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Tells the Facts, Names the Names

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Terminal Decline? Fukushima and the Deepening Crisis of Nuclear Energy

Saturday March 11 marks the sixth anniversary of the triple-disaster in north-east Japan – the earthquake, tsunami and the Fukushima nuclear disaster.

And the news is not good. Scientists are wondering how on earth to stabilise and decontaminate the failed reactors awash with molten nuclear fuel, which are fast turning into graveyards for the radiation-hardened robots sent in to investigate them.

The Japanese government's estimate of Fukushima compensation and clean-up costs has doubled and doubled again and now stands at ¥21.5 trillion (US$187bn; €177bn).

Indirect costs – such as fuel import costs, and losses to agricultural, fishing and tourism industries – will likely exceed that figure.

Kendra Ulrich from Greenpeace Japan notes in a new report that

> "for those who were impacted by the worst nuclear disaster in a generation, the crisis is far from over. And it is women and children that have borne the brunt of human rights violations resulting from it, both in the immediate aftermath and as a result of the Japan government's nuclear resettlement policy."

Radiation biologist Ian Fairlie summarises the health impacts from the Fukushima disaster:

> "In sum, the health toll from the Fukushima nuclear disaster is horrendous. At the minimum:
>
> ➤ Over 160,000 people were evacuated most of them permanently.
>
> ➤ Many cases of post-trauma stress disorder (PTSD), depression, and anxiety disorders arising from the evacuations.
>
> ➤ About 12,000 workers exposed to high levels of radiation, some up to 250 mSv
>
> ➤ An estimated 5,000 fatal cancers from radiation exposures in future.

➤ Plus similar (unquantified) numbers of radiogenic strokes, CVS diseases and hereditary diseases.

➤ Between 2011 and 2015, about 2,000 deaths from radiation-related evacuations due to ill-health and suicides.

➤ + An, as yet, unquantified number of thyroid cancers.

➤ An increased infant mortality rate in 2012 and a decreased number of live births in December 2011."

Dr Fairlie's report was written in August 2015 but it remains accurate. More than half of the 164,000 evacuees from the nuclear disaster remain dislocated. Efforts to restore community life in numerous towns are failing. Local authorities said in January that only 13% of the evacuees in five municipalities in Fukushima Prefecture have returned home after evacuation orders were lifted.

As for Japan's long-hyped 'nuclear restart': just three power reactors are operating in Japan; before the Fukushima disaster, the number topped 50.

A nuclear power 'crisis'?

Nuclear advocates and lobbyists elsewhere are increasingly talking about the 'crisis' facing nuclear power – but they don't have the myriad impacts of the Fukushima disaster in mind: they're more concerned about catastrophic cost overruns with reactor projects in Europe and the US.

Michael Shellenberger from the Breakthrough Institute, a US-based pro-nuclear lobby group, has recently written articles about nuclear power's "rapidly accelerating crisis" and the "crisis that threatens the death of nuclear energy in the West".

A recent article from the Breakthrough Institute and the like-minded Third Way lobby group discusses "the crisis that the nuclear industry is presently facing in developed countries".

'Environmental Progress', another US pro-nuclear lobby group connected to Shellenberger, has a webpage dedicated to the nuclear power crisis. Among other things, it states that 151 gigawatts (GW) of worldwide nuclear power capacity (38% of the total) could be lost by 2030 (compared to 33 GW of retirements over the past decade), and over half of the ageing US reactor fleet is at risk of closure by 2030.

As a worldwide generalisation, nuclear power can't be said to be in crisis. To take the extreme example, China's nuclear power program isn't in crisis – it is moving ahead at pace. Russia's nuclear power program, to give one more example, is moving ahead at snail's pace, but isn't in crisis.

Nonetheless, large parts of the worldwide nuclear industry are in deep trouble. The July 2016 *World Nuclear Industry Status Report* provides an overview of the troubled status of nuclear power:

➤ nuclear power's share of the worldwide electricity generation is 10.7%, well down from historic peak of 17.6% in 1996;

➤ nuclear power generation in 2015 was 8.2% below the historic peak in 2006; and

➤ from 2000 to 2015, 646 gigawatts (GW) of wind and solar capacity (combined) were added worldwide while nuclear capacity (not including idle reactors in Japan) fell by 8 GW.

US nuclear industry in crisis

The US nuclear industry is in crisis, with a very old reactor fleet – 44 of its 99 reactors have been operating for 40 years or more – and no likelihood of new reactors for the foreseeable future other than four already under construction.

Last September, Associated Press described one of the industry's many humiliations:

> "After spending more than 40 years and $5 billion on an unfinished nuclear power plant in northeastern Alabama, the nation's largest federal utility is preparing to sell the property at a fraction of its cost.
>
> The Tennessee Valley Authority has set a minimum bid of $36.4 million for its Bellefonte Nuclear Plant and the 1,600 surrounding acres of waterfront property on the Tennessee River. The buyer gets two unfinished nuclear reactors, transmission lines, office and warehouse buildings, eight miles of roads, a 1,000-space parking lot and more."

Japanese conglomerate Toshiba and its US-based nuclear subsidiary Westinghouse are in crisis because of massive cost overruns building four AP1000 reactors in the US – the combined cost overruns amount to about US$11.2bn (€10.7bn) and counting.

Toshiba said in February 2017 that it expects to book a US$6.3bn (€5.9bn) writedown on Westinghouse, on top of a US$2.3bn (€2.1bn) writedown in April 2016. The losses exceed the US$5.4bn (€5.1bn) Toshiba paid when it bought a majority stake in Westinghouse in 2006.

Toshiba says it would likely sell Westinghouse if that was an option – but there is no prospect of a buyer. Westinghouse is, as Bloomberg noted, "too much of a mess" to sell. And since that isn't an option, Toshiba must sell profitable businesses instead to stave off bankruptcy.

Toshiba is seeking legal advice as to whether Westinghouse should file for Chapter 11 bankruptcy. But even under a Chapter 11 filing, Reuters reported,

> "Toshiba could still be on the hook for up to $7 billion in contingent liabilities as it has guaranteed Westinghouse's contractual commitments" for the US AP1000 reactors.

The Toshiba/Westinghouse crisis is creating a ripple effect. A few examples:

➤ the NuGen (Toshiba/Engie) consortium has acknowledged that the plan for three AP1000 reactors at Moorside in the UK faces a "significant funding gap" and both partners reportedly want out of the project;

➤ Georgia Power, 45.7% owner of the troubled Vogtle AP1000 project, recently suspended plans for another nuclear plant in Georgia; and

➤ Toshiba recently announced its intention to pull out of the plan for two Advanced Boiling Water Reactors at the South Texas Plant, having booked writedowns totaling US$638m (€605m) on the project in previous years.

The French nuclear industry is in crisis

The French nuclear industry is in its "worst situation ever", former EDF director Gérard Magnin said in November 2016. The French government is selling assets so it can prop up its heavily indebted nuclear utilities Areva and EDF.

The current taxpayer-funded rescue of the nuclear power industry may cost the French state as much as €10bn (US$10.5bn), Reuters reported in January, and in addition to its "dire financial state, Areva is beset by technical, regulatory and legal problems."

France has 58 operable reactors and just one under construction. French EPR reactors under construction in France and Finland are three times over budget – the combined cost overruns for the two reactors amount to about €12.7bn (US$13.4bn).

Bloomberg noted in April 2015 that Areva's EPR export ambitions are "in tatters". Now Areva itself is in tatters and is in the process of a government-led restructure and another taxpayer-funded bailout.

On March 1, Areva posted a €665m (US$700m) net loss for 2016. Losses in the preceding five years exceeded €10bn (US$10.5 bn). A large majority of a €5bn (US$5.3bn) recapitalisation of Areva scheduled for June 2017 will come from French taxpayers.

On February 14, EDF released its financial figures for 2016: earnings fell 6.7%, revenue declined 5.1%, net income excluding non-recurring items fell 15%, and EDF's debt remained steady at €37.4bn (US$39.4bn). All that EDF chief executive Jean-Bernard Levy could offer was the hope that EDF would "hit the bottom of the cycle" in 2017 and rebound next year.

EDF plans to sell €10bn (US$10.5 bn) of assets by 2020 to rein in its debt, and to sack up to 7,000 staff. The French government provided EDF with €3bn (US$3.2bn) in extra capital in 2016 and will contribute €3bn towards a €4bn (US$4.2bn) capital raising this year.

On March 8, shares in EDF hit an all-time low a day after the €4bn capital raising was launched; the stock price fell to €7.78, less than one-tenth of the €86.45 high a decade ago.

Costs of between €50bn and €100bn (US$53-106bn) will need to be spent by 2030 to meet new safety requirements for reactors in France and to extend their operating lives beyond 40 years.

EDF has set aside €23bn (US$24.3bn) to cover reactor decommissioning and waste management costs in France – less than half of the €54bn (US$57bn) that EDF estimates will be required. A recent report by the French National Assembly's Commission for Sustainable Development and Regional Development

concluded that there is "obvious under-provisioning" and that decommissioning and waste management will likely take longer, be more challenging and cost much more than EDF anticipates.

EDF is being forced to take over parts of its struggling sibling Areva's operations – a fate you wouldn't wish on your worst enemy. And just when it seemed that things couldn't get any worse for EDF, a fire took hold in the turbine room of one of the Flamanville reactors on February 9 and the reactor will likely be offline until late March at an estimated cost of roughly €1.2m (US$1.27m) per day.

Half of the world's nuclear industry is in crisis and/or shutting down

Combined, the crisis-ridden US, French and Japanese nuclear industries account for 45% of the world's 'operable' nuclear reactors according to the World Nuclear Association's database, and they accounted for 50% of nuclear power generation in 2015 (and 57% in 2010).

Countries with crisis-ridden nuclear programs or phase-out policies (e.g. Germany, Belgium, and Taiwan) account for about half of the world's operable reactors and more than half of worldwide nuclear power generation.

The Era of Nuclear Decommissioning (END)

The ageing of the global reactor fleet isn't yet a crisis for the industry, but it is heading that way.

The assessment by the 'Environmental Progress' lobby group that 151 GW of worldwide nuclear power capacity could be shut down by 2030 is consistent with figures from the World Nuclear Association (132 reactor shut-downs by 2035), the International Energy Agency (almost 200 shut-downs between 2014 and 2040) and Nuclear Energy Insider (up to 200 shut-downs in the next two decades). It looks increasingly unlikely that new reactors will match shut-downs.

Perhaps the best characterisation of the global nuclear industry is that a new era is approaching – the Era of Nuclear Decommissioning (END). Nuclear power's END will entail:

- ➤ a slow decline in the number of operating reactors (unless growth in China can match the decline elsewhere);
- ➤ an increasingly unreliable and accident-prone reactor fleet as ageing sets in;
- ➤ countless battles over lifespan extensions for ageing reactors;
- ➤ an internationalisation of anti-nuclear opposition as neighbouring countries object to the continued operation of ageing reactors (international opposition to Belgium's reactors is a case in point);
- ➤ a broadening of anti-nuclear opposition as citizens are increasingly supported by local, regional and national governments opposed to reactors in neighbouring countries (again Belgium is a case in point, as is Lithuanian opposition to reactors under construction in Belarus);
- ➤ many battles over the nature and timing of decommissioning operations;

➤ many battles over taxpayer bailouts for companies and utilities that haven't set aside adequate funding for decommissioning;

➤ more battles over proposals to impose nuclear waste repositories on unwilling or divided communities; and

➤ battles over taxpayer bailouts for companies and utilities that haven't set aside adequate funding for nuclear waste disposal.

As discussed in a previous article in *The Ecologist*, nuclear power is likely to enjoy a small, short-lived upswing in the next couple of years as reactors ordered in the few years before the Fukushima disaster come online. Beyond that, the *Era of Nuclear Decommissioning* sets in, characterised by escalating battles – and escalating sticker-shock – over lifespan extensions, decommissioning and nuclear waste management.

In those circumstances, it will become even more difficult than it currently is for the industry to pursue new reactor projects. A positive feedback loop could take hold and then the industry will be well and truly in crisis.

Nuclear lobbyists debate possible solutions to the nuclear power crisis

Michael Shellenberger from the *Breakthrough Institute* argues that a lack of standardisation and scaling partly explains the "*crisis that threatens the death of nuclear energy in the West*". The constant switching of designs deprives the people who build, operate and regulate nuclear plants of the experience they need to become more efficient.

Shellenberger further argues that there is too much focus on machines, too little on human factors:

> "Areva, Toshiba-Westinghouse and others claimed their new designs would be safer and thus, at least eventually, cheaper, but there were always strong reasons to doubt such claims. First, what is proven to make nuclear plants safer is experience, not new designs. …
>
> In fact, new designs risk depriving managers and workers the experience they need to operate plants more safely, just as it deprives construction companies the experience they need to build plants more rapidly."

Shellenberger has a three-point rescue plan:

1/ 'Consolidate or Die':

> "If nuclear is going to survive in the West, it needs a single, large firm — the equivalent of a Boeing or Airbus — to compete against the Koreans, Chinese and Russians."

2/ 'Standardize or Die': He draws attention to the "*astonishing*" heterogeneity of planned reactors in the UK and says the UK

"should scrap all existing plans and start from a blank piece of paper", that all new plants should be of the same design and "the criteria for choosing the design should emphasize experience in construction and operation, since that is the key factor for lowering costs."

3/ 'Scale or Die': Nations

"must work together to develop a long-term plan for new nuclear plant construction to achieve economies of scale", and governments "should invest directly or provide low-cost loans."

Wrong lessons

Josh Freed and Todd Allen from pro-nuclear lobby group Third Way, and Ted Nordhaus and Jessica Lovering from the Breakthrough Institute, argue that Shellenberger draws the wrong lessons from Toshiba's recent losses and from nuclear power's "longer-term struggles" in developed economies.

They argue that

"too little innovation, not too much, is the reason that the industry is on life support in the United States and other developed economies".

They state that:

➤ The Westinghouse AP1000 represents a fairly straightforward evolution in light-water reactor design, not a radical departure as Shellenberger claims.

➤ Standardisation is important but it is not a panacea. Standardisation and building multiple reactors on the same site has limited cost escalation, not brought costs down.

➤ Most of the causes of rising cost and construction delays associated with new nuclear builds in the US are attributable to the 30-year hiatus in nuclear construction, not the novelty of the AP1000 design.

➤ Reasonable regulatory reform will not dramatically reduce the cost of new light-water reactors, as Shellenberger suggests.

They write this obituary for large light-water reactors:

"If there is one central lesson to be learned from the delays and cost overruns that have plagued recent builds in the US and Europe, it is that the era of building large fleets of light-water reactors is over in much of the developed world.

From a climate and clean energy perspective, it is essential that we keep existing reactors online as long as possible. But slow demand growth in developed world markets makes ten billion dollar, sixty-year investments in future electricity demand a poor bet for utilities, investors, and ratepayers."

A radical break

The four Third Way / Breakthrough Institute authors conclude that

> "a radical break from the present light-water regime … will be necessary to revive the nuclear industry".

Exactly what that means, the authors said, would be the subject of a follow-up article.

So readers were left hanging – will nuclear power be saved by failed fast-reactor technology, or failed high-temperature gas-cooled reactors including failed pebble-bed reactors, or by thorium pipe-dreams or fusion pipe-dreams or molten salt reactor pipe-dreams or small modular reactor pipe-dreams? Perhaps we've been too quick to write off cold fusion?

The answers came in a follow-up article on February 28. The four authors want a thousand flowers to bloom, a bottom-up R&D-led nuclear recovery as opposed to top-down, state-led innovation.

They don't just want a new reactor type (or types), they have much greater ambitions for innovation in

> "nuclear technology, business models, and the underlying structure of the sector" and they note that "a radical break from the light water regime that would enable this sort of innovation is not a small undertaking and will require a major reorganization of the nuclear sector."

To the extent that the four authors want to tear down the existing nuclear industry and replace it with a new one, they share some common ground with nuclear critics who want to tear down the existing nuclear industry and not replace it with a new one.

Shellenberger also shares some common ground with nuclear critics: he thinks the UK should scrap all existing plans for new reactors and "start from a blank piece of paper". But nuclear critics think the UK should scrap all existing plans for new reactors and not start from a blank piece of paper.

Small is beautiful?

The four Third Way / Breakthrough Institute authors argue that nuclear power must become substantially cheaper – thus ruling out large conventional reactors

> "operated at high atmospheric pressures, requiring enormous containment structures, multiply redundant back-up cooling systems, and water cooling towers and ponds, which account for much of the cost associated with building light-water reactors."

Substantial cost reductions will not be possible

> "so long as nuclear reactors must be constructed on site one gigawatt at a time. … At 10 MW or 100 MW, by contrast, there is ample opportunity for learning by doing and economies of multiples for several reactor classes and designs, even in the absence of rapid demand growth or geopolitical imperatives."

Other than their promotion of small reactors and their rejection of large ones, the four authors are non-specific about their preferred reactor types. Any number of small-reactor concepts have been proposed.

Small modular reactors (SMRs) have been the subject of much discussion and even more hype. The bottom line is that there isn't the slightest chance that they will fulfil the ambition of making nuclear power "substantially cheaper" unless and until a manufacturing supply chain is established at vast expense.

And even then, it's doubtful whether the power would be cheaper and highly unlikely that it would be substantially cheaper. After all, economics has driven the long-term drift towards larger reactors.

As things stand, no country, company or utility has any intention of betting billions on building an SMR supply chain. The prevailing scepticism is evident in a February 2017 Lloyd's Register report based on "insights and opinions of leaders across the sector" and the views of almost 600 professionals and experts from utilities, distributors, operators and equipment manufacturers.

The Lloyd's Register report states that the potential contribution of SMRs

> "is unclear at this stage, although its impact will most likely apply to smaller grids and isolated markets."

Respondents predicted that SMRs have a

> "low likelihood of eventual take-up, and will have a minimal impact when they do arrive".

The Third Way / Breakthrough Institute authors are promoting small reactors because of the spectacular failure of a number of large reactor projects, but that's hardly a recipe for success. An analysis of SMRs in the Bulletin of the Atomic Scientists sums up the problems:

> "Without a clear-cut case for their advantages, it seems that small nuclear modular reactors are a solution looking for a problem. Of course in the world of digital innovation, this kind of upside-down relationship between solution and problem is pretty normal. Smart phones, Twitter, and high-definition television all began as solutions looking for problems.
>
> "In the realm of nuclear technology, however, the enormous expense required to launch a new model as well as the built-in dangers of nuclear fission require a more straightforward relationship between problem and solution. Small modular nuclear reactors may be attractive, but they will not, in themselves, offer satisfactory solutions to the most pressing problems of nuclear energy: high cost, safety, and weapons proliferation."

Small or large reactors, consolidation or innovation, Generation 2/3/4 reactors … it's not clear that the nuclear industry will be able to recover – however it responds to its current crisis.

Dr Jim Green is the national nuclear campaigner with Friends of the Earth Australia and editor of the Nuclear Monitor newsletter, where a longer version of this article was originally published.

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