Life in a Nuclear Powered Crowd

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The idea of a wondrous future powered by atomic energy is now a hundred years old. Fredrick Soddy and Ernest Rutherford discovered in 1901 that radioactivity was part of the process by which atoms changed from one kind to another and involved the release of energy. Soon, Soddy was writing in popular magazines that radioactivity was a potentially "inexhaustible" source of energy, and offering a vision of an atomic future where it would be possible to "transform a desert continent, thaw the frozen poles, and make the whole earth one smiling Garden of Eden."[1] The promise of an "atomic age," with nuclear energy as the global, utopian technology for the satisfaction of human needs, has been a recurring theme ever since.

Soddy also saw that atomic energy could possibly be used to create terrible new weapons. It is perhaps no surprise in an international system dominated by competing, armed nation-states that the first practical application of atomic energy came in 1945 when the United States built the first atomic bombs and used them to destroy the Japanese cities of Hiroshima and Nagasaki. The bomb was, American leaders said, the "winning weapon."

This display of the awesome power of atomic technology served to revive and strengthen the visions of an atomic solution to economic and social problems. American newspapers, for instance, predicted an atomic utopia, "a world of unlimited power, unlimited abundance – a world limited only by man's capacity to imagine new wants and needs."[2] Lewis Strauss, the head of the United States Atomic Energy Commission famously declared in 1954 that nuclear energy meant "our children will enjoy in their homes electrical energy too cheap to meter."[3]

What the world saw over the past fifty years was the construction of vast facilities for the production of highly enriched uranium and plutonium for nuclear weapons. The United States and Soviet Union produced tens of thousands of nuclear weapons, and were joined as nuclear weapons states by the United Kingdom, France, China, Israel, India, and Pakistan, and recently perhaps North Korea. Many other states tried and for a variety of reasons abandoned their nuclear weapons ambitions. Iran still persists. Others may also try, as the United States becomes ever more belligerent in remaking the world as it sees fit and meets resistance.

At the same time, the peaceful use of nuclear power has fallen far short of what was promised because of the enduring problems of nuclear safety, high costs, nuclear proliferation, and public opposition. Nuclear industries have stagnated in the states that were pioneers in the technology such as the United States, the United Kingdom, and Russia. Some states set up nuclear energy programs and then decided to phase them out. What little new building is taking place, is in states that came late into the nuclear age, such as China and India.

Despite this, a large-scale expansion of nuclear energy is being urged by some proponents as a way to grapple with the problem of climate change now being brought on by the accumulation of greenhouse gases from burning fossil fuels over the past hundred or so years. But amidst the talk of a second chance for nuclear energy, there is some recognition that a nuclear future may be dark.

We outline below some particular concerns about nuclear safety and nuclear proliferation and suggest that any large-scale global expansion of nuclear energy generation will bring new dangers and not be of much help in dealing with climate change.

Normal Nuclear Accidents

It is one of humanity's oldest and most hard-earned pieces of wisdom that even the best-trained people make mistakes, in particular when performing routine-operations over extended periods. The past six decades have shown that nuclear technology does not tolerate error.

Nuclear energy is perhaps the primary example of what are called 'high-risk technologies' with 'catastrophic potential'; for such technologies, "no matter how effective conventional safety devices are, there is a form of accident that is inevitable, and such accidents are a 'normal' consequence of the system."[4] There is, in short, no escape from failures of the system. For those countries that have nuclear facilities but have not yet had a nuclear accident, it may only be a matter of time and luck. Continuing reliance on nuclear energy and building and operating more nuclear reactors only serves to increase the risk.

The consequences of a severe accident at a large nuclear power reactor were made apparent by the 1986 Chernobyl disaster, which was triggered by errors of judgment by the reactor operators. In its report on the accident, the United Nations Scientific Committee on the Effects of Atomic Radiation noted that there was severe radioactive contamination of about 150,000 square kilometers of the former Soviet Union, and the fallout affected "practically every country in the northern hemisphere," and smaller amounts of radioactivity penetrated into the southern hemisphere.[5] Humanity was unavoidably linked together on a global scale.

A 2005 study by the Chernobyl Forum estimated that around 4,000 people will eventually die due to radiation exposure from the accident.[6] However, the Chernobyl Forum's Expert Group on Health, coordinated by the World Health Organization, suggested in its report that there might be over 8,000 deaths from cancer and leukemia because of the accident.[7] There have also been long-term consequences for the survivors and their fellow citizens. A 2002 study commissioned by UNDP and UNICEF with the support of UN-OCHA and WHO found that in Ukraine, Belarus, and Russia a total of over 118,000 people were evacuated and over 230,000 resettled (and over 11,000 still expecting resettlement) because of the accident and observed that "[t]he affected population – those exposed to radioactive fallout, remaining in the affected areas, or forced to relocate – continue to face disproportionate suffering in terms of health, social conditions, and economic opportunity… Many have found it difficult to adapt and continue to face serious psychological, economic, and social problems."[8]

The study went on to note that there have been broader and more enduring social and economic consequences, observing that "[t]he accident has also had a continuing impact on the opportunities and well-being of a much wider circle of the inhabitants of Belarus, Ukraine, and Russia, through the negative image that it has created for large areas of these countries. It has imposed a heavy burden on the national budgets through the cost of clean-up, compensation and recovery… These commitments have diverted resources away from other priorities, such as health, education and investment."[9] Future generations will pay the price.

Normal Nuclear Proliferation

The fact that a nuclear energy complex can be established for peaceful purposes and then put to use for producing weapons materials was recognized very early on. Robert Oppenheimer, the head of the United States' Manhattan project that produced the first atomic bombs in 1945, noted in 1946 that if there were an effort to ban all nuclear weapons:

"We would not make atomic weapons, at least not to start with, but we would build enormous plants, and we would design these plants in such a way that they could be converted with the maximum ease and the minimum time delay to the production of atomic weapons saying, this is just in case somebody two-times us; we would stockpile uranium; we would keep as many of our developments secret as possible; we would locate our plants, not where they would do the most good for the production of power, but where they would do the most good for protection against enemy attack."[10]

The difference in scale between civilian and military nuclear programs is important. A 40 MW(th) reactor like CIRUS in India produces enough plutonium for about two nuclear weapons a year, while one of India's small, roughly 700MW(th) power reactors (which produces ca. 200 MW electric power) can yield about ten times that much plutonium a year. A similar case holds for uranium enrichment; about 150 tSWU (or 150,000 separative work units) are required to produce the annual low-enriched uranium fuel for a 1,000 MW(e) nuclear power reactor, while ten percent of this enrichment capacity could produce 100 kg of highly enriched uranium, enough for several nuclear weapons.

There is a long history of how states have inter-woven their civil and military nuclear ambitions and capabilities. UK, France, China, Israel, India, and Pakistan built their nuclear weapons programs on an infrastructure developed supposedly for nuclear energy. Iraq, North Korea, and Iran, all signatories of the 1970 nuclear Non-Proliferation Treaty, concealed their nuclear weapons ambitions behind a 'peaceful' nuclear program. At the same time, it should be noted, the US has started producing tritium for its nuclear weapons stockpile at civil power reactors.[11]

It was recognition of the overlap between civil and military nuclear materials and capabilities that led to the system of safeguards on civil nuclear facilities, starting in the 1950s. As part of the NPT, non-nuclear weapon states are required to declare and open their civil nuclear facilities for international inspection, so as to detect significant amounts of material being diverted for illicit nuclear weapons purposes. One measure of the failure of these efforts is that the United States has been seeking to deny North Korea, Iraq, and Iran key elements of the nuclear fuel cycle, and is now proposing to limit future access to uranium enrichment and plutonium reprocessing to all but a handful of states (even though under the NPT all signatories are allowed to develop and exploit these technologies). These policies are a clear recognition of the proliferation dangers of civil nuclear power and the particular problems of uranium enrichment and plutonium reprocessing facilities and attendant capabilities.

Nuclear Futures

Nuclear energy is now being offered as a way to solve the problem of global-warming-induced climate change. To significantly reduce greenhouse gas emissions, nuclear power would have to expand several-fold. It is worth asking what would be the proliferation implications of such an expansion. We ignore for the moment whether nuclear energy would in fact help lessen climate change as well as the political and economic obstacles that make such an expansion scenario unrealistic in the first place.

Here, for illustrative purposes, let us assume that nuclear power grows to about 1,500 GW(e), which corresponds to a four-fold expansion from today's level and, if achieved by 2050, would be equivalent to only about 28% of the estimated global electricity supply, compared to about 15% today. This is about the upper limit for nuclear capacity for 2050 adopted in a 2003 MIT study, *The Future of Nuclear Power*.[12]

Most studies on the future of nuclear power simply assume a global nuclear capacity of 1,000 GW(e), 1,500 GW(e), or sometimes even 10,000 GW(e), as if it would "just be there," i.e. assuming nuclear power plants located nowhere in particular. The MIT study did not shy away from making predictions about the actual distribution of nuclear capacities in a global expansion scenario and estimated that 56 countries could have commercial nuclear plants in a 1,500 GW(e) world, including many that currently have none, such as Vietnam, Indonesia, the Philippines, Malaysia, Thailand, Australia, New Zealand, Norway, Italy, Austria, Poland, Turkey, Venezuela, Portugal, Israel, Libya, Algeria, Uzbekistan, Morocco, Kyrgyzstan, Kazakhstan, Egypt, etc.[13]

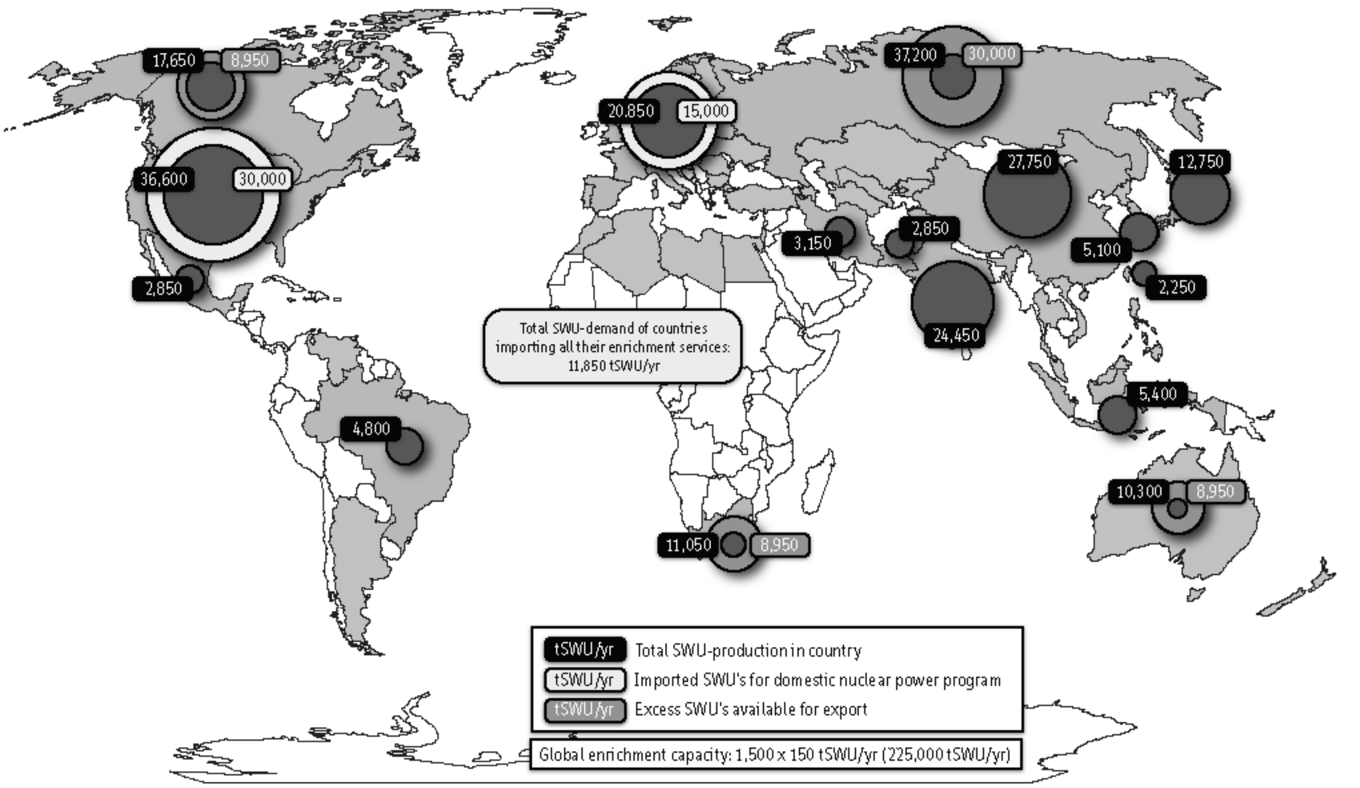

FIGURE 1: Hypothetical distribution of enrichment capacities for a 1,500 GW(e) nuclear world, in which 56 countries operate commercial power reactors and 16 countries operate large-scale uranium enrichment facilities with a global capacity of 225,000 tSWU per year. Note that only 5 tSWU suffice to produce sufficient highly enriched uranium for one nuclear weapon a year.

One can infer the nuclear fuel cycle infrastructure required to support such a crowd of nuclear powered countries. We assume continued reliance on the currently dominant pressurized water reactor technology, using low-enriched fuel based on the once-through fuel cycle. From a non-proliferation perspective, this is superior to alternative scenarios involving reprocessing and separation of plutonium, which is a directly nuclear-weapon-usable material. This reactor-fleet, however, would require a huge global enrichment capacity (see *Figure 1*).[14]

The projected enrichment infrastructure is daunting, both in size and distribution. Countries with no or negligible current commercial nuclear power programs – such as Iran, Pakistan, Mexico, or Indonesia – would deploy and operate large-scale enrichment facilities. It is predictable that global enrichment operations at this scale would periodically lead to suspicions, allegations, and international crises. Iran's plan for its Natanz facility to have a maximum capacity of 250 tSWU/yr have incited fears about proliferation, but in a future built around a large expansion of nuclear power, Iran might operate enrichment facilities with a total capacity of almost 3,000 tSWU/yr. For comparison, less than 5 tSWU are enough, in principle, to produce sufficient highly enriched uranium for one nuclear weapon a year.

Similarly, more countries may explore plutonium reprocessing, in spite of its extremely unfavorable economics and environmental and proliferation concerns, as a way to defer decisions about the final disposal of nuclear waste. This reckless strategy of kicking the nuclear can down the road for future generations to deal with has already been adopted by a few states, including Japan and perhaps soon by the United States as part of its Global Nuclear Energy Partnership.

The much greater stocks and flows of uranium and plutonium associated with nuclear energy programs require an extremely prudent approach with respect to the idea of expanding nuclear power in the future. At the same time, any effort to expand nuclear power around the world will inevitably lead to a further increase in large-scale and small-scale research and development (R&D) activities around the world. With respect to proliferation concerns, this is the single most important dilemma of nuclear power: *a nuclear program that is small – or even completely irrelevant – from a commercial perspective is generally large enough to support a substantial nuclear weapons program.*

It is likely that if nuclear power begins to expand rapidly on a global scale, there would be increasing concerns about nuclear proliferation, as many countries explore many new technologies. Thus, even if nuclear energy ultimately fails to expand as imagined by some today, we will have to face lots of 'proliferation noise' in the international system that mixes up and makes it difficult to identify and deal with 'real' proliferation as well as legitimate and unwarranted fears of covert military programs. As the Iraq war showed, some states may not hesitate in feeding and then taking advantage of proliferation fears as a pretext to go to war.

Nuclear Power and Climate Change

The new argument being advanced for nuclear energy is that it offers a solution to climate change, or at least to lessen the scale of global warming by reducing future greenhouse gas emissions. But nuclear power would primarily contribute to electricity production and, therefore, would be unable to mitigate about two thirds of global CO_2 emissions, which are due to the fuels-used-directly (FUDs) in industry, transportation, and the residential/commercial sectors.[15] The bulk of greenhouse emissions would remain to be addressed.

Nuclear energy can at best hope to substitute for the use of coal, the dominant fossil fuel used to produce electricity. But coal is very abundant and inexpensive, and it will remain so for many decades to come. It is therefore naïve to assume that coal will simply be abandoned on a global scale. Countries with large domestic reserves of low-cost coal and rapidly growing economies *will* use their coal resources; China for instance plans to increase its reliance on both coal and nuclear energy, with predictions of a doubling of the use of coal for power and heat generation in two decades.[16] Concerns about climate change may slow down and limit the scale of this process at best.

It seems that if no solution to the "coal problem" can be found, then no solution to the climate change problem exists. However, compared to FUDs, almost complete "decarbonization" of electricity production is relatively straightforward and can be done using existing non-nuclear technologies.[17] This may be more attractive than investing in large-scale nuclear expansion.

This is recognized in a major 2006 report by the UK government's Sustainable Development Commission which observed that building new nuclear plants is not an answer to tackling climate change. It concluded that doubling nuclear capacity in Great Britain would make only a small impact on reducing carbon emissions by 2035.[18] The report identified five major problems to continued or increased reliance on nuclear power: the absence of a proven method for safe and secure long-term nuclear waste disposal; the uncertain but high future costs of nuclear energy; nuclear energy's need for a large, centralized power generation and distribution system that serves to hinder further development of small-scale renewable and distributed energy supplies; as a large-scale supply-side technological 'fix,' nuclear energy undermines energy efficiency options; and lastly, the security and safety risks associated with nuclear proliferation.[19] These problems are worth keeping in mind in any debate on the future of nuclear energy in any country.

There are alternatives. For example, a 1998 study performed for the European Union developed a scenario for a European energy system based on renewable energy sources that would reduce CO_2 emissions by 80% by 2050 (compared to 1990) and phase out nuclear energy at the same time.[20] A central finding of this and similar studies is that there is no simple, one-size technological solution to energy production that can be applied everywhere. The identified energy systems are very heterogeneous, strongly depending on country-specific conditions: offshore wind electricity dominates in Denmark, while solar-thermal and photovoltaic electricity is strong in Spain and other South European countries. This must be accompanied by substantial reductions in the demand for primary energy in all sectors of modern society. The list of necessary steps is long and these steps have to be taken swiftly. With every year that passes without decisive action, further bottlenecks are created and the costs of changing policy become ever greater.

Conclusion

The hopes invested in nuclear technology are as old as the basic scientific ideas that underlie it. The past hundred years have shown the many problems with nuclear technology. Particularly grave are the risks and consequences of a nuclear accident and the dangers of supposedly peaceful nuclear facilities, material, and knowledge being used for nuclear weapons programs. Continued reliance and any large-scale expansion of nuclear energy would perpetuate and worsen these dangers. And there is no imminent technological fix for these problems, as the 2003 MIT study *The Future of Nuclear Power* was compelled to conclude:

"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."[21]

Nuclear energy also offers a marginal but costly solution to the problem of climate change. The brittleness of nuclear power actually creates dangers for constraining future greenhouse gas emissions.[22] Even a single major accident is likely to stop any attempt to sustain current levels or to expand nuclear power – in fact, if such an accident occurred in the U.S. or Western Europe, it would mean the end of nuclear power in these regions. Building more nuclear power risks the danger of being stranded up the nuclear creek without a paddle, where having invested enormous resources in an expensive and inflexible technology, and having built up a formidable nuclear legacy, there would be no significant contribution to meeting global energy needs. In such a situation, clean and safe renewable alternatives could take a long time to come on stream.

Given all this, it is worth asking why nuclear energy is still on the table as an option. A large part of it may be due to a continuing identification of nuclear technology as an advanced technology, as representing the future. It has been observed that nuclear energy proponents always talk in the 'future tense,' that is "in terms of what it will bring rather than what it has already wrought or what it requires from society to maintain operation."[23] This succeeds in so far as the public and elites continue to believe in an ideology of 'progress,' ceaselessly 'rising living standards,' the need for 'growth' in the production and consumption of material goods, and insist on comfortable habits of inefficient energy consumption, all without regard to consequence for society or planet.

The tension between nuclear fears and a reluctance to give up the actually existing comforts of everyday life is revealed dramatically in a 2006 International Atomic Energy Agency public opinion survey conducted in 18 countries that found most people are opposed to building new nuclear reactors but seem to support continued operation of existing reactors. The poll conducted in states with and without large nuclear industries found that overall 59% were opposed to building new plants while 62% of respondents said existing nuclear facilities should continue to be used.[24] This suggests that the door will slowly close on the nuclear future as old nuclear power plants finally shut down and plans for new plants command no public support.

Rather than wait for nuclear energy to wither away, the international community should make a virtue of a necessity. We need to plan collectively how to phase out reliance on nuclear energy, invest in energy conservation and efficiency and renewable sources of energy, and explore paths towards a safe, more secure, and ecologically sustainable form of social life and economy.

1 Spencer R. Weart, *Nuclear Fear: A History Of Images*, Harvard University Press, 1988, p. 6.
2 Paul Boyer, *By The Bomb's Early Light: American Thought And Culture At The Dawn Of The Atomic Age*, University of North Carolina Press, 1985, pp. 111-113.
3 Arjun Makhijani and Scott Saleska, *The Nuclear Power Deception: U.S. Nuclear Mythology From Electricity 'Too Cheap To Meter' To 'Inherently Safe' Reactors*, Apex Press, 1999, p. xix.
4 Charles Perrow, *Normal Accidents: Living With High-Risk Technologies*, Basic Books, 1984, pp. 3-4.
5 United Nations Scientific Committee on the Effects of Atomic Radiation, *Sources and Effects of Ionizing Radiation: UNSCEAR 2000 report to the General Assembly – Volume 2*, United Nations, 2000, pp. 453-566.
6 *Chernobyl's Legacy: Health, Environmental and Socio-Economic Impacts*, Chernobyl Forum September 2005; www.iaea.org/NewsCenter/Focus/Chernobyl/pdfs/05-8601_Chernobyl.pdf. The Chernobyl Forum includes International Atomic Energy Agency, World Health Organization (WHO), United Nations Development Programme (UNDP), Food and Agriculture Organization, United Nations Environment Programme (UNEP), United Nations Office for the Coordination of Humanitarian Affairs (UN-OCHA), United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), the World Bank, and the governments of Belarus, Russia, and Ukraine.
7 World Health Organization, *Health Effects of the Chernobyl Accident and Special Health Care Programmes*, Report of the UN Chernobyl Forum Expert Group "Health," Working Draft, August 31, 2005; www.who.int/ionizing_radiation/a_e/chernobyl/EGH%20Master%20file%202005.08.24.pdf; Table 16.4 (p. 145) gives a model-based prediction of over 8,000 deaths from excess cancer, and Table 16.2 (p. 141) gives 216 emergency worker deaths eventually attributable to radiation.
8 *The Human Consequences of the Chernobyl Nuclear Accident: A Strategy for Recovery*, A Report Commissioned by UNDP and UNICEF with the support of UN-OCHA and WHO, January 2002; www.undp.org/dpa/publications/chernobyl.pdf.
9 Ibid.
10 J. Robert Oppenheimer, *Failure to Achieve International Control of Atomic Energy*, in: Morton Grodzins and Eugene Rabinowitch (eds.), *The Atomic Age*, Simon and Schuster, 1963, p. 55.
11 Kenneth Bergeron, *Nuclear Weapons: The Death of No Dual-use*, Bulletin of the Atomic Scientists, January/February 2004, pp. 15-17; www.thebulletin.org/article.php?art_ofn= jf04bergeron.
12 Massachusetts Institute of Technology (MIT), *The Future of Nuclear Power: An Interdisciplinary MIT Study*, 2003; http://web.mit.edu/nuclearpower. If this four-fold nuclear expansion was achieved by 2100, nuclear energy would be about the same fraction of total electricity capacity that it is today assuming a business as usual scenario.
13 The MIT study generated a country-by-country distribution of nuclear capacity based on "various country-specific factors, such as current nuclear power deployment, urbanization, stage of economic development, and energy resource base." MIT, op.cit., p. 111.
14 The global distribution of enrichment capacities in Figure 1 is based on our conservative assumption that only countries with an installed nuclear capacity of at least 10 GW(e) would acquire domestic enrichment plants. In addition, only some major exporters of uranium would ultimately do so, too (here: Australia, Canada, and South Africa). Not counting individual countries in Western Europe, 16 countries would provide enrichment services. The remaining users of nuclear energy would be pure "reactor-states."
15 International Energy Agency, *CO_2 from Fuel Combustion - Fact Sheet*, 2005; www.iea.org/textbase/papers/2005/co2_fact.pdf.
16 He Youguo, *China's Coal Demand Outlook for 2020 and Analysis of Coal Supply Capacity*, International Energy Agency; www.iea.org/Textbase/work/2003/beijing/4Youg.pdf.
17 Robert H. Williams, *Advanced Energy Supply Technologies*, in: UNDP, *World Energy Assessment: Energy and the Challenge of Sustainability*, 2000, pp. 274-329.
18 UK Sustainable Development Commission, *The Role of Nuclear Power in a Low Carbon Economy*, 2006; www.sd-commission.org.uk/pages/060306.html.
19 Ibid.
20 LTI-Research Group (ed.), *Long-Term Integration of Renewable Energy Sources into the European Energy System*, Physica-Verlag, 1998.
21 MIT, op.cit., p. 76.
22 For the idea of 'brittle' energy systems, see: Amory B. Lovins and L. Hunter Lovins, *Brittle Power: Energy Strategy for National Security*, Brick House Publishing, 2001; www.rmi.org/sitepages/pid1011.php.
23 John Byrne and Steven Hoffman, *The Ideology of Progress and the Globalization of Nuclear Power*, in: John Byrne and Steven Hoffman (eds.), *Governing The Atom: The politics of risk*, New Brunswick: Transaction Publishers, 1996, p. 12.
24 International Atomic Energy Agency (IAEA), *Global Public Opinion on Nuclear Issues and the IAEA - Final Report from 18 Countries*, 2006; www.iaea.org/Publications/Reports /gponi_report2005.pdf.

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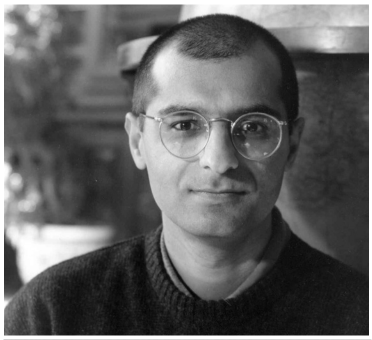

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