A New Nuclear Consensus

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Executive Summary

- A new consensus is emerging that most of the world’s existing nuclear plants need to remain in operation.

- Actual nuclear power generating costs can be the cheapest way to generate electricity in competitive markets (excepting some hydro).

- If a significant number of operating nuclear plants are shut down, some OECD countries will not be able to achieve the Kyoto Protocol commitments.

- The nuclear industry needs to increase its focus on assuring the safe and cheap operation of existing plants.

- Increased confidence in nuclear plant operation will also increase confidence in nuclear waste disposal.

- The nuclear industry needs to provide a less defensive and more practical business-oriented focus.

- The nuclear industry needs to build alliances with those environmental groups who support or are prepared to support the continued operation of existing plants, even if they do not support building new plants.

- Good performance is found among all vendors, owners, and plant characteristics.

- Good management is the key to low-cost operations, although some technologies can be more easily adapted for improved performance.

This paper focuses on the U.S. experience, which has taken us from the promises of “meterless” electricity to a severe loss of public trust. Now we have entered a period in which many of the initial promises are being met as deregulation forces nuclear plants to perform. Today, the U.S. is taking the lead on nuclear economics. But France has much to teach other countries about the value of standardized plants. Had the U.S. standardized its plants, it could be generating electricity even less expensively.

Poor performance is not typically a technological issue, however. It is due to poor management. Management problems are not unique to the United States or to light water reactors. After years of
excellent performance, Ontario Hydro's CANDU units have suffered serious management failures that are not yet overcome.

Ultimately, a robust backend of the fuel cycle is a goal toward which the industry should continue to move. But for now, stretching the timing for the backend may be a small price to pay as we create a highly competitive nuclear generating industry that boosts public confidence in the nuclear industry. Transportation of nuclear material is a serious concern in most countries that can be lessened by public confidence in nuclear power.
Introduction

For the first time in more than two decades, a new consensus is emerging that nuclear power needs to play a vital role as countries attempt to fulfill Kyoto Protocol climate change commitments. This is a still fragile consensus, and can only be sustained if the owners of today’s nuclear power plants are able to prove that they can generate electricity cheaply and safely. Except for some Former Soviet Union type-reactors, the case for safe nuclear operation has been made; now the burden is to show they can be economical in a deregulated environment. The nuclear industry needs to make a significant increase in its efforts to fully restore public acceptance.

The emphasis should shift from the construction of new reactors and commercializing the back end of the fuel cycle to the promise that nuclear plants can be the cheapest way to generate safe electricity. Only certain hydro plants can generate electricity less expensively. If the nuclear community focuses too much of its attention on the immediate need to build new plants, it is likely to continue to create a negative reaction among the environmental community and new players in the electricity business. Some in the environmental community for the first time are willing to give rhetorical respect for the need to eventually build new nuclear plants, but still need further evidence to prove to them that today’s nuclear plants can be operated safely.

If the nuclear industry wants to build trust and a more positive atmosphere, the construction of new plants may be a less important objective than the acquisition and improved operation of existing plants. Although nuclear is the least expensive way to generate electricity today, it is not the cheapest course of action for new generation. Gas turbines are the most economical new investment to make today.

As we move into a new century, about 85 percent of the world’s energy is supplied by fossil fuels, all of which emit air pollutants and greenhouse gases. Nuclear, hydro and renewables share the rest of the marketplace, with nuclear being the dominant non-fossil fuel. There is little short-term prospect of renewables playing significantly larger roles than they do today, even in countries that continue to favor subsidies for these new technologies. Even the most optimistic scenarios about the construction of new nuclear plants do not realistically result in a nuclear-induced cap on fossil fuel growth. At best, nuclear can reduce the growth in fossil fuel use. At worst, we will rely almost entirely on new fossil fuel generation.

While it is true that without continued nuclear plant operation it will be impossible to comply with the Kyoto protocol commitments, there is abundant evidence that OECD countries are not prepared to make uneconomical decisions to meet their environmental obligations. It is very important to emphasize the persistent unwillingness of the OECD countries to sacrifice economic growth to achieve environmental objectives. Therefore, nuclear’s challenge is to be cost-effective and environmentally desirable.
Those that do not include nuclear power in the energy mix of the future but want to meet the Kyoto agreements are simply not dealing with reality. By making some simplifying yet conservative assumptions, we have calculated the impact on carbon emissions of closing all nuclear plants worldwide. If modern coal plants (the kind the U.S. Energy Information Administration projects will be built between 1995 and 2010) replaced all nuclear output, carbon emissions would increase 25 percent over 1995 levels. Under the same set of assumptions, if natural gas plants replaced all nuclear output, carbon emissions would increase five percent. We do not think it is at all realistic to suppose that renewable energy sources could replace all nuclear output.

**World Carbon Emissions If Nuclear Is Replaced With...**

If some in the nuclear industry believe that climate change is good for nuclear power because it will allow uneconomical assets to continue running, they are wrong; they are too pessimistic about nuclear power’s potential. Nuclear power is capable of being economically and environmentally beneficial and there is no need for new protection or subsidies. Until now, the nuclear industry has always argued that the cost of nuclear is justified because it strengthens the national security of resource-poor countries like France and Japan. Most recently, it is being argued that nuclear is necessary for environmental security. Neither argument is any longer compelling. The industry needs to be proud of its economic performance: the best of today’s nuclear plants are much cheaper to operate than today’s renewable technologies. And, of course, nuclear provides a much larger share of the energy supply.

Thus we are entering a new era in which two factors favor nuclear power: competition and climate. The nuclear industry worldwide is not yet convinced that competition is advantageous to existing
nuclear plants because of the very high capital costs that were incurred in building them. But as the United States experience shows, once capital costs are repaid or written off through stranded cost recovery—as part of creating a new social contract with the customer—operating, maintenance and fuel costs make it possible for nuclear to be the cheapest way to generate electricity in the United States. The best plants are able to generate on a sustained basis at a little more than one cent per kilowatt hour; well over half of all plants are able to generate for less than two cents. Over the past decade, many U.S. nuclear plant owners have made dramatic improvements in operation and have proven that they can do so on a sustained basis with capacity factors of more than 85 percent, rivaled only by the best performing coal-fired plants and, of course, by hydro. Although most coal plants will have to spend additional capital to comply with new environmental requirements, all foreseeable environmental costs at nuclear plants are already built into the cost structure. This includes surcharges for decommissioning and waste management which, when spread across the customer base, are not significant on a per-customer basis and do not affect the ultimate retail price of electricity generated from nuclear.

Other countries do not operate nuclear plants at the same cost as the best U.S. companies. But there is no reason to believe that they will not be able to match these companies’ cost of operation as competitive pressures force utilities to cut costs, to downsize, and to do their business in a far more cost-effective manner. The reality is that in countries other than the United States competitive pressures have not yet significantly affected the management organizations that run nuclear plants. There are many inherent advantages to the French standardized reactor business, for example, which already provide significant performance and cost advantages but can provide much more price advantage in the future.
The Washington International Energy Group has done extensive studies of the U.S. industry and has concluded that around 50 percent of the plants and nearly 40 percent of the capacity of existing U.S. nuclear plants may shut down because of high operating costs. In many cases this is the result of poor management—not poor technology—except for some of the smallest and oldest plants where the economies of scale compared to future capital costs are not robust. We have also concluded that nearly all plants can operate successfully in a fully competitive market in which there is constant pressure to reduce costs. Furthermore, those plants that operate at high capacity factors and at low cost are also the safest plants. Good management involves both good economics and safety.

In addition, as has been the case with all other industries that move into competition, the nuclear industry is embarking on a major corporate consolidation which will see mergers and acquisitions of nuclear plants including the internationalization of the industry through multinational ownership of generating units. The first acquisition of a nuclear plant is now underway: the AMERGEN (PECO and British Energy) purchase of GPU’s Three Mile Island (TMI). It appears that AMERGEN intends to apply its experience in nuclear operations to cut costs at TMI. The low market value of nuclear plants—compared to fossil plants that are being sold in the United States—make them excellent “bottom fishing” opportunities. Other opportunities are now being investigated.

Acquiring existing plants by major players does more than anything to renew faith in nuclear. The largest nuclear plant owner in the world, Electricité de France, owns 16 percent of the world nuclear capacity. The next largest companies—including Russia—own less than four percent of total worldwide capacity. EDF owns about 60,000 megawatts of capacity compared to Tokyo Electric Power Co., the second largest nuclear plant owner, which owns about 17,000 megawatts. We will soon see the emergence of strong alliances, joint ventures, maintenance agreements and outright acquisition of nuclear assets by strong players.
Companies Owning More Than Three Percent of World Nuclear Capacity

There are at least two ventures now being organized in the U.S., one in New York state (the New York Nuclear Operating Company) and another in the Midwest (which does not have an official name yet). The Nuclear Regulatory Commission has recently proposed a new rule that would streamline changes in ownership.

Nuclear monopolies that operate in a protected guaranteed rate-of-return world have insufficient incentive to act like other businesses. The electricity sector in virtually all countries has been a monopoly with long-term investment cycles matching the high capital costs associated with large baseload plants. As competition comes to Europe and Japan, the nuclear industries in these countries will learn what American electric industry executives now know: relentless cost-cutting, dramatic productivity increases and market share drive everything else.

More than 100 companies own full or partial shares of nuclear plants in the United States. Only 24 companies own more than one full unit. Many utilities, like GPU, will exit the generating business entirely in the next few years while others, like PECO, Duke and Entergy, try to expand their nuclear and non-nuclear holdings. The Washington International Energy Group expects the number of generating companies world-wide to shrink substantially as the average megawatt capacity owned by the largest players grows dramatically. In a decade, it is reasonable to expect that there will be no more than 10 large nuclear operating companies in the United States.

For today’s nuclear vendors, the prospect of few new orders for the foreseeable future means there will be further reduction in labor forces and consolidation among builders and service companies. It also means additional risk-sharing in which utilities, vendors and service companies invest in and
share the management of operating plants. Fundamentally, it means that there will be fewer nuclear power plant vendors in the future. The BNFL-MK acquisition of Westinghouse nuclear opens the door for further rationalization and redefinition of the market.

As has been the experience in other industries, the paradigm shift we are experiencing creates a culture change that over time breeds creativity, new thinking and a far more entrepreneurial spirit. This will contribute in a positive way to the revival of the nuclear industry. For this transition to be successful, the nuclear industry needs to accelerate the generational shift from those whose pride has been wounded by the decline in the credibility of the nuclear industry and who have become too defensive. What is needed now is a new generation that looks at nuclear as a viable for-profit business that also happens to be environmentally advantageous. The new generation needs to work pragmatically with environmentalists to save today’s reactors without carrying the baggage of the past and its strong ideological commitment to nuclear and strong disparagement of those who disagree.

In the United States, the breakthrough that was needed was the conceptualization of stranded cost allocation. It is the “grand bargain” that allows utilities to clear their debt in return for opening the market. There was a need for a new financial contract where customers pay the remaining debt as a condition for being able to shop for electricity. Working through this process allows nuclear owners to not only survive but to excel. For publicly owned enterprises, paying down debt is more difficult since the taxpayer and the ratepayer are the same person, but experience is now accumulating in North America about how to successfully accomplish this goal.

Eventually, all customers will have a choice of electric suppliers. By the time this happens, it is critical that the public’s confidence in nuclear improves. So far we are finding in the United States that customer interest in changing suppliers is much lower than was expected. In California, where customers have had a year in which to choose, only one percent of customers have opted to do so. Nonetheless, when customers do begin to exercise their new “rights” will those who are selling nuclear output need to prove to customers that nuclear is a form of green power?

European and other countries need a similar catalyst to break open nuclear economics, permanently ending subsidies and clearing away the burden of debt. Doing so is essential for all generation technologies but has the most positive impact on nuclear.

The purpose of this paper is to start a new discussion—to say tough things that need to be said, to refocus the industry’s attention on existing nuclear plants and by so doing to revive the spirits of those in the industry. Slowly, the value of nuclear power is being acknowledged again. The nuclear industry needs to reach out to those who are only now reluctantly acknowledging that a world dominated by fossil fuels will simply not be able to reduce emissions nor achieve the ambitious
global climate goals that have been established in Kyoto. The legacy of distrust, the inability of anti-nuclear people to speak candidly about nuclear and the reluctance of some national governments to talk honestly about nuclear power are all problems.

It is particularly disconcerting that national governments whose mandates are centered on the welfare of their citizens are not treating nuclear plants as a national resource. Until national leaders who are serious about climate are prepared to acknowledge that we simply cannot afford to shut down today’s nuclear plants, a cloud will continue to hang over the industry. Unfortunately, in countries like Germany and Sweden, national leaders are unwilling to either endorse nuclear or acknowledge its role. Too many countries are trapped into a stultifying political correctness that hinders good decision making. In the United States, the Clinton administration has pointedly ignored nuclear power as an economic and environmental resource despite the dramatic record of improvement in cost and output—and the important role it plays in the statistical underpinnings of the Administration’s climate plan.

Today much of the conflict in nuclear power is focused on the back-end of the fuel cycle. The excellent overall performance of reactors in the OECD has not itself provided a target for opponents at which to shoot. But the alleged relationship of the commercial nuclear fuel cycle with the weapons cycle if using the reprocessing option, combined with the purported risks of transportation, provide a continued target for the opposition. If trust and credibility are to be restored, those countries still pursuing reprocessing and an active back-end of the fuel cycle system need to face the fact that they will continue to provoke the opposition.

In the United States, the termination of nearly all back-end of the fuel cycle activities has created a situation in which proponents are now in a position to begin building bridges with the environmental community in favor of continued operation of existing plants. There is even relatively strong support, with some exceptions, for the burning of weapons origin MOx in light water reactors. This emerging consensus is still fragile and over the next decade, as the industry consolidates, there will be many management issues to be resolved by boards of directors, who ultimately must look at the bottom line.

The industry needs to move toward consolidation especially in the United States. The industry shares an obligation to get rid of poor performers. It is to be expected that some nuclear vendors and operators will leave the business and that more utilities will also shut down marginal nuclear plants that are not attractive acquisition targets. This should not be looked upon as a negative process, this should be looked upon as a natural consequence of competition and the need to make the most effective use of resources.
Finally, to be successful in restructuring the ownership of the international nuclear industry there will need to be changes in national regulatory systems. The very invasive American style of regulation needs to be modified, recognizing the good performance of many of the players.

**What Does the Nuclear Industry Have to do to be Successful?**

1. Continue to cut costs and to bring total nuclear O&M and fuel costs to less than two cents a kWh. The industry must prove world-wide that today's nuclear plants can be at the cheap end of the generating scale for the foreseeable future.

2. Negotiate to reduce capital costs through stranded cost recovery and accelerated depreciation in return for the opening of electricity markets. This will provide funds for efficiency improvements. Changing from rate regulation to competition breaks the social contract on which long-term repayment of debt was based.

3. Further reduce operating costs by consolidating and teaming with other nuclear companies to share knowledge and take advantage of economies of scale in management. As competition has come to other industries around the world, consolidation has occurred. The nuclear industry is technologically highly international but financially still very decentralized. The industry needs to move toward consolidation, especially in the United States.

4. Encourage the opening of markets so that nuclear's low operating costs can stand out as a clear advantage. In Europe, as well as in the United States, a fully competitive market favors nuclear. Unfortunately, even in the United States, some states have moved to shield nuclear plants from some aspects of competition, fearing they will not be competitive.

5. Encourage the further consolidation of vendors and service companies and explore alliances between operators and vendors. To be cost effective, the service business also has to consolidate and continue internationalization. Framatome, the largest dedicated vendor, certainly realizes that and one can expect that further rationalization will occur in Europe, the United States and Japan.

6. Make building new plants a lesser test of success in the short term. For much of the nuclear industry winning orders for the few new plants being built has been the most important goal. The industry should continue to look for opportunities in Asia but should not measure its collective viability on the number of new plants ordered. It should shift its fundamental measure of success to how many existing plants stay in operation and how much improvement in the cost of operation can be achieved.
7. Build bridges with those in the environmental community supporting the continued operation of today's nuclear plants. It will be difficult to build trust after so many years of negativism. But in the United States, at least, some in the environmental community have—albeit reluctantly—realized that there is no way to fulfill Kyoto Protocol targets if there are significant nuclear plant shutdowns. Even the most optimistic energy-efficiency and renewable forecasts miss the mark.

8. Do not allow controversy over back-end of the fuel cycle policies to prevent an alliance with some environmentalists on operation of today's plants. Those countries that intend to continue commercializing the back-end of the fuel cycle need to work harder to minimize the impact of these decisions on the overall attitude toward nuclear.
The Nuclear Consensus

The Washington International Energy Group believes that continued operation of today's nuclear plants is by far the highest industry priority. The industry has to focus much more of its energy and attention to proving that the decisions it has made over the past three decades are prudent and profitable. The industry needs to follow the lead of those owners that are running nuclear plants on a for-profit basis with margins that are comparable with other generation. Many in the nuclear industry do not believe this is an achievable goal. Until they do, the industry will not be sufficiently motivated and will continue to be in a defensive mode. An attitudinal transformation is the industry's most important need.

For some countries particularly, Japan and France, nuclear has traditionally provided security against potential supply disruptions. All countries spend taxpayers' money to assure national security and it is perfectly appropriate for electric industry customers in countries like France and Japan to be taxed to support the construction of new nuclear plants alongside the growth of a competitive market. In energy markets in which competition is being introduced, a critical goal is to be sure customers who have a choice of suppliers, including those selling "green power", will understand the contribution of nuclear and will not hesitate to buy their energy from nuclear suppliers.

The challenge for the nuclear industry is to refocus on what is achievable, and to build on the promises that were made 40 years ago. Being able to achieve environmental goals without additional governments subsidies makes nuclear attractive.
The U.S. Experience

Outside the United States there is still considerable skepticism about the ability of nuclear plants to generate at low prices. The U.S. nuclear industry experience provides a road map for other countries to use in meeting this challenge.

Data for the past decade indicates a steady improvement in nuclear plant economics, output and performance. This is combined with an improvement in safety, as illustrated through the data published by INPO on the number of scrams and other unplanned events.

The cost of generating electricity by the best plants in the United States has declined from US$20.50/MWh in 1988 to just over $13/MWh in 1997, about a 35 percent drop. In 1997, the ten most expensive plants ran at 60 percent capacity or higher and are nearly three times as expensive as the ten cheapest ($37.60/MWh compared to $13/MWh).

The experience of U.S. nuclear operations in 1997 reconfirms that nuclear plants can run cheaply. North Anna, owned and operated by Virginia Power Co., produced electricity in 1997 at $10.26 per megawatt hour (MWh) calculated on the basis of fuel and non-fuel O&M cost. This plant also holds the record for the lowest average cost over the last 10 years ($12.33/MWh) and the last 3 years ($11.36/MWh). Its O&M costs are similar to the lowest cost U.S. coal plants. For both fuels, costs are declining for the best plants, as well as for the overall average.

To investigate what can be expected for nuclear, we reviewed how plants have performed in recent years. The following chart shows the costs of the 10 lowest cost stations for the last 10 years and then the 10 lowest cost stations for the last 3 years.

### 10-Year Top Performers List

<table>
<thead>
<tr>
<th>Operator</th>
<th>Plant</th>
<th>$/MWh</th>
<th>Reactor</th>
<th>Vendor</th>
<th>Units/Size</th>
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<tbody>
<tr>
<td>Virginia Power</td>
<td>North Anna</td>
<td>12.33</td>
<td>PWR</td>
<td>WH 3L</td>
<td>2/893 &amp; 897</td>
</tr>
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<td>Northern States Power</td>
<td>Prairie Island</td>
<td>14.18</td>
<td>PWR</td>
<td>WH 2L</td>
<td>2/513 &amp; 512</td>
</tr>
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<td>Byron</td>
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<td>PWR</td>
<td>WH 4L</td>
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<td>Wolf Creek</td>
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<td>Callaway</td>
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<td>PWR</td>
<td>WH 4L</td>
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<td>Catawba</td>
<td>16.11</td>
<td>PWR</td>
<td>WH 4L</td>
<td>2/1120 &amp; 1120</td>
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<tr>
<td>Southern Nuclear</td>
<td>Vogtle</td>
<td>16.18</td>
<td>PWR</td>
<td>WH 4L</td>
<td>2/1162 &amp; 1162</td>
</tr>
<tr>
<td>Commonwealth Edison</td>
<td>Braidwood</td>
<td>16.37</td>
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<td>Houston Light &amp; Power</td>
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<td>PWR</td>
<td>WH 4L</td>
<td>2/1251 &amp; 1251</td>
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- Plants in bold are on both the 10-year and the 3-year list.

<table>
<thead>
<tr>
<th>Operator</th>
<th>Plant</th>
<th>$/MWh</th>
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<td>WH 2L</td>
<td>2/513 &amp; 512</td>
</tr>
</tbody>
</table>

* Covers 1995 to 1997.


There are some common threads in understanding the comparative costs of U.S. nuclear plants, but there are also unique aspects for each plant that affect costs. First the common threads.

The dominance of Westinghouse plants over other vendors is striking. Although Westinghouse is the vendor for slightly more than half the operating reactors (53 percent), all but one plant in the low-cost spectrum for the 10-year period is a Westinghouse plant. The majority of plants in the three-year average and one-year average are also Westinghouse. However—a note of caution—of six plants that have closed or announced pending closures since the beginning of 1997, four are Westinghouse. Owning a Westinghouse plant may make it easier to operate at low cost but it doesn’t guarantee low costs. For both periods, PWRs (Westinghouse, Babcock & Wilcox, and Combustion Engineering) clearly dominate in low cost over BWRs (General Electric). Only one of the lowest cost plants, the PECO Energy (now AMERGEN) Limerick plant, is a BWR.

The lowest cost plants are generally at multiple-unit stations. There are only two three-unit stations, and they are both low cost: Duke Energy’s Oconee plant is on the 10-year list, and Arizona Public Service’s Palo Verde plant is on the 3-year list. There are only two one-unit plants, and they are both on the 10-year list: Wolf Creek Nuclear Operating Co.’s Wolf Creek plant, and Union Electric’s Callaway plant. Interestingly, these two plants are “twin plants,” in neighboring states. They were the only Westinghouse “Standard Nuclear Power Plant Systems” (SNUPPS) series plants that were ever completed and brought into operation. Neither station is on the 3-year lowest cost list.

Related to the number of units is the size of the station. Stations with over 2200 MW capacity dominate the 10-year and 3-year lists. However, there are nine stations larger than 2200 MW that are not on either the 10-year or the 3-year list. This demonstrates that the largest plants that should
have the best economies of scale do not necessarily perform best if there are management
deficiencies. Commonwealth Edison's poor performance history exemplifies this.

All stations on the 10-year list of best performers are located in the South or Upper Midwest
(Illinois/Wisconsin and farther west). This pattern continues for the three-year period, with two
exceptions: PECO's Limerick, which is in the Mid-Atlantic region, and APS' Palo Verde which is in
the Western region. It is not clear why this is so. Electricity prices in general are lower in these
regions. Nearly all of these plants have more than 20 years left on their operating license. This
provides ample time for them to recover investments in efficiency improvements.
The Impact of Management

Changes in Ranking

Only five plants are on both the 10-year and the 3-year lists. Two reasons stand out:

- Some stations that previously had low costs have in recent years experienced higher costs.
- To continue to be in the top ranking, costs had to be lower, since costs industry-wide have gone down.

The plant which ranked tenth in the 10-year list, Houston Lighting and Power's South Texas plant, had costs of $16.67/MWh. Comparatively, the plant which ranked tenth on the 3-year list, Northern States Power's Prairie Island plant, had costs of $14.91/MWh, or $1.76/MWh less. One of the plants on both lists, Duke's Catawba plant, has a 3-year average cost of $14.42/MWh, about $2.25/MWh (or 13 percent) less than the 10-year average.

Staying Competitive Means Constant Improvement

![Graph showing cost comparisons over time for different plants.]

Cheapest Plant | Tenth Cheapest Plant

Why?

Vendor, size, reactor size, number of units on a site, and age of plant have been scrutinized to determine why performance among plants is so different. But the reactors, except for some minor modifications, have not changed over the past ten years.
The big difference is management. Thus it is difficult to understand why all plant owners have not followed the leaders and taken actions to reduce costs by substantial amounts.

Why did Virginia Power's North Anna plant's O&M costs decline from $15.60/MWh in 1989 to $10.26/MWh in 1997? According to the company, it is focusing on basics—safety, attention to detail and questioning attitudes. Senior vice president for nuclear, James O' Hanlon, says "It's not anything real fancy." He mentions teamwork and the importance of attitudes that encourage high standards of performance from the top down. "You talk to people and they can buy in on that." Furthermore, Virginia Power wants to continue to bring production costs down—to less than one cent per KWh ($10.00/MWh).

Officers at other high performance plants have similar explanations. Southern Nuclear Operating Co.'s Vogtle plant, which was the second best performer for 1997, provides a similar explanation. According to Jack Woodward, executive vice president for nuclear, the most important factor was keeping the plant in excellent physical condition. "That means not putting off modifications or maintenance." Another factor is reducing on-site employment. At Vogtle, employment is shrinking by about two percent a year. None of the comments from these officers or those at other top performing plants relate to kind or size of reactor.

This wide spread in performance of unit costs—three to four times higher for some plants than others—may be much more characteristic of the United States than of other countries. But today it provides strong benchmarking potential for bringing all costs down to those of the best performers and is a strong incentive for improvement. Of course, the characteristics of some reactors make it impossible to ever achieve performance even close to North Anna's.

Trends in Costs

The next area investigated by the Washington International Energy Group is the long-term trends in O&M costs over a period of years. Plant operators may turn in a good performance year on occasion, but sustained good performance is essential. Our figures show that when you compare the average annual change in O&M costs expressed in $/MWh of the ten plants that were cheapest to operate over the ten-year period, three did not show a declining trend—Northern States Power's Prairie Island plant, Wolf Creek Nuclear Operating Co.'s Wolf Creek plant, and Duke's Oconee plant. To no one's surprise, two of these are not among the cheapest plants on the more recent 3-year list.

The plants that made the 3-year cheapest plant list but not the 10-year list are plants that have had significant cost cutting programs. For example, Virginia Power’s Surry, PECO’s Limerick, and Arizona Public Service’s Palo Verde, all have had average annual reductions in O&M costs of over $1.00/MWh. Southern Nuclear Operating Co.’s Vogtle plant also has had cost reductions in this range, but it was already on the 10-year list. This is how it became the second lowest cost plant in 1997. The other two additions to the three-year list, the Tennessee Valley Authority’s Sequoyah plant, and South Carolina Electric and Gas’s Summer plant, also have had strong downward cost trends.
A Look into the Future

A number of U.S. nuclear power plants, in addition to those on the historical low-cost lists, have had great success in reducing O&M costs. We analyzed those plants that could achieve $12/MWh or less in five years by continuing the trend in cost reductions. Only fifteen plants qualify for this list. Even among these, some have had a year or two in the past ten where long shutdowns have occurred. Years of little or no plant output are excluded; therefore, the trend is not a ten-year trend in all instances. These instances are Florida Power and Light's Turkey Point, Toledo Edison's Davis Besse, PECO's Peach Bottom, Arizona Public Service's Palo Verde, and Baltimore Gas and Electric's Calvert Cliffs. Public Service of New Hampshire's Seabrook and Texas Utilities' Comanche Peak are also included even though they do not have a full ten years of operating experience. All these plants are included because they have shown significant downward trends in O&M costs and have the potential of being tomorrow's winners.

If trends continue, there will be a lot of newcomers to low-cost production. Topping the list of greatest cost reductions is Florida Power and Light's Turkey Point 3 & 4 units. Its operator has cut costs by an average of $2.60/MWh per year over the past 10 years, excluding one terrible year. Of course, it started at a very high level, about $40/MWh in the late 1980s. Following close behind is Toledo Edison's Davis Besse plant that has reduced costs at an annual rate of about $2.22. Of 15 plants on this list, any of which may be on the lowest-cost list in a few years, only six are on the current three-year list. Currently, by operating at less than about $15/MWh, a plant can get on the low-cost list. It is quite possible that within a few years the required figure will be around $12. Will the winners be from this group?

Why are only some plants successful in cutting costs? Can the vendor explain these differences? It is becoming less clear that the Westinghouse-manufactured plants will have a cost advantage. The top four most successful in cost cutting are not Westinghouse plants and only one is a PWR. Obviously, since BWRs started from a higher level more cost cutting is possible. And it clearly remains to be seen whether cost cutting can continue to the level of the best Westinghouse plants.

Because of the high degree of customization among American nuclear plants, there are serious economic deficiencies in trying to consolidate management. Nevertheless, major improvements in overhead and performance can still be gained through the consolidation of ownership. When the same data is sorted by owner, it becomes evident that costs are more related to individual plants than to owners. Several owners listed here operate other plants that are too expensive to qualify for this list. This includes Carolina Power and Light (two other nuclear stations). Commonwealth

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2 Additional documentation available upon request.
Edison (five), Entergy Operations (two), the Southern Nuclear Operating Company (two), and Florida Power and Light (one). *

How successful are larger companies in operating a number of nuclear power plants? Two companies, the Southern Nuclear Operating Company and Entergy, were organized within about the last 10 years for the express purpose of owning and operating a number of nuclear power plants to achieve economies that were not possible from independent single site operations.

At this time, it appears that Southern and Entergy may be concentrating on cost reductions at some plants but not others. Although both companies have one or more plants with successful cost cutting (Vogtle for Southern Nuclear Operating Co. and Arkansas and Grand Gulf for Entergy) other plants are lagging in cost cutting. It is possible that economies were achieved at the corporate level, however, the results are very mixed at the individual plant level. Both Farley of Southern Nuclear Operating Co. and Waterford of Entergy show very low success in cost reductions. In fact, the record of U.S. nuclear owners operating plants at more than one location is of very mixed economic success. Virginia Electric Power is the one case where all of its plants are low-cost operators.

In fact, the companies owning the largest number of units in North America—Ontario Hydro, Tennessee Valley Authority and Commonwealth Edison—have been the subject of extensive criticism with very long plant outages. It is not, therefore, a panacea to move nuclear plants into larger companies. But larger operators that have strong management can successfully manage operation of a large number of plants and ought to be able to do so at a competitive cost.

For comparison, we also include the plants now owned by PECO. PECO and now AMERGEN (PECO and British Energy) has made several moves in the past year or so indicating it plans to form a nuclear operating service company. How will it operate its recently purchased TMI? Like Peach Bottom, an average performer, or like Limerick, a top performer? TMI has no downward trend in costs—it is clearly a potential plant for improved cost performance.

* Additional documentation available upon request.

**Value of the Top U.S. Nuclear Plants**

In the United States, plans are taking shape for the great nuclear power plant exchange. Several have been offered for sale, usually encouraged by state public utility commissions (PUCs) as part of an effort to eliminate the vertical integration of electric utilities. In spite of this great
interest. only one has been sold. Three Mile Island is being sold by GPU to AMERGEN for a price excluding nuclear fuel of about $23 million.

What is the value of other plants? Is this a reasonable price for TMI? Although many factors go into developing an acceptable exchange price, probably the most important consideration is how much can the plant produce, how much does it cost to produce, and what is an expected weighted average selling price.

## Estimated Value of Plants

Based on Future Net Revenues

<table>
<thead>
<tr>
<th>Operator</th>
<th>Station</th>
<th>Value per MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virginia Power</td>
<td>North Anna</td>
<td>$425</td>
</tr>
<tr>
<td>Southern Nuclear</td>
<td>Vogtle</td>
<td>$406</td>
</tr>
<tr>
<td>PECO Energy</td>
<td>Limerick</td>
<td>$281</td>
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<tr>
<td>Commonwealth Edison</td>
<td>Braidwood</td>
<td>$280</td>
</tr>
<tr>
<td>Virginia Power</td>
<td>Surry</td>
<td>$275</td>
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<tr>
<td>Arizona Public Service</td>
<td>Palo Verde</td>
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</tr>
<tr>
<td>Commonwealth Edison</td>
<td>Byron</td>
<td>$256</td>
</tr>
<tr>
<td>South Carolina Electric &amp; Gas</td>
<td>Summer</td>
<td>$255</td>
</tr>
<tr>
<td>Tennessee Valley Authority</td>
<td>Sequoyah</td>
<td>$254</td>
</tr>
<tr>
<td>Houston Light &amp; Power</td>
<td>South Texas</td>
<td>$250</td>
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<tr>
<td>Union Electric</td>
<td>Callaway</td>
<td>$234</td>
</tr>
<tr>
<td>Northern States Power</td>
<td>Prairie Island</td>
<td>$231</td>
</tr>
<tr>
<td>Duke</td>
<td>Catawba</td>
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<tr>
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<tr>
<td>Wolf Creek NOC</td>
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<td>Energy Operations</td>
<td>Grand Gulf</td>
<td>$182</td>
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<td>Carolina Power &amp; Light</td>
<td>Robinson 2</td>
<td>$171</td>
</tr>
<tr>
<td>Texas Utilities</td>
<td>Comanche Peak</td>
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<td>Public Service of New Hampshire</td>
<td>Sea Brook</td>
<td>$139</td>
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<tr>
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<td>Duke</td>
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<td>Florida Power &amp; Light</td>
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<tr>
<td>Toledo Edison Co.</td>
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<td>PECO Energy Co.</td>
<td>Peach Bottom</td>
<td>$41</td>
</tr>
<tr>
<td>GPU</td>
<td>Three Mile Island</td>
<td>$19</td>
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</table>


To determine the value of some of the best performing U.S. nuclear plants, we took a set of plants and assumed that plant output and that production costs would be the same as the average over the last three years. In other words, we made no assumption that cost reductions will continue to be
made. We assumed that the selling price of electricity would be $20/MWh. These assumptions were used to estimate the present value of the net revenue over the remaining life of the plants. This is an important indicator of the market value of the plant.

The set of plants we analyzed includes:
1) The 10 lowest-cost plants over the last 10 years,
2) The 10 lowest-cost plants over the last three years, and
3) The 15 plants that could produce electricity for $12/MWh if current cost cutting trends continue for five more years.

Three Mile Island was added to this list since we already have its selling price (reported at about $23 million).

For the purpose of comparison we expressed these figures in a common measure—value per KW. Under this set of assumptions, we find great variation in plant value. The lowest value plant in this analysis is Three Mile Island at $19/KW; the highest value plants, not surprisingly, are North Anna and Vogtle, $425 and $405/KW respectively. Since TMI is about 790 MW, its net revenue present value is $15 million using the above assumptions.
Conclusion

Many of the owners of nuclear power plants have it within their power to make their nuclear plants profitable. They have already met one cost challenge. A crisis was developing in the mid-1980's in U.S. nuclear power industry. O&M costs were increasing steadily year-to-year. The Nuclear Regulatory Commission was blamed for ever increasing regulatory requirements: nuclear opponents were blamed for opposing any solutions to waste management and creating a climate of fear of nuclear power.

Much of the criticism was justified but there was not much the industry could do about these problems. What was done instead was to mount a sustained effort at self-help. This involved a sharing of knowledge among the industry and an evaluation of plant operations for the purpose of cutting costs. The efforts were a success and O&M costs have been on a downward trend for a number of years.

What is not known is why many of the plants are still stuck at operating costs two to three times higher than the best performers. We reported earlier that good performers are found among all vendors, owners, and plant characteristics. We conclude that the main explanation is individual plant management.

Currently operating nuclear plants are in a position to make money for their owners as well as play a significant role in minimizing the growth in greenhouse gas emissions. The Washington International Energy Group assumes that virtually all countries are moving toward opening their electric markets and that until now nuclear has done best in closed markets where cost controls were less important. It remains difficult for many in the nuclear industry to acknowledge to themselves that nuclear plants can compete on price. The biggest challenge today is for the industry to believe in itself and, based on that, convince others that it can succeed.