

NUCLEAR MONITOR

September 24, 2018 | Issue #866

A PUBLICATION OF WORLD INFORMATION SERVICE ON ENERGY (WISE)
AND THE NUCLEAR INFORMATION & RESOURCE SERVICE (NIRS)

WISE / NIRS Nuclear Monitor

The World Information Service on Energy (WISE) was founded in 1978 and is based in the Netherlands. The Nuclear Information & Resource Service (NIRS) was founded in the same year and is based in the U.S. WISE and NIRS joined forces in the year 2000 to produce Nuclear Monitor.

Nuclear Monitor is published in English, 20 times a year, in electronic (PDF) format only. Back issues are published on the WISE website two months after being sent to subscribers (www.wiseinternational.org/nuclear-monitor).

SUBSCRIPTIONS (20 x PDF)

NGOs / individuals 60 Euros

Institutions / Industry 225 Euros

US and Canada: Contact NIRS for details (nirs@nirs.org)

All other countries:
Subscribe via the WISE website
www.wiseinternational.org

ISSN: 2542-5439

CONTACTS

WISE

info@wiseinternational.org
www.wiseinternational.org

NIRS

nirs@nirs.org
www.nirs.org

Nuclear Monitor

monitor@wiseinternational.org
www.wiseinternational.org/nuclear-monitor

Monitored this issue:

New IAEA report sees “possible shrinking role” for nuclear power 2

The International Atomic Energy Agency has released its latest projections for the future of nuclear power. For the first time in many years – perhaps ever – the IAEA is up-front about the grim prospects for nuclear power.

Generation IV nuclear waste claims debunked 3

Lindsay Krall and former US NRC chair Allison Macfarlane have written an important article in the Bulletin of the Atomic Scientists. They argue that Generation IV developers and advocates “are receiving substantial funding on the pretense that extraordinary waste management benefits can be reaped through adoption of these technologies” yet “molten salt reactors and sodium-cooled fast reactors – due to the unusual chemical compositions of their fuels – will actually exacerbate spent fuel storage and disposal issues.”

Film review: ‘The New Fire’ and the old Gen IV rhetoric 5

We review The New Fire, a pro-nuclear propaganda film similar in some respects to the 2013 film Pandora’s Promise. The film’s message is that young entrepreneurs may save the planet and its inhabitants with their Generation IV reactor projects.

The Age of Renewables is here: renewables make the grade in price, performance and reliability 9

Karel Beckman, editor of Energy Post Weekly, summarizes a new Deloitte Global report. According to the report, “three key enablers – price and performance parity, grid integration, and technology – allow solar and wind power to compete with conventional sources on price, while matching their performance.”

Nuclear News 11

- US: Could the last remaining nuclear power project fall over?
- Fukushima clean-up workers, including homeless, at grave risk of exploitation, say UN experts
- 2018 NTI Index: Nuclear security progress in jeopardy

New IAEA report sees “possible shrinking role” for nuclear power

NM866.4749

The International Atomic Energy Agency (IAEA) has released its latest projections for the future of nuclear power.¹ For the first time in many years, perhaps ever, the IAEA is up-front about the grim prospects for nuclear power. The article promoting the new report is titled: ‘New IAEA Energy Projections See Possible Shrinking Role for Nuclear Power’.²

Comparable IAEA reports in September 2016 and August 2017 were headlined ‘IAEA Sees Global Nuclear Power Capacity Growing Through 2030’³ and ‘Long-Term Potential of Nuclear Power Remains High’.⁴

The recent IAEA article states:²

“Nuclear power’s electricity generating capacity risks shrinking in the coming decades as ageing reactors are retired and the industry struggles with reduced competitiveness ...

“Over the short term, the low price of natural gas, the impact of renewable energy sources on electricity prices, and national nuclear policies in several countries following the accident at Japan’s Fukushima Daiichi Nuclear Power Plant in 2011 are expected to continue weighing on nuclear power’s growth prospects, according to the report. In addition, the nuclear power industry faces increased construction times and costs due to heightened safety requirements, challenges in deploying advanced technologies and other factors.”

The IAEA report presents low and high projections. The high projection is best ignored: the IAEA has previously assessed its own performance and found that even its low projections tend to be too high!^{5,6}

The IAEA report notes that in its latest low projection, nuclear generating capacity falls by more than 10% from 392 gigawatts (GW) at the end of 2017 to 352 GW in 2030. The high projection of 511 GW in 2030 is 45 GW less than that predicted by the IAEA just a year ago.

The IAEA has sharply reduced its low and high projections since the Fukushima disaster, so much so that its current high projection for 2030 is 35 GW lower than its 2010 low projection for 2030:

	2010 ⁷	2018 ¹	CHANGE 2010–18
Low estimate 2030 nuclear capacity (GW)	546	352	–36% –194 GW
High estimate 2030 nuclear capacity (GW)	803	511	–36% –292 GW
Actual nuclear capacity (including idled reactors) (GW)	375	400	+7%
Actual nuclear capacity (excluding idled reactors) (GW)	375	363 ⁸	–3%

According to the IAEA report, nuclear’s share of global electricity generation in 2017 remained at about 10.3% while the share of renewables (including hydropower) was 25.1%.¹ In the IAEA’s low projection, nuclear’s share will fall to 7.9% in 2030.¹

The IAEA report notes the high degree of uncertainty about reactor retirements: in its low projection, 139 GW of nuclear capacity is retired by 2030 compared to 55 GW in the high projection.

The average age of the reactor fleet has been steadily rising and reached 30 years in mid-2018 according to the latest World Nuclear Industry Status Report (WNISR).⁸

The WNISR doesn’t make projections about the future of nuclear power, but it includes calculations based on assumptions about reactor lifespans. WNISR-2018 notes that if one assumes a 40-year reactor lifespan (and ignoring 81 reactors already past that lifespan, and also ignoring 32 reactors in long-term outage), 216 reactors will enter the post-operational phase by 2030.⁸

WNISR-2018 states: “If all currently operating reactors were shut down at the end of a 40-year lifetime – with the exception of the 81 that are already operating for more than 40 years – by 2020 the number of operating units would be 12 below the total at the end of 2017, even if all reactors currently under active construction were completed, with the installed capacity declining by 2 GW. In the following decade to 2030, 190 units (168.5 GW) would have to be replaced – three and a half times the number of startups achieved over the past decade.”⁸

Here are the IAEA’s regional low projections:²

- Northern America: Nuclear capacity decreases by almost one-third by 2030.
- Latin America & the Caribbean: Increase by 2030 but nuclear’s role will remain small.
- Northern, Western and Southern Europe: Decrease by as much as 30%.
- Eastern Europe: Maintain current levels.
- Africa: Remain at current low levels.
- Western Asia: Significant increase.
- Southern Asia: Continued growth.
- Central and Eastern Asia: Significant increase.

References:

1. International Atomic Energy Agency, 'Energy, Electricity and Nuclear Power Estimates for the Period up to 2050: 2018 Edition', www-pub.iaea.org/books/IAEABooks/13412/Energy-Electricity-and-Nuclear-Power-Estimates-for-the-Period-up-to-2050
2. IAEA, 10 Sept 2018, 'New IAEA Energy Projections See Possible Shrinking Role for Nuclear Power', www.iaea.org/newscenter/pressreleases/new-iaea-energy-projections-see-possible-shrinking-role-for-nuclear-power
3. IAEA, 23 Sept 2016, 'IAEA Sees Global Nuclear Power Capacity Growing Through 2030', www.iaea.org/newscenter/pressreleases/iaea-sees-global-nuclear-power-capacity-growing-through-2030
4. Irena Chatzis / IAEA, 7 Aug 2017, 'Long-Term Potential of Nuclear Power Remains High: IAEA Report', www.iaea.org/newscenter/news/long-term-potential-of-nuclear-power-remains-high-iaea-report
5. IAEA, 2007, Energy, Electricity and Nuclear Power: Developments and Projections – 25 Years Past and Future', tables 33 and 34, p.56, www-pub.iaea.org/mtcd/publications/pdf/pub1304_web.pdf
6. Nuclear Monitor #811, 23 Sept 2015, 'Fanciful growth projections from the World Nuclear Association and the IAEA', www.wiseinternational.org/nuclear-monitor/811/fanciful-growth-projections-world-nuclear-association-and-iaea
7. IAEA series: 'Energy, Electricity and Nuclear Power Estimates', iaea.org
8. Mycle Schneider, Antony Froggatt et al., Sept 2018, 'The World Nuclear Industry Status Report 2018', www.worldnuclearreport.org/Nuclear-Power-Strategic-Asset-Liability-or-Increasingly-Irrelevant.html

Generation IV nuclear waste claims debunked

NM866.4750

Lindsay Krall and Allison Macfarlane have written an important article in the *Bulletin of the Atomic Scientists* debunking claims that certain Generation IV reactor concepts promise major advantages with respect to nuclear waste management. Krall is a post-doctoral fellow at the George Washington University. Macfarlane is a professor at the same university, a former chair of the US Nuclear Regulatory Commission from July 2012 to December 2014, and a member of the Blue Ribbon Commission on America's Nuclear Future from 2010 to 2012.

Krall and Macfarlane focus on molten salt reactors and sodium-cooled fast reactors, and draw on the experiences of the US Experimental Breeder Reactor II and the US Molten Salt Reactor Experiment.

The article abstract notes that Generation IV developers and advocates "are receiving substantial funding on the pretense that extraordinary waste management benefits can be reaped through adoption of these technologies" yet "molten salt reactors and sodium-cooled fast reactors – due to the unusual chemical compositions of their fuels – will actually exacerbate spent fuel storage and disposal issues."

Here is the concluding section of the article:

"The core propositions of non-traditional reactor proponents – improved economics, proliferation resistance, safety margins, and waste management – should be re-evaluated. The metrics used to support the waste management claims – i.e. reduced actinide mass and total radiotoxicity beyond 300 years – are insufficient to critically assess the short- and long-term safety, economics, and proliferation resistance of the proposed fuel cycles.

"Furthermore, the promised (albeit irrelevant) actinide reductions are only attainable given exceptional technological requirements, including commercial-scale spent fuel treatment, reprocessing, and conditioning facilities. These will create low- and intermediate-level waste streams destined for geologic disposal, in addition to the intrinsic high-level fission product waste that will also require conditioning and disposal.

"Before construction of non-traditional reactors begins, the economic implications of the back end of these non-traditional fuel cycles must be analyzed in detail; disposal costs may be unpalatable. The reprocessing/treatment and conditioning of the spent fuel will entail costs, as will storage and transportation of the chemically reactive fuels. These are in addition to the cost of managing high-activity operational wastes, e.g. those originating from molten salt reactor filter systems. Finally, decommissioning the reactors and processing their chemically reactive coolants represents a substantial undertaking and another source of non-traditional waste. ...

"Issues of spent fuel management (beyond temporary storage in cooling pools, aka "wet storage") fall outside the scope of the NRC's reactor design certification process, which is regularly denounced by nuclear advocates as narrowly applicable to light water reactor technology and insufficiently responsive to new reactor designs. Nevertheless, new reactor licensing is contingent on broader policies, including the Nuclear Waste Policy Act and the Continued Storage Rule. Those policies are based on the results of radionuclide dispersion models



described in environmental impact statements. But the fuel and barrier degradation mechanisms tested in these models were specific to oxide-based spent fuels, which are inert, compared to the compounds that non-traditional reactors will discharge.

“The Continued Storage Rule explicitly excludes most non-oxide fuels, including those from sodium-cooled fast reactors, from the environmental impact statement. Clearly, storage and disposal of non-oxide commercial fuels should require updated assessments and adjudication.

“Finally, treatment of spent fuels from non-traditional reactors, which by Energy Department precedent is only feasible through their respective (re)processing technologies, raises concerns over proliferation and fissile material diversion. Pyroprocessing and fluoride volatility-reductive extraction systems optimized for spent fuel treatment can – through minor changes to the chemical conditions – also extract plutonium (or uranium 233 bred from thorium). Separation from lethal fission products would eliminate the radiological barriers protecting the fuel from intruders seeking to obtain and purify fissile material. Accordingly, cost and risk assessments of predisposal spent fuel treatments must also account for proliferation safeguards.

“Radioactive waste cannot be “burned”; fission of actinides, the source of nuclear heat, inevitably generates fission products. Since some of these will be radiotoxic for thousands of years, these high-level wastes should be disposed of in stable waste forms and geologic repositories. But the waste estimates propagated by nuclear advocates account only for the bare mass of fission products, rather than that of the conditioned waste form and associated repository requirements.

“These estimates further assume that the efficiency of actinide fission will surge, but this actually relies on several rounds of recycling using immature reprocessing technologies. The low- and intermediate-level wastes that will be generated by these activities will also be destined for geologic disposal but have been neglected in the waste estimates. More important, reprocessing remains a security liability of dubious economic benefit, so the apparent need to adopt these technologies simply to prepare non-traditional spent fuels for storage and disposal is a major disadvantage relative to light water reactors. Theoretical burnups for fast and molten salt reactors are too low to justify the inflated back-end costs and risks, the latter of which may include a commercial path to proliferation.

“Reductions in spent fuel volume, longevity, and total radiotoxicity may be realized by breeding and burning fissile material in non-traditional reactors. But those relatively small reductions are of little value in repository planning, so utilization of these metrics is misleading to policy-makers and the general public. We urge policy-makers to critically assess non-traditional fuel cycles, including the feasibility of managing their unusual waste streams, any loopholes that could commit the American public to financing quasi-reprocessing operations, and the motivation to rapidly deploy these technologies. If decarbonization of the economy by 2050 is the end-goal, a more pragmatic path to success involves improvements to light water reactor technologies, adoption of Blue Ribbon Commission recommendations on spent fuel management, and strong incentives for commercially mature, carbon-free energy technologies.”

Lindsay Krall and Allison Macfarlane, 2018, ‘Burning waste or playing with fire? Waste management considerations for non-traditional reactors’, Bulletin of the Atomic Scientists, 74:5, pp.326-334, <https://tandfonline.com/doi/10.1080/00963402.2018.1507791>

Film review: 'The New Fire' and the old Gen IV rhetoric

Author: Jim Green – Nuclear Monitor editor

NM866.4751

The New Fire is a pro-nuclear propaganda film directed and produced by musician and film-maker David Schumacher. It's similar in some respects to the 2013 film *Pandora's Promise*.^{1,2} *The New Fire* premiere was held in October 2017 and it can be streamed online from 18 October 2018.

Promotional material claims that the film lacked "a supportive grant" (and celebrity endorsements and the backing of a major NGO) but the end-credits list numerous financial contributors: Berk Foundation, Isdell Foundation, Steven & Michele Kirsch Foundation, Rachel Pritzker, Roland Pritzker, Ray Rothrock, and Eric Uhrhane.

The film includes interviews with around 30 people (an overwhelming majority of them male) interspersed with footage of interviewees walking into buildings, and interviewees smiling. The musical underlay is a tedious drone – a disappointment given Schumacher's musical background. A highlight is hearing Eric Meyer – an opera singer turned pro-nuclear activist – bursting into song at various locations around the COP21 climate conference in Paris in December 2015, while he and his colleagues handed out free copies of the pro-nuclear book *Climate Gamble*.

Interviewees are mostly aging but the film's main message is that young entrepreneurs may save the planet and its inhabitants with their Generation IV reactor projects. The film's website states: "David Schumacher's film focuses on how the generation facing the most severe impact of climate change is fighting back with ingenuity and hope. *The New Fire* tells a provocative and startlingly positive story about a planet in crisis and the young heroes who are trying to save it."³

Schumacher writes (in the press kit): "These brilliant young people – some of the most gifted engineers of their generation, who in all likelihood could have cashed in for a fortune by doing something else – believe deeply that nuclear power could play a key role in saving the planet. And they are acting on that conviction. They did the research. They raised the money. They used cutting edge computer technology to perfect their designs. They are the new face of nuclear power, and to me, the newest and most unlikely climate heroes."

These climate heroes are contrasted with anti-nuclear environmentalists. One interviewee says that "people of our generation are the first ones that have the opportunity to look at nuclear power without all the emotional baggage that previous generations have felt." Another argues that anti-nuclear environmentalists are "very good, decent, smart people" but the "organizational DNA ...

that they have inherited is strongly anti-nuclear." Another argues that environmental organizations "have been using nuclear power as a whipping boy for decades to raise funds". Another interviewee attributes opposition to nuclear power to an "irrational fear of the unknown" (which surely poses a problem for the exotic Generation IV concepts promoted in the film) and another says that "once people sort of understand what's going on with nuclear, they are much more open to it".

The film trots out the usual anti-renewables tropes and falsehoods: 100% renewables is "just a fantasy", renewables can contribute up to 20% of power supply and the remainder must be baseload: fossil fuels or nuclear power.

In rural Senegal, solar power has brought many benefits but places like Senegalese capital Dakar, with a population of one million, need electricity whether the sun is shining or not. A Senegalese man interviewed in the film states: "Many places in Africa definitely need a low cost, reliable, carbon neutral power plant that provides electricity 24/7. Nuclear offers one of the best options we have to do that kind of baseload." The film doesn't explain how a 1,000 megawatt nuclear plant would fit into Senegal's electricity grid, which has a total installed capacity of 633MW.⁴ The 'microreactors' featured in *The New Fire* might help ... if they existed.

Accidents such as those at Fukushima and Chernobyl get in the news because they are "so unusual" according to interviewee Ken Caldeira. And they get in the news, he might have added, because of the estimated death tolls (in the thousands for Fukushima⁵, ranging to tens of thousands for Chernobyl⁶), the costs (around US\$700 billion for Chernobyl⁷, and US\$192 billion (and counting) for Fukushima⁸), the evacuation of 160,000 people after the Fukushima disaster and the permanent relocation of over 350,000 people after the Chernobyl disaster.⁹

"Most people understand that it's impossible for a nuclear power plant to literally explode in the sense of an atomic explosion", an interviewee states. And most people understand that chemical and steam explosions at Chernobyl and Fukushima spread radionuclides over vast distances. The interviewee wants to change the name of nuclear power plants to avoid any conflation between nuclear power and weapons. Evidently he didn't get the memo that the potential to use nuclear power plants (and related facilities) to produce weapons is fast becoming one of the industry's key marketing points.

Conspicuously absent from the film's list of interviewees is pro-nuclear lobbyist Michael Shellenberger. We've taken Shellenberger to task for his litany of falsehoods on nuclear and energy issues¹⁰ and his bizarre conversion into an advocate of worldwide nuclear weapons proliferation.¹¹ But a recent article by Shellenberger on Generation IV nuclear technology is informative and insightful – and directly at odds with the propaganda in *The New Fire*.¹²

So, let's compare the Generation IV commentary in *The New Fire* with that in Shellenberger's recent article.

Transatomic Power's molten salt reactor concept

The film spends most of its time promoting Generation IV reactor projects including Transatomic Power's molten salt reactor (MSR) concept.

Scott Nolan from venture capital firm Founders Fund says that Transatomic satisfies his four concerns about nuclear power: safety, waste, cost, proliferation. And he's right – Transatomic's MSRs are faultless on all four counts, because they don't exist. It's doubtful whether they would satisfy any of the four criteria if they did actually exist.

Shellenberger quotes Admiral Hyman Rickover, who played a leading role in the development of nuclear-powered and armed submarines and aircraft carriers in the US: "Any plant you haven't built yet is always more efficient than the one you have built. This is obvious. They are all efficient when you haven't done anything on them, in the talking stage. Then they are all efficient, they are all cheap. They are all easy to build, and none have any problems."

Shellenberger goes on to say:¹²

"The radical innovation fantasy rests upon design essentialism and reactor reductionism. We conflate the 2-D design with a 3-D design which we conflate with actual building plans which we conflate with a test reactor which we conflate with a full-sized power plant.

"These unconscious confluences blind us to the many, inevitable, and sometimes catastrophic "unknowns" that only become apparent through the building and operating of a real world plant. They can be small, like the need for a midget welder, or massive, like the manufacturing failures of the AP1000.

"Some of the biggest unknowns have to do with radically altering the existing nuclear workforce, supply chain, and regulations. Such wholesale transformations of the actually existing nuclear industry are, literally and figuratively, outside the frame of alternative designs.

"Everyone has a plan until they get punched in the face," a wise man once said. The debacles with the AP1000 and EPR are just the latest episodes of nuclear reactor designers getting punched in the face by reality."

Shellenberger comments on MSR technology:¹²

"New designs often solve one problem while creating new ones. For example, a test reactor at Oak Ridge National Laboratory used chemical salts with uranium fuel dissolved within, instead of water surrounding solid



uranium fuel. "The distinctive advantage of such a reactor was that it avoided the expensive process of fabricating fuel elements, moderator, control rods, and other high-precision core components," noted Hewlett and Holl.

"In the eyes of many nuclear scientists and engineers these advantages made the homogeneous reactor potentially the most promising of all types under study, but once again the experiment did not reveal how the tricky problems of handling a highly radioactive and corrosive fluid were to be resolved."

In *The New Fire*, Mark Massie from Transatomic promotes a "simpler approach that gives you safety through physics, and there's no way to break physics". True, you can't break physics, but highly radioactive and corrosive fluids in MSRs could break and rust pipes and other machinery.

Leslie Dewan from Transatomic trots out the silliest advantage attributed to MSRs: that they are meltdown-proof. Of course they are meltdown-proof – and not just in the sense that they don't exist. The fuel is liquid. You can't melt liquids. SMR liquid fuel is susceptible to dispersion in the event of steam explosions or chemical explosions or fire, perhaps more so than solid fuels.

Michael Short from MIT says in the film that over the next 2–3 years they should have preliminary answers as to whether the materials in Transatomic MSR are going to survive the problems of corrosion and radiation resistance. In other words, they are working on the problems – but there's no guarantee of progress let alone success.

Dewan claims that Transatomic took an earlier MSR design from Oak Ridge and “we were able to make it 20 times as power dense, much more compact, orders of magnitude cheaper, and so we are commercializing our design for a new type of reactor that can consume existing stockpiles of nuclear waste.”

Likewise, Jessica Lovering from the Breakthrough Institute says: “Waste is a concern for a lot of people. For a lot of people it's their first concern about nuclear power. But what's really amazing about it is that most of what we call nuclear waste could actually be used again for fuel. And if you use it again for fuel, you don't have to store it for tens of thousands of years. With these advanced reactors you can close the fuel cycle, you can start using up spent fuel, recycling it, turning it into new fuel over and over again.”

But in fact, prototype MSR and fast neutron reactors produce troublesome waste streams (even more so than conventional light-water reactors) and they don't obviate the need for deep geological repositories. A recent article in the *Bulletin of the Atomic Scientists* – co-authored by a former chair of the US Nuclear Regulatory Commission – states that “molten salt reactors and sodium-cooled fast reactors – due to the unusual chemical compositions of their fuels – will actually exacerbate spent fuel storage and disposal issues.”¹³ It also raises proliferation concerns about ‘integral fast reactor’ and MSR technology:

“Pyroprocessing and fluoride volatility-reductive extraction systems optimized for spent fuel treatment can – through minor changes to the chemical conditions – also extract plutonium (or uranium 233 bred from thorium).”

Near the end of the film, it states: “Transatomic encountered challenges with its original design, and is now moving forward with an updated reactor that uses uranium fuel.” Transatomic's claim that its ‘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” after calculation errors were discovered. And the company 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”.^{14,15}

So much for all the waste-to-fuel rhetoric scattered throughout *The New Fire*.

Michael Short from MIT claims MSR will cost a “couple of billion dollars” and Dewan claims they will be “orders of magnitude cheaper” than the Oak Ridge experimental MSR. In their imaginations, perhaps. Shellenberger notes that “in the popular media and among policymakers, there has remained a widespread faith that what will make

nuclear power cheaper is not greater *experience* but rather greater *novelty*. How else to explain the excitement for reactor designs invented by teenagers in their garages and famous software developers [Bill Gates / TerraPower] with zero experience whatsoever building or operating a nuclear plant?”¹²

Shellenberger continues:¹²

“Rather than address the public's fears, nuclear industry leaders, scientists, and engineers have for decades repeatedly retreated to their comfort zone: reactor design innovation. Designers say the problem isn't that innovation has been too radical, but that it hasn't been radical enough. If only the coolant were different, the reactors smaller, and the building methods less conventional, they insist, nuclear plants would be easier and cheaper to build.

“Unfortunately, the historical record is clear: the more radical the design, the higher the cost. This is true not only with the dominant water-cooled designs but also with the more exotic designs – and particularly sodium-cooled ones.”

Oklo's sodium-cooled fast neutron microreactor

The New Fire promotes Oklo's sodium-cooled fast neutron microreactor concept, and TerraPower's sodium-cooled fast neutron ‘traveling wave’ reactor (TerraPower is also exploring a molten chloride fast reactor concept).

Oklo co-founder Jacob DeWitte says: “There's this huge, awesome opportunity in off-grid markets, where they need power and they are relying on diesel generators ... We were talking to some of these communities and we realized they use diesel because it's the most energy dense fuel they know of. And I was like, man, nuclear power's two million times as energy dense ... And they were like, ‘Wait, are you serious, can you build a reactor that would be at that size?’ And I said, ‘Sure.’”

Which is all well and good apart from the claim that Oklo could build such a reactor: the company has a myriad of economic, technological and regulatory hurdles to overcome. The film claims that Oklo “has begun submission of its reactor's license application to the [US] Nuclear Regulatory Commission” but according to the NRC, Oklo is a “pre-applicant” that has gone no further than to notify the NRC of its intention to “engage in regulatory interactions”.¹⁶

There's lots of rhetoric in the film about small reactors that “you can roll ... off the assembly line like Boeings”, factory-fabricated reactors that “can look a lot like Ikea furniture”, economies of scale once there is a mass market for small reactors, and mass-produced reactors leading to “a big transition to clean energy globally”. But first you would need to invest billions to set up the infrastructure to mass produce reactors – and no-one has any intention of making that investment. And there's no mass market for small reactors – there is scarcely any market at all.¹⁷

TerraPower

TerraPower is one step ahead of Transatomic and Oklo – it has some serious funding. But it's still a long way off – Nick Touran from TerraPower says in the film that tests will “take years” and the company is investing in a project with “really long horizons ... [it] may take a very long time”.

TerraPower's sodium-cooled fast neutron reactor remains a paper reactor. Shellenberger writes:¹²

“In 2008, The New Yorker profiled Nathan Myhrvold, a former Microsoft executive, on his plans to re-invent nuclear power with Bill Gates. Nuclear scientist Edward Teller had this idea way back when that you could make a very safe, passive nuclear reactor,” Myhrvold explained. “No moving parts. Proliferation-resistant. Dead simple.”

“Gates and Myhrvold started a company, Terrapower, that will break ground next year in China on a test reactor. “TerraPower’s engineers,” wrote a reporter recently, will “find out if their design really works.”

“And yet the history of nuclear power suggests we should have more modest expectations. While a nuclear reactor “experiment often produced valuable clues,” Hewlett and Holl wrote, “it almost never revealed a clear pathway to success.” ...

“For example, in 1951, a reactor in Idaho used sodium rather than water to cool the uranium – like Terrapower’s design proposes to do. “The facility verified scientific principles,” Hewlett and Holl noted, but “did not address the host of extraordinary difficult engineering problems.” ...

“Why do so many entrepreneurs, journalists, and policy analysts get the basic economics of nuclear power so terribly wrong? In part, everybody’s confusing nuclear reactor designs with real world nuclear plants. Consider how frequently advocates of novel nuclear designs use

the future or even present tense to describe qualities and behaviors of reactors when they should be using future conditional tense.

“Terrapower’s reactor, an IEEE Spectrum reporter noted “will be able to use depleted uranium ... the heat will be absorbed by a looping stream of liquid sodium ... Terrapower’s reactor stays cool”.

“Given that such “reactors” do not actually exist as real world machines, and only exist as computer-aided designs, it is misleading to claim that Terrapower’s reactor “will” be able to do anything. The appropriate verbs for that sentence are “might,” “may,” and “could.” ...

“Myhrvold expressed great confidence that he had proven that Terrapower’s nuclear plant could run on nuclear waste at a low cost. How could he be so sure? He had modeled it. “Lowell and I had a month-long, no-holds-barred nuclear-physics battle. He didn’t believe waste would work. It turns out it does.” Myhrvold grinned. “He concedes it now.”

“Rickover was unsparing in his judgement of this kind of thinking. “I believe this confusion stems from a failure to distinguish between the academic and the practical,” he wrote. “The academic-reactor designer is a dilettante. He has not had to assume any real responsibility in connection with his projects. He is free to luxuriate in elegant ideas, the practical shortcomings of which can be relegated to the category of ‘mere technical details.’”

www.newfiremovie.com

www.facebook.com/NewFireMovie/

www.twitter.com/newfiremovie

www.vimeo.com/240644902

www.youtube.com/channel/UCda0hiEct_t1dNnoX5BNH2g

References:

1. Nuclear Monitor #764, 'Pandora's Promise' Propaganda, 28 June 2013, www.wiseinternational.org/nuclear-monitor/764/pandoras-promise-propaganda
2. Nuclear Monitor #773, 'Pandora's Propaganda', 21 Nov 2013, www.wiseinternational.org/nuclear-monitor/773/pandoras-propaganda
3. <https://newfiremovie.com/>
4. https://en.wikipedia.org/wiki/Energy_in_Senegal
5. Ian Fairlie, 2 April 2014, 'New UNSCEAR Report on Fukushima: Collective Doses', www.ianfairlie.org/news/new-unscear-report-on-fukushima-collective-doses/
6. 24 April 2014, 'The Chernobyl Death Toll', Nuclear Monitor #785, www.wiseinternational.org/nuclear-monitor/785/chernobyl-death-toll
7. Jonathan Samet and Joann Seo, 2016, 'The Financial Costs of the Chernobyl Nuclear Power Plant Disaster: A Review of the Literature', www.greencross.ch/uploads/media/2016_chernobyl_costs_report.pdf
8. Nuclear Monitor #836, 16 Dec 2016, 'The economic impacts of the Fukushima disaster', www.wiseinternational.org/nuclear-monitor/836/economic-impacts-fukushima-disaster
9. World Health Organization, 13 April 2016, 'World Health Organization report explains the health impacts of the world's worst-ever civil nuclear accident', www.who.int/mediacentre/news/releases/2006/pr20/en/
10. Nuclear Monitor #853, 30 Oct 2017, 'Exposing the misinformation of Michael Shellenberger and 'Environmental Progress'', www.wiseinternational.org/nuclear-monitor/853/exposing-misinformation-michael-shellenberger-and-environmental-progress
11. Nuclear Monitor #865, 6 Sept 2018, 'Nuclear lobbyist Michael Shellenberger learns to love the bomb, goes down a rabbit hole', [www.wiseinternational.org/nuclear-monitor/865-nuclear-monitor-865-6-september-2018](http://www.wiseinternational.org/nuclear-monitor/865/nuclear-monitor-865-6-september-2018)
12. Michael Shellenberger, 18 July 2018, 'If Radical Innovation Makes Nuclear Power Expensive, Why Do We Think It Will Make Nuclear Cheap?', www.forbes.com/sites/michaelshellenberger/2018/07/18/if-radical-innovation-makes-nuclear-power-expensive-why-do-we-think-it-will-make-nuclear-cheap/
13. Lindsay Krall and Allison Macfarlane, 2018, 'Burning waste or playing with fire? Waste management considerations for non-traditional reactors', *Bulletin of the Atomic Scientists*, 74:5, pp.326-334, <https://tandfonline.com/doi/10.1080/00963402.2018.1507791>
14. James Temple, 24 Feb 2017, 'Nuclear Energy Startup Transatomic Backtracks on Key Promises', www.technologyreview.com/s/603731/nuclear-energy-startup-transatomic-backtracks-on-key-promises/
15. Nuclear Monitor #849, 25 Aug 2017, 'James Hansen's Generation IV nuclear fallacies and fantasies', www.wiseinternational.org/nuclear-monitor/849/james-hansens-generation-iv-nuclear-fallacies-and-fantasies
16. NRC, 'Advanced Reactors (non-LWR designs)', www.nrc.gov/reactors/new-reactors/advanced.html, accessed 16 Sept 2018
17. Nuclear Monitor #800, 19 March 2015, 'Small modular reactors: a chicken-and-egg situation', www.wiseinternational.org/nuclear-monitor/800/small-modular-reactors-chicken-and-egg-situation

The Age of Renewables is here: renewables make the grade in price, performance and reliability

Author: Karel Beckman – Energy Post Weekly editor

NM866.4752

Renewables have long been considered, by many in the market, as a nice complementary source of energy: clean, but expensive and of course unreliable. Now increasingly awareness in the market is growing that they are much more than a nice addition to our energy system: they are on their way to becoming its mainstay. Expensive they are no longer. And thanks to new enabling technologies they are rapidly becoming reliable as well.

The signs are all around us. In a new addition of its “Global Renewable Energy Trends”, published on 13 September, consultancy Deloitte Global reports that “Renewable energy sources, notably solar and wind, “are reaching price and performance parity on and off the grid”¹.

Deloitte, in fact, sings the praises of renewables in every way.

According to the report, “three key enablers – price and performance parity, grid integration, and technology – allow solar and wind power to compete with conventional sources on price, while matching their performance.”

In addition, “as technologies such as blockchain, artificial intelligence (AI), and 3-D printing continue to advance the deployment of renewables, prices will likely continue to fall, and accessibility will improve.”

Deloitte notes that:

“Longstanding obstacles to greater deployment of renewables have receded as a result of three key enablers:

- *Reaching price and performance parity: The unsubsidized cost of solar and wind power has become comparable or cheaper than traditional sources in much of the world. New storage options are now making renewables more dispatchable – once an advantage of conventional sources.*
- *Cost-effective and reliable grid integration: Once seen as an obstacle, wind and solar power are now viewed as a solution to grid balancing. They have demonstrated an ability to strengthen grid resilience and reliability and provide essential grid services. Smart inverters and advanced controls have enabled wind and solar to provide grid reliability services related to frequency, voltage, and ramping as well or better than other generation sources. When combined with smarter inverters, wind and solar can ramp up much faster than conventional plants, help stabilize the grid even after the sun sets and the wind stops, and, for solar PV, show much higher response accuracy than any other source.*
- *The impact of technology: Technology is accelerating the deployment of renewables: automation and advanced manufacturing are improving the production and operation of renewables by reducing the costs and time of implementing*

renewable energy systems; AI can finetune weather forecasting, optimizing the use of renewable resources; blockchain can enable energy attribute certificate (EAC) markets to help resolve trust and bureaucratic hurdles; and advanced materials are transforming the materials of solar panels and wind turbines.”

Wow. You may want to reread that passage and let it sink in. Who would have thought just two years ago that renewables could be described in these terms?

The report contains many noteworthy insights. For example, it notes that “wind and solar can become important grid assets. Intermittent renewables are already helping to balance the grid. For example, wind power helped decrease the severity of most of the northern Midcontinent Independent System Operator’s steepest three-hour load ramps in 2017.”

Deloitte adds that “When combined with smart inverters, wind and solar can ramp up much faster than conventional plants, help stabilize the grid even after the sun sets and the wind stops, and, for solar PV, show much higher response accuracy (respond faster and with the required amount of power) than any other source. Smart inverters can also turn distributed resources into grid assets with minimal impact on customers and make these resources visible and usable to utilities. The few jurisdictions leveraging these capabilities have mandated them (e.g., Quebec), allowed renewables to sell ancillary services in their markets (e.g., Italy), and/or created new services markets (e.g., the United Kingdom).”

With regard to advanced materials and manufacturing, Deloitte writes that:

“Perovskite and 3D printing are poised to revolutionize the solar and wind industries. Perovskite has been the fastest-developing solar technology since its introduction, making efficiency gains that took silicon over half a century to achieve in less than a decade. In June 2018, a British and German startup demonstrated a record 27.3 percent conversion efficiency on perovskite-on-silicon tandem cells in laboratory settings, beating the laboratory record of standalone silicon cells. Belgian researchers achieved similar efficiency the following month, and both claim that over 30 percent efficiency is within reach. Perovskite has a simpler chemistry, the ability to capture a greater light spectrum, and higher efficiency potential than silicon. Perovskite can also be sprayed onto surfaces and printed in rolls, enabling lower production costs and more applications. Perovskite modules may be commercialized as early as 2019.”

On the wind front:

"[A]dditive manufacturing is paving the way for the use of new materials. Two US national laboratories collaborated with the industry to manufacture the first 3D-printed wind-blade mold, significantly reducing prototyping costs and time, from over a year to three months. The next frontier is to 3D print the blades. This would enable use of new combinations of materials and embedded sensors to optimize the blades' cost and performance, as well as onsite manufacturing to eliminate logistical costs and risks. Manufacturers plan to start with on-demand 3D printing of spare parts at wind farms to reduce costs and downtime for repairs. GE is already using additive manufacturing to repair and improve wind turbine blades. Manufacturers are heavily investing in these new technologies because they anticipate growing demand for solar and wind power."

And this is only the start. "Already among the cheapest energy sources globally, solar and wind have not even run the full course of their enabling trends yet", Deloitte notes.

The result: demand for renewables is growing rapidly:

"As costs continue to fall and accessibility increases, the demand for renewables is growing rapidly, driven by the following stakeholders:

- *Smart renewable cities: Most of the world's population now lives in growing cities, some of which have taken a proactive "smart" approach to managing their infrastructure with connected sensor technology and data analytics. The focus of more advanced smart cities is to enhance quality of life, competitiveness and sustainability. Solar and wind are at the intersection of these goals because they contribute to depollution, decarbonization and resilience while enabling clean electric mobility, economic empowerment, and business growth.*
- *Community energy: Building on the original trend toward "community solar", the addition of storage and management systems give communities more flexibility when implementing renewables. On-grid communities can now be powered independently from the grid, and in off-grid areas, community-owned partnerships enable electrification and reinvestment of profits.*
- *Emerging markets: The cumulative capacity of emerging markets to develop renewable energy is on the verge of surpassing that of the developed world, as emerging markets have helped bring down the cost of renewables and are innovating in ways that benefit the developed world.*
- *Corporate involvement: Corporations are procuring renewables in new ways, with many large corporations pursuing Power Purchase Agreements (PPAs) and smaller corporations turning to aggregation. Furthermore, currently two thirds of Fortune 100 companies have set renewable energy targets and are leading global corporate procurement, signaling an important commitment from the private sector."*

References:

1. Marlene Motyka, Andrew Slaughter, Carolyn Amon, 2018, 'Global renewable energy trends', www2.deloitte.com/global/en/pages/energy-and-resources/articles/global-renewable-energy-trends.html
2. <https://reneweconomy.com.au/taylor-launches-extraordinary-and-ill-informed-attack-against-wind-and-solar-81907/>
3. <https://reneweconomy.com.au/new-solar-and-wind-the-only-thing-pushing-down-power-prices-72578/>

"Wide-scale integration of renewable energy sources is no longer a question of if, but when," says Marlene Motyka, Deloitte Global Renewable Energy leader. "Countries such as China, the United States, and Germany have already reached price parity for certain renewable sources. With prices continuing to drop, developed countries and emerging markets alike have the ability to integrate renewables into their grid systems to ensure competitive advantage."

And you can guess which is the "most renewable" big city in the world? It's San Diego, California:

Top smart renewable cities⁵⁷

City	Population (million)	Wind and solar share of annual electricity generated
San Diego	1.4	33%
Los Angeles	1	20%
Jaipur	3	20%
Hamburg	1.8	14.8%
Toronto	2.8	12%
Bangalore	11	10%
Santiago	7.3	9%
Seoul	10.3	6.6%
Tainan	1.9	5.1%
Paris	2.3	4.2%

Source: Deloitte analysis.

What the Deloitte analysis shows is that the renewables sceptics are being proven wrong. Thus, the new Australian energy minister Angus Taylor who "has launched a new and extraordinary attack against wind and solar, saying they cause 'de-industrialisation' and claiming that Labor's 45 per cent emissions reduction target would send a 'wrecking ball' through the Australian economy", is way behind the curve.²

In fact, a new report, written by respected Australian market specialist Hugh Saddler, finds that it is precisely renewable energy which is helping to reduce wholesale electricity prices in Australia.

Reprinted from Energy Post Weekly, 18 Sept 2018, <https://energypostweekly.eu/the-age-of-renewables-is-here-i-renewables-make-the-grade-in-price-performance-and-reliability/>

NUCLEAR NEWS



US: Could the last remaining nuclear power project fall over?

Last year, the twin AP1000 reactor project in South Carolina was abandoned after the expenditure of at least US\$9 billion. Now, the last remaining reactor construction project – the twin AP1000 reactor project in Georgia – is in jeopardy. The *Wall Street Journal* reported on September 20:

“The sole remaining nuclear power plant under construction in the U.S. is facing mounting opposition from cities and lawmakers concerned about its rising costs. A decision on the expansion of Georgia’s Alvin W. Vogtle Electric Generating Plant is expected by Monday [September 24], when its three primary owners are set to vote on whether to continue going ahead.

“The project is billions of dollars over budget and years behind schedule, and expected to cost upwards of \$27 billion, more than double the original price tag estimated when work began a decade ago. It has received \$12 billion in federal loan guarantees, including \$3.7 billion from the Trump administration last year.

“Southern Co., the utility that serves as the largest owner of the project, announced last month that costs had risen by \$2.2 billion, triggering the vote with the other major owners, Oglethorpe Power and the Municipal Electric Authority of Georgia.

“The Vogtle plant is the only nuclear power plant under construction, or even serious consideration, in the U.S. If work on it stops, the prospects for new nuclear power in the U.S. would dim considerably and raise the question of whether the country can revitalize its nuclear industry.

“On Wednesday, 20 Georgia lawmakers wrote a letter expressing “concern about the ever-escalating cost” of the power plant, under construction in Waynesboro, Ga., and seeking a cap on how much of those costs could be passed on to customers of smaller utilities. Georgia Gov. Nathan Deal, a Republican, wrote a letter in support of finishing work, offering his “full support moving this project forward.”

“Earlier this month, one the biggest future expected customers of the nuclear plant, a public utility in Jacksonville, Fla., filed a lawsuit to try to back out of the deal. The utility, JEA, contracted with the Municipal Electric Authority of Georgia, known as MEAG, to buy

about 10% of the plant’s new units for 20 years. Now, it argues, there are less expensive options.

“On Tuesday, the JEA chairman wrote an open letter urging MEAG – a collection of 49 rural electric cooperatives and cities that operate municipal power companies – to vote against continuing with the project when it takes up the issue Friday, before the Monday vote by the three major partners.

“JEA ran ads in Georgia newspapers on Wednesday, including one published in the Newnan Times-Herald that called Vogtle “a mistake that will cost you and your children for years to come.” ...

“When Southern announced last month that the Vogtle costs had risen by \$2.2 billion, the company said it would not ask its customers to pay for the increase and instead took a \$1 billion charge to its earnings. But as public utilities, some of the other partners have noted that they don’t have shareholders with whom to share the burden.

“Georgia Power said it “has voted to move forward, and we hope the co-owners will also vote in favor to fulfill their obligation.”

“If any of the three owners vote against moving ahead, the project would be imperiled. Southern’s Georgia Power owns 45.7% of the plant, while MEAG owns 22.7% and Oglethorpe roughly 30%. Another company, Dalton Utilities, owns a small share, 1.6%.”

Abridged from: Russell Gold, 20 Sept 2018, ‘Growing Opposition Threatens Completion of Last U.S. Nuclear Plant’, www.wsj.com/articles/growing-opposition-threatens-completion-of-last-u-s-nuclear-plant-1537447935

See also:

Anastacia Ondieki, 19 Sept 2018, ‘Georgia legislators call for cost cap on nuclear plant Vogtle’, *The Atlanta Journal-Constitution*, www.ajc.com/business/economy/georgia-legislators-call-for-cost-cap-nuclear-plant-vogtle/0WZrkWWiJsgtICtu9shbPK/

Jim Galloway, Greg Bluestein and Tamar Hallerman, 20 Sept 2018, ‘The Jolt: ‘Election’ campaign erupts ahead of Plant Vogtle nuke votes’, <https://politics.myajc.com/blog/politics/the-jolt-election-campaign-erupts-ahead-plant-vogtle-nuke-votes/203U6R3avstMMZEYAKmKGO/>

Ross Williams, 20 Sept 2018, ‘Vogtle fate rests in key vote, deadline Monday’, www.mdjonline.com/news/vogtle-fate-rests-in-key-vote-deadline-monday/article_21c60e9a-bc6e-11e8-8054-0fe4cf7e016d.html



Advertisement funded by power utility JEA
‘Don’t pay for a \$30 billion mistake.’

Fukushima clean-up workers, including homeless, at grave risk of exploitation, say UN experts

Japan must act urgently to protect tens of thousands of workers who are reportedly being exploited and exposed to toxic nuclear radiation in efforts to clean up the damaged Fukushima Daichi Nuclear Power Station, say three UN human rights experts: Baskut Tuncak, special rapporteur on the disposal of hazardous substances and wastes, Urmila Bhoola, special rapporteur on contemporary forms of slavery, and Dainius Puras, special rapporteur on physical and mental health.¹

“Workers hired to decontaminate Fukushima reportedly include migrant workers, asylum seekers and people who are homeless,” said the experts. “We are deeply concerned about possible exploitation by deception regarding the risks of exposure to radiation, possible coercion into accepting hazardous working conditions because of economic hardships, and the adequacy of training and protective measures. We are equally concerned about the impact that exposure to radiation may have on their physical and mental health.”

Contamination of the area and exposure to radiation remains a major hazard for workers trying to make the area safe seven years after the catastrophic nuclear meltdown which followed damage to the power plant from an earthquake and subsequent tsunami.

Tens of thousands of workers have been recruited over the past seven years under the decontamination programme. Japan’s Ministry of Health, Labour and Welfare indicates on its website that 46,386 workers were employed in 2016; and the Radiation Worker Central Registration Centre of Japan has indicated that as many as 76,951 decontamination workers were hired in the five-year period up to 2016.

1. UN Office of the High Commissioner for Human Rights, 16 Aug 2018, ‘Japan: Fukushima clean-up workers, including homeless, at grave risk of exploitation, say UN experts’, www.ohchr.org/EN/NewsEvents/Pages/DisplayNews.aspx?NewsID=23458&LangID=E

2. Reuters, 17 Aug 2018, ‘Tens of thousands’ of workers exposed to radiation risks in Fukushima cleanup, U.N. rights experts say, www.japantimes.co.jp/news/2018/08/17/national/u-n-rights-experts-allege-tens-thousands-workers-exploited-exposed-radiation-risks-fukushima-cleanup/

The experts said: “The people most at risk of exposure to toxic substances are those most vulnerable to exploitation: the poor, children and women, migrant workers, people with disabilities and older workers. They are often exposed to a myriad of human rights abuses, forced to make the abhorrent choice between their health and income, and their plight is invisible to most consumers and policymakers with the power to change it.”

“Detailed reports that the decontamination contracts were granted to several large contractors, and that hundreds of small companies, without relevant experience, were subcontracted, are of concern. These arrangements, together with the use of brokers to recruit a considerable number of the workers, may have created favourable conditions for the abuse and violation of workers’ rights.”

The UN rights experts have engaged in a dialogue with the Japanese government since last year and have taken into account a recent reply to their most recent concerns.

As part of its Universal Periodic Review, Japan recently “accepted to follow up” on a recommendation from other States to restore radiation levels to those before the disaster to protect the human right to health of pregnant women and children, among several other recommendations. The experts strongly urge the government to lower the allowable dose of radiation to 1 mSv/year to protect children and women who may become pregnant.

An official of Japan’s Health, Labor and Welfare Ministry called the UN statement regrettable and one-sided, as did Japan’s Foreign Ministry.²

2018 NTI Index: Nuclear security progress in jeopardy

After years of progress on nuclear security, the fourth edition of the Nuclear Threat Initiative’s NTI Nuclear Security Index finds that the steps countries have taken to reduce the threat of nuclear terrorism are jeopardized by a deterioration of political stability and governance, an increase in corruption, and the expanding presence of terrorist groups around the world. The 2018 NTI Index also finds that many countries remain poorly prepared to defend against rapidly expanding and evolving cyber threats to nuclear facilities.

On a brighter note, the biennial NTI Index finds that there has been some progress reducing the number of countries holding fissile, weapons-usable materials. Twenty-two countries now have fissile materials (highly enriched uranium or separated plutonium), compared with 32 when the first NTI Index was released in 2012. In the past two years, Argentina and Poland have joined the list of countries that have removed or disposed of all highly enriched uranium within their territories.

In another positive development, of the 44 countries and Taiwan that have nuclear facilities where an act of sabotage could cause a dangerous release of radiation, 78% improved their Sabotage Ranking scores by implementing

greater on-site physical protection, enhanced insider threat prevention, improved response capabilities, and other security measures. However, the NTI Index shows substantial room for improvement in this area and finds a troubling deterioration in the risk environment in almost a quarter of the countries with nuclear materials or facilities that could be targeted.

Four global Nuclear Security Summits, held between 2010 and 2016, highlighted nuclear security risks but no more summits are planned. “The summits were crucial for holding states accountable for appropriate and effective security measures,” said NTI President Joan Rohlfing. “Unfortunately, no comparable cooperative global effort has emerged to replace them, leaving dangerous gaps in the current global nuclear security system that terrorist groups or others seeking weapons of mass destruction could exploit.”

Nuclear Threat Initiative, 5 Sept 2018, ‘Important Nuclear Security Progress Now in Jeopardy, According to 2018 NTI Index’, <https://ntiindex.org/news-items/important-nuclear-security-progress-now-in-jeopardy-according-to-2018-nti-index/>

Full report: https://ntiindex.org/wp-content/uploads/2018/08/NTI_2018-Index_FINAL.pdf