James Hansen's Generation IV nuclear fallacies and fantasies

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NM849.4670 The two young co-founders of nuclear engineering start-up Transatomic Power were embarrassed earlier this year when their claims about their molten salt reactor design were debunked, forcing some major retractions.[1]

The claims of MIT nuclear engineering graduate students – Leslie Dewan and Mark Massie – were trumpeted in MIT's *Technology Review* under the headline, 'What if we could build a nuclear reactor that costs half as much, consumes nuclear waste, and will never melt down?'[2]

The *Technology Review* puff-piece said Dewan "introduced new materials and a new shape that allowed her to increase power output by 30 times. As a result, the reactor is now so compact that a version large enough for a power plant can be built in a factory and shipped by rail to a plant site, which is potentially cheaper than the current practice of building nuclear reactors on site. The reactor also makes more efficient use of the energy in nuclear fuel. It can consume about one ton of nuclear waste a year, leaving just four kilograms behind. Dewan's name for the technology: the Waste-Annihilating Molten-Salt Reactor."[2]

A February 2017 article in MIT's *Technology Review* – this one far more critical – said: "Those lofty claims helped it raise millions in venture capital, secure a series of glowing media profiles (including in this publication), and draw a rock-star lineup of technical advisors."[1]

MIT physics professor Kord Smith debunked a number of Transatomic's key claims. Smith says he asked Transatomic to run a test which, he says, confirmed that "their claims were completely untrue."[1]

Transatomic's claim that the 'Waste-Annihilating Molten-Salt Reactor' could "generate up to 75 times more electricity per ton of mined uranium than a light-water reactor" was severely downgraded to "more than twice."[1] And the company abandoned its waste-to-fuel claims and now says that a reactor based on the current design would not use waste as fuel and thus would "not reduce existing stockpiles of spent nuclear fuel".[1]

Hansen's Generation IV propaganda

Kennedy Maize wrote about Transatomic's troubles in *Power Magazine*: "[T]his was another case of technology hubris, an all-to-common malady in energy, where hyperbolic claims are frequent and technology journalists all too credulous."[3] Pro-nuclear commentator Dan Yurman said that "other start-ups with audacious claims are likely to receive similar levels of scrutiny" and that it "may have the effect of putting other nuclear energy entrepreneurs on notice that they too may get the same enhanced levels of analysis of their claims."[4]

Well, yes, others making false claims about Generation IV reactor concepts might receive similar levels of scrutiny ... or they might not. Arguably the greatest sin of the Transatomic founders was not that they inadvertently spread misinformation, but that they are young, and in Dewan's case, female. Aging men seem to have a free pass to peddle as much misinformation as they like without the public shaming that the Transatomic founders have been subjected to. A case in point is climate scientist James Hansen. We've repeatedly drawn attention to Hansen's nuclear misinformation in *Nuclear Monitor*[5-9] – but you'd struggle to find any critical commentary outside the environmental and anti-nuclear literature.

Hansen states that a total requirement of 115 new reactor start-ups per year to 2050 would be required to replace fossil fuel electricity generation – a total of about 4,000 reactors.[10] Let's assume that Generation IV reactors do the heavy lifting, and let's generously assume that mass production of Generation IV reactors begins in 2030. That would necessitate about 200 reactor start-ups per year from 2030 to 2050 – or four every week. Good luck with that.

Moreover, the assumption that mass production of Generation IV reactors might begin in or around 2030 is unrealistic. A report by the French Institute for Radiological Protection and Nuclear Safety − a government authority under the Ministries of Defense, the Environment, Industry, Research, and Health − states: "There is still much R&D to be done to develop the Generation IV nuclear reactors, as well as for the fuel cycle and the associated waste management which depends on the system chosen."[11]

Likewise, a US Government Accountability Office report on the status of small modular reactors (SMRs) and other 'advanced' reactor concepts in the US concluded: "Both light water SMRs and advanced reactors face additional challenges related to the time, cost, and uncertainty associated with developing, certifying or licensing, and deploying new reactor technology, with advanced reactor designs generally facing greater challenges than light water SMR designs. It is a multi-decade process, with costs up to $1 billion to $2 billion, to design and certify or license the reactor design, and there is an additional construction cost of several billion dollars more per power plant."[12]

An analysis recently published in the peer-reviewed literature found that the US government has wasted billions of dollars on Generation IV R&D with little to show for it.[13] Lead researcher Dr Ahmed Abdulla, from the University of California, said that "despite repeated commitments to non-light water reactors, and substantial investments ... (more than $2 billion of public money), no such design is remotely ready for deployment today."[14]

Weapons

In a nutshell, Hansen and other propagandists claim that some Generation IV reactors are a triple threat: they can convert weapons-usable (fissile) material and long-lived nuclear waste into low-carbon electricity. Let's take the weapons and waste issues in turn.

Hansen says Generation IV reactors can be made "more resistant to weapons proliferation than today's reactors"[15] and "modern nuclear technology can reduce proliferation risks".[16] But *are* new reactors being made more resistant to weapons proliferation and are they reducing proliferation risks? In a word: No. Fast neutron reactors have been used for weapons production in the past (e.g. by France[17]) and will likely be used for weapons production in future (e.g. by India).

India plans to produce weapons-grade plutonium in fast breeder reactors for use as driver fuel in thorium reactors.[18] Compared to conventional uranium reactors, India's plan is far worse on both proliferation and security grounds. To make matters worse, India refuses to place its fast breeder / thorium program under IAEA safeguards.[19]

Hansen claims that thorium-based fuel cycles are "inherently proliferation-resistant".[20] That's garbage – thorium has been used to produce fissile material (uranium-233) for nuclear weapons tests.[21] Again, India's plans provide a striking real-world refutation of Hansen's dangerous misinformation.

Hansen states that if "designed properly", fast neutron reactors would generate "nothing suitable for weapons".[20] What does that even mean? Are we meant to ignore actual and potential links between Generation IV nuclear technology and WMD proliferation on the grounds that the reactors weren't built "properly"? And if we take Hansen's statement literally, no reactors produce material suitable for weapons – the fissile material must always be separated from irradiated materials – in which case all reactors can be said to be "designed properly". Hooray.

Hansen claims that integral fast reactors (IFR) – a non-existent variant of fast neutron reactors – "could be inherently free from the risk of proliferation".[22] That's another dangerous falsehood.[23] Dr George Stanford, who worked on an IFR R&D program in the US, notes that proliferators "could do [with IFRs] what they could do with any other reactor − operate it on a special cycle to produce good quality weapons material."[24]

Hansen acknowledges that "nuclear does pose unique safety and proliferation concerns that must be addressed with strong and binding international standards and safeguards."[10] There's no doubting that the safeguards systems needs strengthening.[25] In articles and speeches during his tenure as the Director General of the IAEA from 1997–2009, Dr Mohamed ElBaradei said that the Agency's basic rights of inspection are "fairly limited", that the safeguards system suffers from "vulnerabilities" and "clearly needs reinforcement", that efforts to improve the system were "half-hearted", and that the safeguards system operated on a "shoestring budget ... comparable to that of a local police department".

Hansen says he was converted to the cause of Generation IV nuclear technology by Tom Blees, whose 2008 book 'Prescription for the Planet' argues the case for IFRs.[26] But Hansen evidently missed those sections of the book where Blees argues for radically strengthened safeguards including the creation of an international strike-force on full standby to attend promptly to any detected attempts to misuse or to divert nuclear materials. Blees also argues that "privatized nuclear power should be outlawed worldwide" and that nuclear power must either be internationalized or banned to deal with the "shadowy threat of nuclear proliferation".[26]

So what is James Hansen doing about the WMD proliferation problem and the demonstrably inadequate nuclear safeguards system? This is one of the great ironies of Hansen's nuclear advocacy – he does absolutely nothing other than making demonstrably false claims about the potential of Generation IV concepts to solve the problems, and repeatedly slagging off at organizations with a strong track record of campaigning for improvements to the safeguards system.[27]

Waste

Hansen claims that "modern nuclear technology can ... solve the waste disposal problem by burning current waste and using fuel more efficiently."[16] He elaborates: "Nuclear "waste": it is not waste, it is fuel for 4th generation reactors! Current ('slow') nuclear reactors are lightwater reactors that 'burn' less than 1% of the energy in the original uranium ore, leaving a waste pile that is radioactive for more than 10,000 years. The 4th generation reactors can 'burn' this waste, as well as excess nuclear weapons material, leaving a much smaller waste pile with radioactive half-life measured in decades rather than millennia, thus minimizing the nuclear waste problem. The economic value of current nuclear waste, if used as a fuel for 4th generation reactors, is trillions of dollars."[28]

But even if IFRs – Hansen's favored Generation IV concept – worked as hoped, they would still leave residual actinides, and long-lived fission products, and long-lived intermediate-level waste in the form of reactor and reprocessing components ... all of it requiring deep geological disposal. UC Berkeley nuclear engineer Prof. Per Peterson notes in an article published by the pro-nuclear Breakthrough Institute: "Even integral fast reactors (IFRs), which recycle most of their waste, leave behind materials that have been contaminated by transuranic elements and so cannot avoid the need to develop deep geologic disposal."[29]

So if IFRs don't obviate the need for deep geological repositories, what problem do they solve? They don't solve the WMD proliferation problem associated with nuclear power. They would make more efficient use of finite uranium ... but uranium is plentiful.

In theory, IFRs would gobble up nuclear waste and convert it into low-carbon electricity. In practice, the IFR R&D program in Idaho has left a legacy of troublesome waste. This saga is detailed in a recent article[31] and a longer report[32] by the Union of Concerned Scientists' senior scientist Ed Lyman (see the following article in this issue of *Nuclear Monitor*). Lyman states that

The EBR-II reactor in Idaho – the prototype 'integral fast reactor'.

attempts to treat IFR spent fuel with pyroprocessing have not made management and disposal of the spent fuel simpler and safer, they have "created an even bigger mess".[31]

Japan is about to get first-hand experience of the waste legacy associated with Generation IV reactors in light of the decision to decommission the Monju fast spectrum reactor. Decommissioning Monju has a hefty price-tag – far more than for conventional light-water reactors. According to a 2012 estimate by the Japan Atomic Energy Agency, decommissioning Monju will cost an estimated ¥300 billion (US$2.74bn; €2.33bn).[30] That estimate includes ¥20 billion to remove spent fuel from the reactor – but no allowance is made for the cost of disposing of the spent fuel, and in any case Japan has no deep geological repository to dispose of the waste.

Generation IV economics

Hansen claimed in 2012 that IFRs could generate electricity "at a cost per kW less than coal."[33,34] He was closer to the mark in 2008 when he said of IFRs: "I do not have the expertise or insight to evaluate the cost and technology readiness estimates" of IFR advocate Tom Blees and the "overwhelming impression that I get ... is that Blees is a great optimist."[35]

The US Government Accountability Office's 2015 report noted that technical challenges facing SMRs and advanced reactors may result in higher-cost reactors than anticipated, making them less competitive with large light-water reactors or power plants using other fuels.[36]

A 2015 pro-nuclear puff-piece by the International Energy Agency (IEA) and the OECD's Nuclear Energy Agency (NEA) arrived at the disingenuous conclusion that nuclear power is "an attractive low-carbon technology in the absence of cost overruns and with low financing costs".[37] But the IEA/NEA report made no effort to spin the economics of Generation IV nuclear concepts, stating that "generation IV technologies aim to be at least as competitive as generation III technologies ... though the additional complexity of these designs, the need to develop a specific supply chain for these reactors and the development of the associated fuel cycles will make this a challenging task."[37]

The late Michael Mariotte commented on the IEA/NEA report: "So, at best the Generation IV reactors are aiming to be as competitive as the current − and economically failing − Generation III reactors. And even realizing that inadequate goal will be "challenging." The report might as well have recommended to Generation IV developers not to bother."[38]

Of course, Hansen isn't the only person peddling misinformation about Generation IV economics. A recent report states that the "cost estimates from some advanced reactor companies – if accurate – suggest that these technologies could revolutionize the way we think about the cost, availability, and environmental consequences of energy generation."[39] To estimate the costs of Generation IV nuclear concepts, the researchers simply asked companies involved in R&D projects to supply the information!

The researchers did at least have the decency to qualify their findings: "There is inherent and significant uncertainty in projecting NOAK [nth-of-a-kind] costs from a group of companies that have not yet built a single commercial-scale demonstration reactor, let alone a first commercial plant. Without a commercial-scale plant as a reference, it is difficult to reliably estimate the costs of building out the manufacturing capacity needed to achieve the NOAK costs being reported; many questions still remain unanswered – what scale of investments will be needed to launch the supply chain; what type of capacity building will be needed for the supply chain, and so forth."[39]

Hansen has doubled down on his nuclear advocacy, undeterred by the Fukushima disaster; undeterred by the economic disasters of nuclear power in the US, the UK, France, Finland and elsewhere; and undeterred by the spectacular growth of renewables and the spectacular cost reductions. He needs to take his own advice. Peter Bradford, adjunct professor at Vermont Law School and a former US Nuclear Regulatory Commission member, said in response to a 2015 letter[10] co-authored by Hansen:[40]

"The Hansen letter contains these remarkably unself-aware sentences:

'To solve the climate problem, policy must be based on facts and not on prejudice.'

'The climate issue is too important for us to delude ourselves with wishful thinking.'

'The future of our planet and our descendants depends on basing decisions on facts, and letting go of long held biases when it comes to nuclear power.'

Amen, brother."

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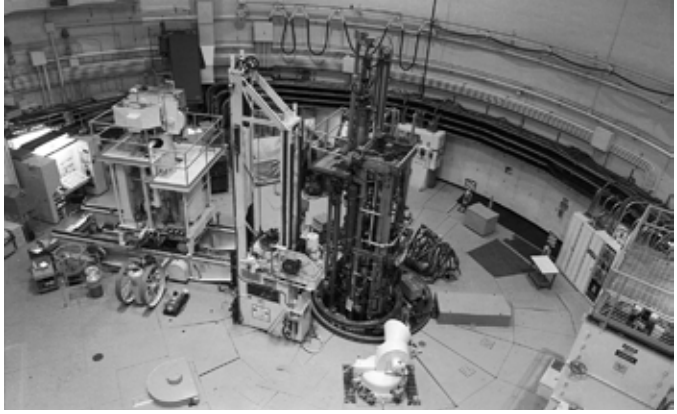
Pyroprocessing: the integral fast reactor waste fiasco



NM849.4671 In theory, integral fast reactors (IFRs) would gobble up nuclear waste and convert it into low-carbon electricity. In practice, the IFR R&D program in Idaho has left a legacy of troublesome waste. This saga is detailed in a recent article[1] and a longer report[2] by the Union of Concerned Scientists' senior scientist Ed Lyman.

Lyman notes that the IFR concept "has attracted numerous staunch advocates" but their "interest has been driven largely by idealized studies on paper and not by facts derived from actual experience."[1] He discusses the IFR prototype built at Idaho – the Experimental Breeder Reactor-II (EBR-II), which ceased operation in 1994 – and subsequent efforts by the Department of Energy (DOE) to treat 26 metric tons of "sodium-bonded" metallic spent fuel from the EBR-II reactor with pyroprocessing, ostensibly to convert the waste to forms that would be safer for disposal in a geological repository. A secondary goal was to demonstrate the viability of pyroprocessing – but the program has instead demonstrated the serious shortcomings of this technology.

Lyman writes:[1]

"Pyroprocessing is a form of spent fuel reprocessing that dissolves metal-based spent fuel in a molten salt bath (as distinguished from conventional reprocessing, which dissolves spent fuel in water-based acid solutions). Understandably, given all its problems, DOE has been reluctant to release public information on this program, which has largely operated under the radar since 2000.

"The FOIA [Freedom of Information Act] documents we obtained have revealed yet another DOE tale of vast sums of public money being wasted on an unproven technology that has fallen far short of the unrealistic projections that DOE used to sell the project to Congress, the state of Idaho and the public. However, it is not too late to pull the plug on this program, and potentially save taxpayers hundreds of millions of dollars. …

"Pyroprocessing was billed as a simpler, cheaper and more compact alternative to the conventional aqueous reprocessing plants that have been operated in France, the United Kingdom, Japan and other countries.

"Although DOE shut down the EBR-II in 1994 (the reactor part of the IFR program), it allowed work at the pyroprocessing facility to proceed. It justified this by asserting that the leftover spent fuel from the EBR-II could not be directly disposed of in the planned Yucca Mountain repository because of the potential safety issues associated with presence of metallic sodium in the spent fuel elements, which was used to "bond" the fuel to the metallic cladding that encased it. (Metallic sodium reacts violently with water and air.)

"Pyroprocessing would separate the sodium from other spent fuel constituents and neutralize it. DOE decided in 2000 to use pyroprocessing for the entire inventory of leftover EBR-II spent fuel – both "driver" and "blanket" fuel – even though it acknowledged that there were simpler methods to remove the sodium from the lightly irradiated blanket fuel, which constituted nearly 90% of the inventory.

"However, as the FOIA documents reveal in detail, the pyroprocessing technology simply has not worked well and has fallen far short of initial predictions. Although DOE initially claimed that the entire inventory would be processed by 2007, as of the end of Fiscal Year 2016, only about 15% of the roughly 26 metric tons of spent fuel had been processed. Over $210 million has been spent, at an average cost of over $60,000 per kilogram of fuel treated. At this rate, it will take until the end of the century to complete pyroprocessing of the entire inventory, at an additional cost of over $1 billion.

"But even that assumes, unrealistically, that the equipment will continue to be usable for this extended time period. Moreover, there is a significant fraction of spent fuel in storage that has degraded and may not be a candidate for pyroprocessing in any event. …

"What exactly is the pyroprocessing of this fuel accomplishing? Instead of making management and disposal of the spent fuel simpler and safer, it has created an even bigger mess. …

"[P]yroprocessing has taken one potentially difficult form of nuclear waste and converted it into multiple challenging forms of nuclear waste. DOE has spent hundreds of millions of dollars only to magnify, rather than simplify, the waste problem. This is especially outrageous in light of other FOIA documents that indicate that DOE never definitively concluded that the sodium-bonded spent fuel was unsafe to directly dispose of in the first place. But it insisted on pursuing pyroprocessing rather than conducting studies that might have shown it was unnecessary.

"Everyone with an interest in pyroprocessing should reassess their views given the real-world problems experienced in implementing the technology over the last 20 years at INL. They should also note that the variant of the process being used to treat the EBR-II spent fuel is less complex than the process that would be needed to extract plutonium and other actinides to produce fresh fuel for fast reactors. In other words, the technology is a long way from being demonstrated as a practical approach for electricity production."

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