Nuclear Power in the Dusk

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Man is an excellent energy converter, twice as efficient as a horse which cannot convert more than 10% of the calories it consumes into working labor. No wonder that slavery has been a wide spread pest throughout cultures and centuries. The working animal was the first energy luxury for mankind but not the last.

The industrial revolution, essentially fueled by coal, left a bitter taste of polluted air, black environment and sick lungs. The politics of high stacks - according to the motto: the solution of pollution is dilution - came as a relief to many local coal mining and industrial communities but turned out to come back down far away as a different disaster in the form of acid rain devastating forests and fields.

It is the invention of combustion motor and automobile which led to the spectacular development of oil as primary energy source. The Second World War was also a gigantic energy battle field. The war years led to the discovery of the phenomenal power of nuclear energy and to the horrifying demonstration of its military potential. While uranium was the primary ingredient of the Hiroshima bomb, plutonium created the deadly atomic mushroom over Nagasaki. The world would never be the same again after this month of August 1945.

Strange enough, directly after the war, under American inspiration, it was indeed possible to convey to the international public opinion the miraculous conversion of the terror of the nuclear bombings into the so-called Atoms-for-Peace program. The military for a long time kept the control of the developments in the "civil" sector. The nuclear reactor technology, the pressurized water reactor, which represents the majority of the world's installed capacity, was derived from a submarine reactor. Other commercial reactor types, like the Soviet RBMK, the Canadian CANDU or the British and French gas-graphite reactors, have originally been developed for the production of weapons grade plutonium.

The original nuclear energy dream was fascinating. Nobody will challenge that impression. The idea was simple and breath taking. A first generation of nuclear reactors was supposed to produce electricity "too cheap to meter". In fact - this is not a joke - it has really been suggested that electricity would become so cheap that it would not be worthwhile to invest in measuring devices on the consumer side. A second generation of power plants, so called fast breeder reactors, were to produce more plutonium than they consume - the ultimate energy machine, a sort of power perpetuum mobile. No resource problems anymore nor worries over ending supplies of uranium, no thought over independence, no air pollution, no environmental degradation. That was the promise.

50 years later reality turns out to be quite different. Whereas the first nuclear electricity was indeed produced by the first "Experimental Breeder Reactor" in the USA on 20 December 1951, already of the fundamental design the nuclear energy concept ultimately aimed at, literally every aspect of the energy sector has radically changed in the course of the four decades after.

Rise and fall of the nuclear programmes

The 1950s were dominated by the needs of the military nuclear establishments in the Nuclear Weapon States, whether the USA, Russia, France or the UK. Reactors were built to serve the fissile material needs of the bomb programmes. At the same time it has been always a goal to have the civil nuclear sector profit from the military sector and vice-versa. In France, for example, separate civil and military nuclear fuel chains have never been established.[1]

In the 1960s the nuclear industry boomed in the USA. *All* of the currently operating American reactors have been ordered over a 10 year period between 1963 and 1973, date of the last order which has not subsequently been canceled. But at least 138 plant orders have been withdrawn over the years.

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[1] The issue has been extensively discussed in the study M.Pavageau, M.Schneider, *"Japanese Plutonium and the French Nuclear Weapons Programme"*, WISE-Paris, commissioned by Green Action et al., August 1995

In the 1970s the European industry tried to catch up and launched not only massive reactor construction programmes but also very ambitious plans for the rapid introduction of a plutonium economy. For the end of the century, meaning now, the IAEA had forecasted up to 2,500 nuclear power stations worldwide and the French Atomic Energy Commission, in 1976 yet, had calculated 540 Superphenix type breeder reactors on earth. A few months *before* the accident of Three-Mile-Island in March 1979, Austria decides after a referendum not to commission the almost finished Zwentendorf reactor. In 1980, the European nuclear industry outside France, in Germany and the UK, registers the last entries in their order books for *any* type of reactor while Sweden decides by referendum to limit its programme to 12 reactors to be phased out by 2010 (target date which recently became victim of political bargaining).

In the 1980s only France continued to massively supply work for its reactor building industry. At the same time it became clear that the plutonium dream did not work out as planned. Sky rocketing construction costs for spent fuel reprocessing plants and breeder reactors, huge quantities of immobilized plutonium at the various industrial stages, endless technical problems and lack of social acceptability led to the abandoning of the commercial reprocessing plant Wackersdorf (in spite of US $ 1 billion already spent on the construction site) and the European fast breeder reactor project Kalkar (in spite of US 5 billion already spent) in Germany. Italy phased out nuclear power after the Chernobyl accident by referendum in 1987. In 1989 the number of reactors operating in Western Europe and North America, two thirds of the world total, peaked at 294 units. From then onwards the tendency has been down hill.

The 1990s have confirmed the slow decline of the number of reactors in Western Europe and North America. Further more, for the first time, in 1997 the nuclear electricity production and in 1998 the number of operating plants decreased also worldwide. In 1999, the last reactor still under construction in France, since 1993, will be coupled to the grid. In North America and Western Europe there is no further reactor neither under construction, nor ordered or planned.

Nuclear power, a marginal energy source for a few countries only

The international energy picture has dramatically changed if compared to the forecasts of the 1970s. The entire development was grossly miscalculated. Instead of doubling

every 10 years the energy consumption of the industrialized countries leveled out and grew considerably slower than economic growth. The break up of the Eastern bloc relaxed the resource situation further. As a consequence, the oil price is on a level lower than before what is known as the first oil shock in 1973. The price of natural uranium fell from one historical low to the next and stands currently at about one quarter of the level it showed in the early 1980s. The situation on the natural gas market does not give any sign for contraction in spite of a boom into gas technologies for electricity generation which went through the 1990s. The incredible technical advances in particular in the field of gas turbine systems led to a dramatic drop in price. A modern combined cycle gas plant today costs only half the price electricity companies had to invest ten years ago. And the efficiency now reaches 56% - the share of primary energy which is effectively transformed into electrical energy - as compared to about 25% for a nuclear plant or 36% for a modern coal plant.

Nuclear energy today represents about 7% of the primary commercial energy and about 17% of the electricity in the world. At the same time, oil comes in for 40%, coal for 27% and natural gas for 23% of the primary energy. One should stress that those figures leave aside a significant amount of energy which is non-commercial, in particular biomass, key energy source for a large part of humanity. On the electricity side, coal provides the lions share with 36%, renewable energies (mainly hydro) are second with 22% - significantly more than nuclear power - while gas and oil with 16% and 9% respectively are on the lower end.

On the contrary to the other energy sources, nuclear power is by no means a generalized worldwide phenomenon. In total, 32 out of 185 UN member countries operate nuclear power plants. Only five countries produce more than 100 TWh (billion kWh) on the basis of atomic fission: the three nuclear weapon states USA, France and Russia plus Japan and Germany. These five countries represent about two thirds of the entire nuclear electricity production in the world.

What future for nuclear energy?

What next? These were the mere facts. The future, by definition, always holds a certain degree of uncertainty. However, one can reduce the level of uncertainty by carefully analyzing current trends, economic conditions and political agendas.

Nuclear capacity cannot be put up over night. And instead of decreasing, construction times have gone up, to 23 years in the case of the last US reactor which came on line in 1996. Even in France, the four units of the latest design (N4) averaged over eight years active building until they produced electricity. In the Eastern countries, most of the reactors now in the international statistics as "under construction" have held that status for more than 15 years. Work started in Russia on those reactor sites in the years 1978-94, in Ukraine 1981-84, in the Czech Republic 1982-85, in Romania 1980-86, in Slovakia 1983-84. The situation is similar in Argentina, Brazil, India and Iran. In reality, many of these building sites have either already been abandoned or are entirely unrealistic to ever be accomplished. Russia has four 800 MW fast breeder reactors in the statistics, the first with a construction start up date in 1985, the last in 1994... Romania has four Canadian CANDU reactors listed under construction, the first since 1980, the last since 1986...

The Asian continent does by no means change the global picture. There are currently four reactors listed under construction in China, four in South Corea, two in North Corea and two in Japan. Ten of these units are scheduled to come on line until 2003. Both Japanese reactors are being built by Tohoku Electric Power Company. None of the other Japanese utilities have any nuclear capacity under construction. Tokyo Electric Power Company, for example, has 4,300 MW of hydro power and over 11,000 MW of fossil fuel power plant capacity already under construction or firmly planned. No nuclear capacity is in its equipment plan to 2010.

There are no prospects for many of the construction sites, especially in the former Eastern bloc, to get beyond the building ruin stage, leave alone the launch of new projects. On the contrary, on the worldwide scale there are many economic and political parameters which almost certainly will accelerate the decline of the nuclear industry.

The economic decline of Eastern Europe

The economic decline of the former Eastern bloc countries led to a sharp decrease of the electricity consumption. Between 1990 and 1995 alone, the power consumption in Russia and Ukraine - the two countries combined account for 80% of the installed nuclear plants in the former Eastern bloc - dropped by more than the total output of all operating reactors in the two countries together! The heated discussion over the "need"

of replacement power capacity to make up for the loss if the worst of the dangerous reactors in Ukraine, the two then still operating Chernobyl reactors, were finally shut down, is the bluff of the century: while the Chernobyl units produced some 9 billion kWh, the drop in national consumption reached some 80 billion kWh - thus as much as *all* of the 14 Ukrainian reactors produced in 1997. In 1996, Chernobyl unit 1 was shut down permanently and the last remaining, unit 3, is the second entire winter down for repair. The best demonstration that there is simply no need for replacement power. This of course does not stop the discussion over the completion of the two Ukrainian reactors Kmelnitsky-2 and Rovno-4 (commonly referred to as K2/R4). The outstanding work until completion is estimated to be about US$ 1 billion each. That alone would buy a lot of gas and coal for existing power plants, not to speak about the number of energy efficient light bulbs.
One might say the Ukraine, just as Russia and the other former Eastern bloc countries, will hopefully not be stuck in the current economic situation and future development will rapidly increase the need for electricity again. However, there are no credible economic development scenarios which would lead to such a sharp increase in the energy consumption to get anywhere near the 1990 consumption levels over the next 10 years in these countries. A general situation of overcapacity adds to the negative prospects for nuclear power. Today it seems obvious that in the former Eastern bloc countries, there will be generally no new projects and the current building sites can only be saved from being turned into ruins with massive financial assistance of Western countries. Is this realistic? Is this desirable taking into account the entirely outdated technology? It is certainly not economical.

In the mean time there is a unique opportunity for reasonable and cheap energy efficiency programmes and intelligent resource management leading to the possibility to permanently and sustainably save the nuclear power output away. The potential is enormous. The lack of coherent energy systems in the former Eastern bloc countries and their infrastructural decline leads to perverse situations. Many of the cities have urban heating systems, in principle a very efficient energy use, especially if fueled by combined heat and power plants. However, the heat losses in these systems as well as the lack of maintenance leads to a very negative balance. Frequent heat cuts incited consumers to install back up electric space heaters which lead in the winter to significant peak load for a small number of hours. The current approaches tend to work on the availability of sufficient power capacity for peak load instead of assuring reliable and efficient heat supply through urban heating which would bring down the peak load, reduce the need for supply capacity as well on the heat as on the electricity

side. Not necessary to be an energy expert to realize the incredible waste of energy in former Eastern bloc countries. Whether in Russia or in Ukraine, in Bulgaria or in Lithuania, people regulate the heat over the window. I have experienced myself open windows in December in Moscow because of lacking or broken valves to shut off radiators, not to talk of thermostats.

The liberalization of the energy markets in Western Europe and in the USA

There are parameters linked to the reorganization of the economic conditions of the energy markets which will have a significant impact on the competitiveness of nuclear power. Up to 40% of the currently operating reactors might be victim of the deregulation of the US energy market over the next few years, forecast utility experts and independent consultants. The "window of profit", the period of time after the investment is paid back and the installation actually makes good money before running into heavy backfitting, repair and maintenance, becomes increasingly narrow. Safety criteria become more and more stringent and the operation of nuclear plants stay a significant risk for the capital invested. Therefore the economic analysis of, for example, steam generator replacement versus shut down has already in several cases tipped the choice towards ending the operation of a plant in the US. Further more, under certain conditions, the investment into energy efficiency programmes or even combined cycle natural gas plants have turned out to be cheaper than the mere operational expenditures of an existing nuclear plant. No wonder, that the World Bank does not fund nuclear projects since more than 20 years.

In Europe, the step by step introduction of a common energy market will lead to harsh competition in the field. It is by no means guaranteed that nuclear plants will have a better stand in Europe than in the US once they have to face market oriented competition. While the French state utility EDF enters competition with the advantage of a relatively young, standardized nuclear power production capacity, other European countries have much more practice in dealing with competitive markets and decentralized production and distribution systems. Germany has about 800 utilities of various sizes, operating anything from small scale hydro to coal and gas plants of any size. They are highly flexible, extremely rapid to adjust their production capacities through very short lead times in the non-nuclear sector.

EDF is clearly fearing the future competition as witnesses a statement in an internal newsletter: "The competition, which already exists on the demand side, will increase tomorrow at the front end, meaning on the production side, with an increased pressure effect on the prices and therefore on the costs. In this situation the competitiveness of the kWh more than ever will be crucial, because the price will make the difference. The production costs added to the transport costs will have to be sufficiently low to keep a price advantage over decentralized production."[2] Whether the nuclear operators as well as the operators of large coal fired plants will achieve that goal remains to be seen.

Political constraints for nuclear power

The nuclear industry worldwide has made a significant error. It has generally considered that their representatives are the only ones to know, therefore they are right and therefore it does not matter what citizens think and feel. "Public opinion, public opinion, what is that public opinion?", threw Pierre Guillaumat, De Gaulle's Minister of Defense and key architect of the French civil and military nuclear programmes, once at me. The Parliament ? "What is it good for, these parliamentary discussions?", Guillaumat told the stunned interviewer. The only thing which mattered was the access to the political power centers. This led to a quite unhealthy situation causing hundreds of billions of dollars being spent without any social benefit - outside any kind of parliamentary control.

The top technocrat elite - in France members of the Corps des Mines, in Japan owners of Tokyo University engineering degrees - by definition, is always right. Therefore even obvious errors in forecasting, system analysis or macro-economic strategy stay without any consequence for the careers of the authors. André Giraud, the man who forecasted 540 breeder reactors for the year 2000 as head of the French Atomic Energy Commission and who was instrumental in driving France into the plutonium dead-end, has not been sanctioned for his misguidance. He was promoted Minister of Industry and then Minister of Defense instead. The electricity industry in most of the industrialized countries has pushed for the establishment of gigantic overcapacities: France exports the production of more than 10 nuclear reactors to neighboring countries (and still has more capacity to run)... which have established themselves

[2] La Lettre d'Information du Parc Nucléaire, n°33, janvier 1999

significant overcapacities. Only dumping prices attract foreign utilities (essentially British, German, Italian) to go for French nuclear electricity... yet.

You will find nobody within EDF or in any German or UK utility to say they would repeat the multi-billion investments into the plutonium industry's infrastructures. Since the early 1990s EDF puts a zero value to its plutonium stocks. A request by Dutch utilities to find out whether EDF would want to take over its plutonium was kindly denied. Most obviously, the decision makers had it all wrong, ill advised by a small group of technocrats, the same top level civil servants and industry leaders who are still there to stay... yet.

The full scale of the economic burden of the investment into the plutonium economy is not yet known. The dismantling cost estimates for the first small reprocessing plant UP1 at Marcoule went in a few years from 11 billion to 40 billion FRF. The La Hague site, where not only French but also foreign fuel including Japanese one is processed, is about four times the size of the Marcoule facility reaching much higher levels of radioactivity because of different fuel caracteristics.

Times change. The result of the German elections in September 1998 leading to the establishment of a coalition government between the social-democrats and the Green Party (Bündnis90/Die GRÜNEN) will have a profound impact on international politics. The significance of change - in particular in the energy field - is not yet well understood abroad, although many of the decisions which are currently being fine-tuned are integral part of the 50-page long coalition agreement signed on 20 October 1998. The first sentence of the chapter on nuclear power states: "The phase out of the use of nuclear power will be comprehensively and irreversibly regulated by law within this legislative period." And, reprocessing is to be prohibited. Instead of accepting the fact that the profound opposition to nuclear power by the German population has finally found its way into a federal government, the nuclear establishment reacted by starting a power play aimed at winning time. As one utility boss publicly stated: "Governments come and go. Nuclear power will stay!"

Times change. Nuclear power is up for scrutiny. And while the nuclear industry is usually very much aware of industrial dynamics, in this case it underestimates the dynamics which can be created by a strong government of a strong economic power to stimulate a significantly different orientation. Everybody in Germany knows that there will never a new reactor be built in the country. Therefore the only question is,

for how long the existing power plants will be allowed to operate. Instead of trying to take the forefront of a fatale evolution, the big nuclear utilities play to gain time. Instead of promoting their willingness to turn their companies into high-tech ventures capable of providing a broad range of energy services, they stick to the old approach: "We know how to produce kWh not how to save them", as a top utility manager put it to me in January 1999.

While the new German government has stated that there will be a one year period to negotiate over a consensus solution on nuclear phase out with the power industry, the coalition agreement clearly says that "after that delay has passed, the coalition will introduce a law which would enforce the phase out of the use of nuclear energy without compensation; therefore the operating licenses will be limited in time".

Too bad for the dinosaurs. The energy future has already begun. 153 of the 185 UN member states and 7 of the 15 European Union member states do not have nuclear programmes. Do they all use candles for light and firewood for heat?

Italy is a particularly interesting case. It has abandoned nuclear power by referendum in 1987 after the Chernobyl accident came as a deep shock over the country. Until then, Italy had spent about 90% of its energy research and development expenditures on nuclear technologies. The three reactors operating until the Chernobyl accident were shut down for good. The country found itself basically from one day to the other without any long term strategy for the electricity sector. Even the promoters of the referendum had not prepared for success. The country imports about 80% of the primary energy sources for the production of electricity with an unusually high dependence on oil (about two thirds of the production). It took until 1991 when the parliament passed a new law to redefine priorities. Inspired by the American PURPA (Public Utility Regulatory Policy Act), the new legislation created a strong incitement for autoproduction of electricity and combined heat and power (CHP) facilities in particular in lifting any limitations for installed capacities. CHP plants allow to recover the waste heat and use it either in form of industrial applications or to feed it into urban heating systems. The energy efficiency reaches over 80%. At the end of 1996, about 2,500 MW of additional CHP capacity were installed, an additional 5,500 MW were granted and therewith the share of autoproduction in the Italian power system will increase from 18% to 30%. A further 10,000 MW to be installed until 2002 were under evaluation in 1997. Currently, Italy is still a strong importer of electricity, in particular from France, over 15% of its consumption in 1997. But at what price and

for how long? The new CHP capacity alone could make up for the electricity imports any time. The current trend is strong diversification and decentralization. Therefore the system becomes extremely efficient, with low transport losses and short lead times: the exact opposite to the French neighbour's system. EDF's nightmare at the wake of full scale European competition. Already in the early 1990s, EDF had designated CHP and autoproduction as "threats" in a confidential strategy paper.

In parallel in Italy there is a strong incentive to keep the domestic electricity capacity and consumption needs low. The tarification for a subscription to 6 kW and a consumption of 7,500 kWh per year is twice as expensive per kWh than for a 3 kW subscription and 2,500 kWh consumption per year. In France, EDF promoted the large scale installation of electrical space heating systems, an energetic absurdity: water is heated in a power plant, on average two thirds of the electricity are lost as waste heat, an additional 7% is lost in transport before you transform the electricity back into heat. A central or urban heating system delivers the heat with an efficiency between 80% and over 90%. Today EDF makes 25% or 30 billion FRF of its turnover on electric space heating! The social consequences are often disastrous. Numerous households are unable to pay for electricity bills reaching 10,000 FRF per winter.

But electric space heating leads also to very inefficient production capacity management. France has a total installed capacity of over 110,000 MW of which 63,000 MW nuclear while the daily peak load in winter reaches 70,000 MW, more than three times the lowest day in summer. One cannot just add up the figures since the nuclear capacity is never 100% available not more than other energy production capacity. In the middle of September 1998, the heating systems were already going, not less than 19 reactors of the 58 French units totaling over 20,000 MW were down for repair or refuelling. Thus there must be a significant reserve capacity, often old, inefficient and polluting coal and oil fired plants. The higher the difference between base and peak load, the larger the production capacity which comes on line only for a very short time, a stupid thing to do with a type of capacity which causes high capital and relatively low operating costs, like nuclear compared to fossil fuels. In other words, the French EDF drives a Formula-1 racing car in the city trafic of Paris.

Those who believed that Germany, the third economic power in the world, radically changes its approach to energy policy without any effect on other countries have already proven extremely short-sighted. Belgium has cancelled its reprocessing contracts with France in December 1998 and announced the creation of a working

group, essentially composed of independent experts, to look into the future of the Belgian power system, the after nuclear power. And even in France, a profound shake up of the establishment took place. The government issued a 9-page statement on 9 December 1998 which explicitely states that "it is necessary to prepare a real diversification of ressources because the share of nuclear power is destined to decrease as compared to current levels". The main stream media asks on the cover page "Should we abandon nuclear power" (Le Point) or "What should be done with nuclear power?" (Le Monde). Opinion polls show that 51% of the citizens are in favor of the phase out of nuclear power in France (L'Evénement). Public acceptance is at an all time low. Politicians have to pay and pay more attention to public opinion on the issue than they ever did. The December 1998 government statement also announces the creation of a three member committee to look into the *real* costs of nuclear power with particular emphasis on reprocessing.

Times have changed. Since 1990 Germany, almost unnoticed, put together a very ambitious programme on renewable energy. Almost 3,000 MW of wind power machines have been installed in seven years, more than in any other country in the world. While the installed capacity increased by a factor of about 50, the electricity output increased by a factor of more than 110 over the same time period, thus productivity doubled. The whole programme was established at a federal research and development cost of less than 250 Mio DM, thus about 10% of the French State expenditure into R & D on plutonium technology. As a side effect, about 15,000 jobs have been created in the wind industry, about three times as much as at stake - on the long run - at La Hague. Oh, before I forget, this was achieved of course under the former ultra pro-nuclear German government. The current government intends to increase federal budgets for renewable energies by several hundred percent.

Japan's current plan to fuel light water reactors with plutonium fuel (so called MOX fuel) is a mere expression of the artificiel fait-accompli-situation the plutonium lobby intends to maintain and eternalize. It will not solve the stockpile problem because the outlook of a potential use of plutonium on a commercial scale induces an industrial dynamic tending to justify the separation of even greater quantities of plutonium. The French example is a shocking illustration of that self perpetuating mécanisme: when the first reactor was loaded with MOX fuel in 1987, there was practically no French plutonium stock. In January 1999, while 17 reactors are loaded with MOX fuel, the French stockpile has climbed to over 40 tonnes - equivalent to about 100 reactor-years of MOX use - and will continue to rise for the forseeable future if the plutonium

production rate is not scaled down. A situation where the plutonium industry continues to twist the arm of the politicians who do not feel free anymore to act according to current analysis but on an argumentation based on past decisions. This is the vicious circle to be broken. This is what the new German government is up for. Reaquire the freedom of political choice beyond the arguments of the past.

A recent study by the Washington, D.C. based Institute for Energy and Environmental Research, comes to the result that off-shore wind power installed off the Japanese coast line would be at least 40% cheaper than the use of MOX fuel in Japanese light water reactors. That is precisely what the choice is about: either to perpetuate the erreur of the present century and start up a long term plutonium programme - dangerous, expensive, proliferation prone - or get into the race over the next century's energy systems. They will be high tech, decentralised, ultra efficient, based on the fundamental requirements of the society's energy service needs. In one word - the future of energy belongs to *intelligence !*

Box

The World Bank on Nuclear Power
(Excerpt from the World Bank's web site http://www-esd.worldbank.org/cc/)

Questions and Answers about the World Bank, Fall 1998

Nuclear Energy

Q. Will the Bank fund nuclear energy and, if not, why not?

A. The Bank has never financed a nuclear power station. Nuclear power produces no particulates, sulfur, or greenhouse gas emissions and thus appears to offer a clean, non-fossil-fuel alternative for power generation. However, world experiences with high investment costs, time-consuming and costly approval processes, lack of sustainable waste disposal options, risks of major accidents-together with the

Chernobyl disaster-have raised grave doubts about the future viability of nuclear power. Private investors shy away from such risky high-cost investments.

Financing for nuclear development is usually available from suppliers' credits and export financing agencies.

Q. Given its work on shadow prices of carbon, at what price does the Bank believe that nuclear energy is warranted in the fight against global warming?

A. The issues surrounding nuclear power go beyond economic costs alone. Nuclear energy is not acceptable in many parts of the world because of concerns over reactor safety, disposition of nuclear wastes and proliferation of fissile materials. The trade-offs are thus complex and cannot be boiled down to a single carbon shadow value.