Energy: Looking Back, Looking Forward 90 Years

Council on Foreign Relations 90th Anniversary Series on Renewing America

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Introduction- The Role of Foreign Affairs in US Energy Policy

We all hope to live to be a healthy 90 years old and the Council on Foreign Relations has succeeded. As a member since 1983, I have had the opportunity to observe the Council for almost 30 years but my first association with it came in 1976 when Bill Bundy asked me to travel to Iran to complete the manuscript of the article entitled: *Can the World Afford OPEC Oil*.[1] At that time my boss was Carroll Wilson, Vice Chair of the CFR and the first manager of the AEC who had written several pieces in Foreign Affairs on energy, including *A Plan for Energy Independence*.[2] My colleague, Joseph Perkowski, of Idaho National Lab, crunched the numbers. Alongside Dr. Perkowski, and also working with Carroll Wilson, was Amory Lovins, who later published *Energy Strategy: The Road Not Taken* in Foreign Affairs, where he spoke of Soft Energy Paths,[3] an policy approach based on energy efficiency and renewable energy development.

Several of us were also working with Maurice Strong out of our MIT offices as Maurice pulled together the first UN environmental conference in Stockholm and reported his lessons learned in a 1973 Foreign Affairs article entitled *One Year After Stockholm*.[4] One can track the analytical and substantive views on energy policy in other significant articles in Foreign Affairs, among them articles by Daniel Yergin and Edward Morse. Most Foreign Affairs articles not only looked at energy methodologies and projections but also put them in a global geo-political context. This was a very key theme in a Trilateral Commission study we conducted in 1997 entitled*: Maintaining Energy Security in a Global Context*.[5] It was also the central theme in the Department of Energy's major study on energy security in 1987 entitled: *Energy Security: A Report to the President*[6] and is a key element of the ongoing work of the Department of Energy, the Energy Information Administration and the International Energy Agency. The studies are noted here are to call attention to the substantial intellectual investment made by the analytical and policy community of the United States over the last forty years. This is in addition to the US

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[1] Khodadad Farmanfarmaian, Armin Gutowski, Saburo Okita, Robert V. Roosa and Carroll L. Wilson, "How Can the World Afford OPEC Oil?" July 1975, http://www.foreignaffairs.com/articles/24538/khodadad-farmanfarmaian-armin-gutowski-saburo-okita-robert-v-roo/how-can-the-world-afford-opec-oil.
[2] Carroll L. Wilson, "A Plan for Energy Independence." *Foreign Affairs*, July 1973, http://www.foreignaffairs.com/articles/24435/carroll-l-wilson/a-plan-for-energy-independence.
[3] Amory B. Lovins, "Energy Strategy: The Road Not Taken?" *Foreign Affairs*, October 1976, http://www.foreignaffairs.com/articles/26604/amory-b-lovins/energy-strategy-the-road-not-taken.
[4] Maurice F. Strong, "One Year after Stockholm." *Foreign Affairs*, July 1973, http://www.foreignaffairs.com/articles/24438/maurice-f-strong/one-year-after-stockholm.
[5] http://www.wpainc.com/PDF/Maintaining_Energy_Security.pdf
[6] Energy Security, A Report to the President, Department of Energy Report, 1987, http://www.wpainc.com/PDF/Energy_Security.pdf.

experts, such as my colleagues on this panel, and government agencies that have a good grasp on the fundamentals of energy; including its opportunities and challenges. Unfortunately these are subjects too long for the Nightly News as it focuses exclusively on the gasoline price.

History

As part of the 90th anniversary of the Council, this session is looking at the role of energy and the environment. My friend and DOE colleague David Sandalow is better qualified to discuss the environment, so I will defer to his thoughts. This piece will look more at the geo-politics of global energy and, within that framework, examine options for the United States. After all, it was probably the oil embargo of 1973 that brought energy to the forefront of modern policy debates. The world had become hooked on oil, in part due to the development of the gas powered engine and rapid economic growth of the post World War II period.[7] Many countries before and after World War II began to use coal and indeed, as Professor Wilson predicted, coal use would expand rapidly as a key element of industrialization. As the first general manager of the Atomic Energy Commission, he was less optimistic about nuclear power, but foresaw it contributing as much as 20% of electricity by the year 2000. This was a major conclusion of the Workshop on Alternative Energy Strategies, our energy project that he headed which involved several Council on Foreign Relations members, including Carroll Wilson, John Conner, Dick Gurstenberg, Thornton Bradshaw and Guy Stever.

During the 70s, we also saw the beginning of the International Energy Agency, the organization of consuming countries established by Henry Kissinger. It was unique in that it had super-national powers. If one member was short on oil by as much as 7%, then other members were obliged to share oil. In essence, we all shared the burden. But as the Iranian Revolution and second oil shock demonstrated, IEA countries could face dramatic price increases even from a modest shortfall. Although the market only lost 2% of its oil, prices went up by a factor of four in 1979 to $45 per barrel. The cause: overbuilding of stocks by nations. Like consumers who top off their gas tanks in a shortage, countries did the same thing and put added pressure on the market, inducing large price increases. At the onset of the Iran-Iraq war, IEA countries followed a different strategy: the coordination of stocks at levels of disruption below the 7% trigger, and it worked.

Stock-build, coupled with stockpile coordination in times of an emergency remains the key international element for emergency preparedness whether it be from natural forces, as was the case for Katrina, or oil supply disruptions brought about by geo-political events. This remains a very important, and little known, factor of US energy policy. Although we have built sizeable stocks in the Strategic Petroleum Reserve, their use is largely dependent on coordination with other oil consumer nations. Our protection is based not just on the oil in the SPR, but rather the collective total reserves of all energy consuming nations. In the event of an oil market crisis, the best economic and political strategy for the US is to coordinate our stock draw so as not to aggravate further the price of oil. The oil price gradually declined during the 80s to a point that it reached $10 per barrel in 1987, a price that, among other things, is credited with collapsing the

[7] James E. Akins, "The Oil Crisis: This Time the Wolf Is Here," *Foreign Affairs*, April 1973, http://www.foreignaffairs.com/articles/24416/james-e-akins/the-oil-crisis-this-time-the-wolf-is-here.

Soviet economy, which was dependent on oil earnings for two-thirds of its hard currency on energy sales.[8]

Energy policies of free markets and deregulation brought about relief from the government controlled policy of the 1970s and unleashed the power of market forces. Indeed, the slow economy of the early 1980s was replaced by rapid economic and energy growth for almost twenty years as market forces and free trade expanded around the world. As predicted by our MIT models,[9] energy intensive industries were exported to developing nations with cheap labor and a hunger for economic development. As these countries industrialized, they purchased more goods and appliances.[10]

There were two dynamics at play that resulted in a doubling of world energy demand in the last forty years. First, the growth of manufacturing in less developed nations (particularly East Asia) and second, the increase in energy use by industrializing countries as their appetite for a higher standard of living increased. For example, at $1000 per capita income, a family may purchase a cooker; at $2000 per capita a heating system; and at $5,000 per capita a first car. We are seeing these dynamics in newly industrializing nations today. Free trade and investment policies have resulted in manufacturing transfer from the US to abroad and this has raised the standard of living of the world, increased the world's energy appetite and provided US consumers with less expensive goods, many of which are energy intensive. In a CFR meeting five years ago, I presided over a session with Senator Joseph Lieberman. We came to the counter-intuitive conclusion that the energy demand growth in China was induced largely by consumer needs in the US. If one considers the energy content of imports into the US, our energy use was much higher and, in fact, China's was lower in terms of manufacturing used for purely domestic use. This reminds us of the field of "energy accounting" that gained popularity in the late 70s; essentially calculating the content of energy in individual products.

Current Situation

Markets are fundamentally different today than they were in 1972. At the same time the percentage of energy sources contributing to overall demand has remained relatively stable. The issue is: who is producing the energy and who is consuming it? In the 1970s, 70% of Middle Eastern oil went to Europe and the US; in sharp contrast today 70% goes to Asia. Also in the 1970s, 70% of the world's oil was controlled by the major western oil companies (the so-called seven sisters); today almost 90% is controlled by state oil companies.

In the last thirty years we have seen natural gas and LNG emerge as important sources of energy and nuclear power now meets about 15% of the world's electrical needs. New technology for exploration and drilling has dramatically increased the recoverable reserves of oil and gas. OPEC produced 25 mbd in 1975 and today it produces about 29 mbd, therefore, most of the world's incremental oil supply increase has been achieved by greater production outside OPEC through enhanced recovery in places such as the North Sea and the United States.

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8 Peter Schweizer, *Victory*, Page 75.
9 WAES Report of 1997: Energy Supply to the Year 2000, http://www.wpainc.com/PDF/Energy_Supply_to_the_Year_2000.pdf.
10 See work of Allen Strout of the World Bank http://dspace.mit.edu/bitstream/handle/1721.1/27275/MIT-EL-86-020WP-19615368.pdf?sequence=1

Coal has also seen a significant increase as the "electricity workhorse" of India, China and the United States. Ulf Lantzke, the former Executive Director of the International Energy Agency, said in Foreign Affairs that coal use could increase threefold between 1970 and 2000.[11] Finally, shale gas has emerged as a tremendous source of energy for the United States. Rather than import LNG in the future, the US is in the position to be completely self sufficient and export gas. LNG terminals built to receive gas can now send it abroad, helping the US trade balance in the long-term.

Nuclear power has grown steadily throughout this period, but concerns raised by the Fukushima accident will slow development. Fukushima was not a nuclear accident (compared to TMI and Chernobyl); it arose out of a natural disaster. Fortunately, the situation has thus far been contained. We applaud our Japanese friends, both in government and in industry, for their tremendous bravery and skill in managing this dangerous situation. The IAEA team's recent evaluation was critical of the lack of sufficient seawall protection against the tsunami but also noted: "The response on the site by dedicated, determined and expert staff, under extremely arduous conditions has been exemplary and resulted in the best approach to securing safety given the exceptional circumstances."[12]

There will be lessons to be learned from Fukushima. But first we need the facts, then the assessments, followed by the application of the lessons in the US and worldwide. Next week, the DOE Nuclear Energy Advisory Committee will receive our first briefing on the situation and we hope to analyze the impact of Fukushima on not only the Japanese situation, but importantly the US.[13] We also hope that the President's Blue Ribbon Commission on America's Nuclear Future will make recommendations about the future of high-level waste storage in the US.

Clearly, nuclear power must continue to play an important role in the US, Japan, Europe and elsewhere. As newcomers to nuclear seek the benefits of this non-emitting source, an effort must be put forth to ensure they are abiding by strict safety, as well as non-proliferation guidelines. It is essential that the IAEA be strengthened. This was a major recommendation of the Nuclear Security Summit convened by President Obama during the spring of 2010 attended by fifty heads of state. The resulting communiqué calls for action in fifty areas of concern.[14] In addition to this effort, a good set of recommendations for strengthening the IAEA can be found in the 2008 IAEA 20/20 project report. As the report states, "The IAEA will have the responsibility to help newcomer states put in place the necessary infrastructure needed to develop nuclear energy safely, securely and peacefully."[15]

Energy efficiency has also played an important role, perhaps the most important role, in the last forty years. Early US standards for autos mandated better performance (CAFÉ Standards), but the major contributor to better efficiency was the price itself, essentially reliance on market forces. The one to one relationship between energy and economic growth has been cut in half and even more so in the OECD countries where the service economy has largely taken the place

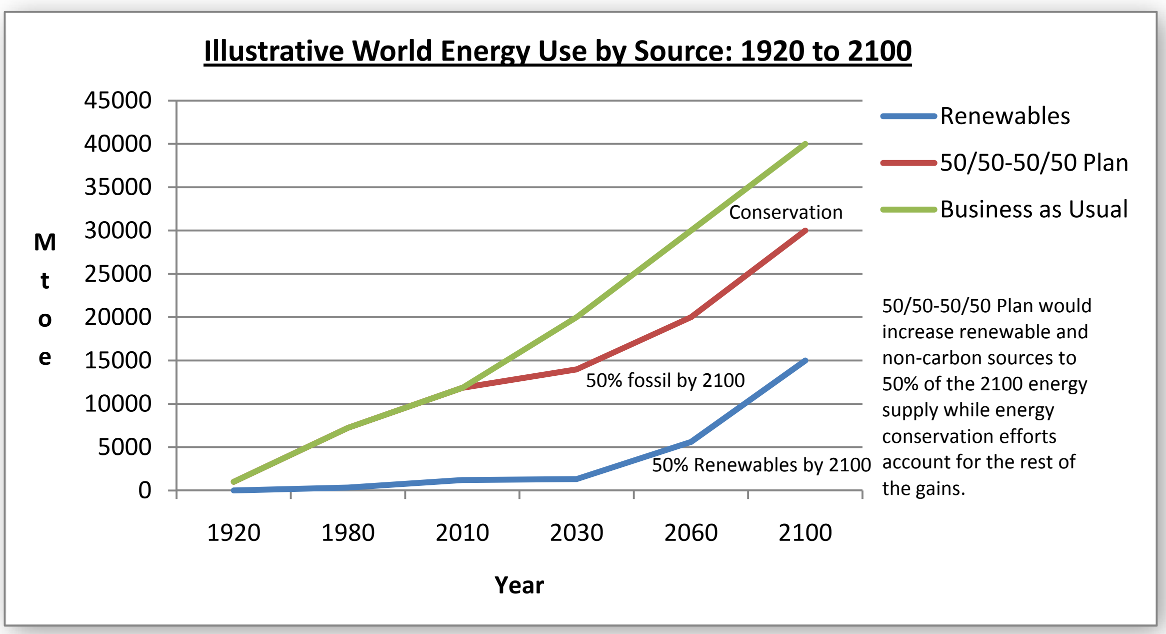
[11] Ulf Lantzke, Expanding World Use of Coal." *Foreign Affairs*, Winter 1979/1980, http://www.foreignaffairs.com/articles/33332/ulf-lantzke/expanding-world-use-of-coal.
[12] http://www.world-nuclear-news.org/RS_First_IAEA_report_on_Fukushima_0106111.html
[13] http://www.ne.doe.gov/neNeacOverview.html
[14] http://www.whitehouse.gov/the-press-office/communiqu-washington-nuclear-security-summit
[15] The IAEA 2020 Report, 2008, Page VI: http://www.iaea.org/newscenter/news/pdf/2020report0508.pdf.

of the manufacturing sector. With political stability and freedom in Eastern Europe, we see energy growth rising. And, as the Middle East Spring continues to progress into fall and winter and beyond, there are hopes that economic prosperity will follow and, with that, energy demand in the Middle East will increase.

The Future

For the foreseeable future, there will be great need to rely on fossil fuels: oil, gas and coal. Energy systems change slowly. It takes 12 years to replace the auto stock; 50 years to replace housing and as much as 100 years to turnover industry. The good news is that major growth of energy development will be in industrializing countries and nations such as China, India and Brazil will be able to leap frog to better, newer and more efficient technologies than those which supported OECD industrialization.

The following illustrative energy chart spans almost two centuries of energy supply and demand, going back to 1920 and going forward to 2100. Projections are hazardous but for simplification's sake, we've used the same economic growth rate (1.4%) of the last ninety years carried forward over the next ninety years. We've then utilized a 50/50 and 50/50 plan. Energy growth is assumed to be 0.7% per year (roughly 50 % of economic growth) and half of all supply is assumed in the year 2100 to be non-carbon sources (wind, hydro, tidal and nuclear) and half carbon sources (oil, gas and coal). If one looks at what it would take to achieve these levels (more than a doubling of energy by the year 2100), it is clear that the ramp for renewables will have to be swift and steep. Fortunately, the world has abundant fossil fuels to begin making the transition to more sustainable energy sources by the end of the century. Again, this chart is only illustrative and one can make several alternative assumptions; this is only one case. The projections to 2030 are in fact the current official EIA and International Energy Agency projections but may be optimistic given the Fukushima accident and continued global economic lag.



It is appropriate for the world leaders to endorse renewable energy sources, especially as they seek climate friendly energy policies. As the chart suggests, however, the world will be dependent for several more decades on fossil fuels and a key issue is burning these fuels more cleanly. A high priority is the clean burning of coal. Second is greater efficiency in thermal electricity generation. We point, for example, to the already high standards of the thermal plant in Sendai Japan, which recently received the prestigious Edison Award for outstanding energy project of the year. This plant reaches 58% efficiency, compared with thermal plants elsewhere as low as 33%. Third, nuclear power must play a role if we are to achieve the 50/50 balance between fossil and non-carbon energy sources. Today the world has approximately 450 nuclear reactors globally. Over a ninety-year period, existing plants will need to be decommissioned and new plants built. We will need hundreds of additional reactors if nuclear is to maintain its share of the global electrical market. This will be a very hard task in light of Fukushima but one expects the lessons of Fukushima will make nuclear power safer and more secure.

We expect that oil may level off at about 120 million barrels per day. This rate of production can continue well into the next century, assuming that advances in recovery continue. We would expect that oil producing states, especially Saudi Arabia and the Gulf states, will want to use the valuable molecules of oil and gas for 'higher added value,' thereby maximizing their economic potential in the century ahead. It is also noteworthy that Saudi Arabia maintains some 3 million barrels per day spare capacity that can be brought on stream in the event of an emergency in oil markets. Elsewhere, we are seeing that natural gas and shale gas are abundant globally. Given the positive attributes of these sources (in terms of carbon production), we expect that many nations will opt for gas to produce their electricity especially in the 'short-term' of the next 30 years as nuclear slows and nations continue to generate more energy with less carbon release.

Today's session comes in a series on Renewing America. What can be said of the US energy situation in light of the geopolitical setting described earlier? The focus of this paper has been largely international, in essence because it is difficult to separate US policy from world energy development, emergency preparedness and geo-political developments. But from a domestic perspective, the US is blessed with perhaps the best energy situation of any nation, although wary consumers worry and complain about $4.00 per gallon gasoline. Abundant supplies of fossil fuels, coupled with nuclear power and the potential for technological advances guarantees energy sufficiency for the US, especially compared to our friends in Asia and Europe.

Imports from the Western hemisphere will remain important, especially from our Canadian and Latin American neighbors. Today, major investment is taking place in oil sands to import to the United States and higher global prices have stimulated the rig count and oil production is not in decline. The large opportunity for shale gas is being tapped. It is significant, widespread and will allow the US to export LNG in the future. Nuclear power safety is being evaluated in light of Fukushima but the more than 100 US nuclear plants provide 20% of US electricity. As a framework for considering US energy futures, please see the charts at the end of this paper which are matrices for the evaluation of the world's current and future energy profile.

The STEP chart shows major uses on the left hand side and major supplies on the top. This is a standard form of reporting energy statistics popularized by WAES (MIT) and the IEA in the 1970s. It is an accounting approach to energy statistics and projections. What makes it valuable is that the sums, in term of energy and carbon released, are shown on one page and practice with the matrix shows that there are no easy solutions. This matrix was the basis of the recommendation provided to the DOE in evaluating alternative climate strategies. If, for example, one wants to reduce carbon by 82% by 2050, as the President has suggested, then this framework can evaluate different technological pathways. Rather than talk of overall energy limits, this disaggregated approach allows for better analysis and policy contemplation, step by step.

European countries approach energy in a somewhat different way. We would expect France to maintain a strong nuclear program. Germany may opt for more gas from Russia and even imports of electricity from nuclear powered France. Italy has the benefit of close sources in North Africa and the Middle East. Collectively, we would expect the EU to move toward greater reliance on renewables and conservation, recognizing that politicians' hopes for quick renewable development may not succeed given the lead times for making a difference and generally higher costs per Btu produced. Russia will benefit from markets in Western Europe and Asia but growing demand domestically may mean that Russia will support more nuclear power, freeing up valuable natural gas for export.

Further, it is expected that Japan will seek greater renewables and maintain its existing nuclear power program after safety evaluations are completed in the post-Fukushima environment. Japanese talent for innovation will also present itself in greater reliance on renewables and advanced designs for automobiles that rely on less fossil fuel use. China is already greatly expanding all possible avenues of energy development and imports with an attitude of 'clean energy' but with the most probable path is of greater coal use. China is likely to pursue an ambitious nuclear power program. We expect India to also rely on coal and greater nuclear power use, and it is well positioned to benefit from greater gas imports, especially from the Middle East.

Over the next 90 years, we would hope that there would be some resolution of political difficulties in Iran which will open up its tremendous export potential for natural gas, which Europe and South Asia could benefit from. Complex transit and gas development in Central Asia could also provide gas to both Europe and Asia, benefiting the economic development of former states of the Soviet Union. In Latin America, we could also expect continued indigenous development of energy, namely oil and gas, and the expansion of alternative fuels for transportation as is the case today of Brazil. African nations could benefit from indigenous energy resources, namely plentiful oil and gas, and turn to state of the art renewable energies. A key issue in Africa, parts of Asia and Latin American is electrification, an essential element of raising the quality of life in the next fifty years. Efforts should be made by OECD nations to transfer clean low carbon emitting energy technology to industrializing nations.

In summary:

1. The world has the need for energy for economic development, energy security and environmental quality both individually for nations and collectively as members of the global community. World population is estimated to increase from 7 billion to over 10 billion by 2100. Maintaining economic progress and an increase in quality of life will require a three-fold increase in energy supply by 2100.

2. Oil will remain a very key source of energy as nations industrialize. There may not be peak oil, but rather a plateau of oil as producer states seek to maintain production and

fuel their economies over the longer term and to seek value added in oil and gas production by expansion of petrochemicals.

3. Natural gas and shale gas use are likely to increase significantly in all regions. Gas is competitively priced, available and a less carbon intensive fuel compared to coal and oil.

4. Nuclear energy will remain important, but the renaissance of nuclear that was hoped for is clearly set back. The challenge will be enhancing the safety of old reactors, continuing research into new reactors (especially small modular reactors) and finding solutions to long-term storage, all balanced against the need for a strengthening of non-proliferation and greater responsibility of the IAEA. (By 2100, we should begin to see the fruits of fusion energy as hoped for from the global energy project ITER.)

5. Renewable energy resources are on the rise, but remain less concentrated and therefore less economical than conventional sources for the moment. But political commitments from Washington to Bonn to Tokyo raise the opportunity for research that can lead to more rapid deployment. By 2100 renewables (solar, wind, hydro and tidal) and nuclear energy, the non-carbon sources of energy, could be half of all energy supplies: a challenging but achievable goal.

6. The clean use of coal is perhaps the number one challenge of the energy community. Coal will be used; in fact, the use of coal will be accelerated. Coal production could at least double by the year 2100. Coal is the easy economic choice as it is widely available but for reasons of local, regional and global environmental concerns it must be used more cleanly. This can be accomplished in three ways: first, greater efficiency of thermal conversion for electricity; second, cleaner ways of burning coal; and finally, developing capacity for carbon capture and sequestration.

7. Concentration on how energy is used is also important. Energy efficiency is a number one priority in meeting future needs. It is interesting to note the evolving energy policy in Japan which challenges consumers to not only seek energy efficiency for the short-term, but to make a long-term commitment to Mottainai (conservation).

8. Energy emergencies will need to be met by strengthened international efforts. This will require the expansion of the existing IEA to include China, India, Brazil, Russia and oil producing states. If the IEA does not expand to include non-members, then a new mechanism will be necessary so that a truly global energy agency is created.

9. By the year 2l00, ninety years from now, we will see fundamental shifts in the world's economy toward Asia and hope for economic expansion in the Middle East, Africa and Latin America. OECD countries will comprise a smaller percentage of the world economy and world energy use but it will take the technological leadership capabilities of the OECD nations, especially the US, Japan and Europe, to bridge to the new century.

10. The United States is as well positioned as any country in the world to succeed and to make the transition to affordable, energy-secure and environmentally responsible energy sources over the next 90 years. We have abundant natural resources and rich human intellect and innovation capital in our universities and national laboratories. Continued reliance on market forces will induce success in achieving greater efficiency and new supplies. And we have friendly neighbors with accessible rich exports and continued geo-political presence that can maintain the global environment necessary for a flourishing energy trade, thereby benefiting all nations.

As we face a planet of 10 billion people in 2100, compared to less than 2 billion in 1920, the challenge grows for clean and affordable energy to fuel future world needs. A child born today will likely be alive in 2100. Interestingly, as we increase the longevity of human life we also create greater energy needs per person. Looking back from 2100, one wonders about the many interesting articles that will be written on energy, the environment and geo-political concerns as the Council on Foreign Relations celebrates its 180th anniversary.

William F. Martin has served as Special Assistant to President Reagan, Executive Secretary of the National Security Council and Deputy Secretary of the US Department of Energy. He has also served as President of the Council of the United Nations University for Peace in Costa Rica. He has held positions in the MIT Energy Laboratory, Department of State, Department of Defense and the National Security Council. During the second oil crisis he served as the special assistant to the Executive Director of the International Energy Agency. He currently serves as Chairman of the Department of Energy's Nuclear Energy Advisory Committee and for eight years served as Chairman of the Council on Foreign Relations Energy Security Group. This paper represents his personal views and not those of the Department of Energy.

Illustrative World Energy Use by Source: 1920 to 2100[16]

Mtoe	**1920[17]**	**1980**	**2010**	**2030[18]**	**2060**	**2100[19]**
Oil	96	3107	4360 (37%)	4925 (35%)	5000 (25%)	3750 (12.5%)
Gas	-	1235	2958 (25%)	3304 (24%)	4600 (23%)	7500 (25%)
Coal	910	1788	3285 (28%)	4423 (32%)	4800 (24%)	3750 (12.5%)
Hydro and Tidal	-	148	378 (3%)	321 (2.2%)	600 (3%)	2250 (7.5%)
Nuclear	-	186	697 (6%)	750 (5%)	1000 (5%)	2250 (7.5%)
Renewables (Solar/Wind)	-	12	126 (1%)	250 (1.8%)	4000 (20%)	10500 (35%)
Total World Energy Demand	**1006**	**7223**	**11854**	**13973**	**20000**	**30000**
Total World Population in Billions[20]	1.86	4.45	7	8	9.5	10

World Energy Demand by Region

Mtoe	**1920**	**1980**	**2010**	**2030**	**2060**	**2100**
OECD	-	4072	4742	5542	8000	12000
Non-OECD	-	3043	7112	8431	12000	18000
World	1006	7223	11854	13973	20000	30000

The 50-50-50-50 Plan

These charts demonstrate the historical trends of energy and make some illustrative projections. For the period 1920 to 2010, the world grew at approximately 1.4% on average GNP.[21] In this same period the average energy growth rate was about 1.5% percent per year. For the 50/50-50/50 plan, there would be a 50% decrease in energy intensity, so the rate of energy growth would be 0.75%. Thus by 2100, the world can meet its increased energy needs while incorporating environmental and carbon concerns by cutting down the share of fossil fuels to 50% of the total supply.

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[16] This is assuming the success of the '50/50' plan where there is 50% added conservation and 50% added supply.
[17] In 1920, the world was primarily reliant on coal and oil to meet its energy needs as other forms (nuclear, hydro etc) had not been developed yet.
[18] Forecasts for the years 2010 and 2030 are supplied by a combination of information from the IEA and EIA, though these were forecasted before the events of Fukushima and are in some cases optimistic in regards to nuclear and renewable development, so they have been slightly modified.
[19] Projections for 2060 and 2100 are rough approximations and rely on the world embracing the 50-50-50 plan to achieve these goals.
[20] Population projections taken from the US Census Bureau and the UN Dept. of Economic and Social Affairs.
[21] University of California Berkeley Dept. of Economics
http://econ161.berkeley.edu/TCEH/1998_Draft/World_GDP/Estimating_World_GDP.html

STEP Supply-Demand Integration Model and Methodology

STEP Assumptions and Scenario Cases

1. Energy Prices (EIA base case; higher prices to induce conservation, fuel switch)
2. Government Policies (business as usual; carbon reduction policies; R and D budgets)
3. Technology Assumptions (historical, current best, future best)
4. Pace of Capital Stock Turn-Over (autos - l0 years; homes -50 years; industry 75-100 years)
5. Energy Security/Carbon Reduction Cases (historical, current best technology, projected "best" technology)

STEP Methodology

For different scenario cases, determine energy demand by category, energy supply, and energy supply-demand integration

1. Determine energy consumption and carbon emissions for each category (ie. economic activity x energy efficiency).
   - A. Economic activity derived from macro-economic model (tons of steel) to ensure consistency of categories (ie. tons of steel consistent with autos produced) based on GNP
   - B. Each demand sector has energy efficiency or carbon intensity based on technology choice (historical, current, best) determined by price and technology availability
2. Determine fuel mix for each demand category (historical and based on price of fuels and government policy)
3. Add up final demand for key demand sectors
4. Determine energy transformation sector
   - A. Fuel mix for electrical generation (depends on price, government policy)
   - B. Efficiency of electricity generation process (historically 33%; current 37%; best future?)
5. Add up columns (across and down) and determine "primary energy demand"
6. Determine energy supply parameters (domestic, imports or exports)
   - A. Impact of price and policy on fuel choices in demand sectors
   - B. Impact of price and policy on electricity
7. Determine most effective government R&D
8. Feasibility of scenarios in real-world business applications

STEP Results

1. Each demand line item would afford opportunity to showcase key technologies (transport, commercial, residential, industrial)
2. Integration would occur as fuel choices for each sector are made (oil, coal, renewables, electricity)
3. Renewables can be both direct (remote power) or part of electrical transformation (large-scale)
4. Total energy (energy efficiency) and total carbon output is thus determined by demand sectors, supply options and energy transformation
5. Alternative Scenarios chosen would bracket
   - A. Base EIA case—no change in policy
   - B. 450 ppm reduction case—what set of assumptions would be required to achieve this case (economic growth, energy prices, technology success).
6. Leads to the conclusion that 450 ppm case can be achieved if . . .
7. What are the costs and benefits of this? Key issue is to quantify the externalities of not achieving this 450 ppm case (and lower oil imports)
8. A key factor is the discount rate used for the future. A high interest rate devalues the future and makes adjustments very expensive.
9. Translate model results into practice in the presentation

STEP Goals

1. STEP endeavors to seek efficiency in energy and carbon in every cell of this matrix
2. STEP seeks to ensure consistency of forecast (economic, policy)
3. STEP seeks to showcase key technologies in each cell
4. STEP seeks to determine what sets of assumptions achieve 450 ppm and the costs/benefits
5. STEP approach allows for framework to discuss government-business partnership
6. STEP methodology enables comparison of US with other nations, a framework for bilateral/IPCC/IEA discussions

Major Sectors	Petroleum	Natural Gas	Electricity	Coal	Renewable Sources*	Nuclear	TOTAL
Transportation							
Light-duty vehicles							
Commercial light trucks							
Bus Transportation							
Freight Trucks							
Passenger Rail							
Freight Rail							
Domestic Shipping							
International Shipping							
Recreational Boats							
Air							
Military Use							
Lubricants							
Pipeline Fuel							
Other							
Industrial							
Manufacturing							
Aluminum							
Cement							
Chemicals							
Computers, Electronics, Appliances, Electrical Equipment							
Fabricated Metals							
Food and Beverage							
Forest Products							
Foundries							
Glass and Fiber Glass							
Heavy Machinery							
Mining							
Petroleum Refining							
Plastics and Rubber Products							
Steel							
Textiles							
Transportation Equipment							
Other							
Commercial							
Space Heating							
Space Cooling							
Water Heating							
Ventilation							
Cooking							
Lighting							
Refrigeration							
Office Equipment (PC)							
Office Equipment (non-PC)							
Other							
Residential							
Space Heating							
Space Cooling							
Water Heating							
Refrigeration							
Cooking							
Clothes Dryers							
Freezers							
Lighting							
Clothes Washers							
Dishwashers							
Color Televisions and Set-Top Boxes							
Personal Computers and Related Equipment							
Furnace Fans and Boiler Circulation Pumps							
Other							
Primary Energy Demand							
Energy Transformation							
Electricity							
Synthetic Gas							
Synthetic Liquids							
Heat							
Energy Sector							
Total Energy Demand							
Domestic Supply							
Imports							
Exports							

*Renewable Sources currently include hydropower, solar, wind, geothermal, biomass, and ethanol.