Energy Endurance

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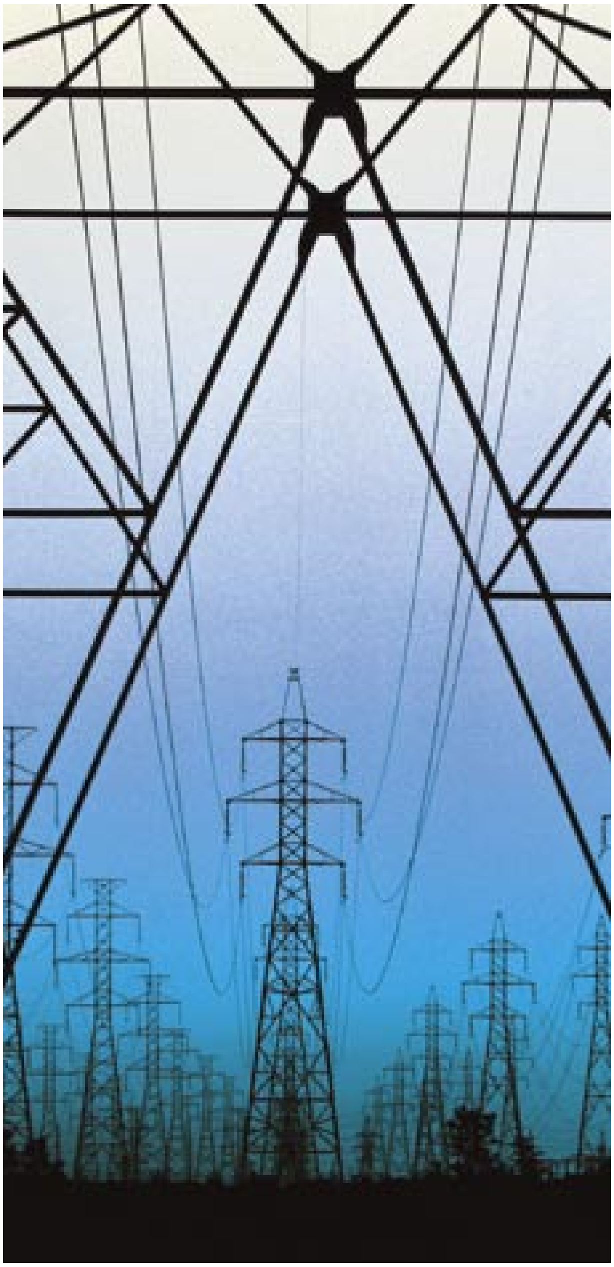
As consumers, we want safe, reliable, affordable and clean energy. We want energy with all these attributes at the same time, now and tomorrow, but we are reluctant to compromise on any of the attributes. For example, in spite of occasional reminders in the form of power blackouts and price spikes at the gas pumps, we do not want to trade reliability against affordability. We have come to take the availability of energy, not least electric power and fuel for vehicles, more or less for granted.

The 20th century started as a coal- and steam-based economy and transformed into an oil- and electricity-based economy. Recognizing that the oil reserves may be depleted in 50 years and also recognizing increased environmental concerns, not least about global warming, there is a vision to reach an electricity- and hydrogen-based economy well before the end of the 21st century.

Achieving such a vision will be very challenging and will take a substantial amount of time. Hydrogen is not freely available but must be produced. At present, most hydrogen is produced from oil and natural gas by cracking the hydrocarbon molecules. However, it is not a consistent or long-term solution. If oil and natural gas are the scarce resources to be replaced by hydrogen, why lose energy in the conversion to hydrogen? More logical within the intent of the vision is to produce hydrogen by electrolysis – that is, splitting water into hydrogen and oxygen. The "only" problem is that the electrolysis will require access to inexpensive and clean electricity! Potentially, there may be a third way to produce hydrogen using biological processes. It is too early to tell whether this will be a viable approach.

Until we can achieve the vision of an electricity- and hydrogen-based economy, we will have to depend on existing energy sources. With a growing consumption of energy from the finite sources of economically available hydrocarbon fuels, we will need to be more energy efficient in an increasingly sustainable way. We need what may be termed "energy endurance" to allow us more time for making the transition as seemless as possible.



The challenge is significant. The United States has 280 million people. We consume close to 100 quadrillion British thermal units (BTUs) of energy, but we produce only 72 quadrillion BTUs. The difference is covered by import. In relation to the rest of the world, the U.S. population is 4.5 percent, but the consumption of energy is 25 percent. We import more than 50 percent of the oil refined to gasoline for our cars. From being self-sufficient on natural gas, we have become an importer of natural gas and, even after expanded supply from Canada, will increasingly need to import natural gas from overseas.

The United States is not alone having an energy deficit. Among the Organisation for Economic Co-operation and Development (OECD) countries, only Canada, the United Kingdom, Norway and Denmark are currently net exporters of energy. However, in a not too distant future, it will be just Canada and Norway. The OECD countries' consumption is almost 60 percent of the world's production, but more regions and countries in the future will demand or want a bigger share of the available energy. The developing and newly industrialized countries' demand on energy is growing rapidly and is forecast to exceed the energy consumption of the OECD countries by the year 2020.

The oil reserves in relation to production have not been growing since 1990. The reserves are now estimated to last about 40 years. Natural gas reserves are estimated to last about 60 years. The only fossil fuel in relative abundance is coal, and the reserves are calculated to last about 220 years. Coal gasification processes may be used to produce synthetic oil and gas with a reduced environmental impact, but not without a cost premium.

If securing affordable energy is not challenging enough, the environmental challenges – both the ones related to global warming and those related to air quality – as well as the national security challenges make the energy equation more complicated. Without claiming to present anything radically new or to offer a complete action list, I would suggest attention to seven items.

International Cooperation

Global problems require global solutions. Global warming is no exception. In order to include all countries, such as the United States, Russia, Australia, China and India, fundamental differences in fuel diversity need to be better recognized. Further, to achieve the desired hard results of reduction of the greenhouse gases, not only CO_2 but also methane, a more flexible incentive/penalty system would be needed.

There are already several excellent examples of how international cooperation can yield regional benefits. Internationally/regionally interconnected natural gas and electric grids in North America and Europe, for example, have significantly helped improve reliability and reduce costs by better balancing local differences in fuel diversity, power generation and consumption.

National Plans

Energy infrastructures are very capital intense. Accumulated on a global basis, the investments are in the trillions of dollars. These infrastructures take a long time to build. For example developing new oil and gas fields, building nuclear power stations, building high-voltage transmission systems can take a decade to get done even without major permitting issues. The large capital expenditures and the lengthy times from concept to completion spell risk. Uncertainty about the future market conditions and regulatory frameworks increases the risk.

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In that light, it is important on the national level to have some pronounced direction or energy policy. Few countries have it. However, it is not a trivial task, as can be illustrated in the United States, where the National Energy Policy Development Group presented its report regarding a national energy policy in May 2001. The report looked out 20 years and outlined a strategy for "reliable, affordable and environmentally sound energy for America's future." In spite of major efforts, including many political compromises and reduced ambitions for setting a clear, long-term energy strategy, Congress has not yet managed to turn the policy into an energy bill.

In the U.K., a new energy bill was recently announced. It was based on the Energy White Paper, published in February 2003. The bill sets out a low-carbon-economy vision with a long-term strategy based on four goals: "environmental protection, energy reliability, competitive markets and affordable energy for all."

Considering the large differences between countries and between states, their respective plans and policies will be different. Regardless of the specific goals, however, it will help the process if more countries and states will formulate their own energy policies.

Countries with a large proportion of nuclear energy will have to decide on the next step when the present generation of nuclear power plants starts to be retired. Nuclear energy has many strong pros (for example, no CO_2 emissions) and some serious cons (for example, the long-term storage of nuclear waste). Views and opinions tend to be polarized, but the fact remains that nuclear energy is such a significant source for power generation that it cannot be easily replaced. On the contrary, for countries making global warming a high priority, strong arguments for expanded use of nuclear energy can be made. Expanding or reducing, it will in any case be important to formulate energy policies that include provisions for nuclear energy.

Markets

Markets work! In most parts of the world, the energy sector has been and still is regulated. In the short and near term, developing markets can be the fastest way to achieve improved energy efficiency.

An example of markets designed to drive or change behavior is the high gasoline prices in Europe. The high prices, which include a large tax component, are a significant contributing factor to much more fuel-efficient vehicles in Europe compared to the United States. Thomas L. Friedman, who writes a column for the *New York Times*, has suggested a tax of $1 per gallon for gasoline in the United States. He projects that the tax would be more than enough to cover the reconstruction of Iraq. Equally or more important, it would trigger a consumer-driven demand for more fuel-efficient vehicles.

A large contributing factor to the California energy crisis was that the end-users for a long time were "protected" or, more accurately, disconnected from price increases. When prices eventually were substantially increased, the consumers responded with reduced demand. In combination with negotiating long-term contracts instead of relying only on the daily wholesale spot market, the energy crisis disappeared as quickly as it had started.

The California case and the Enron scandal caused many negative experiences and perceptions about deregulation of the electric industry. However, the U.K., Scandinavian countries and PJM Interconnect in the United States have demonstrated that functioning wholesale markets can be developed. PJM's model of locational market prices demonstrates an approach to quantifying transmission congestion economically and stimulating investments in new generation in locations where they make the most economic sense.

In the retail electricity market, Japan can demonstrate customer response to differentiated prices based on time of day. Having a substantial distinction between nighttime (lower-cost) and daytime (higher-cost) power motivates consumers to reduce demand or use onsite generation for peak-shaving during the daytime.

Markets can also be used for emission reductions. By most means and measures, creating a market for SO_2 helped achieve even larger reductions than originally targeted. One can dispute certain imperfections, in particular regarding local emission reductions, but an aggregated emission markets model could work nationally and eventually internationally for reducing toxic emissions, including NOx, as well as greenhouse gasses, including CO_2 and methane.

Energy Conservation

Energy conservation, the "negawatts," is probably the most direct approach for better energy efficiency. Fortunately, it has been utilized for many years with impressive results. In fact, the much-improved energy intensity (expressed, for example, in BTU-per-dollar gross domestic product) is a success story that deserves more recognition. The energy intensity is forecasted to continue to improve (decrease) between 1.3 percent and 2.1 percent per year depending on the industrialization level of the country.

Several factors have contributed to improved energy intensity, including increased electric efficiency in power generation thanks to combined-cycle gas turbines (CCGT); more energy-efficient buildings, appliances and lights; and greater use of variable-speed drives in industrial applications. In several cases, governmental support has helped bring new technology to market or stimulated initial demand, but the dominant driving factors have been basic economics in the form of reduced costs.

More can be done by making industrial processes, buildings and homes more energy efficient, but the transportation sector has probably one of the best potentials for improvement. In the United States, vehicles account for more than 20 percent of the total energy consumed.

The hybrid electric vehicle (HEV) achieves much-improved energy efficiency compared to conventional vehicles by capturing the wasted energy when braking, by using the electric motor when it is most efficient (acceleration from 0) and by using the reciprocating engine when it is most efficient (constant speed at optimal rotations per minute). The large environmental benefits in reduced CO_2 as well as reduced NOx will come as an additional benefit.

Toyota and Honda are leading the way for the passenger HEV. The fuel-efficiency numbers are already impressive, but there is room for further improvements, especially in terms of the energy and power storage components of the system.

As an example, the Toyota Prius achieves 52 miles per gallon (mpg) in city traffic. Compared with a regular midsize car like the Ford Focus at about 26 mpg, the HEV is a significant improvement in fuel efficiency. For a person driving 15,000 miles a year, it means almost 600 fewer gallons of gasoline and a fuel cost reduction of $1,000. The tradeoff is a higher initial price for the HEV, but with increased volumes, this gap will shrink. This is important, since ultimately the economics will be the single most decisive factor for mainstream acceptance.

Combined Heat and Power

Fossil fuel is, for most countries, the dominant fuel source for electric generation. For example, in the United States, coal represents about 52 percent and natural gas 30 percent of the power generation. Trying to identify realistic substitutes for such a large proportion of the bulk power generation is very difficult. In terms of improved energy efficiency of fossil fuels, combined heat and power (CHP) represents one of the best opportunities. Capturing the exhaust heat for heating or cooling purposes can improve the thermal efficiency to 70-90 percent.

Large-scale CHP was early identified as economically attractive in the paper industry and for district heating. Some countries have come far. Holland, for example, produces about 40 percent of its power with CHP. Even though such a high number may not be possible in all countries, CHP represents a large energy-savings potential. In a recent study, the U.S. Combined Heat and Power Association (USCHPA) estimates that a 43 percent expansion of efficient CHP (almost all of it natural-gas fired) in California, Texas and the northeast United States would reduce total natural gas consumption by 6.4 percent across those regions.

Still, most of the untapped CHP opportunities are in the commercial and residential sectors, each of

which represents about one-third of all electric power consumption. The challenge is that the smaller the load, the more it tends to fluctuate, making it more difficult to find economic technical solutions. Recent initiatives in Europe and Japan for residential CHP are interesting and worth our attention. Stirling engines promise to have the necessary robustness and, thanks to their external combustion, should be very suitable for CHP.

Renewable Energy

Renewable energy and nuclear energy are the non-fossil fuel sources. About 15 percent of the world's energy consumption comes from renewable energy. In general, there is a broad acceptance of the benefits of renewable energy. In spite of governmental support for expanding renewable energy, there are many challenges just to grow to 20 percent.

Historically, hydroelectricity has been the largest source of renewable energy. The source has limited growth opportunities, however, because of the environmental impact of large-scale hydro and because many of the available rivers are already developed. Additional hydropower opportunities, like capturing wave or tidal energy, are at a very early stage.

Wind has emerged as the fastest-growing renewable energy technology during the last 10 years. Large-scale deployments and unit sizes of several megawatts have reduced costs, making wind increasingly competitive for bulk power. However, new wind farms tend to be sited at remote locations, resulting in high costs to connect to the electric grid.

Solar power, in particular photovoltaics, continues to grow at a two-digit annual rate. Still, costs need to be further reduced in order to make solar an integral part of new buildings, which would be the breakthrough necessary for high-volume adoption. For large-scale power generation, one should not completely lose sight of the potential of solar thermal power.

There is no single "holy grail" to achieving energy endurance. Instead, we need actions in several areas.

Biomass and biogas represent great potential for growth thanks new technologies and to capturing avoided costs for depositions of biomass waste and livestock manure. The development of efficient small and medium-sized technologies help the economics by reducing the cost of collecting and transporting the feedstock, which – because of their low energy density and disperse locations – can be the most decisive cost element for the economic viability of a biomass/biogas project.

Distributed Energy

Distributed energy (DE), both generation and storage, is not a substitute for bulk power generation and transmission. DE is a supplement, but an important one. On an aggregated level, DE can reduce the demand on the transmission and distribution (T&D) infrastructure. Particularly in areas with weak electric grids and slow demand growth, it can be better, economically, to choose a DE solution instead of building new transmission capacity.

Well-designed electrical-demand response programs can be a cost-efficient solution in locations with, or at times of, power constraints. In emergency situations, the ability to shed load can mean the difference between keeping the system stable or losing it. New, low-cost technologies for two-way communication, control coupled with price signals, could enable more use of demand response programs – instead of turning off load as the demand response, the desired result can be achieved by turning on DE equipment. It is a win-win situation. Thanks to the DE equipment, the consumer does not lose any power, while the system operator gets the desired load relief.

DE can also be justified for the sole purpose of improving power quality and/or reliability. It is estimated that in the U.S. about 80 GW of back-up power generation capacity is presently installed, equivalent to about 10 percent of total grid capacity. It represents a partly untapped resource. One of the most intriguing aspects of DE is its ability to combine several functions in one package – including back-up power, power quality, peak-shaving and CHP.

Conclusion

There is no single "holy grail" to achieving energy endurance. Instead, we need actions in several areas. For example, we will need the political will for change and direction expressed in long-term national energy plans and international cooperation. We will need to develop markets with more transparency in order to get a better response in the supply and demand for energy and, possibly, also for emissions. We will need new business concepts and new technologies to further develop and supplement the traditional infrastructures with enhanced energy conservation/increased energy efficiency, expanded CHP and more distributed and renewable energy. ■

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Before relocating to the United States in 1991, Dr. Almgren was president of Autoliv. Under his leadership, the automotive restraint systems company established a North American presence and also expanded into new products such as airbags.

Dr. Almgren is on the board of managers of PJM Interconnect of Valley Forge, Pennsylvania, and serves as advisor to several companies, including Active Power Technology of Texas, Stirling Technology Company of Washington, Hot/Shot Radar Inspections of Colorado, Current Technologies of Maryland and Nuvonyx of Missouri.

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