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A NUCLEAR POWER RENAISSANCE?

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and Friends of the Earth, Australia http://www.foe.org.au/anti-nuclear

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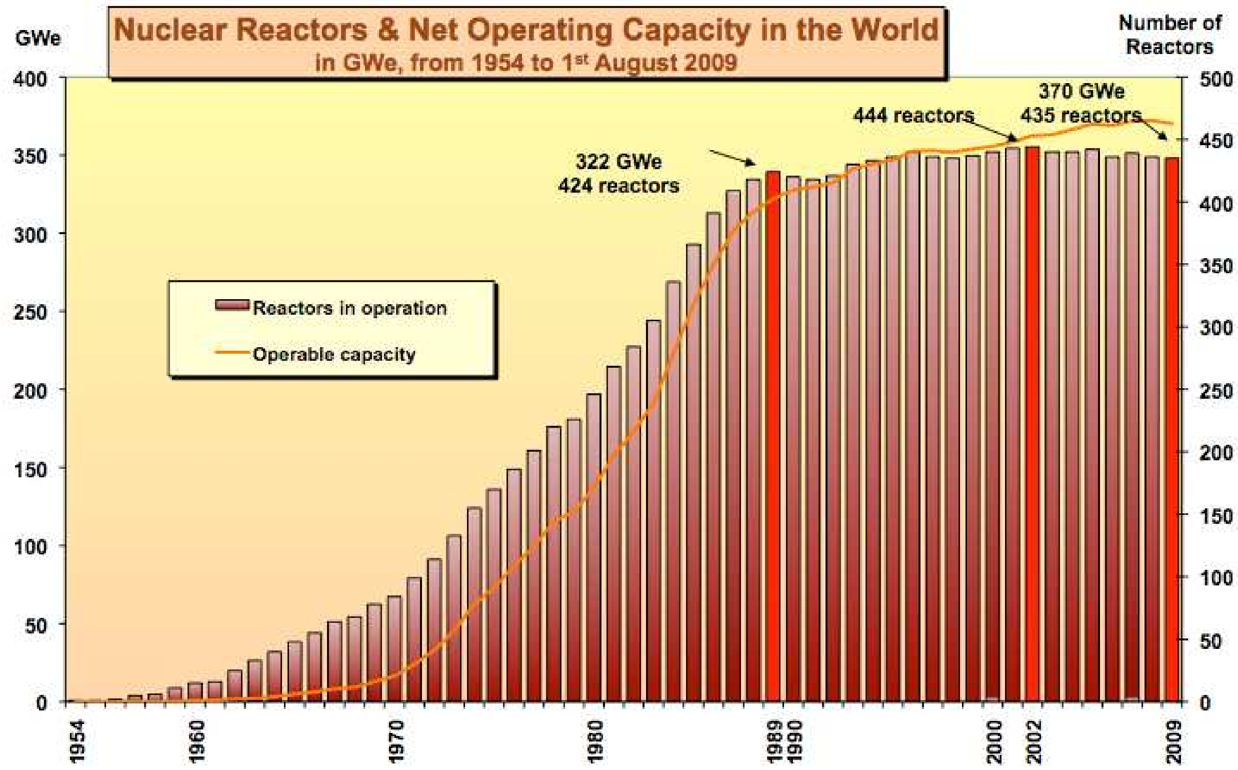
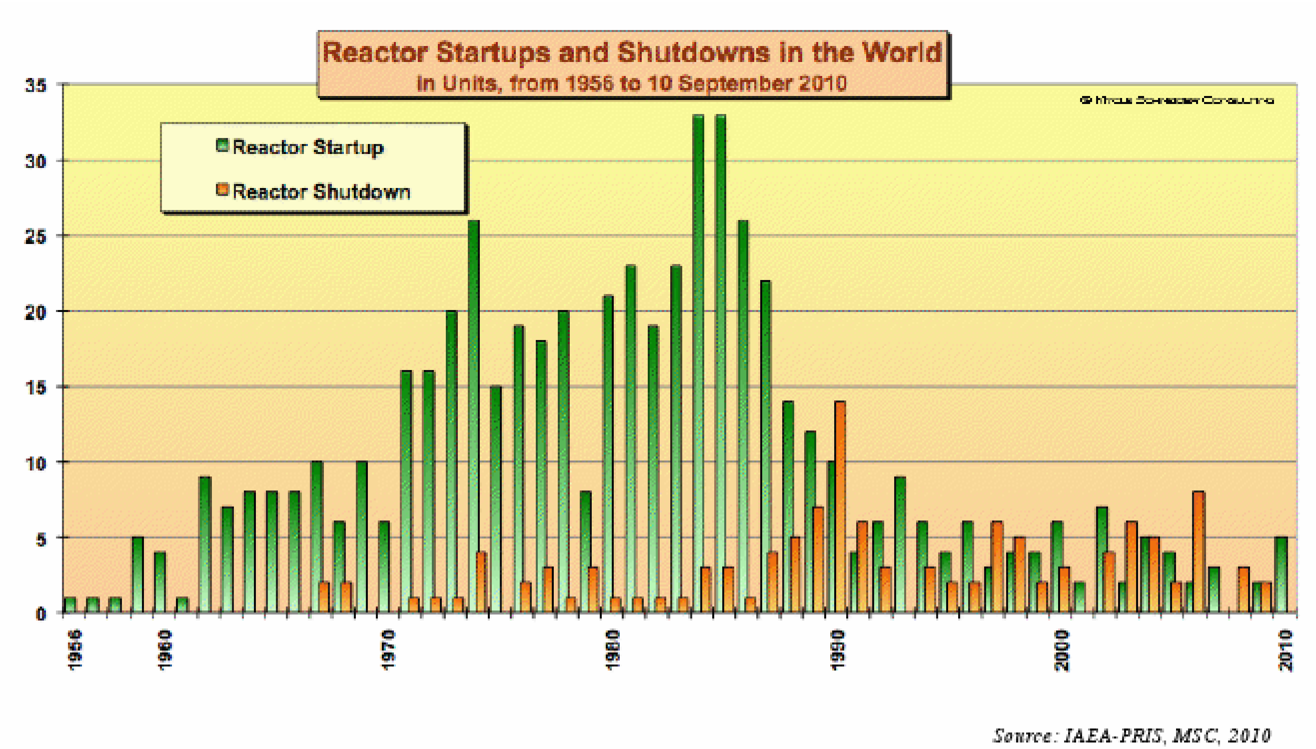
Key points:
* There is a great deal of uncertainty about the future of nuclear power worldwide.
* By most parameters nuclear power has been stagnant for the past 20 years.
* Modest growth is likely from 2010–2030. However even in the 2010-2030 period there is a great deal of uncertainty and estimates of nuclear growth beyond 2030 are so uncertain as to be of little value.

1. THE PAST 20 YEARS

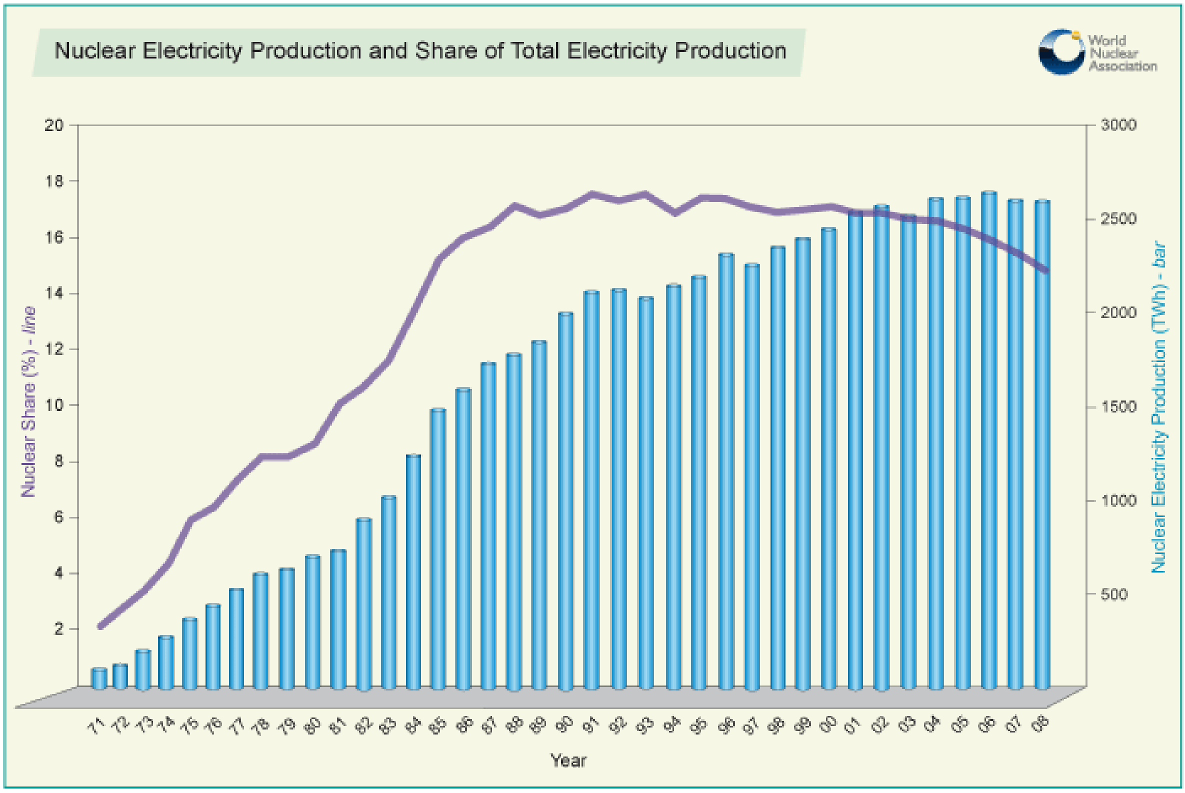
Nuclear power generating capacity has been stagnant for the past 20 years as the following graphs illustrate:



Source: Schneider et al., 2009.



Source: Schneider, 2010.



Source: World Nuclear Association <www.world-nuclear.org/info/inf01.html>

One important parameter has shown growth in the past 20 years: nuclear electricity generation. This has occurred through:
1. Reactor 'uprating', i.e. increasing the power level (see WNA 2010b for details);
2. Operating reactors for more time per year (capacity factor); and
3. Extending the operating lifespan of reactors.

As the above graph shows, the potential to increase electricity generation without increasing the number of reactors appears to have reached its limit. Thus all four parameters are stagnant (capacity, electricity generation, number of reactors) or in decline (nuclear power's percentage contribution to electricity generation from all sources).

In recent years:
* In 2007 world nuclear electricity generation fell by 2% – more than in any other year since the first reactor was connected to the grid in 1954. (Schneider et al., 2009)
* In 2008 not a single new plant was connected to the grid – the first time that happened since 1955; and uprates were offset by plant closures resulting in a net world nuclear capacity decline of about 1.6 GW. (Schneider et al., 2009; BP, 2009)
* In 2009 there were two reactor start-ups but four permanent shut-downs and net capacity fell by 0.86 GW. (World Nuclear Association, 2010, 2010c).

2. CURRENT SITUATION AND FUTURE GROWTH

As at 1 December 2010, 441 reactors are operating in 31 countries (including Taiwan). Global nuclear generating capacity is 376 GW. Nuclear power accounts for 14% of global electricity generation. (www.world-nuclear.org/info/inf01.htm)

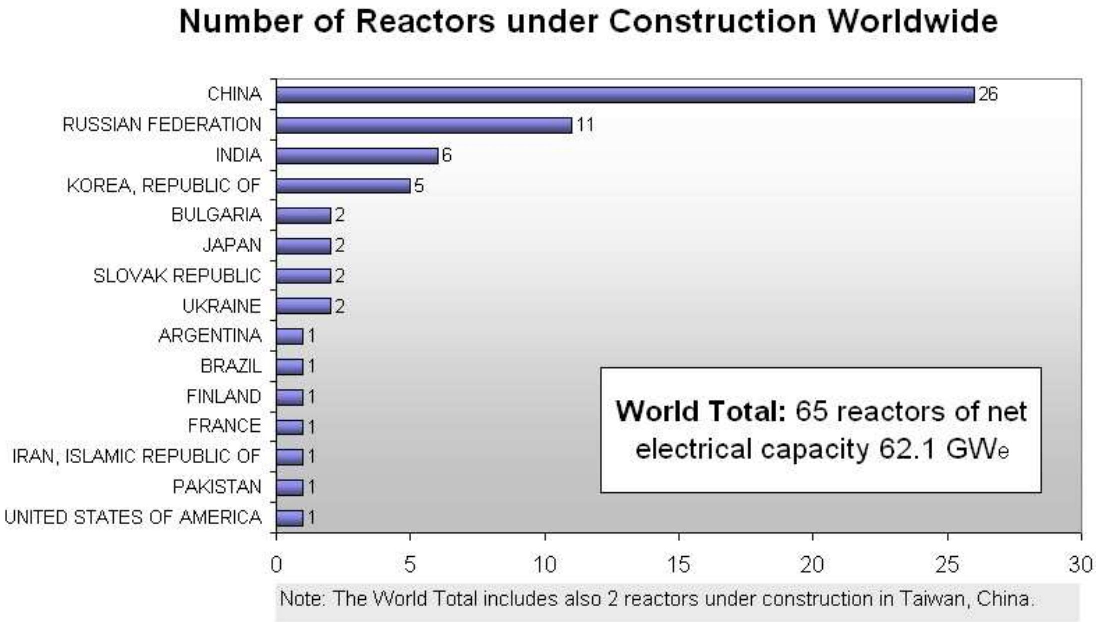
In 2010, net nuclear generating capacity is likely to increase by about 3.7 GW − a 1% increase. Stronger growth is predicted in 2011 and beyond. (IAEA, 2010)

The IAEA provides the following figures on the contribution of different fuels to global electricity supply in 2008 (IAEA, 2010c):
* Thermal (solids, liquids, gases, biomass and waste) 67.15%
* Renewables 18.82%
* Nuclear 14.03%

The 18.82% figure for renewables is dominated by hydro (17.66%) with other renewables (geothermal, wind, solar and tide energy) accounting for 1.16%.

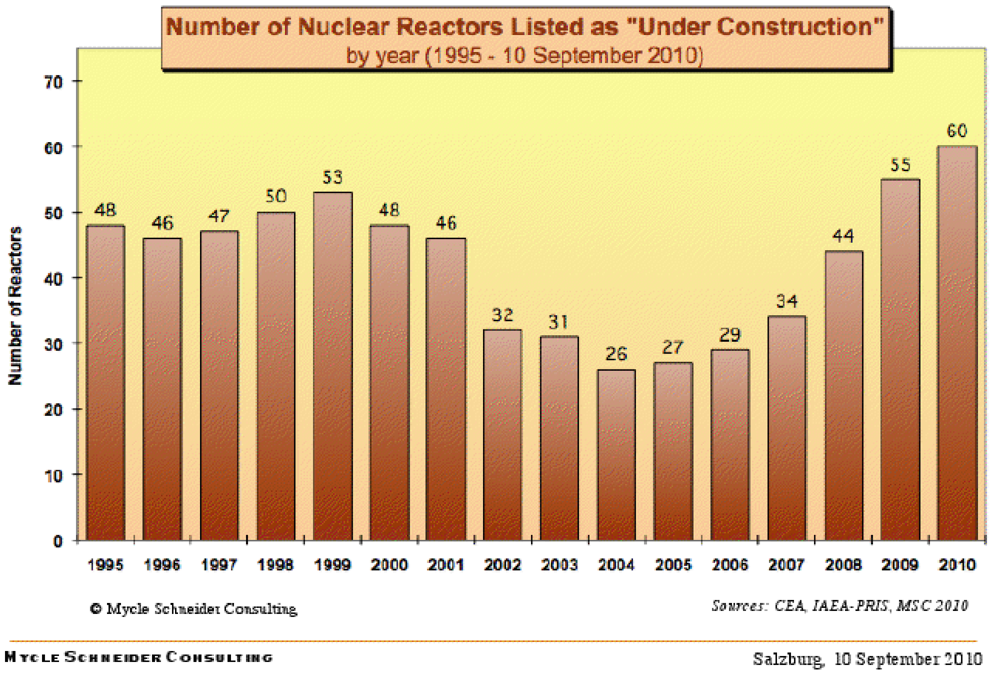
Numbers of reactors under construction, on order, planned or proposed.

As at December 2010, 65 reactors (65 GW) are under construction.



Source: IAEA, http://www.iaea.org/cgi-bin/db.page.pl/pris.opercap.htm

The following graph (from September 2010, when 60 reactors were under construction) illustrates the growth in the number of reactors under construction over the past five years. The number grew slowly from 26 in 2004 to 34 in 2007, and from 2007-2010 it has increased at a rate of about 10 per year. The current number of 65 reactors under construction is still well short of the historical peak of 233 reactors under construction in 1979.



Source: Schneider, 2010.

Construction delays are common. Schneider et al. (2009) noted in late 2009 that of the 52 reactors then under construction around the world, 26 had encountered construction delays, most of the significant, and 13 had been listed as under construction for over 20 years.

The French Atomic Energy Commission published statistics on "cancelled orders" until 2002, by which time it had recorded 253 cancelled orders in 31 countries, many of them in advanced construction stage. The USA alone accounted for 138 cancellations. (Schneider et al., 2009.)

There is still greater uncertainty about reactors listed as 'on order or planned' or 'proposed'

The IAEA (2010b, 2007b) provides the following figures allowing for a comparison between March 2007 and November 2010:
* 61 GW of nuclear capacity under construction (up from 23 GW in 2007)
* 163 GW 'on order or planned' (up from 69 GW in 2007)
* 376 GW 'proposed' (up from 124 GW in 2007).

Reactor shutdowns

One source of uncertainty regarding the future of nuclear power is the extent to which plans for new reactors materialise. Another is the extent to which 'new build' is offset by reactor closures.

The average lifespan of reactors currently operating or under construction is a matter of considerable uncertainty and there is little experience with 40+ year old reactors to inform forward estimates of average reactor lifespan.

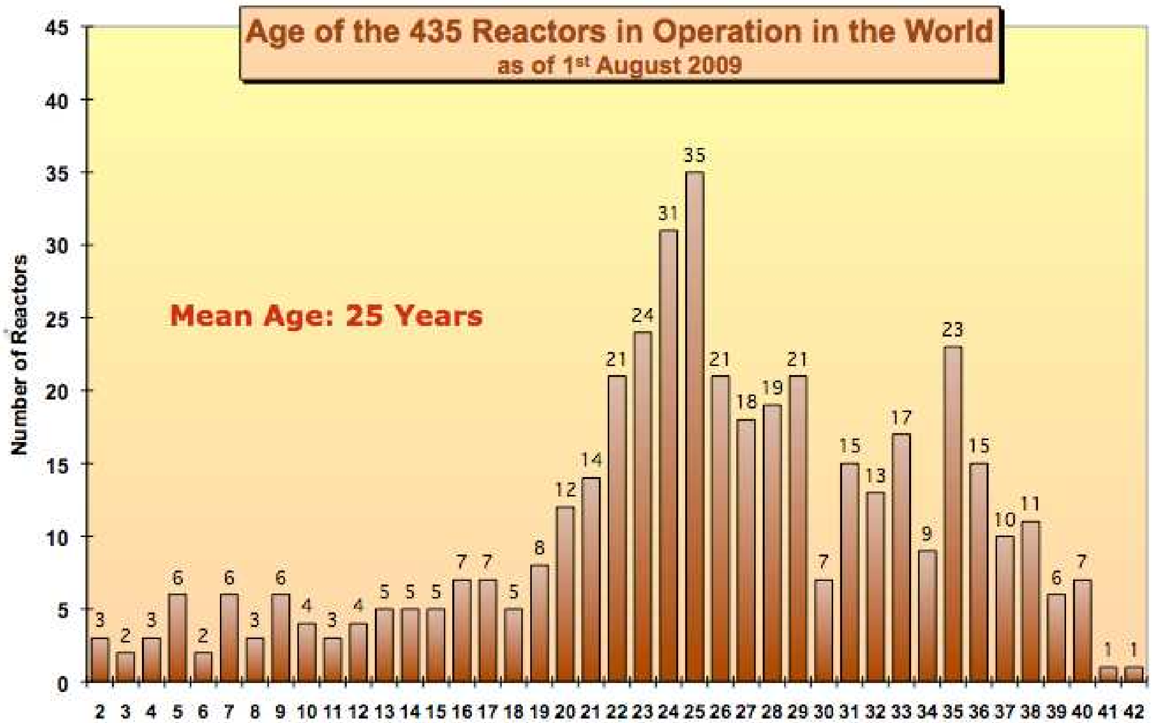
The World Nuclear Association (2010b) notes that most nuclear power plants originally had a nominal design lifetime of 25 to 40 years, but engineering assessments of many plants have established that many can operate longer.

Schneider et al. (2009) assume an average lifespan of 40 years and they note that the OECD's World Energy Outlook 2008 estimates a 40-50 year time frame with an average 45 years expected operation. The mean average age of operating reactors is 25 years, older than the average age of all shut-down reactors – 22 years. By the year 2019, 135 reactors will have operated for 40 years or more. In the following decade an additional 216 reactors – more than half of the current global fleet – will reach a 40 year lifespan (apart from those that are shut down before that time). In total, 351 reactors –about 80% of the current global fleet of reactors – will be at least 40 years old by 2029. (Schneider et al., 2009)

The World Nuclear Association (2010b) assumes a longer average lifespan and estimates that at least 60 and up to 143 reactors will be retired by 2030.

In general terms, roughly 300 reactors might need to be replaced by 2030 just to maintain current output based on the assumptions of Schneider et al. Using World Nuclear Association assumptions, the number of reactors retired will be roughly 100.

In the US, numerous reactors have been licensed to operate for 60 years, but no reactor has yet operated for that long and the average lifespan may be considerably shorter.



Source: Schneider et al., 2009.

Estimates of future growth

Estimates of the future growth of nuclear power rely on highly uncertain assumptions about the number of reactors to be built and equally uncertain assumptions about reactor retirements. Thus the IAEA (2010c) notes that "there remains substantial uncertainty in projections about nuclear power".

In the 2008 OECD International Energy Agency's World Energy Outlook, the reference scenario projects that nuclear generation will increase by one-third by 2030, with nuclear's contribution to total electricity generation falling from 14% in 2007 to 10% in 2030. (Schneider et al., 2009)

The IAEA's low and high projections in 2010 for nuclear power in 2030 are 510−807 GW (IAEA, 2010c). The World Nuclear Association's (2010e) estimate for 2030 is 602−1350 GW.

IAEA 'high' projections have always been out by a wide margin, and IAEA 'low' projections have historically overestimated by an average of 13% (IAEA, 2007).

If the current IAEA 'low' projection for 2030 turns out to overestimate nuclear capacity by 13%, nuclear power capacity in 2030 will be 444 GW, an 18% increase above the 2010 level of 376 GW.

If the IAEA's low projection of 510 GW is realised, it will represent a 36% increase compared to the 2010 level of 376 GW, but nuclear power's market share will still fall, from 14% in 2010 to 13% in 2030 (IAEA, 2009).

Alger (2010) notes: "Historical projections for nuclear power capacity have invariably been overly optimistic. For example, the IAEA projected that during the 1980s − when more reactors were connected to the grid than any other decade − there would be 14 new countries using nuclear power with a combined low-end predicted capacity of 52 GWe by 1989. As it turns out, the actual capacity of these countries by 1989 was just shy of 9 GWe, nearly 6 GWe of which belonged to South Korea alone, with reactors in only 4 of the 14 countries. However, the ability of the IAEA to make accurate projections is dependent on the predictions of its member states, which are often overly optimistic for political reasons. Past predictions, be they from the IAEA, governments or others have almost always been wrong."

To summarise:
* Notwithstanding the high level of uncertainty about the future of nuclear power, there will probably be a modest increase in global nuclear power capacity from 2010−2030.
* Given that estimates for the 2010-2030 period are highly uncertain, it follows that projections beyond 2030 are still more uncertain.

3. CONSTRAINTS ON NUCLEAR POWER GROWTH

One constraint on the growth of nuclear power is the considerable time it takes to build reactors. An average construction timespan is nine years based on the 14 most recent grid connections as at late 2009 (Schneider et al., 2009). There is great variation in reactor construction times, from less than five years to well over 20 years.

The IAEA estimates a period of 11−20 years for countries establishing nuclear power for the first time: pre-project phase 1 (1-3 years); project decision-making phase (3-7 years); and construction phase (7-10 years). (WNA, 2010d)

Prof. Ian Lowe (2007) notes: "[N]uclear power is far too slow a response to the urgent problem of climate change. Even if there were political agreement today to build nuclear reactors, it would be at least 10 years before the first such reactor could deliver electricity, while some have suggested that between 15 and 25 years is a more realistic estimate. We can't afford to wait decades for a response given the heavy social, environmental and economic costs that global warming is already imposing. If we were to start today expanding the use of solar hot water in Queensland to cover half the households in that state – a similar level to the Northern Territory – we could save about as much electricity as a nuclear power station would provide, and do it years before any reactor would be up and running.

In addition to reactor construction, more time elapses before nuclear power has generated as much as energy as was expended in the construction of the reactor. A report commissioned by the Switkowski Review states that: "The energy payback time of nuclear energy is around 6.5 years for light water reactors, and 7 years for heavy water reactors, ranging within 5.6–14.1 years, and 6.4–12.4 years, respectively." (University of Sydney, 2006) By contrast, construction times for renewable energy sources are typically months not years, and likewise the energy pay-back period is typically months not years.

Another constraint is bottlenecks in the reactor manufacturing sector. (Schneider et al., 2009, section II.5; Ferguson, 2007). Squassoni (2009) notes that: "A significant expansion will narrow bottlenecks in the global supply chain, which today include ultra-heavy forgings, large manufactured components, engineering, and craft and skilled construction labor. All these constraints are exacerbated by the lack of recent experience in construction and by aging labor forces. Though these may not present problems for limited growth, they will certainly present problems for doubling or tripling reactor capacity."

Another constraint is the general pattern of ageing nuclear workforces. In addition, research and training facilities and courses have been on the decline. (Schneider et al., 2009, section II.6).

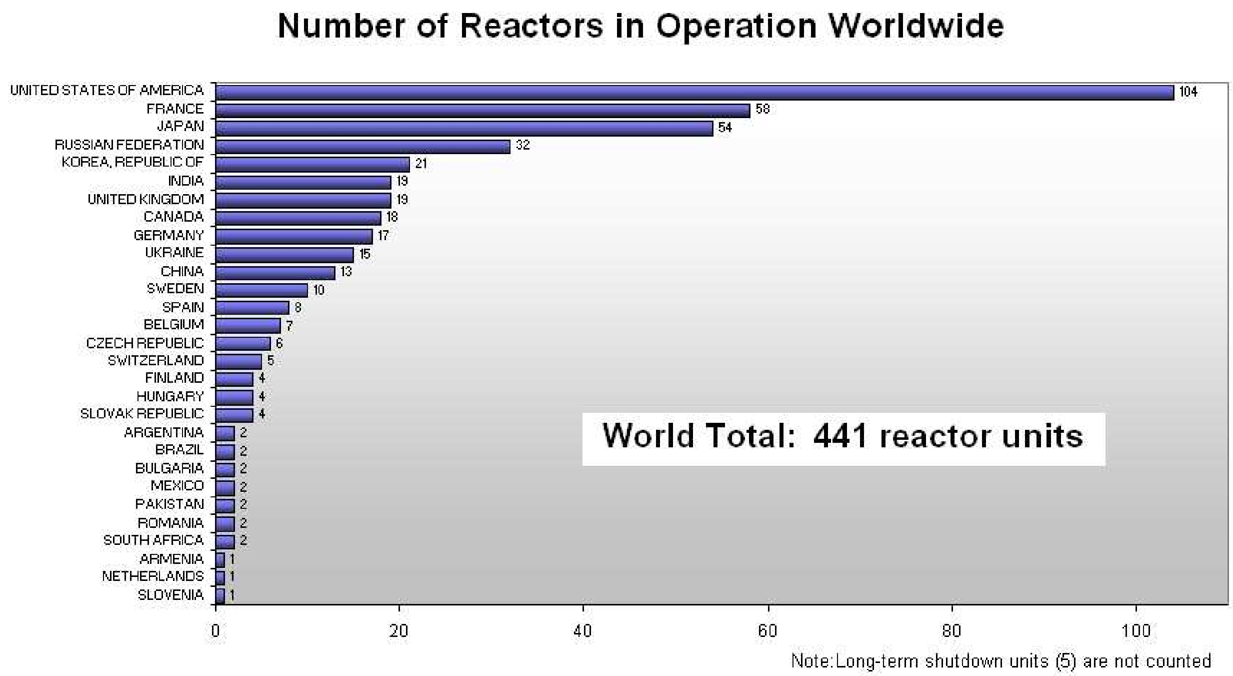
Other constraints include high capital costs, slower-than-projected growth in demand for electricity, scarcity of capital in developing countries, nuclear waste management problems, and problems with public acceptability (IPFM, 2010; CIGI, 2010). An IAEA-sponsored opinion poll of 18 countries in 2005 found that about two-thirds of those expressing an opinion opposed building new reactors (Globescan, 2005). South Korea was the only country with majority support for new reactors.

4. NUMBER OF COUNTRIES WITH POWER REACTORS

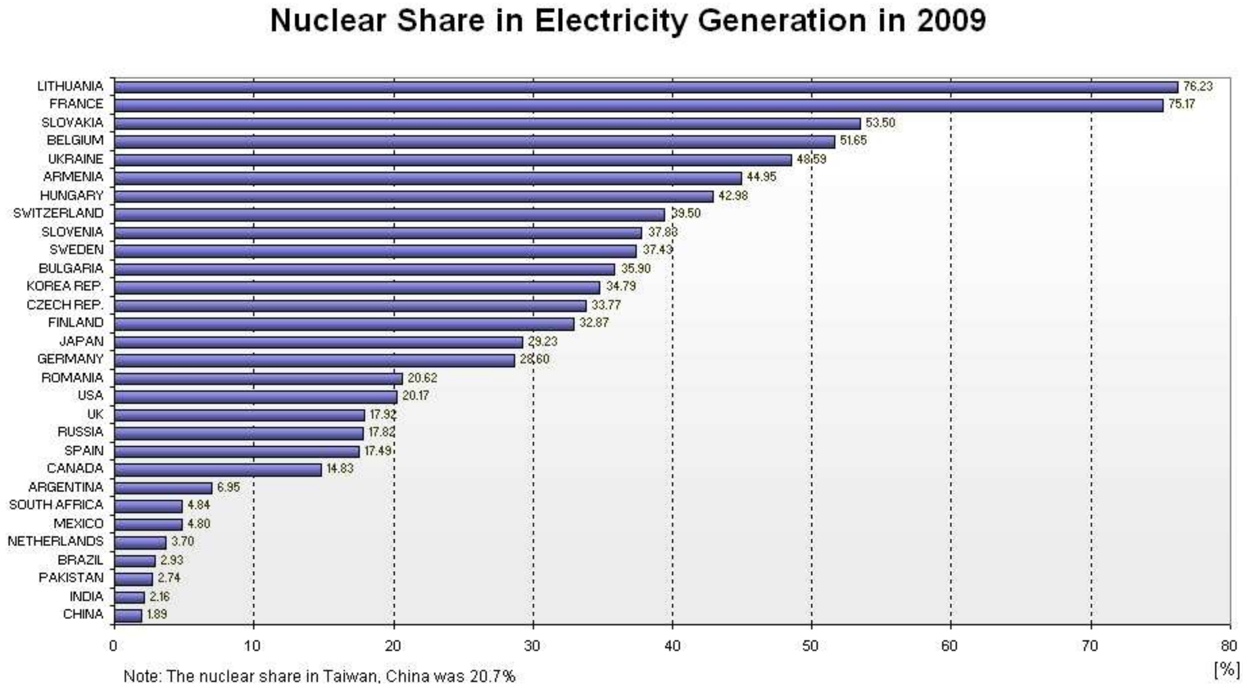
Thirty-one countries operate nuclear power reactors; 163 do not.

Eight countries account for 80% of global nuclear power capacity: the US, France, Japan, Germany, Russia, South Korea, Ukraine, and Canada.

This pattern is likely to persist. All 22 of the construction starts in 2008 and 2009 were in three countries: China, South Korea and Russia (IAEA, 2010c).



Source: IAEA, http://www.iaea.org/cgi-bin/db.page.pl/pris.oprconst.htm



Source: IAEA, http://www.iaea.org/cgi-bin/db.page.pl/pris.nucshare.htm

Countries considering their first nuclear power reactors

The IAEA (2010c) states that "some 65 countries are expressing interest in, considering, or actively planning for nuclear power" but almost half (31) are "not planning" nuclear power and a further 14 are just "considering" nuclear power. Only three of the 65 countries have either ordered a reactor or have a reactor under construction. The IAEA (2010c) states that 10-25 countries "might" have their first ever reactor in operation by 2030 − though most analysts consider that the figure will be fewer than 10.

Gourley and Stulberg (2009) note that of the countries that have expressed an interest in obtaining nuclear power, only a few have the odds in their favour. They point to the following constraints: adequate water for cooling, adequate financial resources, the will and ability to assume the burden of risk, an electrical grid of sufficient capacity to absorb the addition of a big plant, the ability to develop or absorb technological innovation, and a highly specialised workforce or the resources to attract such a workforce from abroad. (See also Goldemberg, 2007.)

Steve Kidd (2009) from the World Nuclear Association notes that it is "unlikely" that many new countries will develop nuclear power "particularly by 2020, where even the optimists can see no more than four or five likely candidates."

The International Panel on Fissile Materials (2010) notes that countries with annual GDP of less than US$50 billion, and electricity grid capacity of 5 GW or less, are poorly placed to be introducing nuclear power. Only 24 of the 61 countries interested in acquiring a first nuclear power plant pass both a $50 billion annual GDP and a 5 GW grid capacity screening requirement.

The IAEA (2010c) states: "Seventeen of the 31 countries considering or planning for nuclear power have grids of less than 5 GW(e), which would make them too small, according to the 10% guideline, to accommodate most of the reactor designs on offer without improved international grid interconnections. Grid issues may also place limitations on technology options for additional countries with grids smaller than 10 GW(e)."

More information: Centre for International Governance Innovation, Survey of Emerging Nuclear Energy States, <www.cigionline.org/senes>

Countries already operating power reactors

Most expansion of nuclear power in the short- to medium-term will take place in countries already operating power reactors. Most growth is expected in China, India and Russia. The World Nuclear Association (2010e) estimates the following growth from 2010−2030:
* China 9 GW to at least 50 GW
* India 4 GW to at least 20 GW
* Russia 22 GW to at least 45 GW

The World Nuclear Association (2010e) also anticipates significant growth in the US from 99 GW to at least 120 GW by 2030. However the situation in the US illustrates the uncertainty surrounding the trajectory of nuclear power. In 2002, President George W. Bush launched the Nuclear Power 2010 programme for the construction of at least three major nuclear power plants by 2010. No plants have come online since 2002 in the US, only one is under construction, and Fortune Magazine estimates "three new nuclear power plants in the next ten years, max". Fortune cites three reasons: the global recession, sinking natural gas prices, and the credit crunch. (Whitford, 2010)

Despite multi-billion dollar loan guarantees and other subsidies provided and offered by the US government to nuclear utilities, Bradford (2009) notes that most of the 26 new reactor license applications submitted to the Nuclear Regulatory Commission since 2007 have been cancelled or delayed. He states: "Much of this chaos is because cost estimates for new reactors tripled while natural gas prices declined precipitously. The recession and energy efficiency programs postponed estimated need for the power − often exaggerated in any case − by at least five years. In short, year seven of the ostensible U.S. nuclear renaissance looks a lot like the 1980s, a decade of no new orders, multiple delays and cancellations, and emerging cheaper alternatives." (Bradford 2009; see also Beyond Nuclear Initiative, 2010.)

5. POWER AND PROLIFERATION

There is concern about the potential contribution of the expansion of nuclear power to the proliferation of nuclear weapons. Of the thirty-one nations that have nuclear power today, seven are nuclear-weapon states and almost all the others are part of the European Union and NATO or have a close alliance with the United States (e.g. Japan, South Korea). Such arrangements do not exist for most of the countries that have expressed an interest in acquiring their first nuclear power plants.

The US National Intelligence Council (2008) states: "The spread of nuclear technologies and expertise is generating concerns about the potential emergence of new nuclear weapon states and the acquisition of nuclear materials by terrorist groups." The Council also warns of the possibility of a nuclear arms race in the Middle East and noted that a number of states in the region "are already thinking about developing or acquiring nuclear technology useful for development of nuclear weaponry".

Alger (2010) states:

> *"The main proliferation concern − potential new entrants in volatile regions − have shown little rigour in pursuing their nuclear energy ambitions. The Survey of Emerging Nuclear Energy States (SENES) ... currently lists 34 states pursuing nuclear energy. Of these, only Iran has actually made significant headway in the past decade to connect a nuclear power reactor to its electrical grid, but it began its ongoing quest to do so under the Shah in the 1970s. All states pursuing nuclear power will face some problems of cost, industrial bottlenecks, personnel constraints and nuclear waste, but aspiring states face unique challenges of their*

own. Since many of these states are poorer, less developed countries, they often lack the institutional capacity, physical infrastructure and finances to support a large-scale, multi-billion dollar nuclear power plant project."

"The risk, or concern, is that these new states will obtain the expertise in nuclear engineering and related disciplines that would allow them to go on to eventually develop nuclear weapons, most notably in the form of highly-trained scientists. Though the relationship between nuclear energy and weapons is complex, a nuclear power programme is nonetheless a potential stepping stone toward weapons development, and also a potentially highly effective cover for masking nefarious intent. Many fear that Iran is using its nuclear power programme for exactly that reason."

6. 'GENERATION 4' NUCLEAR POWER

'Next generation' or 'generation 4' reactors are still far off. For example the Generation 4 International Forum website states that "commercial deployment of Gen-IV reactors is not foreseen before 2030 at the earliest, and all current activities involving Gen-IV designs are at the level of R&D." The World Nuclear Association (2009b) is also downbeat, noting that "progress is seen as slow, and several potential designs have been undergoing evaluation on paper for many years."

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