The State of Energy: Then, Now, and in the Future—Revisited

An effective national energy plan must lay out a clear direction for the short term, mid term, and long term for all possible energy solutions

By Alfred Guntermann, PE

Editor's note: In September 2006, HPAC Engineering published "The State of Energy: Then, Now, and in the Future," by Alfred Guntermann, which provided an overall picture of both the U.S. and world energy situations. This article is a follow up.

In August, oil cost approximately $120 a barrel. The price now is less than $40 a barrel. An article published in the Nov. 13, 2008, Wall Street Journal (WSJ), "Fading Oil-Field Production Threatens Supply," summarizes an International Energy Administration (IEA) report and states that the recent economic downturn is reducing capital spending on energy demand and new projects. Further, the IEA said, "When demand starts to pick up, in, say, 2010 ... we may see a supply crunch much stronger than we saw last year and prices that are much higher." The IEA's report analyzed 800 of the world's oil fields, accounting for two-thirds of the world's supply and found that the 16 largest fields have peaked and some are far below their peak output. The output is declining at a 6.7-percent rate, which is expected to increase to 8.6 percent by 2030.

The IEA projects world demand to increase by 1.3 percent per year. Even with no increase in demand, the IEA projects that 45 million barrels a day will be required to replace the existing oil-field production--the 2007 world oil production was only 85,802,000 barrels per day. Future oil fields, including off shore, are smaller, will not last long, and are more expensive. And if the world energy supply already has peaked, the projected 1.3-percent annual increase in world demand for developing countries cannot be met without reduced U.S. demand.

According to the results of a poll published in a recent *WSJ* article, "Voters Want Everything on Energy," voters want:

1. Alternate energy sources	73%
2. More fuel-efficient cars	67%
3. More refineries	50%
4. The expansion of off-shore drilling	45%
5. More nuclear power plants	40%
6. The opening of protected areas in Alaska to exploration	38%
7. The encouragement of conservation	35%
8. The taxing of oil companies' profits	30%
9. The release of some of the strategic petroleum reserve	20%
10. A gas-tax holiday	18%

While the first six alternatives offer reasonable mid-term and long-term solutions, only encouragement of conservation can have a significant impact on our energy usage or costs within 10 years. The poll shows a lack of understanding of the size, difficulties, and time required to enact the solutions. To find workable solutions, the limits and possibilities of all energy-solution alternatives must be understood.

A new national energy policy is being developed by the Obama administration.
The Obama team has proposed a national energy policy that has a number of valuable ideas, but also some major problems. The administration's first problem is that the U.S. trade deficit is a disaster in the making that requires short-term solutions. The second problem is a concept to ensure that 10 percent of the nation's electricity comes from renewable sources by 2012 and 25 percent by 2025.

A common belief is that we need all of the energy solutions. But solar energy, wind energy, biofuels, nuclear energy, coal liquefaction, oil shale, and hydrogen are long-term solutions that need to go through a thorough process of research and development before producing major amounts of energy. Off-shore drilling, tar sands, and natural-gas shale are realistic alternatives but require time to develop and will be costly.

We cannot afford a trial-and-error approach because the consequences of wasted time are too great. Though we have had three energy crises since 1973, higher energy costs, and several calls for project independence, new technology is not any closer to providing a solution to the massive world-energy requirements than it was 35 years ago. The only possible energy solution that can have an impact in the next 10 years is a massive energy-conservation program.

Energy is an extremely complicated problem without any easy answers. This article defines the trade deficit and then identifies a massive energy-conservation program that may reduce or eliminate it. The article then discusses problems with possible energy solutions, including solar energy, wind power, nuclear energy, traditional and nontraditional oil, traditional and nontraditional natural gas, biofuels, and hydrogen. The importance of massive energy conservation becomes important when all other alternatives are evaluated and then eliminated.

U.S. TRADE DEFICIT

In 2006, oil imports accounted for $252 billion of our $800 billion trade deficit. According to a recent CRS Report for Congress, the 2007 oil trade deficit rose to $293 billion, or 36 percent of our $815 billion trade deficit. For the first four months of 2008 with oil prices below $100 a barrel, the oil-trade deficit rose to 47 percent of our trade deficit. At $120 a barrel, the annual oil-trade deficit would increase to $533 billion, and at $140 a barrel, the annual oil-trade deficit would increase to $613 billion.

The federal trade deficit has become the most immediate and important issue facing the United States. If oil imports continue to increase in both quantity and cost per barrel over the next 10 years, the result could be a transfer of $10 trillion to $20 trillion of U.S. wealth to oil-producing countries--approaching 25 percent to 50 percent of the total U.S. wealth. The oil exporters could own half of America. T. Boone Pickens, a Texas oil tycoon, points out, “The oil-trade deficit could result in the greatest transfer of wealth the world has ever seen.”

This already is occurring with Sovereign Wealth Funds, which are controlled by governments in China, United Arab Emirates, and Russia--placing large investments in U.S. companies. This raises the question of whether foreign investments will give other nations political power over U.S. policies.

Continued large U.S. deficits also require the sale of enormous quantities of U.S. treasuries to foreign countries. Failure to sell our debt can lead to a downgrading of the U.S. credit ratings, resulting in higher treasury and related interest rates. Some South American countries have gone through this, and it leads to inflation followed by a painful recession.

The large U.S. trade deficit also is responsible for the falling U.S. dollar, and this, in turn, is a cause of high U.S. oil prices. The price of international oil is in U.S. dollars, and when the U.S. dollar fell, foreign companies raised the price of imported U.S. oil accordingly.

The oil-trade deficit and cost of oil imports takes all of the mid-term and long-term energy solutions off of the table. We need solutions that will reduce both energy-import quantities and energy costs.

ENERGY CONSERVATION

Energy conservation is an energy solution that can reduce our trade deficit in the short term. Also, it can buy the time that is necessary to find optimum solutions from the research and development of mid-term and long-term energy options. Further, it can reduce the size and capital costs of mid-term and long-term energy solutions once they are implemented. Lastly, it reduces carbon dioxide and global warming.

Energy conservation attacks the energy problem by reducing energy demand instead of increasing energy supply. The United States is only 4 percent of the world’s population, yet it consumes 25 percent of the world’s energy.

Of the total 2006 U.S. energy consumption of 99.5 quads (1 quad is 10^{15} Btuh) (including electricity), residential used 22.25 quads, commercial used 17.91 quads, and industrial used 33.32 quads--a total of 73.5 quads. Transportation used 28.5 quads. Renewable energy accounted for 0.67 quads. Of the 73.5 quads of non-transportation energy, electric end-use accounts for 12.48 quads, and at 31.5 percent, electrical efficiency and electrical losses account for 27.2 quads. Reducing the non-transportation energy consumption of 73.5 quads by half would save 36.7 quads.

The European economy has a larger Gross National Product (GNP) than the United States with a similar population and standard of living. But the European economy has half the energy consumption per capita. Europe and Japan have been far ahead of us in producing energy-efficient products, such as the compact fluorescent light bulb. Reducing our energy consumption by half therefore is a realistic goal. But we need government leadership. The free market will not get it done in the short term to reduce the trade deficit.

Instead of offering extensive tax credits to uneconomic and alternative energy strategies or to oil companies, we should put government assistance where it will do the most good--energy conservation. We need to implement a massive energy-conservation program now. For the same tax credits, we will receive several times more energy saving from conservation than from solar energy. This also will reduce carbon dioxide several times more. It is the most feasible method for Obama to keep his campaign pledge of achieving energy independence.

Industry is the easiest and greatest source of energy savings. When energy prices were low, less-efficient industrial processes often were installed. Higher energy prices will justify more efficient industrial operations, but the existing industrial processes must be replaced. And it will cost more than the incremental cost to initially provide energy-efficient equipment. Tax credits for industrial energy-process improvements will make it more profitable to stay in business, create more U.S. jobs, and increase federal and state tax revenues.

Many commercial and institutional buildings can be retrofitted to meet most of the current high-efficiency standards. New fluorescent, LED, and ceramic metal halide energy-efficient light fixtures will allow a substantial lowering of building electrical consumption through reduced lighting, which will reduce HVAC fan horsepower to the cube root and air-conditioning loads. The addition of occupancy sensors and daylighting controls can reduce it further. And new ventilation heat-recovery heat exchangers can improve indoor-air quality with a minimal increase in energy.

Much of the built environment needs to be retrofitted. The "built" environment consists of new buildings and older buildings. New buildings typically use half of the energy per square foot of older buildings because new buildings were built to higher energy-efficiency standards. But replacing inefficient buildings with new buildings only can occur at the rate of a few percent per year.

The Obama energy plan calls for weatherizing 1 million low-income homes a year, but 28 million low-income homes are eligible. At that rate, it will take 28 years to complete the projects. We need to increase the number of low-income weatherization to 4 million a year. Further, we need to provide large incentives for middle- and upper-income people to upgrade their homes within 10 years. Independent engineers can be used to verify the retrofit work and 10-percent to 25-percent retainers can be withheld until "adjusted" annual utility bills confirm the energy reduction.

The Obama energy plan also sets national efficiency standards to improve new building efficiency by 50 percent and existing-building efficiency by 25 percent over the next decade. However, the goal to raise existing-building efficiency should be raised to an overall average of 50 percent. Massive incentives such as tax credits or increased energy taxes are necessary to accomplish the task in 10 years.

While most buildings have an average useful life of 50 to 100 years, some existing buildings are hundreds of years old. Typically, buildings constructed prior to 1975 are more energy wasteful, and we can retrofit many of them to be more efficient. Some buildings already have been upgraded, while others can be upgraded cost-effectively. But some older buildings may need to be torn down and replaced. It is easy to compare building efficiency by comparing total annual energy consumption in Btu divided by building square footage to arrive at a comparative efficiency of Btu per square foot per year.

Annual energy usage and costs will help decisions regarding whether to tear down or retrofit an existing building. A new "green" industry can help retrofit existing buildings by adding insulation to walls and roofs, adding new glazing, and upgrading existing electrical and mechanical systems. By upgrading all of a building's systems at once and financing them as long-term debt, we can cost-justify the retrofit of many older buildings. Some energy-conservation strategies are more cost-effective than others. Life-cycle costs should be used to analyze which ones are to be implemented.

Another approach to reducing energy demand is to improve the efficiency of electrical generation and energy-delivery systems--either directly through combined-cycle gas turbines or indirectly with cogeneration central systems. These can replace dirty, inefficient coal-fired electricity-generating power plants that are only 31.5-percent efficient, according the IEA 2008 World Energy Outlook, Table 2A. Existing electricity generation wastes 68.5 percent through heat loss to cooling towers, rivers, etc. Large cogeneration systems, which reclaim much of the waste, have found limited use in industrial processes, hospitals, and universities, in which they simultaneously generate electricity and use waste heat for heating and air conditioning or process loads--thereby reducing electricity losses by half.

New small decentralized energy systems, such as fuel cells or micro-turbine systems, also can provide decentralized electricity generation and heating to individual buildings. But they require incentives, research, and development to be competitive. The additional natural gas necessary to meet these demands can be supplied from retrofitted buildings and natural-gas shale.

Geothermal HVAC systems also may reduce our energy consumption--especially in areas in which natural gas is not available and oil or electric heat is required.

The transportation sector utilizes 28.25 percent of U.S. energy consumption. However, the average life of the existing 250 million[1] automobiles and trucks is 17 years, and we replace vehicles at approximately 6 percent a year. The current CAFÉ standards were passed in 1975, and they required 27.5 mpg for autos and 20.7 mpg for light trucks. In

January 2008, Congress passed legislation to increase the CAFÉ standards to a combined auto/light-truck average of 35 mpg to be phased in from 2010 to 2020. Therefore, the new mileage standards will have a limited ability to reduce the transportation sector's short-term energy consumption and the trade deficit. The recent high energy prices have done more to reduce transportation energy use than all of the mandated mileage standards, and they are a mid-term solution at best. With higher fuel standards, new vehicles gradually will replace less-efficient vehicles and reduce transportation energy. But even hybrid vehicles are not proven. Higher energy costs or taxes will reduce the number of autos and trucks and encourage more efficient mass transit and freight trains. Electric cars still have major limitations and will not replace the oil-based transportation system anytime soon.[2]

A final method of energy savings is to change the way we do things, such as manufacturing and lifestyles. The high cost of oil raised the cost of shipping from the Far East from $2,000 a container to $8,000. This will alter imports and exports and justify relocating manufacturing closer to home. Similarly, truck transportation can be shifted to rail. And workers may want to relocate closer to work to reduce commuting.

A massive energy-conservation program will require the knowledge that future energy prices will increase substantially, such as from future energy taxes, targeted tax credits, and long-term low-interest loans. This will encourage energy conservation without causing pain. Accounting changes, such as making business energy costs taxable or providing accelerated depreciation, also can be helpful. Government agencies or utilities could be used to coordinate energy-saving strategies and even combine financed retrofit payments with reduced energy utility bills so that new utility costs plus finance payments are less than existing utility bills. And in place of home-heating financial assistance, we should help low-income individuals by either retrofitting their homes or apartments or relocating them to newer energy-efficient housing.

A massive energy-conservation program could reduce energy demand sufficiently to slow down the need for new energy supplies. For example, the reduction of electricity through energy conservation can reduce the requirement for additional energy generation, including nuclear as well as photovoltaic (PV) solar and wind power. Substantial conservation reduced electricity demand during the early 1980s so much that the construction of new electricity-generating power plants was delayed for several years.

To be effective, an energy-conservation policy must be implemented on a national scale to wring an energy waste out of the industrial and "built" residential, commercial, and institutional environments. This would require a national policy similar to the interstate highway program of the 1950s and 1960s. A massive energy-conservation program can be phased in quickly because all of the technology is proven and available. It will provide jobs and be cost-effective because the initial cost of retrofit will be paid for with future energy savings. A cash-flow analysis using life-cycle costing will ensure a positive cash flow. Not only is this the only short-term solution, it is the lowest-cost solution. Further, it would greatly reduce the federal trade deficit.

The proof that this is feasible is that Europe has half the energy consumption per capita as the United States with a similar standard of living.

SOLAR ENERGY

President Obama's energy plan calls for utilities to provide 10 percent of their electricity from renewable energy by 2012 and 25 percent by 2025. This mandates utilities to increase their photovoltaic and wind power by 1.9 quads by 2012 and 3.1 quads by 2025. Mandating utilities to provide renewable energy does not cost the federal government because the renewable-energy costs will be passed on when the renewable-energy systems become operational. Several states already have a mandate to provide up 20 percent of their energy with renewable energy by the end of 2010. This may lead to doubling electric rates while providing few benefits. California recently voted down a proposition to increase their renewable energy to 50 percent by 2025.

On a per-project basis, Connecticut has some of the largest PV solar energy rebates in the country, which are funded primarily through the Connecticut Clean Energy Fund (CCEF), which is funded by a surcharge on electric bills. Together, the rebates offer a solar PV rebate program of $4 for the first 5 kw and $2.50 for the next 5 kw. The rebates have funded over $48 million in renewable energy, primarily PV solar. The rebates often are over 60 percent of the installed cost and sufficient to encourage some buyers.

PHOTOVOLTAIC SOLAR ENERGY

PV solar converts sunlight into electricity, not heat. Unfortunately, current PV solar systems are only 10-percent to 15-percent efficient, while thermal solar systems are 60-percent efficient. PV solar generates electricity throughout the year and, therefore, has a better utilization rate than winter thermal solar space-heating.

A computer program[3] was used to evaluate PV solar to provide 50 percent of the annual 9,996 kwh electricity usage for a typical home with air conditioning in New Haven, Conn. This is a life-cycle-cost analysis using discounted cash flow:

TABLE 1

SOLAR PHOTOVOLTAIC ELECTRIC COST ANALYSIS

New Haven, Conn.

Required annual kwh	9,996 kwh
Average electric rate	16.61 cents per kwh
Installed peak watts	3,980
Roof area needed	398 sq ft
Installed cost	$35,820
Financed payment per year	$ 2,688
Federal tax credit	$ 2,000
State rebate	$16,200
Net cost	$17,700
Financed payment per year	$ 1,344 per year
Solar rating	4.65 kwh/SM/day
Gross energy saved	4,998 kwh
Energy delivered	4,333 kwh
First-year savings	$725
Av. annual savings	$1,212
25-year lifetime saving	$30,422

The $35,820 initial cost has annual payments of $2,688 per year when financed at 6.5 percent for 30 years. The first year electricity savings of 16.61 cents per kwh are $725. With a 3.78-percent annual electricity rate increase, the 30-year average annual savings is $1,212 per year with the savings in the 30th year $1,699. The total savings over the expected life of 25 years is $30,422. Federal and state tax credits reduce the installed cost to $17,700, and the financed cost at 6.5 percent for 30 years is $1,344 per year. With the 50-percent tax credits, the "cash flow" will become positive around the 20th year. However, at the end of the 25-year expected life of the solar system, a new system is required, but five years remain to be paid.

The initial cost of the solar system is $35,820. It is more than the $30,422 lifetime savings (with fuel-cost adjustments). The total cost of the financed payments for 25 years is $67,200 without the tax credits and $33,600 with the tax credits. The real financed cost of the solar system would be 62 cents per kwh ($2,688 per year divided by 4,333 kwh per year, or the cost of electricity would have to rise to 62 cents per kwh for the cash flow to break even. That is the base cost that utility would want to be reimbursed from the rate payer.

The cost analysis of the New Haven example illustrates the poor utilization factor of solar energy because of the day/night (diurnal), sun/cloud, and summer/winter cycle variations. The peak 4 kw solar collector provides gross annual energy savings of 4,998 kw. This is 1,250 equivalent full-load hours (4,998 kwh per 4 kw), or a 14.5-percent full-load utilization rate (1,250 EFLH divided 8,640 hr per year).

There is a big difference between reducing PV-solar peak electricity-generating capacity and reducing PV annual electricity usage. Comparatively, while 4 kw of PV solar would produce 4,998 kwh per year at a 14.5-percent utilization rate, 4 kw of nuclear power at a 91.5-percent utilization rate would produce 32,062 kwh per year. To save the equivalent 32,062 kwh per year with solar energy, 25.24 kw ([91.5 percent divided by 14.5 percent] x 4 kw) of PV peak solar-generating capacity would need to be installed, and the initial cost would be $227,172 at $9,000 per kw compared with nuclear power, which is estimated to cost $32,000 at $8,000 per kw. The cost of providing the same amount of electricity from future PV solar is almost eight times the cost of providing the same amount of electricity from future nuclear power.

Even though PV solar-energy output appears to be 100-percent efficient, there are additional electrical wiring and inverter losses that lower the efficiency to 85 percent. Further, the outer glass surface has some reflection and degrades in time, similar to a light fixture's light-loss factor. Some manufacturers provide a reflective film to reduce reflectance, but reflective films are certain to degrade over time. The glass-maintenance factor over the life is 20 percent, and typically an average 10-percent loss factor is added to the 85-percent inverter and wiring losses for a total of 75-percent solar efficiency. Therefore, the above example of 4 kw PV solar output is 4,988 kw, but it would only deliver 4,333 kwh, and the equivalent cost to deliver the 32,062 kwh would be $302,896 ($227,172 divided by 0.75)

The utility typically provides back-up electricity when PV power is not available and requires duplicate electricity-generating capacity. Storage systems, such as battery, compressed-air, and stored hydro, are not cost-effective. PV solar energy is produced only when sunlight is available, and the non-solar peak electricity demand becomes more pronounced during nonsolar periods. That reduces the utility's electricity-generation utilization rate and increases the cost of generated electricity. The solar energy costs will be shared with nonsolar users through hidden costs that average the higher solar PV costs with electric utility rates. The electric rates will increase slowly, but dramatically, as more PV solar systems are installed.

Further, the life expectancy of PV solar systems is yet to be determined. Most solar manufacturers offer a 10- or 20-year warranty. UL testing requires that they must be able to withstand 120-mph wind gusts and 1-in. hail stones. We know that 1980s thermal solar systems seldom lasted 10 years, in large part because the manufacturers cheapened the materials to lower costs. Further, there are other annual maintenance problems and potential costs, such as PV solar cells delaminating over time, moisture leaking into enclosures, decay factors from ultra violet rays, temperature cycling from high to low, and glass surfaces needing to be cleaned. While rain water is all that is typically used to clean glass enclosures, dust on glass in low-rain areas can reduce solar radiation and electrical output substantially. Snow and ice must be cleared from solar collectors during winter. And average inverter life is 10 to 15 years.

To obtain large amounts of PV solar energy, large solar power plants are required. Recently, two new PV solar power plants in California are being planned by the utility, and they will use 12.5 square miles in central California to provide 550 MW of thin film collectors at a fixed 20-degree angle and 250 MW of silicon-crystal tracking collectors, which are more efficient but more costly. The installed costs, which should include the cost of 12.5 square miles of land, have not been released. These systems are not based on economics or tax credits, but a California state mandate that requires utilities to provide 20 percent of their electric power by renewable energy by the year 2010. Ultimately, the high PV solar costs will be passed on to rate payers through higher electricity rates.

Many solar enthusiasts quote a January 2008 article in Scientific American magazine, "Solar Grand Plan," as "fact." The article proposes installing 2,930 GW of thin-film photovoltaic solar collectors by 2050 to provide 65 percent of our electricity and 35 percent of our total energy, requiring 30,000 square miles in the Southwest desert where the solar heat gain is greatest. Compressed air-storage systems are proposed to store excess PV electricity for use during nonsolar periods. It proposes the U.S. government provide subsidies for a new $400 billion HVDC transmission line to transport electricity across the country to eastern population centers. It assumes that new technology will reduce current solar system costs from $4 per watt to $1.20 per watt, and the thin-film efficiency will improve from the current 10-percent efficiency (conversion of total sunlight to energy produced) to 14 percent. Is the Solar Grand Plan feasible?

Solar energy is capital-intensive, and this is coming at a time of serious economic problems. The current average cost for small roof-mounted PV solar installations is $9,000 per watt. While very large PV solar installations such as the Solar Grand Plan would have lower PV installed costs, they require the added cost of land area and use $9,000 per watt.

At $9,000 per kw, the cost of providing 1 GW of PV solar-generating capacity is $9 billion. The cost of providing 65-percent electrical production by 2050 would be $26.5 trillion in today's dollars (spent over 42 years). A 50-percent tax credit would increase our government deficit by $13.3 trillion and require the rate payers to pay $13.3 trillion. Alternately, mandating utilities to install PV collectors would result in a $26.5 trillion in utility-rate increases.

Solar advocates believe that technology will greatly reduce future solar-system costs, such as the Solar Grand Plan, thereby making them cost-effective. However, even though there has been considerable research and development on solar energy for many years, their cost-effectiveness has not significantly improved over the last 35 years. There are several reasons for this, such as sunlight is very dilute and irregular, solar cells have a maximum low theoretical efficiency and the possible improvements are limited, solar systems are material-intensive, and solar systems are energy-intensive.

<u>Solar availability</u>

Solar heat gains are published in the American Society of Heating, Refrigerating and Air-Conditioning Engineers' (ASHRAE's) 1982 Application Handbook. Table 2 summarizes total annual solar energy per square foot at 40 degree North latitudes for one day each month. The number of cloudy days and partly cloudy days for each month can be obtained from the U.S. Climate Atlas Website and subtracted from the annual gross solar heat gain. The following is a summary of the calculations for thermal solar for New Haven, Conn.:

Table 3 provides a summary of the maximum available solar heat gain for three locations using ASHRAE data.

TABLE 3

SUMMARY OF SOLAR IRRADIATION HOURLY AND DAILY VALUES FOR 32 AND 40 DEGREE NORTH LATITUDE

	Connecticut	**Ohio**	**New Mexico**
Annual gross solar HG (Btuh/SF/yr)[1]	768,698[1]	768,698[1]	803,718[2]
No. days per year	365	365	365
No. cloudy days per year[3]	161.4	186.4	82.5
No. partly cloudy days per year[4]	93.4	95.9	87.4
No. solar-heat-gain days per year[5]	159.6	130.7	238.7
Annual gross solar HG (Btuh/SF/yr)[6]	331,022	278,558	527,139
Annual net gross solar HG @ 60%-eff. collector (Btuh/SF/yr)	198,613	167,135	316,283
Annual net oil saved gal./SF/yr[7]	1.4	1.2	2.2

Notes:

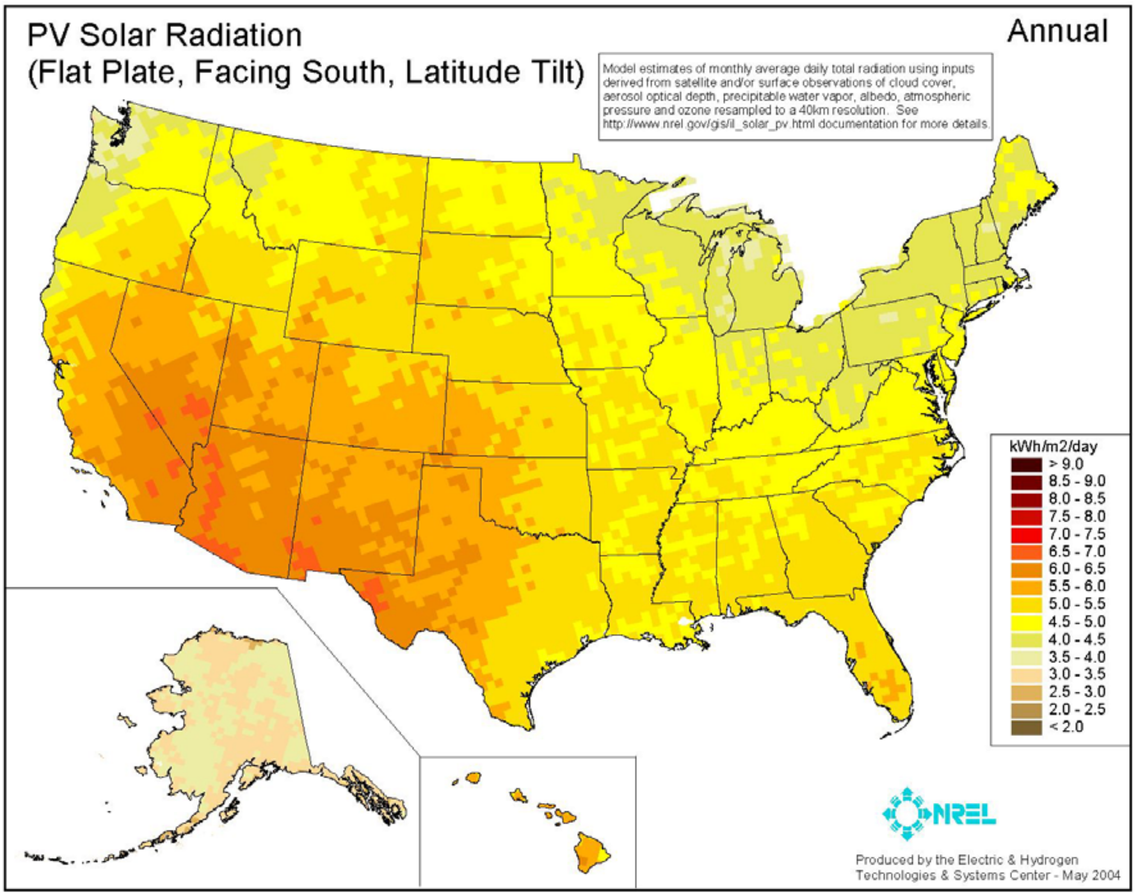
1. The annual gross solar heat gain from 1982 ASHRAE Handbook, Chapter 57, 40 degrees North Latitude.
2. Ditto, 32 degree North Latitude.
3. U.S. Climate Atlas.
4. U.S. Climate Atlas.
5. The number of solar HG days per year is the number days per year less (number cloudy days per year plus half number of partly cloudy days per year).
6. The annual net solar HG is the annual gross solar HG multiplied by the ratio of the number of solar HG days per year and the number of days per year.
7. The annual net solar HG (Btuh per sq ft per year) divided by 140,000 Btus per gal.

Table 3 shows annual gross solar heat gain considering clouds that fall on 1 sq ft per year. Note that the maximum in New Mexico is only 1.6 times the amount in Connecticut. And with a 60-percent-efficient thermal collector, the maximum amount of oil that at

140,000 Btuh per gallon that can be saved is 1.4 gal. per sq ft per year for Connecticut and 2.2 gal/SF/yr for New Mexico.

The following PV Solar Radiation map shows Annual Solar Radiation available in the United States.

U.S. FIGURE 1



Solar Efficiency

Future technology improvements in solar-cell efficiency are limited, according to research by William Shockley and Hans Queisser, who found “thermodynamic efficiency limits” for PV solar cells. Their top efficiency limits for PV solar cells still are widely accepted. (March 2007, “Solar Energy Conversion,” Physics Today). The most common commercially available PV solar cells use single-crystal silicon solar cells; average 15-percent efficiency, with a top efficiency of 18 percent and a current laboratory best of 25-percent efficiency; and have a maximum thermodynamic efficiency of 31 percent. Thin-film collectors typically have 7-percent to 8-percent efficiency with a top commercially available efficiency of 10 percent and a laboratory best of 16.5 percent. Concentrating solar cells have thermodynamic efficiency limits of 41 percent, while complex multijunction solar cells have possible thermodynamic-efficiency limits of 66 percent.

Considerable efficiency improvements have been made, and further improvements for all types will be more difficult. Generally, the greater the solar-cell efficiency, the greater the solar-cell costs per sq ft.

TABLE 4

RESEARCH WORK BY SHOCKLEY AND QUEISSER FOUND MAXIMUM THEORETICAL "THERMODYNAMIC EFFICIENCY LIMITS" FOR PV

TYPE	CURRENT AVERAGE	CURRENT TOP	CURRENT LAB BEST	THEORETICAL LIMIT
SINGLE CRYSTAL SILICON SOLAR	15%	18%	25%	31%
THIN FILM SOLAR CELL	7%-8%	10%	16.5%	
CONCENTRATING SOLAR CELL				41%
MULTIJUNCTION SOLAR CELL				66%

Doubling efficiency reduces the number of modules and commodities by half. Silicon-wafer manufacturers, who have been successful in reducing wafer thickness by almost 50 percent, from about 340 μm to 180 μm, and are approaching diminishing returns because of the cost of wafer sawing and the large kerf loss, which are approaching 50 percent, can see the difficulty in increasing efficiency.

Solar-material requirements

In an evaluation of future costs for solar collectors, material availability must also be considered. The "Solar Grand Plan" article projected the initial costs to drop from a current $4 per sq ft to $1.20 per sq ft by 2050. But the 2,930-GW required PV Solar Grand Plan generating capacity would increase material costs and PV solar initial costs.

The material requirements for PV solar were evaluated in a report prepared by the U.S. Department of Energy (DOE) titled "Will We Have Enough Materials for Energy-Significant PV Production." The study evaluated the quantities of materials for a major PV effort, based on achieving an annual U.S. production rate of 20 GW by 2050. The study used a current solar-cell efficiency of 10-percent and 15-percent efficiency for 2050. However, the report compares U.S. requirements for PV solar materials to the world supply of materials and does not reflect future material requirements for the rest of the world's PV solar systems.

Recent world demand has resulted in skyrocketing U.S. oil and commodities prices. Similarly, world demand for PV solar materials will raise future costs for U.S. PV solar materials.

The DOE analysis should consider a world annual production rate for 2050 of 100 GW in lieu of the report's U.S. production rate of 20 GW. The current world annual PV production rate is 0.7 GW. Assuming a uniform rate of production increase from 0.7 GW to 100 GW by 2050, the world annual production rate would be an average 50 GW per year for 40 years and would provide a total of 2,000 GW installed generating capacity by 2050.

The EIA's 2008's World Energy Outlook lists the total U.S.- and world-installed generating capacity (GW) and annual power generation (kwh 10^9) as:

TABLE 5

	U.S		**World**	
Year	GW	kwh 10^9	GW	kwh 10^9
2006	1,074	4,300	3,889	17,500
2030	1,213	5,000	7,033	36,364
2050[1]	1,523		9,429	

Note:

1. 2050 installed electric-power-plant generating capacities have growth rates of 1.3 percent and annual power generation of 2.4 percent.

Therefore, PV solar energy should consider the material requirements to achieve 2,000-GW generating capacity, or 21.1 percent of the world-installed-generating capacity for traditional electric power plants of 9,429 GW for 2050. The 25-percent U.S. share of the world PV solar-generating capacity would be approximately 400 GW--much less than the 2,930 GW required in the Solar Grand Plan, and this would provide only 8.9 percent of our annual electrical energy consumption by 2050 at a 14.5 percent PV solar utilization rate.

An evaluation of the materials required for PV solar must include consideration of basic commodity materials for the modules and arrays housing and balance of systems (BOS), which includes the inverter, wiring, switchgear, and specialty materials for the PV solar cells and semiconductors.

Module and array housings for solar cells must be water-tight and dust-proof, have mounting frames, and be strong enough to withstand 120-mph winds, 1-in. hail, rain, snow, and hurricanes. Module housings and BOS require glass, plastic, concrete, copper, steel, and aluminum. Extrapolation from the DOE study projects that 32 percent of the world's production of glass, 9.4 percent of the world's production of aluminum, and 1.4 percent of the world's production of copper would be required to reach a total annual production rate of 100 GW 2,050 and to reach a total world-generating capacity of 2,000 GW of solar energy.

Further, the specialty materials are the semiconductor materials used in PV solar cells. Extrapolation from the DOE study projects that it would take a 2,600-percent increase in the world production of purified silicon or a 1,036-percent increase in telluride to reach a total annual production of 100 GW by the year 2050 with a total generating capacity of 2,000 GW of solar energy. Other semiconductor materials may be used.

For PV solar to supply 20 percent of the world's installed generating capacity by 2050, the total PV demand for glass, copper, and aluminum must include the commodity materials for PV solar, BOS, thermal solar energy, production of all other energy sources, and basic commodity materials for undeveloped countries, which are modernizing their infrastructures. Therefore, the combined increased commodity demand will certainly cause solar material prices to explode, and this could overwhelm the world's commodities production capacity. Comparatively, the increased requirement for corn-based biofuels has led to worldwide increases in the cost of food. And, it is both inflationary and destabilizing. World demand for basic commodity solar materials likely will do the same. And, cost-effective material availability for the Solar Grand Plan appears unreachable.

An example of specialty-materials problems is the recent shortage of purified silicon. Silicon-based PV systems have been the most widely used PV systems in recent years. However, silicon-based PV costs have not decreased, even though silicon is plentiful because of high manufacturing costs for silicon wafers.

PV solar cells also are energy-intensive.

Because of the numerous types of photovoltaic solar cells with proprietary designs, the amount of energy that is used in PV solar manufacturing is difficult to quantify, but numerous studies are available. Several studies show energy pay backs times (EPBTs) vary from 1.7 year to never. The average EPBT is four years for rooftop PV systems and longer for larger PV systems.[4] It takes four years to recoup the energy that went into manufacturing.

The reason for the large variations in EPBT is what is included in studies. Some studies include only electrical energy output and not generation input. Some studies include the energy required for concrete foundations in ground-mounted systems and even energy in labor. The use of cost with life-cycle costing to evaluate the net energy of solar systems is recommended because it uses all of the materials and labor that goes into manufacturing a solar system.[5]

THERMAL SOLAR

Solar energy was the energy source "du jour" during the late 1970s and early 1980s, but failed badly. Those systems were almost entirely "thermal" solar systems for domestic hot water and space heating. Projected annual savings were exaggerated; capital costs seldom were returned even with tax credits; and most systems failed before their design life was reached.

The most cost-effective thermal-solar application is domestic hot water because it can be used throughout the year, while space-heating demand can be used only during winter. Because winter space heating is a much larger load than domestic hot water, space-heating solar collectors are effective only one-third of the time, when daylight is the shortest and sunlight is least available.

A solar-cost-analysis program[6] analyzed the cost-effectiveness of thermal solar. The solar program calculated the initial cost and payback for a domestic-hot-water system used to preheat makeup water sized at a 3 sq m (32.3 sq ft) collector with an initial cost of $4,000. Based on a 15-year life expectance, natural-gas costs of $1.10 per therm, and a 3.67-percent annual fuel-cost increase, the following solar analysis summarizes three locations:

TABLE 6

SOLAR DOMESTIC-HOT-WATER HEATER

	New Haven, Conn.	Cleveland	Los Alamos, N.M.
Installed cost	$4,000	$4,000	$4,000
Fed. tax credit	$1,200	$1,200	$1,200
Net Cost	$2,800	$2,800	$2,800
Financed Payment/yr	$288	$288	$288
Solar Rating	4.5 kwh/SM/day	4.5 kwh/SM/day	6.0 kwh/SM/day
Energy produced	83 therm/yr	78 therm/yr	107 therm/yr
Fuel saved	11.9 million Btuh/yr	11.2 million Btuh/yr	15.3 million Btuh/yr
Annual savings	$91 1st year	$83 1st year	$129 1st year
Av. annual savings	$124/yr	$113/yr	$176/yr
Fifteen-year savings	$1,860	$1,697	$2,637

For New Haven, Conn., a $4,000 solar system saves $91 the first year, an average of $124 a year for 15 years and $157 the 15th year, with a 3.67-percent fuel-cost increase for a total savings of $1,860. The after-tax-credit installed cost is $2,800, and the annual payment is $288 per year at 6.5 percent for 15 years. The "cash flow" is negative because the annual payment is more than the annual energy cost saved. The system never pays for itself. New technology improvements are not expected to reduce the capital costs or efficiencies of thermal solar systems.

There appears to be little published data quantifying the amount of materials and energy that goes into a thermal-solar collector, but in 1976 the average solar thermal collector used 1 lb of copper, 3 lb of glass, and 1 gal. of oil per square foot. The future material costs will increase, and there is little research to improve the technology. Therefore, solar energy's future cost analysis will not change and thermal solar will not be cost-effective without large tax credits.

SOLAR ENERGY SUMMARY

Solar energy does work, but that does not mean it is a solution to our energy problems. The question is, "Will large scale solar energy provide cost-effective, plentiful, future energy supplies?

Solar energy has been a hopeful solution to the energy crisis. We are told that solar energy is free and available in vast and usable quantities. But, solar energy still is dilute and irregular. New solar installations are very expensive, requiring large tax credits that reduce their true costs. We need an object analysis.

While current PV solar systems are not cost-effective, future large applications of solar systems likely will cause material shortage. Future installed costs of solar systems will increase at least as fast as the rate of inflation. The promise of low solar costs is similar to the promise of lower utility costs resulting from electric deregulation, which instead has led to much higher utility costs. Rather than solar energy being free, it may be the most expensive energy solution. We should continue research and development until we can provide PV solar that is cost-effective, and we should eliminate mandated solar systems or provide massive tax credits.

Solar energy cannot be a short-term solution and cannot help reduce the trade deficit. It does not appear that it can be a mid-term or long-term solution. Perhaps research and development will offer some new unforeseen technological advances, but now we have to focus our limited resources where they will do the most good.

The use of life-cycle costing to evaluate the viability of solar energy as a major energy solution has shown it is not economically viable. Even though the cost of energy has greatly increased over the last 30 years, the life-cycle-cost analysis of solar energy has not improved. That is because the initial cost of a solar system has increased as much as the cost of energy. Further, we have no history with solar-energy systems operating over their 30-year advertised life expectancy. It seems folly to base a national energy policy on an energy solution that has not stood the test of time.

Exxon has stated that it believes renewable energy may only account for 2 percent of our energy by 2030, which seems realistic.

WIND POWER

President Obama's national energy plan's renewable-energy mandate includes wind power along with solar energy for the utilities to provide 10 percent electricity by 2012 and 25 percent by 2025. A May 2008 report, "20% Wind Energy by 2030," published by the U.S. DOE's Efficiency and Renewable Energy supports the feasibility of using wind power.

Wind power is the process of using wind turbines to convert the kinetic energy of the wind into mechanical power to rotate electric generators and make electricity. Wind speed is highly variable geographically, seasonally, and with the weather. Compounding the variability of wind power is that it varies with the cube root of wind speeds.[7] This creates problems with the existing electrical grid and backup electricity generation.

To improve efficiency, wind turbines have increased in size to several megawatts each and 400 ft tall. They often are grouped into wind farms to provide bulk power to electric utility grids. The best wind locations are at the tops of hills and mountains extending high into the earth's boundary layer. Coastal regions often are windy because of temperature differences between land and water. And cold air from mountains can sink down to plains, causing strong winds. Seasonally, winter winds are twice the strength of summer winds. Spring and autumn equinoxes are windier and can cause extreme conditions, such as tornados. Summer winds often are vertical (thunder storms) caused by highland temperatures. Because of these characteristics, wind does not usually exist during the peak electrical demand periods that occur during daytime summer air-conditioning periods.

Designing for extreme conditions increases the initial cost of wind turbines. Unfortunately, periods of extreme weather conditions are beyond the operating limits of wind turbines and electric generation does not occur.

Back-up traditional electric generation is required for low-wind periods. This back-up generation will have a low utilization rate, and wind power may require shutting down base-load electric power, resulting in higher electricity rates, also. It is difficult to coordinate the supply of wind-generated electricity to meet the demand of electricity users, as both can change rapidly. Unfortunately, the storage of wind energy has the same difficulties as PV solar energy, and it further reduces the efficiency of wind power and adds to its cost. The lack of storage means that there are periods when wind energy cannot be used.

Wind farms typically are located in rural areas away from areas of major energy use. Therefore, new transmission lines often are necessary to transport wind-farm electricity to areas of energy demand.

There are numerous on-shore areas with plentiful wind, and it is estimated that 6 percent of the contiguous U.S. area could provide more than 1-1/2 times current electric consumption in the United States. Only a few U.S. locations are considered suitable for wind farms. Their average wind energy can have a 30-percent utilization rate, while the best wind-energy locations can have utilization rates of 40 percent.[8] The capital costs[9] for wind-energy projects built in 2007 ranged from $1,240 per kw to $2,700 per kw, with an average cost of $1,710 per kw, up 10 percent from 2006 costs and up 27 percent from projects installed from 2001 to 2003. The 2008 average installed costs are up to $1,920 per kw, resulting in a break-even cash flow of 7.4 cents per kw. These cost increases show that new technology no longer is reducing wind-turbine costs.

Production costs have been between $35 and $60 per mw. However, these include federal, state, and production tax credits, and the actual costs are approximately 25-percent higher. The lowest production costs are in Texas, and the highest production costs are on the East Coast and California. Without substantial government assistance in the form of federal-tax incentives, production tax credits, state renewable portfolio standards (RPS), concern about global warming, and concern about long-term energy availability, it is unlikely that wind power would be considered. The increased size of wind turbines has produced most of the increases in efficiency, but they have reached sizes that are limited by their ability to be transported by trucks over roads.

Off-shore wind-turbine farms can have plentiful wind. However, the problems are more difficult, and the estimated installed costs are $2,400 per kw to $5,000 per kw.[10] The East Coast continental shelf allows their installation at shallower depths than the West Coast. Larger, more efficient wind turbines still may be developed for off-shore wind farms because they could be transported by barge.

Small individual wind turbines typically cost $5,000 to $7,000 per kw[11] and will have lower utilization rates because of lower efficiencies and less suitable wind power. There, they have a poor payback and a limited ability to increase U.S. electrical supply.

Wind turbines have annual operation and maintenance costs that must include the cost to lease land. Further, wind turbines are complex machines that will require regular maintenance and replacement at the end of their projected 30-year life. Even large turbine blades are subject to stresses.

To provide 20 percent of our generation capacity with wind turbines, it is estimated that new turbine production will have to be increased to 7,000 new turbines per year by 2017 to have 100,000 turbines in operation by 2030 and provide 20 percent of our electricity.

Wind energy has been the most cost-effective renewable-energy source because their installed costs are near the cost of standard electrical generation, and the utilization rate is much better than solar. However, they still require substantial tax credits or government mandates.

An environmental concern that was not covered in the DOE report is, “Can wind farms change the weather as large scale wind power is implemented?” Wind turbines remove energy from the wake of a turbine.[12] With 400-ft-high wind towers, the size of a 40-story building, spaced close together, it would seem that average wind speeds could be reduced enough to affect existing weather patterns. The DOE report to supplying 20 percent of our energy from wind calls for 300 GW of generating capacity. Will concentrated large wind farms remove sufficient kinetic energy from wind to affect the weather downstream? While Europe is far ahead of the United States in its use of wind power, it has had a substantial change in its weather. The disappearance of glaciers in the Alps is blamed on global warming, but could wind farms be part of the problem?

While wind energy is acceptable in limited quantities, the question of whether wind farms will impact weather must be evaluated before large-scale wind farms are constructed across large areas of the United States. New large wind turbines have not withstood the test of time. They are complex machines subjected to wind and weather extremes, and they have substantial maintenance costs. Further, because the current wind turbines are new designs, there is insufficient operational experience for maintenance costs, life expectancy, replacement costs, and cost-effectiveness. It is dangerous to establish a national energy policy based on costly tax credits without long-term operating experience.

NEW TRANSMISSION LINES AND SMART GRID

Typically, both large-scale wind farms and very large PV solar-energy systems are located long distances from major areas of population and energy use. New long-distance power-transmission lines will be needed to transport wind and PV solar power to consumers in population areas. Unfortunately, PV solar power has a 14.5-percent utilization rate, and wind power has 30- to 40-percent utilization rates. Therefore, costs to transport power are higher because the transmission-line cost is averaged over fewer kwh. The cost of power-transmission lines can be substantial and change the economics of an entire project.

All electrical-power transmission lines have voltage drops and power losses. Typical power-transmission lines are AC voltage. For an equal kw and wire size, higher voltage reduces the electrical current, lowers the voltage drop, and reduces the electrical losses. The transmission-line losses typically are 7 percent. Longer transmission lines require higher voltages to minimize the line losses. Transformers must be used to increase the transmission voltage at the start and reduce the transmission voltage at the end. High-voltage transmission lines vary from 110 kv up to 765 kv. At the highest voltages, high temperatures can cause a wire to sag. Typical power-transmission lines are run overhead because they are 1/10 the cost of underground lines, However, a 1-GW overhead transmission line from a power plant requires a strip of land about 600-ft wide and is more exposed to disruptions caused by weather. To provide PV solar electric for the Grand Solar Plan that proposes a 2,940-GW PV power-transmission line from the Southwest desert to populated areas would require 2,940 1-GW power-transmission lines with a 14.5 percent utilization rate. The costs and material requirements for these transmission lines must be added to PV solar.

New high-voltage direct-current lines may be able to allow the transmission of wind and solar PV electricity over longer distances with lower costs and losses. But it is unlikely that the low utilization rate of PV solar or wind power would justify the high costs of HVDC.

Prior to President Obama's national energy plan committing to a large-scale "Smart Grid,"[13] the future electrical requirements of PV solar energy, wind energy, and the electric auto must be established. We may not require new transmission lines and a smart grid.

The valid reason for a "smart grid" is to adjust electrical loads because sunlight is highly variable. Wind power is highly variable because of cube root and variable wind speeds. Both of these can require starting and stopping traditional electric generation to prioritize renewable-energy production. Therefore, the cost for a "smart grid" is justified mainly by poor utilization rates and inconsistent electricity generation. Much of its costs must be added to the high costs of PV solar and wind power, and the expenses will be passed on to everyone--either through higher taxes or higher electric-rate payers.

The "smart grid" should be a research-and-development tool for possible mid-term and long-term solutions, such as high-temperature superconductivity, visualization and controls, renewable- and distributed-system integration, and energy-storage and power electronics.[14]

Generally, these are old ideas that have never been cost-effective, and we must not jump into its production prematurely to create jobs as a solution to our economic problems prior to effective research and development.

ETHANOL AND BIOMASS

Ethanol cannot be a major energy source because it requires large amounts of land, using almost as much energy to make as it produces. As ethanol becomes a bigger part of energy supplies, its costs would increase greatly. Other biofuels would face similar problems, with tax credits and loan grants temporarily lowering costs and hiding these problems.

In 2006, the government passed the renewable-fuel standard (RFS), which mandated the amounts of corn-based ethanol used in gasoline. The current ethanol-production capacity has grown from 5.7 billion gal. in 2007 to 9.9 billion gal. in August 2008. Last year, additional legislation was passed to double ethanol production to 36 billion gal. by 2022. Europe and other foreign countries followed the United States' lead and increased their requirements for biofuels.

Predictably, the price of corn rose from $2 a bushel in 2004, before the mandates, to $8 a bushel. This devastated the price of food staples and corn-fed livestock. Texas Gov. Rick Perry led a fight against meeting the U.S.-mandated ethanol requirements. Globally, the Organization of Economic Cooperation and Development recently said, “Biofuels production would push food prices higher and contribute to food insecurity for the most vulnerable populations in developing countries, while having a limited impact on reducing greenhouse gases and improving energy security.” The International Monetary Fund’s food-commodity index showed that biofuels have contributed up to 10 percent of the overall rise in food prices, and this has led to riots in some countries. Moreover, some experts are saying biofuels are causing up to 25 percent to 35 percent of the increases in food costs.

In addition to problems with corn’s availability and cost, ethanol has corrosion problems. It cannot be transported through regular piping systems; it must be transported by stainless-steel tanker trucks, thereby increasing costs. In lieu of ethanol, biomass can be produced as biodiesel. This is not corrosive. Also, because corn and soybeans require substantial fertilizer, these biofuels have environmental problems. And some biodiesels fuels have problems in cold weather.

Europeans recently announced they are reconsidering their use of biofuels mandates and may reverse their policy, which was based on global warming and climate-changing emissions. In addition to the food shortages, they believe that deforestation from the burning of tropical forests to clear land for biofuel plants is leading to increased greenhouse gases. It is hoped that future U.S legislation will stop the 2020 biofuels mandate.

Currently, the emphasis is away from corn and soybean feedstock that compete with food production and toward cellulosic biomass feedstock, such as switchgrass, agricultural waste, and forestry residues. But cellulosic feedstock, such as corn stalks, is plowed into the ground to decompose and fertilize the next crop. There are environmental consequences to harvesting switchgrass in tidal areas. And the land area required for switchgrass could be as large as that required for ethanol.

While traditional biomass is land-intensive, a new possibility is biomass made from algae, which is grown in water and can produce large amounts of biofuels. Notably, the pharmaceutical industry reportedly grows algae that can produce 5,000 gal. of biodiesel per acre, compared with 70 gal. of biodiesel from soybeans and 420 gal. of ethanol.

Research is under way to develop more cost-effective methods of mass-producing cellulosic biofuel. We already have mass-produced ethanol-production facilities in farm country, and many of those are being idled and bankrupted because ethanol is proving to be uneconomical. This is a perfect example of skipping research and development to save time and money, but instead wasting them. Optimum energy solutions need adequate time for the phases of research and development, building prototype plants to vet the processes and economics, and finally building manufacturing plants.

Ethanol is not a cost-effective solution, and the mandated ethanol production is causing worldwide food shortages and high prices.

WORLD CRUDE OIL

Conventional crude oil, or “low sulfur, sweet crude,” has been the world’s primary energy source for transportation, heating oil, and some electric-power generation for 100 years. When we discuss running out of oil or the increased cost of a barrel of oil, it is primarily about conventional crude oil. U.S. oil production has declined from a peak of 9.64 million barrels a day in 1970 to a projected 4.9 million barrels a day in 2008 and has been declining at a rate of 15 percent per year.

The world has depleted much of its traditional crude oil, as most of the world’s largest fields have peaked, and their output is declining. Most of the new replacement oil is heavy, high-sulfur crude, toxic, under dangerous pressure, and difficult to refine. This includes new fields in Saudi Arabia, Eastern Russia, Kazakhstan, and Venezuela.

In 2006 article, the EIA projected world oil supplies would increase substantially for 20 to 30 years before peaking. The EIA has since downgraded its previous energy projections, and the view that the world has reached its peak oil production is accepted by more experts.

The best proof that world oil supply is peaking is that even though oil prices have more than doubled during the last two years, world energy supplies have not increased appreciably. Current energy prices are declining based on reduced demand caused by high prices, not by increased supply. While oil prices have increased U.S. oil production, it is only a trickle, and as oil prices fall, the most unprofitable oil production will shut down and most exploration will stop.

While some believe that the increase in energy prices has been caused by oil-company manipulation, the energy-price increases primarily have been caused by normal supply and demand. Only 5 percent of the world’s oil is controlled by private oil companies. The other 95 percent of the world’s oil is controlled by state-owned oil companies, such as Saudi Arabia, Mexico, Norway, Venezuela, and Russia. It is not logical to think that only 5 percent of private oil companies are able to control world energy prices. Further, most other commodities had large price increases similar to oil.

Windfall oil-profit taxes have some merit, primarily because big oil companies have abused tax incentives. Only 40 percent of oil companies recent profits went to increased exploration and production. The other 60 percent went to increased dividends and stock buybacks. Eliminating existing oil-tax incentives makes sense.

The potential for U.S. off-shore oil production includes Alaska, the East Coast, the West Coast, and the gulf coasts. Gulf of Mexico off-shore oil production is reported to break even at $95 a barrel. Increased Alaskan oil is estimated to meet 2 percent of our current demand, and it would not be available for 10 years, would last only approximately 10 years, and require higher costs. Similarly, production from new U.S. off-shore fields cannot be expected for up to 10 years because Brazil has leased all available oil platforms for its recent off-shore discoveries, and there will be few spare oil platforms for several years. Two to three years are required to build new platforms, there is limited platform production capability, and new off-shore oil platforms cost several billion dollars each. This is not a short-term solution that can reduce the federal trade deficit.

Regardless, we should begin off-shore oil exploration in feasible areas as soon as possible to quantify our proven oil reserves. Just as enormous oil discoveries have been found off-shore in Brazil, we should have large discoveries off our shores. Off-shore production may be necessary--not to reduce our dependence on foreign oil, but to replace the depletion of our existing oil fields or else our oil import-trade deficit will be even greater in 10 years.

Increases in future oil supplies must come from unconventional oil, such as oil from the Alberta tar sands, coal liquefaction, and Rocky Mountain oil shale. The increased cost of oil is increasing unconventional oil's economic viability. Even though unconventional oil has major cost advantages because existing oil pipelines, refineries, automobiles, gasoline stations, and oil burners can be used, there are limitations and problems for all three.

The Canadian tar sand contains enormous quantities of oil and is economically viable at $50 a barrel. Current production is 1.5 million barrels a day, and the output is expected to double by 2010. However, it also is labor-intensive, water-intensive, energy-intensive, environmentally dirty, and more expensive to refine. To increase capacity and because of the vast quantities required, there will be shortages in labor and water. Further, the tar sands are Canadian and will not solve the U.S. trade deficit.

Coal liquefaction converts coal into a liquid. The production problems are similar to those of tar sands because vast quantities of water, energy, and labor are required. But the technology is not available. Experimental prototype plants that are environmentally clean, reduce CO_2 emissions, and provide a liquid fuel that is cost-competitive have yet to be completed. The energy can be obtained, but it will take decades to build and test prototype plants and then mass-produce production plants. While it is a realistic solution, it is an expensive and mid-term solution at best.

The U.S. has enormous Rocky Mountain oil-shale deposits. However, the oil is very difficult and expensive to extract. Large amounts of water and chemicals are required. The water is converted to high-pressure steam and injected into the ground for several months to liquefy the oil and fracture the shale. Some techniques also require freezing the surrounding areas to prevent the added chemicals from migrating and contaminating ground water. I recently was told by a Shell executive that the company's experimental work with in-situ oil-shale processes shows that it was expected to be profitable at $200 a barrel. Even though Shell and others have been experimenting with oil-shale production for many years, they probably are decades away from economical production.

U.S. and world conventional oil production likely will continue at this peak and then decline. It still is the premier fuel for transportation, and that is not likely to change anytime soon. Conservation will extend our supplies of oil. Unconventional oil replacements will not be a short-term solution, and future supplies will be expensive.

NATURAL GAS

Natural gas is the cleanest and preferred fossil fuel for residential-, commercial-, and industrial-heating applications and increasingly has been used for electric generation. The current U.S. demand is 23 trillion cu ft, of which 4 trillion cuft is imported--adding to our trade deficit.

Until recently, the traditional U.S. natural-gas (NG) reserves had been declining over more than 20 years. After nearly two decades of development and using new technology, non-traditional NG production from the Texas Barnett Shale has increased tenfold since 2001. Last year, 7,500 wells supplied 1.2 trillion cu ft, or 7 percent of our nation's supply, and production has increased by 8.8 percent this year. The Barnett Shale estimated reserves are 27 trillion cu ft and approximately one-year U.S. consumption.

This new technology can be used to develop several other shale deposits. A Deutsche Bank analyst predicts NG-shale production is likely to more than double by 2011, resulting in a quarter of our nation's NG production. At least two other shale formations, the Haynesville in Louisiana and the Marcellus in Appalachia, are believed to be larger, but two to five years is necessary to obtain substantial production. The Haynesville shale already has a few large producing wells, and some estimate that it could produce up to 250 trillion cu ft. And, there are two dozen other shale formations in the United States that may have even more. Little testing of these new fields has been completed, and experts are disagreeing on the extent of the finds, which could be as much as 842 trillion cu ft--a 40 year's supply at today's consumption rate, or as little as a replacement for existing declining fields.

These NG-shale fields have become economic because of new technology and higher natural-gas prices. Natural-gas prices increased from $2 to $13 per thousand cu ft from 1999 to last year. The recent increases in supply changed the dynamics, and the NG prices dropped to $8 per thousand cu ft, which is equivalent to oil at $106 a barrel. The economic downturn has reduced demand further, and the price has dropped to below $5 per thousand cu ft. This has resulted in the shutting down of unprofitable wells.

The NG shale requires long horizontal wells and the injection of enormous amounts of water and chemicals to fracture the shale. These natural-gas-shale deposits often are in populated areas in which wells and pipes will need to be run, and there will be competition for water and a possible danger that the chemicals will contaminate ground water. However, NG shale has great potential and could increase U.S. natural-gas production in the short term at reasonable prices and help cut our trade deficit. Unfortunately, not all experts agree that shale NG production will be sustainable and able to replace the existing declining natural-gas fields. It still is too early to know how soon, how much, how long, and at what cost natural-gas shale can be used and whether it can replace some of our oil imports.

Natural gas can be converted to a liquid with greatly reduced volume by sub-cooling to very low temperatures and transporting it in tankers. The Middle East has been developing liquidifed-natural-gas (LNG) terminals and ships to transport LNG over long distances. The United States had planned to build eight LNG terminals to unload and convert LNG back to natural gas for distribution through existing piping and to replace declining NG fields. For political and environmental reasons, we have not built most of the LNG terminals and most of the Middle East LNG is now under contract to China and other parts of the world. Imported LNG would not solve our trade deficit. If natural-gas-shale production lives up to expectations, we may not need it.

T. Boone Pickens recently proposed converting automobiles from gasoline to natural gas. This is not an equivalent alternative to gasoline because NG tanks allow only half the travel distances, and twice the storage capacity is required. It would be an expensive conversion to add natural gas to our current gas stations. This may be limited to large corporate and public fleets and specialized locations, but should be pursued because we need to reduce transportation energy to reduce our trade deficit.

It would be much cheaper to replace existing oil-fired furnaces and boilers with natural gas to reduce the trade deficit. Many commercial and industrial boilers have dual-fuel burners, and it is easy to switch from oil to NG. Residential and commercial fuel oil currently accounts for more than 1 quad of U.S. consumption. Where feasible, new natural-gas storage and piping systems can be added. In remote areas with less population density, oil-fired furnaces can be converted to LPG, geothermal heat pumps, or new compressed natural-gas systems, which should be developable if it can be used in cars. Many new natural-gas boilers and furnaces are 15 percent to 25 percent more efficient than the best fuel-oil boilers and burners. The increased availability of NG from conservation can be used for other applications.

Moreover, coal, nuclear, and fuel-oil utility power plants average only 33-percent efficiency, and more than two-thirds of their heat is wasted. New combined-cycle gas-turbine power plants achieve 68-percent efficiency. Conversion of oil- and coal-fired power plants to combined-cycle gas turbines will reduce U.S. energy consumption by approximately 12 percent, or 12 quads. While coal-generated electricity is cheaper, if it is required to meet more stringent environmental standards and higher energy taxes, that will change.

To reduce our trade deficit, we should convert all nontransportation oil and liquids to natural gas. And, if we develop more natural gas from natural-gas shale and obtain more from energy conservation, we always can build our own LNG terminals and export the excess to China. A LNG terminal could be built in Alaska and save the cost of the natural-gas pipeline to the lower 48 states. This will reduce our trade deficit and allow us to import oil for transportation without the expense of converting the auto industry to natural gas. Overall, by reducing energy consumption and converting coal-power plants to more efficient combined-cycle gas plants, our CO_2 output could be cut by half.

It is important to provide substantial investment in the clean gasification of coal as a long-term replacement as existing natural-gas supplies are depleted.

This may be a short-term solution because the technology and extra production capacity can be available soon and help reduce the trade deficit and global warming. Some federal and state assistance may be required to mass-produce and expedite the changes.

NUCLEAR ELECTRIC POWER

In 2007, the United States had 104 nuclear reactors providing 97 GW, or 19 percent of our total annual electricity at an average 91.8-percent utilization factor.[15] Several existing nuclear-power plants are approaching the end of their design life and must be replaced. The average operational cost of electricity from existing nuclear plants is 1.66 cents per kilowatt-hour compared with new gas-fired combined-cycle electricity costs of approximately 10 cents per kilowatt-hour.

The nuclear industry essentially has been shut down in the United States for the last 35 years.[16] The last nuclear power plant started in the U.S. in 1977 was estimated to cost $5,000 per kilowatt. During this period, the construction more than 100 nuclear-power plants was canceled--not because of 3 Mile Island, but because the high costs of nuclear power required electric costs so high that energy conservation and reduced electric demand were enacted.

While new U.S. manufacturing companies will start to manufacture nuclear components and materials, most of the required nuclear components will be manufactured overseas. We will need to train and develop nuclear engineers and manufacturing facilities to make pressure vessels, valves, and pipes.

The Energy Policy Act of 2005 is providing up to $18.5 billion in federal tax benefits for new nuclear-power plants. Thirty-eight power companies have started the expedited regulation and license-application permitting process. The latest cost estimate for the Florida P&L nuclear power plant is $8,000 per kw, and some initial cost estimates are up to $12,000 per kw. With the recent increase in steel and other material costs, facility-cost overruns, and construction delays, it does not seem prudent to rely on nuclear energy until we know the capital costs and have proven the operation of the new power plants to verify the future cost of electricity. At $10,000 per kw, 8,000 kw per year, and 10-percent interest rates, just the capital-cost component of nuclear power would be 12.5 cents per kilowatt-hour.

New nuclear power plants are expected to have very high capital costs that could result in unaffordable electric rates, and high electric rates will encourage conservation. We have seen the damage that high energy costs can do to inflation and the economy. Moreover, uranium shortages are expected by 2030.[17] And, we still need to resolve the nuclear-waste issue.

There are several nuclear power plants in the design phase, and the first nuclear-power plant is hoped to be operational in 2016. Further, the DOE has been funding the development of several new designs, including producing hydrogen as a byproduct. It will take decades to build and test these new prototypes before building a meaningful number of nuclear power plants.

This is at best a mid-term solution. Generally, nuclear power may become an effective energy source by 2030. However, it cannot solve the current trade deficit, and it still has to withstand the test of time.

HYDROGEN ECONOMY

Hydrogen can be made from numerous energy sources, such as solar, wind, nuclear, and fossil fuels.

Experts now see hydrogen as a possible long-term solution, and considerable progress has been made in research and development. Federal decisions regarding the long-term goal of using hydrogen for transportation are to be made in 2015 and again in 2020.

The current areas of research[18] are thermochemical processes generating hydrogen from coal, natural gas, petroleum, and biomass and electrolytic processes that use nuclear, solar, and wind-electricity to generate hydrogen.

1. Hydrogen from natural gas. This is the traditional method to make hydrogen. However, it is expensive and does not resolve the energy-security issue or global-warming problems.
2. Hydrogen from coal. Research is under way to produce hydrogen from coal-derived-synthesis gas to build a high-efficiency, zero-emissions plant to co-produce electricity and hydrogen.
3. Hydrogen from nuclear. Research into both high-temperature electrolysis and high-temperature thermochemical is under way.
4. Hydrogen from renewable resources. PV solar and wind can use electrolysis to make hydrogen that can be stored for off-peak usage, but it is costly. Other research is in the areas of the thermochemical conversion of biomass, photolytic and fermentative micro-organism systems, photo-electrochemical, and high-temperature chemical-cycle water splitting.
5. Hydrogen delivery. Transporting hydrogen from the point of production to the point of use can be one of the significant costs and energy inefficiencies.

> Hydrogen has a low-volumetric energy density, which makes storage and transportation difficult. Alternative materials are required.

Fuel-cell research using hydrogen is proceeding, but it is not expected to offer any short-term solutions.

ECONOMICS

Economics often is misunderstood and unappreciated, but it is through economics that all energy problems and solutions will be reflected. Energy is causing a crisis in five areas: the U.S. trade deficit, sufficient world energy supplies to maintain and improve the world's standard of living, global warming, stagflation or simultaneous inflation and recession, and world peace and security. Reducing energy demand is one way to solve them all.

The fight against U.S. inflation is waged typically by the Federal Reserve with monetary policies, such as raising federal interest rates and decreasing the money supply to cause a recession and slow down the economy. But recent inflation was caused by increased world energy and commodity demand, which, in turn, caused high world prices. Raising U.S. interest rates to slow down the U.S. economy to reduce world energy demand is limited and inefficient. There are other government actions that can fight inflation when it primarily is caused by energy--fiscal policies or laws and regulations passed by Congress and the president. These policies can cause inflation. For example, laws passed by our government mandating ethanol are causing inflation with food prices. Therefore, we must be careful which laws are passed. Laws that enact energy taxes and provide energy-conservation tax incentives will target energy as the cause of inflation, will reduce energy prices, and will not cause a recession.

Many opponents of energy taxes said taxes will not reduce demand, but recent high oil prices have reduced U.S. demand 5 percent.

The current U.S. free-market approach to energy has resulted in large swings in energy costs. The cost of oil rose from $10 a barrel in 2000 to a recent high of $147 a barrel and since has declined to below $40 a barrel. The recent slowing of the world economy and high energy prices has reduced energy demand and energy prices, but the reductions will be temporary. When the world economy picks up, increased world demand will again cause energy shortages. The large swings in energy prices are destabilizing and causing business losses and difficulties in long-range planning. The U.S. automobile industry is a perfect example.

World-energy supplies have not increased sufficiently to meet world demand, causing energy shortages, higher energy prices, and, ultimately, reduced energy demand. Energy taxes would have artificially raised prices, which in turn would reduce energy demand and reduce real energy prices. Unfortunately, without energy taxes, the increased revenue from higher energy prices has gone to foreign countries and oil companies, which increases the trade deficit and lowers our standard of living. With energy taxes, this money would have gone to our government, reduced other taxes, reduced the trade deficit, stretched out our energy supplies, and lowered the real cost of energy.

In 2006, when oil and gas prices were low, a gradual increase in energy taxes was easier to implement. With high energy prices, it is politically more difficult, but energy taxes still should be phased in over time using future energy-cost increases as an incentive to encourage change. Further, they should provide an "artificial bottom" to prevent energy costs from dropping too much. For example, U.S. automotive companies are investing heavily in high-quality and smaller energy-efficient vehicles. Low gasoline prices could hurt their future sales.

Energy costs now have been high enough that they probably reached a tipping point, and it is unlikely that lifestyles ever will go back to the way they were. Large gas guzzlers, such as the Hummers and SUVs, are disappearing. The automotive companies may be asking the government for energy taxes to stimulate the demand for small cars. Now, U.S. businesses realize that everything has changed.

The increase in the trade deficit has largely been caused by recent oil-price increases, which were caused by the weak U.S. dollar, which fell 40 percent compared with the Euro. Because most of the world oil is priced in U.S. dollars, when the dollar fell, the oil countries raised their oil prices to the United States' accordingly. This increased the trade deficit and increased inflation, and the weak U.S dollar allowed foreign companies to buy America's assets at a discount. Recently, the drop in world oil prices has been followed by a drop in the U.S. dollar.

Oil-price increases have been responsible for much of the world's high inflation because it is passed on throughout the world economy in food production, living costs, manufacturing, and transportation costs. And it is causing basic survival choices between energy and food for many low-income and unemployed individuals.

Currently, a massive energy-conservation program is the most cost-effective energy solution. The free market has resulted in lower energy costs that do not encourage energy-conservation retrofits. Without tax credits and energy taxes, it unlikely that sufficient energy conservation will occur. Further, most energy suppliers, especially those of renewable energy and nuclear energy, are lobbying for and obtaining sufficiently large energy-tax credits or benefits to pass the tipping point that makes them economic viable. This puts energy conservation at a free-market disadvantage and is similar to placing a tax on energy conservation relative to all other energy sources. It is important that energy conservation obtain similar incentives to keep the playing field level.

GLOBAL WARMING

Energy conservation in the existing "built" environment could reduce U.S. global warming by 25 percent from today's CO_2 levels by reducing energy consumption. Further, converting residential, commercial, and industrial oil-burning systems to natural gas will improve the quality of air. Moreover, converting 33-percent-efficient oil- and coal-fired power plants to 68-percent-efficient combined-cycle gas-turbine systems reduces energy consumption and converts dirty fuels to clean natural gas. These steps will have a far greater effect than all of the solar-energy and wind-power systems that can be installed in the same period, but at a much greater cost.

While we have promoted an energy tax to enact a massive energy-conservation policy, perhaps we should have a carbon tax. However, it would make sense to vary the carbon tax to penalize dirty coal the most, fuel oil less, and clean natural gas the least. A carbon tax would eliminate the tax on nuclear power, wind power, PV power, and solar thermal energy, giving them an annual operating energy-savings advantage over fossil fuels. But because their manufacturing is energy-intensive, it will increase their first costs based on the amount of fossil energy used during manufacturing, and life-cycle payback will not improve.

CONCLUSION

The size of the United States' energy consumption is unwarranted. As 4 percent of world's population, it consumes 25 percent of the world's energy. Developing countries, such as China and India, have increasing energy demands--just as existing world supplies are peaking. Our energy appetite is causing the U.S. economy and the rest of world problems. The federal trade deficit can be a silent death to America's world preeminence. Inflation is causing pain to Americans and the world's energy-consuming countries. It was a contributor to the economic recession—conversely, the world's oil-producing countries have benefited greatly from the high energy prices.

The primary emphasis for the past 35 years has been on increasing conventional world oil and natural-gas supplies. But, they are believed to be declining. Our transportation infrastructure is geared toward oil, and it will be hard to replace. Unconventional oil does not look promising. Unconventional natural-gas shale could be a pleasant surprise, but the quantities, problems, development times, and costs are unproven. Research into clean-coal technology and nuclear energy is proceeding, but will take time to develop. Hydrogen still is questionable. The current facts show that alternative energy sources have limited capability.

A common belief is that we need all energy solutions: solar energy, wind energy, biofuels, conservation, nuclear, off-shore drilling, coal liquefaction, gas shale, tar sands, and hydrogen, but not all of those solutions are equal. Most require substantial research and development, most need to build and test prototype plants, most will take longer to mass produce, some will provide only minor energy supplies, and some will be too costly. Solar energy, wind power, and ethanol are not likely to be short-term energy solutions.

The U.S. government has failed to provide any feasible national energy plans or reliable short-term, mid-term, or long-term solutions. The 35 years of free-market policies have put us in a hole, and we are still digging. Now time is running out. The current energy crisis is another warning. If we do not take action soon, the next time oil prices will reach $200 a barrel.

We need a more realistic energy perspective. If we delude ourselves with false hopes and unrealistic solutions, and we allow special-interest money to warp the political process, it will prevent us from finding the best solutions. If we believe that technology will save us, then we must recognize that free-market technology has not accomplished much in 35 years. The government must get involved and heavily invest in research and development for mid-term and long-term solutions. While the DOE recently increased its R&D spending after failing to adequately do so since the 1970s, it may be too little, too late. We need to prioritize and focus our capital resources where it will do the most good and can be accomplished quickly.

The first priority is to start to reduce the U.S. trade deficit now. We need a massive energy-conservation program that retrofits industry and the "built" environment and reduces our energy consumption by half in 10 years. The free market will not enact a massive energy-conservation program until energy prices have at least doubled, and by then, the trade deficit will weaken America. This can be phased in with revenue-neutral energy taxes, targeted tax credits, and government laws and mandates. These will reduce energy demand, real-energy prices, and our trade deficit. Energy conservation also is the least expensive energy solution.

Energy taxes are the most efficient method of converting the United States to a more energy-efficient society. Europe's energy taxes are double ours, and that is why they use half the U.S.'s energy per capita with an equivalent gross national product. Energy taxes place an artificial value on all types of energy consumption, and the free market will make the most energy-efficient decisions, including changes in lifestyles, such as mass transit and relocating closer to work. The combination of energy taxes and tax credits can be revenue-neutral or have no effect on our overall tax payments. And with proper incentives for energy conservation, technology will provide new energy-efficient systems that will further reduce our energy consumption.

America has over-spent and is over-extended. The accumulated U.S. budget deficit and future commitments for Social Security and Medicare are threatening the country's future. We need to invest our limited capital resources carefully. We need to use our energy capital efficiently based on sound business analysis. Both PV and thermal solar energy are capital-intensive and may never be cost-effective. Some states, such as California, have mandated that utilities provide 20 percent of their electricity from renewable energy by 2010. Others, such as Connecticut, are providing a 60-percent tax credit for solar energy. These are a very poor use of capital.

An effective national energy plan must lay out a clear direction for the short term, mid term, and long term for all possible energy solutions to avoid duplication and waste. For example, an effective energy-conservation program could reduce existing and future electricity demand, which delays the demand for PV solar energy, wind power, and nuclear power. Electricity consumption typically has grown between 1 percent and 2 percent. Most large electric-power construction projects that are based on meeting this growth may be tabled. However, the Nov. 21, 2008, *WSJ* article "Surprise Drop in Power Use Delivers Jolt to Utilities" recognizes an unexpected drop in the recent U.S. electricity consumption of 3.3 percent could be a permanent shift in consumption patterns. Reducing electricity demand while simultaneously increasing electricity supply can result in costly duplication and excessive supply and waste. This occurred during the late 1970s and early 1980s. Because of over-building electric generation, no new plants were needed or built for approximately eight years. Similarly, energy conservation can reduce the immediate demand for Alaskan and off-shore oil. While reducing oil and natural-gas demand and increasing NG-shale supplies could result in surpluses, the surpluses could be exported to developing countries.

Our national energy policy should first reduce our federal-trade deficit, which can only be accomplished through a massive energy-conservation program, our second priority is to buy some time to determine which mid-term and long-term solutions are best. Our third priority is to invest heavily and wisely in mid-term and long-term research and development. The fourth and final priority is to mass-produce the mid-term and long-term optimum solutions at some later date, which will be determined by results of research-and-development programs.

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