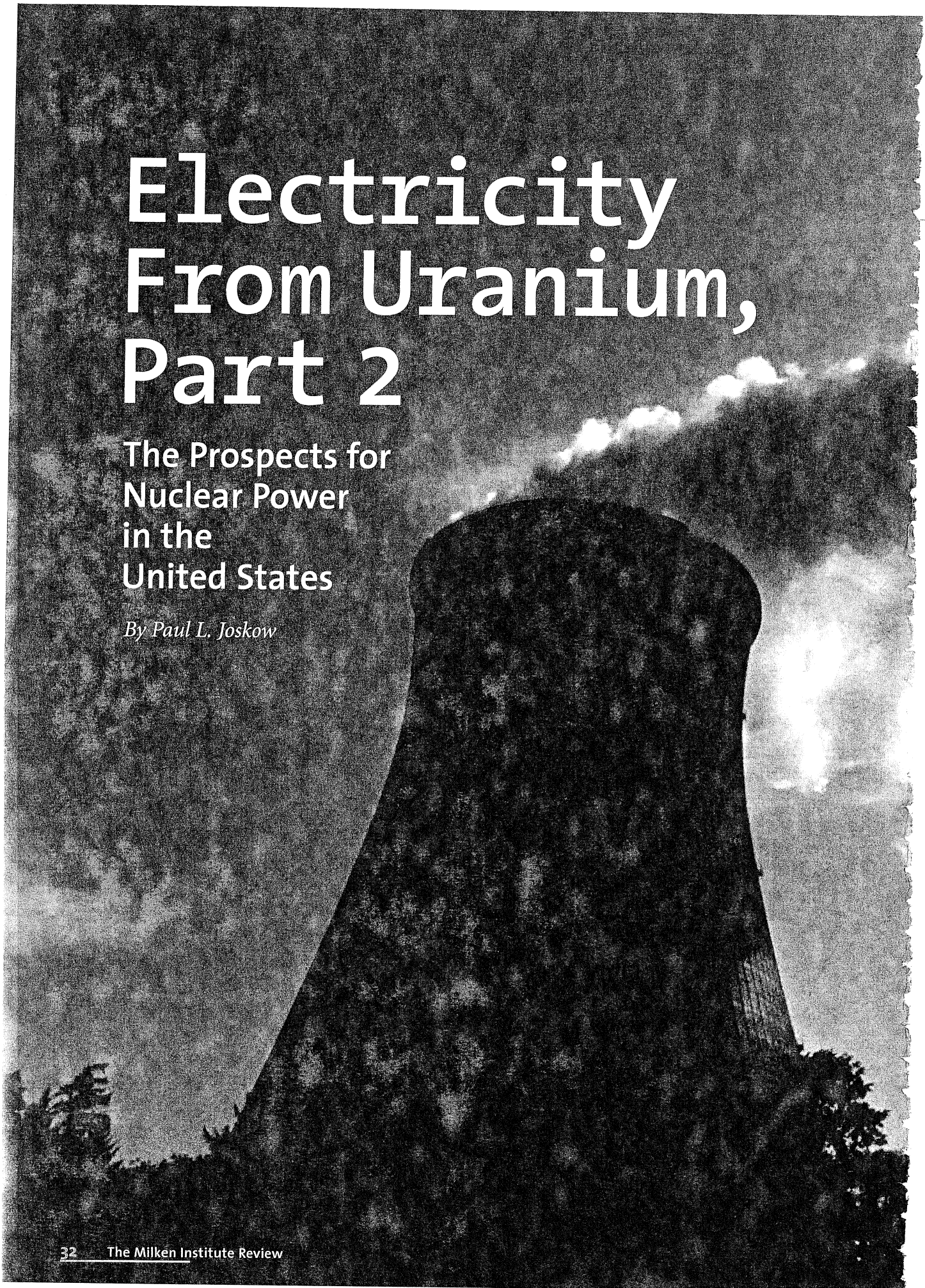
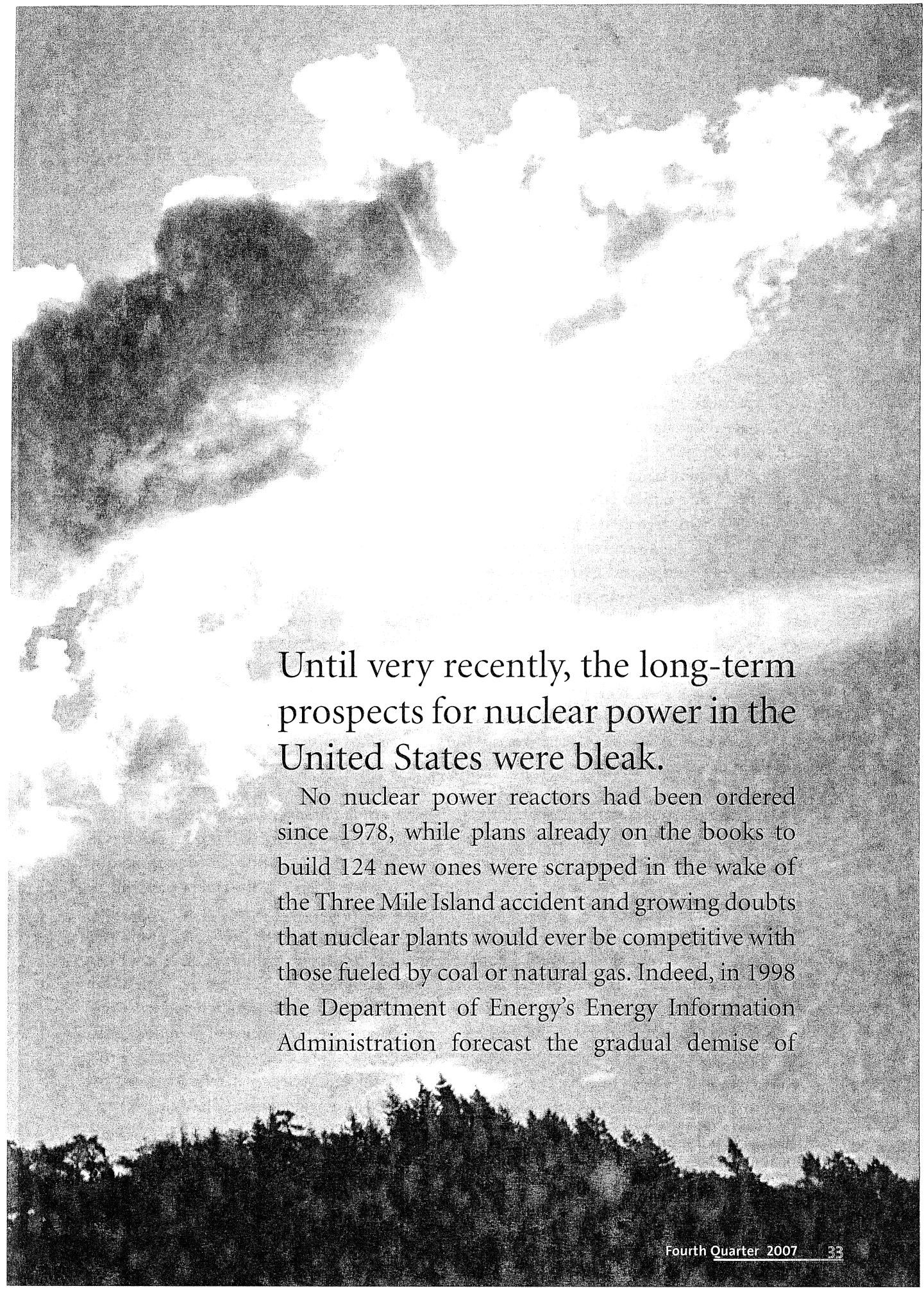


Electricity From Uranium, Part 2

The Prospects for Nuclear Power in the United States

By Paul L. Joskow

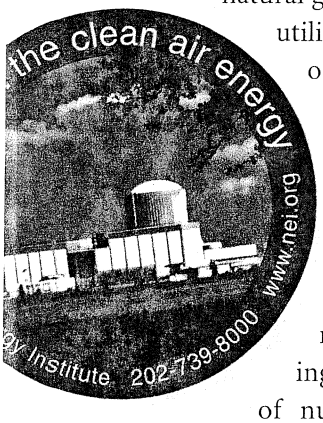


Until very recently, the long-term prospects for nuclear power in the United States were bleak.

No nuclear power reactors had been ordered since 1978, while plans already on the books to build 124 new ones were scrapped in the wake of the Three Mile Island accident and growing doubts that nuclear plants would ever be competitive with those fueled by coal or natural gas. Indeed, in 1998 the Department of Energy's Energy Information Administration forecast the gradual demise of

nuclear power in the United States, as aging plants were retired and building new ones remained uncompetitive with the alternatives. If, as projected 10 years ago, the existing plants were to run only until their original 40-year licenses expired, the supply of electricity from nuclear power – today about 20 percent of total generation in the United States – would begin to decline in about 2015 and reach zero in about 2030.

What a difference a decade can make. With natural gas prices in the stratosphere and utilities facing the prospect of caps on carbon dioxide emissions from coal- and gas-fired plants, the owners of existing nuclear plants are lining up to apply for 20-year extensions of their operating permits. More important, potential investors in new generation capacity are taking a fresh look at the economics of nuclear energy. And while the choice of nuclear over the alternatives is still far short of a slam dunk (thanks to high construction costs along with regulatory and electricity marketing uncertainties), the pressure to contain U.S. carbon emissions may prove the decisive factor.



YOU'RE NOT JUST OLDER, YOU'RE BETTER...

Most of the 104 commercial nuclear power plants now operating in the United States were built in the 1970s and 1980s. And, it is safe to say, the initial experience with these plants typically left their owners sorry they persevered. It took too long to build the plants and too long to meet the safety demands of federal regulators scarred by memories of the Three Mile Island accident in 1979. Once the plants were operating, they were plagued with high maintenance costs and poor reliability for many years.

What's more, several utilities completing plants in the 1980s and early 1990s faced serious financial difficulties as state regulators balked at allowing them to pass cost overruns through to electricity customers in the form of higher rates. One utility went bankrupt, while others came close. Meanwhile, the problem of what to do with the highly radioactive waste continues to dog the long-term viability of nuclear power. Washington has yet to deliver on its promise to accept and store the spent fuel underground in geologically stable formations for thousands of years.

What really sealed the verdict on nuclear power in the 1980s, though, was the falling cost of producing electricity by burning natural gas. Everyone expected nuclear plants to cost more to build than fossil-fuel plants. What they didn't expect was that the ongoing operating and maintenance costs for nuclear plants would in some cases exceed the market value of the electricity they produced. Nearly a dozen nuclear plants closed during the 1990s (several prior to the end of their initial license periods) because of the poor economics of continuing operation. Investment in natural-gas-fueled combined-cycle gas turbine technology (CCGT) plants, with their modest size, efficient operation and low construction costs, was seen as a less risky and politically more acceptable alternative to both coal and nuclear generating technology – especially as competitive wholesale electricity markets began to emerge in the mid-1990s. Not surprisingly, most of the electricity generating capacity added in the United States

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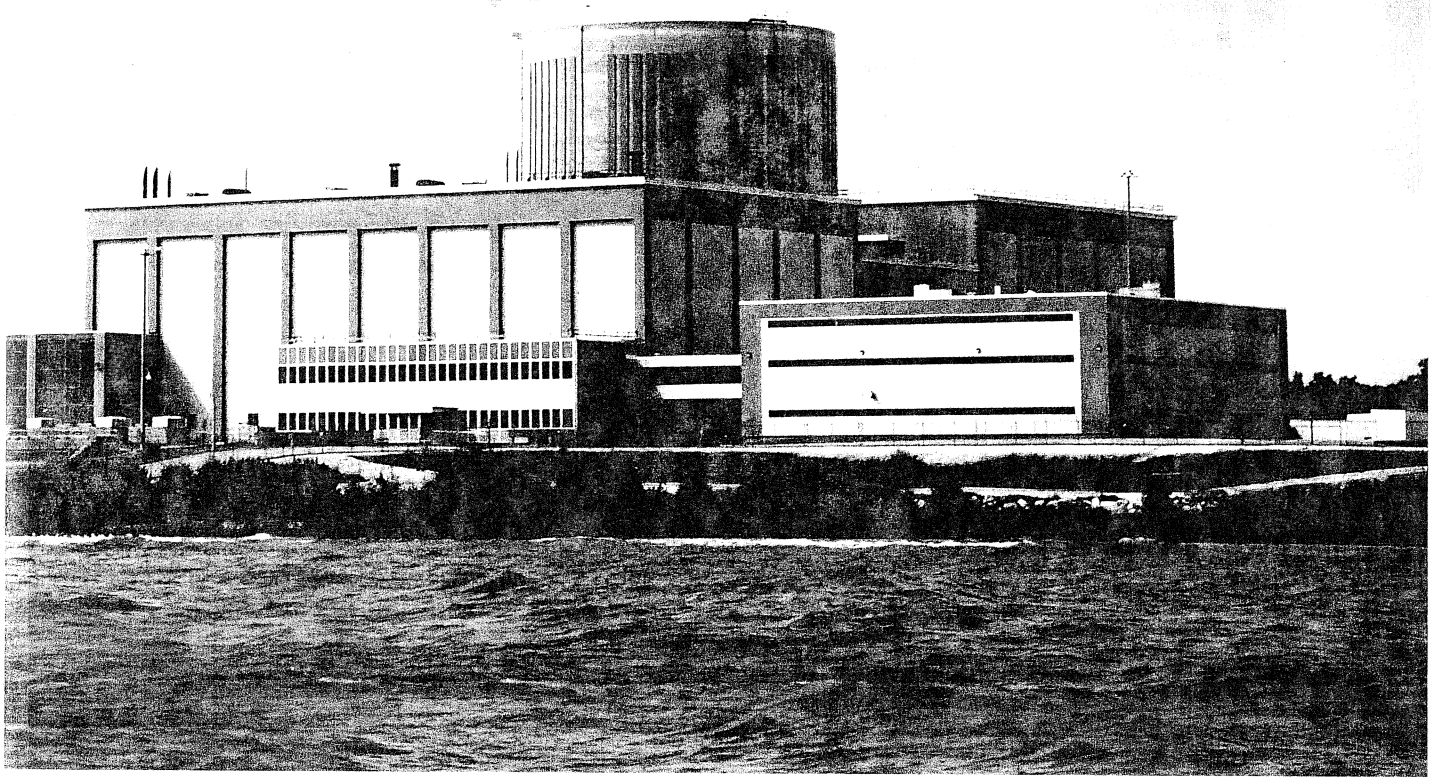


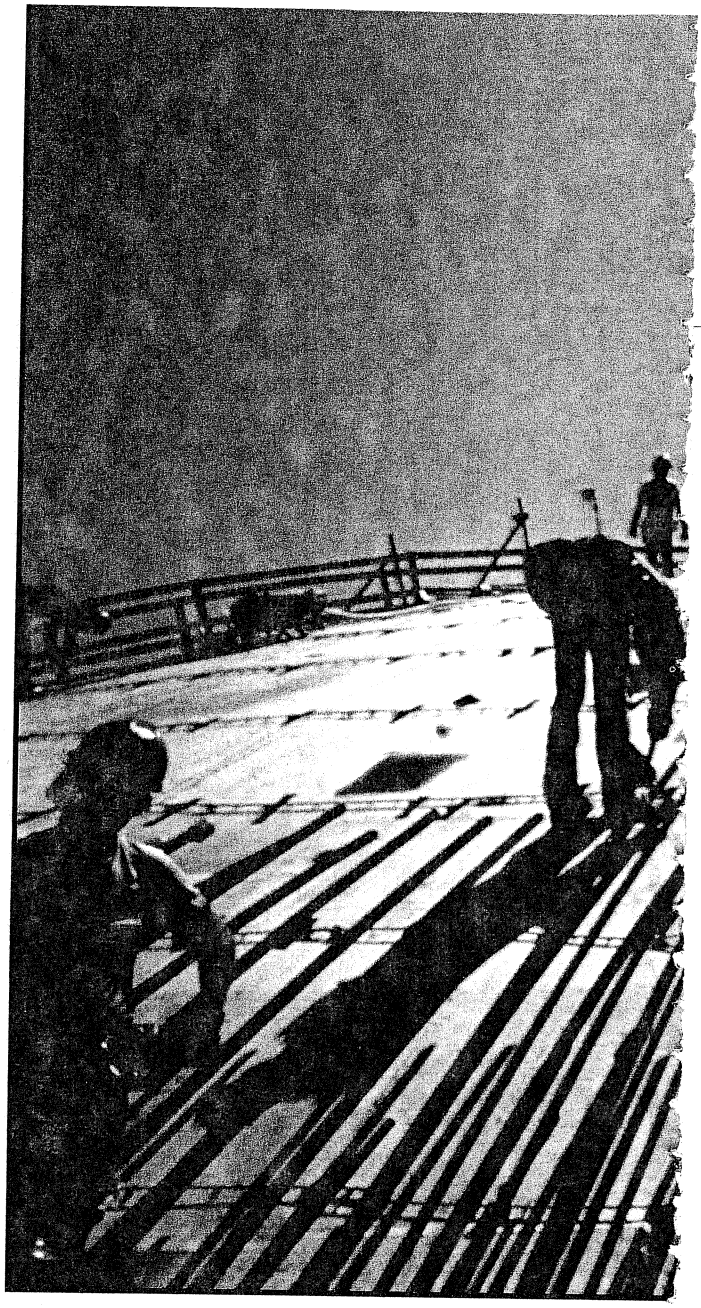
in the last decade is fueled by natural gas.

But the 1990s proved the nadir of nuclear power's fortunes. The performance of existing nuclear plants has improved significantly since then. Measured in 2003 dollars, operation and maintenance costs (excluding fuel) fell on average from about 2 cents per kilowatt-hour in 1992 to 1.25 cents in 2005, while total real operating costs fell from over 2.7 cents per kilowatt-hour to less than 1.7 cents during this period. Nuclear plants are more reliable today: average capacity utilization is up from less than 60 percent in the late 1980s to 90 percent in the last five years, reflecting sharp improvement in plant reliability. And various indicators of plant safety have improved significantly as well. These gains, combined with steep increases in natural-gas prices and wholesale electricity market prices in the last few years, have significantly improved the economics of extending the operating lives of existing plants.

As of May 2007, 48 plants had received 20-year license extensions, 10 more license-extension applications were pending, and the operators of another 27 plants had confirmed that they, too, expected to apply for extensions. This will lengthen the life of the existing cohort of nuclear plants considerably, with significant plant retirements not beginning until about 2035.

THE ECONOMICS OF NEW PLANTS

The most significant obstacles to investment in nuclear power are uncertainty about construction and financing costs, potential regulatory delays that can increase these costs, and uncertainty about the revenues that these plants will earn once they are completed. These uncertainties are compounded by broad changes in the market for electricity over the last decade.



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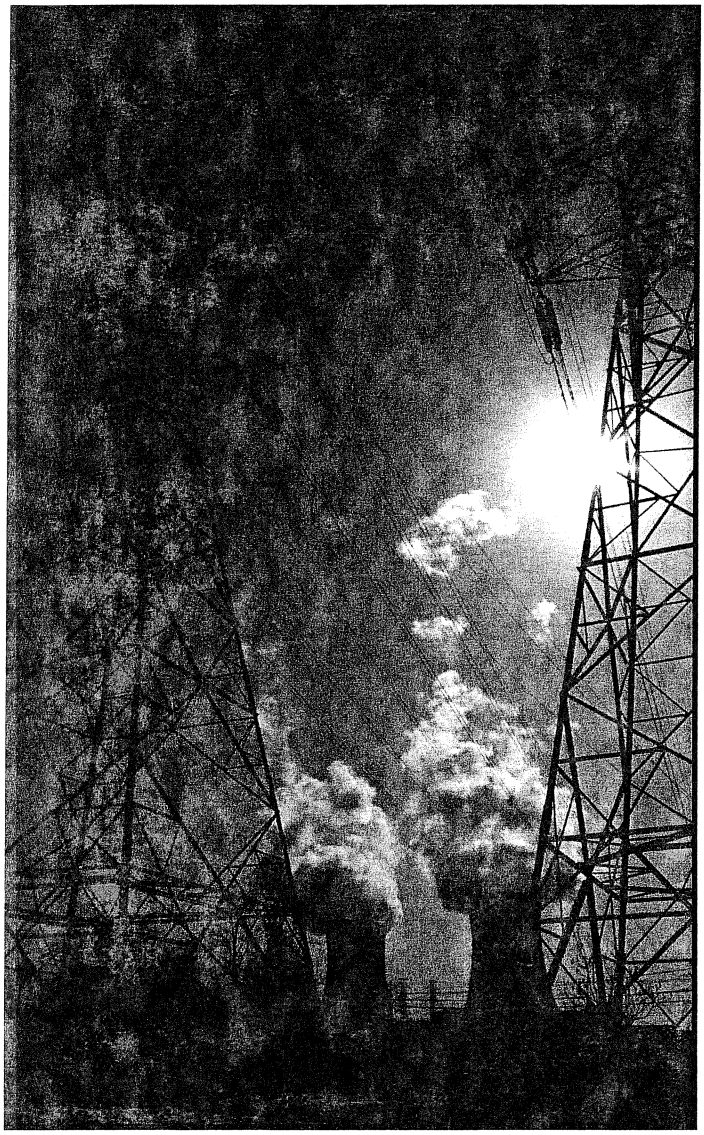
Until the late 1990s, most nuclear plants were built by heavily regulated utilities protected by geographic monopolies and the statutory right to charge their customers enough to earn a market rate of return on their investments. Except in some extreme cases, regulation effectively insulated utilities from lower-cost competition and typically allowed them to bill electricity customers for unanticipated construction cost increases and the costs of unreliable operations.

Some states have since adopted competitive market models in which investors must bear the risks associated with building, licens-

ing and operating new generating plants, regardless of the technology employed. In most of the Northeast, portions of the Midwest and Texas, competitive wholesale electricity markets are the rule; merchant generators are free to to supply to these wholesale markets. Moreover, as transition arrangements come to an end, retail consumers are expected to pay rates that reflect wholesale market prices rather than some regulator's calculation of the cost of providing the service.

This transition changes the financial risks associated with nuclear investments in states that have adopted market models in a number of ways. Costs associated with licensing, site studies and engineering studies can be recovered only if a plant is eventually completed and can earn revenues from sales of its output in competitive electricity markets. By the same token, investors must bear the risk of cost overruns and equipment replacement, as well as the vagaries in electricity market prices.

The rush to adopt competition in electricity came to an abrupt halt in 2001 after the California power crisis. A majority of states still use the traditional regulated monopoly approach in which utilities can assume that



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prudently incurred costs can be passed through in mandated retail rates. However, change is afoot here, too. Many utility commissions now require utilities to benchmark proposals to build their own generating plants against proposals from independent power producers to supply equivalent quantities of electricity under long-term contracts.

Accordingly, in order to get permission to build a new plant under cost-of-service regulation, the regulators must be convinced that the project would be less costly to consumers than outsourcing electricity purchases from independent suppliers. Moreover, when regulators do allow traditional utilities to build additional plants under cost-of-service rules, they are likely to include performance incentives that create risks (negative and positive) parallel to the risks borne by independent suppliers in long-term purchased-power contracts. In particular, they are more likely to place caps on allowable construction costs, apply minimum reliability standards and adopt other incentives to control the costs that consumers are required to cover with their monthly checks.

Other things equal, the net impact of shifting risk to investors is to make nuclear power relatively less attractive than fossil-fuel power because nuclear plants are more capital-intensive and there is more uncertainty about construction costs, construction time and operating reliability.

NUKES VS. THE ALTERNATIVES

In the end, decisions to invest in new nuclear plants will turn on the expected return (adjusted for risk) compared with that for other technologies. The necessary revenues must come either from sales of power at market prices in states that have adopted competitive market models, or through regulated retail prices set by commissions in states that have retained the basic regulated monopoly model.

Once nuclear plants are built, their operating costs are generally low and it is economical to operate them virtually all the time. Accordingly, nuclear power is referred to as a "base load" generation source and must be compared with potential base-load generating alternatives that could be economical to operate for an equivalent number of hours across the year.

This raises the question of what we know about the future costs of producing electricity

from a new nuclear power plants compared with the cost for a comparable pulverized coal or a CCGT plant – the two base-load alternatives to nuclear in most places. Or, put it another way: which technology will investors perceive as being the most profitable way to produce electricity to meet base-load demand?

A handful of factors determine the expected life-cycle costs of technologies with a given generating capacity:

- the capital outlay required to license and build the plant
- the cost of financing these capital expenditures both while construction is going on and after commercial operation begins
- fuel costs
- operation and maintenance expenses other than fuel
- replacement-capital costs during the life of the plant
- the expected hours of operation each year
- the economic life of the plant

There is no recent construction cost experience for nuclear plants in the United States or Europe. Nuclear plant vendors have advertised very low numbers based on their own proprietary engineering calculations. But these estimates should be viewed with some skepticism because (a) they are not based on actual construction experience, (b) they are not backed by firm financial commitments, (c) they do not include all of the costs an owner would incur, and (d) the United States nuclear industry has a poor record in forecasting construction costs.

Several analyses of the total life-cycle costs of new nuclear power plants have been produced in the last few years. My discussion here relies on the MIT "Future of Nuclear Power" study (2003), the International Energy Agency's (IEA) *2006 World Energy Outlook*, and the most recent *Annual Energy Outlook* (2007) prepared by the Energy Information Administration (EIA). All three studies come to essentially the same conclusions: If no financial penalties are placed on CO_2 emissions from fossil-fueled alternatives and no special subsidies are provided to new nuclear plants, investments in new nuclear power plants are unlikely to be competitive with comparable pulverized coal plants. Investments in nuclear plants will, however, be competitive with new CCGT plants if real gas prices remain above $7.50 per 1,000 cubic feet, as now appears likely.

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Since these studies were completed, construction costs for major infrastructure projects of all kinds have increased across the board. And because nuclear plants require more concrete and steel, etc., the burden of these increases is likely to fall more heavily on nuclear plants than on coal or CCGT plants. Thus, if nuclear is to be competitive with coal, the external cost of carbon emissions (the portion borne by society as a whole) must be part of the equation.

Both the MIT study and the IEA study examined how the relative costs of generating electricity from the alternative technologies changes as CO_2 emissions charges, varying from zero to about $50 per ton, are applied to coal and CCGT plants. These charges could result from the cost of emissions permits

established in a mandatory "cap and trade" program limiting total emissions (as is already in place in the European Union) or from a broad-based tax on CO_2 emissions. Obviously, CO_2 charges of any sort make nuclear plants relatively more attractive in economic terms than alternatives that emit CO_2. Indeed, at somewhere between $25 per ton and $50 per ton of CO_2 emitted, an investment in a new nuclear plant becomes more economical than investments in coal and gas alternatives, provided real natural gas prices remain at their recent (historically high) levels.

While Washington has yet to agree on a plan for containing carbon, the likelihood of legislation in the near future has increased significantly. Moreover, a growing number of states are adopting their own CO_2 mitigation programs and public opposition to new coal plants – more than 100 were on the drawing boards as recently as a year ago – is also increasing rapidly. These developments have significantly increased enthusiasm for investment in new nuclear plants in the last couple of years because they do not emit CO_2.

CUTTING COSTS

With concerns about global warming now gaining traction, Washington is acting to increase the incentives to invest in nuclear plants.

Streamlined Licensing

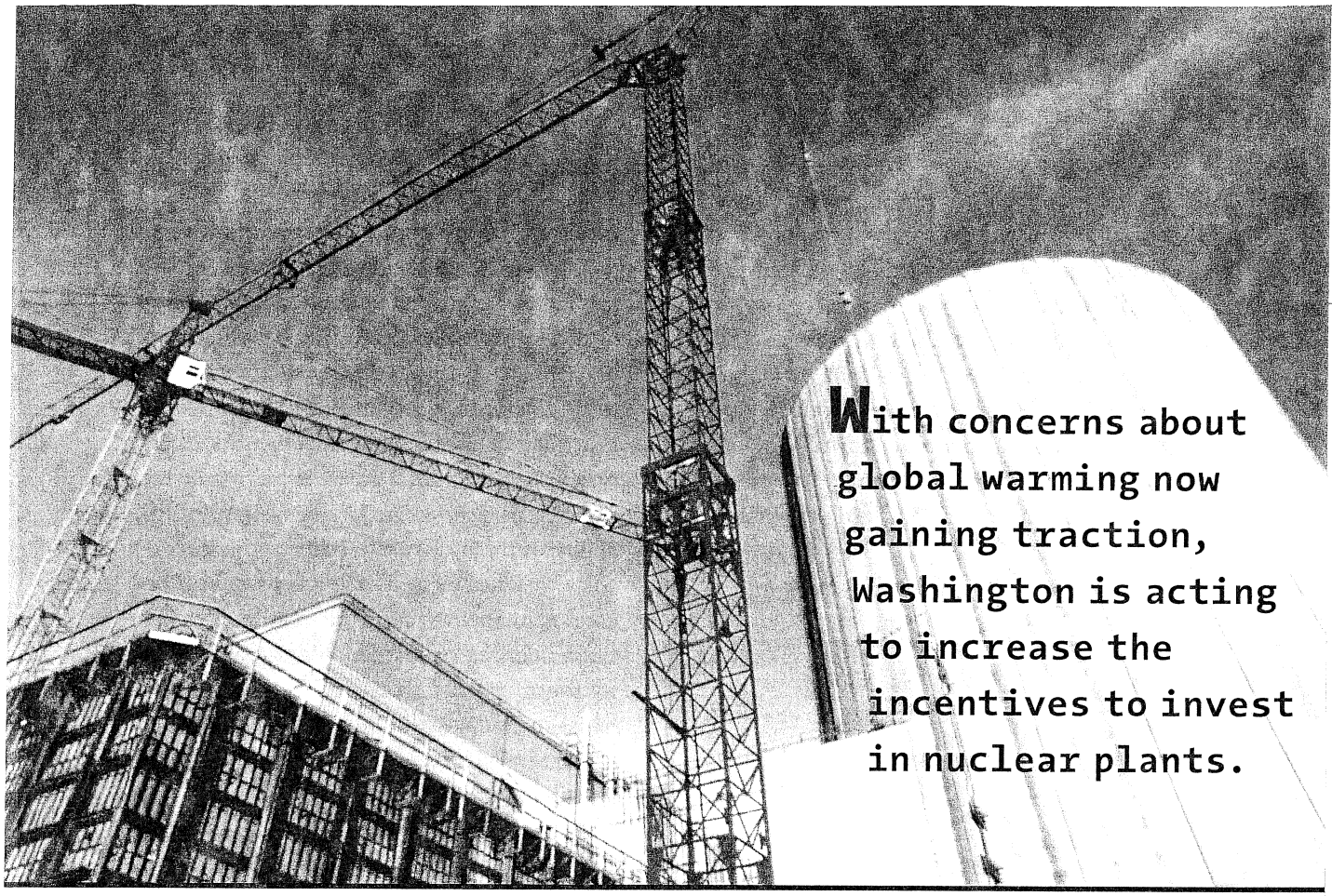
Start with the Nuclear Regulatory Commission (NRC), which has adopted procedures to reduce the costs and delays associated with plant licensing. The agency says it will now certify the safety of "standard plant design specifications" before a plant runs the gantlet of a construction and operating license application. And once a standard plant design has received safety certification, a developer does not have to go through a separate design safety review for each plant built with the same design. As of May 2007, three plant designs had been certified this way, another design review was nearly complete, and five more were in the pre-application stage.

The NRC has also created a new early site-permitting process that allows companies to pre-license sites where they may ultimately choose to build a new nuclear plant. Thus, site certification can be separated from the construction and operating license process. As of May 2007, four applications had been made under this early site-permitting process and two had been approved in this calendar year.

With the old NRC rules, each plant had to go through a construction license process that involved a safety review of both the plant and the site. Once a construction permit was issued, the developer could then proceed to build the plant. But when the plant was completed, the operator had to apply for a separate operating license. There were significant delays at each stage of this process, including delays resulting from outside challenges and resulting extensions of evidentiary hearings.

Under a new streamlined NRC combined construction permit and operating license (COL) process, a proposal to build a plant with an NRC-certified plant design can go directly into the COL review. Once the COL is granted, the developer can build the plant. And when the plant is completed, the NRC will inspect it to verify that the plant was built in accord with the license. A second regulatory proceeding to review a separate application for an operating license is no longer required.

Note, however, that the COL process has not been tested in practice, as no proposed plants have yet gone through it. Note, too, that the COL review still takes a good deal of time: the NRC currently expects a 42-month



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schedule. Moreover, applications may still be vulnerable to delaying tactics by nuclear plant opponents concerned about safety issues, who may again turn to the federal courts to delay or overturn NRC decisions.

Financial Incentives in the Energy Policy Act of 2005

In most battles, the soldiers at greatest risk are generally the ones who lead the charge. Acknowledging this reality, the Energy Policy Act of 2005 offered significant financial incentives to the owners of the first handful of plants built under the new licensing process. These incentives, combined with the others discussed earlier have clearly stoked interest in nuclear power.

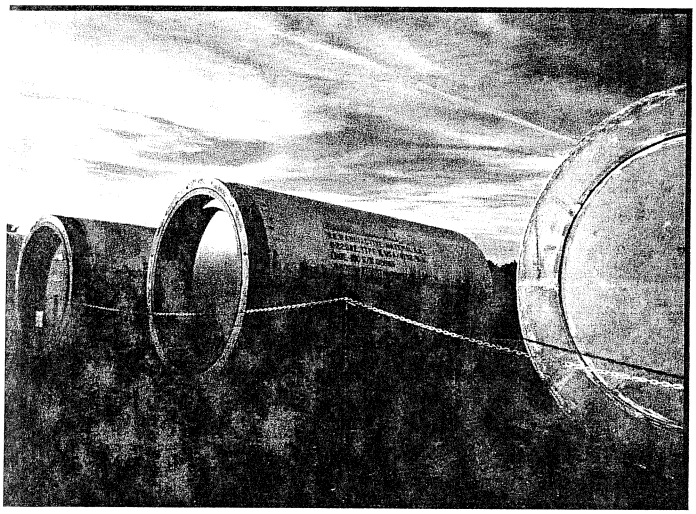
The act provides a 1.8 cent per kilowatt-hour investment tax credit for new nuclear capacity during the plant's first eight years of operation. This subsidy is limited to no more than $125 million per year per 1,000 megawatts of capacity (an average-size plant) and no more that 6,000 megawatts of new capacity in total can receive this subsidy. In addition, builders of new nuclear plants are eligible for loan guarantees for up to 80 percent of a plant's construction costs, though important details have yet to be hammered out. These loan guarantees will allow the financing of the projects to be more highly leveraged at lower interest rates, and are likely to be especially important for plants proposed for states that have adopted competitive market models.

Altogether, these subsidies reduce the life-cycle costs of a new nuclear plant by roughly one-third, creating a financial advantage for nuclear power that is equivalent to about a $25-a-ton CO_2 emissions charge placed on competing pulverized coal plant investments.

The act also provides insurance against regulatory delays for the first six plants that go through the COL regulatory process. The first two plants are eligible for up to $500 million of payments for the costs of regulatory

delay, and the next four plants for up to $250 million each.

As noted above, the rationale for these financial incentives is the "first mover" costs, including the potential for regulatory delays, that serve as barriers to restarting the nuclear power industry. If the first 6,000 megawatts of new capacity are subsidized, the argument goes, nuclear investment will become competitive without further subsidies.



AURORA/GETTY IMAGES

The spoiler in any nuclear scenario is the continuing inability of the federal government to fulfill its commitment to take spent nuclear fuel and to provide for its long-term storage.

Since the passage of the act, intentions to pursue plans for some 30 new nuclear plants have been announced. Many of these developers have substantial nuclear operating experience. Announcing the intent to build and making the significant financial commitment required to actually build a plant are not the same thing, however. The first COL applications are expected in early 2008. It is thus unlikely that any new nuclear capacity will enter service before 2016. Moreover, since the subsidies are available only for the first 6,000 megawatts, their long-term impact on investment in nuclear capacity will depend on the ability of the industry to reduce construction costs to a level significantly below the base-case estimates used in the cost studies discussed earlier, or for the federal government to adopt policies that place a price on CO_2 emissions of at least $25 per ton.

These conclusions are consistent with the EIA's latest forecasts of investment in new nuclear plants between now and 2030, which are contained in its 2007 Annual Energy Outlook. The EIA's reference case (which does not assume a price is placed on CO_2 emissions or that investments in new coal-burning plants are otherwise constrained by state regulations) reflects the subsidies included in the 2005 act. It projects 12,500 megawatts of new nuclear capacity and an increase of about 10,000 megawatts of nuclear capacity net of plant retirements by 2030. That amounts to a 10 percent increase over today's nuclear capacity in the next 25 years.

Since the supply of electricity will have to grow by considerably more to meet projected demand, however, nuclear power's share of generation would actually fall from about 20 percent today to about 15 percent in 2030. Electricity from new nuclear plants is still forecast to be more expensive than supplies from new pulverized coal plants in 2030 and (absent CO_2 emissions charges and after the 2005 act's subsidies are exhausted) electricity generated with coal is forecast to increase much more rapidly during this period. Further construction cost reductions or CO_2

emissions charges would be necessary to make nuclear power a clear winner over coal without continuing subsidies.

OTHER POTHOLES ON THE ROAD TO A NUCLEAR FUTURE

First, the unsettled state of electricity sector restructuring and deregulation suggests that it is unlikely that we will see much, if any, investment in nuclear capacity in states that have adopted competitive market models. Second, investors will still have to deal with state and local regulators, along with private anti-nuclear groups that have been quiet during the long hiatus in new nuclear plant construction. The publicity surrounding the recent release of tiny amounts of radioactive materials at a Japanese plant after a serious earthquake suggests that concerns about nuclear plant safety may not have abated as much as it may appear.

On the other hand, many existing nuclear plant sites were originally designed to accommodate more plants than were built. In most cases, those who live near these sites have come to accept nuclear power plants. Indeed, they have come to count on the property-tax windfall the plants produce and are likely to be favorably disposed to investments to expand capacity.

Arguably, the spoiler in any nuclear scenario is the continuing inability of the federal government to fulfill its commitment to take spent nuclear fuel and to provide for its long-term storage. Nearly 60,000 metric tons of spent fuel is sitting in temporary storage facilities on nuclear plant sites today. The opening of the storage site under Yucca Mountain, some 150 miles northwest of Las Vegas, continues to be subject to delays. And, in light of opposition from powerful politicians in Nevada, including the Senate majority leader, Harry Reid, that opening is still far from certain. While investment in new plants might proceed without a decisive resolution of waste disposal issues, the failure to glimpse a little light at the end of the tunnel is likely to test the enthusiasm of investors committing tens of billions of dollars to new plants, as well as the public's.

THROUGH A GLASS, DARKLY

All things considered, investment in new nuclear plants is likely to proceed more quickly than was expected a few years ago – but more slowly than suggested by the recent euphoria in the industry. Most of the new investment will be in states that have retained a regulated monopoly framework and the first new plants are likely to be situated on existing sites with room to spare. Among the states that have adopted competitive markets to determine electricity prices, Texas is the most likely candidate for investment for both economic and political reasons.

A nuclear investment program will be larger and proceed more quickly if nuclear equipment vendors and construction firms are willing to take on more of the construction cost and operating performance risk than they did during the 1970s and 1980s.

The biggest wild card, though, is the nature of the carbon-containment program that, in one form or another, is likely to be adopted by Washington in the next few years. If the system imposed by Washington – a tax on carbon emissions or a cap-and-trade program that effectively constrains carbon emissions – puts an implicit price on emissions in the range of $25 to $50 per ton, new nuclear power plants have a good chance of competing successfully in the marketplace, even after the 2005 act's subsidies are exhausted.

The nuclear phoenix has a fighting chance of rising from the ashes. But the vitality of the newborn chick is far from assured. M