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Nuclear Power

THE MISPLACED HYPE

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Nuclear Power : The Misplaced Hype

Published in Public Interest by

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Contents

PREFACE

The issue of increased generation of Nuclear Power has assiduously been pushed to the forefront of the Energy scenario by the Government of India. Way back in 2002, the government had announced an ambitious plan for producing 20,000 MW of nuclear power by the year 2010, including generation from dual-use Fast Breeder Reactor technology. But the plan could not be realized. Earlier, the government in 1983 estimated that by using 73,000 tones of uranium reserves, India could produce 10,000 MW of nuclear power till 2000 but the country could only produce 2,720 MW of nuclear power till 2003 and hence the 10, 000 MW target was revised to 2010. Undaunted by the continuous failures, the government again set the target to generate 20,000 MW of nuclear power by 2020. Hawking for more Nuclear Energy, the Tenth Five Year Plan (2002-07) said, "...to aggressively build capabilities and capacity in nuclear power to progressively raise its share in India's fuel mix." Though since 2004 the target for nuclear power has been to provide 20 GWe by 2020, but in 2007 the Prime Minister referred to this as "modest" and capable of being "doubled with the opening up of international cooperation.

Similarly, Planning Commission's draft of India's Integrated Energy Policy released in 2006 says the following:

"Nuclear Energy theoretically offers India the most potent means to long term energy security. India has to succeed in realising the three-stage development process and thereby tap its vast thorium resource to become truly energy independent beyond 2050. Continuing support to the three-stage development of India's nuclear potential is essential. With meager availability of Uranium in the country and vast resources of Thorium, any long-term nuclear strategy has to be based on Thorium. The three stage strategy of development of nuclear power from pressurized heavy water based reactors to fast breeder reactors to thorium based reactors requires a sustained R&D effort. Success in these efforts could deliver some 2,50,000 MW of nuclear power by 2050 and much more thereafter. Given the limited resources of oil, gas and uranium, solar energy and thorium based nuclear option are the only two sizeable sources (apart from fusion) of energy for the country. Thus, the thorium option must be pursued. Failure to economically develop India's Thorium based nuclear potential to the fullest will significantly increase India's dependence on domestic and imported coal. Nuclear power will not only enhance energy security but also yield rich dividends by reducing carbon emissions."

Late in 2008 NPCIL projected 22 GWe on line by 2015, and the government was talking about having 50 GWe of nuclear power operating by 2050. Then in June 2009 NPCIL said it aimed for 63 GWe nuclear by 2032, including 40 GWe of PWR capacity and 7 GWe of new PHWR capacity, all fuelled by imported uranium. The Atomic Energy Commission however envisages some 500 GWe nuclear on line by 2060, and has since speculated that the amount might be higher still: 600-700 GWe by 2050, providing half of all electricity.

So the government has continuously been making tall projections while the reality has been quite different. Installed capacity in 1979-80 was about 600 MW, in 1987 about 950 MW and in 2000 just 2720 MW. In late 2009 the government said that it was confident that 62 GWe of new capacity would be added in the 5-year plan to March 2012, and best efforts were being made to add 12.5 GWe on top of this, though only 18 GWe had been achieved by the mid point of October 2009, when 152 GWe was on line.

These continued failures to meet the targets were not due to paucity of funds, as almost all the governments occupying the seat of power at the centre have favoured nuclear energy and hence budgets for the Department of Atomic Energy have always been full with high allocations.

In fact we are in habit of setting high goals for us without putting in the matching efforts to realize them. Such is our obsession with creating hype that we often fall into the trap of hyperbole. This can be seen in Homi J Bhabha announcing in 1950s that there would be 8000 MW of nuclear power in the country by 1980 and then the predictions started increasing with each passing year. By 1962, the prediction was that nuclear energy would generate 20-25,000 MW by 1987 and by 1969 the Atomic Energy Commission predicted that by the year 2000 nuclear generation capacity would reach 43,500 MW. All these predictions were made before a single unit of electricity was produced in the country. Even today, despite over five decades of sustained and lavish government support, nuclear power constitutes just 3 per cent of the country's electricity generation capacity. Thus it can be said that a ***Myth*** is being created as far as the nation's capacity to generate nuclear power is concerned.

In fact a number of ***Myths*** are in circulation about the need, cost and impacts of nuclear energy. Of late, it is being promoted globally on the count of being cheap, clean, competitive, secure, reliable, vital for fuel security and essential for climate protection. Whereas 'The Economist' observed in 2001 that "Nuclear Power, once claimed too cheap, is now too costly to matter-cheap to run but very expensive to build. Since then, it has become several fold costlier still to build - and in a few years, as old fuel contracts expire, it is also expected to become several-fold costlier to run." It is said that in 1970s and 1980s, the US experience with nuclear construction was quite dismal, as was observed by Forbes - It was" the largest managerial disaster in US business history, involving 100 billion dollars in wasted investments and cost overruns." Similar had been the experience of countries like Canada, Britain, Germany, France, Japan, and the Soviet Union who also suffered substantial nuclear-cost escalation, and their nuclear construction forecasts collapsed in similar fashion.

Scientists Amory B. Lovins and Imran Sheikh, thus, observed in 2008 in an article published in AMBIO, an international journal - "The case for nuclear power to protect the climate and enhance the security is purely rhetorical and can not withstand analytic security. The supposed nuclear revival is a carefully manufactured illusion that seeks to become a self-fulfilling prophesy, yet it can not actually occur in a market economy, as many energy-industry leaders privately acknowledge."

We bring here a few summarised opinions analysing and exposing the 'Reality' of much applauded Nuclear Power. Besides, chapters 7 & 8 give in details the Nuclear scenario in India and US.

Piyush Pant
Manidipa Baul

1

The Nuclear Illusion

By Physicist Amori B. Lovins and Research Scholar Imran Sheikh

Published in AMBIO, A Journal of Royal Swedish Academy of Sciences, Sweden on Human Environment, November 2008

(A widely heralded view holds that nuclear power is experiencing a dramatic worldwide revival and vibrant growth, because it's competitive, reliable, secure, and vital for fuel security and climate protection. Whereas the fact is that nuclear power is continuing its decades-long collapse in the global marketplace because it is grossly uncompetitive, unneeded, obsolete and so uneconomic that one need not debate whether it is clean and safe; it also weakens electric reliability and national security; and it worsens climate change compared with devoting the same money and time to more effective options.

Longtime nuclear commentator Watler C. Patterson noted in 2006 that "those suffering from nuclear amnesia have forgotten why nuclear power faded from the energy scene in the first place, how many times it has failed to deliver, how often it has disappointed its most determined advocates, how extravagantly it has squandered unparalleled, unstinting support from taxpayers around the world, leaving them with burdens that may last for millennia.)

A quick look at the track record

At the end of 2007, the world had 439 operating nuclear stations totaling 372 GW (billion watts)of net generating capacity with an average age of 23 years - a year older than the 117 reactors already shut down. The International Atomic Energy Agency (IAEA) says 31 nuclear units were under construction in 13 countries - eight more than at the end of 2004. All but five were in Asia or Eastern Europe; yet the Asian Development Bank has never financed one, and reaffirmed this policy in 2000, nor has the World Bank. Much of the reported activity is not new: of the 31 units listed as under construction, 12 have been so far at least 20 years, some were started in the 1970s, and two long-moribund projects have been relisted.

The economic evidence confirms that new nuclear power plants are unfinanceable in the private capital market because of their excessive costs and financial risks and the high uncertainty of both. During the nuclear revival now allegedly underway, no new nuclear project on earth has been financed by private risk capital.

The Economist observed in 2001 that "Nuclear power, once claimed too cheap, is now too costly to matter" - cheap to run but very expensive to build. Since then, it has become several-fold costlier still to build - and in a few years, as old fuel contracts expire, it is also expected to become several-fold costlier to run. US nuclear operators' impressive success in improving reliability and performance have been unable to offset prohibitive capital costs. To de-emphasize this hurdle, the industry emphasizes its low operating costs, often comparing the cost of just running plants already built with the total costs of building and operating other kinds of new plants. The term 'generating costs' or 'production costs' widely used in such misleading comparisons, refers to bare operating costs without capital costs for construction or for major repairs.

The nuclear industry has consistently underestimated its capital costs, often by large factors, and then claimed its next low forcasts will be accurate. Of 75 US plants operating in 1986, the US Energy Information Administration found two-year-cohort-average cost overruns of 209-382%. This bankrupted a New Hampshire Utility. In the Northwest, the Washington Public Power Supply System (WPPSS) fiasco caused the biggest-ever US municipal bond default ($2.25 billion), saddled the Bonneville Power Administration with a $6-billion debt, and raised wholesale electric rates more than 500%.

The US experience with 1970s and 1980s nuclear construction was uniquely dismal - as Forbes put it, " the largest managerial disaster in US business history, involving $100 billion in wasted investments and cost overruns". The economic failure is the main reason why no US nuclear plant ordered after 1973 was completed, and all orders placed since 1978 and 48% of all 253US orders ever placed were cancelled. Moreover, no new orders have yet been placed: recent license applications are placeholders in the queue for subsidies, but are not orders and are not yet financed. The industry blames its US disappointments chiefly on citizen intervention. Some other countries with big nuclear programmes, such as Canada, Britain, Germany, France, Japan, and the Soviet Union, also suffered substantial nuclear-cost escalation, and their nuclear construction forecasts collapsed in similar fashion.

What would new nuclear plants cost?

In 2003, a prominent MIT team published an independent and evidence-based economic analysis. It found that new nuclear plants could not compete with new central power plants burning coal or natural gas, though the gap might be considerably narrowed by high carbon taxes plus, if effective, and huge subsidies for the next half dozen US nuclear units to be built.

In June 2007, a Keystone Centre group sponsored by eleven organisaions- nine of which sell, buy, or are allegedly about to buy nuclear plants - raised the MIT study's nuclear cost estimates from 7.7-9.1c/kWh to 8.3-11.1c/kWh. This was mainly due to rapidly escalating capital costs, and due to long-mismanaged uranium and enrichment activities. A leading trade journal Nuclear Engineering International remarked that the industry's choice "to either focus on other aspects - in particular the finding that nuclear is a viable option for dealing with climate change - or ignore the Keystone report altogether" is "anomalous, and suggests a certain amount of discomfort with the findings". For instance, the Nuclear Energy Institute continues deliberately to misrepresent the Keystone findings.

Since the Keystone findings, new nuclear plants' uniquily rapid capital - cost escalation, far from abating, has accelerated. In September 2007, Lew Hay, CEO of FPL Group, said the total cost of a new nuclear plant could be ~ $5000 - 7000/KW, or, "on the order of magnitude of $13 to $14 billion" for a two-unit plant. Yet just five month later in early 2008, FPL filed formal cost estimates up to nearly twice that high -- $ 22-24 billion for a 2.2 - 3.04-GW two-unit plant, equivalent to $4,200-6,100/KW in 2009 dollars. Even that cost may be understated, because FPL's implicit cost escalation rate is ~1.1 - 1.%/ y, severalfold slower than recent experience.

Five months earlier, when Mr. Hay thought FPL's plant would cost $10 billion less than the high end of that range, he warned even $13-14 billion is "bigger than the total market capitalization of many companies in our industry with exception of Exelon". In June 2007, the Nuclear Energy Institute told the US Department of Energy that the largest US electric company, with a market cap "in the $40 billion range" would be hard pressed to finance even a $5-6 Billion nuclear plant without Federal loan guarantees. In 2008, any buyer who still projects such low costs appears to be headed for nasty collision with reality.

Why are nuclear costs rising so rapidly?

Rising actual prices for commodities like steel, copper, and cement are often blamed for nuclear power's uniquely rapid capital-cost escalation, but do not actually appear to be a factor. The real cause for escalation of costs for nuclear power is severe manufacturing bottlenecks and scarcities of critical engineering, construction, and management skills that have decayed during the industry's long order lull. These bottlenecks and scarcities have put the flagship new-build project - Finland's Olkiluoto-3 reactor - at least 24 months behind schedule after 28 months' construction, at least 50% over budget (losing the fixed-price builders at least 1.5 billion euro and customers twice that), and harshly criticized by the Finnish nuclear safety regulator. The industry has deftly shifted from describing the project as plain proof of the superiority of advanced reactors to a normal case of the unique challenges of building first-of-a-kind plants. But even competitors are anxious that "If the nuclear industry does not deliver this time, there will not be third time", and that Olkiluot-3 is already contradicting rosy forecasts and starting to be seen as evidence that " the nuclear industry cannot deliver" on even one new plant.

The construction challenges driving cost escalation are most formidable in the United States, currently the world leader in nuclear-revival rhetoric. US nuclear manufacturing went from ~400 suppliers and 900 certifications in the 1980s to fewer than 80 and 200 today.

Nuclear workers are becoming scarce too. What the World Nuclear Industry Status Report 2007 calls "rapid loss of (construction and operating) competence and lack of manufacturing infrastructure" is not the only obstacle. The nuclear industry and utilities face challenges in a radically changing industrial environment. Today the sector has to deal with waste management and decommissioning expenses that far outweigh estimates of the past, it has to compete with a largely modernized gas and coal sector and with new competitors in the new and renewable energy sector.

Further, many countries now expose builders to the risks of free-market competition - both with micropower and with efficient use of electricity-rather than shielding investors via traditional utility rate-basing. Enthusiasm is no basis for guarantee of market success: high-flying US merchant builders of combined-cycle gas-fired plants recently wrote off about $100 billion worth of plants they have built for which there was no demand.

Nuclear plants worldwide enjoy unique legal exemption from liability for catastrophic accidents. The United States even offers its next half-dozen nuclear plants with new federal insurance against regulatory delays, even though meaningful public participation in licensing has already been virtually eliminated.

A further issue arises in states that still rate-base new power plants: financial comparisons between power plants typically use levelized costs, but utility customers would feel sticker shock. A 'death-spiral' of rising price and falling demand may ensue because customers now have more choices than just buying ever more grid electricity: they can vote by buying less electricity, more efficiency, and more onsite generation-all now becoming widely available.

The investors' appropriate concerns about the financial risks posed by its high cost, long lead time, and the uncertainty of both have already stifled nuclear investment. Yet the capital markets have not yet understood an even greater risk: that nimbler competitors with lower and decreasing costs could grab nuclear projects' revenue. So even if construction went as planned, the costly nuclear electricity may not sell, let alone continue to sell for the decades required to repay and reward nuclear investors. Whether or not the utility is traditionally regulated, customers can at any time buy more efficient lights, motors, appliances, buildings, and industrial equipment if efficiency looks cheaper than the kilowatt-hours they are offered.

But regardless of market preferences, should governments encourage or require the revival of nuclear power to help combat the menace of climate change? Is nuclear, as claimed, the only big, fast, proven way to combat global warming? Or could it make climate change worse than if other options were bought instead?

Generating electricity causes two-fifth of US and more than one-third of global fossil-fueled carbon dioxide emissions, which in turn are about three-fourth of total carbon dioxide emissions, excluding the additional effects of other greenhouse gases. Nuclear power's potential climate solution is further restricted by its slowness of deployment and its higher relative cost than nearly all competitors, per unit of net carbon dioxide displaced, means that every dollar invested in nuclear expansion will worsen climate change by buying less solution per dollar.

Coal is by far the most carbon-intensive source of electricity, so displacing it is the yardstick of carbon displacement's effectiveness. A kilowatt-hour of nuclear power does displace nearly all the 0.9-plus kilograms of carbon dioxide emitted by producing a kilowatt-hour from coal. But so does a kilowatt -hour from wind, a kilowatt-hour from recovered-heat industrial cogeneration, or a kilowatt-hour saved by end-use efficiency. And all of these carbon-free resources cost at least one-third less than nuclear power per kilowatt-hour, so they save more carbon per dollar.

Combined-cycle industrial cogeneration and building-scale cogeneration typically burn natural gas, which does emit carbon, so they displace somewhat less net carbon than nuclear power could: around 0.7 kilograms of carbon dioxide per kilowatt-hour. With a net delivered cost per kilowatt-hour approximately half of nuclear's, cogeneration delivery twice as many kilowatt-hours per dollar, and therefore displaces around 1.4 kilograms of carbon dioxide for the same cost as displacing 0.9 kilograms of carbon dioxide with nuclear power.

Nuclear power, being the costliest option, delivers less electrical service per dollar than its rivals, so, not surprisingly, it is also a climate-protection loser, surpassing in carbon emissions displaced per dollar only centralized, non-cogenerating combined-cycle power plants burning natural gas at the relative prices assumed. Firmed windpower and cogeneration are 1.5 times more cost-effective than nuclear at displacing carbon. So is efficiency at even an almost unheard of 7c/KWh. Efficiency at normally observed costs beats nuclear by a wide margin -for example, by about ten-fold for efficiency costing one cent per kWh.

New nuclear power is thus so costly that shifting a dollar of spending from nuclear to efficiency protects the climate severalfold more than shifting a dollar of spending from coal to nuclear. Indeed, under plausible assumptions, spending a dollar on new nuclear power instead of on efficient use of electricity has a worse climate effect than spending that dollar on new coal power.

Whether existing nuclear plants have displaced and are displacing any carbon emissions, as is often claimed, depends on what assets would have been bought instead to generate the same electricity. Buying coal-fired plants instead would have released more carbon. But buying low or no-carbon micropower or megawatts instead would have released less carbon, because more of those cheaper coal-displacing resources could have been bought with the same money.

The nuclear industry is eager that the public does not understand this argument, which has not previously been explained in major public or business media in the US, and rarely elsewhere. Rather, the industry emphasizes its belief that properly pricing carbon will make nuclear power cost-competitive.

However, nuclear industry's increasingly explicit assumption that governments must guarantee an above-market-clearing carbon price sufficient to ensure nuclear power's competitiveness not only jettisons market logic and EU rules; it also reveals how thoroughly both the industry and those governments misperceive the competitive landscape.

How does the competitors' reliability compare with nuclear power's?

The nuclear industry's central stated reason for omitting renewable, such as windpower, from its list of admissible competitors with nuclear power is that windpower is not "24/7" or "reliable". Unlike some important sources of distributed renewable power that can be dispatched whenever desired, windpower do produce varying output depending on the weather. Technical reliability of single generating units is not the issue: modern wind turbines are ~98-99% available, far better than any thermal plant. A review of more than 180 European analyses through 2005 confirmed that windpower's variability is manageable at modest cost if renewables are properly dispersed, diversified, forecasted, and integrated with the existing grid and with demand response. Moreover, all sources of electricity are unreliable-to differing degrees, for differing reasons, with differing frequencies, durations, failure sizes, and predictabilities.

Research is increasingly showing that if we properly diversify renewable energy supplies in type and location, forecast the weather, and integrate renewable with existing demand and supply-side sources on the grid, then renewables' electrical supplies will be more reliable than current arrangements. Already today, in wind-rich regions of North Germany, Spain, and Denmark, variable renewable power production exceeds regional demand, and annually provides 20-39% of all electricity, with no integration problems nor significant integration costs.

Though micropower's unreliability is an unfounded myth, nuclear power's unreliability is all too real. Nuclear plants are capital-intensive and run best at constant power levels, so operators go to great pains to avoid technical failures. These nonetheless occur occasionally, due to corrosion, fatigue, and other wear and tear, Some nuclear power failures are major and persistent: of the 132 US nuclear units that were built and licensed to operate, 21% were permanently shut down because of intractable reliability or cost issues, while a further 27% have suffered one or more forced outages of at least a year.

Can nuclear power enhance energy security?

It also says that in this time of oil jitters, some political leaders conflate electricity with all forms of energy and suggest that nuclear power can help relieve oil dependence. This is fallacious. Nuclear power makes electricity, whose link to oil is extremely tenuous. Only 1.6% of US electricity in 2007 was made from oil and 1.6% of US oil made electricity; in the UK in 2006, it was 1.3% and 0.8% and globally in 2006 it was 7% and 7%; and falling virtually everywhere.

Though France has striven with unique fervor since 1974 to substitute nuclear power for oil, but when this shift began, less than an eighth of French electricity was made from oil. France today, making 78% of its electricity or 18% of its total delivered energy from nuclear power, consumes only one-tenth less fossil fuel than in 1973. Nuclear overcapacity has become a serious problem, requiring 'dumping' a dozen reactors, surpluses on neighbouring countries and even weekend shutdowns of reactors that can not sell their output. Moreover, France heavily promoted electric space-heating to create a market for the excess nuclear power, so the winter peak load is 55 GW higher than the summer one - three-fourths of the 71-GW nuclear capacity, but very uneconomic to meet with baseload plants- forcing France to reactivate 2.6 GW of very old oil-fired plants and to import very costly fossil-fueled winter peak power. And electric heat is so costly that about three-fourths of French households still heat with fossil fuels; heavy financial losses throughout the nuclear value chain have required massive taxpayer bailouts and still opaque subsidies.

Nuclear power is a very slow and costly way to displace gas-fired electricity, and has less domestic content and lower reliability than a diversified and integrated portfolio of renewable and efficiency resources. For the main use of gas - heating buildings, water, and industrial processes, and as a petrochemical feedstock-nuclear electricity is unsuitable technically or economically or both.

A common concern is that sustaining or increasing reliance on gas for generating electricity risks making gas scarce and costly. This could occur if gas, and gas-fired electricity, continued to be used very wastefully.

One more dimension of energy and security requires mention. It is proliferation. Commercial nuclear power is the biggest driving force behind the proliferation, providing do-it-yourself bomb kit in innocent-looking civilian disguise, all concealed within a vast flow of civilian nuclear commerce. Acknowledging nuclear power's market failure would unmask and hence penalize proliferators by making the needed ingredients harder to get, more conspicuous to try to get, and politically costlier to be caught trying to get, thus revealing the motive for wanting them as unambiguously military. This would make proliferation far more difficult, and easier to detect sooner by focusing scarce intelligence resources on needless not haystacks.

Therefore, nuclear power, then, cannot in principle deliver the climate and security benefits claimed for it.

Are nuclear power's new competitors already significant?

Nuclear power is promoted as the " only energy option available today that can provide large-scale electricity 24/7 at a competitive cost without emitting greenhouse gases". Each part of this case is false. As with the climate-protection claim, the truth is just the opposite.

Global industry and government data compiled annually by Rock Mountain Institute show that micropower surpassed nuclear power in 2006 in total electricity production, surpassed nuclear generation capacity in 2002, and is growing enormously faster. In 2005, global micropower provided one-fourth of the world's new electricity. In 2006, nuclear lost 0.2% or 0.75 GW of net capacity as retirements exceeded new units, offset this loss by 2.2 GW of upratings for a 1.44 GW net gain, and raised its output 1.3%. Yet in 2006, micropower added 43.4 GW, or 57.7 GW including peaking and standby units that can generally be made dispatchable. In the 21st century, nuclear power has remained stagnant while micropower has burgeoned.

Which power sources are faster to deploy?

Nuclear power is often claimed to be the only power source that can be deployed quickly enough to deal with urgent issues like climate change. For it to displace much coal-fired power would require an immensely larger nuclear industry: in perhaps the most ambitious vision, John Ritch, director-general of the World Nuclear Association, envisages a 20× nuclear expansion by 2100, starting with more than 1000 reactors in the next 25 years and 2000 to 3000 by 2050. Yet during 2004-07, global nuclear installations averaged just 1.5 GW/y, or about one big plant's worth per year. Nuclear power had only a roughly 2% share of global growth in electric generating capacity while windpower had 10%, all renewable 17%, and all micropower 28%.These empirical data contradict the claim that nuclear is fast and big while its non-central-thermal plant alternatives are small and slow.

What is the ultimate potential of nuclear power's new competitors?

The need for new nuclear build as part of a least-cost portfolio to meet the energy service needs of a dynamic national or global economy is often highlighted, but has no analytical foundation. Many careful analyses published over the past few decades show the opposite.

Consider China, which at the end of 2007 got 20% of its electricity from eleven nuclear plants and had by far the world's most ambitious nuclear target - 40 GW by 2020 exceeding China's 2030 windpower goal of 30 GW. Nuclear construction, currently five units totaling 3.3 GW, seems threefold slower than this schedule would require. Yet China's impressive and widely heralded nuclear ambitions have been far eclipsed by its little-noticed world leadership in distributed renewable.While China's nuclear expansion falters, partly due to escalating construction costs, its renewable expansion is rapidly accelerating. In 2007, windpower alone grew 3.4 GW to 6 GW, exceeding the 5-GW target for 2010. China's renewable industries stated in November 2007 that by 2020, 50 GW of windpower is likely under current policies, and with a supportive policy environment, 122 GW would be feasible. China's installed wind capacity doubled in 2006 alone, and in that year, China was the world's second biggest investor in renewable power, the world's third biggest photovoltaic producer, and the world's fifth largest windpower installer, rising quickly in all categories. In 2007, China's wind capacity grew another 156%; it has more than doubled in each year since 2004, surpassing even the most optimistic projections.

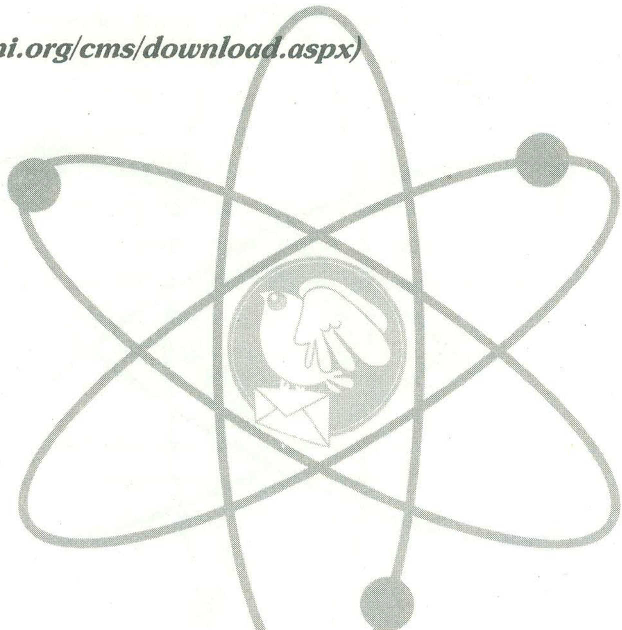
Renewables other than windpower, not yet counted, also have immense potential. Solar technologies are not resource-limited nor even, in practice, area-limited. In short, a world that is carbon-constrained but needs more electrical services has a large, diverse, and expanding menu of options. Choosing among them requires a balanced portfolio fitting appetite and wallet. The successful alternatives to nuclear are cheaper, bigger, and faster, so rational market choices of what to buy next won't favour a nuclear plant over a competitor with similar or better climate impacts, no matter if or how carbon is priced or what politicians prefer.

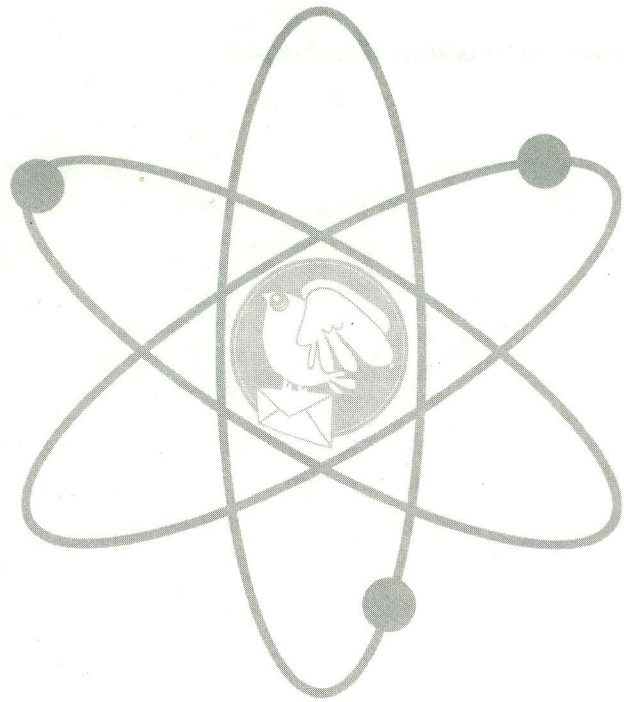
Historically, featuring and favouring nuclear power in national energy policy has ultimately harmed its progress by weakening market discipline and suppressing legitimate regulatory concerns, leading to failed projects and unpleasant accidents. But such policies' greatest damage is typically to competing technologies.

Advocates often plead for 'retaining the nuclear option' rather than "abandoning" or "closing off" new nuclear build. But "keeping the nuclear option open" does not mean benign neglect or mere tolerance of free market investments. Rather, it means, and has always meant, massive government intervention - ever-larger subsidies and other advantages to try to sustain or revive an industry dying of an incurable attack of market forces. Inevitably, such largesse comes at competitors' expense in funds, attention, markets, and time. In the United States, that opportunity cost is now reaching a critical stage as the industry, still unable to attract private investors, desperately seeks ever-greater public funding.

Thus it becomes clear that the nuclear industry's sales pitch is false. The case for nuclear power to protect the climate and enhance security is purely rhetorical and cannot withstand analytic scrutiny. The supposed nuclear revival is a carefully manufactured illusion that seeks to become a self-fulfilling prophecy, yet it cannot actually occur in a market economy, as many energy-industry leaders privately acknowledge.

(Link: www.rmi.org/cms/download.aspx)





2 THE ECONOMICS OF NUCLEAR POWER

By: *Greenpeace International, The Netherlands, May 2007*

(This is a report providing a blueprint showing how to apply existing technologies to halve global carbon dioxide emission by 2050, whilst allowing for an increase in energy consumption. It demonstrates how a 'business as usual' scenario is not an option if we are to attain a secure and stable energy supply.)

Over the last two decades there has been a steep decline in orders for new nuclear reactors globally. Poor economics has been one of the driving forces behind this move away from nuclear power.Country after country has seen nuclear construction programmes go considerably over-budget. In the United States, an assessment of 75 of the country's reactors showed predicted costs to have been 45 billion dollars but the actual costs were 145 billion dollars. In India, the country with the most recent and current construction experience, completion costs of the last 10 reactors have averaged at least 300% over budget. Also average construction time for nuclear plants has increased from 66 months for completions in the mid 1970s to 116 months for completions between 1995 and 2000.

The demand for nuclear reactors is also falling down.There are currently only 22 reactors under active construction in the world. The majorities (17) are being constructed in Asia and 16 of the 22 are being built to Chinese, Indian or Russian designs. None of these designs is likely to be exported to OECD countries.

Construction started on five of the reactors over 20 years ago and consequently the likelihood of the reactors being built to their current timetable is open to question. There are a further 14 reactors on which construction has started but is currently suspended, 10 of which are in Central and Eastern Europe. This low level of nuclear construction provides little relevant experience on which to build confidence in cost forecasts. Following the situation, the nuclear industry is promoting a new generation of reactors (Generation III and III+) and hoping that a wave of orders will be placed for them in the next few years.

Generation III reactors currently in operation are the Advanced Boiling Water Reactors (ABWR) developed in Japan. By the end of 2006, four ABWRs were in service and two under construction in Taiwan. Total construction costs for the first two units were well above the forecast range. Further problems have now arisen as cracking has been found in the blades of the turbines of two plants. A temporary repair might allow the plants back into service in 2007, operating at 10-15% below their design rating until new turbines can be supplied.

No Generation III+ plant has yet been completed and only one is under construction. The most widely promoted of these latest designs are new generation of Pressurized Water Reactors (PWRs) and in particular Avera's European Pressurised Water Reactor (EPR) and the Westinghouse AP1000, which has so far been offered in only one call for tenders. Other designs being developed include the Advanced CANDU Reactor (ACR-1000) and High Temperature Gas Reactors(HTGRs).The most developed of the latter is a South African version of the Pebble Bed Modular Reactor (PBMR). The project was first publicized in 1998 when it was expected that the first commercial orders could be placed in 2003. However, the factors like greater than anticipated problems in completing the design, the withdrawal of funders and uncertainties about the commitment of other partners has meant that the project's time-scale has slipped dramatically and the first commercial order cannot now be taken before 2014. Even more speculative are the 'paper' designs for Generation IV plutonium-fuelled reactors.

Unfavourable market place: The economics of nuclear power have always been questionable. The fact that consumers or governments have traditionally borne the risk of investment in nuclear power plants meant that utilities were insulated from these risks and were able to borrow money at rates reflecting the reduced risk to investors and lenders.

However, following the introduction of competitive electricity markets in many countries, the risk that the plant would cost more than the forecast price was transferred to the power plant developers, which are constrained by the views of financial organizations such as banks, shareholders and credit rating agencies. Such organizations view investment in any type of power plant as risky, raising the cost of capital to levels at which nuclear is less likely to compete.

In recent years there have been numerous studies of the economics of nuclear power. The values of the key parameters used to generate the forecast cost of nuclear power vary significantly from one study to another. For example, the assumed cost of construction ranges from 725-3600/KW euro, while the assumed construction time varies from 60 to 120 months. The resultant price of electricity consequently also varies significantly, producing a range of between 18-76/ MWh. An important parameter is the price of oil, which affects the price of electricity. The price of oil can also significantly impact on inflation and therefore increase interest rates, as happened in the 1970s oil shocks. These resulted in both lower energy demand and significant impact on the economics of nuclear power, due to its large construction costs.

The price of carbon also may have a significant impact on the economics of nuclear power. A recent study by Massachusetts Institute of Technology (MIT) calculated that 'With carbon taxes in the $50/tC range, nuclear is not economical under the base case assumptions'. The study went on to assess that nuclear power would only break even under its base case assumptions when carbon prices are in excess of $100/tC.

It is now 29 years since the last order for a new nuclear power plant in the US and 34 years since the last order for a plant that was actually completed. Utilities suffered heavy losses in the 1980s as economic regulators became increasingly unwilling to pass huge cost over-runs from nuclear projects on to consumers, forcing utilities to bear the extra costs. The introduction of power markets has meant that plant owners are now fully exposed not just to the risk of cost over-runs but also to plant unreliability. The nuclear provisions of the US Energy Policy Act of 2005 (EPACT 2005) are an effort to reverse these changes and protect investors from that large economic risk. The most important nuclear provisions of EPACT 2005 offer three types of support:

- A limited number of new nuclear power plants can receive an $18/MWh (13.7 euro) production tax credit for up to $125m (93.75m euro) per 1000MW (or about 80% of what the plant could earn if it ran 100% of the time);
- A provision for federal loan guarantees covering up to 80% of project costs.
- Up to $500m (375m euro) in risk insurance for the first two units and $250m (187.5m euro)for units 3-6. This insurance is to be paid if delays, not the fault of the licensee, slow the licenses of the plant.

These subsidies are said to be worth between $2-20/MWh. Without these subsidies, it is unlikely that any company would be considering investing in a new nuclear plant.

Government financial or contractual guarantees would effectively take nuclear power out of the market so that it is paid for, as in the past, by electricity consumers and taxpayers. If nuclear power is to be subsidized in this way, there needs to be clear and compelling evidence that this is a cost -effective and worthwhile way to use taxpayers' and electricity consumers' money.

Contemporary case study: Finland's Olkiluoto plant

Olkiluoto construction project in Finland is rapidly becoming an example of all that can go wrong in economic terms with nuclear new build. It demonstrates the key problems of construction delays, cost overruns and hidden subsidies.

In August 2005, the first concrete was poured. Almost immediately, things began to go wrong. In September 2005 problems with the strength and porosity of the concrete delayed work. In February 2006, work was reported to be at least six months behind the schedule.

In July 2006, TVO admitted the project was delayed by about a year and the Finnish regulator, STUK, published a report which uncovered quality control problems. In September 2006, the impact of the problems on Avera started to emerge in its results for the first six months of 2006, Avera attributed a 300m euro fall in the first-half 2006 operating income of its nuclear operations to a provision to cover past and anticipated costs at Olkiluoto. The scale of penalties for late completion was also made public. The contractual penalty for Avera is 0.2% of the total contract value per week of delay for the first 26 weeks, and 0.1% per week beyond that. The contract limits the penalty to 10%, about 300m euro. In December 2006, after only 16 months of construction, Avera announced the reactor was already 18 months behind schedule, which seems likely to assure that the full penalty will be due. It now seems likely that the project will fall at least 700m euro over budget.

Implications

The scale and immediacy of the problems at Olkiluoto have been taken even skeptics by surprise. It remains to be seen how far these problems can be recovered, what the delays will be and how far these problems will be reflected in higher costs. However, a number of lessons do emerge:

- The skills needed to be successfully build a nuclear plant are considerable. Lack of recent experience of nuclear construction projects may mean this requirement is even more difficult to meet.

- There are serious challenges to both safety and economic regulatory bodies. The Finnish regulator had not assessed a new reactor order for more than 30 years and had no experience of dealing with a 'first-of-a-kind' design.

The Alternative

In contrast to the historical problems and future uncertainties of the economics of nuclear power there are energy sources and measures whose financial performance is more predictable.

There is a growing awareness of the need to move away from the predominant use of fossil fuels, for climate and security of supply reasons. Energy efficiency and renewable energy sources can supply this need.

Energy efficiency

Energy efficiency must be the cornerstone of future energy policies. The potential for energy efficiency is huge. According to the French Ministry of Economy, changes in the production, transmission and use of global energy consumption - from the business as usual scenario - resulting in the saving of 9,000 million tons of oil equivalent (Mtoe) per year by 2050. In 2005 global nuclear energy production was 627 Mtoe.

An energy efficiency action plan proposed by European Commission in October 2006 called for a 20% increase in energy saving across the EU.

Renewable electricity sources

The contribution of renewable is growing at a rapid rate with the annual investment increasing from about $7bn (5.3bn euro) in 1995 to $39bn (29bn euro) in 2005. During 2005 the total installed capacity of non-large-hydro renewables increased by 22 GW, which compares to a 3.3 GW increase in nuclear.

Hydroelectricity and wind energy are expected to deliver the biggest increases in electricity production by 2020 - roughly 2000 TWh/year in each case. Both technologies are expected to deliver electricity at around 40-50/MWh euro, which is likely to be competitive with nuclear, gas and coal.

Technology: Status and Prospects

Construction costs of nuclear plants completed during 80s and 90s in the United States and in most of Europe were very high and much higher than predicted today by the few utilities now building nuclear plants and by nuclear industry generally. The evidence shows that, historically, cost estimates from the industry have been subject to massive underestimates. For example, according to data published by the US Department of Energy (DOE), the total estimated cost of 75 of the reactors currently in operation was $45bn. The actual costs turned out to be $145bn. This $100bn cost overrun was more than 200% above the initial cost estimates.

In UK, the most recent reactor, a PWR at Sizewell B, experienced increases in capital costs from 1,691m pounds to 3,700m pounds while the construction costs of the Torness AGR nuclear reactor in Scotland increased from 742m pound to a final cost 2,500m.

That the last decade has seen a decline in construction of new nuclear power plants. From a peak in the 1980s of over 30 GW of new capacity per year it declined to an average of 4 GW per year. This decline impacts upon the experience the nuclear industry can bring to new projects. The European investment Bank noted that very few nuclear power stations have been built in the last few years and thus the cost of recent plants does not seem a good reference to assess future costs.

A Nuclear revival or decline?

The current list of plants under construction is a short one. Sixteen out of 22 units are being supplied by vendors from China, Russia and India. It seems unlikely that any of these vendors would be considered in Western Europe or North America, the market that would need new orders if a global revival were to take place.

In terms of markets, 17 of the 22 units are located in Asia, eight of these in the Pacific Rim and eight in the Indian sub-continent. The only current orders for Western vendors are the long-delayed Lungmen plant in Taiwan, the Olkiluoto plant in Finland and four orders, placed in December, after a lengthy delay, for China.

Of the plants under construction, 5 were ordered 20 or more years ago. Work on a further 14 units has stopped and while there are frequent reports that work may restart at these sites, it is far from clear if and when this will happen.

These 'hangover' plants raise a number of issues. These are:

- The designs on which these orders were originally based are now well out of date.

- Much of the equipment already bought has been in store, untouched, for at least 15 years.
- There must be issues about the quality of work carried out so far. Demonstrating that existing work is up to standard will be expensive, and if it proves not to be up to standard will be expensive, and if it proves not to be up to standard, remedial work could be prohibitively expensive.

The most relevant designs for orders to be placed in the next decades in the West are so-called Generation III and Generation III+ designs. The main distinction between Generation II plants and Generation III and III+ plants claimed by the industry is that the later incorporate a greater level of 'passive' compared to engineered safety. This is contradicted by a report released by Greenpeace international, 'Nuclear reactor hazards' which argues that some of these technological changes are unproven and that relying on them could comprise safety. A large number of designs have been announced, but many are not far advanced, do not have regulatory approval and have limited prospects for ordering. There is no clear definition of what constitutes a Generation III design. The main common features claimed by the nuclear industry are:

- A standardized design to expedite licensing, and reduce capital cost and construction time;
- A simpler and more rugged design, making them easier to operate and less vulnerable to operational upsets;
- Higher availability and longer operating life - typically 60 years;
- Reduced possibility of core melt accidents;
- Minimal effect on the environment;
- Higher burn-up to reduce fuel use and the amount of waste; and
- Burnable absorbers ('poison') to extend fuel life.

Whether the new designs will actually achieve their stated objectives, for example in improved safety, remains to be seen. The characteristics listed are clearly very imprecise and do not define well what a Generation III plant is other than the design was evolved from existing models of PWR, BWR and Candu.

Pressurised Water Reactors (PWRs)

European Pressurised Water Reactor (EPR)

The only Generation III+PWR yet ordered, apart from the four orders placed by China in December 2006, is the Areva European Pressurised Water Reactor (EPR), for the Olkiluoto site in Finland.

It is not clear what the consequences would be if the US Nuclear Regulatory Commission (NCR) was to demand significant modifications to the design approved for use in Europe. Politically, for European countries to be building a design apparently not regarded as safe enough for the USA would raise serious concerns. Any modifications could also have significant cost consequences. Experience licensing the AP600 is relevant. By the time the AP600 had met all the requirements imposed by the NCR and a license had been given, the design had become uneconomic.

AP1000 (Advanced Passive) is a Generation III+ plant designed by Westinghouse and developed from the AP600 design(Generation III). The rational for the AP600 was to increase reliance on passive safety and also that scale economies (from building larger units as opposed to building larger numbers) had been over-estimated. The AP600 went through the US regulatory process and was given safety approval in 1999 after a 10 year procedure. By then, it was clear that the design would not be economic and the AP600 was never offered in tenders.

Westinghouse recognized that the current estimate of 4.1 to 4.6c/kWh for the AP600 is not competitive in the US market. It therefore, embarked on the development of the AP1000, which applies economies of scale to passive safety plants to reduce the cost per KWh to an estimated 3.0 to 3.5c/KWh. The AP1000's modular design is asserted to allow it to be built in 36 months at a cost of $1200/kW. However, until details of actual bid costs are available and until units are built, these figures are assertions from an industry with a long history of cost overrun.

Boiling Water Reactors (BWRs)

Advanced Boiling Water Reactor (ABWR)

The ABWR (Generation III) was developed in Japan by Hitachi and Toshiba and their US technology licensor General Electric (GE). The first two orders were placed in Japan around 1992 and completed in 1996/97. By the end of 2006, there were four ABWRs in service, all in Japan, and two under construction in Taiwan. Total construction costs for the first two Japanese units were reported to be $3,236/kW for the first unit in 1997 dollars and estimated to be about $2,800/kW for the second. These costs are well above the forecast range.

The operating units in Japan have suffered technical problems in 2006. In June, the problems were due to design faults in the turbine rather than problems with the nuclear island. A temporary repair might allow the plants back in service in 2007 operating 10-15% below their design rating until new turbines can be supplied. This is likely to take several years while a new turbine design is completed, manufactured and installed. Operation at reduced power will cause large additional costs.

Generation IV Plants

A new optimism, in some policy arenas, about the future of nuclear power has revived the research into plutonium fuelled reactors, which are now categorized as Generation IV designs.

The majority of the Generation IV reactors currently exists only on paper. In order for even prototype versions to be built, technological breakthroughs in material development will have to be made. This relates, in particular, to the ability of materials to withstand the high temperatures needed within the Generation IV designs. The GIF Road Map reports that for the lead-cooled fast reactor, gaps exist in the development of the systems and materials for the 550 degree C options, and large gaps for the 750-800 degree C options, with similar situations found in other reactor design. Other major potential problems have been identified in the ability of the materials and structures to withstand the expected corrosion and stress cracking imposed by the reactor's conditions. Some nuclear regulators in the US are not enthusiastic about the new reactor concepts.

Economics

Given the technological uncertainties and timescales involved, many questions remain over the economics of the Generation IV reactors. The costs of the fuel cycle concepts-the use of reprocessing-required in most Gen IV designs would be very high. According to 'The Future of Nuclear Power' by the US Massachusetts Institute of Technology (MIT), a convincing case has not yet been made that the long term waste management benefits of advanced closed fuel cycles involving reprocessing of spent fuel are not outweighed by the short term risks and costs, including proliferation risks. Also, the MIT study found the fuel cost with a closed cycle, including waste storage and disposal charges, to be about 4.5 times the cost of a once-through cycle. Therefore, it is not realistic to expect that new reactor and fuel cycle technologies that simultaneously overcome the problems of cost, safe waste disposal and proliferation will be developed and deployed for several decades, if ever.