the challenge?

Of course, some of the reason for our failures in energy policy and action have to do with:

1. Downright foolishness and irresponsibility: Industry

- Big Auto using its political pressure to push back against more stringent mileage and emission standards (and its advertising clout to push gas-guzzling SUVs and light trucks where they made the most profit)

- Big Oil using its political clout to get tax breaks and international actions (e.g., Iraq) to keep the oil and the profits flowing, and in the process destroying major industries such as automobiles and air transportation.

- And, of course, using its hired guns to suppress the growing evidence of global warming from fossil fuels, in a manner almost as reprehensible as Big Tobacco denying nicotine addiction and the health implications of smoking.

2. Extraordinary myopia: Federal and State Government

EXAMPLE: DOE's effort during the Clinton administration to kill nuclear power by zeroing out R&D.

- DOE mafia of anti-nuclear policy wonks

- Note that if it had not been for Senator Pete Domenici and Michigan's own Congressman Joe Knollenberg (and Judy Biggert), the entire U.S. nuclear R&D program might have disappeared during the 1990s.

- Fortunately, PCAST eventually intervened and demanded the White House keep alive the nuclear option.

- But the residue of insanity remains, as DOE is still trying to kill off any effort to support education in nuclear science and engineering, despite the fact that a massive turnover in these fields with retirements over the next decade in both industry and the federal government.

- Electrical energy production remains heavily regulated at the state level, in which public service commissions are politically pressured to keep utility rates too low to allow the capital investments necessary either for new energy development or ongoing maintenance (e.g., transmission systems).
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- Several states have stumbled badly in moving toward deregulation of energy to allow the more efficient operation of markets–California and Michigan being two notable examples–confusing the industry even further

3. Penny wise and pound foolish

- As we heard yesterday from Keith Trent of Duke Energy, in many if not most cases, it is far less expensive to improve energy efficiency than build additional supply. The problem is that without a major overhaul of government policy (e.g., regulation of utilities), there is little incentive to do this in many areas.

- As Secretary Bodman noted yesterday, the administration has proclaimed energy R&D as a priority through their new advanced energy initiative with proposed funding of $2.7 billion. But compare this with $17 billion in the NASA budget, $30 billion in the NIH budget, or $83 billion in the DOD R&D budget to get a better sense of the real research priorities of the federal government.

- Universities also deserve their share of blame, for example by discontinuing nuclear engineering programs or decommissioning research reactor facilities even as the nation looks to a major rebirth of nuclear power as an important clean energy option. (Of course here Michigan is not alone, since two-thirds of the 67 university reactors have been shut down over the past 20 years.)

4. And, of course, some of this was just the “not on my watch syndrome”

- Corporate executives and government leaders with the attitude that by the time the real energy crisis takes hold, I’ll be outta here and retired in Florida… or Texas (although they could well find themselves underwater with the projected rise in the sea level with global warming or surrounded by desert from drought).
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- But, of course, our children and grandchildren will still be around…and they will be faced with the challenge of cleaning up the mess we leave behind from our procrastination and neglect.

Characteristics of energy itself:

Both Gary Was and Nate Lewis highlighted the particular characteristics that make it so challenging: magnitude, timescale, and complexity.

- Magnitude of investment

    - While it takes a watt to run a cellphone and a kilowatt to power a home, it takes a gigawatt (a billion watts) to power a small city–one nuclear power plant’s worth–or, perhaps in more understandable terms, an investment of about $2 billion in capital costs. An offshore oil platform runs as much as $5 billion.
    - Furthermore, it will require over $16 trillion in capital investments over the next two decades just to expand energy supply to meet growing global energy demands–compared to

global domestic product of $44 trillion and U.S. GDP of $12 trillion (and the total worth of the U.S. at $47 trillion).

  - Put another way, to track the project growth in electrical demand, we will need a new $2 billion gigawatt power plant every other day!
  - So what is our federal government proposing to invest in energy R&D next year? About $2.7 billion for the President's Advanced Energy Initiative, roughly one-sixth as much as NASA will spend on space R&D, one-tenth as much as NIH spends on medical research each year, and one-thirtieth as much as we will spend on weapons R&D. About two day's worth of the pace of energy investment needed by the world
  - Not exactly on a "footing with war", is it?

- Timescales (generations)

  - Energy transformations take time. It took centuries to switch from wood to coal; then another century to petroleum. Nuclear energy was a bit more rapid, evolving in about a generation from Fermi's "pile" to the nuclear power plants that now dot the landscape and the world–over 440 in number, contributing 20% of the U.S. and 16% of the world's electricity
  - But this is glacial speed, compared to more recent technologies such as computers and networks that double in power every year or so.
  - And it is glacial as well compared to the election timescales of politics or the quarterly earnings demanded by Wall Street.
  - Which naturally raises the question of how do we develop and implement and sustain an energy strategy over a time scale many times that of politicians and shareholders, not to mention the career of the scientists and engineers who develop and implement the technology.

- Complexity

- It is hard to imagine a technology more complex than energy, interwoven with every aspect of our society.
- Involving not simply technology and economics, but complex issues of social priorities, international relations, and politics, politics, and more politics.

Little wonder then that one commonly hears the complaint that "The energy crisis is like the weather…everybody complains about it, but nobody is able to do much about it!"

While I certainly do not claim to have any new or profound wisdom on the subject, let me be so bold as to share with you several lessons I have learned from fighting the energy wars over the past four decades…

Lesson One: To make any progress at all, you have to get serious about things. Simply ranting about it or making token investments will simply bounce off without a dent–although they might make things work.

- Key are actions that are both significant and sustained.
- Not like the past two decades, energy research has been sharply curtailed by the federal government (75% decrease), the electrical utility industry (50% decrease), and the domestic automobile industry (50% decrease).
- So where does one get the billions of dollars necessary for energy R&D? I could remind you that last month Exxon-Mobil announced the largest profits last year in American history, roughly $36 billion. However, the suggestion of windfall taxes on oil profits, even if intended to support R&D, would be akin to suggesting exploring nuclear options in the Middle East .
- Hence, instead, the key is to take action to deal simultaneously with the need to control carbon emissions, stimulate conservation, and establish a more realistic marketplace for energy alternatives by implementing a carbon tax–or possibly a cap and trade policy. There have long been suggestions of adding a $1 per gallon tax on gasoline to generate funds for R&D. Tom Friedman suggests an alternative of using taxes to set a floor of $3.50 for gasoline, thereby providing pricing predictability and generating R&D funds. Whatever… The funding is clearly available if the need is urgent. And most today feel it is!

Lesson Two: Today we need a much greater sense of urgency. Here I would only note two very large clouds on the horizon:

- Hubbert's Peak: Recent analyses of world petroleum production and known reserves suggest that global oil production could peak as early as the next decade (with gas production peaking roughly a decade later).

  - The consequence of passing over the global production peak is not the disappearance of oil; roughly half of the reserves would remain.
  - Rather it would be a permanent imbalance between supply and demand that would drive oil prices dramatically higher than today's levels–$100/bbl, $200/bbl, and beyond–with corresponding increases at the pump.
  - The rapidly increasing oil and gas demands from developing economies such as China, India, and Latin America make this imbalance even more serious, particularly when it is noted that the United States currently consumes 25% of world production.
  - A recent assessment by the U. S. Department of Energy in the spring of 2005 warned, "The world has never faced a problem like this. Without massive mitigation more than a decade before the fact, the problem will be pervasive and will not be temporary.
  - Previous energy transitions (wood to coal and coal to oil) were gradual and evolutionary; oil peaking will be abrupt and revolutionary." (Hirsch, 2005)

- Global Climate Change: To this should be added the increasing consensus that utilization of fossil fuels in energy production is already causing significant global climate change.
  - Evidence of global warming is now incontrovertible–increasing global surface and air temperatures, receding glaciers and polar ice caps, rising sea levels, and increasingly powerful weather disruptions, all confirm that unless the utilization of fossil fuels is sharply curtailed, humankind could be seriously threatened.
  - Although there continues to be disagreement over particular strategies to slow global climate change–whether through regulation that restricts the use of fossil fuels or through market pressures (e.g., "cap and trade" strategies)–there is little doubt that energy utilization simply must shift away from fossil fuels toward non-hydrocarbon energy sources.

Lesson Three: We simply must think and act far more boldly.

- Let's stop being penny wise and pound foolish and begin to make investments commensurate with the challenges before us.
- If we can waste a $100 billion on the International Space Station or a trillion dollars in Iraq, we can certainly invest considerably more to deal with the staggering crisis of building a sustainable energy future!
- More specifically, developing a sustainable energy future for the nation and the world requires a commitment comparable to the Manhattan Project, the Apollo Program, and the Cold War.
- It requires a total commitment on the part of the federal government, the states, industry, and higher education, as well as a much deeper understanding on the part of the American public.
- Finally, beyond dollars and technology, it will require a new generation of scientists and engineers–something that both the federal government and industry generally put last on their priority list!

Lesson Four: Brace yourself: We must be prepared for quite dramatic paradigm shifts.

Nate Lewis laid out the "experiment" we will be performing on Spaceship Earth over the next several decades–one that could determine the future of both the planet and of humanity itself.

But let me suggest another such paradigm shift–that in information and communications technology or "cyberinfrastructure".

So, beyond the fact that such cyberinfrastructure is increasingly dependent on energy infrastructure (just witness the growing number of megawatt generators in the parking lot of Internet2 in south Ann Arbor), what else might this technology suggest?

Remember, while energy infrastructure evolves on timescales of a generation, the new technologies driving such profound changes in our world–technologies such as information technology, biotechnology, and soon nanotechnology–are characterized by exponential growth.

When applied to microprocessor chips, this remarkable property, known as Moore's Law, implies that every 18 months computing power for a given price doubles. And for other elements of digital technology, such as memory and bandwidth, the doubling time is even shorter: 9 to 12 months. Scientists and engineers today believe that the exponential evolution of these microscopic technologies is not only likely to continue for the conceivable future, but in fact, the pace may be accelerating. (Computer engineers call this "riding the exponential", since whichever parameter is increasing the most rapidly determines the characteristics of the technology.)

Put another way, digital technology is characterized by an exponential pace of evolution in which characteristics such as computing speed, memory, and network transmission speeds for a given price increase by a factor of 100 to 1000 every decade. Over the next decade, we will evolve from "giga" technology (in terms of computer operations per second, storage, or data transmission rates) to "tera" to "peta" and eventually "exo" technology (one billion-billion or 10^{18}).

Put another way, in the 30 years that it will take to transform our energy infrastructure, info-bio-nano technology will increase in power a billion-fold!!

By 2020 the thousand-dollar notebook computer will have a data processing speed and memory capacity of petaherz, roughly comparable to the human brain (Kurzweil, 1999). Furthermore, it will be so tiny as to be almost invisible, and it will communicate with billions of other computers through wireless technology.

EXAMPLE: Intel's recent announcement of a teraflop chip, requiring only 62 watts (rather than the megawatt required before this).

Compared to today’s technology, we can assume that within a decade we will have available infinite bandwidth and infinite processing power (at least compared to current capabilities). We will denominate the number of computer servers in the billions, digital sensors in the tens of billions, and software agents in the trillions. The number of people linked together by digital technology will grow from hundreds millions to billions. We will evolve from “e-commerce” and “e-government” and “e-learning” to “e-everything,” since digital devices will increasingly become predominant interfaces not only with our environment but with other people, groups, and social institutions.

Beyond acknowledging the extraordinary and unrelenting pace of evolution of this technology, it is important to recognize that it is disruptive in nature. The impact on social institutions such as corporations, governments, and learning institutions is profound, rapid, and quite unpredictable. As Clayton Christensen explains in *The Innovators Dilemma*, while many of these new technologies are at first inadequate to displace today’s technology in existing applications, they later explosively displace the application as they enable a new way of satisfying the underlying need.

While it may be difficult to imagine today’s digital technology replacing human interactions, as the power of this technology continues to evolve 100- to 1000-fold each decade, the capacity to reproduce all aspects of human interactions at a distance with arbitrarily high fidelity could well spell the death of distance–and perhaps even of today’s transportation technologies and the manner in which we utilize energy.

Remember, such profound developments are likely to occur on the same timescales that we now are planning for the transformation of our energy infrastucture!

Put another way, during one “tech turn” in energy, info-bio-nano technology will, under truly explosive exponential change, increase in power a billion fold!

So, what to do?

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Well, let me tell you what we're trying to do!

Fifty years ago, the University of Michigan made one of the most extraordinary commitments in the history of American higher education. In the aftermath of WWII, it sought to build a memorial to honor the 579 members of the University community who gave their lives for their country.

Interestingly enough it was students themselves, many of them veterans of the war, who proposed the appropriate memorial. Rather than building "a mound of stone, the purpose of which might be soon forgotten", they proposed building as a living memorial, a research effort, known as the Michigan Memorial Phoenix Project, that would conduct research and education on the peaceful applications of atomic energy. Just as the atomic bomb had ended the war, the students sought to create from its ashes the tools that humankind could use for peace and prosperity.

When it was launched in 1948 to conduct research on peaceful uses of atomic energy, President Ruthven called the Phoenix Project "the most important undertaking in the University's history."

- The University was paying tribute to the sacrifices of its men and women during the war by accepting the momentous responsibility of studying the peaceful applications of atomic energy.
- Even President Eisenhower highlighted the importance of the Phoenix Project: "Few causes are more urgent today and more noteworthy of your support. In war or in peace, the atomic research being done at the University of Michigan will strengthen America."

During the next half-century, the Phoenix Project had a remarkable impact both through its research on nuclear science and technology and its educational programs.

- It pioneered the sciences of neutron inelastic scattering and radiography, developed new radiopharmaceuticals, and developed the technology to shift research reactors around the world to low-enrichment (non weapons-grade) uranium, thereby making major contributions to nuclear nonproliferation efforts.

- It attracted world-renowned scholars such as Robert Oppenheimer and Hans Bethe as visitors to Michigan. And it supported the activities of thousands of students and faculty in nuclear research and education.

As we begin a new century, the challenges facing our world have changed significantly. And in particular, energy today poses just as profound challenges and opportunities as atomic energy did a half-a-century ago. Today it seems altogether appropriate that the phoenix bird should rise from the ashes once again–that the Michigan Memorial Phoenix Project be rededicated to a new purpose, befitting its war memorial status and sustaining its impact, transforming it into the Michigan Memorial Phoenix Energy Institute.

The new mission approved in 2004 by the Regents*, to conduct research on the development of energy sources and energy policies that will promote world peace, the responsible use of the environment, and economic prosperity*, seems appropriate within this historical context.

So too does the proposed role of the Phoenix Project in *coordinating the research activities from a variety of disciplines that are presently dispersed among multiple schools and colleges, including research on energy generation from sources such as nuclear, hydrogen, solar, wind, and geothermal, as well as energy storage, energy management, and energy policy*.

The interdisciplinary nature of the Phoenix Project is intended to encompass *perspectives from the natural and social sciences, engineering, medicine, and the arts and humanities.*

The Michigan Memorial Phoenix Energy Institute is being created as an *enabling* rather than an operational or managing organization. Its functions would be

- to *coordinate* (research projects, partners, or clients),
- to serve as a *clearinghouse* linking expertise both on and off campus,

- to assist in identifying and *developing* research opportunities (perhaps enabled with seed funding),
- to *market* the University's capabilities in energy research (to government, industry, and the public),
- to stimulate the development of *educational* programs, and
- to manage those *facilities* designed to support University-wide, multidisciplinary research activities.

The re-dedication of the Michigan Memorial Phoenix Project to this imperative by reconfiguring it as the Michigan Memorial Phoenix Energy Institute is a timely reminder of the sacrifices of previous generations of the University of Michigan community–and the responsibility of institutions such as ours to address the dominant issues of our times.

It is intended to enable the University to respond once again to the challenges of our era, "by charting the path to a clean, affordable, and sustainable energy future by applying our strengths in public policy, economics, business, and social sciences to lay the foundation for successful implementation of our scientific and technological achievements."