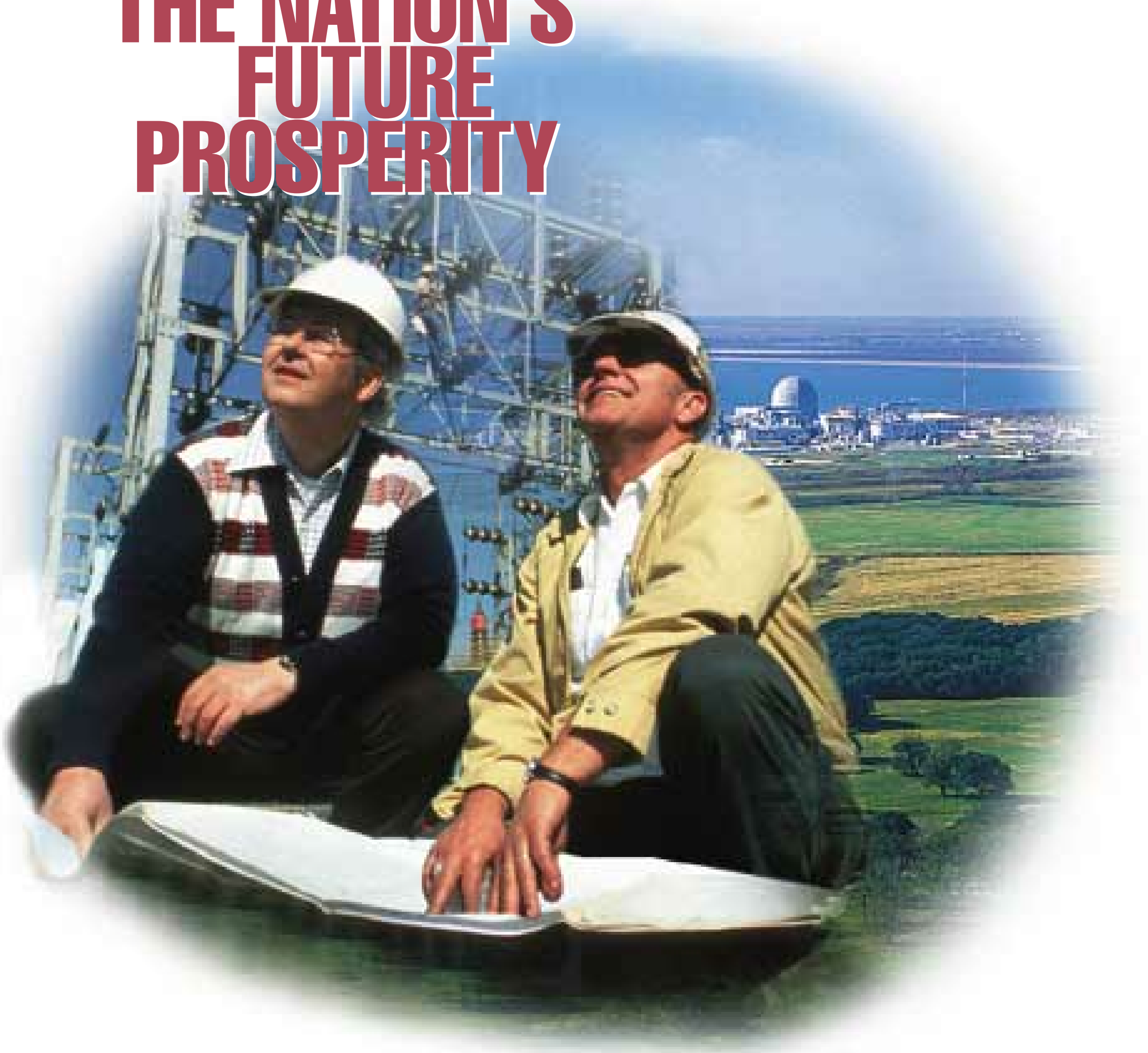
Vision 2020

NUCLEAR ENERGY AND THE NATION'S FUTURE PROSPERITY



NUCLEAR ENERGY INSTITUTE

“Men make history,
and not the other way
around. ...Progress occurs
when courageous, skillful
leaders seize the
opportunity to change
things for the better.”

Harry S. Truman

VISION 2020 PART I

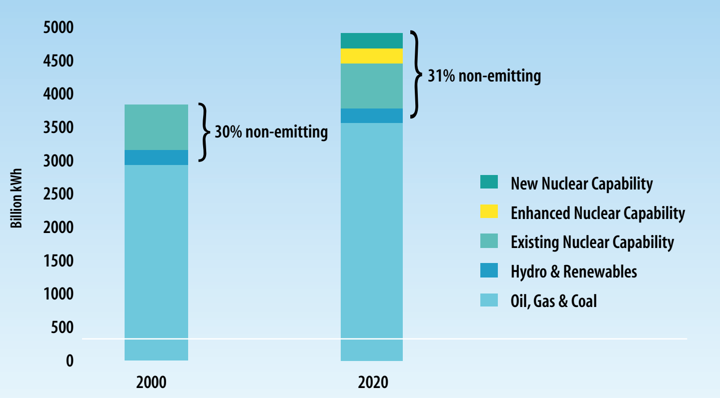
Because reliable and affordable electricity is the backbone of the nation's economy and national security, the nuclear energy industry in 2001 set forth a long-term vision of the industry's future. The cornerstone of that vision is adding 50,000 megawatts of new nuclear electric generating capacity to the national grid by 2020.[1]

The industry expects to add 10,000 megawatts of capacity through increased efficiency and improved performance of its existing fleet of 103 nuclear electric reactors. All told, this additional 60,000 megawatts of capacity would generate the electricity necessary to maintain nuclear energy's current market share of generation at about 20 percent, thereby helping to maintain diversity of the nation's energy portfolio. Equally important, this added capacity would keep stable the nation's 30 percent share of emission-free, sustainable electricity generation (see Fig. 1).

The industry's *Vision 2020* initiative came shortly after the Bush administration's release of its comprehensive national energy policy. The White House energy policy development group recommended that "the President support the expanded use of nuclear energy in the United States as a major component of our national energy policy."[2] The administration's plan also made other core recommendations: significantly increase domestic energy supply; promote diversity in the national energy mix; revitalize an increasingly antiquated national energy infrastructure; improve upon an already impressive record of energy conservation and efficiency; and protect the nation's environment. In presenting the plan, President Bush noted that "America must have an energy policy that plans for the future, but meets the needs of today."

Both the president's energy policy and the nuclear industry's *Vision 2020* are rooted in two basic concepts. The Energy Department's Nuclear Power 2010 program that proposes the construction of new nuclear power plants in the United States before the end of the decade has the same roots. First, sufficient energy supply—as the engine of the U.S. economy—is fundamental to America's prosperity and national security. Second, long-term efforts are necessary to rectify the years of neglect of energy supply and national infrastructure issues because of the long lead times required in large, capital-intensive projects.

FIG. 1 MAINTAINING AMERICA'S CLEAN AIR



This report sets forth the industry's vision. It outlines the key strategic objectives that form the plan's core and illustrate nuclear energy's essential role in the nation's economic and environmental well-being. In so doing, it will underscore how energy issues in general—and nuclear energy in particular—are vital components of U.S. national security. Finally, as the industry transitions toward an increasingly competitive electricity market, the report emphasizes the strategic importance of addressing national electricity supply issues on a long-term basis.

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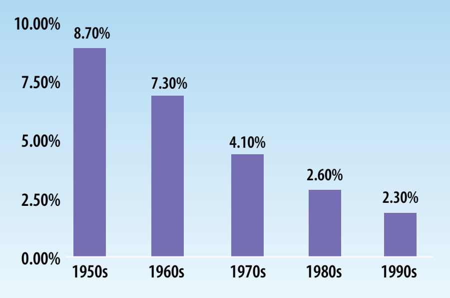
Within the next two decades, the nation will need 355,000 megawatts of new and replacement electrical generation, assuming that electricity demand grows at the modest rate of 1.8 percent per year.

SOBERING ELECTRICITY DEMAND BY 2020

Sobering electricity supply and demand projections underscore the seriousness of the challenge ahead. According to the Energy Information Administration (EIA)—the statistical arm of the U.S. Department of Energy—the nation will need 355,000 megawatts of new and replacement electrical generation within the next two decades, assuming electricity demand grows at the modest rate of 1.8 percent per year.[3]

FIG. 2 ELECTRICITY DEMAND GROWTH BY DECADE



Although EIA's demand growth projection is a conservative estimate and below that of the previous five decades (see Fig. 2), it nonetheless constitutes an enormous amount of electricity because of the nation's size and projected population growth.[4] To put the magnitude of this potential electricity supply gap into perspective, it is approximately equivalent to the combined installed electrical capacity of France, Germany, Great Britain and Italy in 1999.[5]

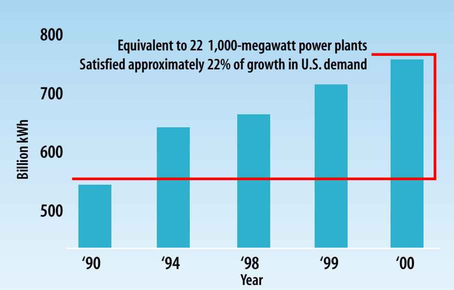
How did this looming electricity supply imbalance occur? It is a function of electricity demand far outstripping new supply. For example, despite rapid growth of electricity consumption in the United States during the 1990s, construction of new power plants fell to half the rate of the previous decade.[6] Failure to match electricity demand with new generation during the 1990s consumed the capacity reserves of the past and placed the nation on the precipice of a massive electricity shortfall in the coming decades.

Put another way, in order to sustain the diversity of the U.S. energy portfolio—and nuclear energy's 20 percent of our nation's electricity—the nuclear industry over the next 20 years must add approximately 50 large power plants, or the total nuclear generating capacity of France in 1999.[7] The amount of generation to be added translates into about 3,000 megawatts per year.

EFFICIENT ELECTRICITY PRODUCTION AND ENVIRONMENTAL PROTECTION

The U.S. nuclear energy industry provided an essential buffer against electricity shortfalls in the 1990s through tremendous efficiency improvements. The nuclear energy industry increased generation by 22 percent from its reactors (see Fig. 3)—one of the most significant energy efficiency efforts in the nation during that period.

FIG. 3 NUCLEAR PLANT OUTPUT: GROWTH IN THE '90s



In addition to producing a record 754 billion kilowatt-hours of electricity in 2000[8], from 1990 to 2000 nuclear power plants increased the industry's average capacity factor—the basic measure of power plant efficiency—from about 65 percent to about 90 percent. This improved efficiency added 177 billion kilowatt-hours to the nation's electrical grid, or the equivalent of 22 new 1,000-megawatt power plants. Moreover, this additional generation satisfied about 22 percent of the growth in national electricity demand over the same period.[9]

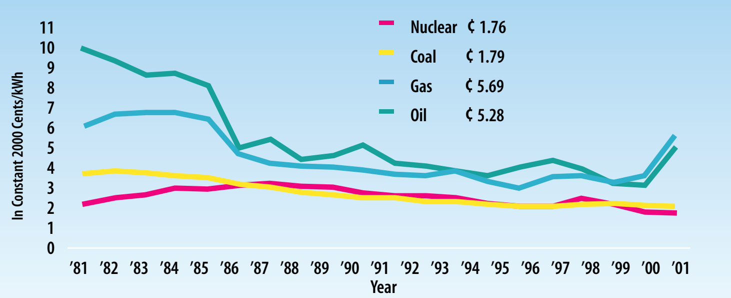
This improved capacity factor—a function of better management practices, higher reliability/ production[10] and shorter refueling outages—also resulted in a concomitant reduction in nuclear power production costs. Reflecting an ongoing trend, the industry's average production cost in 2001[11] dropped to 1.76 cents per kilowatt-hour (kWh), lower than its closest competitor, coal-fired production, with average costs of 1.79 cents per kWh (see Fig. 4). Moreover, these efficiency improvements have had a positive impact on the nuclear energy industry's already unrivaled operational safety record. The industry's most cost-efficient plants are also the safest: Management attention improves both safety and efficiency.

Importantly, the industry achieved record production and efficiency levels while improving the nation's air quality. By producing electricity that otherwise would have been generated by power plants that release air pollutants, nuclear energy avoided the emission of vast quantities of materials that create smog, acid rain and particulate matter. For example, in 2000 nuclear energy avoided emissions of 2 million tons of nitrogen oxide and 4 million tons of sulfur dioxide. Over that same period, the nuclear industry avoided 174 million metric tons of carbon that may contribute to global warming.[12] From 1973 to 2000, emissions avoided by nuclear energy totaled: 66 million tons of nitrogen oxide, 34 million tons of sulfur dioxide and nearly 3 billion metric tons of carbon.

ELECTRICITY'S ROLE AS AN ECONOMIC MULTIPLIER

In 2000, a panel of the National Academy of Engineering designated electrification—the increased availability of electricity nationwide—as the 20th century's greatest achievement.[13] In itself, this is not surprising. Another panel of research scientists reached a similar conclusion in 1987.[14] As Chauncey

FIG. 4 U.S. ELECTRICITY UTILITY PRODUCTION COSTS



Starr, president emeritus of the Electric Power Research Institute, noted soon thereafter, "This confirms the intuitive belief of most technologists that the process of electrification during the past century has been a major factor in the sociologic and economic development of modern industrial societies."[15]

What is revealing about the National Academy of Engineering's ranking of the past century's greatest achievements is the extent to which most are dependent on electricity—in whole or in part—for their operation.[16] Equally important is the academy's recognition of nuclear power—and its associated technologies—as one of the century's 20 greatest accomplishments.

More than half of the academy's top 20 achievements depend on electricity. What is more striking, however, is how the diffuse items on the list interact, in combination with electricity, to power the nation's economic progress. One prominent example is the country's technology-reliant digital economy. Such an economy could not operate, let alone prosper, without reliable electricity to power computers (ranked eighth), electronics (ranked ninth) and the Internet (ranked thirteenth) that are so basic to our economic success. In other words, electricity is an economic multiplier—a gateway technology that fosters economic growth and additional technological progress.

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FIG. 5 CORRELATION BETWEEN ELECTRICITY AND GROSS DOMESTIC PRODUCT

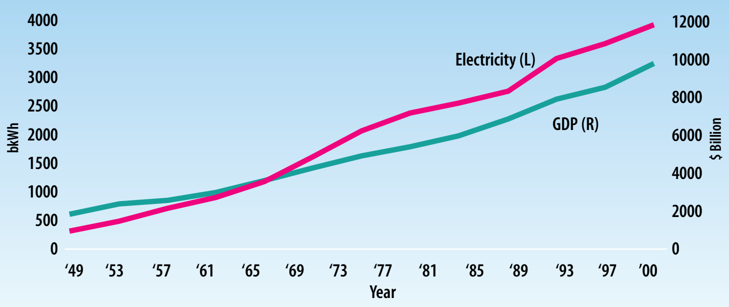
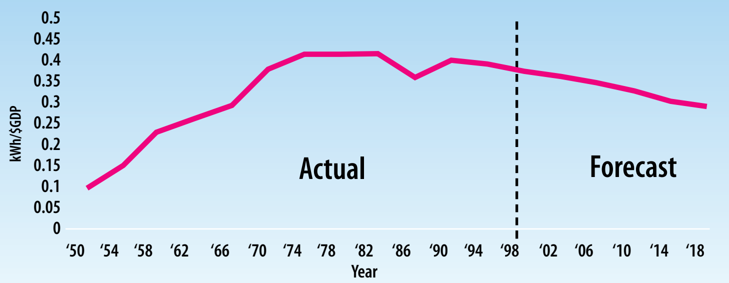


FIG. 6 ELECTRIC INTENSITY 1950-2020



The strong historical correlation between electricity demand and Gross Domestic Product (GDP) is powerful evidence that electricity plays an essential role in economic growth (see Fig. 5). As the nation's GDP rises, electricity demand follows with near lock-step precision. Stated differently, increased availability of electricity spurred wider and more diverse applications of that electricity. This in turn spawned increasing economic growth as the nation developed new ways to derive increased economic value from electricity and to improve the overall standard of living.

While these supply and demand variables remain in balance, electricity prices remain stable and economic growth continues. Moreover, the wider application of electrotechnologies results in greater productivity gains and the more efficient use of this valuable commodity. This can be seen in the measure of electricity intensity—the ratio of kilowatt-hours per unit of GDP. As electricity demand increases over time, electricity intensity has fallen since 1974 (see Fig. 6).

As this trend continues, projections are that by 2020 the nation's measure of electricity intensity will approximately equal that of 1960, despite a seven-fold increase in electricity demand.

ELECTRICITY SUPPLY, DEMAND AND EFFICIENCY

The relationship of electricity supply, demand, efficiency and economic growth is particularly sensitive because, unlike other commodities, electricity cannot be stored to meet unanticipated demand increases. As Federal Reserve Board Chairman Alan Greenspan told the Economic Club of Chicago in 2001:

> Because inventory buffers are not feasible for electrical systems, capacity buffers must absorb the full brunt of supply-demand imbalances. Such a system, confronted with relatively inelastic demand, cannot avoid extreme price increases or, alternatively, blackouts when demand for power. . . approaches or exceeds available supply. This would be the case whether power is being generated in a wholly free market or in wholly controlled markets that in decades past were governed by public utility commissions.[17]

In 1986, the National Research Council also described this relationship.

> The strong and persistent relationship between electricity use and gross national product requires that close attention be paid to the adequacy of electricity supply to sustain a high future rate of economic growth. The adequacy of electricity supply can be maintained not only through new generation facilities but also through efficiency improvements that use existing generating capacity better. Although favorable electricity supply conditions of themselves will not insure economic growth, a lack of adequate supply would almost certainly constitute a serious impediment to such growth.[18]

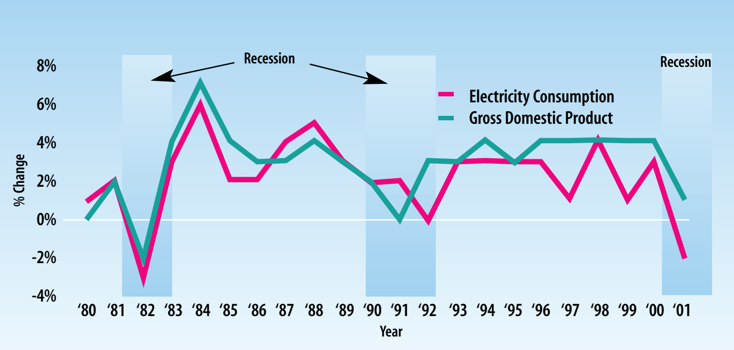
Clearly, the key to maintaining electricity supply is sufficient generating facilities to meet demand. Otherwise, increased generation must be obtained by gaining greater efficiencies from existing plants. As previously noted, the country has made impressive efficiency gains in electricity usage, and that trend must continue. What continues to lag, however, is the sustained development of a balanced electric generating portfolio to meet future increases in demand.

Historically, economic downturns compound this particularly vexing problem. Although electricity demand grows with GDP, short-term electricity demand slows with cyclical downturns in the economy. The two lowest periods of national electricity consumption correspond with the recessions of 1982 and 1992 (see Fig. 7). True to form, as the nation entered a recession in late 2001, electricity consumption—particularly in the industrial sector—took a corresponding downturn.[19]

The difficulty this presents is twofold. First, in pursuing long-term national priorities the country's short-term market emphasis fails to account for cyclical downturns in the economy. As pressure on electricity demand lessens in the short-term, support for long-term investment in new electricity generation similarly wanes. This phenomenon can clearly be seen in California, where anxiety over blackouts and lost revenue has vanished since lower gas prices, an economic slowdown and mild weather have lessened electricity demand and corresponding perceptions that an electricity shortage exists.[20]

Second, as electricity market deregulation continues, it becomes more difficult for executives of investor-owned energy companies to justify significant capital-intensive investment in new power plants absent confidence that the investment risk is

FIG. 7 YEARLY % CHANGE IN ECONOMIC ACTIVITY AND ELECTRIC CONSUMPTION



commensurate with the prospective financial return. Nevertheless, unless long lead-time construction on new power plants begins in the near-term, there will be insufficient time to build the capacity needed to meet demand. The same holds true for other long-term initiatives, such as improving electricity transmission, distribution and fuel transportation infrastructure.

THE NEXUS BETWEEN ENERGY AND NATIONAL SECURITY

Implicit in both the industry's *Vision 2020* and the administration's energy policy is the clear nexus between national security and energy security. On a strategic level, nuclear energy's role is profound: It provides the nation with much-needed fuel diversity; it consumes former weapons material to produce electricity; it provides the economy room to grow by supplying competitive bulk electricity; it provides critical emission-free generation; and, it helps maintain the integrity and reliability of the national power grid.

As a vital component of the nation's critical energy infrastructure, nuclear energy directly promotes national energy security. The events of September 11, 2001, brought this relationship into sharp focus and underscored the importance of the industry's enduring commitment to nuclear power plant security. Immediately following the terrorist attacks on New York City and Washington D.C., the industry

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moved swiftly to augment its already robust protection against potential threats. Nuclear plants went on highest security alert, increased patrols, expanded security forces and capabilities, and heightened coordination with local, state and federal law enforcement and military authorities. In February 2002, the Nuclear Regulatory Commission established new security requirements that incorporate many of the voluntary actions initially taken by the nuclear industry.

With the goal of creating a seamless defensive shield integrating and capitalizing on the special talents of private industry, government officials and agencies, and the military, the nuclear industry also called for a comprehensive review of all credible threats to the nation's critical energy infrastructure—including nuclear power plants. Such a review could clearly delineate those responsibilities best assumed by the federal government—such as terrorist acts of war—and those best assumed by private industry and local governments. In this way, the industry-government partnership can maximize security effectiveness and efficiency, while simultaneously fueling the economy that keeps our nation strong.

President Bush reinforced this principle in his recommendation to Congress that the nation move forward with the Yucca Mountain site as the deep geologic repository for disposal of used nuclear fuel and high-level radioactive waste from the nation's defense activities:

> A deep geologic repository, such as Yucca Mountain, is important for the national security and our energy future. Nuclear energy is the second largest source of U.S. electricity generation and must remain a major component of our national energy policy in the years to come. The cost of nuclear power compares favorably with the costs of electricity generation from other sources, and nuclear power has none of the emissions associated with coal and gas plants.[21]

After two decades of exhaustive scientific study, the president's landmark decision will enhance national security by centralizing and isolating used nuclear fuel in a secure underground disposal facility. It will also promote national environmental cleanup goals as a repository for defense-related nuclear waste. And, finally, it will support national energy and economic security by ensuring that nuclear power will continue to generate the large amounts of emission-free electricity upon which the nation depends.

A NEW ENERGY PARADIGM

In addition to increased nuclear electric generation, the second vital element of *Vision 2020* is that over the next two decades: *Policymakers and the public are demanding further increases in the share of sustainable nuclear energy to satisfy national economic growth and environmental objectives.* This dimension of the industry's vision recognizes how critical it is that policymakers and the public support building more nuclear capacity in the United States.

The administration's energy policy is a clear indication that policymakers increasingly embrace this notion. So, too, is the Energy Department's *Nuclear Power 2010* initiative[22] aimed at building new nuclear power plants in the United States by the end of the decade. Like *Vision 2020*, these initiatives appreciate the importance of new nuclear power plants to national energy and environmental policy.[23] They also recognize that nuclear energy is an effective environmental and risk-management tool for the nation and plant owners.

For example, the uranium used in nuclear power plants diversifies the national energy mix. Nuclear fuel derived from surplus Russian nuclear weapons

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President George W. Bush

adds to U.S. national security. And while the country imports significant amounts of uranium, the world's largest producers are among the staunchest of U.S. allies. Because it is abundant, storable, concentrated and easily transportable, uranium is much less susceptible to price volatility resulting from supply and distribution disruptions. Advanced fuel purchases based on long-term contracts also help in this regard. Similarly, because a great deal of energy value remains after initial use, used nuclear fuel constitutes a strategic fuel reserve that could serve as a hedge against potential long-term supply risks.

Equally important, nuclear energy helps insulate the nation from a growing air emissions problem and constitutes an important insurance policy against the potentially deleterious effects of air pollution and global warming. This is particularly important for large urban areas that generally have the largest baseload electricity demand and face the most challenging air quality issues. Likewise, avoided emissions are a vital part of an integrated compliance strategy to meet the increasing regulatory challenge of the Clean Air Act. As Congress considers proposals to control a range of emissions, energy companies with a diversified fuel mix can use their emission-free nuclear plants to offset emissions from other fuel sources.

The third important element of the industry's *Vision 2020* is that within 20 years: *Nuclear technologies are widely used in medicine, food safety, water management and to produce complementary clean fuels such as hydrogen.*

More than 10 million diagnostic and therapeutic nuclear medicine procedures are performed each year in the United States. These safe and painless procedures provide unique information about the function and structure of virtually every major organ system and save countless lives through early diagnosis and treatment. Likewise, there is a growing appreciation of the role of radiation in the sterilization of food products and everyday household items.[24]

What is less well-appreciated is that water desalination and hydrogen production using nuclear power facilities may be as important in the 21st century as electrification was to the 20th century.

By 2025, according to the International Water Management Institute, nearly 2 billion people will live in countries or regions with absolute water scarcity. Already, most countries in the Middle East and North Africa have dire water scarcity problems, and water usage doubles every 20 years.[25] Like reliable energy supplies, clean water is a prerequisite for political stability, economic growth and public health.[26]

The International Atomic Energy Agency believes nuclear desalination has distinct advantages. It is cost competitive with other water purification technologies, can produce electricity and fresh water simultaneously, and reactors of almost all designs are suitable for desalination.[27] Already, demonstration projects in Kazakhstan and Japan have validated this process, and construction is under way in India on a desalination plant coupled with a 170-megawatt reactor. Domestically, nuclear desalination could help ever-worsening fresh water shortages throughout the West and in Florida.[28]

Nuclear power plants can also produce complementary clean fuels such as hydrogen at nuclear power facilities. During the 1990s, the transportation sector accounted for about 26 percent of U.S. greenhouse gas emissions. Moreover, the number of vehicles traveling the nation's highways has grown faster than the overall population since 1970.[29] Consequently, there is growing support for using

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Producing clean fuel with an emission-free energy source multiplies the benefits for the environment. Nuclear power can play a significant role in large-scale hydrogen production by providing the electricity needed in this production process. Most hydrogen is extracted from fossil fuel raw material. Replacing fossil-based raw materials with nuclear electricity allows those fossil resources to be used for higher end-value processes, such as chemical feedstock, and reduces emissions to the environment.

hydrogen fuel for fleet transportation systems, particularly in metropolitan mass transit systems.

Producing clean fuel with an emission-free energy source multiplies the benefits for the environment. Nuclear power can play a significant role in large-scale hydrogen production by providing the electricity needed in this production process.[30] Most hydrogen is extracted from fossil fuel raw material.[31] Replacing fossil-based raw materials with nuclear electricity allows those fossil resources to be used for higher end-value processes, such as chemical feedstock, and reduces emissions to the environment.

In January 2002, Energy Secretary Spencer Abraham announced a government-auto industry partnership to pursue advanced research on hydrogen fuel cell vehicles. One month later, while announcing the department's Nuclear Power 2010 initiative, Abraham noted: "Another reason we are excited by these (nuclear) technologies is that they are capable of generating the very high temperatures required...to generate large quantities of hydrogen. ...I believe hydrogen has tremendous potential as a transportation fuel in the future."[32]

Importantly, using nuclear electricity in water desalination and hydrogen production could also serve as risk management tools to hedge against downturns in electricity demand. The added business flexibility of parallel revenue streams—electricity and fresh water or hydrogen—could allow plant operators to better balance supply and demand curves of each of these vital commodities.

IMPLEMENTING VISION 2020

Vision 2020 updates the industry's *Strategic Direction for the 21st Century,* and outlines the next step in advancing the nation's energy security and the industry's future. It is important, however, to keep in mind that elements of the *Strategic Direction* will continue, even as the industry moves forward. The industry will continue to pursue used fuel disposal at Yucca Mountain, based on the scientific evidence that the site is suitable. The industry also will continue to pursue regulatory reform for nuclear facilities based on the principles of safety-focused and performance-based oversight. And the industry will continue its commitment to safety and environmental protection.

There are six strategic objectives within *Vision 2020*:

1. **Attain prominent and equitable acknowledgment of nuclear energy as a necessary and vital component of national and international energy and environmental policy.**

Diversity is a fundamental strength of the United States—in its richness of culture, natural resources, economic activity, political process and in its energy supply. To be most effective, the nation's long-term planning must embrace and maintain the great strengths that diversity has brought to the country.

Planning for a secure energy future to protect the environment, sustain economic growth and maintain an advancing quality of life must embrace diversity as well. Within the diversity of energy use and supply, nuclear power produces electricity for one of every five homes and businesses in America. It is both necessary and vital, as are all forms of electrical generation.

Nuclear energy in the United States provides enough electricity to meet the total electricity needs of all but three countries in the world—China, Russia and Japan—on a nation-by-nation basis. It provides this power with greater efficiency and at prices that are lower than all other sources of expandable electricity. Price stability enhances its competitive position because the nuclear fuel cycle is virtually independent of short-term market forces. Together, competitive pricing and price stability are essential to economic growth.

Nuclear energy is also, to a large extent, insulated against international political considerations affecting energy supply. There is sufficient supply of natural uranium on the North American continent to provide continued availability of this fuel resource, even in times of conflict. This independence not only strengthens national security, but also enables other national objectives to be achieved, such as the peaceful use of uranium from excess inventories of weapons.

Electricity production with nuclear power has an extraordinarily low environmental impact. The clean air benefits of nuclear energy place national clean air goals within reach, assuming other baseload electricity generation employs effective emission-control technology (see Fig. 8). The significant percentage of electricity produced by nuclear

The significant percentage of electricity produced by nuclear energy helps compensate for the continued use of other fuels because it produces no greenhouse gases or nitrogen and sulfur compounds linked to environmental harm.

FIG. 8 NUCLEAR PLANTS HELP AVOID POLLUTION IN COUNTIES WITH OZONE NONATTAINMENT UNDER THE CLEAN AIR ACT

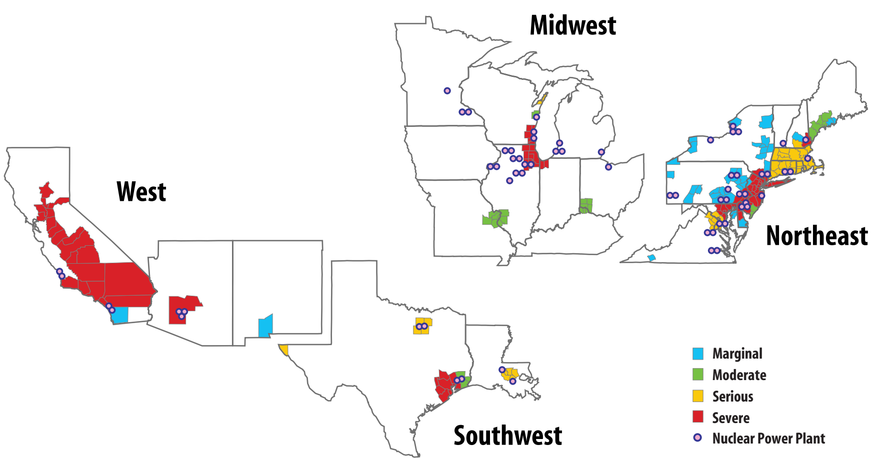

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FIG. 9 NUCLEAR SAFETY RECORD COMPARED TO OTHER INDUSTRIES

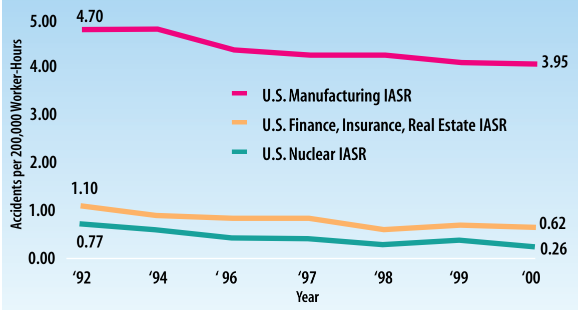
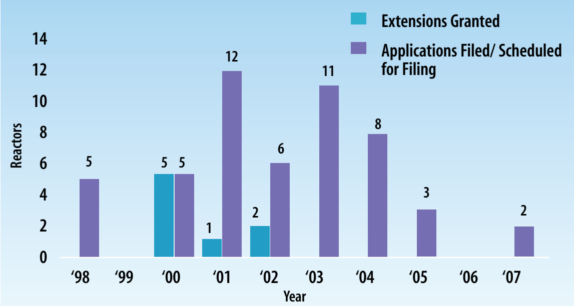


FIG. 10 PLANT APPLICATIONS FOR LICENSE RENEWAL (APRIL 2002)



energy helps compensate for the continued use of other fuels because it produces no greenhouse gases or nitrogen and sulfur compounds linked to environmental harm. Nor does it produce other compounds and particulates considered hazardous to human health.

Another advantage to nuclear energy is that the uranium used to generate electricity has virtually no other beneficial use. It is, however, capable of producing large quantities of energy from very small amounts of fuel on relatively small plant sites ideally suited to provide the vast amounts of electricity needed for concentrated populations and heavily industrialized areas. Nor does it consume fossil resources used in other industries with competing high-order needs such as plastics, textiles, fertilizers, transportation or agriculture.

In a global context, nuclear energy is an essential component of sustainable development. As world populations continue to urbanize, nuclear energy's emission-free dimension becomes even more important. Likewise, economic development, spurred by nuclear electricity and associated technologies, can improve economic productivity, food availability, water purity and disease prevention.

A sound energy supply that supports economic growth and clean air is vital in the truest, life-sustaining sense. Clearly, nuclear energy must expand in proportion to the growth in electricity demand to sustain the diversity of supply. All goals under this strategic objective serve to place this imperative squarely on the national agenda.

2. Maintain excellence in safe, reliable nuclear energy operations supported by a consistent and predictable regulatory process.

The case for increased reliance on nuclear energy was thoroughly demonstrated during the 1990s. Safe nuclear plant operations is the most fundamental basis for expanding nuclear energy. Owners of nuclear plants responded to industry deregulation with a single focus: Maintain the highest standards of safety, performance and reliability—and economic efficiency will result.[33]

The results have been dramatic, and policymakers nationally and internationally recognize the excellent safety and efficiency of U.S. reactors. Production from nuclear plants is approaching maximum levels. The industry's sharp focus on safety (see Fig. 9) has resulted in more efficient management practices and greater production at reduced cost for consumers. The steady and sustained performance improvement of the country's nuclear reactors met 22 percent of the national increase in demand for electricity throughout the 1990s. Simultaneously, the increased operating efficiency resulted in the lowest cost per kilowatt-hour of all expandable sources of electricity.

A clear indication of this is the industry's trend toward renewing the operating licenses for nuclear power plants beyond their original 40-year term. Already, the Nuclear Regulatory Commission has renewed the licenses of eight reactors for an additional 20 years of operation. Fifteen reactors have applications under review and an additional 28 applications are expected within three years (see Fig. 10). Eventually, almost all nuclear reactors are expected to submit license renewal applications.[34]

The connection between operational safety and effective safety-focused regulation is a significant component influencing a vibrant future for nuclear energy. An advanced regulatory program that focuses on essential safety issues while avoiding unnecessary regulation will support the increased use of nuclear power. The regulatory process in place for today's plants protects public safety. In the early years of nuclear energy, it was necessary to base this regulatory approach on deterministic criteria because of the lack of plant operating experience. Today, an advanced understanding of the relationship of regulatory requirements to operations allows regulatory oversight to use the more than four decades of operating experience to focus most effectively on safety.

The application of safety insights to reactor operations has substantially improved the Nuclear Regulatory Commission's oversight process, and also improved the transparency and public understanding of the new process. This same approach should now be used to improve the focus of NRC regulations using similar processes and safety and performance insights. This should be a model for future regulatory activity.

Business decisions depend on a stable regulatory environment. In parallel with applying a safety focus to performance-based regulations, advances must be made in the efficiency and effectiveness of those regulations. As societal understanding of radiological and environmental matters advances, coordination must be achieved between independent regulatory bodies affecting nuclear energy to avoid overlap and ensure a sound, safety-focused scientific basis for all regulatory activity.

All activities in support of this objective depend upon the sustained excellence of operations at nuclear plants and supporting facilities. The continued evolution of safety-focused regulation will provide a consistent and effective regulatory process and growing public confidence in the safety of nuclear energy through efficient regulation.

3. Attain an integrated and flexible approach to nuclear fuel management.

Expanded use of nuclear energy is a necessary component of societal well-being. Considerations of national security, energy independence, economic growth, plant performance and environmental protection are linked to the fuel cycle for every energy source. Relative to all other fuel sources capable of supporting the nation's electricity needs, nuclear fuel offers distinct advantages. These advantages, however, are highly dependent on the successful integration and resolution of all aspects of the complete fuel cycle.

As noted by Energy Secretary Abraham in his recommendation to President Bush to move forward with development of Yucca Mountain, Nev., as the nation's used nuclear fuel disposal site, a secure geologic repository is in the country's "compelling national interests." The federal government has a legal responsibility to dispose of used nuclear fuel. After two decades of exhaustive scientific and technical study, the policy decision to dispose of used fuel in a central underground repository is signifi-

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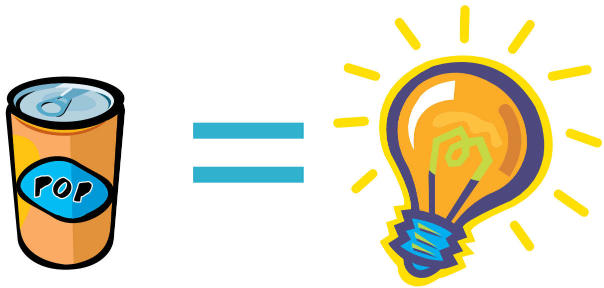
FIG. 11 LIFETIME PER CAPITA SHARE OF USED NUCLEAR FUEL



An individual's lifetime share of the amount of used nuclear fuel generated by America's nuclear power plants, which provide 20 percent of the country's electricity, would not fill a single soft drink can.

cantly closer to becoming a reality. Although current practices of storing used fuel at nuclear plant sites are safe and environmentally effective, a central repository offers the most viable long-term strategy for used fuel management, and provides a secure framework for the completion of the fuel cycle.

Nuclear energy is an efficient energy source. It produces less than 1.2 percent of the waste by weight than the best competing fuel—natural gas—and a much smaller percentage, if measured by volume (see Fig. 11).[35] All used fuel produced over the past 40 years remains safely stored at nuclear plant sites. While not a barrier to industry expansion, on-site used fuel storage for the long-term is counter to sound public policy and scientific consensus for management of used nuclear fuel. This makes decisions for increased investment in nuclear energy more difficult. Once long-term disposal of used fuel becomes assured at a federal repository, the decision-making process for new nuclear plants will become more predictable and stable.

Approval of Yucca Mountain as a repository is a key issue in establishing the necessary predictability to support the future use of nuclear energy. Approval will then lead to the resolution of many ancillary issues, such as transportation of fuel to the repository. The United States government and the nuclear energy industry have safely and successfully transported used nuclear fuel for nearly five decades. Nearly 3,000 shipments of used nuclear fuel have been transported over 1.7 million miles with no public safety or environmental impacts.

Eventually, selection of alternative sites or expanded storage capability to serve greater volumes of used fuel, and the potential of new or alternative technologies for disposition of used fuel, must be addressed. Reprocessing, transmutation or other technologies may become important during the course of the next 20 years.

The North American continent has ample raw uranium resources to meet our near- and medium-term nuclear energy needs. Well-developed, competitive domestic resources for reactor fuel fabrication are available. Capability for conversion of uranium ore to a form ready for enrichment is less competitive, and existing enrichment technology in the United States is outdated. Policies to use surplus quantities of highly enriched uranium and plutonium—both foreign and domestic—in commercial reactors enhance national nonproliferation goals. Nevertheless, those same policies are a disincentive to making the long-term political and financial commitments necessary for developing advanced national enrichment capabilities. It will be necessary to balance and integrate these competing but valuable objectives to ensure the development of a complete and secure North American capability to manufacture nuclear fuel.

Increasing sophistication and efficiency in reactor fuel design is capable of increasing reactor operating cycle lengths, which will reduce both refueling frequency and the volume of used fuel. These are desirable objectives, but they influence the manufacturing and enrichment processes, the operating characteristics of the fuel and the required packaging, handling and ultimate disposal of the used fuel. It will be important as the use of nuclear energy expands to maintain both the flexibility and the integration of these potentially conflicting effects in a way that produces optimal economic efficiency.

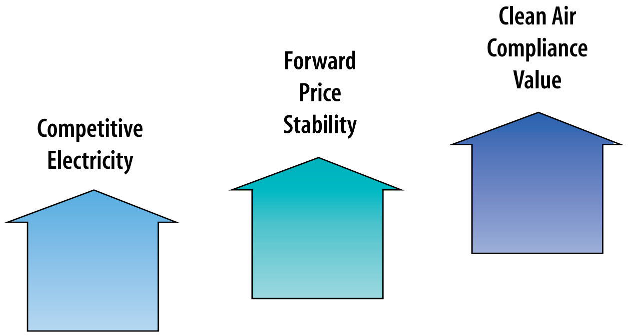
4. Maximize the value of nuclear energy assets in a competitive electricity market.

For most of its 50-year history, nuclear energy has operated in an environment of economic regulation. This environment focused largely on accounting mechanisms to describe "value." Accordingly, return to shareholders was established at a set rate and was calculated on invested capital, thereby guiding how plant owners managed their nuclear energy assets.

Many operating nuclear plants were completed after long licensing proceedings and extended construction periods at a time of high inflation, resulting in high capital costs. Owners experienced significant financial losses because of this confluence of circumstances, despite existing economic regulatory mechanisms. Electricity prices increased, sometimes dramatically, because of the impact of these events. These factors, together with an isolated view of perceived risks associated with nuclear plants, obscured the many inherent benefits of nuclear energy.

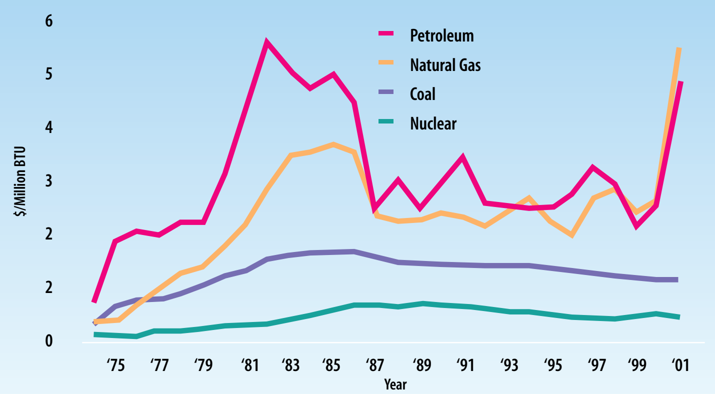
In the past decade, many nuclear plants entered competitive electricity markets. Nuclear plants are thriving in competitive markets. Investors and analysts increasingly view low production costs, stability of prices, safety and reliability of operation, and environmental factors as important factors in "value" assessments (see Fig. 12).

FIG. 12 NUCLEAR ENERGY'S VALUE CHAIN



Throughout the history of commercial nuclear power, the price of nuclear fuel has been substantially less than coal, gas or oil when calculated in

FIG. 13 FUEL COST TO ELECTRIC GENERATORS



terms of energy concentration. In more recent decades, the price of uranium fuel has been very stable by comparison (see Fig. 13). As the industry matured, nuclear operations improved substantially in terms of reliability and management efficiency. Improved reliability has resulted in increases in production so large that during the 1990s, the impact of increased nuclear production from these highly reliable facilities has been the equivalent of adding 22 large 1,000 megawatt power plants to the national power grid.

Improvements in management efficiency also have resulted in decreased operating costs. This powerful

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combination of efficiency, reliability of operation and low-cost fuel has resulted in the ability to deliver a vital product at stable and competitive prices. This is an extremely valuable service to industrial, business and residential consumers. Predictable energy prices are important and valuable to any competitive business and indeed to any organization or person that operates on a budget. This desirable characteristic of nuclear energy already commands a premium in many markets.

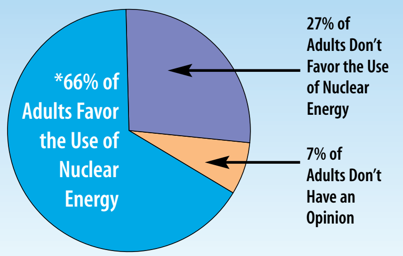
To date, issues associated with the environmental aspects of electricity production have focused on those fuels that produce air emissions. Allowances have been created and emissions standards set for emitting sources of electric generation, but there has been little value placed on the sources of electricity that avoid emissions completely—such as nuclear energy and renewables. Because of the presence of emission-free nuclear power plants in many regions of the country, emitting electricity sources in those regions are able to reduce their environmental compliance costs significantly. As the national focus sharpens on air quality issues, such as global climate change, acid rain and airborne particulates from power production, the environmental value of nuclear energy must be captured in economic terms.

5. Increase public and policymaker demand for nuclear energy and associated technologies.

Broad public acceptance and demand for greater use of nuclear energy and other beneficial applications will depend on three factors: an enhanced appreciation of the importance of clean and plentiful electricity, a solid awareness of the overwhelming benefits of nuclear technology, and a better understanding of radiation science. This understanding and awareness will require forthright and clear communications with the public.

As described earlier, the benefits of nuclear energy are significant. Nuclear power plants are by far the largest source of emission-free electricity. This reduces acid rain, particulate emissions affecting respiratory ailments and greenhouse gases that some scientists believe are affecting the global climate. Nuclear power plants operate reliably and safely, producing electricity vital to the economy and our standard of living at a lower, more stable price than any other source of electricity meeting the needs of urban populations. Waste products are carefully managed and fully accounted for without environmental or public health impacts. Nuclear power uses a fuel that is abundant domestically and has the capability to produce enormous amounts of energy from relatively small quantities of raw material. Uranium has virtually no other beneficial application, so that its use will not deny any known alternative uses for future generations. Nuclear power plants are compact and efficient in terms of land use devoted to power generation.

FIG. 14 SUSTAINED PUBLIC SUPPORT FOR NUCLEAR ENERGY



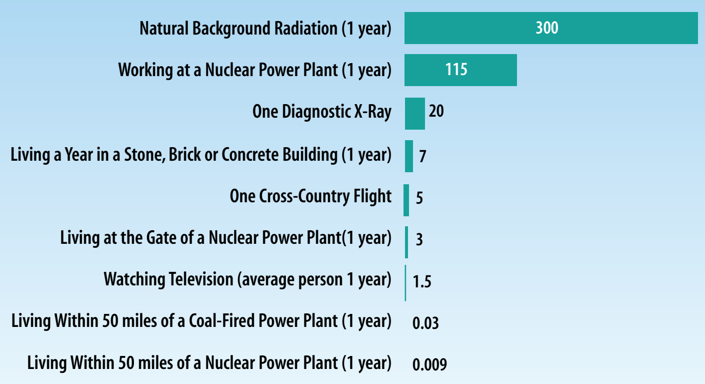
*February 2002 National Survey

These benefits would seem sufficient to create high demand from both the public and policymakers for expanded use of nuclear energy. Yet there is a perceived public reluctance concerning nuclear energy, despite public opinion research that demonstrates a majority favors the use of nuclear energy and building new nuclear power plants. For example, a February 2002 national survey of public attitudes about nuclear energy showed that 66 percent of adults favor the use of nuclear energy as one of the ways to generate U.S. electricity (see Fig. 14).[36] However, this majority also believes that it is in the minority when it comes to public opinion. This so-called "perception gap" is an indication that supporters of nuclear energy recognize its many benefits but question whether their peers have a similar knowledge of the technology. Antinuclear groups generally present the potential radiological impacts associated with nuclear energy to the public absent any reference to naturally occurring radiation or to the health risks of other energy sources. The potential impacts are also usually presented with substantial exaggeration, knowing that the public is ill-equipped to recognize the hyperbole. Nevertheless, Bisconti Research shows that two-thirds of all U.S. adults support building new nuclear plants at existing nuclear plant sites.

The nuclear industry itself tends to use a science- and technology-based vocabulary that is poorly suited to public communications. Some terms carry a sense of alarm and scientific jargon. Radiation is a common element of everyday life. It is omnipresent from natural and man-made sources (see Fig.15). Radiation from beneficial applications of nuclear energy has had no impact on public safety. There is some public reluctance to use radiation to eliminate bacterial contamination of food products but no parallel reluctance to use microwave radiation for cooking. With time, an increased public understanding of radiation and the benefits of nuclear technology will permit a greater awareness of the full benefits of nuclear energy.

Some beneficial uses of nuclear technology have suppressed the association with "nuclear" and "radiation" so that the technology will be accepted without confronting perception issues. This is often the case in health applications ranging from direct applications of nuclear medicine to sterilization of

FIG. 15 RADIATION EXPOSURE FROM DIFFERENT ACTIVITIES (IN MILLIREM)



post-operative and wound dressings. Other nuclear technologies with great potential to benefit society are not in the public consciousness because those who understand the applications are hesitant to advance the ideas or invest in the technologies out of concern for lack of public acceptance.

The lack of clean water is a major problem for public health in large areas of the world. Desalination is a technology that could meet the growing need for water for drinking and agriculture, even in the United States. In some regions, access to potable water may easily become a source of international conflict. Whether it is needed for sterilization or for desalinization, nuclear energy is ideally suited to this purpose. It is efficient, potentially very compact, and can do the job without collateral pollution.

Production of clean fuels for transportation and distributed generation is also on the public agenda. Fuels suited to these purposes consume energy in their production. Unless such fuels are produced by an equally clean source, there will be no environmental gain. Instead, there will be an economic loss because energy will have been consumed without benefit. Nuclear energy is an environmentally clean source and should be linked directly to the production of alternative clean fuels, such as hydrogen.

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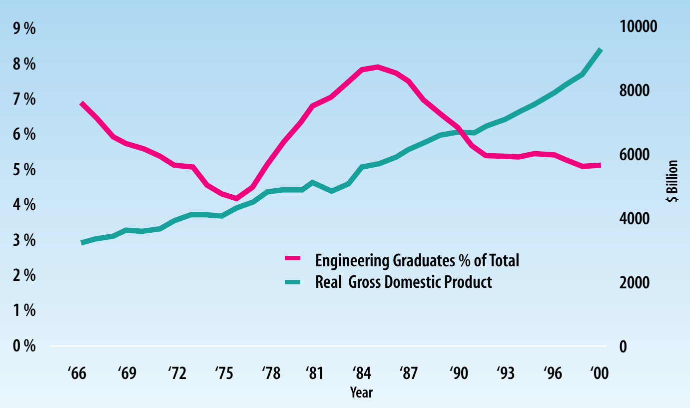
FIG. 16 ENGINEERING GRADUATES AS A PERCENT OF TOTAL COLLEGE GRADUATES



When these benefits are evident to the public and policymakers, the demand for increased use of nuclear energy will continue to grow.

6. Develop the necessary infrastructure and qualified human resources to meet the future needs of the nuclear industry.

Assessments of electricity consumption in the United States project a need for nearly 50 percent more power generation by 2020—electricity that will provide the continued foundation for economic growth and our quality of life. It must be affordable and environmentally sound. A proportionate increase in nuclear production is essential to sustain a proper balance of national security, energy security, reliability and environmental responsibility. The nuclear industry expects to meet a share of this need with the addition of 50,000 megawatts of new nuclear capacity by 2020 and an additional 10,000 megawatts gained from increased generation at today's nuclear power plants.

At the outset of this 20-year period, many of the resources needed to support predicted growth in energy use are insufficient to meet both the needs of existing energy infrastructure and the demands for expansion. This is true for all elements of the energy infrastructure.

Two structural trends in the economy of developed nations have influenced the availability of qualified human resources—design and manufacturing capability, and investment capital for infrastructure needs. First, in the United States there has been a transition to a service and information economy. This has been made possible by the second economic trend, the development of sophisticated technology. Return on investment for both human resources and capital are greater in the "new" economy applications. As a result, manufacturing capability has moved overseas to countries that have not achieved the same level of development. A significant demand for all of these resources can be expected over the next few decades.

The new economy remains highly dependent on the foundation of the "old" economy that the nation established during the first two-thirds of the 20th century. Continued economic growth will be either supported or limited by the ability to expand critical infrastructure.

New approaches will be required to attract and supply the necessary resources for growth of the critical infrastructure.[37] Creative and cooperative programs are needed to attract students to acquire the skills supporting design, construction, operation, regulation and maintenance of nuclear facilities. The number of new workers must be sufficient to allow for new growth and to replace the "graying" work force.

The nation will be constrained in meeting this challenge, partly because of a limited supply of qualified professional and labor personnel. The shift to the "new" economy has created a corresponding shift in preferred college majors. For example, the number of engineering graduates as a percentage of total college graduates (see Fig.16) has declined since 1986, despite a steadily rising

Gross Domestic Product and an overall increase in the number of students obtaining college degrees.

In significant part, the decline in engineering enrollment since the late 1980s reflects a decrease in demand for engineering services stemming from an over-reliance on existing power plants. In terms of skilled labor, the U.S. Bureau of Labor Statistics projects more than 1.2 million openings in excess of labor supply in the construction trades and related workers by 2010.[38] Industry projections also show a substantial demand for replacement personnel in engineering and the skilled trades over the next two decades, without taking into account new plant construction and operation. Similar demand will exist for energy infrastructure improvements and expansion. Nominal supply and demand mechanisms eventually will compensate for this shortfall in qualified personnel. Nevertheless, absent anticipatory action, this will be an unnecessarily lengthy process.

New reactor designs also must make efficient use of support and manufacturing resources through standardization. The industry will team to build new plants through innovative capital formation, risk-sharing and capital recovery techniques. Global markets must be available to permit efficient use of manufacturing capability introduced.

None of these issues can be resolved in the short term. All of them will require sustained, focused effort. Each has the opportunity to be sidetracked by emerging events, new opportunities and changes in the political climate and public opinion. The need for the infrastructure will not dissipate, but the will to carry out the required actions may be intermittent, driven by successive crises. Lacking a national resolve and long-term focus on sustainable energy policy, this objective will be difficult to meet.

CONCLUSION

Men's hopes call upon us to say what we will do. Who shall live up to the great trust? Who dares fail to try?

Woodrow Wilson, Inaugural address
March 4, 1913.

The industry vision of America's energy future over the next two decades is, indeed, ambitious. At its core, *Vision 2020* is rooted in advancing the country's national, economic and energy security. Moreover, the plan seeks to expand nuclear energy's vital and necessary role in the nation's diverse energy portfolio, while laying the foundation for its ultimate expansion.

To prosper in an uncertain world, a nation must have a secure energy supply. To grow in an unpredictable international economy, a nation must have reliable electricity generation. To reap the benefits of its natural resources and protect the environment, a nation must have significant sources of clean energy. The nuclear energy industry meets all these needs.

Vision 2020 also calls upon the industry's collective strength to bring to the fore the full spectrum of benefits that associated nuclear technologies offer the nation. While this, too, is an ambitious goal, it is equally important. Nuclear energy is the key to sustainable development for future generations—clean air, clean water and abundant electricity.

President Truman believed that, "Progress occurs when courageous, skillful leaders seize the opportunity to change things for the better." In order to help ensure the prosperity and well-being of the nation, should not the nuclear industry ask President Wilson's poignant question, "Who dares fail to try?"

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ENDNOTES

[1] A megawatt is a unit of electrical power typically used to describe the size of generating plants. One megawatt equals 1,000 kilowatts. The typical nuclear power plant is about 1,000 megawatts, so 50,000 megawatts is the equivalent of 50 new nuclear power plants, or a larger number of smaller power plants under 1,000 megawatts.

[2] *National Energy Policy: Report of the National Energy Policy Development Group*, May 2001, pp. 5-17.

[3] In its *2001 Annual Energy Outlook,* EIA projections actually totaled 393,000 megawatts of new and replacement capacity. NEI adjusted that number downward due to slower economic growth and to compensate for EIA's assumption that the industry will retire 26,000 megawatts of nuclear generation. In its 2002 *Annual Energy Outlook,* EIA reflected a similar downward revision, while maintaining the 1.8 percent electricity demand growth rate. By definition, demand forecasts vary year to year.

[4] Over the course of *Vision 2020*, the U.S. population is projected to grow from 251.5 million to 322.7 million.

[5] Energy Information Administration, *International Energy Annual 1999,* pp. 98-99.

[6] Electricity consumption in the 1990s grew about 706 billion kilowatt-hours, as opposed to 536 billion kilowatt-hours during the 1980s. Nevertheless, the nation built approximately 6,000 megawatts of new generation per year. During the 1980s, the country built approximately 12,000 megawatts of new generation per year.

[7] EIA *International Energy Outlook 2001,* p. 189.

[8] The industry estimates that production figures for 2001 will set another record totaling 762 billion kilowatt-hours.

[9] Customers are billed for electricity use over a given period. The energy required to illuminate ten 100-watt light bulbs for one hour is 1,000 watt-hours or 1 kilowatt-hour (kWh). Residential and small retail electricity use is measured in kilowatt-hours. Industrial and wholesale use is measured in megawatt-hours (MWh) to accommodate greater usage. The 754 billion kilowatt-hours produced by nuclear energy in the United States in 2000 was only 20 percent of the electricity consumed nationally. That year, only three countries in the world—China, Russia and Japan—consumed more than 754 billion kilowatt-hours of electricity.

[10] From 1977 to 2001, the industry implemented 72 reactor power uprates totaling nearly 10,000 megawatts. Another eight are under review by the Nuclear Regulatory Commission.

[11] As energy restructuring proceeds, exact comparative production cost figures are less available. Nevertheless, the 2001 numbers illustrate that nuclear power is competitive, if not lower than all other baseload replacement generation.

[12] The Department of Energy's Energy Information Administration oversees a voluntary greenhouse gas reduction program. Even though nuclear power plants constituted only 2.6 percent of the 1,882 reduction projects reported by U.S. companies, EIA cited them as the largest factor in reducing national greenhouse gas emissions in 2000.

[13] National Academy of Engineering, press release, February 22, 2000.

[14] Research and Development, National Academy Press, 1987, p. 65.

[15] Chauncey Starr, *Production, Consumption, and Consequences,* National Academy Press 1990, p. 53. Starr is the Founding President and President Emeritus of the Electric Power Research Institute (EPRI), and one of the founding fathers of the civilian nuclear power industry.

[16] The National Academy of Engineering's list of achievements of the 20th century: electrification, automobile, airplane, water supply and distribution, electronics, radio and television, agricultural mechanization, computers, telephone, air conditioning and refrigeration, highways, spacecraft, Internet, imaging, household appliances, health technologies, petroleum and petrochemical technologies, laser and fiber optics, nuclear technologies and high-performance materials.

[17] Remarks by Chairman Alan Greenspan before the Economic Club of Chicago, Chicago, Ill., June 28, 2001.

[18] *Electricity in Economic Growth,* Committee on Electricity in Economic Growth, National Research Council, 1986, p. 14. This remains a valuable and concise analysis of electricity as an economic force even today.

[19] The Federal Reserve reported on October 16, 2001, that industrial output fell for the 12th consecutive month in September. While indica-

tions of economic recovery began to surface in the first quarter of 2002, the principle remains valid. The only other 12 months of consecutive decline in industrial output was from November 1944 through October 1945. *New York Times,* October 16, 2001.

[20] The cause of the electricity disruptions in California were numerous and included a flawed approach to market restructuring, a failure and unwillingness to invest in new capacity, inadequate transmission flows, volatile natural gas prices and an over reliance on imported energy. While a modest increase in generating capacity helped ease California's problems, EPRI estimates that the crisis cost the state $50 billion in direct costs. See *The Western States Power Crisis,* an EPRI White Paper, June 25, 2001, p. 22. In a letter to Vice President Richard Cheney, California's Secretary of State Bill Jones estimated that the planned recovery strategy would cost ratepayers $66 billion in future charges (May 2, 2001).

[21] Letter from the president to the speaker of the House of Representatives, February 15, 2002.

[22] Nuclear Power 2010 is a Department of Energy proposed public-private partnership for a multi-year program to explore both federal and private sites for new nuclear plants, to demonstrate the efficiency and timeliness of Nuclear Regulatory Commission licensing processes and to conduct advanced research on new reactor technologies. The administration has requested initial funding of $38.5 million for fiscal year 2003.

[23] The industry has developed a comprehensive plan to pave the way for new nuclear plant construction. The plan helps resolve external cost and schedule issues by: clarifying policies and regulations on project structure and financing; achieving an efficient licensing process and policymaker support for new plants; and helping to maintain the workforce and infrastructure necessary to support new plant construction concurrent with the continued operation of the existing plants.

[24] Following the death of a Florida man and two postal workers and the October 15, 2001, discovery of the anthrax bacteria in mail sent to Sen. Tom Daschle's office, the U.S. Postal Service leased irradiation facilities in Ohio and New Jersey to decontaminate the mail.

[25] *Projected Water Scarcity 2025,* International Water Management Institute, January 2000.

[26] In the mid-1960s, the Johnson administration launched what it termed the "Water for Peace Program." Modeled on its predecessor, the Atoms for Peace program, the effort envisioned using nuclear power plants to produce clean water, particularly in the Middle East. The administration viewed the program as a conflict management and development tool. See *Foreign Relations of the United States, 1964-1968,* Volume XXXIV, Energy, Diplomacy and Global Issues, Documents 130-171, U.S. Department of State.

[27] The IAEA has published numerous technical reports on the viability of nuclear desalination. For a general overview of ongoing research, see the IAEA Bulletin, 43/2/2001.

[28] A February 20, 2002 article in the *New York Times,* "Drought on East Coast: Worries of Water Rationing," notes that in addition to the entire East Coast, the lingering effects of a multi-year drought are also affecting the Mountain States and Southern California.

[29] *Recent Trends in U.S. Greenhouse Gas Emissions,* U. S. Environmental Protection Agency, 2001.

[30] IAEA-TECDOC-1805. It should also be noted that nuclear power plants could be used to supply the process heat needed to extract hydrogen from fossil resources, and in other industrial processes. While existing nuclear power plants are suited to these purposes, research continues into the perceived advantages of using high-temperature gas-cooled reactors for hydrogen production.

[31] Over 90 percent of hydrogen is produced from fossil fuels. Ibid, p. 101.

[32] Energy Secretary Spencer Abraham, Global Energy Summit, Washington, D.C., February 14, 2002.

[33] Nuclear Regulatory Commission Chairman Richard Meserve acknowledged this point at the NRC's 14th Regulatory Information Conference (RIC) on March 5, 2002. "It is no surprise that strong safety performance and strong economic performance should move in parallel. A safe plant is a reliable plant...."

[34] Chairman Meserve acknowledged this point at RIC. "[W]e still expect that virtually the entire operating fleet will ultimately apply [for license renewal]."

[35] Because nuclear energy is emission-free, the waste-by-weight comparison with natural gas is calculated based on solid waste for nuclear energy and air emissions for natural gas. A natural gas plant producing the equivalent amount of electricity as a 1,000-megawatt nuclear plant operating at 90 percent capacity for one year will also produce: 4,300 tons of nitrogen oxide, 3,000 tons of carbon, 555 tons of volatile organic compounds, 175 tons of particulates and 15.2 tons of sulfur dioxide. By comparison, the nuclear plant in question will produce 30 tons of high-level radioactive waste and 65 tons of low-level radioactive waste.

[36] The survey captured a national sample of 1,000 adults and has a margin of error of plus or minus three percentage points. The survey was conducted by telephone interviews on February 1-3, 2002, by Bisconti Research, Inc. with Roper/ASW.

[37] NEI has set in motion a long-term plan to ensure an adequate workforce in nuclear-related fields. The goal is to provide the industry with accurate information projecting staffing needs and shortfalls, and to develop an evolving action plan to address areas of concern and to sustain existing productive programs.

[38] U.S. Bureau of Labor Statistics, November 2001 Monthly Labor Review, Table 2.

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