The State of Energy: Revisited

Only through massive energy conservation can the U.S. hope to have success in the near term

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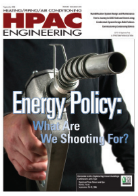
Editor's note: In 1976, Alfred E. Guntermann, PE, presented a paper titled "The Mystery of Future Energy Prices," which one industry executive described as "nothing less than monumental." Thirty years later, in the September 2006 HPAC Engineering *article "The State of Energy: Then, Now, and in the Future," Guntermann examined progress that had been made and work that lied ahead. "Much has happened since 2006," he recently said, "reflected by large energy-price swings, which have caused an enormous amount of consumer interest—even anger—and resulted in vast media coverage. While there is agreement on some issues, there is confusion on a lot of others." In an effort to clear up some of that confusion, Guntermann offers the following, a condensed version of an article available at* http://hpac.com/fastrack/Energy-feature-final.pdf*:*



In 2008, the International Energy Agency (IEA) analyzed 800 of the world's oil fields—accounting for two-thirds of the world's supply—finding that the 16 largest fields have peaked, and some are far below their peak output.[1] Output is declining at a 6.7-percent rate, which is expected to increase to 8.6 percent by 2030. While the IEA projects world demand to increase by 1.3 percent per year, even if it were to remain flat, 45 million barrels per day of gross capacity would need to be built by 2030 to offset the effect of oil-field decline. With world oil production at 85,802,000 barrels per day in 2007, new fields must be found to replace 52 percent of current production just to maintain current levels of consumption. Future oil fields, including those off shore, are smaller, will not last as long, and will be more expensive to tap. And if the world's energy supply has peaked, as many believe, the projected 1.3-percent annual increase in world demand for developing countries cannot be met without reduced U.S. demand. According to the IEA, the recent economic downturn is reducing capital spending on new energy projects. Further, the IEA says, "When demand starts to pick up, say, in 2010, ... we may see a supply crunch that is much stronger than what we saw last year and

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prices that are much higher."

Energy is reaching a crisis point on five fronts: (1) the U.S. trade deficit, (2) world supplies, (3) global warming, (4) stagflation, or simultaneous inflation and recession, and (5) world peace and security. Government action is required, but what action?

The Obama administration has proposed a national energy policy with a number of good ideas, but also some major problems. The first problem is the U.S. trade deficit is a disaster in the making and requires short-term solutions. Nothing in the energy policy solves that. The second problem is the new economic-stimulus bill mandates that 10 percent of the country's electricity come from renewable sources by 2012 and that 25 percent of it come from them by 2025. The energy policy is based on technology that costs a lot for little benefit, is likely to fail, and will lead to higher energy costs and possible energy shortages.

We cannot afford a trial-and-error approach because the consequences of wasted time are too great. Despite three energy crises since 1973, higher energy costs, and several calls for project independence, we are no closer to meeting the world's massive energy requirements than we were 35 years ago.

This article discusses the U.S. trade deficit and how a massive energy-conservation program could help reduce it. Then, it discusses problems with proposed energy solutions, such as solar, wind, nuclear, conventional and unconventional oil, conventional and unconventional natural gas, biofuels, and hydrogen.

U.S. TRADE DEFICIT

In 2006, oil imports accounted for $252 billion of the United States' $800 billion trade deficit. According to a recent Congressional Research Service report, at a cost of $140 a barrel and import quantities at 2007 levels, the oil-trade deficit would increase to $613 billion.

The federal trade deficit is the most pressing issue facing the United States. If oil imports continue to increase in quantity and cost per barrel, the transfer of U.S. wealth to oil-producing countries over the next 10 years could be $10 trillion, nearly 25 percent of total U.S. wealth. As oil tycoon T. Boone Pickens said, this would be "the greatest transfer of wealth in the history of mankind."[2]

Continued large U.S. deficits will necessitate the sale of enormous quantities of U.S. treasuries to foreign countries. Failure to sell debt can lead to a downgrading of national credit ratings, resulting in higher treasury and related interest rates. Some South American countries have gone through this; it led to hyperinflation, followed by a painful recession. Continued large U.S. deficits also can cause steep declines in the U.S. dollar, which can cause high U.S. oil prices, as international oil is priced in U.S. dollars, and allow foreign countries to buy American companies and property cheaply.

The oil-trade deficit and cost of oil imports takes all mid- and long-term energy solutions off of the table. The United States needs solutions that will reduce energy-import quantities and energy costs *now*.

ENERGY CONSERVATION

Conservation is the only energy solution that can reduce the U.S. trade deficit in the short term. Meanwhile, it can buy time for the research and development of optimal mid- and long-term energy solutions, reduce the size and capital costs of mid- and long-term energy solutions once they are implemented, and reduce carbon-dioxide (CO_2) emissions and global warming.

Energy conservation attacks the energy problem by reducing energy demand instead of increasing energy supply. With 4 percent of the world's population, but 25 percent of the world's energy consumption, the United States needs to reduce its energy demand. Europe has a larger gross national product with a similar population and standard of living, but with half of the energy consumption per capita. Reducing U.S. energy consumption by half is a realistic goal. But government leadership is needed; the free market will not get it done, particularly in the short term.

Total U.S. energy consumption in 2006 was 99.52 quads (1 quad equals 10^{15} Btuh).[3] Of the 73.5 quads of non-transportation energy, electric end use accounted for 12.48 quads, while, at 31.5-percent electrical efficiency, electrical losses accounted for 27.2 quads. Reducing non-transportation energy consumption by half would save 36.7 quads.

Energy conservation in buildings has been around for years, but the fact Europe's energy consumption per capita is half of the United States' shows how much potential there is. To become truly energy-efficient, the United States needs to implement economic incentives.

A massive energy-conservation program would slow the need for new energy supplies. For example, during the early 1980s, conservation reduced electricity demand to the point new power plants were delayed for several years.

To be effective, an energy-conservation program would have to be implemented on a national scale, much like the interstate-highway program was during the 1950s and '60s. A massive energy-conservation program could be phased in quickly because of the availability of proven technology and production. It would provide jobs and be cost-effective, as the initial cost of retrofitting would be paid for with energy savings.

Conservation is the lowest-cost energy solution.

SOLAR ENERGY

Despite its popularity, solar energy

is not a practical energy solution. The question of its viability as a national energy policy is important. For an in-depth discussion of the economics of solar energy, see the expanded edition of this article. Following is a summary of the main points:

• A solar-thermal domestic-hot-water-heating system is the most economical solar system, but in a typical location, such as New Haven, Conn., it saves only 1.4 gal. of oil per square foot per year; in New Mexico, which has the greatest amount of solar energy in the United States, it saves only 2.2 gal. of oil per square foot per year. Space heating requires substantially more energy than domestic-hot-water heating; however, space heating generally is required only four months out of the year, so the amount of usable solar energy available for space heating equates to only 0.47 gal. of oil per square foot per year in Connecticut. Photovoltaic (PV) solar provides usable electricity throughout the year; however, current commercial PV-solar efficiencies are 10 to 15 percent, compared with 60 percent for thermal solar. (Efficiency is the amount of usable solar energy compared with the amount that hits the earth.)

PV solar's annual utilization rate is 14.5 percent (1,252 equivalent full-load hours). With an installed cost of $9,000 per kilowatt and 10-percent, 30-year financing, the break-even cash-flow electricity cost is 62 cents per kilowatt-hour. That is the minimum cost utilities will need to be reimbursed by rate payers.

There are additional questions about service life, annual maintenance, backup power, and the need for new transmission lines and a "smart grid." Further, PV solar has electrical-efficiency losses of 25 percent.

• PV solar has theoretical limits that cannot be improved upon. For example, the most popular solar cell is a single-crystal silicon cell with an average commercial efficiency of 15 percent, a top commercial efficiency of 18 percent, a laboratory-best efficiency of 25 percent, and a maximum theoretical efficiency of 31 percent.[4]

• The material requirements of PV solar—solar cells, module housing, balance of system (wiring, inverter, switchgear)—are substantial. It is unlikely materials to supply even 25 percent of the United States' generating capacity or 3.6 percent (25-percent generating capacity times 14.5-percent annual utilization rate) of the country's electricity consumption by 2050 can be obtained. As solar production increases, material demand increases, creating shortages and increasing the first cost of systems.

• PV solar is energy-intensive, with an estimated average payback of four years. Thus, as production costs increase, so will first costs.

It is unlikely solar energy will ever be more cost-effective than it is today.

The high solar-energy costs arising from the new economic-stimulus bill's mandate that utilities provide 10 percent of their electricity from renewable sources by 2012 and 25 percent of it by 2025 will be passed on to rate payers.

WIND POWER

It is estimated that 6 percent of the contiguous United States could satisfy more than 1½ times the country's current electricity consumption with wind energy. The average wind-energy location has a utilization rate—total annual electrical output divided by peak kilowatts—of 30 percent, while the best wind-energy locations (Texas and the heartland) have utilization rates around 40 percent.[5] The average installed cost in 2008 was $1,920 per kilowatt, for a break-even cash flow of 7.4 cents per kilowatt-hour.

In addition to capital costs, wind turbines have annual operating costs, including land-lease costs. Further, they are complex machines requiring regular maintenance over their 30-year lives.

Wind energy is the most cost-effective renewable-energy source because its installed costs are near those of standard electricity generation, and its utilization rate is much better than solar's. However, it still requires substantial tax credits or government mandates.

NEW TRANSMISSION LINES AND A 'SMARTER' ELECTRICAL GRID

Typically, large-scale wind farms and PV solar-energy systems are located far from major areas of population and energy use. Thus, if wind and PV solar energy were widely adopted, new long-distance power-transmission lines would be needed. With utilization rates of only 14.5 percent for PV solar power and 30 to 40 percent for wind power, the costs of transportation would be particularly high, as transmission-line cost is averaged over kilowatt-hours. The cost of power-transmission lines can be substantial, changing the economics of an entire renewable-energy project.

Before the United States commits to the "less-centralized and more consumer-interactive"[6] Smart Grid, the future electrical requirements of PV solar energy, wind energy, and electric automobiles must be established.

Smart Grid should be a research-and-development tool for possible mid- and long-term solutions, such as high-temperature superconductivity, visualization and controls, renewable and distributed system integration, and energy storage and power electronics.[7]

ETHANOL AND BIOMASS

In 2006, the U.S. government passed the Renewable Fuel Standard, which mandated the amount of corn-based ethanol used in gasoline. Ethanol-production capacity was 5.7 billion gal. in 2007. In 2008, additional legislation was passed, raising the ethanol-production mandate to 36 billion gal. by 2022. Europe and other foreign countries followed suit, increasing their requirements for biofuels.

Europe recently announced it is reconsidering its use of biofuel mandates and may reverse its policy, which was based on global-warming and climate-changing emissions. In addition to food shortages, Europe believes the burning of forests to make room for biofuel plants is leading to increased greenhouse gases.

Focus appears to be shifting from corn and soybean feedstocks that compete with food production to cellulosic biomass feedstocks, such as switchgrass, agricultural waste, and forestry residues. However, large land areas still will be required for sufficient quantities to be produced.

Considerable research to develop more cost-effective methods of mass-producing cellulosic biofuels is under way. This will take time, and the final approach will need to be vetted before production facilities are built. Many ethanol-production facilities already in existence are being idled and bankrupted because ethanol is proving to be uneconomical. This is a perfect example of what can happen when research and development are skipped in an effort to save time and money.

WORLD CRUDE OIL

U.S. oil production has declined from a peak of 9.64 million barrels a day in 1970 to an estimated 4.9 million barrels a day in 2008 and been declining at a rate of 15 percent a year. The world's total oil production appears to have peaked and soon will decline. As T. Boone Pickens has said, "We can't drill our way out of this crisis."

The potential for U.S. off-shore oil production includes Alaska and the East, West, and Gulf coasts. Although production from new U.S. off-shore fields cannot be expected for up to 10 years, exploration in feasible areas should begin as soon as possible to quantify proven oil reserves and replace diminishing production.

If oil supplies are to increase, unconventional sources must be tapped. These include:

- Oil from tar sands in Alberta, Canada.
- Coal liquefaction.
- Rocky Mountain oil shale.

Although these unconventional oil sources have major cost advantages because existing pipelines, refineries, automobiles, gasoline stations, burners, etc. can be used, each has limitations and problems.

Conventional oil remains the premier fuel for transportation, and that is unlikely to change anytime soon. Conservation can greatly extend supplies. Unconventional oil is not a short-term solution, and future supplies will be expensive.

NATURAL GAS

Natural gas is the cleanest and most preferred fossil fuel for heating and has been used increasingly for electricity generation. U.S. demand is 23 trillion cu ft, of which 4 trillion cu ft is imported.

Thanks to nearly two decades of development and the use of new technology, unconventional-natural-gas production from the Barnett Shale in Texas has increased tenfold since 2001. Barnett Shale reserves are an estimated 27 trillion cu ft,[8] or approximately one year of U.S. consumption.

New technology can be used to develop other shale deposits. Some experts think those deposits could yield as much as 842 trillion cu ft[9]—a 40-year supply at today's consumption rate—while others believe they amount to no more than a replacement for existing declining fields. The cheapest source of additional natural-gas supplies is energy conservation.

T. Boone Pickens has proposed converting automobiles from gasoline to natural gas. However, it would be much cheaper to convert oil-fired furnaces and boilers to natural-gas units. Many commercial and industrial boilers have dual-fuel burners, which would make switching from oil to natural gas easy.

Coal, nuclear, and fuel-oil utility power plants average only 33-percent efficiency. New combined-cycle gas-turbine power plants are 60-percent efficient; when combined with heat recovery, they are up to 85-percent efficient. Converting oil- and coal-fired power plants to combined-cycle gas turbines would reduce U.S. energy consumption by approximately 12 percent, or 12 quads.

To reduce the U.S. trade deficit, all non-transportation oil use should be converted to natural gas. By reducing energy consumption and converting coal-fired power plants to more efficient combined-cycle gas plants, CO_2 output could be cut in half.

NUCLEAR ELECTRIC POWER

In 2007, the United States had 104 nuclear reactors providing 97 GW, or 19 percent of the country's total annual electricity, at an average utilization factor of 91.8 percent.[10] The average operational cost of electricity from nuclear plants was 1.66 cents per kilowatt-hour.[10] In comparison, the average operational cost of electricity from new gas-fired combined-cycle plants was approximately 10 cents per kilowatt-hour.

Construction of the newest nuclear power plant in the United States began in 1977 at an estimated cost of $5,000 per kilowatt. Since then, the U.S. nuclear industry essentially has been shut down.[11]

The Energy Policy Act of 2005 is providing up to $18.5 billion in federal tax benefits for new nuclear power plants. Cost estimates range from $8,000 to $12,000 per kilowatt. With a $10,000-per-kilowatt installed cost and 10-percent interest rates, the capital cost of a new nuclear power plant operated 8,000 hr (8,000 kwh) a year would be 12.5 cents per kilowatt-hour.

New nuclear power plants are expected to have high capital costs that could result in unaffordable electricity rates, which would encourage conservation. Moreover, uranium shortages are expected by 2030.[12] And the nuclear-waste issue still needs to be resolved.

The Department of Energy (DOE) has been funding the development of several new designs of plants, including one that produces hydrogen as a byproduct. It will take decades of building and testing prototypes before a meaningful number of nuclear power plants can be built.

HYDROGEN ECONOMY

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

Experts see hydrogen as a possible long-term solution. Progress has been made in terms of research and development. Federal decisions regarding the use of hydrogen for transportation are to be made in 2015 and 2020.

ECONOMICS

The United States' free-market approach to energy has resulted in large price swings. Oil prices rose from $10 a barrel in 2000 to $147 a barrel recently and since have fallen to below $40 a barrel. Recent high energy prices have slowed the world economy and reduced energy demand, but once the world economy recovers, increased demand again will cause energy shortages.

A massive energy-conservation program is the most cost-effective energy solution. An energy tax can be an important energy policy. For evidence an energy tax would reduce demand, one needs to look no further than the recent high oil prices, which have reduced U.S. demand by 5 percent.

In 2008, world energy supplies did not increase enough to meet world energy demand, leading to energy shortages, higher energy prices, and, ultimately, reduced energy demand. Energy taxes would have raised prices artificially, which would have reduced energy demand and real energy prices. Unfortunately, without energy taxes, the increased revenue from higher energy prices went to foreign countries and oil companies, which increased the trade deficit and lowered the United States' standard of living. With energy taxes, that money would have gone to the government, reduced other taxes, reduced the trade deficit, stretched energy supplies, and lowered the real cost of energy.

Energy taxes should be phased in over time, with future energy-cost increases used to encourage change.

Energy costs have been high enough to change some lifestyles forever.

Higher energy taxes/prices and/or additional tax incentives are necessary to complete the change to an energy-efficient society and "built" environment and to reduce the trade deficit. If the country waits for the free market to create another world energy shortage, oil prices could be $200 a barrel.

GLOBAL WARMING

Energy conservation in the existing built environment could reduce U.S. CO_2 levels by 25 percent or more. Further, converting residential, commercial, and industrial oil-burning systems to natural gas would improve the quality of air. Moreover, converting 33-percent-efficient oil- and coal-fired power plants to 60-percent-efficient combined-cycle gas-turbine systems would reduce energy consumption and convert dirty fuels to clean natural gas. These steps would have a far greater effect than all of the solar-energy and wind-power systems that could be installed over the same period, but at a much greater cost.

A carbon tax is an alternative to an energy tax. Varying a carbon tax so that it penalizes dirty coal the most, fuel oil less, and clean natural gas the least would make sense. 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. The first costs of nuclear power, wind power, PV power, and solar thermal energy, however, would increase, based on the amount of fossil energy used during manufacturing, while life-cycle paybacks would remain the same.

CONCLUSION

For the size of its population, the United States consumes an inordinate amount of energy. Developing countries such as China and India have increasing energy demands just as existing world supplies are peaking. Energy shortages are causing the world's energy-consuming countries pain, while the world's oil-producing countries are benefitting greatly.

The U.S. government has yet to provide a feasible national energy policy or reliable short-, mid-, or long-term energy solutions, while 35 years of free-market policies and technologies have largely failed, as U.S. oil imports have increased from 10 percent in 1970 to 70 percent today.

For 35 years, the world's focus primarily has been on increasing conventional-oil and natural-gas supplies, but they are declining. Unconventional oil does not look promising. Unconventional natural-gas shale, on the other hand, could be a pleasant surprise, but the quantities, development times, water requirements, and costs are unproven. Research into clean-coal technology is proceeding, but will take time, as will research into nuclear. Hydrogen still is questionable and has the longest way to go to becoming reality. Alternative energy sources have limited capability.

The United States' first priority should be reducing the federal trade deficit. A massive energy-conservation program that retrofits industry and the built environment and reduces energy consumption by half in 10 years is needed. If left to the free market, a massive energy-conservation program will not be enacted until energy prices have at least quadrupled, and by then, the trade deficit will have weakened America. An energy-conservation program can be implemented fairly quickly, with revenue-neutral energy taxes, targeted tax credits, laws, and government mandates. Additionally, it is the least expensive energy solution.

Energy taxes are the most effective tool in making the United States a more energy-efficient society. Europe's energy taxes are double the United States', which is why Europe's energy consumption per capita is half of the United States' with an equivalent gross national product and standard of living. The combination of energy taxes and tax credits can be revenue-neutral.

The United States needs to invest its limited capital resources carefully, based on sound business analysis. Both PV and thermal solar energy are material- and capital-intensive and may never be cost-effective.

A national energy policy must clearly identify a direction for all possible energy solutions over the short, mid, and long terms to avoid duplication and waste. For example, an effective energy-conservation program would reduce electricity demand, which would delay the need for PV solar energy, wind power, and nuclear power. Reduced electricity demand occurred during the late 1970s and early 1980s, resulting in excess electricity-generation capacity and no need for new plants for approximately eight years. Similarly, energy conservation can reduce the immediate need for Alaskan and off-shore oil. The DOE recently increased its research-and-development spending after having failed to adequately do so since the 1970s. The United States must invest heavily in research and development, focusing its capital resources where they will do the most good and produce results quickly.

With its national energy policy, the United States should look to:

1) Reduce the federal trade deficit, which can be accomplished only with a massive energy-conservation program.

2) Buy time to determine which mid- and long-term solutions are best, which would best be accomplished with a massive energy-conservation program.

3) Invest heavily and wisely in short-, mid-, and long-term research and development.

4) Implement optimum mid- and long-term solutions at a later date.

The devil is in the details. The United States needs a national energy policy based on solid engineering and business decisions. It is important that top scientists and engineers be tapped to perform short-, mid-, and long-term research and development. In the short term, a number of legislative and financial incentives would be needed for a massive energy-conservation program to be enacted.

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