INFO PACK

Nuclear Power The Misplaced Hype

PREFACE

The issue of increased generation of Nuclear Power has assiduously been pushed to the forefront of the Energy scenario by 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, "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 20GWe 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 followings:

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 some of the opinions underlying the 'Reality' of much applauded Nuclear Power.

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The Nuclear Illusion

By Physicist Amori B. Lovins and Research Scholar Imran Sheikh

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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)

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.

The promise of cheap power (infamously,' power too cheap to meter') has been one of the main claims of the nuclear industry, but this promise of cheap power has seldom been kept. There are several important determinants of the cost of electricity generated by a nuclear power plant. The usual-rule-of thumb in the past for nuclear power has always been that about two thirds of the generation cost is accounted for by fixed cost, that is, costs that will be incurred whether or not the plant is operated, and the rest by running costs. The main fixed costs are the cost of paying interest on the loans and repaying the capital, but the decommissioning cost is also included. The main running cost is the cost of operation, maintenance and repair, rather than the fuel cost.

Construction cost and time

Prices quoted by those with a vested interest in the technology, such as promotional bodies, plant vendors and utilities committed to nuclear power, clearly must be viewed with skepticism. Bid prices by vendors are more realistic than forecasts by international agencies. Civil engineering and installation, often contracted from bodies other than the nuclear power plant vendors, are generally a larger portion. Problems in controlling the cost of site work have been the cause of cost escalation more often than poor cost estimation of individual components. Contract prices may also be subject to escalation clauses that mean the final price is significantly higher so even bids cannot be taken as reliable indicators of the final cost unless the equipment is supplied under 'turnkey' term.

The real cost of capital varies from country to country and utility to utility, according to the country risk and the credit-rating of the company. There will also be a huge impact on the cost of capital from the way in which the electricity sector is organized. If the sector is a regulated monopoly, the real cost of capital could be as low as 5-8% but might be as high as 15% in a competitive electricity market, especially for nuclear power.

Frequent shutdowns or variations in output reduce both efficiency and the lifetime of components. As a result, nuclear power plants are operated on 'base-load' (continuously at full power) except in very few countries. A good measure of the reliability of the plant and how effective it is at producing saleable output is the load factor. To illustrate the impact of the economics of nuclear power, if we assume fixed costs represent two thirds of the overall cost of power if the load factor is 90%, the overall cost would go up by a third if the load factor was only 60%.

Only seven of the 414 operating reactors with at least a year's service and which have full performance records have a lifetime load factor in excess of 90% and only the top 100 plants have a lifetime factor of more than 80%.

Variable costs: non-fuel operations and maintenance cost

The non-fuel operations and maintenance costs are seldom given much attention in studies of nuclear economics. The Assumption of low running costs was proved wrong in the late 80s and early 90s when a small number of US nuclear power plants were retired because the cost of operating them was found to be greater than cost of building and operating a replacement gas-fired plant.

It is also worth noting that British Energy, which was essentially given eight nuclear plants when it was created in 1996, collapsed financially in 2002 because income from operation of the plants barely covered operating costs, especially the cost of reprocessing spent fuel, an operation only carried out now in Britain and France. Average O&M costs for British Energy's eight plants, including fuel, varied between about 24.5-28.0 euro/MWh from 1997-2004. However, in the first six months of fiscal year 2006/07, operating costs including fuel were 35.5euro/MWh because of poor performance at some plants.

Impact of Liberalization of Electricity Industries

When the electricity industry was invariably a monopoly, utilities were normally guaranteed full recovery of costs found to be used and useful as well as prudent. This made any investment a very low risk to those providing the capital because consumers were bearing most of the risk. The cost of capital varied according to the country and whether the company was publicly or privately owned.

Arguably, this low cost of capital was a distortion and led to utilities building more capital-intensive options than they should have done, because they were not being exposed to the economic risk they were taking. Building a power station of almost any type is a highly risky venture; fuel choice could prove wrong, construction cost could escalate and demand might not grow at the forecast rate. But because consumers and taxpayers usually picked up the tab if things went wrong, this risk was ignored by utilities and financiers. If the risks were reduced, for example, by government guarantees, the cost of capital would be lower, but this would represent a government subsidy (state aid).

Competitive power supply markets came into being largely as a result of US nuclear power experience in the 1970s. As nuclear plants came on line at prices far above their cost estimates and customer bills tripled between 1970 and 1980, public outrage resulted in the passage of legislation requiring US utilities to buy power from any supplier offering it at prices below the utility's own projected cost of supplying it. Between 1980 and 2002, the percentage of US power supplied by independent companies rose from 2.2% to 35%.

In the US during the period when some 120 nuclear plants were built and as many again were ordered and later cancelled, most of the risk was borne by the customers. The economic risk, that the plant would cost more than the guaranteed price, was transferred to the power plant developers.

Electricity Reforms elsewhere

During the 1990s, following reforms in Chile and Great Britain, many of the vertically integrated utilities in the US were broken up into separate generation, transmission and distribution companies, a process known as restructuring. However, transforming electricity generation from monopoly to some form of market remains the rule rather than the exception, and competitive power supply procurement has spread widely in Europe and Latin America as well as sporadically in Asia and Africa.

In many cases, these reforms have been accompanied by the introduction of competitive day-to-day power markets. If these markets are effective, this will add further to the risk faced by power plant owners. In such a market, the owners will not only face risk of having to bear additional costs if the plant does not perform to expectations, they also bear the risk because they will not know how much power they will be able to sell and at what cost.

In countries still building nuclear power plants, the risk that the units will cost too much or perform badly is borne by someone other than private investors. Sometimes risks are borne by the government and by taxpayers; sometimes they are borne by the electricity consumers.

Construction Time

Guarantees on construction time for a nuclear plant will be highly risky. In November 2006, it has been reported that for the Olkiluoto contract: "According to industry sources, the contractual penalty for Areva is 0.2% per week of delay past the May 1, 2009 commercial operation target for the first 26 weeks, and 0.1%

beyond that. The contract limits the penalty to 10% of the total contract value, or about 300m euro".

By November 2006, the expected delay at Olkiluoto was indeed 17 months. In this context, the existing losses for Areva by end 2006 of 700m euro seem likely to be an underestimate, the penalties for late completion accounting for 60% of this figure. If the costs over-run, by, say, 20%, in a modest over-run by nuclear industry standards, Areva will end up losing 900m euro on this order.

Reliability

Poor performance can be particularly costly for a utility. For example, 1,000MW plant that operates at a load factor of 80% rather than 90% and the wholesale price of power is 50/MWh euro, the lost income from electricity sales alone will be 44m per year euro. The overall losses could be much higher if the poorer reliability increases operations and maintenance cost and the cost of buying the replacement power from the market is high.

Experience with the most recent Framatome design, N4, shows that reliability is still not assured, especially for new, untested designs. Until all new plants operate from the start of service at levels of 85-90% load factor, it will be too great a risk for the nuclear vendors to offer a guarantee of performance.

Power Purchase Agreements

If electricity markets are not a sham, long-term power purchase agreements at prices not related to the market will not be feasible unless the cost offered is very low. A long-term power purchase contract to buy the output of the plant at pre-determined prices will either be a huge risk, or will not be worth the paper it is printed on. If retail markets are well-used, no retailer will know from one year to the next what their market will be and the risk of company failure will be significant.

While the moves towards liberalization are now experiencing difficulties and may be halted in some places, it seems unlikely that even where generation remains a regulated monopoly that regulators will allow generators to pass on imprudently incurred costs to consumers.

Long-term Liabilities

From the economic appraisal perspective, long-term liabilities such as waste disposal and decommissioning should have little impact on the economics of nuclear power. At the start of the life of the plant, decommissioning will be 60 or more years away and final disposal of spent fuel will also be many decades away. In the type of discounted cash flow calculation used in project appraisal, costs and income are discounted to a net present value. In other words, if there is a cost to say. 100m euro in 10 years' time, and it was assumed the discount rate was 5%, the discounted value of this cost would be 61.3m euro. The rationale is that a sum of 61.3m euro was invested today at a real (net of inflation) interest rate of 5%, after 10 years it would have grown to 100m euro. By the same logic, income of 100m euro earned in 10 years would be worth only 61.3m euro today.

While this has an intuitive logic but over longer periods and at higher discount rates, the effect is alarming and seems to trivialize huge long-term liabilities.

Long-term Forecasting

The large construction costs and long operating times make nuclear power vulnerable to changes in markets. UBS Investment Research undertook an assessment of the European market for equity investors which concluded that 'endorsing new nuclear is a potential courageous 60-year bet on fuel prices, discount rates and promised efficiency gains'. Other economic forecasters agree with the importance of these parameters and would include the price of carbon as an additional important factor.

Fuel Prices

In the time of the oil shocks in the 1970s and 1980s the world was much more dependent on oil than currently is the case. This is partly the reason why the oil price increase from 1998-2005, where the price of oil has increased five fold, has not had the same economic impact as a similar price spike had during the 1970s.

The period of higher oil prices from the mid 1970s to mid 1980s was also one of the optimism for the nuclear industry, with orders still being made in the United States and in Europe before the orders tailed off following Chernobyl.

The European Commission has undertaken analysis on the impact of higher oil and gas prices on the use of different energy technologies. In their base case scenario the price of oil in 2030 in terms of value of dollar in 2005 is $63/barrel, but under a high price scenario it reaches $99/barrel. In the high oil and gas price scenario the use of nuclear energy increases, but only by 6.5%, compared to the increased use of renewable of

12.5%.

Interest Rates

Large construction costs of nuclear power make it susceptible to changes in interest rates and in fact more susceptible than over energy sources that have power construction costs and time. The amount of interest that a utility has to pay for borrowing the necessary finance to construct a nuclear power plant impacts significantly upon expected costs of the electricity produced. This has a significant impact on the economics of nuclear electricity. Based on the economic data put forward by the Nuclear Energy Agency, it is possible to see that increasing the discount rate from 5% to 10% in the economic models increases by 50% the cost of nuclear electricity.

The Buyer

The buyer Teollisuuden Voima Oy (TVO) is an organization unique to Finland. For the Olkiluoto 3 unit, the largest shareholder, PVO, holds 60% of TVO's shares.PVO is a not-for-profit company owned by Finnish electric-intensive industry that generated about 16% of Finland's electricity in 2005. The other main shareholder in TVO is the largest Finnish electricity company, Fortum, with 25% of the shares. The majority of shares in Fortum are owned by the Finnish Government.

Experience to date

In August 2005, first concrete was poured, but almost immediately things began to go wrong. Issues about the strength and porosity of the concrete delayed work in September 2005. By February 2006, work was reported to be at least 6 months behind schedule, partly due to the concrete problems and partly to problems with qualifying pressure vessel welds and delays in detailed engineering design.

In February 2006, STUK, the Finnish safety regulator launched an investigation into these delays. By April 2006, TVO's project manager for the plant, Martin Landtman acknowledged the delays were now 9 months. The plant suppliers appeared partly to blame lack of local skills and instability in the Finnish regulatory environment for the delays.

In March 2006, it emerged that Electricite de France (EdF) expected the second EPR order, for its Flamanville site, to cost 10% more than the contracted Olkiluoto price(3.3bn euro) and that the lead-time would be 54 months instead of the 48 month period forecast for Olkiluoto. In July 2006, TVO admitted the delay was now about a year and STUK report into the delays was published. The report revealed a range of problems. It has been very difficult to find the root cause, because there are so many interconnected factors.

In September 2006, the impact of Areva started to emerge. In its results for the first six months of 2006, Areva attributed a 300m euro fall in operating income of its nuclear operations to a provision to cover past and anticipated costs at Olkiluoto. The scale of penalties for the late completion was also made public. The contractual penalty of Areva is 0.2% of the total contract value per week of delay past May 1, 2009 commercial operation target for the first 26 weeks, and o.1% beyond that. The contract limits penalty to 10%, about 300m euro. More technical problems emerged in October and Areva announced it was replacing the head of project. Further unconfirmed reports suggested that Olkiluoto was then 2-3 years behind schedule and Capital, citing nuclear industry sources, reported on 20 October that Areva could lose over 1bn euro in Finland because it had botched the negotiation of the Olkiluoto contract.

Lessons

Whilst there were suspicions amongst skeptics that the Olkiluoto plant would be problematic, the scale and immediacy of the problems have taken even the skeptics by surprise. It remains to be seen how far these problems can be reflected in higher costs and how these additional costs will be distributed between Avera and TVO. However, a number of lessons do emerge:

- The contract value of 2000/KW euro now appears likely to be a gross underestimate and any forecasts of nuclear costs should probably be based on a figure higher than that forecast by EdF.
- Turnkey contracts represent a huge risk for plant vendors and the experience at Olkiluoto may well mean that vendors will see contracts that offer such a high degree of price assurance as Olkiluoto are unjustifiable;
- There are serious challenges to a regulatory body. 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.

France: Flamanville

French nuclear industry has been lobbying government and Electricite de France (EdF) for nearly a decade to place an order for an EPR. After a long process, the Flamanville site was selected and is expected to receive the French equivalent of a construction permit in 2007. Work on site was started in October 2006, but the main orders for the plant will not be placed before second part of 2007 with first concrete expected to be poured in December 2007. The plant is scheduled to take 54 months to build with first power in mid-2010, 6 months longer than Olkiluoto's original schedule.

Whether EdF will be able to keep to the costs it forecasts remains to be seen, but the fact that the most experienced nuclear utility in the world expects the EPR to cost more than 10% more than an inexperienced utility like TVO does suggest that the Olkiluoto contract price is totally unrealistic.

The UK

In May 2006, pre-empting the publication of the UK Government's Energy Policy Review in July 2006, Tony Blair said 'Nuclear power is back on the agenda with a vengeance'. His chief scientific adviser and other government spokespeople suggested that up to 20 new nuclear units would be needed. This was taken by many, internationally, as a signal that the UK was about to launch an aggressive new programme of nuclear power stations.

Scale of Programme, Government Support and Benefits

What is perhaps most striking is that the scale of the programme is modest.

Scale: The Case Benefit Analysis(CBA) case states:

Should the private sector take commercial decisions to invest in new nuclear, the economic analysis suggests that there is scope for adding a relatively small amount of new nuclear capacity in the period upto 2025.

It is likely that the first new nuclear plant could be added by around 2021, if not before, assuming an eight year predevelopment period (for pre licensing, public enquiry, licensing, etc) starting in 2007, and six years construction.

The analysis identifies scope for replacing existing capacity by adding 6 GW of new nuclear capacity by 2025 in the base case.

The scale of the government support offered is also extremely limited. The Review stated:

Any new nuclear power stations would be proposed, developed, constructed and operated by the private sector, who would also meet full decommissioning costs and their full share of long-term waste management costs. The Government does not take a view on the future relative costs of different generating technologies. It is for the private sector to make these judgments, within the market framework established by government. The actual costs and economics of new nuclear will depend on, amongst other things, the contracts into which developers enter, and their cost of capital for financing the project.

The Flamanville3 order, expected to be placed in 2007, is expected to cost 3.3 bn euro. However, this cost does not include the cost of the first fuel core or the interest during construction. The UK Government's CBA notes that Electricite de France expects Flamanvolle3 will cost 10% more than Olkiluoto. However, adding on the first fuel core will significantly increase this cost, perhaps by 10-20%. This already takes the cost estimate up to the level assumed by the UK Government for the first UK unit.

Construction Time

The assumed construction period is 72 months from placement of order to commercial operation. This compares to the 48 months forecast for Olkiluoto and 54 months forecast for Flamanville 3. However, these periods appear to be from first structural concrete to first critically so the assumption is similar to that adopted by EdF. Olkiluoto is already 18 months late after only 18 months construction, so this assumption is far from conservative.

Renewable Energy: Resources, Economics and Prospects.

The annual investment in renewable energy has grown from about $7bn in 1995 to $38bn in 2005.During 2005 the total installed capacity of non-large hydro renewable increased by 22 GW, which compares to an increase of 3.3 GW in nuclear, much of which relates to increased capacity from existing reactors.

The prospect for renewable energy may be assessed by examining progress towards the projections for 2010 set out in the European Commission's White Paper on renewable energy.

Wind energy has performed very well, with current European capacity already in excess of the 2010 projection. Hydro (large and small) had more modest growth targets but the projection has already been met, with good performance at the large-scale compensating for slower growth at small-scale. Although biomass electricity output has increased by factor of three since 1995, the further three-fold increase necessary to meet the target is unlikely to be realized. Finally, geothermal energy is expected to come very close to meeting its target.

Economic Overview

Among the 'new renewable' energy sources, wind is becoming increasingly competitive where wind speeds are high, example are Germany, Denmark, Northern France, Britain, Ireland, Southern Spain, Portugal, China, India and some US states as well as Canada. Numerous islands are also ideal locations for wind and solar energy, as many are not connected to mainland grids and so electricity costs are high, due to their modular nature and minimal maintenance requirements.

Costs

The larger-scale developments in renewable energy technologies deliver economies of scale and currently have the lowest generation costs and are able to produce energy in quantities to match the output of thermal plant. In the case of wind energy, for example, not only are installed costs per kilowatt lower with large wind turbines and wind farms but higher energy yields are achieved as the bigger machines reap the benefit of the higher wind speeds that are found at greater heights. There is a much wider range of costs at smaller scales.

Wind Energy

Wind energy has a good combination of resource, proven status and cost. Worldwide growth is following an exponential path, increasing at 25-30% per annum. Capacity at the end of 2006 was over 74,000MW.

Solar Thermal Electric (concentrating Solar power)

The world solar thermal electric capacity is currently modest(around 400MW). There is a wide spread of current costs (between 1700-2400/kW euro) and load factors are around 21%. By 2020, installed costs are expected to fall to around 1000/KW euro, with load factors reaching 30%.

Hydro

All the renewable technologies hydroelectric is the best established. 740,000MW are spread across the world and generated 2620 TWh, 17% of all electricity in 2005. Capacity has grown at just under 2%p.a. over the past 10 years. The scope for further development of large-scale hydro in the developed world is modest. In the developing world there may be further scope, subject to such projects being environmentally and socially acceptable. The scope for further deployment lies in ingenuity in installing new 'small' (under 10MW) systems, including run of river schemes.

Biomass

Biomass when converted to energy is low or zero carbon, as the carbon dioxide emitted is not from fossil fuel origin, but from the current/recent carbon cycle. As well as dedicated biomass plant using e.g. forestry or agricultural residues, biomass can be grown specifically for the energy uses. These 'energy crops' are grown for power generation, heat production or for the manufacture of transport bio-fuel.

Municipal solid waste - MSW or industrial and commercial waste/ ICW can also comprise of or contain significant proportions of biomass. MSW in the UK typical comprises about 65% biomass.

Worldwide biomass electricity-generating capacity is now about 39 GW and electricity production is expanding in Europe, driven mainly by the developments in Austria, Finland, Germany, and the United Kingdom.

Landfill gas and waste combustion are among the cheapest electricity generating costs.

Geothermal Energy

The best geothermal resources are in the Pacific Rim, especially New Zealand and the Philippines, the United States, Iceland and Italy, which has the highest capacity of geothermal electric generation in the EU, but France, Germany and Belgium have several schemes for thermal purposes and smaller amounts for electricity generation. Most schemes use warm water reservoirs, but research is in progress into ways of improving drilling processes, using 'hot dry rocks' as a heat source, and into alternative thermal cycles for harnessing heat.

Conclusions

Hydro electricity and wind energy are expected to deliver biggest increases in electricity production by 2020 - roughly 2000TWh in each case, depending on the growth rate in wind. Each of these technologies is expected to deliver electricity at around 40-50/MWh euro, which is likely to be competitive with nuclear, gas and coal - although this depends on the price of carbon by that time. The prospect for solar thermal electric, wave and tidal stream energy are more uncertain but their generation costs may also be competitive with the fossil fuel sources. The downward trend in costs for wind energy and photovoltaics has halted recently but is expected to resume, due to a combination of improved production techniques, larger installations and the impacts of research and development. The slowdown in cost reduction, in each case, has been partly due to increased commodity prices but it should be noted that further increases in these would also affect the costs of nuclear power as this is, similarly, very capital-intensive.

Exporting Reactors

The civilian nuclear reactors generate electricity in 31 countries around the world. Of these, eight have become technology exporters. These are all members of the G8, (Canada, France, Germany, Japan, Russia, UK and USA), plus China. The only non-exporting G8 member is Italy, which phased out nuclear power following a referendum in 1987. The UK no longer has a commercial reactor design and manufacture capability, while France and Germany have effectively merged theirs through the creation of Areva. Japan has yet to win an export order for a reactor although it is becoming increasingly active in bidding contests. In two other countries a domestic industry has now been developed, India and Republic of Korea.

In all other countries significant technology import would be required to construct further nuclear reactors.

In recent years the major nuclear vendors have merged or created strategic alliances, which has significantly reduced the range of separate companies or consortia now offering nuclear reactors.

Nuclear Power and International Financial Institutions

Despite the significant number of nuclear exports, to date the International Financial Institutions (IFIs) have not funded nuclear power development to any great extent. For example:

European Bank for Reconstruction and Development(EBRD)

The EBRD is the only International Financial Institution that has a specific remit to lend for nuclear power projects. In 2006 the Bank relaxed its rules on lending for nuclear projects. Previously, the Bank would only lend for the completion or upgrading of nuclear power projects on the condition that 'they are directly linked with the closure of high-risk reactors operating in the country concerned'. However, this linkage requirement has been removed and now the major requirements for the Bank's involvement are:

- The Bank will not consider providing finances to new reactors;
- It will provide financing to an operating facility in relation to nuclear safety improvement;
- The safety and secure management of radioactive waste and spent fuel;
- Nuclear projects will have to meet the same least-cost criteria (including the review of supply and demand-side energy alternatives) as non-nuclear projects.

The EBRD has assessed three projects: the completion of the Mochovce 1 and 2 units in Slovakia(1995); the completion of Khmelnitsky 2 and Rovno 4 (K2R4) in Ukraine (2000) and a post completion upgrading project of the K2R4 project (2004).

However, the Bank has ever given only one loan, 50m euro for the second of this project.

World Bank

In 1998 on its web site, the World Bank stated that the Bank has never financed a nuclear power station. In 2006, it expanded on its policy.

In its Environment Assessment Sourcebook it makes the following comments on nuclear power:

- The Bank takes the position that, as the financier of last resort, it is unnecessary for its funds to be used for this purpose;
- Given the limited number of suppliers, procurement on the basis of International Competitive Bidding is not possible.
- Cost of nuclear projects typically come in at two to three times the original estimates, delays have been substantial, and production problems have resulted in output well below capacity.
- The economic case is clear: under present cost structures, the Bank would not finance new plants because they are uneconomic. In the unlikely event that nuclear plants become economic, the Bank would not finance them because there are other sources of funds available and, as financier of last resort, Bank funds are not required.

Asian Development Bank (ADB)

The Asian Bank is clear in its view that it should not fund nuclear power. In its 1995 energy policy it states that the Bank has not been involved in the financing of nuclear power generation projects in the DMCs (Developing Member Countries) due to a number of concerns. These concerns include issues related to transfer of nuclear technology, proliferation risks, fuel availability and procurement constraints, and environmental and safety aspects. The Bank will maintain its policy of non-involvement in the financing of nuclear power generation.

Other IFIs or regional development banks do not mention nuclear power within their energy policy and have not to date provided finance for commercial nuclear power plants. These includes:

- European Investment Bank;
- Inter-American Development Bank; and
- African Development Bank

Export Credit Agencies

The controversy around nuclear power has tended to reduce the involvement of IFIs in the funding of nuclear power. To compensate for this, government Export Credit Agencies (ECAs) have provided guarantees for a large number of nuclear projects. For example, it is suggested that the US Export-Import Bank has granted financial assistance of over $8bn of nuclear projects since the 1960s. The following table indicates recent ECA involvement in nuclear power projects throughout the world.

ECA Financing of Nuclear Power

Exporting Country	Recipient Country	Project
Canada	China	Quinshan III
	Romania	Cernavoda I and II
France	China	Ling Ao I and II
	Finland	Olkiluoto
Germany	China	Lianyungang
Italy	Romania	Cernavoda II
Japan	China	Quinshan II and III
	Mexico	Laguna Verdi
Russia	China	Lianungang
	India	Kudankulam
	Iran	Busher
UK	China	Quinshan II
		Ling Ao
US	Bulgaria	Kozloduy 5 and 6
	China	Quinshan II and III
	Czech Republic	Temelin 1 and 2

The most recent is that of the Olkiluoto project in Finland, where French and Swedish ECA guarantees were involved in project within the European Union. This arrangement is now the subject of the European Commission State Aid complaint and formal investigation.

Energy Revolution: A Sustainable World Energy Outlook

The development of the electricity supply sector is characterized by a dynamically growing renewable energy market and an increasing share of renewable electricity. According to 'Energy revolution: A Sustainable World Energy Outlook', produced by the European Renewable Energy Council (EREC) and Greenpeace International renewable energy sources could compensate for the phasing out of nuclear energy and reduce the number of fossil fuel-fired power plants required for grid stabilization. By 2050, 70% of the electricity produced worldwide could come from renewable energy sources. New renewable - mainly wind, solar thermal energy and PV- could contribute 42% of electricity generation. The following strategy paves the way for a future renewable energy supply:

- The phasing out of nuclear energy and rising electricity demand will be met initially by bringing into operation new highly efficient gas fired combined-cycle power plants, plus an increasing capacity of wind turbines and biomass. In the long term, wind will be the most important single source of electricity generation.
- Solar energy, hydro and biomass will make substantial contributions to electricity generation. In particular, as non-fluctuating renewable energy sources, hydro and solar thermal, combined with efficient heat storage,

are important elements in the overall generation mix.

(Link: www.greenpeace.org/international/.../the-economics-of-nuclear-power.pdf)

The Future of Nuclear Power

An Interdisciplinary MIT Study 2003
Massachusetts Institute of Technology Cambridge

The study analyzes what would be required to retain nuclear power as a significant option for reducing greenhouse emissions and meeting growing needs for electricity supply. The analysis is governed by a global growth scenario that would expand current worldwide nuclear generating capacity almost threefold, to 1000 billion watts, by the year 2050. This study also recommends changes in government policy and industrial practice needed in the relatively near term to retain an option for such an outcome.

In 2002, nuclear power supplied 20% of United States and 17% of world electricity consumption. Experts project worldwide electricity consumption will increase substantially in the coming decades, especially in the developing world, accompanying economic growth and social progress. However, official forecasts call for a mere 5% increase in nuclear electricity generating capacity worldwide by 2020, while electricity use could grow by as much as 75%. These projections entail little new nuclear plant construction and reflect both economic consideration and growing anti-nuclear sentiment in key countries. The limited prospects for nuclear power today are attributable, ultimately, to four unresolved problems. These problems are:

Cost: In deregulated markets, nuclear power is not now cost competitive with coal and natural gas. Nuclear power has higher overall lifetime costs compared to natural gas with combined cycle turbine technology (CCGT) and coal, at least in the absence of carbon tax or an equivalent 'cap and trade' mechanism for reducing carbon emissions.

Safety: Nuclear power has perceived adverse safety, environmental, and health effects, heightened by the 1979 Three Mile Island and 1986 Chernobyl reactor accidents, but also by accidents at fuel cycle facilities in the United States, Russia, and Japan. There is also growing concern about the safe and secure transportation of nuclear materials and the security of nuclear facilities from terrorist attack.

Waste: Geological disposal is technically feasible but execution is yet to be demonstrated or certain. Nuclear power has unresolved challenges in long-term management of radioactive waste. The Unite States and other countries have yet to implement final disposition of spent fuel or high level radioactive waste streams created at various stages of the nuclear fuel cycle. Since these radioactive waste present some danger to present and future generations, the public and its elected representatives, as well as prospective investors in nuclear power plants, properly expect continuing and substantial progress towards solution to the waste disposal problems. Successful operation of the planned disposal facility at Yucca Mountain would ease, but not solve, the waste issue for the US and other countries if nuclear power expands substantially.

Proliferation: The current international safeguards regime is inadequate to meet the security challenges of the expanded nuclear deployment contemplated in the global growth scenario. The reprocessing system now used in Europe, Japan, and Russia that involves separation and recycling of plutonium presents unwarranted proliferation risks.

To preserve the nuclear option for the future requires overcoming the four challenges described above. These challenges will escalate if a significant number of new nuclear generating plants are built in a growing number of countries. And the global growth scenario indicates that by mid-century we would see 1000 to 1500 reactors of 1000 megawatt-electric (MWe) capacity each deployed worldwide, compared to 366 such reactors now in service. This scenario would displace a significant amount of carbon-emitting fossil fuel generation.

A critical factor for the future of an expanded nuclear power industry is the choice of the fuel cycle - what type of fuel is used, what type of reactors 'burn' the fuel, and the method of disposal of the spent fuel. This choice affects all four key problems that confront nuclear power. For this study, three representative nuclear fuel cycle deployments were examined. These are:

1) Conventional thermal reactors operating in a "once through" mode, in which discharged spent fuel is sent directly to disposal
2) Thermal reactors with reprocessing in a "closed" fuel cycle, which means that waste products are separated from unused fissionable material that is re-cycled as fuel into reactors.
3) Fast reactors with reprocessing in a balanced "closed" fuel cycle, which means thermal reactors operated world wide in "once-through" mode and a balanced number of fast reactors that destroy the actinides

separated from thermal reactor spent fuel. The fast reactors, reprocessing, and fuel fabrication facilities would be co-located in secure nuclear energy parks in industrial countries.

The result of the detailed analysis of the relative merits of these representative fuel cycles with respect to key evaluation criteria can be summarized as follows: The once-through cycle has advantages in cost, proliferation, and fuel cycle safety, and is disadvantageous only in respect to long-term waste disposal; the two closed cycles have advantages only in long-term aspects of waste disposal, and disadvantages in cost, short-term waste issues, proliferation risk, and fuel cycle safety. Cost and waste criteria are likely to be the most crucial for determining nuclear power's future.

We have not found, and based on current knowledge do not believe it is realistic to expect, that there are new reactor and fuel cycle technologies that simultaneously overcome the problems of cost, safety, waste, and proliferation.

Thus, it can be concluded that once-through fuel cycle best meets the criteria of low costs and proliferation resistance. Closed fuel cycles may have an advantage from the point of view of long-term waste disposal and, if it ever becomes relevant, resource extension. But closed fuel cycles will be more expensive than once-through cycles, until ore resources become very scarce. This is unlikely to happen, even with significant growth in nuclear power, until at least the second half of this century, and probably considerably later still.

Public Attitudes Towards Nuclear Power

A survey was undertaken to gauge the public opinion. The results show that a majority of American and Europeans oppose building new nuclear power plants to meet future energy needs. Three important and unexpected results emerged from that survey:

- The U.S. public's view on nuclear waste, safety, and costs are critical to their judgments about the future deployment of this technology. Technological improvements that lower costs and improve safety and waste problems can increase public support substantially.
- In the United States, people do not connect concern about global warming with carbon-free nuclear power.
- The US public's attitudes are informed almost entirely by their perceptions of the technology, rather than by politics or by demographics such as income, education and gender.

There are two implications of these findings for the study: first, the US public is unlikely to support nuclear power expansion without substantial improvements in costs and technology. Second, the carbon-free character of nuclear power, the major motivation for the study, does not appear to motivate the US general public to prefer expansion of the nuclear option.

Economics

Nuclear power will succeed in the long run only if it has a lower cost than competing technologies. This is especially true as electricity markets become progressively less subject to economic regulation in many parts of the world. We constructed a "merchant" cost model to evaluate the real cost of electricity from nuclear power versus pulverized coal plants and natural gas combined cycle plants, over their economic lives.

The model results make clear why electricity produced from new nuclear power plants today is not competitive with electricity produced from coal or natural gas-fueled CCGT plants with low or moderate gas prices, unless all cost improvements for nuclear power are realized. The cost comparison becomes worse for nuclear if the capacity factor falls. It is also important to emphasize that the nuclear cost structure is driven by high up-front capital costs, while the natural gas cost driver is the fuel cost; coal lies in between nuclear and natural gas with respect to both fuel and capital costs.

Nuclear does become more competitive by comparison if the social cost of carbon emissions is internalized, for example through a carbon tax or an equivalent "cap and trade" system.

The carbon-free nature of nuclear power argues for government action to encourage maintenance of the nuclear option, particularly in light of the regulatory uncertainties facing the use of nuclear power and the unwillingness of investors to bear the risk of introducing a new generation of nuclear facilities with their high capital costs. Advanced fuel cycles add considerably to the cost of nuclear electricity. We considered reprocessing and one-pass fuel recycle with current technology, and found the fuel cost, including waste storage and disposal charges, to be about 4.5 times the fuel cost of the once-through cycle. Thus use of advanced fuel cycles imposes a significant economic penalty on nuclear power.

Safety

We believe the safety standard for the global growth scenario should maintain today's standard of less than one serious release of radioactivity accident for 50 years from all fuel cycle activities. International adherence to such a standard is important, because an accident in any country will influence public attitudes everywhere. Though we do not believe that there is a nuclear plant design that is totally risk free. Safe operation requires effective regulation, a management committed to safety, and skilled work force. Because of the accidents at Three Mile Island in 1979 and Chernobyl in 1986, a great deal of attention is focused on reactor safety. However, the safety record of reprocessing plants is not good, and there has been little safety analysis of fuel cycle facilities using, for example, the probabilistic risk assessment method. More work is needed here.

Waste Management

The management and disposal of high-level radioactive spent fuel from the nuclear fuel cycle is one of the most intractable problems facing the nuclear power industry throughout the world. No country has yet successfully implemented a system for disposing of this waste. The global growth scenario, based on the once-through fuel cycle, would require multiple disposal facilities by the year 2050.

We have analyzed the waste management implications of both once-through and closed fuel cycles, taking into account each stage of the fuel cycle and the risks of radiation exposure in both the short and long term. We do not believe that a convincing case can be made on the basis of waste management consideration alone, that the benefits of partitioning and transmutation will outweigh the attendant safety, environmental, and security risks and economic costs.

Non-Proliferation

Nuclear power should not expand unless the risk of proliferation from operation of the commercial nuclear fuel cycle is made acceptably small. We believe that nuclear power can expand as envisioned in our global growth scenario with acceptable incremental proliferation risk, provided that reasonable safeguards are adopted and that deployment of reprocessing and enrichment are restricted. The international community must prevent the acquisition of misuse of weapon-usable material and the responsible governments must control, to the extent possible, the know-how relevant to produce and process either highly enriched uranium or plutonium.

There are three issues that are of particular concern: existing stocks of separated plutonium around the world that are directly usable for weapons; nuclear facilities, for example in Russia, with inadequate controls; and transfer of technology, especially enrichment and reprocessing technology, that brings nations closer to a nuclear weapons capability.

Analysis, Research, Development, and Demonstration Programme (ARD&D)

Every industry in United States develops basic analytical models and tools such as spreadsheets that allow firms, investors, policy makers, and regulators to understand how changes in the parameters of a process will affect the performance and cost of that process. But we have been struck throughout our study by the absence of such models and simulation tools that permit indepth, quantitative analysis of trade-offs between different reactors and fuel cycle choices, with respect to all key criteria.

Expensive programmes that plan for the development or deployment of commercial reprocessing based on any existing advanced fuel cycle technologies are simply not justified on the basis of cost, or the unproven safety, proliferation risk, and waste properties of a closed cycle compared to the once-through cycle. Reactor concept evaluation should be part of the Nuclear System Modeling Project.

(Link: web.mit.edu/nuclearpower)

Nuclear Energy in the Years Ahead

Published By: Federal Reserve Bank of Chicago, 2007

The document is a compilation of studies done with a view to assess the Nuclear Energy scenarios by 2015 and beyond 2015 in United States of America. Besides other issues, it dwells into the aspects like types of Nuclear reactors, individual financial policies, and cost of nuclear power plants and competitiveness of nuclear energy.

No-Policy Scenarios

Three nuclear plant costs were considered in the no-policy scenario. They are patterned after three candidate reactors: (1) a mature plant such as the ABWR and ACR-700, the FOAKE (first-of-a-kind-engineering) costs on which have already been paid, with an overnight cost of 1,200 dollar per kW; (2) a design not yet built, such as the AP1000, the FOAKE costs on which are yet to be paid, with an overnight cost of 1,500 dollar per kW; and (3) the Framatome SWR 1000, similar to a larger version in advanced planning stages in Finland, whose overnight cost is estimated at 1,800 dollar per kW. The cost range also allows for uncertainty in cost estimates for reasons other than reactor type. The study investigates what would be necessary to allow nuclear power to come into the market place in the event that first plants were found to be not competitive with fossil power generation.

The financial model has been used to estimate the effects of various financial policies. According to the financial model, a loan guarantee of 50 percent of construction costs would reduce nuclear LCOE for the lowest cost reactor to 49 dollar MWh under likely business expectations. It says that accelerated depreciation whose most liberal terms would extend to immediate expensing, could reduce the LCOE for the lowest cost reactor in this case to 47 dollar per MWh. It says that none of the foregoing policies alone would achieve competitiveness even for the lowest cost reactor under likely business expectations of a seven year construction period and added debt and equity risk premiums of 3 percent for nuclear power. A production tax credit of 18 dollar per MWh for the first 8 years would reduce the LCOE of the lowest cost reactor under likely business expectations to 38 dollar per MWh, which is within range of competing coal and gas LCOEs. It would, however, achieve competitiveness only for the most optimistic cost outcome. It further says that from the above it can be derived that no single financial policy alone can definitely be counted on to bring about nuclear competitiveness by 2015.

While no single financial policy may be sufficient to enable nuclear power to enter the marketplace competitively, the financial model indicates that a combination of policies at reasonable levels could do so. It says that the study assumes that, in distinction to current business expectations, actual experience may turn out to be more favourable to nuclear power. This study has been limited to traditional financial instruments and has not considered any other possible means of finding and convincing a group of investors to participate in new construction.

The estimates mentioned are for policies needed to bring about construction of first new nuclear facilities beginning in 2015. A question of importance is the extent to which the policies would need to be extended beyond the first plants. Of course learning by doing will reduce the costs beyond the first plants. It will make a contribution but by itself is not sufficient to safely ensure self-sufficient competitiveness.

The rising gas prices would disadvantage electricity generated by gas, but coal prices appear unlikely to rise. So the major effect could be substitution of coal for gas, with nuclear still competing against coal generation at essentially the same cost per MWh as in the analysis. It further says that stringent measures to control greenhouse gases would disadvantage both gas and coal, making nuclear energy easily competitive in the marketplace.

Among the financial instruments considered in this study, production tax credits are most effective in reducing LCOEs, followed by investment tax credits. Loan guarantees and accelerated depreciation are less effective. It says that still considering first new nuclear plants, applying two policies together as a package, yields a policy combination that could bring two of the reactor designs well into a competitive LCOE range with fossil- fired generation.

Taking into account the competitiveness of later nuclear plants, the learning effects can be expected to reduce overnight capital costs. Successful construction and operation experience, aided by streamlined regulation, should reduce expected construction time and also permit a reduction of risk premiums. With learning rate of 3 to 5 percent, construction period of 5 years, and financing rates comparable to those of fossil plants, the 1,200 dollars and 1,500 dollar per kW reactors would be competitive with fossil power by the fifth plant. It further says that if successful contractor and operator experience with early plants permitted the reduction of risk premiums on debt and equity finance for fifth plants, both of these reactors would operate well within the competitive range, and 1,800 dollar per kW reactor would reach the upper end of the competitive range. The results suggest that nuclear power could become competitive on its own after a fairly brief period of policy assistance.

Nuclear Energy Scenarios: Beyond 2015

The long gestation periods involved in nuclear research, the long lags entailed in gearing up the nuclear industry for production, to say nothing of the long term nature of security and environmental problems bearing on nuclear energy, make it prudent to attempt to look several decades ahead in making decisions about nuclear energy policy.

Uncertainties of virtually every kind increase as a longer time horizon is considered. While achieving precision becomes increasingly difficult as one attempts to look out farther to the future, the direction of some events has been persistent over the past few decades and shows every sign of continuing. These include perhaps most clearly the continued growth in demand for electricity and continued growth in severity of environmental problems.

Continued experience in construction and operation of the generation III reactors built by 2015 can be expected to continue lowering their costs. Generation IV reactor designs are expected to still be in demonstration stages in 2015, and some may still be in research stages. Some generation III+ or early Generation IV designs may reach commercialization by 2025 or soon after. As a non-polluting electricity source, nuclear power can be expected to benefit from tightening of environmental policies on fossil generation.

A third major area of uncertainty affecting nuclear power in the more distant future is the possible emergence of a hydrogen economy. Large-scale substitution of hydrogen for oil in the transportation sector could increase the demand either for heat or for electricity substantially. Producing hydrogen by steam methane reforming would release carbon emissions that would have been emitted otherwise from the direct burning of oil, making nuclear power a more attractive source of hydrogen production.

There is every reason to believe that cost reductions from FOAKE (first-of-a-kind-engineering) type of experience will continue. If presently available Generation III technologies are deployed for several years beginning in 2015, cost reduction from their replications could extend to 2025 and beyond. New designs from R&D work on Generation III+ and IV reactors, with many specifics now already in motion, may be commercialized soon after 2025. R&D in general has the potential to reduce the costs. Moreover, cost reduction will be a prerequisite to commercialization. The Pebble Bed Modular Reactor (PBMR), a relatively near-term technology, could make a particular contribution towards reducing costs in view of its modularity.

Attention to potentials for cost reductions as a major consideration in planning nuclear R&D directions will increase the likelihood of commercial viability. The important findings of the study are that reducing construction time and risks premiums greatly reduce nuclear energy costs.

Second matter of concern is **global warming**. Longer the time horizon in the future that is considered, the more likely it is that the priority given to global warming will increase, leading to urgent need to replace coal-and-gas-fired electricity generation.

A third major consideration is **hydrogen**. The widespread introduction of hydrogen-powered vehicles to replace gasoline-powered vehicles would greatly increase the demand for energy to produce hydrogen. Assuming success in meeting the expressed national commitment to developing a commercially viable hydrogen vehicle, use of hydrogen vehicles will be widespread by 2025 and beyond.

There is possibility that heat from nuclear reactors will be the energy source of choice for producing hydrogen. Alternative possibilities include continued use of steam methane reforming and electrolysis using electricity from fossil generation, but if there were serious restrictions on the use of coal and gas because of their carbon emissions, nuclear energy would have a clear competitive edge. Moreover, a contingency that could become real by 2025 could favour the demand for nuclear power.

(Link:www.chicagofed.org/digital_assets/.../2007/.../2007_emissions_tolley.pdf)

The Indian Nuclear Industry: Status and Prospects

By: M.V. Ramana
The Centre for International Governance Innovation
Ontario, Canada, December 2009

I*n September 2008, the Nuclear Supplies Group (NSG) offered a special waiver to India, exempting it from the nuclear export guidelines its members set for themselves. Under the terms of the waiver, usually referred to as the US-India deal, India was allowed to import nuclear reactors and other technology without becoming a party to the 1968 Nuclear Non-Proliferation Treaty (NPT). It was also allowed to import uranium for fueling those domestically constructed reactors that it put under international safeguards. This waver has raised expectations of a tremendous increase in nuclear trade with India.*

History

The Atomic Energy Commission (AEC), the apex body in charge of nuclear policy in India, was founded in 1948, soon after independence from Britain. The commission was created not only to generate nuclear electricity, but to develop "atomic energy for all purposes" M.R. Srinivasan, who headed the AEC in the year of 1980s, explicitly stated that nuclear technology was developed to be solely available for its own benefit, whether for peaceful purposes or for military applications. This ability to use the technology for both military and peaceful purposes was an implicit criterion in many of the choices the AEC made over the coming decades. The AEC also claims it wanted to achieve self-reliance, and so plans for nuclear programme, even at the very early stages, were ambitious and encompassed the entire nuclear fuel chain.

Despite relatively small amounts of uranium ore in the country the nuclear establishment had come up with a three-phase strategy for nuclear capacity. The first phase involved using uranium fuel in heavy water reactors, followed by reprocessing the irradiated spent fuel to extract plutonium. In the second phase, the accumulated plutonium stockpile is used in the nuclear cores of fast breeder reactors. These nuclear cores could be surrounded by a so-called blanket of either depleted uranium or natural uranium to produce more plutonium; if the blanket was composed of thorium, it would produce uranium-233. So as to ensure that there was adequate plutonium to fuel these second stage breeder reactors, a sufficiently large fleet of them would have to be commissioned before thorium blankets were introduced. The third phase involves breeder reactors using uranium-233 in their cores and thorium in the blankets.

Next two decades until the nuclear test in 1974, were marked by India's acquisition of technologies related to the entire nuclear fuel chain from different countries. Important among these technologies was the Canada India Reactor (CIR), which later became known as the Canada-India Reactor US (CIRUS) when the United States supplied the heavy water for it. In addition to heavy water for CIRUS, the US was also the source of the technology used in the first reprocessing plant at Trombay, which separated plutonium from spent fuel rods irradiated at the CIRUS reactor. In 1959, the AEC turned to the United Kingdom's Atomic Energy Authority (UKAEA) for India's first power reactor The UKAEA promised to sell India a Gas Graphite Reactor, which used natural uranium as fuel. But surprisingly the winner was the US firm General Electric, whose bid for 200megawatt (MW) Boiling Water Reactor (BWR), which were to be fueled with enriched uranium was that of half of the UK and the General Electric began constructing two BWRs in Tarapur on the western coast.

In parallel, Bhabha Atomic Commission also managed to work out a deal with Atomic Energy Canada Limited (AECL) and the Montreal Engineering Company (MECO) to construct a 200 MW Pressurized Heavy Water Reactor (PHWR).In April 1964, an agreement was signed between the Government of India and the Export Credit Insurance Corporation of Canada to cover financing of materials and services from AECL and MECO.

The extensive foreign support for the Indian nuclear programme ended only after the 1974 nuclear test. Canada and the US were incensed by India's use of plutonium from the CIRUS reactor given to India for purely peaceful purposes. India's attempt to portray the event as a peaceful nuclear explosion made little difference. These countries led the international community in establishing norms for exporting nuclear technology. Eventually these efforts resulted in the formation of the Nuclear Suppliers Group (NSG) with the aim of preventing export for peaceful purposes from being used to make nuclear weapons. NSG guidelines list nuclear materials, equipment and technologies subject to export controls.

In addition, in 1978 the US Congress passed the Nuclear Non Proliferation Act that required any country, other than the five Nuclear Weapon States designated by the NTP, to accept International Atomic Energy

Agency (IAEA) safeguards on all nuclear facilities before the US would engage in any nuclear cooperation with it. Safeguards are procedures to ensure that no fissile material (plutonium or enriched uranium) is diverted from peaceful purposes to make nuclear weapons. The Indian government's refusal to give up nuclear weapons and put its nuclear facilities under safeguards meant that no NSG state, including the US, would sell nuclear technology to it.

To some degree, the NSG restrictions achieved their desired effect. All nuclear facilities built in India since 1974 have taken longer to build and have been repeatedly scaled back. Replacement parts and equipment became harder to come by. The first reactors affected by the fallout of the 1974 test were those already under construction. One reason for these delays was the unreasonable expectations of the capabilities of domestic industry, which was unable to manufacture some of the specialized equipment fast enough. The problem was not that the industry lacked the technological base and knowledge needed to carry out the fabrication, but that the Department of Atomic Energy (DAE) did not issue enough orders to make such manufacturing economical. Many businesses were therefore reluctant, and those that fulfilled the DAE's manufacturing orders did so at great expense. This was reflected in much higher costs for such equipment. For example, the turbo-generator for Rajasthan Atomic Power Station-I (RAPS-I) was imported from Canada for Rs. 64 million, whereas the same component for RAPS-II from a domestic manufacturer cost Rs.130 million.

At the same time, even before the NSG's recent removal of restrictions on nuclear trade with India, the embargo was not strictly followed and commercial or other institutional interests sometimes overrode non-proliferation considerations. One example is the Tarapur I and II reactors supplied by US with a fuel supply guarantee; NSG members like France and Russia have also sold enriched uranium fuel for these reactors by using an exception clause that allows for the sale of material or equipment. Likewise Russia also started supplying the Koodankulam reactors. Apart from these noticeable instances, there were many cases when various nuclear facilities in India procured components from abroad and foreign consultants were hired for projects.

The delays imposed by the sanctions did not deter the DAE from making confident projections. In 1984, the DAE drew up a new atomic energy profile. It proposed constructing a number of 235 MW and 500 MW PHWR units so nuclear power generation capacity would reach 10,000 MW by 2000. The results were shocking. Not a single one of the proposed new reactors was constructed on time, despite expenditures in excess of Rs. 50 billion. The 1984 projection was just one in a long list made by the DAE. In 1962, it predicted that by 1987 nuclear energy would constitute 20,000 to 25,000 MW of installed electricity generation capacity. This was subsequently updated to 43,000 MW of nuclear power by 2000. In reality, installed capacity in 1979-80 was only about 600 MW, about 950 MW in 1987, and 2,720 MW in 2000. As of June 2009, nuclear power amounts to just 4,120 MW, roughly 2.8 percent of the country's total electricity generation capacity. Six reactors with a combined capacity of ,160 MW are currently under construction.

Notwithstanding this less than modest history, the Department of Atomic Energy (DAE) continues to make wild claims about the contribution of nuclear power to the country's electricity generation capacity. In the early 2000s, the DAE projected 20 gigawatts (GW) by the year 2020 and 275GW by 2052; the latter figure amounts to 20 percent of India's total projected electricity generation capacity. Following the September 2008 waiver from the NSG, these estimates have gone up. The AEC chairman has promised that nuclear power will contribute 35 percent of Indian electricity by 2050.

The failure of the DAE to meet its projections cannot be attributed to lack of resources. Since its inception, it has received unstinted financial and political support from the government. Since the 1998 nuclear weapons tests, the DAE's budget has increased from Rs. 19.96 billion in 1997-98 to Rs. 67.77 billion in 2008-09.

Safety Regulation

The Department of Atomic Energy established the Atomic Energy Regulatory Board (AERB) to oversee and enforce safety in all nuclear operations in 1983, which was modified in 2000 to exclude facilities involved, even peripherally, in the nuclear weapons programme. The AERB reports to the Atomic Energy Commission (AEC), whose chairman is always the head of the DEA. The chairman of Nuclear Power Corporation (NPC) is also the member of AEC. Thus, both the DAE and NPC exercise administrative powers over AERB. This administrative control is compounded by the AERB's lack of technical staff and testing facilities. A former chairman of the AERB, A Gopalakrishnan, had observed that 95 percent of the members of the AERB's evaluation committees are scientists and engineers on the payrolls of the DAE. This dependency is deliberately exploited by the DAE management to influence directly and indirectly, the AERB's safety evaluations and decisions. The interference has manifested itself in the AERB toning down the seriousness of safety concerns, agreeing to the postponement of essential repair to suit the DAE's time schedules, and allowing continued operation of installations when public safety considerations would warrant their immediate shutdown and repair.

Finally, the AREB's ability to force the DAE to carry out its directives is limited. In this context, the document here quotes A. Gopalakrishnan - " The AERB had directed the DAE to carry out an integrated Emergency Core Cooling System (ECCS) testing in Kaiga I and II as well as RAPS III and IV before start up. It also wanted proof and leakage tests conducted on the reactor containment. And finally, a full-scope simulator was to be installed for operator training. None of these directives have been compiled with so far.

Environmental Regulation

The Environmental Impact Assessment (EIA) Notification of 1994 listed "nuclear power and related projects such as heavy water plants, nuclear fuel complex, rare earths" while the EIA Notification 2006 lists "nuclear power projects and processing of nuclear fuel" as requiring environmental clearances. However, not all facilities involved in processing nuclear fuel are subject to this procedure. For example, the nuclear reprocessing plants at Trombay, Tarapur and Kalpakkam that chemically process radioactive spent fuel discharged from nuclear reactors do not fall under the EIA Notification. Even the EIA process has not been effective. All nuclear projects, barring one, have received environmental clearances. In the case of the one project that was rejected, the location had to be shifted because of fears of contamination of drinking water. However, even in that case, the pathway and potential impact of such contamination were not identified in the EIA. The EIA reports that form the basis of the clearance have been mostly shoddy, with technical flaws and crucial oversights. As with government committees concerned with energy policy, expert committees that recommend whether or not a project should be given environmental clearance always include representatives from the DAE and its allied organization.

In practically all cases, the overwhelming opinion expressed by participants at public hearings for nuclear facilities has been in opposition to the project. These views have been uniformly ignored by decision makers. Local administrative authorities conducting public hearings have clearly sided with project proponents, allowing them to dominate the proceedings, denying members of the public the right to present their views and preparing minutes of the meetings that make it appear as though there was little opposition and that project proponents have assuaged any remaining public concerns.

US-India Nuclear Deal

India is no longer subject to various nuclear trade regulations imposed primarily as a result of the 1974 and 1998 nuclear tests, because the Nuclear Suppliers Group (NSG) has given a special waiver to India. The waiver was the result of a three-year process that began publicly in July 2005, when US President George Bush and Indian Prime Minister Manmohan Singh issued a joint statement laying the ground for resuming US and international nuclear aid to India. In March 2006, the Indian government designated several domestically constructed nuclear facilities as civilian, and volunteered them for IAEA inspection in a phased manner. This was followed by the US Henry Hyde Act and a 123 agreement between the two countries. The US plays a key role in putting in place the very nuclear export control norms the NSG waived for India. The main motivations of the United States were geo-strategic and commercial. The DAE's motivations derived from the need for external assistance to increase the scale of the Indian nuclear programme and a shortfall of uranium production due to inadequate mining capacity. The deal is expected to result in a substantial number of reactor imports by India.

Economics

Department of Atomic Energy has promised that nuclear power not only would form an important component of India's electricity supply, but also it would be cheap. The DAE claims that for distances greater than about 600 km, nuclear power would be cheaper than coal.. But when the first few reactors were constructed, it was apparent that construction costs were substantially greater than projected. By the 1980s the DAE was forced to revise its claims to the cost of nuclear power comparing with coal fired stations located 800 km away from the pithead. It also promised that in the 1990s nuclear power would be even cheaper than coal fired stations at pit heads. That projection, too, was not fulfilled. By the late 1990s, all the DAE could claim was that the "cost of nuclear electricity generation in India remains competitive with thermal for plants located about 1200 km away from coal pit head. Not even the 1200 km projection was borne out when tested empirically by comparing the construction and operating costs of actual reactors and coal plants, as opposed to generic cost estimates.

The document points out that nuclear power, a very capital intensive technology, is competitive only for low discount rates which are not realistic. At a real discount rate of five percent, roughly what is recommended by the Central Electricity Regulatory Commission (CERC), nuclear power from the Kaiga reactors is about eight percent expensive than thermal power from Raichur.

The Raichur plant is somewhat atypical because of the assumption about where the coal came from - 1400 km away. In reality, over a third of all of India's coal plants are at the pithead and a further quarter or more are within 500 km of one. Thus, except for isolated cases, nuclear power will generally be far more expensive than thermal power.

This economic comparison is largely based on assumptions favourable to nuclear power. For example, the comparison does not include liability insurance against accidents.

Most important, following the methodology adopted by the DAE they have not included the costs of dealing with radioactive waste from nuclear power. In essence, the NCP, which operates the Heavy Water Reactor, simply hands over the irradiated spent fuel from its reactors to the DEA. However, since reprocessing is a service rendered by the DAE to the NPC, the rational choice for the DAE would be to charge a fee for it. If even half the cost of reprocessing is included in the tariff for nuclear power, it would be 25 percent more expensive than thermal power from coal.

Department of Atomic Energy has been pursuing its breeder programme without over examining the economics of producing electricity using such reactors. The argument offered for this pursuit is that India has only "modest uranium reserves" of about 60,000 tones. While widely articulated, this formulation is misleading. India's uranium resource base cannot be represented by a single number. For example, the Nuclear Energy Agency's Red Book states that the known conventional resources amount to 91,000 tones of uranium, with 61,100 tones in the Reasonably Assured Resources (RAR) and 30,000 tones in the Interred Resources (IR) categories. It also reported an additional 67,900 tones in unconventional resource categories in which less confidence can be placed and which are likely more difficult to mine.

As with any other mineral, at higher prices it becomes economic to mine lower grade and less accessible ores. Exploiting these would increase the amount of uranium available. Therefore, the uranium resources can only be specified as a function of price. In other words, if the PHWR operator is willing to bear a higher cost for fueling the reactor, the amount of uranium available will be much larger to address the argument about India's limited uranium reserves, an economist and the writer compared the cost of generating electricity at the PFBR, India's first commercial scale breeder reactor, with a PHWR, the mainstay technology of the country's nuclear programme.

The PFBR cost estimate could be compared to estimates of breeder reactor construction costs elsewhere. Construction costs for the French Phenix reactor totaled 800 million US dollar at 2004 values. However, a further 870 million US dollar was spent on Phenix upgrades between 1997 and 2003. The 1240 MW Superphenix was far more expensive, with an initial investment of 4.9 billion US dollar at 2004 values. The 300 MW Kalkar reactor in Germany cost DM7 billion (3.6 billion US dollar).

Technically, breeder reactors can be expected to be more expensive for two reasons. First, the use of molten sodium as coolant has several operational requirements, such as heating systems to keep the sodium molten at all times, and safety requirements, such as extensive firefighting equipment. The second reason stems from the realization that accidents at breeder reactors could lead to the release of large quantities of explosive energies. They therefore need even more extensive safety features, which are a significant component of the total capital cost.

Even with this low estimate, and for an optimistic load factor of 80 percent, at a real discount rate of six percent and at a uranium price of US$200/kg, electricity from the PFBR will be approximately 40 percent more expensive than from PHWR. If the PFBR was compared with future 700 MW PHWRs, which should have lower construction costs, electricity from the PFBR will be about 80 percent more expensive.

The main rationale offered for pursuing expensive breeders is the shortage of uranium. They examined this by increasing the price of uranium from US$200/kg to the crossover value where breeders become competitive. For the optimistic base case with PFBR load factor of 80 percent and a construction cost lower than that of the PHWR, the levelized costs of the electricity from the PFBR and PHWR are equal at a uranium price of US$890/kf. If the PFBR was compared to future PHWRs that are expected to be cheaper, the crossover value is US$1,375/kg. These prices are much higher than current value.

Moreover, of all electricity generating technologies, nuclear power alone comes with the possibility of catastrophic accidents. This was illustrated by the Chernobyl accident of 1986, but there have been other accidents that have resulted in damage to public health and the environment. While the DAE, like other organizations involved in nuclear activities, often verbalizes safety goals, performance and decision making often depart from public pronouncement. DAE stated that safety is accorded overriding priority in all activities. All nuclear facilities are sited, designed, constructed, commissioned and operated in accordance with strict quality and safety standards. As a result, India's safety record has been excellent in over 260 reactor years of operation of power reactors and various other applications.

However, the actual historical record has not been as excellent as this statement projects. Practically all nuclear reactors and other facilities associated with the nuclear fuel cycle operated by DAE have had accidents of varying severity. The description of some accidents offer a sense of the lack of importance given to nuclear safety by the DAE.

Narora 1993: The most serious accident at an Indian nuclear reactor occurred on March 31, 1993. Two blades of the turbine at the first unit of the Narora power station broke off due to fatigue destabilizing the turbine and making it vibrate excessively. The vibrations caused pipes carrying hydrogen gas that cooled the turbine to break, releasing hydrogen which soon caught fire, spreading to the oil and through it to the entire turbine building.

The Narora accident has been the DAE's closest approach to a catastrophic accident which could have been foreseen and prevented. In 1989, General Electric Company communicated information to the turbine manufacturer, Bharat Heavy Electricals Limited (BHEL), about a design flaw which led to cracks in similar turbines around the world. In addition to General Electric, the manufacturer of the turbine, BHEL, also recommended that NPC replace the blade design before an accident occurred. However, NPC did not take any action until months after the accident.

Moreover, the DAE had not taken any serious steps towards fire mitigation despite earlier fire accidents at its own reactors. In 1985, an overheated cable joint at RAPS II caused a fire that spread through the cable trays and disabled four pumps. A few years later, in 1991, there were fires in the boiler room of the same unit and the turbo generator oil systems of RAPS I.

In 1985, the first unit of the Madras Atomic Power Station (MAPS I) was shutdown repeatedly because of high bearing vibrations in the turbine generator. RAPS I had to be shutdown due to high bearing vibrations in 1985, 1989, and 1990. Oil leaks have also been common in Indian reactors. Such leaks started with RAPS, the first heavy water reactor constructed in India. Despite much effort-understandable because heavy water is expensive and hard to produce - the DAE has not managed to contain the leaks. In 1997 alone, such leaks occurred at the Kakrapar I, MAPS II and Narora II reactors. The leaks were significant. For example, on April 15, 2000, there was a leak of seven tons of heavy water at the Narora II reactor. Three years later, on April 25 2003, there was a six ton leak at the same reactor. The DAE simply did not take these experiences into account while designing the Narora reactor. Another example is:

Kalpakkam 2003: On January 21, 2003, some employees at the Kalpakkam Atomic Reprocessing Plant (KARP) were tasked with collecting a sample of low level waste from a part of the facility called the Waste Tank Farm (WTF). Unknown to them, a valve had failed, resulting in the release of high level of radioactive into the part of the WTF where they were working. Although the plant was five years old, no radiation monitors or mechanisms to detect valve failure had been installed in that area. Six workers had been exposed to high doses of radiation. Apart from the lack of monitoring mechanisms, the greatest cause of concern was the response of management, in this case BARC. Despite a safety committee's recommendation that the plant be shut down, BARC's upper management decided to continue operating the plant. The BARC Facilities Employees Association (BFEA) wrote to the director setting forth ten safety related demands, including the appointment of a full time safety officer. The letter also recounted two previous incidents where workers were exposed to high levels of radiation in the past two years, and how officials had always cited the existence of an emergency situation as a reason for Health Physics Department's failure to follow safety procedures.

Once the news became public, management grudgingly admitted that this was the worst accident in radiation exposure in the history of nuclear India. But later on the management also tried to blame the workers for not wearing their thermoluminescent dosimeter badges, but this has nothing to do with the accident.

Another notable and disturbing trend is the frequent failure of safety devices. These are the mechanisms by which control of the reactor ought to be maintained under unanticipated circumstances. If they do not work as expected, it is more likely that a small event could cascade into a major accident. A related problem is that of safety devices left in an inoperative state or neglect of periodic maintenance. What is alarming is that many of these problems are recurring. In 2005. for example, the AERB found instances of failure in the detectors at Kakrapar and in the power supply for emergency cooling at the Madras Atomic Power Station. In 2004, MAPS-2 was shut down for eight days because the two main primary coolant pumps were unavailable.

Waste Management

One major concern about nuclear power has been the production of radioactive waste; this concern has been an important factor in the decision by some European countries to phase out nuclear power. Even in those that continue to pursue nuclear power, dealing with spent fuel has been a problem. For the DAE, however, spent fuel is not waste to manage but a resource to extract plutonium from and consequently it has pursued reprocessing as the way of dealing with spent fuel. The DAE has not revisited practice, despite several studies based on the experiences of Western Europe countries and the US which found that reprocessing is uneconomical. Reprocessing results in large quantities of waste, because radioactive substances are separated from spent fuel into multiple waste streams. Gaseous wastes produced during routine operations at nuclear reactors and reprocessing plants are released through stacks into the environment after filtration. Likewise low level liquid wastes - consisting of mostly of tritium but also small quantities of Cesium-137 and Strontium-90 - are released into nearby water bodies. Data on such releases are scarce - and often conflicting - but suggest that releases at Indian reactors are much higher compared to similar reactors elsewhere.

The DAE proposes to dispose of vitrified High Level Wastes (HLW) in geological repositories about 500-600 metres below the ground in some appropriate host rock such as granite or basalt. A number of bore holes 0.6 miles deep were dug in an abandoned chamber of the Kolar gold mines to test the formation's behaviour under simulated radioactive decay heat. Those tests evidently did not yield the desired results and in 1999 it was reported that an area of about 100square kilometre in the state of Rajasthan in the western part of the country had been identified as suitable for burying wastes. This led to public protests from local communities.

As far public as perception is concerned, in contrast to the enthusiasm for nuclear power that successive governments have displayed, plans for every new nuclear reactor and uranium mine since the early 1980s have been met with strong opposition from local groups.

Unlike in the West, however, the reasons have less to do with concerns about safety or radioactive waste, though these do cause apprehension among locals. The vast majority of the population does not have any understanding about radiation and the associated hazards. A 1993 survey near Kalpakkam nuclear complex, home to multiple nuclear reactors and other facilities, revealed that on average about 53 percent knew nothing about radiation, whereas a further 34.5 percent had some knowledge but were quite unclear. Rather because of the much greater dependence on natural resources like land and water, the primary concern with nuclear facilities is their impact on lives and livelihoods. Reactors, for example, require cooling water and land, for which farmers compete, and discharge hot water and radioactive effluents into sea, affecting fish workers. Similar factors also drive opposition to large hydroelectric dams, thermal power plants, and automobile factories.

Future of the Nuclear Power Programme

Following the Nuclear Suppliers Group's exemption Indian policy makers have been predicting their country will produce significant amounts of nuclear electricity in future. The Ministry of Power, for example, hopes to add 40 GW of nuclear power by 2020, as a result of the US-India nuclear deal. This is a tall order by any scale. One motivation behind making such large projection seems to be need to hype up the demand for that nuclear reactors and other technology so nuclear vendors will be tempted to lower their prices in order to gain a foothold in a potentially large market. Lowered prices will be necessary if nuclear power is to compete in an Indian electricity sector that has been restructured over the decades to promote competition. This process has resulted in an increased sensitivity to electric tariffs and costs of generation. Recent cost projections show that if an LWR were to be imported from France, the cost of electricity would be too high for the Indian consumer.

But it is not clear how far international nuclear vendors are willing to go down the route of localizing manufacturing in India. Lowered costs achieved by local manufacture in India would reduce profits and not allow for job creation efforts., despite promises made to the contrary by nuclear vendors in countries like the US and France as a reason to support India's nuclear deal. Therefore, vendors would obtain reduced profits, that too after a lengthy wait, and following a substantial investment in Indian facilities. The growth of nuclear power, using imported reactors, is likely to be slow and limited.

NPC has reportedly shortlisted four major reactor manufacturers. Westinghouse Electric Company with its

Advanced Passive 1000 reactors; General Electric-Hitachi with its Advanced Boiling Water Reactors; Areva with its European Pressurized reactors; and Russia's Rosatom with its Vodo-Vodyanoi Energetichesky Reactor (VVER1000). The plan is to devote one site each to clusters of reactors from each vendor. Sites have been identified across the country. At the first of these, Jaitapur, south of Mumbai, land acquisition efforts have already been initiated. This site seems to have been earmarked for Areva. Another site that has been identified is Mithi Virdi in the western state of Gujarat, likely for a US vendor. At both sites, public protest against the proposed construction of reactors has already commenced.

While the primary focus has been on importing reactors, there are also plans to export nuclear technology. In addition to the NPC, the state-owned BHEL is emerging as an important player. Following the establishment of a joint venture to manufacture 700MW turbines, NPC and BHEL are reported to be in talks aimed at setting up a joint venture company to export Pressurized Heavy Water Reactors.

Signiciantly, there seems to be widespread realization that, in view of the enormous costs involved, a large-scale expansion of nuclear power in India will require the involvement of the private sector. There has been interest in setting up nuclear reactors from large industrial houses like Tatas and Reliance. However, there remain several uncertainties with regard to private companies, especially foreign ones, operating nuclear power plants in India. The first uncertainty is whether private parties can be legally involved in this activity. The second uncertainty is the question of liability.

As for the Breeder Reactors in future, although the NSG waiver might result in India importing LWRs, in the longer term the DAE's projections are dependent on breeder reactors. The DAE's projection of 275 GW by 2052 includes 262.5 from breeders. Not surprisingly these estimates are based on very optimistic assumptions that can not be substantiated on the basis of historical experience. But even if one were to give DAE the benefit of doubt, these projections are erroneous. The DAE has simply not accounted properly for the likely availability of plutonium. The performance of one breeder reactor India currently operates, the FBTR, has been mediocre. Over the first 20 years of its life, it has operated for only 36,000 hours, or only 20 percent of its life thus far. The FBTR experience does not offer a good basis for optimism about Indian breeder performance.

As mentioned earlier, the DAE's methodology is flawed and does not account correctly for plutonium flows. A more careful calculation, taking into account plutonium flow constraints, shows the capacity for breeders in 2052 would be at best about 40 percent of the DAE's projections. If a more realistic out-of-pile time of three years were taken into consideration, India's breeder capacity in 2052 based on plutonium from PHWRs will drop to about 17 percent of the DAE's projections. These calculations are based on assumptions that there will be no delays because of infrastructure and manufacturing problems, economic disincentives due to the high cost of electricity, or accidents. All these are real constraints and render even the lower end of the 2052 projections quite unrealistic.

Conclusion

Nuclear power is likely to remain a major part of India's energy plan. Though it has had some success, India's atomic energy programme has not achieved any of its promises. The most important failure has been that after more than 60 years, nuclear power constitutes only three percent of the nation's electricity generation capacity. The limited amount of nuclear electricity generated has been at a relatively high cost. The DAE's reactor construction costs have not dropped over the years. The DAE claims safety is its primary concern, but it has been a low priority, as demonstrated by India's history of small accidents, unsafe design choices and operating practices.

Nuclear electricity remains more expensive than coal-based thermal power that is and will remain the staple source of electricity in the country. Unless foreign offer cheap loans for purchasing imported reactors, India is unlikely to be able to afford them. Such financing is unlikely to be a viable means.

Despite media hype and continued government patronage, nuclear power is unlikely to contribute significantly to electricity generation in India for several decades. Apart from the high cost of the power it produces, one important factor that will reduce the potential contribution of nuclear power even further is the reliance on breeder reactors, a technology shown to be unreliable in most countries that have experimented with them. In any case, nuclear power will only contribute a modest share of electricity to India's energy needs for several decade at the very least.

(Link: www.cigionline.org)

Radio Active Waste in India

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India claims that safe and effective management of radioactive waste has been given utmost importance from the very inception of its nuclear industry and that it covers the entire range of activities from handling, treatment, conditioning, transport, storage and finally disposal. While sources and varieties of radioactive waste are many, the underlying objective that is said to govern the management of all such waste in the protection of man and environment, now as well as in the future, from potential hazards arising from such waste.

In India, the necessary codes and safety guidelines for achieving this objective are provided by the Atomic Energy Regulatory Board (AERB) in conformity with the principles of radiation protection as formulated by the International Commission for Radiation Protection (ICRP).

Besides Storage, Treatment and Conditioning, Disposal is the final step in the radioactive waste management system. Although disposal of most types of radioactive waste is by concentration and containment, disposal may also comprise the discharge of effluent (for example, liquid and gaseous waste) into the environment within authorized limits, with subsequent dispersion. The authorized limits are site specific and vary from coastal to inland sites.

Residual Waste From Front-end Fuel Cycle

Uranium Mining and Waste Rock.

Uranium ore is currently mined in the mineralized zone of the Singhbhum Thrust Belt. Both surface and underground mining of uranium ores produce large amounts of radioactive waste material. Uranium mining waste comprise several types of waste. These are:

- Overburden (It usually contains at least trace amount of ore i.e. uranium plus radioactive decay products) soil and rock that is covering a deposit of ore, such as Uranium;
- Unreclaimed, sub-economic ores that have too little uranium to be profitable, called 'protores';
- 'Barren' rock (rock containing no ore) ; and
- Drill cuttings.

Since it overburden is also referred to as 'waste rock', contains elevated concentrations of radio-isotopes compared to normal rock, these are a matter of concern.

Waste rock is produced during both-open cut and underground mining. In case of open cut, the soil, vegetation, and rock above the ore body must also be removed. This waste rock is put in piles or dumps. All these piles threaten people and the environment even after the shutdown of the mine due to the release of radon gas and seepage water that contains radioactive and toxic materials.

Out of the five mines currently operational in India (all in Jharkhand State), only the Banduhurang mine is an open cut mine. A visit to the site revealed large heaps of waste rock on the road side in Narwapahar, East Singhbhum, an underground mine in India. Although the status of waste rock at other sites is not known, it may not be wrong to expect similar practice at other mining sites as well.

The Uranium Corporation of India Limited (UCIL), officials, however, report disposing of the waste rock in a 'well engineered waste yard created within the mine premises.

In the case of undisturbed uranium deposit, the activity of all decay products remains constant for hundreds of millions of years. But the situation changes completely when the deposit is mined. Radon gas can escape into the air, ore dust can be blown by the wind, and contaminates can leach and seep into surface water bodies and groundwater. The alpha radiation presents a radiation hazard upon ingestion or inhalation of uranium ore dust and radon. The gamma radiation, together with beta radiation, presents an external radiation hazard.

The Atomic Energy Act does not specify controls on uranium mining overburden. Neither the AERB nor the DAE regulates the disposal of conventional (open pit and underground) mining wastes. There is no exact total of these wastes. The quantum is expected to be significant and with new open pit mines under development, this is expected to increase manifold. One such dump of overburden located at Narwapahar is hardly a kilometer away from the agricultural fields and the nearest village. The UCIL, may have added a thin layer of mud over the waste rock to prevent erosion as well as radiation exposure to nearby communities, but it seems inadequate since the mud cover, along with the overburden, is continuously blown away with the wind and rains into people's homes, agricultural fields and the nearby river.

Waste rock and overburden has often been processed into gravel or cement and used for road and railroad construction. The overburden from Jaduguda and Bhatin mines were given out to people to use in their houses as well as used during road construction. This practice poses a threat to people's health and the environment due to continuous release of radon gas and other radionuclides from such sources. No inventory of such sites where the overburden may have been used is presumably maintained by UCIL.

Transportation of waste rock to the dump is also critical. The current practice involves transporting the ore or the waste rock in open trucks covered by tarpaulin. People claim that earlier there was no cover and the spill over of the content from the overloaded trucks, with at times even people sitting over those piles, was a common sight. They feel that the tarpaulin cover is still not adequate though it may have reduced the spillage.

It also points out that to keep groundwater out of the mine during operation, large amounts of contaminated water are pumped out and released into rivers and lakes. When the pumps are shut down after the closure of the mine, there is a risk of groundwater contamination from the rising water level.

Milling and the Tailings

Ore from Jadugada, Bhatin and Narwapahar mines is processed in the centralized processing plant/mill located close to Jaduguda mines. The uranium is extracted in the mills through the hydro metallurgical process. After three stages of crushing, the crushed ore undergoes two stages of wet grinding. The slurry is filtered to obtain uranium liquor and after filtering and drying the liquor, it is packed and transported to the Nuclear Fuel Complex in Hyderabad to be processed into fuel pellets. The slurry or the 'tailings' are left behind for disposal.

Uranium mill tailings are dumped as sludge in the 'tailing pond'. Jaduguda has three such ponds. The mining operation in Jaduguda and Bhatin started in 1967 and the mill commissioned in 1968 with more operations being added to it over the years. The net result is accumulation of huge piles of waste in the three ponds. These ponds impound tens of millions of tones of radioactive waste and cover more than 100 acres.

Characteristics of Uranium Mill Tailings

Apart from the portion of uranium removed, the sludge contains all the constituents of the ore. As long lived decay products such as thorium-230 and radium-226 are not removed, the sludge contains 85% of the initial radioactivity of the ore. Due to technical limitations, all of the uranium present in the ore can not be extracted. Therefore, the sludge also contains 5% to 10% of the uranium initially present in the ore. In addition, the sludge contains heavy metals and other contaminants such as arsenic, as well as chemical reagents used during the milling process.

Mining and milling removes hazardous constituents in the ore from their relatively safe underground location and converts them to fine sand first and then to sludge, whereby the hazardous materials become more susceptible to dispersion in the environment. Moreover, the constituents inside the tailings pile are in a geochemical disequilibrium that results in various reactions causing additional hazards to the environment. For example, in dry areas, salts containing contaminants can migrate to the surface of the pile, where they are subject to erosion. If the ore contains minerals pyrite, then sulfuric acid forms inside the deposit when accessed by precipitation and oxygen. This acid causes a continuous automatic leaching of contaminants.

Radon-222 gas emanates from tailing piles and has a half life of 3.8 days. With a steady 10 km per hour wind, Radon gas could travel nearly 1000 km before half life of it has decayed. This gas presents a major threat to mine workers and nearby residents alike. It emits alpha radiation as it decays into radioactive bismuth, polonium and lead. Inhaling and ingesting Radon (it is water soluble) poses a unique health hazard as the body becomes exposed to the chemical properties of various decay products as well as their radioactivity.

Potential Hazards from Uranium Mill Tailings

Radionuclides contained in uranium tailings emit 20 to 100 times as much gamma-radiation as natural background levels on deposit surfaces. The radium-226 in tailings continuously decays to the radioactive gas radon-222, the decay products of which can cause lung cancer. Some of this radon escapes from the interior of the pile. Radon releases are a major hazard that continues even after uranium mines are shut down.

Since radon spreads quickly with the wind, many people receive small additional radiation doses. EPA has estimated that the uranium tailings deposits existing in the United States can cause 500 lung cancer deaths per century.

Tailings deposits are subject to many kinds of erosion. After rainfall, erosion gullies can form; floods can destroy the whole deposits; plants and burrowing animals can penetrate into the deposit and thus disperse the material, enhance radon emanation and make the deposit more susceptible to climate erosion. When the surface of the pile dries out, the fine sands are blown by the wind over adjacent areas. Storms blowing up radioactive dust over villages located in the immediate vicinity of Jadugoda mill tailings piles have been reported. There have been occurrences of tailings pond overflowing during rains, resulting in contaminated water coming into villages and flowing into the river. Around 30,000 people live in 15 villages within 5 km of the Jadugoda complex. The first tailings pond is located 50m away from the village, Dungridih and the tailing pipe to other ponds is just outside the village boundary. Since the issue came under a scanner after being widely reported, UCIL has, in the last decade, put efforts in fencing the area and deploying guards which may have made access for the villagers to graze livestock difficult but not totally impossible. One could see women from nearby villages collecting wood and fodder barely 10 metres from the active tailing pond.

Seepage from tailings piles is another major hazard, which poses a risk of contamination to ground and surface water. Residents are also threatened by radium-226 and other hazardous substances like arsenic in their drinking water supplies and in the fish from the area. The seepage problem is very important with acidic tailings. In tailings that contain pyrite, acidic conditions automatically develop due to the inherent production of sulphuric acid, which increases the migration of contaminants to the environment. In village Chatukocha (in Jaduguda), located half a kilometer from the third tailing dam, villagers reported ground water contamination. They reported a rise in skin diseases, cancer cases and miscarriages in early 2000. But the UCIL officials completely deny the charge and claim the groundwater to be free from the radioactivity. The UCIL collects water samples from all the nearby villages on a monthly basis and have not found any reason for concern. Interestingly though, these test results have never been made public.

Structural integrity of the tailings dam is another concern. Tailings dams are often not of stable construction. Further danger to the pond may arise, if these are built on geological faults. This would subject them to the risk of an earthquake. Threat to the dam failure due to these reasons can not be ruled out.

Due to their fine dandy texture, dried tailings have been used for construction of homes or for landfills. In homes built on or from such materials, high levels of gamma radiation and radon were found. The U.S. EPA estimates the lifetime excess lung cancer risk of residents of such homes at 4 cases per 100. Such use has been reported from Jadugoda.

Besides these issues, accidents have been a common occurrence at the tailing sites in Jadugoda. The most recent case of trailings pipe burst took place on August 16, 2008, near Jadugoda village of Dungridih, spewing the village with uranium waste. The waste entered five houses in the village as well as spread onto the village lane. Earlier, in June 2008, there were reports of a flow-in of uranium waste from the Turamdih tailings pond in the Talsa village following heavy rainfall. The radioactive waste had spilled over into the village ponds, wells and fields. The UCIL admitted the spillover but said there was no threat to life due to radiation. A team of scientists from the BARC visited the affected area and collected water samples for analysis but the results are not known. According to UCIL, the affected family has been given compensation equivalent to one year's crop. In fact, in 2006, the East Singhbhum district administration had served show-cause notice on the UCIL for unauthorized mining in Fuljhari, Turamdih and two other new mines in Keuradungrui.

On February 21, 2008, there was a new tailings pipelines burst in the area, causing a uranium mill tailings spill that reached nearby homes. And then on April 10, 2007, again a pipeline burst near Jadugoda caused a uranium mill tailings spill.

On December 25, 2006, the tailings pipeline carrying uranium mill tailings from the Jadugoda uranium mill to the third tailings dam broke, spreading tailings into a tributary of the river Subarnarekha. The toxic sludge spewed into a creek for nine hours before the flow of the radioactive waste was shut off. Consequently, a thick layer of toxic on the surface of the creek killed scores of fish, frogs, and other riparian life. The waste from the leak also reached a creek that feeds into the Subarnarekha River, seriously contaminating the water resources of communities living hundreds of kilometers along the way.

It says this was not the first such accident. In 1986, a tailings dam had burst open and radioactive water flowed directly into the villages. Surprisingly, UCIL had no alarm mechanism to alert the company in case of such disaster.

Tailings Treatment and Disposal

Two types of waste are generated while processing uranium ore liquor depleted in uranium from ion exchange and after uranium recovery and filtered cake depleted in uranium from filtration of leached slurry. The neutralized slurry is classified and the coarse fraction is pumped back to the mines for backfilling the voids.

According to UCIL, it has a composite scheme for reclamation of water and effluent re-treatment to make the final discharged effluent environmentally safe. Water from all the mines is collected, clarified and reused in the ore processing plant. The tailings pond effluent is also clarified and part of it is sent to the plant for reuse. The remaining part is treated and clarified and the settled precipitates are sent back to tailings pond. The harmless liquor is discharged.

The local activists, however, challenge this claim. They say that the company has been directly discharging waste water into the river without treating it. In support of their claims, they point at the high incidence of dead fishes in the river. Sources also point out that although most of the uranium was extracted from the material, it has not become less hazardous. Most of the contaminants (85% of the total radioactivity and all the chemical contaminants) are still present, and the material has been brought by mechanical and chemical processes to a condition where the contaminants are much more mobile and thus susceptible to migration into the environment. Therefore, dumping the tailings in an underground mine cannot be afforded in most cases. There they would be in direct contact with groundwater after halting the pumps.

The situation is same for deposit of tailings in former pit mines. Here too, immediate contact with ground water exists, or seepage presents risks of contamination of groundwater.

Standards for Uranium Mill Tailings Management

In the early years of uranium mining after the World War II, the mining companies often left sites without any cleaning up after the ore deposits were exhausted. Often, in the United States, the mining and milling facilities were not even demolished, not to mention reclamation of the wastes produced. In Canada, uranium mill tailings were often simply dumped in one of the numerous lakes.

The untenability of this situation was, for the first time, recognized by the US legislation, which defined legal requirements for the reclamation of uranium mill tailings in 1978.On the basis of this law, regulations were promulgated by the EPA and the Nuclear Regulatory Commission.

Based on these regulations, various technologies for the safe and maintenance-free confinement of the contaminants were developed in the United States during the subsequent years. The reclamation efforts also include the decontamination of nearby homes built from contaminated material or on contaminated landfills.

In Canada, on the contrary, authorities decide the measures to be taken for reclamation on a site-by-site basis. There are no legal requirements. Canada has much lower level of protection.

In India are governed under the Atomic Energy Act, but the implementation of its provisions is clearly lax. For example, the Atomic Energy Act states that there should be no habitation within five kilometers of a waste site or uranium-tailings pond and even though Jadugoda has been in operation for more than 30 years, seven villages stand within one and a half kilometers of the danger zone. One of them, Dungardihi, begins just 40 metres away. UCIL has also found a way to go past the AERB guidelines that limits the effective dose to occupational workers at 100mSv/yr in a sliding block of five years and not more than 30mSv/yr in a year. The workers are dismissed as soon as they show signs of increased doses.

Further, the requirement of a protective barrier such as a water cover to check radiation has not been maintained. Tailings have been discharged without any kind of cover. So although the solids are mostly contained, the liquids, gases and fine dust particles are being rapidly cycled into the environment.

Pubic information has again been poor. The radiation levels and related sickness have never been revealed to the workers as well as the general public by the UCIL.

The chapter further says that when closing down a uranium mill, large amounts of radioactively contaminated scrap are produced which have to be disposed off in a safe manner. Nevertheless, the Jadugoda tailings dams became the nuclear waste dump for the entire country. Wastes from the Nuclear Fuel Complex in Hyderabad and the BARC Rare Materials Plant in Mumbai, Mysore, Gopalpur on sea, as well as medical radwastes from an unknown number of sources were being returned to Jadugoda. This came to light when local people began to find syringes, bags and IV pipes from hospital wastes buried in the tailings. Drums were also reportedly seen on trains coming to Jadugoda. It is now widely believed that the company still imports this waste and is feeding it through the mill, crushing it before discharging it into the dams. UCIL refutes this completely and asserts that no waste from other sites is being cast off into the dams. It is likely that some of these materials are gamma radiation emitters, adding to the radiation hazard posed to everyone in the area.

UCIL affirms disposing all other waste generated at the mill site into the tailing ponds. Used contaminated pipes were seen lying scattered in large numbers near and around the tailings site. It would not be surprising to see these pipes landing in the scrap market, along with other scrap and thus up in some industrial/ consumer product. For example, France's Nuclear Safety Authority (ASN) found that the elevator buttons used by Otis and supplied by French Company, Mafelec were using materials sourced from an Indian supplier. 20 French workers who had handled these buttons had been exposed to excessive levels of radiation. Mafelec informed ASN about the radiation levels emitted by the elevator buttons. ASN found that the contaminated material, which had arrived in August and was used by Otis Elevator Co, contained faint traces of cobalt 60, a radioactive form of the metal cobalt in its elevator buttons.

Meanwhile, the Swedish government said that the steel items imported from India and delivered to four factories in Sweden had showed faint traces of radioactivity, but it was not recalled since the levels of cobalt 60 in the steel were considered as not harmful.

Health and Environmental Impact: Some Reports

There is enough evidence available to support that tailings are hazardous and contains 85% of the radioactivity in the original ore along with heavy metals and chemical toxic materials from mill reagents. These cause permanent production of a radioactive gas radon-222, which is known to be carcinogenic. The chemical toxicity, heavy metals and acid can be 100kg/ton.

The damage is not always obvious. A phenomenon known as 'genomic instability' allows mutations to skip generations, lying dormant until called into play in the grandchildren or great-grandchildren of the exposed person. Seen in this context, uranium mines emitting substances in their most dangerous form: millions of tons crushed into particles as fine as dust, ready for uptake into the biosphere. Likewise, any impact on environment cannot be zeroed down to any one factor. The fact that radiation does have an impact on human health and environment cannot be ignored.

For example, at the insistence of JOAR, the State of Bihar conducted its own survey on the health impact of the mine. A medical team sampled water around the tailings dams and examined 54 people suspected of suffering from radiation-related illness. The report confirmed that UCIL was dumping nuclear waste from other sites into the tailings dams, and that uranium was reaching into the river and also that people were living too close to the mine. The team expressed concern at the fact that the tails dams were unfenced, that waste water was returning to the treatment plant in open drains and that there was no warning sign around the plant.

The environment committee had, however, recommended that people be evacuated to a distance of 5 km from the mines and tailings ponds. This recommendation, like much of the bulk of the report, has been ignored by UCIL and the government alike.

Radioactive wastes are generated in various forms: Solid, Liquid or gaseous. Radioactive waste management facilities have been set up at various sites in India. Some of these facilities have been in operation for more than 40 years.

In the context of India's nuclear fuel, spent fuel is not considered a waste but a resource. Since India ha adopted a closed fuel cycle on a 'reprocess to recycle mode', the storage of spent fuel prior to reprocessing forms a part of the spent fuel management policy. While spent fuel is not a waste in the strict sense of the term, the fact remain that it requires cooling five to ten years before the same can be reprocessed. During this period it is considered as 'waste' since it cannot be put to any immediate use. So spent fuel poses severe risks The most serious risk being loss of the pool water that cools and shields the highly radioactive spent fuel assemblies. Water loss could expose spent fuel leading to a catastrophic fire with consequences potentially worse than a reactor meltdown.

On average, spent fuel ponds hold five to ten times more long-lived radioactivity than a reactor core. Particularly worrisome is the large amount of cesium 137 in fuel ponds, which contain 20 to 50 million curies of this dangerous isotope. Cesium 137 gives off highly penetrating radiation and is absorbed in the food chain. As much as 100 percent of a pool's cesium would be released into the environment in a fire. For example, the 1986 Chernobyl accident released about 40 percent of the reactor core's 6 million curies of cesium 137 into the atmosphere, resulting in massive off-site radiation exposure. Storing this waste in dry casks introduces separate storage, packaging and security. This triggers an evacuation requirement, and could render large area of land uninhabitable and cause cancer fatalities in large numbers.

Issues from back-end processes

Nuclear reactors themselves have serious environmental and public health impact. Radioactive air and water pollution is released through the routine operation of all nuclear reactors. Studies elsewhere have revealed that living near a nuclear facility increases chances of dying from breast cancer. A nationwide survey of 268 countries within 80 km radius of 51 nuclear reactors found breast cancer deaths in these nuclear counties to be ten times the national rate. Furthermore, Strontium-90, a pollutant released only from nuclear reactors, ended up in milk and bones, contributing to bone cancer and leukemia.

Licensed to Kill: Impact on Marine Life

It is known that reactors require huge amounts of cooling water, which is why they are often located near rivers, lakes or oceans. The damage to marine life caused by the nuclear power industry using the once-through cooling system, has been sparsely reported and largely overlooked. The initial devastation to marine life and ecosystems stems from the powerful intake of water into the nuclear reactor. Marine life, ranging from sea turtles down to delicate fish larvae and microscopic planktonic organisms vital to the ocean ecosystem, is sucked irresistibly into the reactor cooling system. Some of these animals are killed when trapped against filters, grates and other structures, or, in the case of air-breathing animals like turtles, seals and manatees, they drown or suffocate. The reactors present additional hazards by expelling water warmed to a higher temperature than the water into which it flows. Recent research findings suggest that even small elevation in temperature over long period can alter the abundance of many species of marine life. Thermal discharges from the plant are liable to affect the precious biological reserve, including the region's marine fisheries. The three districts namely, Tarapur, Kalpakkam, and Kondakulam, account for 70 percent of the state's fish catch and generate over Rs. 2000 crore in annual exports.

Health Consequences of Routine Operation in India

The only power station in India around which there has been a scientific study of health consequences on the local population is the Rajasthan Atomic Power Station (RAPS) located at Rawatbhata near Kota. They found chronic health problems which included long-duration fevers, skin and eye problems, continual digestive tract problems, joint pains, body aches, lethargy and general debility, were two to three times higher than was found in the control villages 50 km away. Tumours were far above the national average and deformities were recorded at 77.5 per thousand compared to a 14-state average of 9.8 per 1000. Abortions, stillbirths, one-day death and congenital abnormalities were all much higher in the villages close to the power station. The average life expectancy of those close to the reactor was low.

Contamination at the BARC

A major radioactive leakage from ill-maintained pipelines in the vicinity of the CIRUS and Dhruva reactor complex at the BARC, is found to have caused severe soil contamination. Evidence also points to the possibility of the leakage having taken place for a number of years, thereby causing an outflow of contamination towards the sea.

The presence of the radioactivity in the area may never have come to light had it not been for an alert official in the office of the Radiation Health Inspectorate at the complex, who got wind of the incident and sent for a water sample from the puddle in the excavated pit. The activity recorded in the water sample was 40 becquerel/ml. The contract labourers who had worked for almost eight hours inside the pit on December 13 and 14, 1991, were quickly pulled out.

On December 19, department personnel dug a small portion from the bottom of the excavated pit. During a 12-minute period, the whole body dose recorded by the DRD ranged from 10 to 30 millirems (mR). Extrapolating on this observation, the radiation exposure of the contract labourers was held to be in the range of 300 to 1000 mR. Tests done in the excavated pit showed a radiation dosage ranging from 200 to 700 mR/hour, while in one specific spot, described as "Hot Spot area below the chamber", it zoomed to 2000 mR/hour. Recording of the 'soil specific activity level' revealed the presence of Cs-137. Samples of vegetation in the area also revealed contamination, and birds and insects in this area are its carriers into a wider area.

The radioactive wastes come from the Rod Cutting Building, where all uranium and plutonium fuel used in the reactor is stored for years in large pools of water to allow to decay and cooling of radioactivity before further treatment. To maintain purity, the storage pool is periodically washed with acid and the effluents are dangerously radioactive. This discharge is piped to the waste treatment facility in a planned manner and should never be allowed into the sea, atmosphere or sea. Yet, the pipeline carrying this deadly waste, also at other times, acted as a storm-water outlet. The system envisaged that by closing valves, the active discharge would be diverted to waste management, but in reality, for whatever reason, the untreated wastes flowed towards the sea.

It also points out that the plant management was aware of leakage occurring in this same pipe, at the same spot in 1978, but did nothing. At that time, during the construction of the Dhruva septic tank, several hundred metres away towards the sea, Cs-137 was found in the soil. The source of leakage was traced to this same pipeline and inspection chamber. Apart from isolating the pipeline and inspection chamber for a while, no attempt was made to replace the decaying pipeline.

Irregularities Reported at BARC

The Comptroller and Auditor General (CAG) pointed out irregularities in the procurement of components for nuclear waste management at the BARC Tarapur plant. The CAG observed that BARC bought important components for the Tarapur plant's incinerator system for Rs. 53 lakh between May 1993 and March 1999. But these components were not installed even after nine years later though they relate to the vital nuclear waste management system at the plant. However, the equipment was yet to be commissioned. The delay in commissioning of the system led to disposal of radioactive waste by the existing method of being stored in trenches without reduction in volume.

(Link: www.boell_india.org; www.toxicslink.org)

Nuclear Power in India

(Updated 29 September 2010)
By World Nuclear Association

- ***India has a flourishing and largely indigenous nuclear power programme and expects to have 20,000 MWe nuclear capacity on line by 2020 and 63,000 MWe by 2032. It aims to supply 25% of electricity from nuclear power by 2050.***
- ***Because India is outside the Nuclear Non-Proliferation Treaty due to its weapons programme, it has been for 34 years largely excluded from trade in nuclear plant or materials, which has hampered its development of civil nuclear energy until 2009.***
- ***Due to these trade bans and lack of indigenous uranium, India has uniquely been developing a nuclear fuel cycle to exploit its reserves of thorium.***
- ***Now, foreign technology and fuel are expected to boost India's nuclear power plans considerably. All plants will have high indigenous engineering content.***
- ***India has a vision of becoming a world leader in nuclear technology due to its expertise in fast reactors and thorium fuel cycle.***

Electricity demand in India has been increasing rapidly, and the 534 billion kilowatt hours produced in 2002 was almost double the 1990 output, though still represented only 505 kWh per capita for the year. In 2006, 744 billion kWh gross was produced, but with huge transmission losses this resulted in only 505 billion kWh consumption. The per capita figure is expected to almost triple by 2020, with 6.3% annual growth. Coal provides 68% of the electricity at present, but reserves are limited. Gas provides 8%, hydro 15%.

Nuclear power supplied 15.8 billion kWh (2.5%) of India's electricity in 2007 from 3.7 GWe (of 110 GWe total) capacity and this will increase steadily as imported uranium becomes available and new plants come on line. In the year to March 2010, 22 billion kWh is forecast. Some 300 reactor-years of operation had been achieved by mid 2009. India's fuel situation, with shortage of fossil fuels, is driving the nuclear investment for electricity, and 25% nuclear contribution is foreseen by 2050, from one hundred times the 2002 capacity. Almost as much investment in the grid system as in power plants is necessary.

In 2006 almost US$ 9 billion was committed for power projects, including 9.35 GWe of new generating capacity, taking forward projects to 43.6 GWe and US$ 51 billion. 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. The government's 5-year plan for 2012-17 was targeting the addition of 100 GWe over the period. Three quarters of this would be coal- or lignite-fired, and only 3.4 GWe nuclear, including two imported 1000 MWe units at one site and two indigenous 700 MWe units at another.

A KPMG report in 2007 said that India needed to spend US$ 120-150 billion on power infrastructure over the next five years, including transmission and distribution (T&D). It said that T&D losses were some 30-40%, worth more than $6 billion per year. A 2010 estimate shows big differences among states, with some very high, and a national average of 27% T&D loss, well above the target 15% set in 2001 when the average figure was 34%.

The target since about 2004 has been for nuclear power 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." However, it is evident that even the 20 GWe target will require substantial uranium imports. 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 60 GWe nuclear by 2032, including 40 GWe of PWR capacity and 7 GWe of new PHWR capacity, all fuelled by imported uranium. This target was reiterated late in 2010.

Longer term, 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.

Indian Nuclear Power Industry Development

Nuclear power for civil use is well established in India. Its civil nuclear strategy has been directed towards complete independence in the nuclear fuel cycle, necessary because it is excluded from the 1970 Nuclear

Non-Proliferation Treaty (NPT) due to it acquiring nuclear weapons capability after 1970. (Those five countries doing so before 1970 were accorded the status of Nuclear Weapons States under the NPT.)

As a result, India's nuclear power program has proceeded largely without fuel or technological assistance from other countries (but see later section). Its power reactors to the mid 1990s had some of the world's lowest capacity factors, reflecting the technical difficulties of the country's isolation, but rose impressively from 60% in 1995 to 85% in 2001-02. Then in 2008-10 the load factors dropped due to shortage of uranium fuel.

India's nuclear energy self-sufficiency extended from uranium exploration and mining through fuel fabrication, heavy water production, reactor design and construction, to reprocessing and waste management. It has a small fast breeder reactor and is building a much larger one. It is also developing technology to utilise its abundant resources of thorium as a nuclear fuel.

The Atomic Energy Establishment was set up at Trombay, near Mumbai, in 1957 and renamed as Bhabha Atomic Research Centre (BARC) ten years later. Plans for building the first Pressurised Heavy Water Reactor (PHWR) were finalised in 1964, and this prototype - Rajasthan-1, which had Canada's Douglas Point reactor as a reference unit, was built as a collaborative venture between Atomic Energy of Canada Ltd (AECL) and NPCIL. It started up in 1972 and was duplicated Subsequent indigenous PHWR development has been based on these units.

The Indian Atomic Energy Commission (AEC) is the main policy body.

The Nuclear Power Corporation of India Ltd (NPCIL) is responsible for design, construction, commissioning and operation of thermal nuclear power plants. At the start of 2010 it said it had enough cash on hand for 10,000 MWe of new plant. Its funding model is 70% equity and 30% debt financing. However, it is aiming to involve other public sector and private corporations in future nuclear power expansion, notably National Thermal Power Corporation (NTPC) - see subsection below. NTPC is largely government-owned, and the 1962 Atomic Energy Act prohibits private control of nuclear power generation, though it allows minority investment. As of late 2010 the government had no intention of changing this to allow greater private equity in nuclear plants.

India's Operating Nuclear Power Reactors

Reactor	**State**	**Type**	**MWe net, each**	**Commercial operation**	**Safeguards status**
Tarapur 1&2	Maharashtra	BWR	150	1969	item-specific
Kaiga 1&2	Karnataka	PHWR	202	1999-2000	
Kaiga 3	Karnataka	PHWR	202	2007	
Kakrapar 1&2	Gujarat	PHWR	202	1993-95	in 2012 under new agreement
Kalpakkam 1 &2 (MAPS)	Tamil Nadu	PHWR	202	1984-86	
Narora 1&2	Uttar Pradesh	PHWR	202	1991-92	in 2014 under new agreement
Rajasthan 1	Rajasthan	PHWR	90	1973	item-specific
Rajasthan 2	Rajasthan	PHWR	187	1981	item-specific
Rajasthan 3&4	Rajasthan	PHWR	202	1999-2000	early 2010 under new agreement
Rajasthan 5&6	Rajasthan	PHWR	202	Feb & April 2010	Oct 2009 under new agreement
Tarapur 3 4	Maharashtra	PHWR	490	2006, 05	
Total (19)			**4183 MWe**		

Kalpakkam also known as Madras/MAPS
Rajasthan/RAPS is located at Rawatbhata and sometimes called that
Kaiga = KGS, Kakrapar = KAPS, Narora = NAPS
dates are for start of commercial operation.

The two Tarapur 150 MWe Boiling Water Reactors (BWRs) built by GE on a turnkey contract before the advent of the Nuclear Non-Proliferation Treaty were originally 200 MWe. They were down-rated due to recurrent problems but have run well since. They have been using imported enriched uranium and are under International Atomic Energy Agency (IAEA) safeguards. However, late in 2004 Russia deferred to the Nuclear Suppliers' Group and declined to supply further uranium for them. They underwent six months refurbishment over 2005-06, and in March 2006 Russia agreed to resume fuel supply. In December 2008 a $700 million contract with Rosatom was announced for continued uranium supply to them.

The two small Canadian (Candu) PHWRs at Rajasthan nuclear power plant started up in 1972 & 1980, and are also under safeguards. Rajasthan-1 was down-rated early in its life and has operated very little since 2002 due to ongoing problems and has been shut down since 2004 as the government considers its future. Rajasthan-2 was restarted in September 2009 after major refurbishment, and running on imported uranium at full rated power.

The 220 MWe PHWRs (202 MWe net) were indigenously designed and constructed by NPCIL, based on a Canadian design.

The Kalpakkam (MAPS) reactors were refurbished in 2002-03 and 2004-05 and their capacity restored to 220 MWe gross (from 170). Much of the core of each reactor was replaced, and the lifespans extended to 2033/36.

Kakrapar unit 1 was repaired and upgraded in 2009, as was Narora-2.

More Recent Nuclear Power Developments in India

The new Tarapur 3&4 reactors of 540 MWe gross (490 MWe net) are developed indigenously from the 220 MWe (gross) model PHWR and were built by NPCIL.

The first - Tarapur 4 - started up in March 2005, was connected to the grid in June and started commercial operation in September. Tarapur-4's criticality came five years after pouring first concrete and seven months ahead of schedule. Its twin - unit 3 - was about a year behind it and criticality was achieved in May 2006, with grid connection in June and commercial operation in August, five months ahead of schedule.

Future indigenous PHWR reactors will be 700 MWe gross (640 MWe net). The first four will be built at Kakrapar and Rajasthan. According to NPCIL in March 2010, work on all four has started and they are due on line by 2017 after 60 months construction from first concrete to criticality.

Russia's Atomstroyexport is building the country's first large nuclear power plant, comprising two VVER-1000 (V-392) reactors, under a Russian-financed US$ 3 billion contract. A long-term credit facility covers about half the cost of the plant. The AES-92 units at Kudankulam in Tamil Nadu state are being built by NPCIL and will be commissioned and operated by NPCIL under IAEA safeguards. The turbines are made by Leningrad Metal Works. Unlike other Atomstroyexport projects such as in Iran, there have been only about 80 Russian supervisory staff on the job.

Russia is supplying all the enriched fuel, though India will reprocess it and keep the plutonium. The first unit was due to start supplying power in March 2008 and go into commercial operation late in 2008, but this schedule has slipped by more than two years. The second unit is about 6-8 months behind it. While the first core load of fuel was delivered early in 2008 there have been delays in supply of some equipment and documentation. Control system documentation was delivered late, and when reviewed by NPCIL it showed up the need for significant refining and even reworking some aspects. Fuel loading of unit 1 will not now take place until late 2010, though in October 2009 NPCIL said the unit was 94% complete and that 99% of the equipment was on site.

A small desalination plant is associated with the Kudankulam plant to produce 426 m3/hr for it using 4-stage multi-vacuum compression (MVC) technology. Another RO plant is in operations to supply local township needs.

Under plans for the India-specific safeguards to be administered by the IAEA in relation to the civil-military separation plan, eight further reactors will be safeguarded (beyond Tarapur 1&2, Rajasthan 1&2, and Kudankulam 1&2): Rajasthan 3&4 by 2010, Rajasthan 5&6 by 2008, Kakrapar 1&2 by 2012 and Narora 1&2 by 2014.

India's Nuclear Power Reactors Under Construction

Reactor	Type	MWe net, each	Project control	Commercial operation due	Safeguards status
Kaiga 4	PHWR	202 MWe	NPCIL	5/2010	

Kudankulam 1	PWR (VVER)	950 MWe	NPCIL	12/2010	item-specific
Kudankulam 2	PWR (VVER)	950 MWe	NPCIL	mid 2011	item-specific
Kalpakkam PFBR	FBR	470 MWe	Bhavini	9/2011, or 2012	-
Total (4)		**2572 MWe**			

Rajasthan/RAPS also known as Rawatbhata

Kaiga 3 started up in February, was connected to the grid in April and went into commercial operation in May 2007. Unit 4 was scheduled about six months behind it, but is about 30 months behind original schedule due to shortage of uranium - it is not safeguarded so cannot use imported uranium. RAPP-5 started up in November 2009, using imported Russian fuel, and in December it was connected to the northern grid. RAPP-6 started up in January 2010 and was grid connected at the end of March. Both are now in commercial operation.

In mid 2008 Indian nuclear power plants were running at about half of capacity due to a chronic shortage of fuel. The situation was expected to persist for several years if the civil nuclear agreement faltered, though some easing in 2008 was due to the new Turamdih mill in Jharkhand state coming on line (the mine there was already operating). Political opposition has delayed new mines in Jharkhand, Meghalaya and Andhra Pradesh.

A 500 MWe prototype fast breeder reactor (FBR) is under construction at Kalpakkam by BHAVINI (Bharatiya Nabhikiya Vidyut Nigam Ltd), a government enterprise set up under DAE to focus on FBRs. It was expected to start up about the end of 2010 and produce power in 2011, but this schedule appears to be delayed about 12-15 months. Four further oxide-fuel fast reactors are envisaged but slightly redesigned by the Indira Gandhi Centre to reduce capital cost. One pair will be at Kalpakkam, two more elsewhere. (See also section below.)

In contrast to the situation in the 1990s, most reactors under construction are on schedule (apart from fuel shortages 2007-09), and the first two - Tarapur 3 & 4 – were slightly increased in capacity. These and future planned ones were 450 (now 490) MWe versions of the 202 MWe domestic products. Beyond them and the last three 202 MWe units, future units will be nominal 700 MWe.

The government envisages setting up about ten PHWRs of 700 MWe capacity to about 2023, fuelled by indigenous uranium, as stage 1 of its nuclear program. Stage 2 - four 500 MWe FBRs - will be concurrent.

Nuclear Industry Developments in India Beyond the Trade Restrictions

Following the Nuclear Suppliers' Group agreement which was achieved in September 2008, the scope for supply of both reactors and fuel from suppliers in other countries opened up. Civil nuclear cooperation agreements have been signed with the USA, Russia, France, UK and Canada, as well as Argentina, Kazakhstan, Mongolia and Namibia.

The Russian PWR types were apart from India's three-stage plan for nuclear power and were simply to increase generating capacity more rapidly. Now there are plans for eight 1000 MWe units at the Kudankulam site, and in January 2007 a memorandum of understanding was signed for Russia to build four more there, as well as others elsewhere in India. The new units are expected to be the larger 1200 MWe AES-2006 versions of the first two. Russia is reported to have offered a 30% discount on the $2-billion price tag for each of the phase 2 Kudankulam reactors. This is based on plans to start serial production of reactors for the Indian nuclear industry, with much of the equipment and components proposed to be manufactured in India, thereby bringing down costs. Rosatom has published a proposed schedule for Kudankulam phase 2, involving financing agreement mid 2010, EPC contract by end of 2010, and first concrete in June 2011.

Between 2010 and 2020, further construction is expected to take total gross capacity to 21,180 MWe. The nuclear capacity target is part of national energy policy. This planned increment includes those set out in the Table below including the initial 300 MWe Advanced Heavy Water Reactor (AHWR). The benchmark capital cost sanctioned by DAE for imported units is quoted at $1600 per kilowatt.

In 2005 four sites were approved for eight new reactors. Two of the sites - Kakrapar and Rajasthan, would have 700 MWe indigenous PHWR units, Kudankulam would have imported 1000 or 1200 MWe light water reactors alongside the two being built there by Russia, and the fourth site was greenfield for two 1000 MWe LWR units - Jaitapur (Jaithalpur) in the Ratnagiri district of Maharashtra state, on the west coast. The plan has since expanded to six 1600 MWe EPR units here.

NPCIL had meetings and technical discussions with three major reactor suppliers - Areva of France, GE-Hitachi and Westinghouse Electric Corporation of the USA for supply of reactors for these projects and for new units at Kaiga. These resulted in more formal agreements with each reactor supplier early in 2009, as mentioned below.

In April 2007 the government gave approval for the first four of these eight units: Kakrapar 3 & 4 and Rajasthan 7 & 8, using indigenous technology. In mid 2009 construction approval was confirmed, and late in 2009 the finance for them was approved. Site works at Kakrapar were completed by August 2010. First concrete for Kakrapar 3 was due in June 2010, but Atomic Energy Regulatory Board (AERB) approval for this is awaited. The AERB approved Rajasthan 7 & 8 in August 2010, and site works then began. First concrete is expected in December and construction is then expected to take 66 months to commercial operation. Their estimated cost is Rs 123.2 billion ($2.6 billion). In September 2009 L&T secured an order for four steam generators for Rajasthan 7 & 8, having already supplied similar ones for Kakrapar 3 & 4.

In late 2008 NPCIL announced that as part of the Eleventh Five Year Plan (2007-12), it would start site work for 12 reactors including the rest of the eight PHWRs of 700 MWe each, three or four fast breeder reactors and one 300 MWe advanced heavy water reactor in 2009. NPCIL said that "India is now focusing on capacity addition through indigenisation" with progressively higher local content for imported designs, up to 80%. Looking further ahead its augmentation plan included construction of 25-30 light water reactors of at least 1000 MWe by 2030.

The AEC has said that India now has "a significant technological capability in PWRs and NPCIL has worked out an Indian PWR design" which will be unveiled soon - perhaps 2010.

Meanwhile, NPCIL is offering both 220 and 540 MWe PHWRs for export, in markets requiring small- to medium-sized reactors.

Power Reactors Planned or Firmly Proposed

Reactor	**State**	**Type each**	**MWe net, control**	**Project construction**	**Start operation**	**Start**
Kakrapar 3	Gujarat	PHWR	640	NPCIL	June 2010	2015
Kakrapar 4	Gujarat	PHWR	640	NPCIL	2011	2016
Rajasthan 7	Rajasthan	PHWR	640	NPCIL	Dec 2010	June 2016
Rajasthan 8	Rajasthan	PHWR	640	NPCIL	2011	Dec 2016
Kudankulam 3	Tamil Nadu	PWR-AES 92 or AES-2006	1050-1200	NPCIL	6/2011	2016
Kudankulam 4	Tamil Nadu	PWR-AES 92 or AES-2006	1050-1200	NPCIL	2012?	2017
Jaitapur 1&2	Maharashtra	PWR-EPR	1600	NPCIL	by 2012	2017-18
Kaiga 5&6	Karnataka	PWR	1000/1500	NPCIL	by 2012	
Kudankulam 5&6	Tamil Nadu	PWR-AES 92 or AES-2006	1050-1200	NPCIL	2012?	2017
Kumharia 1-4	Haryana	PHWRx 4 (or x2)	640	NPCIL or NPCIL-NTPC	by 2012?	
Bargi 1&2	Madhya Pradesh	PHWR x 2	640	NPCIL or NPCIL-NTPC	2012?	
Kalpakkam 2&3	Tamil Nadu	FBR x 2	470	Bhavini	2012?	2017
Subtotal		**20 units**	**25,240 -**			

planned		**26,240**	**MWe**			
Kudankulam 7 & 8	Tamil Nadu	PWR - AES 92 or AES-2006	1050-1200	NPCIL	2012?	2017
Rajauli	Bihar	PHWR x 2	700	NPCIL		
Mahi-Banswara	Rajasthan	PHWR x 2	700	NPCIL		
?		PWR x 2	1000	NPCIL/NTPC	by 2012?	2014
Jaitapur 3&4	Maharashtra	PWR - EPR	1600	NPCIL	by 2016	
?	?	FBR x 2	470	Bhavini		2017
?		AHWR	300	NPCIL	by 2012	2020
Jaitapur 5&6	Maharashtra	PWR - EPR	1600	NPCIL		
Markandi (Pati Sonapur)	Orissa	PWR	6000 MWe			
Mithi Virdi 1-6, Saurashtra region	Gujarat	6 x AP 1000?	1250			
Pulivendula Kadapa	Andhra Pradesh	PWR? PHWR?	2x1000? 2x700?	NPCIL 51%, AP Genco 49%		
Kovvada 1-6 Srikakulam	Andhra Pradesh	6 x ESBWR?	1350-1550 (1400?)	NPCIL	site works	
Nizampatnam 1-6 Guntur	Andhra Pradesh	6x?	1400	NPCIL1-6		
Haripur 1-4	West Bengal	PWR x 4 VVER-1200	1200		2017	2022?
Chutka	Madhya Pradesh	?	1400	BHEL-NPCIL -GE?		
Subtotal		**approx**	**45,000**			
proposed		**39**	**MWe approx**			

For WNA reactor table: first 20 units 'planned', next (estimated) 40 'proposed'.

Nuclear Energy Parks

In line with past practice such as at the eight-unit Rajasthan nuclear plant, NPCIL intends to set up five further "Nuclear Energy Parks", each with a capacity for up to eight new-generation reactors of 1,000 MWe, six reactors of 1600 MWe or simply 10,000 MWe at a single location. By 2032, 40-45 GWe would be provided from these five. NPCIL says it is confident of being able to start work by 2012 on at least four new reactors at all four sites designated for imported plants.

The new energy parks are to be:

Kudankulam in Tamil Nadu: three more pairs of Russian VVER units, making 9200 MWe. Environmental approval has been given for the first four. A general framework agreement for construction of units 3 & 4 was planned to be signed by the end of June 2010, but has apparently been delayed on account of supplier liability questions. Equipment supply and service contracts for units 3 &4 were to be signed by the end of December 2010 and the first concreting was expected by the end of June 2011.

Jaitapur in Maharashtra: Preliminary work at is likely soon with six of Areva's EPR reactors in view, making 9600 MWe. Environmental approval has been given for these. In July 2009 Areva submitted a bid to NPCIL to build the first two EPR units, with a view to commissioning in 2017 and 2018. These will have Alstom turbine-generators, accounting for about 30% of the total EUR 6 to 7 billion cost.

Mithi Virdi (or Chayamithi Virdi) in Gujarat: to host US technology (possibly Westinghouse AP1000, maybe

GE Hitachi ESBWR). NPCIL says it has initiated pre-project activities here, with groundbreaking planned for 2012.

Kovvada in Andhra Pradesh: to host US technology (possibly GE Hitachi ESBWR). NPCIL says it has initiated pre-project activities here, with groundbreaking planned for 2012. GE Hitachi says it expects to sign a contract in 2010 to supply six ESBWRs to NPCIL.

Haripur in West Bengal: to host four further Russian VVER-1200 units, making 4800 MWe. NPCIL says it has initiated pre-project activities here, with groundbreaking planned for 2012. However in August 2010 it was reported that Rosatom has asked for another site due to political unrest in this vicinity.

Kumharia in Haryana is earmarked for four indigenous 700 MWe PHWR units and the AEC had approved the state's proposal for a 2800 MWe nuclear power plant. The northern state of Haryana is one of the country's most industrialized and has a demand of 8900 MWe, but currently generates less than 2000 MWe and imports 4000 MWe. The village of Kumharia is in Fatehabad district and the plant may be paid for by the state government or the Haryana Power Generation Corp. NPCIL says it has initiated pre-project activities here, with groundbreaking planned for 2012.

Bargi in Madhya Pradesh is also designated for two indigenous 700 MWe PHWR units. NPCIL says it has initiated pre-project activities here, with groundbreaking planned for 2012.

At Markandi (Pati Sonapur) in Orissa there are plans for up to 6000 MWe of PWR capacity. Major industrial developments are planned in that area and Orissa was the first Indian state to privatise electricity generation and transmission. State demand is expected to reach 20 billion kWh/yr by 2010.

The AEC has also mentioned possible new nuclear power plants in Bihar and Jharkhand.

NTPC Plans

India's largest power company, National Thermal Power Corporation (NTPC) in 2007 proposed building a 2000 MWe nuclear power plant to be in operation by 2017. It would be the utility's first nuclear plant and also the first conventional nuclear plant not built by the government-owned NPCIL. This proposal became a joint venture set up in April 2010 with NPCIL holding 51%, and possibly extending to multiple projects utilising local and imported technology. One of the sites earmarked for a pair of 700 MWe PHWR units may be allocated to the joint venture.

NTPC says it aims by 2014 to have demonstrated progress in "setting up nuclear power generation capacity", and that the initial "planned nuclear portfolio of 2000 MWe by 2017" may be greater. NTPC, now 89.5% government-owned, is planning to increase its total installed capacity from 30 to 50 GWe by 2012 (72% of it coal) and 75 GWe by 2017. It is also forming joint ventures in heavy engineering.

Other Indigenous Arrangements

The 87% state-owned National Aluminium Company (Nalco) has signed an agreement with NPCIL relevant to its hopes of building a 1000 MWe nuclear power plant on the east coast, in Orissa's Ganjam district. It already has its own 1200 MWe coal-fired power plant in the state at Angul to serve its refinery and smelter of 345,000 tpa, being expanded to 460,000 tpa (requiring about 1 GWe of constant supply). A more specific agreement is expected in 2010.

India's national oil company, Indian Oil Corporation Ltd (IOC), in November 2009 joined with NPCIL in a memorandum of understanding "for partnership in setting up nuclear power plants in India." The initial plant envisaged is at least 1000 MWe, and NPCIL will be the operator and at least 51% owner. IOC will take a 26% stake in it. The cash-rich Oil and Natural Gas Corporation (ONGC) is having talks with AEC about becoming a minority partner with NPCIL on 700 MWe PHWR projects.

Indian Railways have also approached NPCIL to set up a joint venture to build two 500 MWe PHWR nuclear plants on railway land for their own power requirements. The Railways already have a joint venture with NTPC - Bhartiya Rail Bijlee Company - to build a 1000 MWe coal-fired power plant at Nabinagar in Aurangabad district of Bihar, with the 250 MWe units coming on line 2012-13. The Railways also plans to set up another 1320 MWe power plant at Adra in Purulia district of West Bengal for traction supply at economical tariff.

The government has announced that it intends to amend the law to allow private companies to be involved in nuclear power generation and possibly other aspects of the fuel cycle, but without direct foreign investment.

In anticipation of this, Reliance Power Ltd, GVK Power & Infrastructure Ltd and GMR Energy Ltd are reported to be in discussion with overseas nuclear vendors including Areva, GE-Hitachi, Westinghouse and Atomstroyexport.

NTPC is reported to be establishing a joint venture with NPCIL and BHEL to sell India's largely indigenous 220 MWe heavy water power reactor units abroad, possibly in contra deals involving uranium supply from countries such as Namibia and Mongolia.

In September 2009 the AEC announced a version of its planned Advanced Heavy Water Reactor (AHWR) designed for export.

In August and September 2009 the AEC reaffirmed its commitment to the thorium fuel cycle, particularly thorium-based FBRs, to make the country a technological leader.

Overseas Reactor Vendors

As described above, there have been a succession of agreements with Russia's Atomstroyexport to build further VVER reactors. In March 2010 a 'roadmap' for building six more reactors at Kudankulam by 2017 and four more at Haripur after 2017 was agreed, bringing the total to 12. The number may be increased after 2017, in India's 13th 5-year plan. A Russian fuel fabrication plant is also under consideration.

In February 2009 Areva signed a memorandum of understanding with NPCIL to build two, and later four more, EPR units at Jaitapur, and a formal contract is expected in December 2010. This followed the government signing a nuclear cooperation agreement with France in September 2008.

In March 2009 GE Hitachi Nuclear Energy signed agreements with NPCIL and Bharat Heavy Electricals (BHEL) to begin planning to build a multi-unit power plant using 1350 MWe Advanced Boiling Water Reactors (ABWR). In May 2009 L&T was brought into the picture. In April 2010 it was announced that the BHEL-NPCIL joint venture was still in discussion with an unnamed technology partner to build a 1400 MWe nuclear plant at Chutka in Madhya Pradesh state, with Madhya Pradesh Power Generating Company Limited (MPPGCL) the nodal agency to facilitate the execution of the project.

In May 2009 Westinghouse signed a memorandum of understanding with NPCIL regarding deployment of its AP1000 reactors, using local components (probably from L&T).

After a break of three decades, Atomic Energy of Canada Ltd (AECL) is keen to resume technical cooperation, especially in relation to servicing India's PHWRs, and there have been preliminary discussions regarding the sale of an ACR-1000.

In August 2009 NPCIL signed agreements with Korea Electric Power Co (KEPCO) to study the prospects for building Korean APR-1400 reactors in India. This will depend on establishing a bilateral nuclear cooperation agreement.

The LWRs to be set up by these foreign companies are reported to have a lifetime guarantee of fuel supply.

Fast Neutron Reactors

Longer term, the AEC envisages its fast reactor program being 30 to 40 times bigger than the PHWR program, and initially at least, largely in the military sphere until its "synchronised working" with the reprocessing plant is proven on an 18-24 month cycle. This will be linked with up to 40,000 MWe of light water reactor capacity, the used fuel feeding ten times that fast breeder capacity, thus "deriving much larger benefit out of the external acquisition in terms of light water reactors and their associated fuel". This 40 GWe of imported LWR multiplied to 400 GWe via FBR would complement 200-250 GWe based on the indigenous program of PHWR-FBR-AHWR (see Thorium cycle section below). Thus AEC is "talking about 500 to 600 GWe nuclear over the next 50 years or so" in India, plus export opportunities.

In 2002 the regulatory authority issued approval to start construction of a 500 MWe prototype fast breeder reactor (PFBR) at Kalpakkam and this is now under construction by BHAVINI. It is expected to start up in October 2010 and be operating in 2011, fuelled with uranium-plutonium oxide (the reactor-grade Pu being from its existing PHWRs). It will have a blanket with thorium and uranium to breed fissile U-233 and plutonium respectively, taking the thorium program to stage two, and setting the scene for eventual full utilisation of the country's abundant thorium to fuel reactors. Six more such 500 MWe fast reactors have been announced for construction, four of them in parallel by 2017. Two will be at Kalpakkam, two at another site.

Initial FBRs will have mixed oxide fuel or carbide fuel, but these will be followed by metallic fuelled ones to enable shorter doubling time. One of the last of the above six is to have the flexibility to convert from MOX to metallic fuel (ie a dual fuel unit), and it is planned to convert the small FBTR to metallic fuel about 2013 (see R&D section below).

Following these will be a 1000 MWe fast reactor using metallic fuel, and construction of the first is expected to start about 2020. This design is intended to be the main part of the Indian nuclear fleet from the 2020s. A fuel fabrication plant and a reprocessing plant for metal fuels are planned for Kalpakkam, the former possibly for operation in 2014.

Heavy Engineering in India

India's largest engineering group, Larsen & Toubro (L&T) announced in July 2008 that it was preparing to venture into international markets for supply of heavy engineering components for nuclear reactors. It formed a 20 billion rupee (US$ 463 million) venture with NPCIL to build a new plant for domestic and export nuclear forgings at its Hazira, Surat coastal site in Gujarat state. This is now under construction. It will produce 600-tonne ingots in its steel melt shop and have a very large forging press to supply finished forgings for nuclear reactors, pressurizers and steam generators, and also heavy forgings for critical equipment in the hydrocarbon sector and for thermal power plants.

In the context of India's trade isolation over three decades L&T has produced heavy components for 17 of India's pressurized heavy water reactors (PHWRs) and has also secured contracts for 80% of the components for the fast breeder reactor at Kalpakkam. It is qualified by the American Society of Mechanical Engineers to fabricate nuclear-grade pressure vessels and core support structures, achieving this internationally recognised quality standard in 2007. It is one of about ten major nuclear-qualified heavy engineering enterprises worldwide.

Early in 2009, L&T signed four agreements with foreign nuclear power reactor vendors. The first, with Westinghouse, sets up L&T to produce component modules for Westinghouse's AP1000 reactor. The second agreement was with Atomic Energy of Canada Ltd (AECL) "to develop a competitive cost/scope model for the ACR-1000." In April it signed an agreement with Atomstroyexport primarily focused on components for the next four VVER reactors at Kudankulam, but extending beyond that to other Russian VVER plants in India and internationally. Then in May 2009 it signed an agreement with GE Hitachi to produce major components for ABWRs from its new Hazira plant. The two companies hope to utilize indigenous Indian capabilities for the complete construction of nuclear power plants including the supply of reactor equipment and systems, valves, electrical and instrumentation products for ABWR plants to be built in India. L&T "will collaborate with GEH to engineer, manufacture, construct and provide certain construction management services" for the ABWR project. Early in 2010 L&T signed an agreement with Rolls Royce to produce technology and components for light water reactors in India and internationally.

Following the 2008 removal of trade restrictions, Indian companies led by Reliance Power (RPower), NPCIL, and BHEL said that they plan to invest over US$ 50 billion in the next five years to expand their manufacturing base in the nuclear energy sector. BHEL planned to spend $7.5 billion in two years building plants to supply components for reactors of 1,600 MWe. It also plans to set up a tripartite joint venture with NPCIL and Alstom to supply turbines for nuclear plants of 700 MWe, 1,000 MWe and 1,600 MWe. In June 2010 Alstom confirmed that the equal joint venture with NPCIL and BHEL would be capitalized to EUR 25 million, to provide turbines initially for eight 700 MWe PHWR units, then for imported large units. Another joint venture is with NPCIL and a foreign partner to make steam generators for 1000-1600 MWe plants.

HCC (Hindustan Construction Co.) has built more than half of India's nuclear power capacity, notably all 6 units of the Rajasthan Atomic Power Project and also Kudankulam. It has a $188 million contract for Rajasthan 7 & 8.It specializes in prestressed containment structures for reactor buildings. In September 2009 it formed a joint venture with UK-based engineering and project management firm AMEC PLC to undertake consulting services and nuclear power plant construction. HCC has an order backlog worth 10.5 billion rupees ($220 million) for nuclear projects from NPCIL and expects six nuclear reactors to be tendered by the end of 2010.

Areva signed an agreement with Bharat Forge in January 2009 to set up a joint venture in casting and forging nuclear components for both export and the domestic market, by 2012. BHEL expects to join this, and in June 2010 the UK's Sheffield Forgemasters became a technical partner with BHEL in a £30 million deal.

The partners have shortlisted Dahej in Gujarat, and Krishnapatnam and Visakhapatnam in Andhra Pradesh as possible sites.

In August 2010 GE Hitachi Nuclear Energy (GEH) signed a preliminary agreement with India's Tata Consulting Engineers, Ltd. to explore potential project design and workforce development opportunities in support of GEH's future nuclear projects in India - notably the proposals for six ESBWR units - and around the world.

See also India section of Heavy Manufacturing paper.

Uranium Resources in India

India's uranium resources are modest, with 54,000 tonnes U as reasonably assured resources and 23,500 tonnes as estimated additional resources in situ. Accordingly, from 2009 India is expecting to import an increasing proportion of its uranium fuel needs.

Mining and processing of uranium is carried out by Uranium Corporation of India Ltd, a subsidiary of the Department of Atomic Energy (DAE), at Jaduguda and Bhatin (since 1967), Narwapahar (since 1995) and Turamdih (since 2002) - all in Jharkhand near Calcutta. All are underground, the last two being modern. A common mill is located near Jaduguda, and processes 2090 tonnes per day of ore.

In 2005 and 2006 plans were announced to invest almost US$ 700 million to open further mines in Jharkand at Banduhurang, Bagjata and Mohuldih; in Meghalaya at Domiasiat-Mawthabah (with a mill) and in Andhra Pradesh at Lambapur-Peddagattu (with mill 50km away at Seripally), both in Nalgonda district.

In Jharkand, Banduhurang is India's first open cut mine and was commissioned in 2007. Bagjata is underground and was opened in December 2008, though there had been earlier small operations 1986-91. The Mohuldih underground mine is expected to operate from 2010. A new mill at Turamdih in Jharkhand, with 3000 t/day capacity, was commissioned in 2008.

In Andhra Pradesh there are three kinds of uranium mineralisation in the Cuddapah Basin, including unconformity-related deposits in the north of it. The northern Lambapur-Peddagattu project in Nalgonda district 110 km southeast of Hyderabad has environmental clearance for one open cut and three small underground mines (based on some 6000 tU resources at about 0.1%U) but faces local opposition. In August 2007 the government approved a new US$ 270 million underground mine and mill at Tummalapalle near Pulivendula in Kadapa district, at the south end of the Basin and 300 km south of Hyderabad, for commissioning in 2010. Its resources have been revised upwards to 40,000 tU and first production is expected early in 2011, using alkaline leaching for the first time in India. A further northern deposit near Lambapur-Peddagattu is Koppunuru, in Guntur district.

In Meghalaya, close to the Bangladesh border in the West Khasi Hills, the Domiasiat-Mawthabah mine project (near Nongbah-Jynrin) is in a high rainfall area and has also faced longstanding local opposition partly related to land acquisition issues but also fanned by a campaign of fearmongering. For this reason, and despite clear state government support in principle, UCIL does not yet have approval from the state government for the open cut mine at Kylleng-Pyndeng-Shahiong (also known as Kylleng-Pyndengshohiong-Mawthabah and formerly as Domiasiat) though pre-project development has been authorised on 422 ha. However, federal environmental approval in December 2007 for a proposed uranium mine and processing plant here and for the Nongstin mine has been reported. There is sometimes violent opposition by NGOs to uranium mine development in the West Khasi Hills, including at Domiasiat and Wakhyn, which have estimated resources of 9500 tU and 4000 tU respectively. Tyrnai is a smaller deposit in the area. The status and geography of all these is not known.

In Karnataka, UCIL is planning a small uranium mine at Gogi in Gulbarga area from about 2012, after undertaking a feasibility study. A mill is planned for Diggi nearby. Total cost is about $122 million. Resources are sufficient for 15 years mine life, but UCIL plans also to utilise the uranium deposits in the Bhima belt from Sedam in Gulbarga to Muddebihal in Bijapur.

India's Uranium Mines and Mills - Existing and Announced

State, District	Mine	Mill	Operating from	tU per Year
Jharkhand	Jaduguda	Jaduguda	1967 (mine)	
			1968 (mill)	175 total from mill
	Bhatin	Jaduguda	1967	
	Narwapahar	Jaduguda	1995	

	Bagjata	Jaduguda	2009?	
Jharkhand, East Singhbum dist.	Turamdih	Turamdih	2003 (mine) 2008 (mill)	190 total from mill
	Banduhurang	Turamdih	2007	
	Mohuldih	Turamdih	2011	
Meghalaya	Kylleng-Pyndeng-Shahiong (Domiasiat), Mawthabah, Wakhyn	Mawthabah	2012, maybe 2010	340
Andhra Pradesh, Nalgonda dist.	Lambapur-Peddagattu	Seripally / Mallapuram	2012	130
Andhra Pradesh, Kadapa dist.	Tummalapalle	Tummalapalle	2011	220
Karnataka, Gulbarga dist.	Gogi	Diggi	2012?	

However, India has reserves of 290,000 tonnes of thorium - about one quarter of the world total, and these are intended to fuel its nuclear power program longer-term (see below).

In September 2009 state-owned oil company ONJC proposed to form a joint venture with UCIL to explore for uranium in Assam.

Uranium Imports

By December 2008, Russia's Rosatom and Areva from France had contracted to supply uranium for power generation, while Kazakhstan, Brazil and South Africa were preparing to do so. The Russian agreement was to provide fuel for PHWRs as well as the two small Tarapur reactors, the Areva agreement was to supply 300 tU.

In February 2009 the actual Russian contract was signed with TVEL to supply 2000 tonnes of natural uranium fuel pellets for PHWRs over ten years, costing $780 million, and 58 tonnes of low-enriched fuel pellets for the Tarapur reactors. The Areva shipment arrived in June 2009. RAPS-2 became the first PHWR to be fuelled with imported uranium, followed by units 5 & 6 there.

In January 2009 NPCIL signed a memorandum of understanding with Kazatomprom for supply of 2100 tonnes of uranium concentrate over six years and a feasibility study on building Indian PHWR reactors in Kazakhstan. NPCIL said that it represented "a mutual commitment to begin thorough discussions on long-term strategic relationship." Under this agreement, 300 tonnes of natural uranium will come from Kazakhstan in the 2010-11 year. Another 210 t will come from Russia

In September 2009 India signed uranium supply and nuclear cooperation agreements with Namibia and Mongolia. In March 2010 Russia offered India a stake in the Elkon uranium mining development in its Sakha Republic, and agreed on a joint venture with ARMZ Uranium Holding Co.

In July 2010 the Minister for Science & Technology reported that India had received 868 tU from France, Russia & Kazakhstan in the year to date: 300 tU natural uranium concentrate from Areva, 58 tU as enriched UO_2 pellets from Areva, 210 tU as natural uranium oxide pellets from TVEL and 300 tU as natural uranium from Kazatomprom.

As of August 2010 the DAE said that seven reactors (1400 MWe) were using imported fuel and working at full power, nine reactors (2630 MWe) used domestic uranium.

Uranium Fuel Cycle

DAE's Nuclear Fuel Complex at Hyderabad undertakes **refining and conversion of uranium**, which is received as magnesium diuranate (yellowcake) and refined. The main 400 t/yr plant fabricates PHWR fuel (which is unenriched). A small (25 t/yr) fabrication plant makes fuel for the Tarapur BWRs from imported enriched (2.66% U-235) uranium. Depleted uranium oxide fuel pellets (from reprocessed uranium) and thorium oxide pellets are also made for PHWR fuel bundles. Mixed carbide fuel for FBTR was first fabricated by Bhabha Atomic Research Centre (BARC) in 1979.

Heavy water is supplied by DAE's Heavy Water Board, and the seven plants are working at capacity due to the current building program.

A very small centrifuge **enrichment** plant - insufficient even for the Tarapur reactors - is operated by DAE's Rare Materials Plant at Ratnahalli near Mysore, primarily for military purposes including submarine fuel, but also supplying research reactors. It started up about 1990 and appears that it is being expanded to some 25,000 SWU/yr. Some centrifuge R&D is undertaken by BARC at Tromaby.

Fuel fabrication is by the Nuclear Fuel Complex in Hyderabad, which is setting up a new 500 t/yr PHWR fuel plant at Rawatbhata in Rajasthan, to serve the larger new reactors. Each 700 MWe reactor is said to need 125 t/yr of fuel. The company is proposing joint ventures with US, French and Russian companies to produce fuel for those reactors.

Reprocessing: Used fuel from the civil PHWRs is reprocessed by Bhabha Atomic Research Centre (BARC) at Trombay, Tarapur and Kalpakkam to extract reactor-grade plutonium for use in the fast breeder reactors. Small plants at each site were supplemented by a new Kalpakkam plant of some 100 t/yr commissioned in 1998, and this is being extended to reprocess FBTR carbide fuel. Apart from this all reprocessing uses the Purex process. Further capacity is being built at Tarapur and Kalpakkam, to come on line by about 2010. India will reprocess the used fuel from the Kudankulam reactors and will keep the plutonium.

In 2003 a facility was commissioned at Kalpakkam to reprocess mixed carbide fuel using an advanced Purex process. Future FBRs will also have these facilities co-located.

The PFBR and the next four FBRs to be commissioned by 2020 will use oxide fuel. After that it is expected that metal fuel with higher breeding capability will be introduced and burn-up is intended to increase from 100 to 200 GWd/t.

To close the FBR fuel cycle a fast reactor fuel cycle facility is planned, with construction to begin in 2008 and operation to coincide with the need to reprocess the first PFBR fuel. In 2010 the AEC said that used mixed carbide fuel from the Fast Breeder Test Reactor (FBTR) with a burn-up of 155 GWd/t was reprocessed in the Compact Reprocessing facility for Advanced fuels in Lead cells (CORAL). Thereafter, the fissile material was re-fabricated as fuel and loaded back into the reactor, thus 'closing' the fast reactor fuel cycle.

In April 2010 it was announced that 18 months of negotiations with the USA had resulted in agreement to build two new reprocessing plants to be under IAEA safeguards, likely located near Kalpakkam and near Mumbai - possibly Trombay. In July 2010 an agreement was signed with the USA to allow reprocessing of US-origin fuel at one of these facilities. Later in 2010 the AEC said that India has commenced engineering activities for setting up of an Integrated Nuclear Recycle Plant with facilities for both reprocessing of spent fuel and waste management.

Under plans for the India-specific safeguards to be administered by the IAEA in relation to the civil-military separation plan several fuel fabrication facilities will come under safeguards.

Thorium Fuel Cycle Development in India

The long-term goal of India's nuclear program has been to develop an advanced heavy-water thorium cycle.The first stage of this employs the PHWRs fuelled by natural uranium, and light water reactors, to produce plutonium.

Stage 2 uses fast neutron reactors burning the plutonium to breed U-233 from thorium. The blanket around the core will have uranium as well as thorium, so that further plutonium (ideally high-fissile Pu) is produced as well as the U-233.

Then in stage 3, Advanced Heavy Water Reactors (AHWRs) burn the U-233 from stage 2 and this plutonium with thorium, getting about two thirds of their power from the thorium.

In 2002 the regulatory authority issued approval to start construction of a 500 MWe prototype fast breeder reactor at Kalpakkam and this is now under construction by BHAVINI. The unit is expected to be operating in 2011, fuelled with uranium-plutonium oxide (the reactor-grade Pu being from its existing PHWRs). It will have a blanket with thorium and uranium to breed fissile U-233 and plutonium respectively. This will take India's ambitious thorium program to stage 2, and set the scene for eventual full utilisation of the country's abundant thorium to fuel reactors. Six more such 500 MWe fast reactors have been announced for construction, four of them by 2020.

So far about one tonne of thorium oxide fuel has been irradiated experimentally in PHWR reactors and has reprocessed and some of this has been reprocessed, according to BARC. A reprocessing centre for thorium fuels is being set up at Kalpakkam.

Design is largely complete for the first 300 MWe AHWR, intended to be built in the 11th plan period to 2012, though no site has yet been announced. It will have vertical pressure tubes in which the light water coolant under high pressure will boil, circulation being by convection. A large heat sink - "Gravity-driven water pool" - with 7000 cubic metres of water is near the top of the reactor building. In April 2008 an AHWR critical facility was commissioned at BARC “to conduct a wide range of experiments, to help validate the reactor physics of the AHWR through computer codes and in generating nuclear data about materials, such as thorium-uranium 233 based fuel, which have not been extensively used in the past.” It has all the components of the AHWR’s core including fuel and moderator, and can be operated in different modes with various kinds of fuel in different configurations.

In 2009 the AEC announced some features of the 300 MWe AHWR: It is mainly a thorium-fuelled reactor with several advanced passive safety features to enable meeting next generation safety requirements such as three days grace period for operator response, elimination of the need for exclusion zone beyond the plant boundary, 100-year design life, and high level of fault tolerance. The advanced safety characteristics have been verified in a series of experiments carried out in full-scale test facilities. Also, per unit of energy produced, the amount of long-lived minor actinides generated is nearly half of that produced in current generation Light Water Reactors. Importantly, a high level of radioactivity in the fissile and fertile materials recovered from the used fuel of AHWR, and their isotopic composition, preclude the use of these materials for nuclear weapons.

At the same time the AEC announced an LEU version of the AHWR. This will use low-enriched uranium plus thorium as a fuel, dispensing with the plutonium input. About 39% of the power will come from thorium (via in situ conversion to U-233, cf two thirds in AHWR), and burn-up will be 64 GWd/t. Uranium enrichment level will be 19.75%, giving 4.21% average fissile content of the U-Th fuel. While designed for closed fuel cycle, this is not required. Plutonium production will be less than in light water reactors, and the fissile proportion will be less and the Pu-238 portion three times as high, giving inherent proliferation resistance. The design is intended for overseas sales, and the AEC says that "the reactor is manageable with modest industrial infrastructure within the reach of developing countries".

Radioactive Waste Management in India

Radioactive wastes from the nuclear reactors and reprocessing plants are treated and stored at each site. Waste immobilisation plants are in operation at Tarapur and Trombay and another is being constructed at Kalpakkam. Research on final disposal of high-level and long-lived wastes in a geological repository is in progress at BARC.

Regulation and Safety

The Atomic Energy Commission (AEC) was established in 1948 under the Atomic Energy Act as a policy body. Then in 1954 the Department of Atomic Energy (DAE) was set up to encompass research, technology development and commercial reactor operation. The current Atomic Energy Act is 1962, and it permits only government-owned enterprises to be involved in nuclear power.

The DAE includes NPCIL, Uranium Corporation of India (mining and processing), Electronics Corporation of India Ltd (reactor control and instrumentation) and BHAVIN* (for setting up fast reactors). The government also controls the Heavy Water Board for production of heavy water and the Nuclear Fuel Complex for fuel and component manufacture.

** Bhartiya Nabhikiya Vidyut Nigam Ltd*

The Atomic Energy Regulatory Board (AERB) was formed in 1983 and comes under the AEC but is independent of DAE. It is responsible for the regulation and licensing of all nuclear facilities, and their safety and carries authority conferred by the Atomic Energy Act for radiation safety and by the Factories Act for industrial safety in nuclear plants.

NPCIL is an active participant in the programmes of the World Association of Nuclear Operators (WANO).

Nuclear Liability

India's 1962 Atomic Energy Act says nothing about liability or compensation in the event of an accident. Also, India is not a party to the relevant international nuclear liability conventions (the IAEA's 1997 Amended Vienna Convention and 1997 Convention on Supplementary Compensation for Nuclear Damage - CSC). Since all civil nuclear facilities are owned and must be majority-owned by the Central Government (NPCIL and BHAVNI, both public sector enterprises), the liability issues arising from these installations are its responsibility. On 10 September 2008 the government assured the USA that India "shall take all steps necessary to adhere to the Convention on Supplementary Compensation (CSC)". Under existing Indian legislation, foreign suppliers may face unlimited liability, which prevents them from taking insurance cover, though contracts for Kudankulam 1&2 exclude this supplier liability.

A bill related to third party liability has been passed by both houses of parliament. This is framed and was debated in the context of strong national awareness of the Bhopal disaster in 1984, probably the world's worst industrial accident. A Union Carbide (51% US-owned) chemical plant in the central Madhya Pradesh state released a deadly mix of methyl isocyanate and other gases due to operator error and poor plant design, killing some 15,000 people and badly affecting some 100,000 others. The company paid out some US$ 1 billion in compensation - widely considered inadequate.

The new bill places responsibility for any nuclear accident with the operator, as is standard internationally, and limits total liability to 300 million SDR (about US$ 450 million) "or such higher amount that the Central Government may specify by notification". Operator liability is capped at Rs 1500 crore (about US$ 330 million) or such higher amount that the Central Government may notify, beyond which the Central Government is liable.

However, after compensation has been paid by the operator (or its insurers), the bill allows the operator to have legal recourse to the supplier for up to 80 years after the plant starts up if the "nuclear incident has resulted as a consequence of an act of supplier or his employee, which includes supply of equipment or material with patent or latent defects of (or?) sub-standard services." This clause giving recourse to the supplier for an operational plant is contrary to international conventions.

At the same time it is reported that negotiations with Russia for additional nuclear reactors at Kudankulam are held up because of this sub-clause, in this case involving Atomstroyexport. The original Kudankulam agreement said that supplier liability ended with delivery of the plant. US diplomatic sources are similarly opposed to supplier liability after delivery.

The bill does not make any mention of India ratifying the Convention on Supplementary Compensation for Nuclear Damage (CSC), and any international treaty or framework governing nuclear liability under which the supplier cannot be sued in their home country. The CSC is not yet in force internationally, but Indian ratification would bring it closer to being so, and was part of the September 2008 agreement with USA.

Research & Development

An early AEC decision was to set up the Bhabha Atomic Research Centre (BARC) at Trombay near Mumbai. A series of 'research' reactors and critical facilities was built here: APSARA (1 MW, operating from 1956) was the first research reactor in Asia, Cirus (40 MW, 1960) and Dhruva (100 MW, 1985) followed it along with fuel cycle facilities. The Cirus and Dhruva units are assumed to be for military purposes, as is the plutonium plant commissioned in 1965. The government has undertaken to shut down CIRUS in 2010.

BARC is also responsible for the transition to thorium-based systems and in particular is developing the 300 MWe AHWR as a technology demonstration project. This will be a vertical pressure tube design with heavy water moderator, boiling light water cooling with passive safety design and thorium-plutonium based fuel (described more fully above). A large critical facility to validate the reactor physics of the AHWR core has been commissioned at BARC, and by the end of 2010 BARC plans to set up a research laboratory at Tarapur to test various AHWR systems.

A series of three Purnima research reactors have explored the thorium cycle, the first (1971) running on plutonium fuel fabricated at BARC, the second and third (1984 & 1990) on U-233 fuel made from thorium - U-233 having been first separated in 1970. All three are now decommissioned.

In 1998 a 500 keV accelerator was commissioned at BARC for research on accelerator-driven subcritical systems as an option for stage three of the thorium cycle.

There are plans for a new 20-30 MWt multi-purpose research reactor (MPRR) for radioisotope production, testing nuclear fuel and reactor materials, and basic research. It will use fuel enriched to 19.9% U-235 and is to be capable of conversion to an accelerator-driven system later.

Two civil research reactors at the **Indira Gandhi Centre for Atomic Research** at Kalpakkam are preparing for stage two of the thorium cycle. The 40 MWt fast breeder test reactor (FBTR) has been operating since 1985, and has achieved 165 GWday/tonne burnup with its carbide fuel (70% PuC + 30% UC) without any fuel failure. In 2005 the FBTR fuel cycle was closed, with the reprocessing of 100 GWd/t fuel - claimed as a world first. This has been made into new mixed carbide fuel for FBTR. Prototype FBR fuel which is under irradiation testing in FBTR has reached a burnup of 90 GWd/tonne. FBTR is based on the French Rapsodie FBR design. Also the tiny Kamini (Kalpakkam mini) reactor is exploring the use of thorium as nuclear fuel, by breeding fissile U-233. BHAVINI is located here and draws upon the centre's expertise and that of NPCIL in establishing the fast reactor program.

As part of developing higher-burnup fuel for PHWRs mixed oxide (MOX) fuel is being used experimentally in FBTR, which is now operating with a hybrid core of mixed carbide and mixed oxide fuel (the high-Pu MOX forming 20% of the core).

A 150 MWe fast breeder reactor as a test bed for using metallic fuel is envisaged once several MOX-fuelled fast reactors are in operation.

A Compact High-Temperature Reactor (CHTR) is being designed to have long (15 year) core life and employ liquid metal (Pb-Bi) coolant. There are also designs for HTRs up to 600 MWt for hydrogen production and a 5 MWt multi-purpose nuclear power pack.

The Board of Radiation & Isotope Technology was separated from BARC in 1989 and is responsible for radioisotope production. The research reactors APSARA, CIRUS and Dhruva are used, along with RAPS for cobalt-60.

BARC has used nuclear techniques to develop 37 genetically-modified crop varieties for commercial cultivation. A total of 15 sterilising facilities, particularly for preserving food, are now operational with more under construction. Radiation technology has also helped India increase its exports of food items, including to the most developed markets in the world.

India's hybrid Nuclear Desalination Demonstration Plant (NDDP) at Kalpakkam, comprises a Reverse Osmosis (RO) unit of 1.8 million litres per day commissioned in 2002 and a Multi Stage Flash (MSF) desalination unit of 4.5 million litres per day, as well as a barge-mounted RO unit commissioned recently, to help address the shortage of water in water-stressed coastal areas. It uses about 4 MWe from the Madras nuclear power station.

Non-Proliferation, US-India Agreement and Nuclear Suppliers' Group

India's nuclear industry has been largely without IAEA safeguards, though four nuclear power plants (see above) have been under facility-specific arrangements related to India's INFCIRC/66 safeguards agreement with IAEA. However, in October 2009 India's safeguards agreement with the IAEA became operational, with the government confirming that 14 reactor will be put under the India Specific Safeguards Agreement by 2014.

India's situation as a nuclear-armed country excluded it from the Nuclear Non-Proliferation Treaty (NPT)* so this and the related lack of full-scope IAEA safeguards meant that India was isolated from world trade by the Nuclear Suppliers' Group. A clean waiver to the trade embargo was agreed in September 2008 in recognition of the country's impeccable non-proliferation credentials. India has always been scrupulous in ensuring that its weapons material and technology are guarded against commercial or illicit export to other countries.

** India could only join the NPT if it disarmed and joined as a Non Nuclear Weapons State, which is politically impossible. See Appendix.*

Following the 2005 agreement between US and Indian heads of state on nuclear energy cooperation, the UK indicated its strong support for greater cooperation and France then Canada then moved in the same direction. The US Department of Commerce, the UK and Canada relaxed controls on export of technology to India, though staying within the Nuclear Suppliers Group guidelines. The French government said it would seek a nuclear cooperation agreement, and Canada agreed to "pursue further opportunities for the development of the peaceful uses of atomic energy" with India.

In December 2006 the US Congress passed legislation to enable nuclear trade with India. Then in July 2007 a nuclear cooperation agreement with India was finalized, opening the way for India's participation in international commerce in nuclear fuel and equipment and requiring India to put most of the country's nuclear power reactors under IAEA safeguards and close down the CIRUS research reactor at the end of 2010. It would allow India to reprocess US-origin and other foreign-sourced nuclear fuel at a new national plant under IAEA safeguards. This would be used for fuel arising from those 14 reactors designated as unambiguously civilian and under full IAEA safeguards.

The IAEA greeted the deal as being "a creative break with the past" - where India was excluded from the NPT. After much delay in India's parliament, it then set up a new and comprehensive safeguards agreement with the IAEA, plus an Additional Protocol. The IAEA board approved this in July 2008, after the agreement had threatened to bring down the Indian government. The agreement is similar to those between IAEA and non nuclear weapons states, notably Infcirc-66, the IAEA's information circular that lays out procedures for applying facility-specific safeguards, hence much more restrictive than many in India's parliament wanted.

The next step in bringing India into the fold was the consensus resolution of the 45-member Nuclear Suppliers Group (NSG) in September 2008 to exempt India from its rule of prohibiting trade with non-members of the NPT. A bilateral trade agreement then went to US Congress for final approval, and was signed into law on 8 October 2008. Similar agreements will apply with Russia and France. The ultimate objective is to put India on the same footing as China in respect to responsibilities and trade opportunities, though it has had to accept much tighter international controls than other nuclear-armed countries.

The introduction to India's safeguards agreement says that India's access to assured supplies of fresh fuel is an "essential basis" for New Delhi's acceptance of IAEA safeguards on some of its reactors and that India has a right to take "corrective measures to ensure uninterrupted operation of its civilian nuclear reactors in the event of disruption of foreign fuel supplies." But the introduction also says that India will "provide assurance against withdrawal of safeguarded nuclear material from civilian use at any time." In the course of NSG deliberations India also gave assurances regarding weapons testing.

In October 2008 US Congress passed the bill allowing civil nuclear trade with India, and a nuclear trade agreement was signed with France. The 2008 agreements ended 34 years of trade isolation in relation to nuclear materials and technology.

India's safeguards agreement was signed early in 2009, though the timeframe for bringing the eight extra reactors (beyond Tarapur, Rajasthan and Kudankulam) under safeguards still has to be finalised. The Additional Protocol to the safeguards agreement was agreed by the IAEA Board in March 2009, but needs to be ratified by India.

Appendix

BACKGROUND TO NUCLEAR PROLIFERATION ISSUES

India (along with Pakistan and Israel) was originally a 'threshold' country in terms of the international non-proliferation regime, possessing, or quickly capable of assembling one or more nuclear weapons: Their nuclear weapons capability at the technological level was recognised (all have research reactors at least) along with their military ambitions. Then in 1998 India and Pakistan's military capability became more overt. All three remained remained outside the 1970 Nuclear Non-Proliferation Treaty (NPT), which 186 nations have now signed. This led to their being largely excluded from trade in nuclear plant or materials, except for safety-related devices for a few safeguarded facilities.

India is opposed to the NPT as it now stands, since it is excluded as a Nuclear Weapons State, and has consistently criticised this aspect of the Treaty since its inception in 1970.

Regional Rivalry

Relations between India and Pakistan are tense and hostile, and the risks of nuclear conflict between them have long been considered quite high.

In 1974 India exploded a "peaceful" nuclear device at Pokhran and then in May 1998 India and Pakistan each exploded several nuclear devices underground. This heightened concerns regarding an arms race between them.

Kashmir is a prime cause of bilateral tension, its sovereignty has been in dispute since 1948. There is persistent low level military conflict due to Pakistan backing a Muslim rebellion there.

Both countries engaged in a conventional arms race in the 1980s, including sophisticated technology and equipment capable of delivering nuclear weapons. In the 1990s the arms race quickened. In 1994 India reversed a four-year trend of reduced allocations for defence, and despite its much smaller economy, Pakistan pushed its own expenditures yet higher. Both then lost their patrons: India, the former USSR; and Pakistan, the USA.

In 1997 India deployed a medium-range missile and is now developing a long-range missile capable of reaching targets in China's industrial heartland.

In 1995 the USA quietly intervened to head off a proposed nuclear test. The 1998 tests were unambiguously military, including one claimed to be of a sophisticated thermonuclear device. Their declared purpose was "to help in the design of nuclear weapons of different yields and different delivery systems".

It is the growth and modernisation of China's nuclear arsenal and its assistance with Pakistan's nuclear power program and, reportedly, with missile technology, which now exacerbates Indian concerns. In particular, China's People's Liberation Army operates somewhat autonomously within Pakistan as an exporter of military material.

Indian security policies are driven by:

its desire to be recognised as the dominant power in the region;

its increasing concern with China's expanding nuclear weapons and missile delivery programs; and

its enduring concern about Pakistan, with its nuclear weapons capability and now the clear capability to deliver such weapons deep into India.

It perceives nuclear weapons as a cost-effective political counter to China's nuclear and conventional weaponry, and the effects of its nuclear weapons policy in provoking Pakistan is, by some accounts, considered incidental.

India has had an unhappy relationship with China. Soundly defeated by China in the 1962 war, relations were frozen until 1998. Since then a degree of high-level contact has been established and a few elementary confidence-building measures put in place. China still occupies some Indian territory. Its nuclear and missile support for Pakistan is however a major bone of contention.

India's weapons material initially came from the Canadian-designed 40 MWt CIRUS "research" reactor which started up in 1960 (well before the NPT), and the 100 MWt Dhruva indigenous unit in operation since 1985, using local uranium. CIRUS was supplied with heavy water from the USA and it was probably only after the 1962 war that it was employed largely to make weapons-grade plutonium.* Development of nuclear weapons apparently began in earnest in 1967. It is estimated that India may have built up enough weapons-grade plutonium for one hundred nuclear warheads.

** Article III of the 1956 India-Canada Agreement: The Government of India will ensure that the reactor and any products resulting from its use will be employed for peaceful purposes only. Clause 9 of the India-US Heavy Water Agreement: The heavy water sold here under shall be for use only in India by the Government in connection with research into and the use atomic energy for peaceful purposes.*

In response to India's 1974 nuclear test explosion using plutonium from CIRUS, demonstrating that nuclear technology transferred to non-nuclear-weapons states for peaceful purposes could be misused, the Nuclear Suppliers Group was formed and began regulating nuclear trade, particularly with India. This is one reason why the closure of CIRUS is a condition of the NSG waiver in 2008.

Nuclear Arms Control in the Region

The public stance of India and Pakistan on non-proliferation differs markedly.

Pakistan has initiated a series of regional security proposals. It has repeatedly proposed a nuclear-free zone in South Asia and has proclaimed its willingness to engage in nuclear disarmament and to sign the NPT if India would do so. This would involve disarming and joining as non-weapon states. It has endorsed a US proposal for a regional five power conference to consider non-proliferation in South Asia.

India has taken the view that solutions to regional security issues should be found at the international rather than the regional level, since its chief concern is with China. It therefore rejects Pakistan's proposals.

Instead, the 'Gandhi Plan', put forward in 1988, proposed the revision of the NPT, which it regards as inherently discriminatory in favour of the Nuclear-Weapons States, and a timetable for complete nuclear weapons disarmament. It endorsed early proposals for a Comprehensive Test Ban Treaty (CTBT) and for an international convention to ban the production of highly enriched uranium and plutonium for weapons purposes, known as the 'cut-off' convention.

The USA has, for some years pursued a variety of initiatives to persuade India and Pakistan to abandon their nuclear weapons programs and to accept comprehensive international safeguards on all their nuclear activities. To this end the Clinton administration proposed a conference of nine states, comprising the five established nuclear-weapon states, along with Japan, Germany, India and Pakistan.

This and previous similar proposals have been rejected by India, which countered with demands that other potential weapons states, such as Iran and North Korea, should be invited, and that regional limitations would only be acceptable if they were accepted equally by China. The USA would not accept the participation of Iran and North Korea and such initiatives lapsed.

Another, more recent approach, centres on the concept of containment, designed to 'cap' the production of fissile material for weapons purposes, which would hopefully be followed by 'roll back'. To this end India and the USA jointly sponsored a UN General Assembly resolution in 1993 calling for negotiations for a 'cut-off' convention, the Fissile Material Cut-off Treaty (FMCT). Should India and Pakistan join such a convention, they would have to agree to halt the production of fissile materials for weapons and to accept international verification on their relevant nuclear facilities (enrichment and reprocessing). In short, their weapons programs would be thus 'capped'. It appeared that India was prepared to join negotiations regarding such a FMCT under the 1995 UN Conference on Disarmament (UNCD).

However, despite the widespread international support for a FMCT, formal negotiations on cut-off have yet to begin. The UNCD can only approve decisions by consensus and since the summer of 1995, the insistence of a few states to link FMCT negotiations to other nuclear disarmament issues has brought progress on the cut-off treaty there to a standstill. In connection with its 2006 agreement with the USA, India has reiterated its support for a FMCT.

Bilateral confidence-building measures between India and Pakistan to reduce the prospects of confrontation have been limited. In 1990 each side ratified a treaty not to attack the other's nuclear installations, and at the end of 1991 they provided one another with a list showing the location of all their nuclear plants, even though the respective lists were regarded as not being wholly accurate. Early in 1994 India proposed a bilateral agreement for a 'no first use' of nuclear weapons and an extension of the 'no attack' treaty to cover civilian and industrial targets as well as nuclear installations.

Having promoted the CTBT since 1954, India dropped its support in 1995 and in 1996 attempted to block the Treaty. Following the 1998 tests the question has been reopened and both Pakistan and India have indicated their intention to sign the CTBT. Indian ratification may be conditional upon the five weapons states agreeing to specific reductions in nuclear arsenals.

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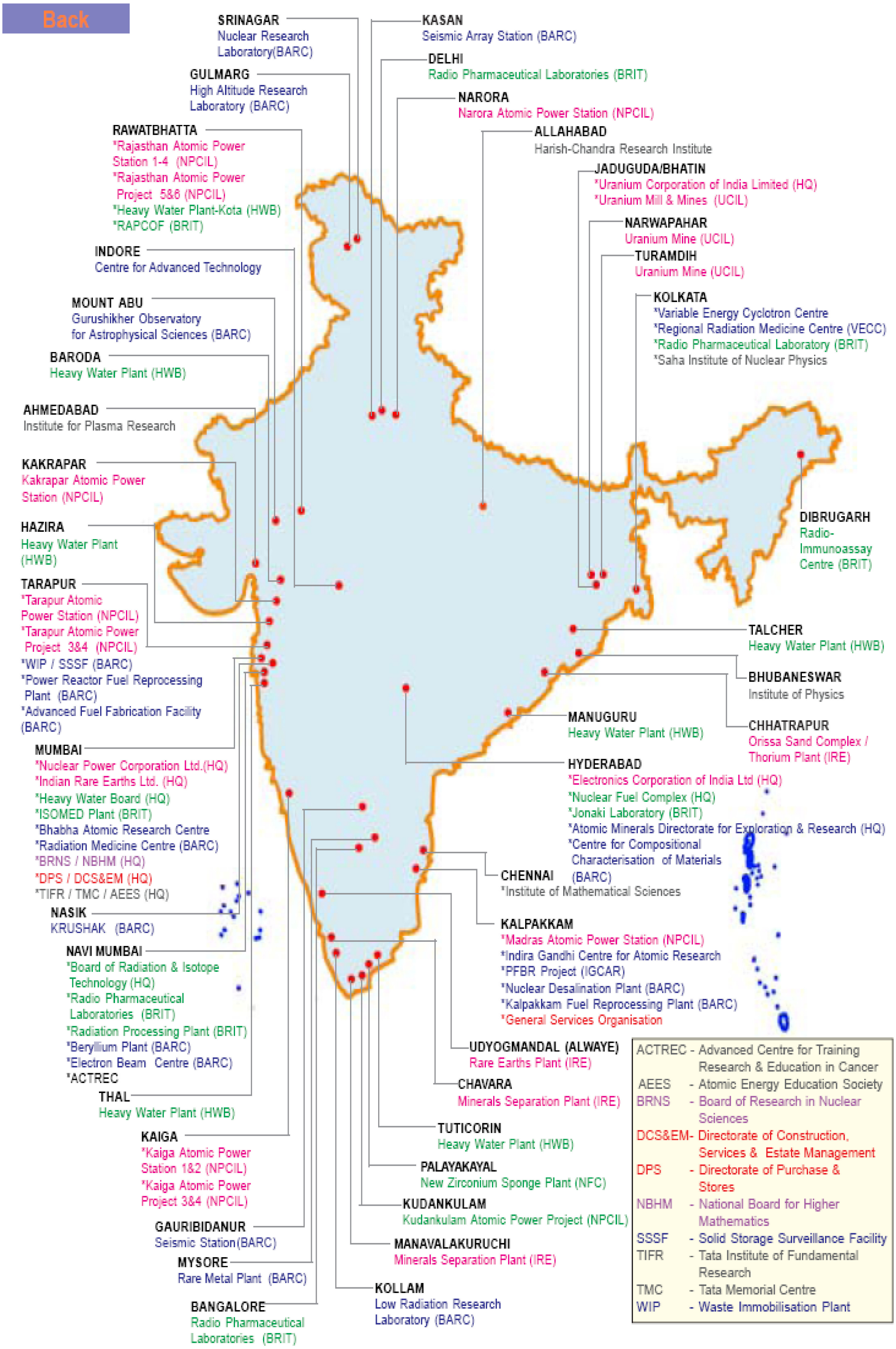
Atomic Energy Establishments in India



US Nuclear Power Policy

(Updated September 2010)
By World Nuclear Association

- ***While the USA has more private sector participation in the production of civilian nuclear power than any other nation, the government is heavily involved through safety and environmental regulations, R&D funding, and setting national energy goals.***
- ***Beginning in the late 1990s, US government policy and funding decisions have encouraged the development of greater civilian nuclear capacity.***
- ***The commitment to nuclear power as part of the USA's long-term energy strategy continues with the Obama administration, but there has been a reduction in some nuclear programs as a result of greater emphasis on alternative sources of energy.***
- ***The disposal and storage of high-level nuclear waste remains a major unresolved issue.***

Government policy is central to any discussion of nuclear power in the USA. The development of nuclear power began as a government program in 1945 following on from the Manhattan Project to develop the wartime atomic bomb. The first nuclear reactor to produce electricity did so at the National Reactor Testing Station (NRTS) in Idaho in December 1951, as the US government reoriented significant resources to the development of civilian use of nuclear power. In the mid-1950s, production of electricity from nuclear power was opened up to private industry. The world's first large-scale nuclear power plant at Shippingport, Pennsylvania, was owned by the US Atomic Energy Commission, but built and operated by the Duquesne Light and Power Company on a site owned by the utility company near Pittsburgh. Today, almost all the commercial reactors in the USA are owned by private companies, and nuclear industry as a whole has far greater private participation, and less concentration, than any other country.

Yet, the government remains more involved in commercial nuclear power than in any other industry in the USA. There are lengthy, detailed requirements for the construction and operation of all reactors and conversion, enrichment, fuel fabrication, mining and milling facilities. The review process preceding the construction of new reactors can take 3-5 years. The US government, through its own national research laboratories and projects at university and industry facilities, is the main source of funding for advanced reactor and fuel cycle research. It also promises to provide incentives for building new plants through loan guarantees and tax credits, although owners have to raise their own capital. US domestic energy policy is also closely linked to foreign, trade and defence policy on such matters as mitigating climate change and nuclear non-proliferation (of weapons).

As of January 2010 the Nuclear Regulatory Commission (NRC) was reviewing 13 applications for combined construction and operating licences (COLs) to build 22 new nuclear reactors, as well as five applications for design certifications for new reactor types. The agency's request for oversight of the 104 operating power reactors was $531.6 million, including 13 reviews of extended power uprate requests and 13 licence renewal applications.

State and local governments also have a major impact on the framework and economics of the US nuclear power industry. Deregulation of electricity prices in some states in the 1990s led to greater concentration in nuclear power production. In 1976, a voter referendum in California led to a law that prohibited the construction of new nuclear plants in the nation's largest state and the prohibition still remains in effect. Opposition in the state of Nevada was a key factor in the decision by the new Democratic administration of Barack Obama in early 2009 to abandon the government's long-standing plans for a 70,000 tonne geological repository in that state for disposal of the high-level nuclear waste that has accumulated at reactor sites across the nation.

Energy Policy Act 2005

After much preliminary debate, the Energy Policy Act 2005 comfortably passed both houses (74-26 in the Senate and 275-156 in the House). It included incentives for the nuclear power industry, including:

- Production tax credit of 2.1 ¢/kWh from the first 6,000 MWe of new nuclear capacity in their first eight years of operation (the same rate as available to wind power on an unlimited basis).
- Federal risk insurance of $2 billion to cover regulatory delays in full-power operation of the first six advanced new plants.

- Rationalised tax on decommissioning funds (some reduced).
- Federal loan guarantees for advanced nuclear reactors or other emission-free technologies up to 80% of the project cost.
- Extension for 20 years of the Price Anderson Act for nuclear liability protection.
- Support for advanced nuclear technology.

Also $1.25 billion was authorised for an advanced high-temperature reactor (Next-Generation Nuclear Plant) at the Idaho National Laboratory, capable of cogenerating hydrogen. Overall more than $2 billion was provided for hydrogen demonstration projects. See later section on NGNP.

In 2006, it was spelled out that the 6,000 MWe eligible for production tax credits would be divided pro-rata among those applicants which filed combined construction and operating licence (COL) applications by the end of 2008, which commence construction of advanced plants by 2014, and which enter service by 2021.

In October 2007, the Department of Energy (DOE) announced that it would guarantee the full amount of loans covering up to 80% of the cost of new clean energy projects including advanced nuclear power plants under the 2005 Energy Policy Act. The first round of loan guarantees went to renewable energy and advanced gas (e.g. integrated gasification combined cycle) projects, those for nuclear then still had to be authorised by Congress.

The Act also addressed climate change, requiring action on a national strategy to address the issue. In 2008, the USA emitted 5.8 billion tonnes of CO2 from energy use.

Federal loan guarantees for new plants (and renewable energy projects)

In mid-2008, the Department of Energy (DOE) invited applications for loan guarantees to support the construction of advanced nuclear power plants (up to $18.5 billion total) and uranium enrichment plants (up to $2 billion initially, but now $4 billion). A further $78.5 billion was offered for renewable energy projects, and $8 billion for 'clean coal'. Loan guarantees are to encourage the commercial use of new or significantly improved energy technologies and "will enable project developers to bridge the financing gap between pilot and demonstration projects to full commercially viable projects that employ new or significantly improved energy technologies."1, a

Any preliminary approvals issued in 2010 will be conditional upon the applicant receiving a combined construction and operating licence (COL) from the Nuclear Regulatory Commission, and the first of these are not expected before 2011.

Applications were lodged in 2008, with a fee of $200,000 for the first part and $600,000 for the second part. The DOE received 19 initial applications from 17 utilities to support the construction of 14 nuclear power plants involving 21 new reactors of five different designs. The total capacity involved was 28,800 MWe. The total requested came to $122 billion, significantly more than the $18.5 billion offered. The aggregate estimated construction cost involved the 14 projects was $188 billion. The DOE also received two applications for enrichment plants, total $4 billion, against $2 billion initially on offer.

In the light of the interest shown and the fact that the scheme is borrower-funded, the industry called for the amount available for power plants to be increased to $100 billion. In February 2010, the Administration added $36 billion to its FY2011 budget proposal to expand the reactor part of the scheme to $54.5 billion, covering 7 to 10 reactors of several different designs. The budget needs to be passed by Congress. In the meantime, DOE granted one application (Vogtle) and sought to increase the sum available before October 2010 by $9 billion through other legislation, so that it could approve the other three short-listed power plant applications involving five reactors.

The amount for enrichment plants was increased to $4 billion early in 2010, evidently to allow for both applicants to receive perhaps $2 billion each. While Areva's technology obviously qualifies, and USEC's as yet doesn’t, Areva is effectively a French government enterprise, so choosing between them would be politically fraught. LESb then asked DOE to reopen the solicitation to it "and others", i.e. Global Laser Enrichment (GLE), on the basis of fair and open competitionc. Neither LES nor GLE has yet applied for a loan guarantee, though GLE has said it would do so for its proposed Wilmington plant, and LES is intending to do so for the expansion of its plant in New Mexico over 2014-17.

Loan Guarantee Applications

	Applicant	Plant	Size (MWe), type	Likely overnight cost	First part	Comments
Power plants	Unistar	Calvert Cliffs 3, MD	1600 EPR	$9 billion	31/7/08	Accepted; short list May 2009
	Dominion	North Anna 3, VA	1550 ESBWR		15/8/08	
	Exelon	Victoria County, TX	1350 ABWR x 2		26/9/08	Plans suspended
	Duke Energy	Lee, SC	1117 AP1000 x 2		29/9/08	delayed 2-3 years
	PPL Corp	Bell Bend, PA	1600 EPR		29/9/08	
	Progress Energy	Levy County, FL	1117 AP1000 x 2		By 29/9/08	
	Ameren UE	Callaway, Missouri	1600 EPR		By 29/9/08	Plans suspended
	Luminant	Comanche Peak, TX	1700 APWR x 2		By 29/9/08	Accepted; first alternative to shortlisted projects
	Unistar	Nine Mile Point, NY	1600 EPR		By 29/9/08	Dropped out
	Entergy	Grand Gulf, MA	1550 ESBWR		By 29/9/08	Plans suspended
	Entergy	River Bend, LA	1550 ESBWR		By 29/9/08	Plans suspended
	NRG & CPS	South Texas Project, TX	1350 ABWR x 2		By 29/9/08	Accepted; short list May 2009
	Southern & Oglethorpe	Vogtle, GA	1117 AP1000 x 2		By 29/9/08	Granted February 2010
	SCEG & Santee Cooper	Summer, SC	1117 AP1000 x 2	$9.8 billion	By 29/9/08	Accepted; short list May 2009
Fuel cycle	USEC	American Centrifuge	3.8 M SWU	$3.5 billion	24/7/08	Refused in July 2009, but discussion ongoing
	Areva Enrichment Services	Eagle Rock Enrichment	3.0 M SWU	$2 billion	29/9/08	Granted May 2010

Subsidies and R&D Support

The US Energy Information Administration (EIA) published an analysis of US government energy subsidies and R&D support in 2007, totaling $16.6 billion – double the 1999 level. Of this, $6.75 billion was related to electricity production, and $6.0 billion of this was split between R&D and subsidies. Apart from transmission and distribution ($875 million), the balance was $1.55 billion for R&D in anticipation of future benefits and $3.55 billion in subsidies for present production. The $1.55 billion for R&D comprised $922 million for nuclear, $522 million for coal and $108 million for renewables – which currently supply 19.4%, 49% and 2.5% (apart from hydro) of US power respectively. Nuclear R&D comprised $319 million for new nuclear plant design and proliferation-resistant fuel cycle, $350 million for clean-up of nuclear energy and research sites and $253 million for Idaho facilities and related management. Two-thirds of coal R&D was for 'clean coal' programs.

The $3.55 billion for subsidies was by way of tax credits, with the lion's share going to coal-based synthetic fuel which achieves some emissions reduction. Nuclear got $199 million and renewables $724 million (0.025 cents/kWh and 0.71 ¢/kWh respectively). The apparent nuclear subsidy was entirely due to a change in tax rules related to decommissioning, under the 2005 Energy Policy Act.

US Department of Energy

The US Department of Energy (DOE) was formed in 1977 in the midst of America's energy crisis. It brought together activities under the Atomic Energy Commission (AEC) founded in 1946 as the civil successor to the Manhattan Project, the Energy Research and Development Administration (ERDA) which succeeded it in 1974, and other bodies. The purpose was to achieve better coordination of policy by putting previously disparate agencies and programs together into a single Cabinet-level department. The Secretary of Energy reports to the President. The DOE's responsibilities include policy and funding for programs on nuclear energy, fossil fuels, hydropower and alternative sources of energy such as wind and solar power.

The DOE also manages (often through a private-sector operations contractor) the government's 21 national laboratories, including the Idaho National Laboratory (INL), which manages a major portion of the govenment's nuclear energy research. The DOE sponsors more basic and applied research, including research done at universities or by industry, than any other government agency. In addition to the DOE's responsibilities for civilian nuclear energy, its National Nuclear Security Administration (NNSA) oversees the military application of nuclear energy, maintaining the country's weapons stockpile and managing the design, production and testing of nuclear weapons.

Most of the federal programs concerned with civilian use of nuclear energy are run by the DOE's Office of Nuclear Energy, including research and development of next-generation nuclear plants, advanced fuel cycle technology, funding for government-industry partnerships for construction of new reactors, and operations and funding for nuclear energy projects at national laboratories. Budgets for these programs have generally grown in recent years as the US government has sought to meet the goals of energy independence, reduction of carbon emissions and meeting the future demand for electricity. In the budget request of the new Obama administration for FY 2010, funding in a number of areas such as next-generation reactor designs and used fuel recycling research would be increased, but the total level of funding for the Office of Nuclear Energy would be reduced by 38%, from $1.36 billion to $875 million. The major increases in the DOE budget are in the areas of alternative energy sources, such as wind, solar and geothermal, and energy efficiency and conservation.

Programs run by the DOE's Office of Nuclear Energy include:

Nuclear Power 2010

In 2002, the DOE announced the Nuclear Power 2010, a government-industry, cost-shared partnership to spur new construction of advanced current generation (Generation III) plants. The program provided matching funds for the preparation of licence applications and encouraged the industry to make use of expedited licensing procedures, such as the combined construction and operating licence (COL) process in seeking approvals from the Nuclear Regulatory Commission. The initiative led to the formation of several utility-vendor consortia, formed to put together proposals to receive matching funds for advanced plant applications, and to the filing of 17 applications for licences under the COL process (see Planned or Proposed Plants section in the information page on Nuclear Power in the USA and Nuclear Power in the USA Appendix 3: COL Applications).

The Obama administration's FY 2010 budget request drastically reduced funding for the Nuclear Power 2010 program, with only $20 million for that fiscal year, versus $177 million for fiscal 2009. For FY 2011 the budget request is zero. The budget cuts brought criticism from the nuclear industry, and the US Congress, which has the final decision of appropriations, allocated $105 million. While the broad outlines of US nuclear policy, on matters such as energy independence and controlling carbon emissions remain the same, each new administration brings shifts in policy.

National laboratories

Much of the USA's applied research, as well as a significant amount of basic research, is conducted at DOE's 21 national laboratories. In 2005, a number of nuclear energy research programs moved to the Idaho National Laboratory (INL), formed from two existing entities on the same site – the Idaho National Engineering and Environmental Laboratory (INEEL) and Argonne National Laboratory West (ANL-W). INEEL was established in 1949 as the National Reactor Testing Station and for many years had the largest concentration of nuclear reactors in the world – 52 different reactors were designed and tested there, including the first reactor to generate electricity from nuclear power (in 1951). ANL-W had been the testing site for research by the University of Chicago, and worked closely with INEEL. It also was developing spacecraft power systems for NASA. All this work was under DOE auspices.

INL now leads US participation in the Generation IV International Forum, and will develop the US Next Generation Nuclear Plant (NGNP) as well as a number of Advanced Fuel Cycle Initiative projects. INL also plays a major role with the Office of Civilian Radioactive Waste Management in developing procedures for high-level waste disposal. Over 6,000 employees work at the INL site.

Other nuclear research facilities owned by the DOE include the Oak Ridge National Laboratory in Tennessee, Los Alamos National Laboratory in New Mexico, Brookhaven National Laboratory in New York and the Argonne National Laboratory in Ilinois. Research funded by the DOE is also conducted at more than 70 universities throughout the country. Employees at the national laboratories come from both the government and the private sector, with many engineers and scientists as well as administrators working under contract.

Several of the DOE laboratory sites have legacy wastes requiring clean-up, and programs are in place to achieve this.

Nuclear Energy Research Initiative

The Nuclear Energy Research Initiative (NERI) was launched in 1999 at a time of renewed concern over meeting the nation's long-term energy needs and increased awareness of the role of nuclear power as part of the energy mix. In 1977, President Clinton asked his Committee of Advisors on Science and Technology to examine the current national energy portfolio and make recommendations that would address the energy needs over the next century. A key recommendation was for a concerted research and development effort to overcome barriers to the expansion of nuclear energy capacity, such as capital costs, nuclear waste disposal and the risks of nuclear weapons proliferation. In response to this recommendation, NERI was established in 1999 to fund research at the national laboratories, universities and industry facilities. In 2004, NERI was refocused to concentrate on university research projects that would advance the government's primary nuclear energy R&D programs: the Advanced Fuel Cycle Initiative (AFCI), the Generation IV Nuclear Energy Systems Initiative (Gen IV) and the Nuclear Hydrogen Initiative (NHI).

Advanced Fuel Cycle Initiative

The Advanced Fuel Cycle Initiative (AFCI) is one of the US government's two major research programs for nuclear energy (see also Generation IV Nuclear Energy Systems below). The development of new fuel cycle technology has been a goal of DOE since its inception, but funding has grown significantly in recent years, driven by the need to manage high-level waste, avoid the production of separated civilian plutonium, recover the energy value of spent fuel, and develop fuel cycles for next generation nuclear plants. The Obama administration's budget request for FY 2010 would provide $192 million in funding for fuel cycle research, a 32% increase over FY 2009.

AFCI research and development efforts include technologies to separate the elements left in used fuel (mainly the UREX processes) and to transmute the most troublesome components of used fuel (such as plutonium and minor actinides) into material that is less hazardous for disposal or can be recycled as fuel for fast reactors. A particular focus of AFCI research is the development of fuel systems and enabling technologies for Generation IV nuclear plants.

Generation IV

The Generation IV Nuclear Systems Initiative (Gen IV) has the mandate to develop new reactor systems that can be deployed over the next 20 years. Like AFCI, funding for Gen IV would rise in the Obama administration budget request – to $191 million, or a 6% increase over FY 2009. DOE supports research on five next generation reactors: the thermal neutron, gas cooled very high temperature reactor (VHTR); the super-critical water cooled reactor (SCWR); the gas-cooled fast neutron reactor (GFR); the lead-cooled fast neutron reactor (LFR); and the sodium-cooled fast neutron reactor.

DOE has given priority to the VHTR, which is being pursued as the Next Generation Nuclear Plant (NGNP, see section below on NGNP) under provisions of the Energy Policy Act of 2005, which authorized $1.25 billion for the NGNP plant over a number of years. VHTR reactors would be capable of producing both electricity and hydrogen on a large scale, but would not have the same capability as fast reactors to burn recycled nuclear fuel. See also information page on Generation IV Nuclear Reactors.

In February 2010, the DOE said that Generation IV systems R&D would continue along with NGNP and small modular reactor R&D under a new Reactor Concepts Research, Development and Demonstration program.

Next Generation Nuclear Plant

In 2004, the DOE sought a partner to develop the Next Generation Nuclear Plant (NGNP), a Generation IV high-temperature gas-cooled reactor, as its leading concept for developing advanced power systems both for electricity and hydrogen production on a very large scale. A $2 billion pilot plant demonstrating technical feasibility is envisaged by 2021 at Idaho National Laboratory (INL) but with international collaboration.

If successful, the NGNP "will be smaller, safer, more flexible, and more cost-effective than any commercial nuclear plant in history. The NGNP will secure a major role for nuclear energy for the long-term future and also provide the United States with a practical path toward replacing imported oil with domestically produced, clean, and economic hydrogen.”2 The DOE goals for a commercial NGNP are: electricity at less than 1.5 ¢/kwh; hydrogen at less than 40 ¢/litre gasoline equivalent; and overnight capital cost less than $1000/kWe, dropping to half that.

Three companies were awarded $8 million in contracts for preconceptual NGNP design: General Atomics, Areva, and Westinghouse/PBMR (Pty). In July 2007, the DOE announced that it was seeking to move to the next stage of defining safety and functional requirements, cost estimates and schedules.

The NGNP licensing plan was submitted to Congress by the DOE and the Nuclear Regulatory Commission (NRC) in August 2008. It features a high temperature gas-cooled reactor configured to provide heat at 750ºC and up to 950°C for a range of industrial uses particularly hydrogen production, or electricity generation. Construction would commence from 2017 and it could start up in 2021. Some regulatory changes would be needed to cope with the innovative design, along with different procedures for used fuel. The NRC expects to take five years to organize for the NGNP, allowing licence application in 2013.

A number of reactor designs fit the NGNP specification, notably: General Atomics' GT-MHR; Areva's similar Antares design; the pebble bed modular reactor (PBMR), which until May 2010 was backed by Westinghouse and South Africa's PBMR (Pty) Limited; and the HTR-PM from Chinad.

In September 2009, the DOE announced that it would offer up to $40 million for an initial planning phase for the project (Phase 1), including a business plan for integrating detailed design, licensing and construction activities, applied to two different reactor designs. The DOE noted that "NGNP will extend the application of nuclear energy into the broader industrial and transportation sectors, reducing fuel use and pollution." In March 2010, the DOE said that it had awarded the $40 million to two teams: Westinghouse, with PBMR (Pty) and The Shaw Group; and General Atomics with General Dynamics, URS Washington, Korea Atomic Energy Research Institute and Fuji. However, in May 2010, the team of Westinghouse, PBMR (Pty) and Shaw were unable to "reach agreement on a way forward," according to Westinghousee. The Westinghouse team did not therefore participate in Phase 1 of the NGNP program, although Westinghouse remains involved in other aspects of the program. The General Atomics consortium is expected to complete the conceptual design phase by the end of 2010.

Phase 2 of the NGNP program would entail detailed design, licence review and construction of a demonstration plant. This phase of the program is subject to a decision to be made by the Energy Secretary, which will follow a Nuclear Energy Advisory Committee report on the program, expected by mid-2011.

In February 2010, the DOE said that NGNP R&D would continue along with Generation IV systems under a new Reactor Concepts Research, Development and Demonstration (RD&D) program.

Nuclear Hydrogen Initiative

The DOE's Office of Nuclear Energy is aiming to demonstrate the commercial-scale production of hydrogen using heat from a nuclear energy system by 2017. This is based on using high-temperature gas-cooled reactors (HTRs) as outlined above, and under its Nuclear Hydrogen Initiative, three technologies are the focus of R&D: thermochemical water splitting; high-temperature electrolysis; and the production interface between the HTR and the process.

The DOE has also selected two teams to investigate the economic feasibility of producing hydrogen using power from existing reactors. A following phase will involve demonstration. One team led by GE Global Research will look at the alkaline electrolysis technique and another team led by Electric Transport Applications will pursue electrolysis using proton exchange membranes, based on a pilot plant in Arizona that produces 212 m3 per day of hydrogen.

Related to this, the University of Texas has approved a scheme to build a $500 million high-temperature reactor at Andrews campus, based on General Atomics' Modular Helium Reactor (MHR) and involving DOE's Sandia National Laboratory. A 2012 completion date is envisaged for the High Temperature Teaching and Test Reactor Energy Research Facility. This program is focused on eventual thermochemical production of hydrogen.

Global Nuclear Energy Partnership

The Global Nuclear Energy Partnership (GNEP) initiative announced by the US government in 2006 proposed that the United States and other developed nations would move forward with proliferation-resistant recycling technologies and provide nuclear fuel to developing countries that promised not to engage in enrichment and reprocessing activities. GNEP has attracted criticism, but has brought increased attention to the possibilities of reprocessing used fuel from commercial reactors, an issue once thought to be decided in the USA since being banned by the Carter administration in 1977. The problem of disposing of used fuel, as well as nuclear weapons proliferation, remain high on the US policy agenda, but GNEP has lost support as a possible solution. In early 2009, under the Obama administration, the DOE removed its GNEP website and did not refer to the program in its budget request for FY 2010. Then, in June 2009, the DOE announced it had decided to cancel the GNEP programmatic environmental impact statement (PEIS) "because it is no longer pursuing domestic commercial reprocessing, which was the primary focus of the prior Administration's domestic GNEP program."3 However, it is pursuing the AFCI initiative described above, which comprises much of the scope of GNEP. (See information page on Global Nuclear Energy Partnership).

Megatons to Megawatts

Megatons to Megawatts is the name of the highly successful program, based on nuclear weapons treaties with Russia, that provides about one-half of the fuel for US commercial reactors. Since 1987, the United States and countries of the former USSR have signed a series of treaties to reduce their nuclear arsenals by about 80%. In 1993, the USA and Russia reached an agreement to convert 500 tonnes of high-enriched uranium (HEU) from dismantled Russian warheads into low-enriched uranium (LEU) that would be brought to the USA for use as fuel in civilian nuclear reactors. The United States Enrichment Corporation (now USEC Inc) acts as the US government's executive agent for the program. By mid-2009, the USA had received 10,500 tonnes of LEU from Russia that had been downblended from 367 tonnes of HEU (equivalent to over 14,500 nuclear warheads, according to USEC). As part of its commitments under the program, the DOE's National Nuclear Security Administration (NNSA) has declared large quantities of HEU and weapons-grade plutonium to be surplus and available to be downblended domestically for civilian power generation. (See information pages on US Nuclear Fuel Cycle and Military Warheads as a Source of Nuclear Fuel.)

Nuclear Regulatory Commission

The US Nuclear Regulatory Commission (NRC) is an independent government agency that regulates all aspects of the nuclear industry in the USA, including reactors, fuel cycle facilities and the transportation, disposal and storage of spent fuel. The NRC's chairman and four other commissioner are appointed by the President. Up until 1974, regulation of the nuclear industry was the responsibility of the Atomic Energy Commission (AEC), which also had the mission of promoting the civilian use of nuclear power. The AEC was abolished in 1974, and its regulatory duties were assigned to the newly created NRC and its promotional activities were placed in the Energy Research and Development Administration (later the US Department of Energy).

A major responsibility of the NRC is the licensing of operating nuclear plants, and of proposed new ones. Both involve the review of detailed engineering, safety and environmental information as well as extended public hearings for any changes or new proposals. In recent years, the NRC has made an effort to expedite its procedures while still adhering to a strict regulatory framework. Power companies considering new capacity have been encouraged to make greater use of the NRC's combined construction and operating licence (COL) process, which had been in place since 1989 but not used until 2007. Companies can also apply for early site permits (ESPs), which allow them to apply for approval at a particular site before specifying the design of the reactor or to apply using one of the generic designs already certified by the NRC. (See information page on Nuclear Power in the USA.)

Initial operating licences for commercial power reactors are 40 years, but the NRC allows owners to apply for extensions of an additional 20 years. With the licences of many reactors built in the 1970s due to expire before 2020, the NRC has streamlined the process for renewal, concentrating on safety issues as opposed to other more procedural rules. Since 2000, the NRC has approved licence extensions for 52 reactors, with applications for a further 18 under review and applications for 15 others expected by 2013.

In addition to the licensing and safety oversight of reactors, the NRC has regulatory authority over uranium mines and mills, conversion and enrichment facilities, waste sites and all non-defence nuclear research laboratories (including those owned by the US Department of Energy). It recovers 90% of its budget (i.e. $911 million in FY2010) from licensees and applicants – an operating power reactor is liable for $4.8 million per year.

Nuclear Wastes

The question of how to store and eventually dispose of high-level nuclear waste has been the subject of policy debate in the USA for several decades and is still unresolved. As well as civil high-level wastes (essentially all US used fuel plus research reactor used fuel of US origin) there is a significant amount of military high-level radioactive waste which Congress intends to share the same geological repository.

Since the beginnings of the commercial use of nuclear power in the USA, used fuel assemblies have been stored under water in pools (and later in dry casks as well) at reactor sites, and remained the responsibility of the plant owners. The prohibition of spent fuel reprocessing in 1977, combined with the continued accumulation, brought the question of permanent underground disposal to the forefront. The Nuclear Waste Policy Act of 1982 established a timetable and procedures for the building of two repositories, funded by fees from utilities, with the federal government taking delivery of the spent fuel along with responsibility for its storage starting in 1998. The Act was amended in 1987 to designate Yucca Mountain in Nevada as the sole initial repository for 70,000 tonnes of high-level wastes. But there have been delays due to underfunding of construction, legal challenges, and political opposition from Nevada along the way. In mid-2008, the DOE submitted to NRC an 8600-page licence application for the repository.

In early 2009, the Secretary of Energy in the Obama administration, Steven Chu, stated that notwithstanding the 1987 Act, Yucca Mountain was no longer considered an option, and funding for the project was cut back. The administration's budget request for FY 2011 envisages shutting down the project altogether. Also the Department of Energy (DOE) filed a motion with the NRC in February 2010 to "stay" the Yucca Mountain licensing review, and said that it intends to withdraw the application "with prejudice", which would prevent it from ever being considered again. Also, the DOE's Office of Civilian Radioactive Waste Management, which has run the repository program, would be eliminated, and work on all nuclear waste management issues would be transferred to the DOE Office of Nuclear Energy. In hearings during June 2010, the DOE acknowledged that withdrawing the licence application was a policy decision, not science-based.

However, in June 2010, the NRC's Atomic Safety and Licensing Board (ASLB) ruled that the DOE had no right to substitute its own ideas in place of those legislated by Congress. The DOE and the NRC are bound by law to complete their work at Yucca Mountain unless Congress acts to supercede the previous (1982) legislation, which itself supercedes DOE's claimed authority under an earlier act. The ASLB stated: "Unless Congress directs otherwise, DOE may not single-handedly derail the legislated decision-making process by withdrawing the Application. DOE's motion must therefore be denied."4

Utilities have paid over $19 billion into the Nuclear Waste Fund for the DOE to take over their used fuel, mostly through a 0.1 cent/kWh levy towards final disposal, so that by September 2008 it had accumulated over $31 billion, including interest. The fund is growing by about $750 million per year from utility inputs and $1 billion per year from interest.

US Energy Secretary Steven Chu on 1 February 2010 announced the formation of a 15-member 'blue ribbon' waste commission which is to evaluate alternatives to direct disposal in the Yucca Mountain geological repository and to suggest how the country should proceed with management of used fuel. In a memorandum to the energy secretary5, President Obama said: "The commission should conduct a comprehensive review of policies for managing the back end of the nuclear fuel cycle, including all alternatives for the storage, processing, and disposal of civilian and defence used nuclear fuel and nuclear waste." (On that basis Yucca Mountain would not be ruled out, since it was a blatant political decision by the Obama administration to reject it.) However, the commission's mandate is strategy, not siting. The review will "include an evaluation of advanced fuel cycle technologies that would optimize energy recovery, resource utilization, and the minimization of materials" – in other words, reprocessing and recycling as undertaken in Europe, Japan and prospectively in China. The commission is to submit an interim report within 18 months and a final report to Congress within 24 months.

One proposal, under discussion in the Senate Energy and Natural Resources Committee, is an incentive program, similar to those in Sweden and Finland, for communities willing to host a repository or reprocessing facility.

State and Local Government

The USA has a federal system of government with some powers and responsibilities carried out by states and municipalities, including the taxation and regulation of property and certain commercial activity within their boundaries. This means that, while the national government in Washington has primary jurisdiction with respect to most nuclear policy matters, states as well as local governments can have a significant impact on nuclear power use and capacity. One consequential case in point is the 1976 state law enacted in California to prohibit the construction of new nuclear power plants until approval of a means to dispose of spent fuel. This measure, which is still in effect, has had an impact not only on the nuclear power industry, but also on the supply and price of electricity in the nation's largest state, which must 'import' much of its electricity and has suffered from a series of blackouts and brownouts since the early 2000s (see information page on California's Electricity).

States also have an impact on the nuclear power industry through the authority of state public service commissions that regulate the retail sale of electricity to consumers (the federal government has jurisdiction over interstate wholesale rates, which are administered by the Federal Energy Regulatory Commission). The deregulation of electricity prices in many states in the late 1990s led to industry consolidation as large power companies purchased plant in deregulated states that allowed them to increase margins by reducing costs and taking advantage of higher market prices (see Ownership consolidation section in information page on Nuclear Power in the USA).

Another notable example of the important role of states is found in the Nuclear Waste Act, which gives individual states veto power on locating a waste repository within their boundaries unless overriden by a vote of both houses of Congress. This provision resulted in a series of legal and political challenges to the Yucca Mountain repository, and probably doomed the project. Finally, county governments have the power of levying property taxes, which makes them a key player in the siting of nuclear facilities. In 2006, for example, Calvert County, Maryland, authorized tax credit incentives for the new reactor that is planned to be built at the Calvert Cliffs plant.

Public Opinion

Public opinion has generally been fairly positive, and has grown more so as people have had to think about security of energy supplies. Polls show continuing increase in public opinion favourable to nuclear power in the USA. More than three times as many strongly support nuclear energy than strongly oppose it. Two-thirds of self-described environmentalists favour it.

A May 2008 survey (N=2925) by Zogby International showed 67% of Americans favoured building new nuclear power plants, with 46% registering strong support; 23% were opposed6. Asked which kind of power plant they would prefer if it were sited in their community, 43% said nuclear, 26% gas, 8% coal. Men (60%) were more than twice as likely as women (28%) to be supportive of a nuclear power plant.

A March 2010 Bisconti-GfK Roper survey showed that strong public support for nuclear energy was being sustained, with 74% in favour of it7. In particular, 87% think nuclear will be important in meeting electricity needs in the years ahead, 87% support licence renewal for nuclear plants, 84% believe utilities should prepare to build more nuclear plants, 72% supported an active federal role in encouraging investment in "energy technology that reduces greenhouse gases", 82% agree that US nuclear plants are safe and secure, 77% would support adding a new reactor at the nearest nuclear plant, and 70% say that USA should definitely build more plants in the future. Only 10% of people said they strongly opposed the use of nuclear energy. In relation to recycling used nuclear fuel, 79% supported this (contra past US policy), and the figure rose to 85% if "a panel of independent experts" recommended it. Although 59 were confident that used reactor fuel could be stored safely at nuclear power plant sites, 81% expressed a strong desire for the federal government to move used nuclear fuel to centralised, secure storage facilities away from the plant sites until a permanent disposal facility is ready. Half of those surveyed considered themselves to be environmentalists.

A more general March 2010 Gallup poll (N=1014) on energy showed 62% in favour of using nuclear power, including 28% strongly so, and 33% against, the most favourable figures since Gallup began polling the question in 1994. However, only 51% of Democrat voters were in favour8.

In mid-2009, a survey of 1,152 people living within 16 km of 64 nuclear power plants in the USA, but without any personal involvement with them, showed very strong support for new nuclear plants9. Some 84% favoured nuclear energy, 90% had a positive view of their local nuclear power plant, and 76% would support construction of a new reactor near them. The survey also found that 88% give the nearest nuclear plant a 'high' safety rating, 91% have confidence in the company’s ability to operate the power plant safely, and 86% believe the company is doing a good job protecting the environment. On nuclear waste, only 56% said it can be safely stored at the plant and 82% said the federal government should get on with developing the Yucca Mountain repository, despite the Obama administration's decision not to proceed with it. A surprising 91% said that the USA should recycle used nuclear fuel. Regarding accurate and reliable sources of information about nuclear energy, various nuclear plant sources were rated 75-76%, compared with environmental groups 42% and anti-nuclear groups 19%.

It was the third time since 2005 that this survey – commissioned by the Nuclear Energy Institute and conducted by Bisconti Research with Quest Global Research – was carried out. The overall findings are slightly more positive than those in 2007, where the researchers concluded that "Nimby (not in my back yard) does not apply at existing plant sites because close neighbours have a positive view of nuclear energy, are familiar with the plant, and believe that the plant benefits the community."10

Non-Proliferation

The USA is a nuclear weapons state, party to the Nuclear Non-Proliferation Treaty (NPT) which it ratified in 1970 and under which a safeguards agreement has been in force since 1980. The Additional Protocol in relation to this was signed in 1998 and ratified in 2004, though arrangements to bring it into force were not completed until the end of 2008. While in NPT weapons states the Additional Protocol is largely symbolic, the State Department noted that US ratification "gives us a stronger foundation from which to encourage other states to adopt the Protocol." IAEA safeguards are applied on all civil nuclear activities. (The USA undertook nuclear weapons tests from 1945 to 1992.)

Further Information

Related information pages
Nuclear Power in the USA
US Nuclear Fuel Cycle
California's Electricity
Global Nuclear Energy Partnership
Three Mile Island

Notes

a. The loan guarantees provide government backing to loans which are therefore more readily available and at lower interest rates. They are ultimately funded by the borrowers through a fee and are expected to act as a catalyst and reduce financing cost by demonstrating government support for particular projects which have undergone thorough scrutiny by the DOE and its outside advisers. The guarantees are not an actual appropriation and, therefore, do not represent an outlay of taxpayer dollars when the clean energy projects are successfully completed. The guarantees are designed to boost investor confidence and allow worthy projects to move ahead with financing on more reasonable terms that ultimately will lower the overall cost of electricity generated by those projects. This is important in the USA where ownership of nuclear plants is widely dispersed, and even the largest companies like Exleon have a market capitalization of only some $30 billion, compared with EDF's $200 billion in Europe.

The federal government already has existing loan guarantee programs for a $1100 billion portfolio that enable investment in shipbuilding, transport, infrastructure, exports and other critical needs. [Back]

b. Louisiana Energy Services (LES) is a wholly-owned subsidiary of Urenco USA. In June 2006, LES was issued a licence to construct and operate a gas centrifuge uranium enrichment plant known as the National

Enrichment Facility (NEF). In January 2010, NEF was rebranded Urenco USA. It is located five miles east of Eunice, New Mexico. LES is so-called because its initial plans launched in 1989 were to build an enrichment plant in the State of Louisiana. [Back]

c. The LES letter of 31 March 2010 challenged the presumed politically comfortable solution, saying: "DOE's recognition of the importance of competitiveness and its adoption of the solicitation process underscores that the available loan guarantee authority should be awarded based on the merits of the projects, not on a 'first-come-first served basis' as would be the case if DOE does not make the additional loan guarantee authority available on an open and competitive basis." [Back]

d. The HTR-PM consists of two 250 MWt reactor modules per unit. It is based on the 10 MWt HTR-10, which was commissioned in 2000, at Tsinghua University's Institute of Nuclear Energy Technology (INET) near Beijing. In July 2005, Westinghouse and INET signed a memorandum of understanding to form a cooperative relationship for bidding on and participating in the Next Generation Nuclear Plant (NGNP).

See the Research and development section in the information page on China's Nuclear Fuel Cycle for more on the HTR-10 and the HTR-PM. [Back]

e. Although PBMR (Pty) dropped out of the Next Generation Nuclear Plant (NGNP) program in May 2010 (see section on PBMR in the information page on Nuclear Power in South Africa), Westinghouse and others continued to participate in the program. Should the NGNP program proceed to Phase 2 (detailed design and construction phase), it is still possible that Westinghouse could participate using its own HTR technology, although no decision has yet been made. [Back]

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5. Blue Ribbon Commission on America's Nuclear Future, Office of the Press Secretary, The White House (29 January 2010). See also Secretary Chu Announces Blue Ribbon Commission on America's Nuclear Future, U.S. Department of Energy, Press Release (29 January 2010) [Back]
6. 67% Favor Building New Nuclear Power Plants in U.S., Zogby International (6 June 2008) [Back]
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9. Third Biennial Nuclear Power Plant Neighbor Public Opinion Tracking Survey, Bisconti Research, Inc (July 2009) [Back]
10. US nuclear neighbours not nimby, World Nuclear News (21 August 2007) [Back]

(Link: www.world-nuclear.org)

ABOUT US

Aims and Activities

Popular Education and Action Centre (PEACE), is a small group of committed and experienced people, working towards strengthening the social action at the grass roots. Though it acquired formal shape only in 1994, ... ght to its fold by ... o the domination ... t to the issue of ... cipation as mere technique to elicit involvement for vindication of few programmes and schemes.

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Popular Education for us implies enabling the deprived, marginalised and oppressed in a manner that they can effectively intervene to transform the processes and structures influencing their lives, to their advantage.

Popular education for us implies:

- Enabling the deprived, marginalised and oppressed in a manner that they can effectively intervene to transform the processes and structures influencing their lives, to their advantage.

PEACE stands committed to:

- To strengthen social action at the grass-roots by assisting groups, individuals and institutions to evolve, consolidate and enrich their perspective, strategies and corresponding competencies;
- To assist people's struggles on issues of survival, identity and democratic space through enhancement of knowledge & information base of such efforts and building the capacity of the grass-root collectives to deal with macro processes and structures;
- To motivate, orient and support youth from minorities and other marginalised communities to join the efforts of social development and transformation;
- To initiate and facilitate networking among the like minded groups and individuals and establishing their linkages with wider movements at macro level.

We are facilitating educational programmes on following themes:

- Motivation and Orientation of Youth for Development Action
- Training of Activists involved in Public Education Campaigns on Issues
- Enhancing People's Participation in Self-Governance
- Social Analysis and Perspective Building Based on Literature and Theatre
- Training in Strategies and Pedagogy of Organising for Change
- Training of Trainers for Action Programme for People's Economics and Allied Literacy
- Capacity Building through Training Interventions on Strategies of People's Struggles and Methods of People's Education.

Apart from the above structured programmes we are involved in assisting individual groups in their HRD/OD requirements.

We are involved in assisting the groups in documentation of the experiences of various efforts of promoting people's organisation and making it available to a cross section of groups for educational purposes.

We are also coordinating People's Information Centre which is devoted to make policy documents of bilateral, multilateral and government agencies accessible to field activists. PIC also strives for keeping the field activists updated on the issues they are working on and other people's struggles.

Popular Information Centre

for private circulation only