Nuclear Power's Prospects in the Power Markets of the 21st Century

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Mr. Yu likened nuclear power plants to "a machine to print money". [1]

Congress has tacked on $35 million here, $29 million there to its annual spending bill to help the nuclear industry conduct site and permit work. When a marked-up energy bill makes the rounds early this year, it will likely suggest further study of options for fuel recycling and earmark $1.8 billion to get new reactors built pronto. The bill does not yet give NuStart what it wants most of all: government guarantees of construction loans for new, untested reactor designs…..The utilities also want two fat tax credits--one allowing them to deduct 20% of their spending on new reactors and a second to lop off 1.8 cents for every kilowatt-hour of power produced by the new plants…..
"Whatever the government needs to spend," counters Gary Taylor, head of nuclear operations at Entergy, "it's a small price to pay for weaning America off its addiction to foreign oil, reducing greenhouse gases and protecting our economy." [2]

Gatsby believed in the green light, the orgiastic future that year by year recedes before us. It eluded us then, but that's no matter - tomorrow we will run faster, stretch out our arms further... And one fine morning –
So we beat on, boats against the current, borne back ceaselessly into the past.[3]

I. Introduction

For the last 20 years, forecasts of an imminent revival of nuclear power plant orders have exceeded in frequency and equaled in accuracy forecasts of the second coming of the Messiah.[4] Today, with the entry into force of the Kyoto Protocol, with the operating costs of the existing nuclear plants at all time lows, with Chernobyl and Three Mile Island receding in public memory, with advanced (though unproven) reactor designs of

[1] Yu Jiechun, senior engineer at the China Guangdong Nuclear Power Holding Company, quoted in "China Promotes Another Boom: Nuclear Power", New York Times, January 15, 2005, p.1.
[2] Christopher Helman, Chana R. Schoenberger, Rob Wherry, "The Silence of the Nuke Protester" Forbes January 31, 2005. http://www.forbes.com/home/free_forbes/2005/0131/084_3.html
[3] F. Scott Fitzgerald, The Great Gatsby, (xxxx), p.
[4] Searching the combination of "nuclear power" and "revival" in Google on January 22, 2005, produced 41,600 items.

improved safety and performance under licensing review, with political support for new nuclear units in the U.S. at a two decade high – how likely is it that the stars have finally aligned themselves in a manner conducive to that elusive revival in nuclear orders, especially orders that will spread nuclear power rapidly to countries that do not use it today?

Not very. This paper will show that nuclear power's Achilles heel – that it is too expensive – has not changed in any fundamental way. Furthermore, the spread of competitive power supply markets, of privatized electric sectors and of transparent governmental decisionmaking tends to undermine the closed selection processes in which nuclear power has historically prevailed over various combinations of alternatives.

Some countries will build nuclear plants for reasons ranging from fuel diversity to national security to national prestige. An occasional country will use nuclear power programs that make little economic sense to mask and to assist programs to develop nuclear weapons. But such decisions are not a sufficient basis for a healthy future nuclear industry and are not likely to lead to the spread of nuclear power plants to many countries that do not already have them. A real revival can only come when privately financed nuclear power plants are being ordered on a regular basis in countries that use transparent and competitive processes to choose their power supply by building the least expensive plants. Of course, these markets should reflect the environmental impacts of the various alternatives, so nuclear power's best hope lies in a world in which the avoidance of greenhouse gases becomes a priority.

However, the basis for assuming that nuclear power will win out over other ways of displacing greenhouse gases is slight, and insufficient to win over investors at affordable returns. Nuclear proponents seem instead to be aiming to persuade governments that theirs is the best option for averting climate change, without going through a serious competition against the alternatives. This effort may succeed for a time in some countries, but – as with past situations in which nuclear power proponents have persuaded government officials to play pin-the-tail-on-the-donkey with power supply policy rather than engage in serious evaluation of alternatives - such successes may well be prelude to expensive disappointments, and no basis for long term prosperity in the nuclear industry.

Nuclear power today produces some 16% of the world's electricity, and about half of the electricity whose generation does not directly emit greenhouse gases. A sample of the countries relying on nuclear power includes the following:

Country	Nuclear capacity (GW) (plants)	Percent of electric generation	Plants ordered since 2000
United States	98.5 (103)	20	0
France	63.8 (58)	79	0
Great Britain	12.3 (33)	22	0
Japan	45.2 (53)	34	0
Russia	20.7 (30)	9	0
Canada	15.2 (22)	13	0
Germany	20.6 (18)		0

South Korea	16.9 (20)		2(?)
India	2.5(14)	3	8
China	6.7 (9)	1	
World total	364.9 (443)	16	

According to the electricity growth projections set forth in the US Department of Energy's Energy Information Agency (EIA) reference case, world energy growth will double over the next 20 years, while nuclear power will increase from 365 to 385 GW in the same time frame. Because nuclear power will grow more slowly than total power supply, its share of the generation market will decline from the current 16% to 12%.

Most of EIA's nuclear growth will take place in Asia, led by China with 19 GW (or approximately one plant per year).[5] Other additions take place in South Korea (15 GW), Japan (11 GW, with 5 GW retiring), and India (6 GW). Elsewhere, Russia is forecast to add 6 GW, but Germany, Sweden and Great Britain are forecast to close plants without adding new ones.

Both the United States and Europe have fewer nuclear plants operating today than in 1990, and more plants are certain to close over the next twenty years. Consequently, some nuclear construction in these regions will be necessary for nuclear power to maintain its current output levels.[6]

[5] Chinese forecasts are somewhat higher, with an upper range of 30 GW.

[6] A recent report prepared for the Green Group of the European Parliament notes that 280 new units (slightly more than one per month) would be needed over the next 20 years just to replace reactors that will reach a 40 year life during that period, Mycle Schneider and Antony Froggatt, "World Nuclear Industry

A significant reason for the slowing of nuclear power plant construction is the advance of privatized and competitive power supply markets throughout the world. Over the last twenty years, North and South America, Europe and Australia and New Zealand have moved overwhelmingly to power procurement processes that require potential generators to be chosen through competitive solicitations.[7] These solicitations produce terms that transfer some risk from customers to private investors. In their more sophisticated forms, they also permit energy efficiency and load management to bid directly against the construction of new power plants.

Competitive power supply solicitation processes and privatization continue to spread to new nations. They are encouraged by international assistance agencies and have made some headway in the former Soviet Union, in Asia and in Africa. Even in China, where power supply procurement is neither competitive nor transparent, the government has announced that power generation will be more competitive in the future. For reasons discussed below, nuclear power has not fared well in these competitive processes.

Other worldwide governance trends of importance for nuclear power include advances both in transparency of energy sector decisionmaking and in democratic governance

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Status Report 2004". However, because many of the existing units will last longer than 40 years and because new units will generally be much larger and probably more reliable than the ones phased out, others argue that the number of new plants necessary to maintain existing nuclear capacity and output is considerably lower.

[7] This is not the same as retail competition, under which customers may choose their power supplier. Retail competition has also made significant advances, but it is less widespread and has been significantly slowed by the California crisis of 2000-2001.

generally.[8] The only fully democratic country recently to select a nuclear power plant through a process that had at least the trappings of transparency and competitiveness has been Finland. That choice will be examined below.

One trend tending to improve the competitive position of nuclear power is increasing worldwide concern with climate change. To the extent that this concern results in measures that increase the cost of fossil fuels, nuclear power's competitive position obviously improves. However, this improvement may not be as great as it would seem at first glance. Nuclear power's role in mitigating climate change is in any case constrained by the fact that its impact is limited to the electric sector. These developments will also be discussed later in this paper.

II. How the Evolution of Power Supply Markets Affects Nuclear Power

IIA. Historical Background

No major industrial technology has had a trajectory comparable to that of nuclear power. The annual report of the U.S. Atomic Energy Commission (AEC) in 1972 forecast that the United States would have one thousand nuclear power plants by the year 2000, in addition to plants to reprocess the spent fuel and breeder reactors that would produce almost as much as fuel as they consumed. The disposal of spent nuclear fuel, said by an AEC chair of that era to be "the greatest nonproblem in history"[9] would be accomplished

[8] "Since 1980 according to the 2002 United Nations Human Development Report, 81 countries have taken 'significant' steps toward democracy, with 33 military governments replaced by civilian governments. Of the world's nearly 200 countries, 140 now hold multiparty elections. That may not make them fully democratic, but 82 of them are, and those have 57% of the world's population." (The Economist, June, 2003, p. 5)

[9] Dixie Lee Ray **Cite**

no later than 1985. By 2000, the U.S. had only 103 operating nuclear plants, no breeder reactors, no reprocessing plants and no waste repository. Indeed, the worldwide total of 443 nuclear power plants generating some 365 gigawatts of electricity is less than half of that 1972 AEC forecast for the U.S. alone.

To understand the implications of this history for the future of nuclear power, one must begin by understanding the past. Is it – as some would have it – a technology brought low by irrational public fears expressed in the form of burdensome overregulation and litigation (compounded by industry mistakes whose lessons have now largely been successfully learned and incorporated into new plant designs)? Or is it a technology force fed into unsophisticated power supply selection processes at a pace far too fast for the industry to assimilate the lessons of operating experience and in ways that concealed or understated the real costs and problems, assuring a series of unpleasant surprises, a deepening public mistrust and ultimately reform of the power supply selection processes under which nuclear power had thrived for a while?

A case can be made for either of these views or for some combination of them in different countries at different times. But if the first scenario is basically correct, then laws streamlining the licensing process and excluding public interventions coupled with a long period of accident free operation should have been enough to revive nuclear construction, especially in countries with few alternative sources of electricity. If the second scenario is the more valid, nuclear power can only revive in the context of power supply markets very different from those in which it took form.

The U.S. experience strongly suggests that forces less tractable than a cumbersome licensing process and irrational public fears have been at work. Indeed, for 25 years now, the U.S. nuclear power industry has enjoyed a regulatory process of its own design,[10] yet not a single new nuclear power plant was ordered during that time. This is not for want of political support at the national level.

To understand why nuclear power did not thrive under favorable circumstances, one needs to look at the utility bills of the customers. Throughout the 1980s plants under construction were coming on line with immense effect on electric rates. Even more infuriating to customers was the fact that they were being required to pay a large portion of the costs of the many canceled plants.

In the U.S. most electric prices are set by state – not national – regulatory bodies called public utility (or public service) commissions. These commissions have their shortcomings, but their proceedings are among the most transparent in the world. Determining the full costs of the nuclear plants and of the alternative choices (including energy conservation) was easier for the press and for customers in the U.S. than in any other country. The more that they learned, the more disenchanted they became with the

[10] Since the last U.S. construction permits were issued in the late 1970s, the nuclear licensing process has been modified in a number of ways, including 1) early site permits, which offer a site permit good for twenty years (and renewable for another twenty); 2) the ability to plug an approved plant design into a site with an early permit without further review, thereby avoiding any local public hearing on the actual proposed power plant; 3) a combined construction permit and operating license issued at the time of construction, thereby avoiding any public hearing in advance of plant operation; and 4) payment by the Department of Energy of one-half of the costs of obtaining a combined construction permit and operating license. These measures significantly reduce both the costs of obtaining a license and the opportunities for public opposition.

way that power supply decisions had historically been made. In the long run, the way that U.S. regulatory processes exposed the high costs of nuclear power is a more likely explanation of the continuing difficulties of nuclear construction than is the industry's obsession with mythical vampire intervenors whose machinations are said to have weighed down the technology for twenty years after they themselves vanished from the public discourse.

The customers' disenchantment with the trend of their electric bills initially manifested itself in two mutually exclusive ways. One group of reformers urged more effective regulation – better commissions, more professional staffs, laws requiring full consideration of all alternatives including energy conservation. Another group urged instead that market forces and competition be relied on to make better power supply choices. As of 1978, U.S. law had been changed to require electric utilities to buy power from any supplier who could match or improve the utility's own cost of building or buying. As this law took effect, the ability of independent power producers to improve on the performance of the private utilities became increasingly clear.

By the end of the 1980s, falling gas and coal prices, coupled with the successes of the independent producers, had created prices for new power plants so low that a new nuclear unit was out of the question. In the states that relied less on competitive processes and more on a regulatory process known as "integrated resource planning" or "least cost planning", the conclusion as to nuclear power was the same. Nuclear advocates and believers in vertically integrated utilities forecast blackouts if regulators didn't stop

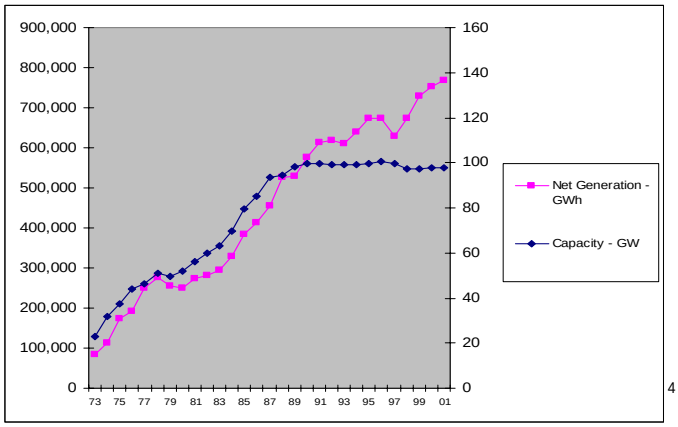
experimenting with untried methods and power producers (many of whom were actually utility subsidiaries operating outside of their parent's home territory). Such blackouts did not materialize, and power prices fell. Advocates of competition were further emboldened. Federal legislation in 1992 required that most transmission systems transmit independently produced power on terms equal to those offered to the home utility. States began to consider allowing customers to shop for their power supplies. The process called "restructuring" or (inaccurately) "deregulation" was underway.

To make matters worse from the standpoint of nuclear plant owners, the newest gas-fired units were coming on line at prices far below those necessary to recover the remaining costs of most of the nuclear units. If customers were truly free to choose their suppliers, many more gas plants would be built, customers would shift to them and nuclear plant owners would go bankrupt.[11] Companies owning nuclear plants adopted two strategies – cost reduction and persuading regulators of the need to allow recovery of the expensive nuclear plant costs as part of a gradual transition to competition.[12]

The effect of the cost reduction efforts at the nuclear plants was dramatic. As Figure 1 shows, the output of U.S. nuclear plants in the 1990s improved by almost 45%.

[11] Two examples from New York illustrate the extent of nuclear power's peril. First, when New York utilities began conducting competitive power supply auctions in the late 1980s, some existing nuclear plants in neighboring states bid their surplus generation. These bids all lost to bids from gas plants that had not yet been built. Second, the owner's study of operating the newly completed Shoreham nuclear power plant showed an insignificant present value benefit when compared to retiring the plant without running it.
[12] The saga of these transitional or "stranded" costs is beyond the scope of this paper. The end result was that the nuclear plant owners were allowed to recover almost all of them.

Figure 1 - U.S. Nuclear Output and Nuclear Capacity, 1973-2002: Productivity Improvement in the Face of Competition



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Since the amount of nuclear generating capacity during this period remained roughly constant, the improved output was due almost entirely to eliminating unnecessary downtime.[13] These increases in output coupled with reduced expenses cut the operating cost of the existing nuclear plants to approximately 2¢/kWh.

These reduced running costs compared favorably with typical running costs both of coal and of combined cycle gas turbine power plants. As a result, predictions that electric restructuring would force many U.S. nuclear plants to close have gone unfulfilled. Nine U.S. nuclear plants did close in the 1990s, but the last was the two unit Zion station in 1998. After that, the viability of the existing plants in competitive wholesale markets became clear. As a result, many nuclear plants were sold to the few U.S. companies

[13] Indeed, during the 1990s the U.S. nuclear fleet increased its output from less than 70% of its potential maximum capacity to 90%.

seeking to operate consolidated fleets of nuclear units,[14] and the number of companies running nuclear plants in the U.S. has been halved. This consolidation has improved management and allowed for further cost reductions to the current level of about 1.8¢/kWh (including fuel).[15] Nuclear power plant owners have been sufficiently encouraged to apply for license extensions – usually for 20 years – and for capacity expansions, usually for up to 5% but for as much as 20% in a few cases.

To date, the NRC has granted all of these requests, so some growth in U.S. nuclear capacity and output from the existing nuclear fleet is assured.[16] However, even with their ability to compete on the basis of operating costs clearly established, the most recent sales of nuclear units have not been at a price that would remotely support the building of a new plant.[17]

The transition toward more advanced competitive power supply markets in the U.S. and elsewhere slowed dramatically following the 2000-01 crisis in the California electric system. However, the basic principle that power procurement should be through

[14] "Sold" is something of a euphemism for many of these transactions. When the value of the spent fuel, the decommissioning fund and the long term contracts to take the power are taken into account, only a few of the plants that have changed hands in the U.S. to date can be said to have done so at a positive price.
[15] John Deutch and Ernest Moniz cochairs, The Future of Nuclear Power, (MIT, 2003), p. 38. The best performing quartile among U.S. plants had operating costs of 1.3¢/kWh.
[16] In addition, the Tennessee Valley Authority, a government-owned power supplier exempt from regulatory review and from competitive requirements, has announced the intention to reopen a nuclear plant closed since 1985 and is considering completing another plant on which construction was suspended at the same time. The restarted unit, which of course has substantial capital investment in place, is forecast to cost some 1300/kWe. However, the plant is already licensed and will not have the future life of a new unit. Also, TVA is able to finance its capital investment entirely with low cost debt.
[17] The MIT Study, in discussing the 2002 sale of 88% of the Seabrook station, notes that the price "implies that the market value of a fully licensed and operational nuclear power plant with a good performance record is less than half of the most optimistic cost estimates for building a new nuclear power plant….Comparable analyses of other nuclear power plant sales come to very similar conclusions. The market value of nuclear plants is far below their replacement cost, a result that is inconsistent with merchant investment in new nuclear plants." (MIT Study, Appendix 5, p. 140)

competitive processes is established in U.S. federal law[18] and is not dependent on policy changes in any state. It is unevenly enforced throughout the country and is not mandatory for government-owned entities like the Tennessee Valley Authority. Nevertheless, no part of the U.S. that has accepted competitive power supply procurement has later renounced it.

Of course, a supportive government can improve the competitive position of nuclear energy in a number of ways. Subsidies, tax credits and financial or power purchase guarantees can be given. Federal authorities can restart shutdown plants and complete unfinished ones that private companies would not touch. Centralized interim storage of spent nuclear fuel can be provided while decisions as to permanent disposal are pending. Projects labeled as "research" can be favored with large grants. As discussed below, undertakings along these lines seem more likely in the U.S. in the near future than at any time since the 1970s. Nevertheless, a nuclear revival does not exist until private capital is willing to build plants for prices that assure competitive success on one hand and profitability on the other.

IIB. The Nature of Competitive Power Markets

As the foregoing narrative indicates, competitive power markets in the U.S. emerged in no small part from public discontent with the nuclear power plant construction experience of the 1970s. In particular, utility customers, environmentalists and potential builders of power plants all asserted that an important lesson of this experience was that competitive

[18] Cite to PURPA and to Richard Hirsch.

processes – processes allowing for participation both by generation alternatives and by suppliers of energy efficiency - should replace regulation in determining which, if any, power plants actually get built.

Such markets inevitably led to competitive bidding and to contracts under which much of the risk involved in building power plants was shifted from customers (theoretically protected by regulators) to investors (protected by their considerably more sophisticated understanding of power supply markets). This in turn led to differences in the return required for investment in different types of projects, depending on investor perceptions of risk. Nuclear projects - with their long construction times and high upfront costs – require that investors wait longer to recover their money. This increases exposure to several types of risk, especially in markets in which customers can change suppliers if more attractive options become available. The increased risk associated with nuclear investment translates into higher capital costs for new nuclear power plant projects. Hundreds of power supply procurement auctions have been held in the United States in the last twenty years. Not once has a new nuclear unit submitted a bid.

The British experience with nuclear power, competitive markets and private capital parallels that of the U.S. When the British government in 1989 undertook to privatize its electric power sector and to introduce generation competition and customer choice, it believed that new nuclear units would decrease both the nation's reliance on high cost British coal and the political power of the coal miners' union.[19] But private investors

[19] The British Electricity Experiment - Privatization: the Record, the Issues, the Lessons, edited by John Surrey, (Earthscan Publications Ltd., London, 1996), pp. 122-23.

were unwilling to take the existing nuclear units, forcing a last minute revamping of the privatization, with the nuclear units remaining in government hands and supported by a "fossil fuel levy" (amounting to a 10% tax on electric revenues)[20] and a "nonfossil fuel obligation", which required the distribution companies to buy the output of the nuclear units. Natural gas proved to be the fuel of choice for new power plants in the 1990s. As in the United States, nuclear units were not even bid.

In 1996, the government was able to privatize its eight newest nuclear units in the form of British Energy, on terms that required the government to pay most of the unrecovered capital costs. Thus in Britain the taxpayers assumed the "stranded costs" that in the U.S. were charged to the customers. For a time the British nuclear plants – freed from the need to recover most of their capital costs - were able to compete successfully, but as power prices fell they were unable even to recover their operating costs, largely because these included the expense of reprocessing the spent fuel[21] as well as a climate change tax that was charged to the nuclear units on the rationale that the proceeds were needed to promote renewable energy.

Despite a substantial government loan, British Energy was unable to survive in the British market of 2000-2004, and its shares were delisted in October, 2004. The share price had gone from two pounds at the time of privatization to a high of seven pounds in

[20] The fossil fuel levy was deemed unfair government aid by the European Commission and eliminated in 1998.

[21] The reprocessing cost that British Energy was compelled to accept at the time of privatization was some $8 per mWh, compared to the $1 per mWh that U.S. utilities pay for a waste disposal regimen that does not include reprocessing. The MIT study estimates that reprocessing costs 4.5 times as much as the once-through fuel cycle. The Economics of Nuclear Power, p. 9.

1999 before falling to 14 pence per share at the time of delisting. British Energy has now been relisted as a result of a reorganization that transfers more than $7 billion in additional costs to the government. Thus a new round of stranded costs were created and redistributed, this time in part to the investors in British Energy and in part again to the British taxpayer.

Other countries with large nuclear programs have not yet subjected them to the degree of transparency and of competition that has occurred in the U.S. and in Great Britain. Indeed, only U.S. regulatory proceedings have produced a fully audited picture of nuclear construction and operating costs, so direct comparisons to countries such as Japan and France are difficult. Certainly the established utilities in both of those countries have begun to lose large customers to suppliers not burdened with nuclear plant costs. Furthermore, the economic difficulties of Electricité de France (EDF) in accounting for the funds set aside to deal with decommissioning and waste management (especially reprocessing)[22] seem likely to echo the British experience, in which they turned out to have been lost in overseas ventures and current expenses with the result that substantial liabilities fell to the taxpayers. The Japanese program has been shaken by highly publicized safety scandals and has yet to examine its reprocessing commitment in the context of its recent steps toward allowing customer choice in its electric markets.[23] It is

[22] See for example "A very big French turnoff", The Economist, July 3, 2004, describing EDF as "a group that has used some questionable accounting practices; that has never really made a profit; that has made imprudent use of funds set aside for nuclear decommissioning and waste management; that lacks transparency over the level of its nuclear provisions; and that has indulged in a reckless and costly strategy of international expansion".

[23] See, for example, "Progress Underway in the Liberalization of Electric Rates", Associated Press, December 3, 2004. This article noted that a third of the large office buildings in Tokyo were buying their power from a supplier other than the traditional utility, TEPCO. The new suppliers were primarily cogenerating industries. As TEPCO's executive officer in charge of sales put it, "We have no chance to

difficult to see major new commitments to nuclear power in either of these bellweather countries until their electric industries have come to terms with the realities of competition and the economics of reprocessing.

Only Finland appears to have chosen a new nuclear unit in recent years through a transparent competitive process involving private capital. Finland ranks first in the world on Transparency International's annual index of the perceived honesty of governmental decisionmaking[24], so that country's choice of a new nuclear unit might appear to refute those who would relegate nuclear power to autocratic energy regimes, but the appearance of open competition is somewhat deceptive.

Finland did indeed decide in December, 2003 to go forward with a 1600MW nuclear plant built by Areva and Siemens. The decision to build a new nuclear unit instead of another type of plant was approved by Finland's Parliament some 18 months earlier. This decision was based on a study of the various alternatives rather than on competitive bidding. It was taken in part to reduce dependence on Russian natural gas and to achieve greenhouse gas emission reduction goals, both legitimate governmental concerns.

The winning bid for the plant has a turnkey price of "about 3 billion Euros" ($3.7 billion when the contract was signed, $4 billion a year later) for the plant plus the first fuel core, a training simulator and some infrastructure[25]. The study on which the decision to go

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win because enterprises newly participating in the electricity industry are certain to come up with lower rate proposals than us".

[24] http://www.transparency.org/cpi/2004/cpi2004.en.html#cpi2004.

[25] Nucleonics Week, December 9, 2004.

forward was made concluded that nuclear power would cost about 1830 euros/kWe, not far off of the turnkey bid, although the diminishing value of the dollar means that the winning bid's dollar value remains above $2000/kWe.

The study relied on by the government used very favorable assumptions to find in favor of nuclear power, including that that the plant would pay no income taxes and would be financed by 100% debt with a cost of 5%, none of which would be true for plants built in a true market environment.[26] Because the plant is a first-of-a-kind advanced pressurized water reactor that EDF hopes will become the basis for renewed nuclear development in Europe, the sellers have strong incentives to assume turnkey risks that they would not normally take on.[27] In addition, a coalition of renewable energy companies have filed a complaint with the European Commission accusing the project of receiving illegal state support in the form of low cost financing from banks and export credit agencies with governmental participation.[28]

[26] The Future of Nuclear Power, pp. 45 n. 13, 139.

[27] A turnkey bid means that the seller guarantees the bid price, perhaps subject to some agreed upon contingencies. Such bids were only used for nine early plants in the U.S., on which the vendors lost money. After that, the initial "bids" were merely estimates, with customers largely at risk for overruns. Although the turnkey plants produced substantial losses for the reactor vendors, they also produced a strategic victory, leading utilities to place a wave of ensuing orders that seemed to treat the turnkey bids as real costs. See Irving Bupp and Jean Claude Derian, Light Water: How the Nuclear Dream Dissolved, (Basic Books, New York, 1978), pp. 48-50, 69-82.

[28] "EC will investigate 'green power' complaint of state aid to TVO EPR", Nucleonics Week, January 13, 2005. According to the complaint, a loan covering 60% of the projected costs of the project carries an interest rate of 2.6%, less than half of the 6-7% that such a project would normally require. The lending bank is half owned by the Government of Bavaria. The complaint also notes that, a 610-million euro export credit guarantee from France's Coface, covering Areva supplies for the reactor, is the second-highest amount the bank has ever covered. Areva is the only company to be ever granted an export credit guarantee for a contract with a buyer from an EU member state. The complainants also place TVO's claim of a turnkey price of "about 3 billion Euros" at an actual figure of 3.2 billion.

When closely examined, the Finland decision bears little resemblance to a truly competitive power procurement. Other alternatives were excluded based on a study, not on competitive bidding. Nuclear costs – both in the study and in the bidding – were held down by artificially cheap financing and by turnkey arrangements unlikely to apply to many reactor sales. Private investor equity capital is not directly at risk.

IIC. The Economics of Nuclear Power

Fundamental to nuclear power's problem in competitive markets is the fact that it is considerably more expensive than the alternatives. The most authoritative recent study of the U.S. experience and prospects[29] estimates the levelized cost of a new nuclear unit operating at an 85% capacity factor[30] to be 7 cents over 25 years or 6.7 cents over 40 years. The comparable numbers for coal are 4.4 cents and 4.2 cents. For natural gas the 25 year figures range from 3.8 cents with low gas prices to 5.3 cents with high prices[31]. The forty year figures were 3.8 and 5.6 cents. In short, nuclear power is not close to being competitive with its two major fossil competitors.[32]

[29] The Future of Nuclear Power, supra, note 17. This study, unlike the many articles and other documents hailing a nuclear revival makes a real effort to analyze nuclear economics using the "assumptions that commercial investors would be expected to use today, with parameters based on actual experience rather than engineering estimates of what might be achieved under ideal conditions…"(p. 7).
[30] Recent U.S. capacity factors have been **xxxx**. Elsewhere, they have generally been lower.
[31] The study was done in 2003. Today's gas prices are at the high end of the study range, and coal prices are about 20% above the study forecast.
[32] Oil is presently used for only 2% of U.S. electric generation, which means that nuclear power has little potential to displace oil at all, to say nothing of Middle Eastern oil, which is not used in U.S. power generation. Nuclear power's only substantial contribution to oil displacement will come in regions in which the natural gas displaced by nuclear power can penetrate further into oil's share of markets, such as space heating in New England.

This study does not evaluate energy efficiency, renewable energy or coal gasification combined with sequestration of the greenhouse gases as alternatives to future nuclear development. About aspects of this omission, Amory Lovins asserts

> In round numbers, electricity from new light water reactors will cost twice as much as from new wind farms, five to ten times as much as from distributed gas-fired cogeneration or trigeneration in buildings and factories (net of the credit for their recovered heat) and three to thirty times as much as energy efficiency that can save most of the electricity now used. Any one of these three abundant and widely available competitors could knock nuclear power out of the market, and there are three, with more on the way (ultimately including cheap fuel cells).[33]

In fact, nuclear power has generally been displaced not by any one option but by fluid combinations of alternatives that combine to meet and to conserve away the energy demand that nuclear power can only satisfy at higher prices.[34]

The authors of the MIT study recognize that nuclear power is too expensive to succeed under present competitive conditions.[35] However, they conclude also that a combination of "plausible but unproven" cost cutting measures can lower nuclear power costs to levels competitive with gas in the high cost case and with coal (assuming that coal achieves no such improvements). These measures are 1) reducing the cost of constructing a nuclear

[33] Amory Lovins et al, Winning the Oil Endgame: Innovation for Profits, Jobs and Security, (Rocky Mountain Institute, 2004), p. 258.

[34] A study done for the European Bank for Reconstruction and Development on whether completing two partially built nuclear power plants represented the best use of EBRD funds promised in return for the closing of the Chernobyl plants describes this process as it might play out in much of the former Soviet Union. The study concluded that a much cheaper package of alternatives – including industrial energy efficiency, reducing losses in electric and gas transmission, and improving operation of existing coal and nuclear units – represented a far more effective use of the available funds. John Surrey and Steve Thomas, "The Chernobyl Replacement Project", Energy and the Environment, vol. 10, no. 3, 1999. After years of debate, Ukraine completed the nuclear units, though with greatly reduced EBRD participation.

[35] "The bottom line is that with current expectations about nuclear power plant construction costs, operating costs and regulatory uncertainties, it is extremely unlikely that nuclear power will be the technology of choice for merchant plant investors in regions where suppliers have access to natural gas or coal resources. It is just too expensive. In countries that rely on state owned enterprises that are willing and able to shift cost risks to consumers to reduce the cost of capital, or to subsidize financing costs directly and which face high gas and coal costs, it is possible that nuclear power could be perceived to be an economical choice". The Future of Nuclear Power, pp. 40-41.

unit by 25% from the base case estimate of $2000/kWe; 2) reducing construction times from five to four years;[36] 3) eliminating regulatory, construction and operating cost uncertainties so as to allow nuclear projects to raise capital on the same terms as new coal or gas (eliminating the estimated difference of 3% at 15% for nuclear versus 12% for the other two);[37] and 4) reducing the already much improved nonfuel operation and maintenance expenditure by another 25%. If all of these are done, nuclear power is still not less costly than coal, though it does beat natural gas in the high and intermediate price cases.

The MIT study also analyzes the implications for nuclear power of decisions imposing additional costs on fossil fuels in order to mitigate climate change.[38] As Table 5.1 from the study[39] shows, at carbon taxes (or measures imposing equivalent costs) between $50/tC and $200/tC[40], nuclear power surpasses coal and, in some of the price cases,

[36] The Finnish nuclear power plant is scheduled to begin construction in early 2005 and commence operation in May, 2009. If achieved, this schedule would be exceptional for a large first-of-a-kind reactor.
[37] In less developed countries, where capital recovery over long periods can be problematic, the gap between capital costs for new nuclear power and other forms of generation would probably be larger.
[38] Those opposed to relying on nuclear power to mitigate climate change point out that a number of activities associated with nuclear energy – especially the enriching of uranium fuel – require large amounts of energy that is likely to come in substantial part from fossil fuels and therefore to result in the release of greenhouse gases. However, properly designed regimes to reduce climate change would increase the cost of such processes and impose this cost on the eventual competitive position of nuclear power itself. So no special effort to trace such emissions seems necessary except in a context in which special assistance for nuclear power as a "nonfossil" energy source is being sought.
[39] p. 42
[40] "The [$50/tC] value is consistent with an EPA estimate of the cost of reducing U.S. CO_2 emissions by about 1 billion metric tonnes per year. The $100/tC and $200/tC values bracket the range of values that appear in the literature regarding the costs of carbon sequestration…These hypothetical taxes should be thought of as a range of "backstop" marginal costs for reducing carbon emissions to meet aggressive global emission goals. The Future of Nuclear Power, p. 42. Note however that the Commission on National Energy Policy proposes a carbon cap-and-trade program with costs capped at $7/tC in 2010 and escalating at 5% per year thereafter. They estimate that this program will produce a reductions between .5 and 1 billion tons per year in U.S. carbon emissions by 2020. Ending the Energy Stalemate: A Bipartisan Strategy to Meet America's Energy Challenges, Commission on National Energy Policy, December 2004, p. 23. This study also reflects estimates of the cost of carbon-eqsuivalent reduction under the McCain-Lieberman bill ranging between $9 and $16 per ton. If these estimates are credible, carbon taxes of $50/tC

natural gas. If the nuclear cost reductions are also achieved, nuclear power surpasses both fossil fuels in all cases. But, as noted earlier, the MIT study chose not to look at energy efficiency, distributed generation or combinations thereof. It also did not take account of possible low carbon emitting ways to use coal that might become economical as carbon constraints increased or at scenarios in which natural gas played a role in displacing coal.

Table 5.1 Costs of Electric Generation Alternatives
Real Levelized Cents/kWe-hr (85% capacity factor)

Base Case	25-YEAR	40-YEAR
Nuclear	7.0	6.7
Coal	4.4	4.2
Gas (low)	3.8	3.8
Gas (moderate)	4.1	4.1
Gas (high)	5.3	5.6
Gas (high) Advanced	4.9	5.1
Reduce Nuclear Costs Cases		
Reduce construction costs (25%).	5.8	5.5
Reduce construction time by 12 months	5.6	5.3
Reduce cost of capital to be equivalent to coal and gas	4.7	4.4

Carbon Tax Cases (25/40 year)	$50/tC	$100/tC	$200/tC
Coal	5.6/5.4	6.8/6.6	9.2/9.0
Gas (low)	4.3/4.3	4.9/4.8	5.9/5.9
Gas (moderate)	4.6/4.7	5.1/5.2	6.2/6.2
Gas (high)	5.8/6.1	6.4/6.7	7.4/7.7
Gas (high) advanced	5.3/5.6	5.8/6.0	6.7/7.0

will be hard to achieve unless the issue of climate change takes on urgency beyond anything now appearing likely in the U.S.

Nuclear power is unlikely to be able demonstrate favorable economics to potential investors for at least twenty years if it must proceed under present market rules. No nuclear power plant applications are pending in the U.S. or in Europe other than Finland. The U.S. Department of Energy has recently moved its target for a new nuclear unit from 2010 to 2014. That plant and others will have to operate for some time before they will have demonstrated their capabilities.

A number of the potential cost reductions depend on standardization, but standardization cannot occur without several plants coming on line per year. A plant every year or two can neither demonstrate nor support a program of standardized plant construction, especially if the orders are divided among more than one reactor design. The best that can be said of savings in this category is that they will be demonstrated at least twenty years from now and therefore cannot be the basis for a large scale nuclear revival before then.

To accelerate this process the MIT authors and other proponents of nuclear power[41] advocate a range of incentives designed to help defray licensing costs and encourage the construction and operation of the first few nuclear power plants. In addition to production tax credits, these measures include construction loan guarantees and requirements to assure that the power will be purchased.

[41] See, for example, Ending the Energy Stalemate: A Bipartisan Strategy to Meet America's Energy Challenges, supra, note 40, p. xii, stating "Government intervention to address these issues and to improve prospects for an expanded, rather than diminished, role for nuclear energy is warranted by several important policy objectives, including reducing greenhouse gas emissions, enhancing energy security, and alleviating pressure on natural gas supplies from the electric-generation sector".

Finally, of course, proponents of nuclear energy are encouraged by recent surges in oil prices, with their upward pull on other fossil fuels. To the extent that nuclear power lessens demand pressure on these other fuels (it does not do so for oil), it may help somewhat in reducing price volatility. However, short term price fluctuations are no basis for investment in a technology with the long-term capital recovery prospects of nuclear power. This is a lesson that should endure from the price spikes of the late 1970s, much higher in real terms than anything seen in 2004. At that time, projections that the price of oil would reach $150 per barrel by the end of the century resulted in continued construction of many nuclear plants that were later cancelled or that produced expensive surplus power when oil prices fell in the 1980s. Investors whose returns depend on competing successfully with fossil fuels will not underwrite nuclear power until they are assured that profitable price relationships rest on something solider than a couple of years trading conditions in a market dominated by an erratic monopolist.[42]

III. Political Support for Nuclear Power in the U.S.

Nuclear power, at least in the form of light water reactors, has enjoyed strong political support in the U.S. federal government since its inception. That support is particularly strong in the present administration and in Congress. The Bush administration energy plan contains a strong endorsement for nuclear power and even for efforts to revive the reprocessing initiatives originally set aside by the Ford administration.

[42] For refutations of the view that sustained world oil shortage is imminent, see José Goldemberg and Thomas B. Johansson, World Energy Assessment Overview: 2004 Update pp. 45-46, and M.A. Adelman, "The Real Oil Problem", Regulation 27, no. 1 (2003), http://web.mit.edu/ceepr/www/R2004-171.pdf.

However, political support and successful times for nuclear power have not been closely linked in the U.S. Indeed, if history is any guide, nuclear power is better off without the renewed outpouring of political support that it is now getting in the administration and in the Congress. Nuclear power's performance has improved steadily during the years when it has been out of the headlines. It has done worst when it is the centerpiece of a presidential energy plan.

Here is the record:

In the early 1970s, when the U.S. had a dozen nuclear power plants, the Atomic Energy Commission forecast that there would be 1000 more by the year 2000, an achievement that would have required the issuance of a construction permit or an operating license once a week for 30 years. It would also have required 20 plants per state, or – to pay attention to where the plants would actually have gone – several hundred plants on each coast.

The exuberant 1000 plant vision was incorporated in President Nixon's "Project Independence". Within a few years, it all went wrong. Because so many hopes were staked on so little operating experience and because so much pressure was placed on regulators to license "expeditiously", various mishaps (fires, pipe cracks, fuel failures and, in 1979, Three Mile Island) required long delays and expensive modifications in plants already half-built. The lasting lesson of Three Mile Island to the financial

community was that licensed NRC operators - not discernibly worse than their colleagues - could transform a two billion dollar asset into a one billion dollar billion cleanup job in 90 minutes.

When President Reagan took office in 1980, the head of the leading industry trade association described the industry's reaction as "halfway between ecstasy and euphoria".[43] Throughout the Reagan years (as well as the following administrations), the nuclear industry had a near veto power over appointments to the NRC, and the Commission's agenda converged ever more closely with that of the industry. In particular, opportunities for public involvement in the nuclear licensing process were cut back to the vanishing point.

If creating a more favorable regulatory and governmental climate had been the answer to nuclear power's problems, the Reagan changes would surely have stimulated a revival, if not immediately then as years rolled by without another accident even as serious as Three Mile Island in March, 1979. But in fact, the Reagan years were the worst in nuclear power's history. By the time President Reagan left office not only was a nuclear revival not in sight but Ralph Nader – the U.S.'s most durable and unyielding nuclear power critic - could count about half of his nuclear agenda to have been achieved.

The breeder reactor program and spent fuel reprocessing collapsed when Republicans who believed in markets insisted that private investors bear some of the risks and no private investors were willing to do so. Despite zealous trimming of the few

[43] Walske **Cite**

opportunities for meaningful public involvement in the licensing process, no new nuclear plants were ordered. Many more plants were canceled than licensed, leaving a financial landscape dotted with nine-figure cancellations and cost overruns. Every northern tier state from Maine to Illinois was involved in at least one. So was every state in a crescent from Mississippi to Washington. Many of the plants that were completed cost several times the original estimates and had significant impacts on electric bills of the companies trying to build them[44]. The estimated date for the opening of a repository for disposal of nuclear waste slipped from 1985 to 1998, and the search for a second repository was abruptly canceled in 1986 in the face of anticipated political reversals in the several states under consideration.

The first President Bush took office pledging to end obstructionist state objections to the few remaining unlicensed plants. His Energy Secretary, James Watkins, chose to draw a line in the sand over New York's 1989 decision to retire the Shoreham nuclear plant because the state and the utility saw little or no benefit to operating it and because Governor Cuomo felt that Long Island could not be effectively evacuated in an emergency.

The U.S. Court of Appeals' reaction when it tossed the Secretary's lawsuit: "The government is seeking to turn a license to operate Shoreham into a sentence to do so".

[44] The champion cost overrun occurred at the Shoreham nuclear plant in New York, where the Long Island Lighting Company had in 1968 estimated the cost of the 8**xx** MW plant to be **xxx** million dollars. The ultimate cost of the plant when it was completed twenty years later was $5.4 billion, about twenty times the original estimate. The plant never went into commercial operation and was sold to New York state for $1 in 1989. The estimates of both Lilco and the New York state agency charged with setting electric rates was that the present value of running and of not running the plant was just about the same. No other nuclear plant overran its original cost estimate by a factor of twenty, but several did so by a factor of 10 or more.

Secretary Watkins learned from the Shoreham experience. His National Energy Plan, issued after extensive public hearings, was favorable to nuclear power, but he had long since stopped touting it. Instead, his Department of Energy supported planning processes and competitive power markets in which new nuclear units had to match the cost of alternatives.

None did, but gradually, quietly, throughout the 1990s the discipline of competitive pressure brought the costs of the existing plants down, and their outputs up. For the most part, their safety records also improved, though cost cutting led to unsafe conduct at Connecticut's Millstone plants and a few others. For the first time, companies were prepared to take the financial risk (albeit subsidized by the federal limit on their liability for accidents) of operating nuclear units without the guarantees of a regulated price. A long-needed reorganization of nuclear ownership concentrated many of remaining plants in more capable hands and organizations.

In short, nuclear power seemed to be outgrowing its status as an uncompetitive technology dependent on subsidy, presidential cheerleading, and licensing shortcuts. Its place in the nation's energy picture had fallen from the one thousand reactor dream to an actual 103 power plants generating some 20% of our electricity, not a trivial achievement for an industry that had not existed forty-five years earlier.

This positive turn was no coincidence. The absence of continuous, high pressure public clamor permitted sober reassessments. Improvement no longer fueled criticism of existing standards. Nuclear power was on its way to becoming a real business.

So the last thing nuclear power now needs is another crusade that will restore its image as a specially privileged technology dependent on shortcut and subsidy. Where such federal enthusiasms are likely to be felt is in the quality of NRC safety reviews and Congressional oversight. Once again, as observed in all of the reviews of the conditions that created the accident at Three Mile Island, careers may come to depend on speeding things up. Those who raise questions will be treated as nuisances. Everything, it will be said, is safe enough already. This need only lead to one serious mishap for a quiet decade of constructive nuclear power progress to come undone and for any prospective benefit from improved future nuclear plants to vanish over the horizon.

IV. Conclusion

Seen in the light of the history of the U.S. nuclear program, the premises underlying the current "revival" forecasts for nuclear power seem more like a confession of failure. After building 112 power plants and canceling as many more, after benefiting from incalculable government support in military programs as well as research, tax incentives and charges to customers, after "streamlining" the most prolific nuclear licensing process in the world to the point that no serious points of skeptical intervention remain, after a decades long effort to shoehorn the spent fuel into Nevada, what exactly does the U.S.

"revival" consist of? Do we have the "mature" industry whose years of experience have been used to justify regulatory curtailments of many sorts stepping forward to say that this same maturity has persuaded private capital to back new nuclear units in competitive power supply markets?

Not exactly. The "revival" rests on the following pillars: 1) DOE will share half of the expenses of obtaining the necessary site permits and reactor licenses; 2) proposed construction financing guarantees; 3) proposed tax deductions of 20% on the cost of building new reactors; 4) a proposed tax credit of 1.8 cents per kWh for all electricity actually generated; 5) $1.8 billion dollars earmarked to assist the construction of "advanced" reactor designs; 6) The NRC licensing process will not permit the need for the power from the new plants to be challenged and will also exclude all challenge based on the uncertainty of the waste situation.

In short, nuclear power's asserted comeback rests not on a newfound competitiveness in power plant construction, but on an old formula: subsidy, tax breaks, licensing shortcuts, guaranteed purchases with risks borne by customers, political muscle, ballyhoo and pointing to other countries (once the Soviet Union, now China) to indicate that the U.S. is somehow "falling behind". Climate change has replaced oil dependence as the bogeyman from which nuclear power will save us.

Nor are nuclear power's prospects brighter in other countries. The fiction that the industry's problems in the U.S. were caused entirely by a whimsical licensing process

that permitted undue litigation – and that nuclear power is thriving elsewhere – is out-of-date, to say the least. The countries building new plants are doing so through processes that are neither truly competitive nor truly transparent, and the same is true of the few countries (Turkey, Belarus, Vietnam, perhaps Poland) that are talking seriously of joining the nuclear power club.

The likelihood of large numbers of new nuclear units being built on the basis of favorable economics over the next twenty years seems very slight. Nuclear power is not competitive today, and the measures necessary to make it so are not firmly in place anywhere. Beyond twenty years, few people with a sense of energy policy history would venture such a prediction with high confidence, but technological developments and breakthroughs favorable to other fuels and technologies seem no less likely than those favoring nuclear power[45].

As competitive power supply markets and improved governance processes spread inexorably throughout the world, the closed processes through which nuclear power was chosen, with an assurance that the customers would pay for uneconomic decisions, is receding. For nuclear power to succeed in the new environment, it must achieve major cost cuts, avoid even one serious accident, resolve the waste storage and disposal issue in an enduring way, sever its remaining links to proliferation of nuclear weapons and get the

[45] One nuclear technology whose development horizons push it beyond the scope of this paper are various new gas cooled reactor designs. Several versions are under possible development, including the South African "pebble bed" the General Atomics GT-MHR and the Chinese HTR. They have potentially attractive safety features and can be built in smaller modules than the advanced light water designs now under development, but it is far too early to tell whether they can improve nuclear power's competitive prospects.

benefit of its status as a lower carbon-emitting power source. Even if all of these things occur over the next decade, success is not assured. In particular, the cost of a nuclear station spent instead on energy efficiency would free up more energy and produce more of every other societal benefit than would a nuclear unit. None of the studies extolling an immediate rush to nuclear construction come to terms with this fact, but – as has happened before – the real commercial world has a way of bringing it on.

A disturbing but inevitable side-effect of nuclear power's need to cut costs is that it will resist costs of all kinds, including safety and safeguards. Competition policy, like safeguards policy, works best when it relies on structural solutions rather than pervasive policing. Because such solutions tend to be less expensive for the industry as a whole – though not for those who seek an edge through cutting it close – the industry itself would be wise to support such measures as centralized waste and enrichment facilities.

The slow pace of any widespread resurgence of nuclear power is bad news for those who see this technology as key to combating climate change, but it is good news for those concerned with the proliferation of nuclear weapons. In particular, both the centralization of spent fuel storage and disposal as well as the inadequacies of the existing safeguard system to deal with the proliferation potential of enrichment facilities and reprocessing plants can be addressed without fear of constraining the accelerated growth of nuclear power in competitive markets in countries now without nuclear weapons. That isn't going to happen soon in any case.