ZNW in Global Priorities
How Does Nuclear Weapons Abolition Fit Among Global Priorities?

Introduction

Evidence, convincing to all but fantasists and fools, points to planetary trends toward crisis. All are anthropogenic. We call the trends

- climate change (including global warming)
- ecological degradation (land, seas, water, arable, air)
- unsustainability of current economic practices

These trends are interconnected, and have a common source:

- population growth

At some point in the 1950s the United States and Soviet Union acquired sufficient nuclear weapons to devastate whole populations and regions, spread fire and radioactivity, and destroy the web of global society and economies. Nuclear weapons—deployed and ready—may not grow more numerous, but are a constant fact, and constant threat. As they exist, they could be used.

- the risk that even one nuclear weapon be detonated in a populated place
- the risk that numbers of nuclear weapons be detonated

Are these trends and risks related? They are, in at least two ways. All are associated with risk that civilization—society, knowledge, and economy as we know them—will be degraded or disrupted. And extremely so, in imaginable extreme cases. Their second connection is that they compete for time, concern, and means. They do so against the vexing backdrop that bedevils every judgment about future risk: the future, which cannot be surely known, sets the near-term against the long-term. There is, necessarily, reasoned disagreement about sequence and priorities. There is hope that the future will deliver political agreement and technological

---

1 In the large, *doctrine of growth* is at the heart of current practice and goals. For the individual, it is the culturally fostered and shared sense of purpose and ‘needs’.

Bruce D. Larkin: ZNW in Global Priorities
means that are absent today, but no assurance that such boons will hove into view, or in useful form and sufficient scale.

And yet these trends and risks appear very different. The first stem from decisions by billions of individuals, and hundreds of millions of groups, and are unintended consequences of their understandable choices. They seek food, fuel, materials and knowledge, and the wonders that human ingenuity can create from those elementals.

Nuclear risk, on the other hand, is the work of a handful of governments, seeking security—by one account—and dominance—by another.

There is a strange parallel, however, by which risk is distanced, or wished out of sight. Heedless economic activity is undertaken in pursuit of growth, and by changing its direction, doctrines of growth argue, coming harms can be postponed and ultimately avoided. Nuclear risk is wished out of sight by the doctrines of management, the conviction that no matter how destructive nuclear weapons can be they can be possessed but never used, or at least never used against the society that possesses them, because government and military will manage them safely.

The thesis of this paper is that each of the bulleted issues we have identified has a compelling claim on our attention, concern, and resources. There are, of course, many other questions which can and should lay claim to our attention, but none of the scope and hazard that the bulleted issues present. The paper centers on the least apparent, arguing that nuclear abolition must be one of the prime objectives of global public policy and, therefore, national policies.

**Why is Nuclear Abolition an Urgent Need?**

No one aware and sentient doubts that nuclear weapons are dangerous. Hence the states which have them, and propose to manage them safely, declare their fear that more states may acquire them: ‘proliferation’. ‘We are safe hands, they pose an existential threat.’ From another perspective proliferation complicates the task of dissuading governments from brandishing or retaining them.

If actually used, beyond the immediate destruction, their use would disrupt networks of collaboration required to supply material needs, just

---

2 Lack of clean water, epidemic disease, self-destructive behaviors (leading, for example, to obesity, diabetes, lung cancer, drug dependence), ‘conventional’ war, destruction of the arable and aquifers, maldistribution of food, failures of justice and accountable governance: all merit concern and action. It will not be hard to extrapolate from my discussion of ‘zero nuclear weapons’ (ZNW) and warming, population, environment, and unsustainability to see how I would approach other facets of the global problematique.

John Holdren, then president of the American Association for the Advancement of Science, speaking at its annual meeting in 2007, urged scientists to contribute 10% of their time to addressing four key problems: poverty, resource competition, the ‘energy-economy-environment dilemma,’ and the threat from nuclear weapons. *Science*, v 315, p. 1068, 23 February 2007. Holdren is today Director of the White House Office of Science and Technology Policy, and Co-Chair of the President’s Council of Advisors on Science and Technology (PCAST).
distribution, and political stability. But even if not used, their existence and availability can color how states press their interests, their so-called ‘vital interests’. This paper explores some of these relationships.

**Why Is Nuclear Abolition an Urgent Need?**

The *status quo* in nuclear weapons has been ‘managed’ since 1945 without any further detonations in war. Nonetheless, thousands of nuclear weapons are actively deployed by eight nuclear weapon states. Can ‘management’ and non-use be sustained?

Possibly, at least for a time. Obviously ‘non-use’ requires that no nuclear weapon state *choose* to use one. In addition, there must be no breach of a management’s intention to retain control and withhold its weapons from use. But governments might be unable to hold that line, despite best intentions. Possible are (i) delivery and detonation by accident, (ii) unauthorized use, and (iii) theft and use by thieves or buyers.

Fissile material leaked from a nuclear weapon program could also be used to make a bomb.

Can we be sure no nuclear weapon state would deliberately use a weapon in its inventory? On the contrary, we can imagine circumstances, such as seeming to lose a ‘conventional’ war, or being deprived of ‘vital’ resources, in which resort to nuclear weapons might be judged ‘undesirable but necessary’. Nor can anyone preclude accident, unauthorized use (for example, by a military command in revolt against central authority), or theft. Even if the *likelihood* of their use is small, the existence of nuclear weapons renders their use *possible*.

Effects of a single nuclear weapon could range from minimal effects of a weapon detonated underground, or above-ground in a remote location, to the destruction of a major city. It is not hard to imagine the wrenching consequences of the use of a few tens of nuclear weapons on targets chosen to disrupt an economy and, with it, the population’s access to necessities. This would be carnage on a horrible scale, and its *possibility* is sufficient to make an urgent case for abolition.

Among the leaderships of the nuclear weapon states there is a sober recognition of deterrence. I accept the argument that no nuclear-armed government would risk its cities by initiating the use of nuclear weapons in war against another nuclear state. But that does not cover all the possible circumstances in which use might be considered. And it leaves unsolved the problems of accidental detonation, unauthorized use, and theft.

**Nuclear Power: A Weapon Risk**

Global warming has renewed interest in nuclear power, but nuclear reactors pose a proliferation risk.
The decades-long avoidance of new nuclear power plants, pronounced in the United States, sprang from one fear and two recognitions: fear that a plant might fail and spread radiation (Three Mile Island, Chernobyl), and recognition [1st] that nuclear power was more costly than power from conventional fossil-fuel sources and [2nd] that handling and storage of spent fuel, followed at close-down by dismantlement of the reactor and remediation of the site, posed long-term environmental requirements. It did not matter that the partial core meltdown at Three Mile Island caused no confirmed casualties, or that the Chernobyl design was peculiarly vulnerable.

Proliferation risk did not figure significantly in decisions to forego new nuclear power plants. The issue is, however, an important one, which proponents of nuclear power must address. The argument is simple. A by-product of nuclear reactors is plutonium (Pu), from which a nuclear bomb can be made. If a reactor is fueled with uranium (U), the ‘spent fuel’ will also contain some $^{235}$U that can, with some difficulty, be recovered.

Every reactor, therefore, poses risk of diversion of Pu to a weapons program. A cloak of commitments has been woven to track $^{235}$U and Pu as it moves through industrial processes, is fabricated into reactor fuel elements, exits the reactor as ‘spent fuel’, and then is placed in storage or processed again. For example, fuel suppliers may stipulate that the spent fuel is returned to them. Reactor operators may contract with a foreign separation plant to recover plutonium from spent fuel and ship the plutonium back to them, with the understanding that the stored plutonium will be subject to IAEA monitoring. States that have adhered to the

---

3 Reactors are fueled by fissile material, uranium (isotope $^{235}$U) or plutonium, or both, in quantities and configurations that achieve a controllable self-sustaining chain reaction. With some exceptions—specialized research reactors and reactors powering ships and submarines—the uranium used for reactor fuel contains too low a concentration of fissile $^{235}$U to be used, without further enrichment, in a bomb. Unless diverted to enrichment, uranium fuel in most reactors does not pose a weapons issue.

However, one consequence of the chain reaction in the reactor is that non-fissile $^{238}$U in the fuel will be changed, in part, to $^{239}$Pu, the isotope of plutonium best-suited to building plutonium weapons. The ‘spent fuel’ withdrawn after use in a reactor is not easily converted to a weapon. Plutonium constitutes only about 1% of the spent fuel, and the plutonium must be separated from other elements in the spent fuel, including ‘unburned’ uranium and some very dangerous radioactive isotopes. Nonetheless, a state with the resources to accomplish plutonium separation can harvest plutonium for fabrication into a nuclear weapon.


---

Bruce D. Larkin: ZNW in Global Priorities
Non-Proliferation Treaty as ‘non-nuclear weapon states’ are required to negotiate ‘safeguards’ agreements with the International Atomic Energy Agency, authorizing the IAEA to monitor the movement of fissile material in their civil nuclear programs.

**Nuclear Power: Fuel Cycle Management?**

The ‘oil crisis’ of 1972-74 catalysed underlying interest in nuclear power as an autonomous energy source. Brazil, for example, sought to import from Germany key industrial components to implement self-contained provision of fuel for nuclear reactors. US President Jimmy Carter—the only nuclear engineer at the helm of a nation’s politics—sought to contain the anticipated ‘plutonium economy’ with its danger of weapons proliferation. The US encouraged the International Nuclear Fuel Cycle Evaluation, which won time to dissuade suppliers from proposed plant transactions.

In 1998 concern for proliferation was sharpened afresh by Indian and Pakistani nuclear tests and plans for weapon militarization. After 9.11 Washington alleged nuclear weapons programs in Iraq and Iran—for both of which no evidence had been made public at this writing—and in North Korea.5

IAEA Director General Mohamed ElBaradei proposed a fuel bank to which countries with civil nuclear generating programs could turn to tap an assured source of fuel for their reactors. By 2007 the United States and Russia were discussing a similar provision. A US official said “We hope to group fuel supplier nations that will offer services on a very attractive commercial basis, maybe on discount terms.” But he also described, at least as the aim of the United States, to separate nations with ‘energy needs’ from those with ‘military ambitions’.6 Given the ongoing dispute between Washington and Teheran about Iran’s nuclear intentions, bringing to fruition a system for fuel supply on which states lacking their own fuel cycle would willingly rely could prove a vexed passage.

**Nuclear Power: Low in Greenhouse Emissions?**

The heat produced in a nuclear reactor can be used to turn a steam turbine, which in turn can generate electricity just as turbines turned by falling water can spin an electric generator.

---

5 Of course, there had been an Iraqi nuclear weapons program until 1991. Iran’s work with uranium can be interpreted, despite Irnn’s denials, as preliminary to a weapons program, and critics have so understood it.

At a first approximation, no hydrocarbons are burnt, and so there should be no contribution to greenhouse gases. But, like water power, nuclear generation requires the capital plant (in the nuclear case, the reactor and its housing, generators, and the processes to produce and manage fuel), a distribution grid, and operations. However, the estimated ‘carbon footprint’ of nuclear power is radically smaller than that for hydrocarbon-generated power, as estimated by the UK Parliamentary Office of Science and Technology: 1000 gCO$_2$ eq/kWh for coal-fired, 800 g for newer coal gasification plants, 600 g for oil-fired, and 500 g for natural gas fired. By contrast, the footprint of nuclear is about 5 gCO$_2$ eq/kWh.

Nuclear power generation has a relatively small carbon footprint (5gCO$_2$ eq/kWh … Since there is no combustion (heat is generated by fission of uranium or plutonium), operational CO$_2$ emissions account for <1% of the total. Most emissions occur during uranium mining, enrichment and fuel fabrication. Decommissioning accounts for 35% of the lifetime CO$_2$ emissions, and includes emissions arising from dismantling the nuclear plant and the construction and maintenance of waste storage facilities. … The most energy intensive phase of the nuclear cycle is uranium extraction, which accounts for 40% of the total CO$_2$ emissions. Some commentators have suggested that if global nuclear generation capacity increases, higher grade uranium ore deposits would be depleted, requiring use of lower grade ores. This has raised concerns that the carbon footprint of nuclear generation may increase in the future …

Nuclear Power: Share of Energy Consumption?

The principal uses of fossil fuels are to generate electricity, power transport, and heat homes and commercial buildings. They are also feedstock to the chemicals, fertilizer, and materials industries. Nuclear-generated electricity cannot substitute for industrial feedstocks, but it can replace coal, oil and natural gas in heating and transportation. This is easily understood for fixed heating installations, but both road and rail transport have been traditionally dependent on liquid fuel. Even in the transportation sector, however, there are strategies to substitute electricity for petrol, or to use nuclear to obtain hydrogen — also transportable — from water.


The US Energy Information Administration is another source of coefficients: coal about 95 kgCO$_2$/MMBtu, oil 75 kgCO$_2$/MMBTu, and natural gas about 53 kgCO$_2$/MMBtu. “Fuel Emission Factors”. These numbers appear to include only those to fuel the generator. www.eia.doe.gov/oiaf/1605/excel/Fuel%20EFs_2.xls
Nuclear Power: Projected Generation

Will reliance on nuclear electric generation grow in response to warming? Requirements for non-proliferation monitoring will be that much greater, if more fissile material—uranium and plutonium—will pass through industrial, transport, electric generation, and ‘spent fuel’ activities. Operators and regulators will need to watch the safety of more reactors. Governments will try to ensure nuclear fuel, hedging against denial of supply.

Nuclear reactors are expensive, to build and to decommission. To avoid pressure to build more, utilities and governments could instead reduce electricity demand. Imagine a chart showing cost on the left and electricity along the x-axis; draw one curve for new nuclear generating capacity and another for conservation measures. The chart will show dramatically that conservation is always a better choice, barring some radical change in technology. There are significant, readily accessible reductions which can be secured ‘inexpensively’, though it is also true that the more you choose to conserve the higher per kwh cost will be paid at the margin. But this is better than nuclear generation, which requires enormous up-front costs before any electricity is delivered to consumers.

Alternatives include conservation, sustainable generation (wind, water, solar), and more efficient use of fossil fuels (favoring natural gas rather than coal, designing and adopting more efficient transport engines, and—if the technology can be proven—carbon sequestration at coal-burning plants). The aim is to achieve today’s utility, and new utilities, while reducing CO$_2$ and other greenhouse gas emissions. There are two ways: (i) conservation, which adjusts present practices and infrastructure to reduce unwanted emissions, and (ii) imaginative design, favoring lower-emission choices.

To the extent architects, transportation engineers, and the heating, cooling, and electricity industries can find and adopt cost neutral or at least cost effective alternatives to conventional designs, and also achieve significant cuts in CO$_2$ emissions, real change will prove attainable, moving toward sustainability. It may be necessary, as a public policy choice, to subsidize research, facilities, and practices that would otherwise cost more and hence be insufficiently attractive in the market.

In the following sections we will sample some estimates of nuclear’s role in the world’s energy future. Estimates of future capacity, and the extent to which nuclear generation will contribute to supply, are guesses based on assumptions about demand, costs of plant and operations, expectations of profit, government subsidy policy and—over longer times—technological innovation.

---

8 I appreciate Marco de Andreis’ calling to my attention his paper “The Economic Prospects of the Nuclear Renaissance,” 14 January 2011. He points out, citing figures from the Autorità per l’energia elettrica e il gas, that in 1997 oil (domestic generation) supplied 40% of Italian electricity; in 2009 just under 5%. Natural gas provided 21.8% in 1997, but 46.46% in 2009. The significance is that burning natural gas as the fuel creates significantly less CO$_2$/kwh. “In rich countries at least,
How Much Electricity? Of That, How Much Nuclear?

Recent and Projected: United States

The US Energy Information Administration summarizes US energy statistics and offers projections to future decades:

<table>
<thead>
<tr>
<th>Billion kwh</th>
<th>2008</th>
<th>2035 ‘Reference Case’</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL</td>
<td>4148</td>
<td>5285</td>
</tr>
<tr>
<td>generation + import</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OF WHICH:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nuclear</td>
<td>806</td>
<td>898</td>
</tr>
<tr>
<td>% Nuclear</td>
<td>19.43%</td>
<td>16.99%</td>
</tr>
<tr>
<td>Coal</td>
<td>1995</td>
<td>2305</td>
</tr>
<tr>
<td>&amp; Coal</td>
<td>48.09%</td>
<td>43.61%</td>
</tr>
</tbody>
</table>

Although a modest increase in nuclear generation is projected, there is a significant decline in the comparative role of nuclear. Coal production increases—though share also declines—and coal remains the production mainstay.

30.8 gigawatts of US nuclear power capacity is to reach a 60-year life by 2035. The figure of 898 Billion kwh for 2035 assumes that they will all receive extension approvals and still be operating in 2035. But what if not? EIA developed an alternative scenario—that all would be retired. They say

Reflecting the different projections for generating capacity additions in the two cases, the projected nuclear share of total generation in 2035 is only 13 percent in the Nuclear 60-Year Life case, compared with 17 percent in the Reference case. Total generation in the Nuclear 60-Year Life case is 1 percent lower than in the Reference case. CO2 emissions are higher in the Nuclear 60-Year Life case, because nuclear power is replaced with fossil fuels. Again, however, the difference between the

oil is used nowadays mainly for transport. Gas is widely used for heating and for electricity production.” It is striking to me that there was such a great change in just twelve years. http://www.crusoe.it

For comparison of coal, oil, and natural gas carbon emissions, see http://www.eia.doe.gov/oiaf/1605/coefficients.html The figures—roughly—are coal (bituminous) ~ 93 kgCO2/MMBtu, oil (middle distillate) ~ 73 kgCO2/MMBtu, and natural gas ~ 53 kgCO2/MMBtu. MMBtu = one million BTU (British thermal unit).


10 For other sources, including natural gas, please see the full report. URL above.
projections is less than 1 percent, because most of the capacity replacing the retired nuclear plants is fueled by natural gas.\footnote{Annual Energy Outlook 2010 \ldots , p. 46.}

Of course, there are nuclear advocates and industry groups that propose a much more ambitious role for nuclear. In a speculative study, the Electric Power Research Institute, an industry research group, canvasses ‘advanced technologies’ which could reduce CO$_2$ emissions. The study projects US need for 64 gigawatts additional nuclear power by 2030, implying about 50 new reactors. On their scenario, nuclear’s target for 2030 is 25.5% of generation, much higher than the US government’s EIA projections.\footnote{Electric Power Research Institute. “Electricity Technology in a Carbon-Constrained Future.” http://mydocs.epri.com/docs/CorporateDocuments/Newsroom/EPRIUSElectricSectorCO2Impacts_021507.pdf}

**Recent and Projected: World**

The next step is to consider figures for the world, and corresponding projections for future years, say, 2030 or 2035 or 2050. The IEA World Energy Outlook 2008 captures the main fact of their ‘reference scenario’ projection to 2030:

Fossil fuels account for 80% of the world’s primary energy mix in 2030 — down slightly on today. Oil remains the dominant fuel, though demand for coal rises more than demand for any other fuel in absolute terms. The share of natural gas in total energy demand rises marginally, with most of the growth coming from the power-generation sector. Coal continues to account for about half of fuel needs for power generation. The contribution of non-hydro renewables to meeting primary energy needs inches up from 11% now to 12% in 2030.\footnote{International Energy Agency. World Energy Outlook 2008, p. 77. http://www.worldenergyoutlook.org/2008.asp ‘Biomass and waste’ includes “traditional and modern uses.”}

The figures underlying their analysis are\footnote{Ibid., p. 78. 2006 is take as a comparison year because it was the last full year for which IEA had gathered and analysed data for its 2008 annual report.}
in million tonnes oil equivalent. The impetus to nuclear stems from it’s near-zero contribution to GHG emissions.

In 2008 IAEA significantly increased its expectations for future nuclear generating capacity:

The IAEA has revised upwards its nuclear power generation projections to 2030, while at the same time it reported that nuclear’s share of global electricity generation dropped another percentage point in 2007 to 14%. This compares to the nearly steady share of 16% to 17% that nuclear power maintained for almost two decades, from 1986 through 2005.

In its 2008 edition of Energy, Electricity and Nuclear Power Estimates for the Period to 2030, the IAEA expects global nuclear power capacity in 2030 to range from a low case scenario of 473GW(e), some 27% higher than today’s 372 GW(e), to a high case scenario of 748 GW(e), i.e., double today’s capacity.

"Over the last five years projections have gone up for several reasons," said Hans-Holger Rogner, Head of the IAEA’s Nuclear Energy Planning and Economic Studies Section.

"Performance has improved greatly since the 1980s, and the safety record of the types of reactors on the market today is excellent. In addition, the average load factor of the global reactor fleet has increased from 67% in 1990 to more than 80% since early 2000. Rising costs of the dominant alternatives, particularly natural gas and coal, energy supply security and environmental constraints are also factors that are contributing to nuclear’s appeal."

The report’s projections reflect major expansion plans that are under way in key countries like China and India, and new policies and interest in nuclear power that are emerging in countries like the UK and USA.

But while projections for nuclear power’s future rose, its share of the world’s electricity generation today dropped from 15% in 2006 to 14% in 2007.\textsuperscript{15}

Enthusiasm continues. In 2011 the World Nuclear Association foresees a bright future for nuclear:

- Nuclear power capacity worldwide is increasing steadily but not dramatically, with over 60 reactors under construction in 15 countries.
- Most reactors on order or planned are in the Asian region, though there are major plans for new units in Europe, the USA and Russia.
- Significant further capacity is being created by plant upgrading.
- Plant life extension programs are maintaining capacity, in USA particularly.

Today there are some 440 nuclear power reactors operating in 30 countries plus Taiwan, with a combined capacity of over 376 GWe. In 2009 these provided 2560 billion kWh, about 15% of the world's electricity.

Over 60 power reactors are currently being constructed in 15 countries plus Taiwan … , notably China, South Korea and Russia.

The International Atomic Energy Agency in its 2010 report significantly increased its projection of world nuclear generating capacity. It now anticipates at least 73 GWe in net new capacity by 2020, and then 546 to 803 GWe in place in 2030 – much more than projected previously, and 45% to 113% more than 377 GWe actually operating at the end of 2010. OECD estimates range up to 816 GWe in 2030. The change is based on specific plans and actions in a number of countries, including China, India, Russia, Finland and France, coupled with the changed outlook due to constraints on carbon emissions. The IAEA projections would give nuclear power a 13.5 to 14.6% share in electricity production in 2020, and 12.6 to 15.9% in 2030. The fastest growth is in Asia.

It is noteworthy that in the 1980s, 218 power reactors started up, an average of one every 17 days. These included 47 in USA, 42 in France and 18 in Japan. These were fairly large - average power was 923.5 MWe. So it is not hard to imagine a similar number being commissioned in a decade after about 2015. But with China and India getting up to speed with nuclear energy and a world energy demand double the 1980 level in 2015, a realistic estimate of what is possible (but not planned at this stage) might be the equivalent of one 1000 MWe unit worldwide every 5 days.16

The pressure for nuclear stems increasingly from concern for fossil fuel emissions of CO$_2$. It is not because nuclear is cheap. But does this mean that emissions of CO$_2$ are increasing? If they are increasing steadily, or even failing to fall, the link between climate and nuclear power will be strengthened. The IEA 2008 report conveniently presents global “energy-related CO$_2$ emissions” of their Reference Scenario, for three past years and three projected:

| WORLD ENERGY–RELATED CO$_2$ EMISSIONS … (Gigatonnes) |
|-----------------|-------------|-------------|---------|---------|---------|---------|
| 18.05           | 20.95       | 23.41       | 27.89   | 36.40   | 40.55   |

The ‘Reference Scenario’ assumes present trends continue: “this scenario embodies the effects of those government policies and measures that were enacted or adopted up to mid-2008, but not new ones. This provides


17 Ibid., Table 16.2, p. 385.
a baseline against which we can quantify the extent to which we need to change course.” There could be policy interventions, and technological measures not foreseen today could permit less use than the ‘reference scenario’ anticipates. [The IEA report investigates how lower emissions could be achieved, spelling out a 450 Policy Scenario (450 ppm CO2-eq) and 550 Policy Scenario, explained below.]

According to the most recent IAEA projection (2010), nuclear will remain a significant but not dominant source of energy for several decades:

<table>
<thead>
<tr>
<th></th>
<th>2030 World ‘Low’</th>
<th>2030 World ‘High’</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nuclear</td>
<td>29,254 TW h</td>
<td>35,854 TW h</td>
</tr>
<tr>
<td>2040</td>
<td>4040 TW h</td>
<td>5938 TW h</td>
</tr>
</tbody>
</table>

Of course, projections reflect their source’s choice among paths to the future. One puts electricity at the center, a second coal, oil, and natural gas, while the third judges the extent of nuclear’s contribution by close scrutiny of recent trends and known plans.

*Fetter’s 1997 Argument and Ongoing Stabilisation Debates*

A different analysis could place nuclear power at the center. To illustrate such an approach, consider a paper that Steve Fetter presented at a 1997 American Nuclear Society meeting, estimating energy demand to 2050 and anticipating subsequent efforts to construct detailed assessments of alternative paths to sustainability.

Fetter assumed that a CO2 equivalent concentration of 560 ppm was the maximum to be chanced. By taking that imperative as his starting-point, and conditioning his claim for the sake of simplicity, he fashioned an ingenious argument. From the strictures on fossil fuel use required by his assumed imperative, Fetter

---

18 560 ppm is simply twice the pre-industrial level of 280 ppm.
generates a range of “requirements for non-carbon-emitting energy supply”:

The implications of this scenario for world energy supply are profound. Today, fossil fuels supply 86% of commercial energy supply. If greenhouse gases are to be stabilized at an equivalent doubling, traditional fossil fuels can supply no more energy in 2050 than they supply today, even while total energy use doubles or triples. Non-carbon-emitting sources must grow from 14% of total commercial supply to 50–80% of total supply in 2050.19

He concludes that

Over the next 50 to 100 years, fission could be expanded to provide over half of the world’s electric power and a third of the non-carbon-emitting energy supply required to stabilize greenhouse gas concentrations at an equivalent doubling.20

More than ten years later, does the global discussion of warming still project that global energy use will “double or triple” by 2050? And what of the prospects for stabilisation? Is there a prospect that “traditional fossil fuels [will] supply no more energy in 2050 than they supply today [that is, in 1997]”? The short answer is that global energy use is expected to double at least, and that there is ‘not a chance’ that 2050 fossil fuel reliance will be no greater in 2050 than 1997. Fetter’s aim—not to exceed ‘doubling’—appears out of reach. But proposals to stabilize at ‘doubling’ or less have been developed and given wide currency.

For a more detailed discussion of stabilisation targets and their requirements, the reader may consult results of ongoing studies by the International Panel on Climate Change and the International Energy Agency.21 The IEA’s World Energy Outlook 2008 contains a brief


comparison of its ‘reference scenario’ and those developed in other studies, including that of the IPCC, centered on the widely discussed targets of 450 and 550 ppm CO\textsubscript{2} and CO\textsubscript{2} equivalent.\textsuperscript{22}

To what extent would nuclear contribute? How much nuclear generating capacity would be required?

Extrapolation of historic evidence suggests it would be theoretically possible in economic terms to construct nuclear plants at a rate that would meet at least 18% and possibly 30% of the IEA forecast of world generating capacity requirements. However, supply-chain and skill constraints are likely to provide a cap on the overall level of new construction.\textsuperscript{23}

In August 2007 the world’s 438 nuclear power plants had a total capacity of 372 GW; 31 plants under construction would add 24 GW. The IEA mapped out scenarios into the future that assume annually from 2007 to 2050 30 GW of capacity would be built.\textsuperscript{24} So that might be more than 1200 additional 1 GW(e) reactors between 2010 and 2050, or more smaller reactors. Daunting.\textsuperscript{25} The IEA also notes that nuclear power could come into the road transportation sector if plans to use nuclear energy to make hydrogen electrolytically or thermo-chemically come to fruition, anticipated “around 2020.”\textsuperscript{26}

This brief canvass of readily-available studies supports the following observations:

- ‘Baseline’ and ‘reference’ scenarios—assuming present policy and technology—project CO\textsubscript{2} doubling by 2050 or earlier; only by introducing ambitious changes in policy and development (and deployment) of new technologies can the planners avert CO\textsubscript{2} doubling.

Especially pp. 407-416.


\textsuperscript{22} IAEA World Energy Outlook 2008 pp. 413-416. CO\textsubscript{2} is simply that, exclusive of other ‘greenhouse gases’ (GHGs). CO\textsubscript{2} equivalent (CO\textsubscript{2}-eq) is inclusive of other GHGs. The IEA study locates a 550 Policy Scenario and 450 Policy Scenario as follows: “The 550 Policy Scenario is compared to the IPCC’s Class III of scenarios (440–485 ppm CO\textsubscript{2}; 535–590 ppm CO\textsubscript{2}-eq; ~3°C temperature rise); the 450 Policy Scenario is compared to the IPCC’s Class I of scenarios (35–450 ppm CO\textsubscript{2}; 445–490 ppm CO\textsubscript{2}-eq; ~2°C temperature rise.”  P. 415.


\textsuperscript{24} Ibid., pp 284-285.

\textsuperscript{25} But the IEA observed in 2008 that from 1970 to 1990 an average of 17 GW per annum of nuclear power plant capacity was built, and another 11 GW planned but abandoned. “ … the world today should have the economic capacity to construct nuclear power stations at twice that rate—between 35 GW and 56 GW per year.”  Ibid., p. 300.

\textsuperscript{26} Ibid., p. 304.
Planners do not anticipate fossil fuel emissions again reaching down to the 1990 level until late in this century, if at all.

Experience supports caution whether ‘planned’ nuclear plants will go on line when anticipated, if at all.

Nonetheless, nuclear remains a proven, performing technology for near-zero-GHG emitting electricity generation, suggesting that if concern about climate change effects intensifies and if optimistic alternatives to reduce energy demand and cut GHG emissions prove disappointing, then the pressure to build more reactors will grow.

Only radical policy measures—including spending on methods other than nuclear generation and regulation, of which there is only scattered evidence today—will change this picture.

Nuclear Weapons and Population Geography

‘Median variant’ UN population projections anticipate growth of the world’s population from 6.085 billion in 2000 to 9.075 billion in 2050. Of this, the urban population would increase from 2.863 billion, 47.1% of the total, to 4.986 billion, 60.6%. We can infer that cities will be about 70% more extensive than today, and that an additional 2 billion people will be dependent on the supply of essential goods to this enlarged urban area.

Urban concentrations and higher population densities place more people at risk from nuclear detonations and their effects. A study simulating the result of a nuclear attack on Russia projected that an attack on populated areas west of the Urals using 192 W88 warheads would result in 49 million dead. That figure of roughly 250,000 deaths per warhead would scale with greater population density.

Unsustainability

The global economy could prove unsustainable because it required more food, fuel or materials than it could supply, or because the

---


28 The IEA explains that in their 2008 Reference Scenario “CO2 emissions from cities increase at 1.8% per annum, faster than global CO2 emissions at 1.6%. By 2030, it is projected that almost 30.8 Gt will be emitted in the world’s cities, a 55% increase over 2006 levels by 2030, the equivalent of adding twice the entire emissions of the United States. The share of cities in global CO2-emissions by 2030 is 76%.” World Economic Outlook 2008, p. 390.

29 Simulation developed and run by the Natural Resources Defense Council. Bret Lortie, “A Do-It-Yourself SIOP,” Bulletin of the Atomic Scientists, July-August 2001, v 57 n 4, pp. 22-29. “NRDC ran nuclear attack scenarios on Russian cities using either 150 single-warhead, silo-based ICBMs or 192 single-warhead, submarine-launched ballistic missiles (SLBMs), essentially the load aboard a single fully loaded Trident submarine. The results from either scenario, each using less than 3 percent of current U.S. nuclear forces, resulted in more than 50 million casualties.”

Bruce D. Larkin: ZNW in Global Priorities
increasingly complex networks on which it relied grew sclerotic or suffered unbearable breakdowns.

The aim of ‘sustainability’ initially sprang from the observation that the modern economy’s productive strategy relied on raiding Nature to obtain—and then consume—food, fuel, and materials. Few practices returned to Nature what had been used. Over the medium to long-term depredation would prove, it became clear, unsustainable. Achieving sustainability required finding ways to meet economic needs—perhaps a reconceived set of economic needs—which could be carried on indefinitely without savaging the planet. The 1987 Brundtland Report, Our Common Future, defined sustainability as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”

Society and economy depends on increasingly complex social, information, banking, and transport networks. Significant interruption of key networks would endanger all of those whose lives and circumstances required delivery of food, fuel, materials, and information. Natural disasters, which in modern experience have been localized and rarely visited on a true metropolis, give just a hint how easily these networks can be disrupted. Consider, for example, the devastation of New Orleans in August 2005 (Hurricane Katrina), the impact of fear on post-9.11 flight bookings, and the temporary collapse of a major US airline’s schedules in the wake of a brief ice storm in mid-February 2007, resulting in cancellation of some 1000 flights. Some argue that the smoke from fires ignited in cities by nuclear strikes could interfere with agriculture, leading to famines.

The consequences of nuclear attack against cities or transport and communications nodes would, of course, depend on the targets, how many key points were struck, and the extent to which networks outside the war region could operate autonomously. Other networks can be likened to the electricity delivery grid. Electricity systems serving tens of millions have been disrupted by faults begun by small events but then propagated through the grid. With that in mind, electric utilities practice prevention of triggering

---

conditions and then, if a threatening anomaly occurs, its early detection and the isolation of that part of the grid which could undo the remainder. A few nuclear weapons detonated in major container ports, for example, would disrupt all industries dependent on the movement of materials and parts through those nodes. Cold War analyses showed that the United States would be profoundly affected by a few nuclear weapons destroying major centers of petroleum refining.

Would striving for sustainability reduce—or increase—the risk of network disruption? It is too early to say. Localizing food production, for example, might mitigate effects of natural disaster or attack. In a famous injunction, Mao Zedong called on the Chinese people to "store grain everywhere." Similarly, a greater portion of electricity could be produced locally, not only by solar, wind, and water, but also by generators with an associated stored supply of fuel.

Would New Orleans have done better if the community had stockpiled food and water, and built a decentralized electric generation system? Or would monies have been better spent on the dikes, the boundaries of a network of waterways? Either course could have been judged ‘wasteful’ in retrospect, a drag on material sustainability, but have reduced effects of network breakdown.

We ridicule today the 1950s stocking of US municipal nuclear shelters with canned water and biscuits, later discarded, because few people would have survived a nearby nuclear strike. Nuclear destruction would overwhelm symbolic, but misplaced, public reassurance. It is sobering to recall, too, the experience of the US Northeast’s electric blackout of August 2003, during which failure of prepositioned ‘emergency’ generators at Columbia University led to loss of frozen specimens vital to long-term research programs.

It’s a sure bet that global sustainability will require networks more elaborate, more closely binding information technology into daily practice, than today’s. How much ‘breakdown’ can be tolerated? The policy question will be how to render networks sufficiently ‘robust’ or inessential, in the face of an estimated risk, and at a tolerable cost. Consider embedded error sensing, pre-programmed response to anomalies, off-site computer backup, and hardware and fuel redundancy, already widely used. If network ‘breakdown’ would imperil human life it might be smart to ready a parallel system, wholly independent, to which a temporary switch could be made. Installing a standby generator, automatically invoked by loss of line current, enacts just that design.\textsuperscript{33}

\textsuperscript{33} Consider the analogy to four-engine aircraft of the 1940s, some of which were equipped with hand cranks to be used to lower the landing gear if hydraulic systems failed. A crew member crawled down to the landing gear housing and turned the crank.

\textit{Bruce D. Larkin: ZNW in Global Priorities}
Economic networks risk nuclear attack. There are many other vulnerabilities: to natural disaster, ‘system failure’, insider abuse, for example. Can we design features to confine, dampen, or even reverse an assault on a key network? The answer would appear to be that all episodes of system endangerment, including even attack using one or a handful of nuclear weapons, are limited naturally by the system’s features, configuration and location (distance from blast, undergrounding). Effects are local, or limited in time (months or years, not decades), subject to workarounds, or to network repair. Nonetheless, nuclear weapon effects would be horrific.

Nuclear weapons impose other costs on global society. There are obvious opportunity costs for [a] the nuclear weapons themselves and [b] military expenses to deploy and protect nuclear weapons, but also for [c] precautionary measures to control fissile material and guard against conversion of civil nuclear materials to bombs. Expansion of reliance on nuclear power would actually increase the aggregate cost of precautionary measures; and in any case going to ZNW would still require unusual vigilance against the unexpected reappearance of nuclear weapons. On balance, however, the saving in [a] weapons + [b] deployment should be much greater than the increment in cost of [c] precautions.

There is, however, a fourth item in any comprehensive calculus: [d] the cost of ‘conventional’ military sufficient to maintain global security in a ZNW world. Costs attributed to ‘security’ could rise, if states attempt to recreate a confrontational world like that before 1945. To exceed total military spending in the early 2000s annual costs would have to exceed $1000 billion. But costs could also fall, if states replaced pre-1945 expectations with a collective security system based on smaller pooled forces normally configured for defense. Other solutions are possible. ZNW will present opportunities to cut costs of [d] ‘conventional’ military, but it is a political question whether leaderships will contrive and seize those options.

Conclusions

We began by asking whether a world beset by climate change, environmental degradation, population growth, and unsustainable economic practices could afford to take ‘nuclear weapons’ as a equally insistent priority issue.

Our approach runs as follows. ‘Nuclear weapons’ pose a significantly more tractable problem than achieving sustainability, but their presence threatens sustainability. Even if nuclear weapons were to

---

be accepted as ‘normal’ or ‘irremovable’ they would still carry an unavoidable risk of use—nuclear attack or nuclear war—which could strike a radial blow against achieving social and environmental sustainability. Therefore because of the compelling threats of environmental and social unsustainability there is a convincing case for nuclear zero.

What of nuclear power? A serious school of thought argues from the threat of nuclear accident—consider Chernobyl—and nuclear war that a technology dependent on uranium and plutonium is inherently too dangerous to be allowed. As long as uranium and plutonium are in commerce, and reactors produce plutonium in spent fuel, there will be a risk that one or many nuclear weapons will be fabricated and used. This line of argument leads to the conclusion that both nuclear weapons and civil nuclear power reactors should be abolished and prohibited.

That is not my view. Because existence of nuclear weapons makes their use possible, and because they have no exclusive redeeming virtue(where by ‘exclusive’ I mean a virtue that cannot be achieved by less dangerous means), the difficult political exercise of prohibiting them and maintaining an effective prohibition is a prudent, urgent necessity. What makes weapons abolition possible is that existing stocks are known to their makers and can be declared. The uranium and plutonium needed for a nuclear weapon be listed and monitored. Given political will, the task is possible. This same fact offers a way to prevent nuclear fuel (in its manufacture, storage, transportation, and use), and spent fuel (containing uranium and plutonium), being move into an illicit, clandestine weapons program.

Barack Obama, in his 5 April 2009 speech in Prague setting the goal of abolition of nuclear weapons, also called for partnerships to “lock down” nuclear materials:

we know that there is unsecured nuclear material across the globe. To protect our people, we must act with a sense of purpose without delay.

So today I am announcing a new international effort to secure all vulnerable nuclear material around the world within four years.35

Among independent analysts systematic work is being done by the International Panel on Fissile Materials, which declares as its aim “to analyze the technical basis for practical and achievable policy initiatives to secure, consolidate, and reduce stockpiles of highly enriched uranium and plutonium.”36

There is no doubt that the best way to reach sustainability is to practice conservation and design for frugality. But society demands usable energy. Some paths to energy are ecologically unsound, perhaps

35 President Barack Obama, Prague, 5 April 2009. He also said “I state clearly and with conviction America’s commitment to seek the peace and security of a world without nuclear weapons.” http://www.whitehouse.gov/the_press_office/Remarks-By-President-Barack-Obama-In-Prague-As-Delivered/

36 http://www.fissilematerials.org/ipfm/pages_us_en/about/about/about.php
threatening in ways we cannot conceive. We should draw back from those paths. Nuclear materials, too, pose harms. My reading of what we know and reasonably understand and infer is that the risks in civil nuclear power are significantly smaller than those posed by reliance on fossil fuels. The difference in degree of risk is very large, not small.

On the other hand, because I consider the risk posed by nuclear weapons to be so great, I also believe that reliance on civil nuclear power requires the most thorough, collaborative, transparent, and accountable control of fissile material that political ingenuity can construct and effect. Hence the conclusion: build a global consensus (a) to practice openness about fissile material under each state’s control and (b) to achieve the joint, collaborative management of that material that prudence requires. Abolish and prohibit nuclear weapons. Do so quickly.
Abbreviations

CO₂ Carbon dioxide
EIA Energy Information Administration
FMCT Fissile Material Control Treaty or Fissile Material Cutoff Treaty
GHG Greenhouse gas
GW, GWe Gigawatt, gigawatt (electric)
IEA International Energy Agency
IAEA International Atomic Energy Agency
ICBM Intercontinental ballistic missile
IPCC International Panel on Climate Change
IPFM International Panel on Fissile Materials
NPR Nuclear Posture Review
NPT Non-Proliferation Treaty [Treaty on the Non-Proliferation of Nuclear Weapons]
NRDC Natural Resources Defense Council
OECD Organization for Economic Cooperation and Development
ppm Parts per million
Pu Plutonium
PCAST President’s Council of Advisors on Science and Technology
SLBM Submarine-launched ballistic missile
TWh Terawatt hours
U, ²³⁵U Uranium, uranium-235
UN United Nations
WEC World Energy Council

Conversion Factors

Energy Units

1 MW(e) = 10⁶ watts
1 GW(e) = 1000 MW(e) = 10⁹ watts
1 GJ = 1 gigajoule = 10⁹ joules
1 EJ = 1 exajoule = 10¹⁸ joules
1 EJ = 23.9 megatonnes of oil equivalent (MTOE)
1 TWh = 1 terawatt-hour = 10¹² kWh = 3.6 x 10³ EJ

### General conversion factors for energy

<table>
<thead>
<tr>
<th>To:</th>
<th>TJ</th>
<th>Gcal</th>
<th>Mtoe</th>
<th>MBtu</th>
<th>GWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>From: multiply by:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TJ</td>
<td>1</td>
<td>238.8</td>
<td>2.388 x 10^3</td>
<td>947.8</td>
<td>0.2778</td>
</tr>
<tr>
<td>Gcal</td>
<td>4.1868 x 10^3</td>
<td>1</td>
<td>10^3</td>
<td>3.966</td>
<td>1.163 x 10^3</td>
</tr>
<tr>
<td>Mtoe</td>
<td>4.1868 x 10^6</td>
<td>1</td>
<td>10^6</td>
<td>3.968 x 10^6</td>
<td>11630</td>
</tr>
<tr>
<td>MBtu</td>
<td>1.0551 x 10^3</td>
<td>0.252</td>
<td>2.52 x 10^4</td>
<td>1</td>
<td>2.931 x 10^4</td>
</tr>
<tr>
<td>GWh</td>
<td>3.6</td>
<td>860</td>
<td>8.6 x 10^3</td>
<td>3412</td>
<td>1</td>
</tr>
</tbody>
</table>


### Revision History

2011.02.11 First published to web.

2014.03.30 Printing changed from A4 to US Letter, with consequent changes in pagination. Corresponding file name is J008=TX.071=2011.02.11.Priorities.[US Letter].rtf
The *Journal of Denuclearization Design* is a cumulative digital-only journal edited and issued by the Global Collaborative on Denuclearization Design.

Access to the *Journal* is at the GC.DD website: www.gcdd.net. Please direct correspondence and submissions to editor@gcdd.net.

Except where otherwise noted, this work is licensed under http://creativecommons.org/licenses/by-nc-nd/3.0/

*Some rights reserved*: this work, its contents pages, or any complete article or set of articles, may be distributed freely subject to the attribution, non-commercial, and no derivative works conditions of the Creative Commons license 3.0. ‘Attribution’ is met by including this page as the last page of the article.

Article Title: ZNW in Global Priorities: How Does Nuclear Weapons Abolition Fit Among Global Priorities?
Author: Bruce D. Larkin
[Email: bruce.larkin@gcdd.net] [Web: http://www.brucelarkin.net]
Date received: 2011.02.11. Date issued to the web: 2011.02.11.
[Draft: DD.105]

Bruce D. Larkin is Professor Emeritus of Politics at the University of California at Santa Cruz, and the Convenor and Director of Studies of the Global Collaborative on Denuclearization Design. He is the author of *Nuclear Designs: Great Britain, France, & China in the Global Governance of Nuclear Arms* (1996); *War Stories* (2001); and *Designing Denuclearization: An Interpretive Encyclopedia* (2008).