KACHAN
& Co.

Emerging Nuclear Innovations

Picking global winners in a race to reinvent nuclear energy

Japan's close call notwithstanding, nuclear will remain an important baseload power source worldwide. And after decades of relative inactivity, companies in Asia, Europe, Canada and elsewhere are poised to reinvigorate the industry with innovations aimed at overcoming the historical objections to big, fission-based nuclear power. Which companies are best positioned to open a new nuclear chapter, and why?

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Cover: India's fast breeder nuclear reactor core being lowered into safety vessel. Source: Defence Forum of India.

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Executive Summary

Nuclear power today provides 14% of the world's electricity.[1]

Nuclear power will continue to play an important baseload power role, but it needs to change

It will continue to play an important and probably growing role in furnishing power and reducing the world's roughly 70% reliance on price volatile and CO_2-emitting fossil fuels. "Green" energy sources like wind and solar will also expand their share but they will not be able to supply the baseload power provided by nuclear.

But for nuclear to gain significant share, it must change. There has never been a better time for mavericks to come forward with safer, better and less costly ways to split atoms or, in the case of the elusive but reachable notion of fusion, to meld them together.

Despite last March's Fukushima nuclear meltdown in Japan, the World Nuclear Association believes that in the 33 countries that currently operate nuclear reactors, capacity will increase 52-200%, to between 559 and 1,087 gigawatts in 2030 (up from 367 gigawatts today).[2] Among countries that don't already use nuclear power, those with plans to do so could add another 30-123 gigawatts, and new potential entrants could increase that by yet another 13-140 gigawatts.[3]

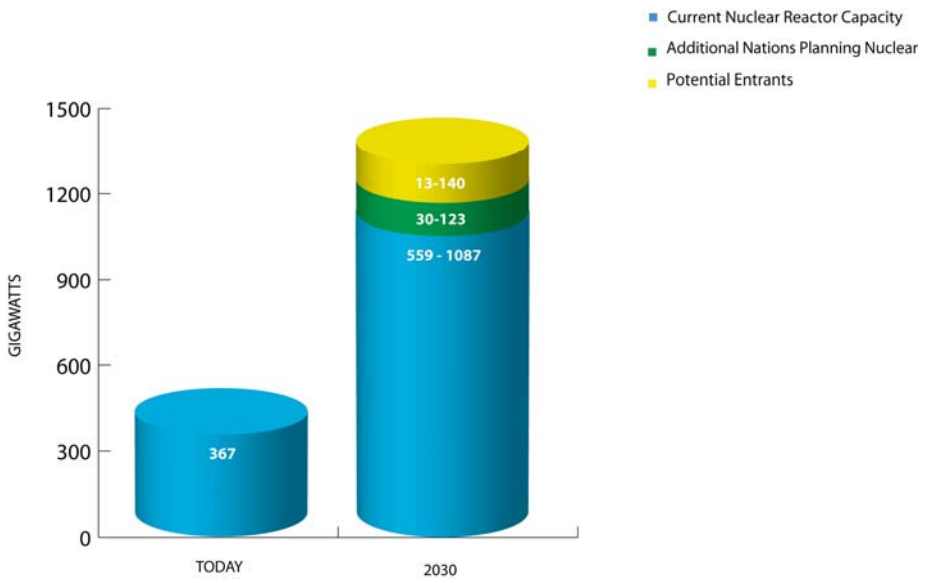

Figure 1: Worldwide nuclear generation capacity could grow significantly from current levels by 2030. Source: World Nuclear Association.

Most of that growth would come from already planned construction of conventional nuclear reactors. The wide range of WNA scenarios assumes different possible levels of government policy support and varying economic factors such as the price of fossil fuel. The higher side of the outlooks assumes a strong level of government support and assumes that fossil fuels will become less competitive.

But in the context of the anti-nuclear backlash following the events at Fukushima, even the low end of the WNA's outlook is surprisingly robust.

Citing Fukushima, two other energy bodies, the International Atomic Energy Agency (IAEA) and the International Energy Agency (IEA) recently tempered their nuclear

[1] World Nuclear Association (WNA) http://world-nuclear.org/info/inf01.html

[2] WNA, http://www.world-nuclear.org/outlook/nuclear_century_outlook.html

[3] Ibid

outlooks. The IAEA cut its low growth projection by 8%, to 501 gigawatts in 2030, and lowered its high growth projection by 7% to 746 gigawatts.[4] In its 2011 Energy Outlook, the IEA pointed out that Fukushima has "increased uncertainty" in the industry. Although it sees a likely scenario in which nuclear's share of the world's energy supply will grow, it also issued a cautionary projection in which the nuclear capacity could shrink by 15% by 2035.[5]

For the industry to continue to grow significantly beyond 2030, it will have to move away from conventional reactor designs of the type that blew up in Japan. As Fukushima demonstrated, nuclear power needs safety improvements. In a back-to-the-future play, the industry will adopt technologies first championed decades ago, we predict.

The fission design on which the industry settled 50 years ago was a VHS victory over superior Betamax alternatives

While most of the world's 432 nuclear reactors split atoms without a hitch, Fukushima illustrated that things can go wrong—and when they go wrong, they go very wrong. It reminded us that the fission design on which the industry settled 50-some years ago—the large water-cooled reactor that burns uranium—was by today's standards a poor choice. It was a VHS victory over several superior Betamax alternatives.

Compared to other reactor schemes that are now poised for a revival, today's production fission design has serious disadvantages.

- It produces a weapons-grade waste (plutonium) that requires careful and expensive storage and safeguarding.
- When improperly maintained and sited (as at Fukushima), a conventional reactor can melt down and release dangerous radioactive material. The cores of three reactors melted down at Fukushima after a tsunami knocked out the power supply that drove their cooling systems.[6] The combination of externally driven cooling in a zone exposed to tsunamis was devastating.
- The waste and radioactivity make the conventional reactor a potential terrorist target.
- Conventional reactors are inefficient at converting fuel to energy, adding significant cost.

As undesirable as plutonium waste is today, it was in demand during the atomic weapons buildup of the Cold War, helping the water-cooled uranium reactor win the day in the 1960s. The Cold War ended some time ago, but not before an entire industry and supply chain grew up around hundreds of such reactors. The entrenched interests of this industry have helped suppress better alternatives. That will change.

The meltdown of the Fukushima nuclear reactor in Japan last March demonstrated the need for safer nuclear power. In fairness, the nuclear industry has a remarkably good safety record and has caused far fewer deaths than the fossil fuel industry.[7] But the potential for disaster is significant.

The Fukushima accident polarized the public's nuclear sentiment. Some countries—most notably Germany—have since abandoned nuclear power. That's the side of the story that makes headlines.

Quietly though, other countries, especially China, are marching steadily along a nuclear path paved by radically different, safer, and less expensive reactor technologies than

[4] International Atomic Energy Agency. http://www.iaea.org/newscenter/news/2011/nuclgrowth.html

[5] International Energy Agency. http://www.worldenergyoutlook.org/docs/weo2011/key_graphs.pdf

[6] WNA. http://www.world-nuclear.org/info/fukushima_accident_inf129.html

[7] International Energy Agency. http://www.ieahydro.org/reports/ST3-020613b.pdf

those operating today. In the United States, President Obama's Blue Ribbon Commission on America's Nuclear Future draft report in late July welcomed near-term improvements to conventional reactors, but pointed out that the longer-term hope lies in "'game changing' innovations that offer potentially large advantages over current technologies and systems." [8]

This report looks at the technologies that will alter nuclear power for the better. Almost all of these ideas date back to the 1950s and '60s, when for reasons including military stockpiling, the water-cooled uranium-fuel reactor prevailed. The incoming technologies include a uranium replacement called thorium, as well as a new idea for cladding and housing uranium that boosts its efficiency. We look at reactor designs including molten salt, pebble bed, fast neutron, gas-cooled and, yes, fusion. We also note that small "modular" reactors will secure a place, especially as users like the U.S. military look for off-grid power sources, and as industrial users look for new sources of process heat.

Disruptive nuclear innovators will unseat Old Nuclear. This report aims to illuminate who is poised to win, and when.

The back-to-the-future nuclear movement faces a tough fight against the status quo of large nuclear companies like Areva, Westinghouse, and GE Hitachi Nuclear Energy (GEH). But the industry is at an inflection point. Just as Skype and Google upended the traditional telecom, media and technology giants, so, too, will the nuclear innovators unseat Old Nuclear. Disruptive forces eventually win the day, if they have merit. Our report shines a light on some of those with the most potential.

Methodology & bibliography

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[8] U.S. President's Blue Ribbon Commission on America's Nuclear Future http://brc.gov/sites/default/files/documents/brc_draft_report_29jul2011_0.pdf, pages xi and xii.

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