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Located at the northern edge of Silicon Valley in Menlo Park, California, the Institute for the Future is an independent, nonprofit research firm that specializes in long-term forecasting. We help businesses identify and evaluate specific opportunities presented by market trends and new technologies. Founded in 1968, the Institute for the Future has become a leader in action-oriented research for business, government, and private foundations. Our members include Fortune 500 companies as well as mid-sized and emerging companies. We analyze policy, forecast alternative future scenarios, and identify markets for new products and next-generation technologies.

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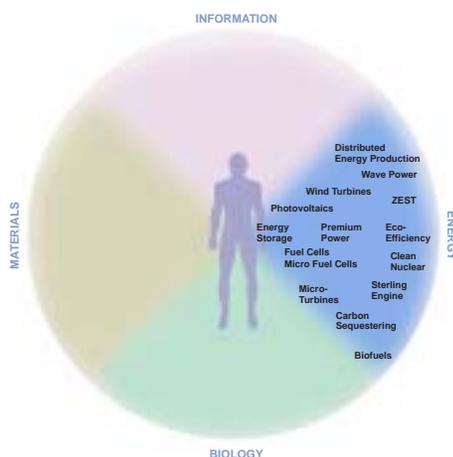
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# Premium Power Trends



Today's technology experts look to tagging to transform the business landscape and to the bio-sciences to change the world. But the big technology sleeper on the ten-year technology horizon is perhaps premium power.

Premium power is a term used by Gerald Ceasar at the National Institute of Science and Technology for a range of alternative energy technologies that offer superior performance for a premium price. Superior is, of course, defined by context:

- A \$5/watt, lightweight, highly portable battery with a month-long charge is a superior power source for a cell phone or laptop computer.
- A \$3/watt fuel cell is perhaps a superior solution for a cellular tower off the beaten track.
- A \$1/watt photovoltaic or fuel cell solution is a superior power source for an urban neighborhood that is already so densely connected that installing more electrical lines is untenable.

The technologies employed in providing premium power solutions have often been characterized as alternative. But premium power is, in fact, additional power. It doesn't replace existing power sources. Rather, it increases demand. It's power above-and-beyond current use.

The question then arises: What will shape this growth market? The answer, of course, lies in a combination of social, economic, and technological factors. But given the events of September 11, one gating factor is likely to be security.

This memo draws on our interviews with experts as well as an expert workshop conducted on February 6, 2002, to survey the complex array of trends that will shape the premium energy horizon over the next decade. It also presents two scenarios based on two very different energy-security policy tracks. It also draws from a larger project that maps the ten-year technology horizon (see "Annotated Bibliography," on page 11).

## What We Bring from the Past: An Infrastructure of Technology and Policy

The growth of electric power networks has been critical to the evolution of modern industrial civilization. The modern factory, mass transit, urban infrastructure, homes, and consumer goods have all been shaped, directly or indirectly, by electric power systems.

The deregulation of substantial portions of the system in the 1990s is the most recent effort to change the way energy is generated, distributed, consumed, and priced. In the old system, public utility companies generated power in central facilities; they distributed it to businesses and homes through a network of power lines and substations; and they charged customers set fees based on load factors determined through negotiation with regulators. This model is now being undermined by a combination of economics, technological innovations, changes in the structure of markets, and regulatory reforms.

But the future of electric power will not be completely divorced from the past. Except in those parts of the Third World that were never wired, these innovations will alter an existing energy landscape, and combine new and old technologies and institutions. All technological innovations are built on their predecessors. Premium energy technologies will have to run existing products and interact with legacy power systems.

## The Emerging Technology “Mix”: Three Ingredients

The premium power market will not be defined by a single technology or even a well-defined set of technologies. Rather it will be characterized by a dynamic mix of technologies and practices. It will certainly include a range of renewable energy resources, such as thermal or photovoltaic solar power, wind, biomass, and geothermal. But it will also depend on new fuel systems, most notably hydrogen. Finally, it will grow in the context of new arrangements in the distribution and economics of energy, such as micro-generation, real-time pricing, and net metering (running the meter backward). New power solutions may consist of only one of these or all three. For example, solutions might include:

- A wind farm operated by a conventional utility selling power at a fixed price.
- A factory drawing electricity from building-integrated photovoltaics and the local grid.
- A house that is equipped with fuel cells to meet its own needs and sell power back to the local utility.

It is important to note that this mix will evolve in the context of new technology for centralized production of power, as well. Current coal-driven power plants have increased efficiency rapidly as these new alternative technologies have developed, and new zero-emission steam turbines may further enhance the position of central utilities.

### **The State of the Market: Under- and Over-performing at the Same Time**

Research on alternative energy dates from the 1960s, driven first by concerns about the ecological costs of coal and oil, and second by NASA-sponsored research on photovoltaics and fuel cells. Since then, federally-sponsored research and tax incentives—depending on the policy of the moment—have alternately encouraged or stifled the growth of a sizeable, viable alternative energy industry. (Interestingly, alternative energy—or “free energy”—has also been a rich territory for hucksters and con men.)

Today, renewable energy accounts for a small percentage of U.S. energy production; in other developed countries, it ranges as high as 7% (in the Netherlands). As analysts have noted, these new energy technologies have underperformed compared to predictions of their market share, largely because the cost of oil has fallen in the last 20 years. But they have overperformed compared to predictions of their efficiency and cost. In parts of the Third World, particularly those with abundant wind and sun but far from existing electric power and gas networks, solar and wind power are already being used to electrify homes and villages.

### **Market Deregulation and Diversification: Toward “Real-Time” Pricing**

The trend to deregulate energy markets will continue, despite the California energy crisis of 2001 and last fall’s Enron debacle. The number and variety of players in energy markets will continue to diversify, and the ways businesses mix and match their products or services will become more varied. Finally, price volatility in electricity markets will increase.

These market and institutional changes will have technological and financial impacts. Power production and distribution systems in the United States were designed to provide reliable levels of power to reasonably well-defined local or state markets. As producers gain the ability to sell electricity in larger markets and to service high-demand areas, the amount of “spinning reserve” will decline.

Pricing for electricity will also become more dynamic. Since the 1930s, electricity has been priced relatively simply, as a function of load factors and time of day. The decrease in spinning reserve, combined with the ability to communicate information about demand and to quickly shift energy from one market to another, will result in a “real-time pricing” regime, with greater price volatility. It will also encourage the differentiation of customers who have to have guaranteed supplies of power—and are willing to pay a premium for it— from those who are can handle interruptions during peak load times.

## Competition Redefined: New Consumer Choices

Market deregulation and diversification, the growth of real-time pricing, and greater price volatility will open the door to competitive innovations. New technologies—in particular, energy generators running on renewable or alternative resources—will emerge as viable choices for consumers who need premium power solutions.

There is already a small but growing market in commercially available electrochemical devices, most notably fuel cells. Fuel cells are already in test markets in the Northeast. As one of our experts said, they are likely candidates not so much for remote, off-the-grid solutions but for regions where power outages or overdevelopment of the power grid reduce the reliability of traditional power.

Bio-fuels will also become substantial enough to support a distinct market for energy crops. Ethanol-derived corn is one product already on the market. Some more exotic crops are currently under development, including hydrogen-producing algae.

Equally important will be experience in designing economical microgrid power systems that exploit local resources while guaranteeing the electricity needs of owners. At the same time, new storage alternatives could provide a competitive breakthrough for photovoltaics. For example, the ability to store electricity generated by photovoltaics during the day for use in the evening would make installed solar energy systems much more attractive, particularly to homeowners. “Economical storage enables renewables,” as one scientist put it.

## CO<sub>2</sub> Emissions Controls? An Uncertain Future

Programs to reduce air pollution and limit global warming, such as tax incentives that subsidize use of renewables, cap-and-trade markets for carbon emissions trading, or regulations limiting non-renewable fuel use, are boosting the attractiveness of alternative energy sources in Europe, and to a lesser degree, the United States. Such programs have built up significant momentum among European nations, and even among some corporations interested in providing services to a CO<sub>2</sub> emissions-trading market.

The current administration’s reluctance to ratify the Kyoto Protocol challenges the future of emissions control. Nevertheless, the consensus among our experts is that some emissions controls are inevitable and that they will ultimately encourage the growth of carbon sequestration programs, emissions trading, and investment in alternative energy.

## Energy Consumption: New Consumer Behaviors

The biggest change in consumer behavior at all levels will be the diversification of consumption. Business consumers and institutions that require guaranteed power—such as hospitals, and fire and police departments—will invest in their own power systems. Companies with unusually strict electricity needs or those that are very sensitive to even short blackouts will also develop a “mutual fund of energy supply,” as one energy expert called it. These off-grid systems will include a range of configurations, such as:

- Backup generators operating only during blackouts.
- Hybrid microgrids that combine utility-generated power with electricity produced locally.
- Independent microgrids that generate power from a mix of fuel cells, photovoltaics, and wind.

As costs fall, opportunities will emerge to move these technologies into homes. The growth of decentralized power generation facilities will help balance energy markets and reduce price fluctuations. They will also create the potential for even more radical changes in the energy market: the transformation of consumers into producers of electricity. Businesses and homes with excess generating capacity could, in theory, sell power back to the grid, to be consumed by other users—a kind of eBay for electricity, with the networks serving as a marketplace connecting small-scale buyers and sellers.

However, our experts warned that the technology to “run the meter backward”—to connect small power suppliers to transmission grids, to manage load balances with hundreds or thousands of small generators, to price such energy and manage billing—is still in its infancy, and a host of legal and regulatory issues have yet to be resolved (or even adequately defined).

## Security Concerns: The High Cost of Protection

The United States has roughly 2 million miles of oil and gas pipelines, and over 150,000 miles of high-powered electrical transmission lines. This massive infrastructure is almost impossible to defend against determined saboteurs with simple equipment. In the wake of September 11, energy security—the protection of existing infrastructure, protection of access to foreign energy, and development of new resources and technologies that are resistant to attack—has become a high priority for everyone. But it means different things to different groups.

Attacks by determined individuals on energy infrastructure are not new. Pipelines were damaged intentionally during labor disputes in the Pennsylvania oil fields in the late 1860s. Today, they are targets of guerillas and terrorists. For example, the 480-mile Caño Limón pipeline, which carries oil from northeastern Colombia to the port of Coveñas, has been attacked some 700 times since its opening in 1986; in 2001, as the guerilla war intensified, it was attacked so often that it was off-line for most of the year.

Major American pipelines are easy targets. In October 2001, a drunken sportsman shot at the Trans-Alaska Pipeline, shutting it down for several days and causing a 285,000 gallon crude oil spill (larger than the Exxon Valdez accident) that cost about \$60 million in lost revenue. A month later, the Department of Justice issued a warning of a possible Al-Qaeda plan to attack natural gas pipelines.

Protecting this infrastructure would be expensive. So too is guaranteeing American access to foreign oil. One analyst estimates that “one-third, or \$100 billion, of the U. S. defense budget is needed to secure and protect essential access to foreign oil and the sea lanes.” The Cato Institute estimated in 1990 that the United States spends about \$40 billion protecting its access to Middle East oil. The cost of protecting foreign infrastructure from terrorists or guerillas is also likely to rise; these facilities are difficult to defend, they symbolize corporate (or American or government) power, and damage to them deprives states of revenue.

The terrorist wildcard, then, has suddenly become a key variable in the future of premium energy—presenting two very different policy choices as described in the next section beginning on page 8.

# Energy Security Policy

In broad terms, there are two ways to achieve energy security: protect extant infrastructure, or develop harder-to-attack alternatives. Decentralized generation would decrease our vulnerability to attack; likewise, as one editorialist put it, “efficiency cannot be bombed.” But the nation’s oil pipeline trade association has already requested federal support for pipeline defense, and this fall President Bush asked Congress for \$98 million to train and equip a new Colombian army brigade to defend the Caño Limón pipeline.

Such expenditures are not just a reflection of the power of the oil and gas industry. Even the most optimistic projections for alternative energy assume that gas and oil—and to a lesser degree, coal and nuclear power—will continue to be indispensable. Hence the conclusion that alternative energy is really

## Scenario 1: Protect the Existing Infrastructure

### Assumptions:

- Current drivers—relatively low gas and oil prices, the war on terrorism, and an interventionist, often unilateralist foreign policy—remain in effect, but that no new emergencies (attacks on dams or power plants, sudden energy crises) occur.
- Efforts to reduce CO<sub>2</sub> emissions proceed at a low level, with some nations developing emissions trading markets or requiring reductions, and corporations and NGOs working (sometimes together) on parallel projects.
- On the defense front, national policy protects access to foreign oil, and strengthens domestic infrastructure.
- Deregulation of the energy industry continues with few constraints.

**Outcome:** In this environment, premium energy products for portable electronics and medical devices grow, but other premium energy markets and real-time pricing both develop slowly. Carbon abatement provides only modest incentives to develop renewable energy or even new zero-emission technology. Federal incentives are few, on the grounds that investment in unproven technologies are not appropriate during an emergency. Some businesses will invest in their own microgrids, both for physical security and as insurance against fluctuating energy prices, but these technologies will not spread widely to the home, so the market for new premium technologies continues to underperform and new research lags. Meanwhile, security concerns over both plants and waste are likely to work against a renaissance in nuclear power. Global warming worsens.

a new market on top of the existing market. Further, decentralization programs do not have a strong record of success in America. Even the threat of thermonuclear destruction was not enough to disperse American industrial and population centers—for example, cities like New York and Detroit—despite the recommendations of architects and government planners.

Ultimately, the choice between these two policies is likely to play out in quite different scenarios as seen below..

## Scenario 2: Decentralize the Infrastructure

### Assumptions:

- The U.S. pursues a more multilateral strategy to combat terrorism, and global events (disrupted global oil markets, for example) lead to a domestic policy of diversifying energy production and distribution.
- Carbon reduction programs are pursued more aggressively with a specific focus on emission caps and credits.
- Homeland security and energy policies offer incentives for renewable energy and decentralized systems.
- Market deregulation occurs more slowly: individuals and businesses are treated as the main guarantors of energy security, rather than markets.

**Outcome:** In this environment, national markets for carbon emissions develop faster and are integrated more smoothly into a global market. Carbon abatement and federal policy both encourage development of renewable energy technologies, and the growth of off-grid production capacity. Businesses and densely populated, upscale urban neighborhoods lead the charge toward mini-grids, with a spillover effect into individual off-grid household generation in the suburbs. These niche markets provide strong, but contained growth for premium energy technologies, bringing the prices of the technology down and setting the stage for wider adoption in the future. However, real-time pricing spreads slowly, with some businesses participating first in more complex energy markets, while the majority of individual consumers continue to pay more traditional fixed rates.

## The Bigger Picture: Emergent Technolog

Absent security concerns, the most energy-efficient, ecologically sound scenario for the future of power in the United States would be a re-commitment to centralized plants using new technologies—especially zero-emission technologies—together with carbon sequestration. Natural gas and nuclear fuels would grow as fuels of choice, at least for the next 25-50 years. Wind turbines would play a slowly growing role. Local fuel cell grids would be used primarily to solve the problem of sites that are remote, overpopulated, or subject to extreme weather.

The threat of terrorism, however, adds a new imperative to the mix, and Americans are particularly likely to cast this imperative in terms of individual solutions. Combine this tendency toward “cowboy” solutions with other trends in technology—particularly the evolution of a more distributed communication and computing infrastructure—and the result is likely to be an increasing preference for distributed energy solutions.

The overall technology horizon is one of emergent systems: many small components interacting according to relatively simple rules to create large complex systems with unanticipated behaviors. There’s no reason to think that energy will be exempt from this trend. The terrorist threat is simply a catalyst for energy markets to participate in this future of emergent systems.

## Annotated Bibliography

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- For additional perspectives, see IFTF's interactive *New World Map* on CD-ROM (SR-774, July 2002).

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