Australian Government

ANSTO
Science. Ingenuity. Sustainability.

23 September 2020

Mr Cesar Melhem MLC
Chair, Environment and Planning Committee
Parliament of Victoria
Via Email: nuclearprohibition@parliament.vic.gov.au

Dear Mr Melhem

Thank you for affording the opportunity for ANSTO to appear at the public hearing of your Committee's Inquiry into Nuclear Prohibition on 28 August 2020.

We took several questions on notice during the hearing. The answers to those questions are provided overleaf and in the attached reports and publications.

Should you or other members of the Committee have further questions in relation to our evidence or regarding matters within the purview of the Inquiry more broadly, please do not hesitate to contact me at [redacted].

Finally, I wish to put on record that we would welcome a visit by members of the Committee to the Australian Synchrotron in Clayton should Covid-19 restrictions be eased. We also would welcome a visit to our Lucas Heights campus in Sydney once interstate travel is permitted.

Yours sincerely

Steve McIntosh
Senior Manager, Government and International Affairs

Parliament of Victoria
Legislative Council
Environment and Planning Committee
Inquiry into Nuclear Prohibition

Agency: ANSTO | Australian Nuclear Science and Technology Organisation
Reference: Questions on Notice (Hansard, 28 August 2020)
In attendance for ANSTO:

- Professor Andrew Peele, Group Executive, Research Translation and Director, Australian Synchrotron
- Professor Lyndon Edwards, National Director, Australian Generation IV International Research
- Dr Robert Gee, General Manager, Minerals and Radiation Services
- Mr Steven McIntosh, Senior Manager, Government and International Affairs

Answers to Questions on Notice

1. *Mr LIMBRICK: Thank you, Chair. And thank you, gentlemen, for appearing today. And yes, I am very disappointed about not being able to visit Lucas Heights and the synchrotron, as it is actually in my electorate. That is very disappointing, but I do intend to go there as soon as we are allowed to. That aside, there have been a number of issues brought up during this inquiry, and two that I would really like to get your expertise on. Firstly, we have had multiple witnesses express concerns about worker safety and community safety around nuclear power plants. One such person was Dr Tilman Ruff, from the Medical Association for Prevention of War. They said that they were not aware of any studies into safety for workers at the Lucas Heights facility and the safety of children in the surrounding radius of the facility. Maybe if you could provide some comments on safety for workers—whether there have been any studies of this sort of thing—and the safety of the surrounding community. And the second question—this has been brought up a number of times. I know that one of the important functions of the reactor in Sydney is the production of medical isotopes, and it has been suggested a number of times that the reactor is not necessary to produce these isotopes and they could be produced using cyclotrons or other technology. I wonder if you would like to comment on those things.*
   Prof. PEELE: Sure. I will make a couple of comments and then I will throw to some of my colleagues. So in terms of the safety aspects, I believe there has been some study done, and we would be happy to take that on notice and provide the full details back to the committee.

   Answer: ANSTO draws the Committee's attention to a long-term epidemiological study that examined incidence of cancer and other health effects among former ANSTO staff. That study was reported in numerous peer reviewed publications, including in the *Journal of Occupational Health*[1] and the *Australian and New Zealand Journal of Public Health*. Results published in the latter journal found that:

[1] Habib R., Abdallah, S., Law, M.G., and Kaldor, J.M., 'Cancer incidence among Australian nuclear industry workers', *Journal of Occupational Health*, vol. 48, iss. 5, September 2006, pp. 358-365, http://dx.doi.org/10.1539/joh.48.358.

'All-cause mortality in workers at LHSTC (the Lucas Heights Science and Technology Centre) was 31% lower than in the national population… Mortality from causes other than cancer was even lower at 40% below the national rates.'[2]

Further information regarding the study and its results can be found at **Attachment A** and **Attachment B**.

ANSTO also provides **Attachment C** for the Committee's reference regarding the planned production of Molybdenum-99 in Canada's nuclear power reactor fleet given ongoing technical feasibility and financial viability challenges with the production of nuclear medicines using cyclotrons, as discussed in our oral evidence.

2. *Dr BACH: Thanks, Chair, and thank you, gentlemen, for coming along this afternoon at the end of our period of hearing. I might take up where Ms Bath left off. As a layman myself, I confess I have found the proceedings of this committee particularly difficult, because even though the vast bulk of the evidence that we have received—the overwhelming majority of the evidence we have received—has been in keeping with the evidence that we have received from you today, we have also received some other evidence from people who are to be respected in their fields of course but that has been radically different. We have heard, for example, that some disasters in the past have caused deaths in the tens of thousands. I think I am correct in saying that we have heard that some nuclear disasters in the past have caused over 100 000 deaths. Certainly this morning we heard from one witness a dark and dystopian vision of the destruction of plant life, a huge number of human deformities, cancers, and so forth. That is difficult for me of course as a layperson, given that now, after today, after our hearing is finished, our job as a committee is to seek to weigh up this evidence. It has also been put to us that every single person who has a view that nuclear energy could be a viable option for us in the future is a paid-up sycophant of the so-called nuclear industry.*
Trying to unpick all of that for me, I confess, is very difficult. I wonder, could I gain your advice or any insights from you, gentlemen, about how we might go about that work of weighing the evidence that we have received that is overwhelmingly in keeping with the evidence that you have given us, but nonetheless in some respects is radically and starkly contradictory?
Prof. PEELE: I think I would have to say that there is a broad range of estimates of impacts of some of the well-known nuclear incidents. The United Nations has commissioned a number of reports on this, which I think most people would take as being fairly definitive. We would be happy to take on notice and provide some more information around the summaries of some of those reports, but I can tell you now that they certainly do not point to numbers in the hundreds of thousands.

Answer: As highlighted in our submission (page 46), nuclear power is a safe technology. Indeed, nuclear power has the lowest number of fatalities of any major electricity source, many times lower than coal, natural gas, and oil, and lower than biomass, as shown in the table overleaf, which presents data on the health effects of electricity generation in Europe by primary energy source (deaths/cases per terawatt hour [TWh]):

[2] Habib, R.R., Abdallah, S.M., Law, M., and Kaldor, J., 'Mortality rates among nuclear industry workers at Lucas Heights Science and Technology Centre', *Australian and New Zealand Journal of Public Health*, vol. 29, no. 3, 2005, p. 233.

Health Effects of Electricity Generation in Europe by Primary Energy Source					
Source	Deaths from Accidents		Air Pollution-Related Effects		
	The Public	Occupational	Deaths*	Serious Illness†	Minor Illness‡
Lignite	0.02 (0.005–0.08)	0.10 (0.025–0.4)	32.6 (8.2–130)	298 (74.6–1193)	17,676 (4419–70,704)
Coal	0.02 (0.005–0.08)	0.10 (0.025–0.4)	24.5 (6.1–98)	225 (56.2–899)	13,288 (3322–53,150)
Gas	0.02 (0.005–0.08)	0.001 (0.0003–0.004)	2.8 (0.70–11.2)	30 (7.48–120)	703 (176–2813)
Oil	0.03 (0.008–0.12)	–	18.4 (4.6–73.6)	161 (40.4–645.6)	9551 (2388–38,204)
Biomass	–	–	4.63 (1.16–18.5	43 (10.8–172.6)	2276 (569–9104)
Nuclear	0.003	0.019	0.052	0.22	–

Data are mean estimate (95% CI). *Includes acute and chronic effects. Chronic effect deaths are between 88% and 99% of total. For nuclear power, data include all cancer-related deaths. †Includes respiratory and cerebrovascular hospital admissions, congestive heart failure, and chronic bronchitis. For nuclear power, data include all non-fatal cancers and hereditary effects. ‡Includes restricted activity days, bronchodilator use cases, cough, and lower-respiratory symptom days in patients with asthma, and chronic cough episodes. TWh=1012 Watt hours.

Source: Markandya, A. and Wilkinson, P., 'Electricity Generation and Health', *The Lancet*, vol. 370, iss. 9591, 15 September 2007, p. 981.

Other studies have shown that nuclear power is safer than all forms of energy generation technologies, including renewable sources. The table below, which draws on data from a range of reputable sources, shows that nuclear power in the United States results in 0.1 fatality per trillion kilowatt hours of electricity produced. Globally, nuclear power results in 90 fatalities per trillion kilowatt hours of electricity produced, lower than that of wind power (150 fatalities) and solar (rooftop) (440 fatalities):

Energy Source	Mortality Rate (deaths/trillion kWhr)	Percentage of Electricity Generation/Energy System
Coal (global average)	100,000	41% of global electricity
Coal (China)	170,000	75% of China's electricity
Coal (United States)	10,000	32% of the United States' electricity
Oil	36,000	33% of global energy; 8% of global electricity
Natural Gas	4000	22% of global electricity
Biofuel/Biomass	24,000	21% of global energy
Solar (rooftop)	440	< 1% of global electricity
Wind	150	2% of global electricity
Hydro (global average)	1400	16% of global electricity
Hydro (United States)	5	6% of United States' electricity
Nuclear (global average)	90 (with Chernobyl and Fukushima)	11% of global electricity
Nuclear (United States)	0.1	19% of United States' electricity

Source: Conca, J., 'How Deadly Is Your Kilowatt? We Rank The Killer Energy Sources', *Forbes*, 10 June 2012, https://www.forbes.com/sites/jamesconca/2012/06/10/energys-deathprint-a-price-always-paid/#731b4278709b. References cited in this article:

- Bickel, P. and Friedrich, R., *Externalities of Energy*, European Union Report EUR 21951, Luxembourg, 2005.
- Cohen, J., et al., 'The global burden of disease due to outdoor air pollution', *Journal of Toxicology and Environmental Health Part A*, vol. 68, no. 13-14, 2005, pp. 1301-1307.
- National Academy of Sciences, *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use*, Committee on Health, Environmental, and Other External Costs and Benefits of Energy Production and Consumption, National Research Council, Washington, D.C., 2010.
- Pope, C.A., et al., 'Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution', *Journal of the American Medical Association*, vol. 287, no.9, 6 March 2002, pp. 1132-1141.
- Scott, J., *The Clean Air Act at 35: Preventing Death and Disease from Particulate Pollution*, Environmental Defense, New York, 2005.
- World Health Organization, *Health effects of chronic exposure to smoke from Biomass Fuel burning in rural areas*, Chittaranjan National Cancer Institute, 2007.

As discussed in ANSTO's submission (page 16), the public perception of the health effects, including deaths, of nuclear power generation differs significantly from the data on actual effects and fatalities, as well as fatalities avoided due to the emissions abatement contributions of nuclear energy.[3]

Information about the health effects of the Fukushima, Chernobyl, and Three Mile Island incidents can be found in the reports and documents at **Attachment D**, **Attachment E**, **Attachment F**, **Attachment G**, and **Attachment H**. As noted in our submission to the Inquiry (pages 47-48), no fatalities due to radiation-related illnesses have been attributed to the Three Mile Island and Fukushima incidents.[4] Guidance produced in 2015 by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) on the health effects of consuming Japanese produce can be found at **Attachment I**. Briefly, that guidance indicates that, '[s]ince the accident in 2011[,] the Japanese Government ha[s] reviewed [its] food safety regulations to control the amount of radioactive material in foods. In April 2012[,] new limits were established and additional testing procedures were introduced to ensure that the food produced in Japan continues to be safe to consume.'

With regard to the Chernobyl incident, as noted in our submission (page 48), the intentional overheating of the reactor resulted in two chemical explosions and a fire that caused the deaths of two workers.[5] Of the 600 personnel involved in the emergency response, 134

[3] See, for example: Ho, J., Lee, P.C., Kao, S., Chen, R., Leong, M.C.F., Chang, H., Hsieh, W., Tzeng, C., Lu, C., Ling, S., and Chang, P.W., 'Perceived environmental and health risks of nuclear energy in Taiwan after Fukushima nuclear disaster', *Environment International*, vol. 73, December 2014, pp. 295-303; Stehlik, D., *Understanding the Formation of Attitudes to Nuclear Power in Australia*, National Academies Forum, Melbourne, April 2010.

[4] GPU Nuclear Corporation, *Radiation and health effects – a report on the TMI-2 accident and related health studies*, GPU Nuclear Corporation, Middletown, PA, 1986; United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), *Sources and Effects of Ionizing Radiation: United Nations Scientific Committee on the Effects of Atomic Radiation: UNSCEAR 1993 Report to the General Assembly, with Scientific Annexes: Annex B. Exposures from man-made sources of radiation*, United Nations, New York, 1993, p. 114; UNSCEAR, *Sources, Effects and Risks of Ionizing Radiation: UNSCEAR 2013 Report: Volume I: Report to the General Assembly: Scientific Annex A: Levels and effects of radiation exposure due to the nuclear accident after the 2011 great east-Japan earthquake and tsunami*, United Nations, New York, 2014, pp. 77, 80.

[5] Nuclear Fuel Cycle Royal Commission, *Nuclear Fuel Cycle Royal Commission Report*, Government of South Australia, 2016, p. 44.

developed acute radiation syndrome, with 28 dying from radiation exposure.[6] Although members of the public were reported to have been exposed to radioactive iodine in low doses, increased cancer incidence owing to that exposure has not been established.[7] Indeed, according to the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR):

> 'There is no scientific evidence of increases in overall cancer incidence or mortality rates or in rates of non-malignant disorders that could be related to radiation exposure. The incidence of leukaemia in the general population, one of the main concerns owing to the shorter time expected between exposure and its occurrence compared with solid cancers, does not appear to be elevated. Although those most highly exposed individuals are at an increased risk of radiation-associated effects, the great majority of the population is not likely to experience serious health consequences as a result of radiation from the Chernobyl accident.'[8]

While there have been very few fatalities and reports of serious illnesses attributed to the three major incidents discussed above, as we noted in our submission (page 48), the incidents have been found to have:

- caused significant mental health effects;
- resulted in the involuntary relocation of hundreds of thousands of residents; and
- resulted in significant economic impacts, including the cost of land remediation and decontamination, lost revenues and economic activity, and site decommissioning expenses.

In the case of Fukushima in particular, in addition to the direct environmental impacts, there have been indirect impacts from the increased use of coal-fired power plants in Japan, including in relation to Japan's ability to meet its CO_2 emissions targets.

3. *Mrs McARTHUR: Chair, if I could just follow up. For the record, I totally support your view. I am technology agnostic, and I happily support all variations on the theme of how we get to increase a reliable, affordable, sustainable supply of energy; it seems critical. Whether it is wave-to-energy, hydrogen, renewables, onshore conventional gas, heated coal-fired power stations, small or large nuclear reactors, I think there should be an absolute mix. So why is it, do you think, that those that want to get to reducing emissions want to eliminate nuclear energy from the argument? ...*
Prof. PEELE: I think also it is a broad question and it does go into the depths of human psychology. What we might also take on notice is to provide you with some further information from the International Energy Agency, which has released a report recently on sustainable recovery and the energy mix that goes into that, and that I think provides some really important information.

Answer: While it might be perceived in Australia that those concerned with reducing emissions also are opposed to nuclear power, this generally is not the case internationally. ANSTO notes the recent movement in favour of nuclear power in several comparable jurisdictions around the world. Canada, the United Kingdom, and the United States have committed to re-invigorating private and public investments in new nuclear energy through the development of smaller, safer, quicker-to-build (three to five years), and lower cost

[6] UNSCEAR, *Sources and Effects of Ionizing Radiation: United Nations Scientific Committee on the Effects of Atomic Radiation: UNSCEAR 2008: Report to the General Assembly with Scientific Annexes: Volume I*, United Nations, New York, 2010, pp. 15-16.
[7] UNSCEAR, *Sources and Effects of Ionizing Radiation*, pp. 15-16.
[8] UNSCEAR, *The Chernobyl accident: UNSCEAR's assessments of the radiation effects*, UNSCEAR, 16 July 2012, https://www.unscear.org/unscear/en/chernobyl.html.

small modular reactors (SMRs). To facilitate this, each country has developed its own 'roadmap' for SMR development and deployment. For example:

- the Canadian SMR Roadmap[9], which has the support of Canada's national, provincial, and territory governments, as well as the independent nuclear safety regulator and industry; and which is 'bolstered by a federal investment of $1.2 billion in infrastructure at Canadian Nuclear Laboratories and investments by New Brunswick to establish an SMR nuclear research cluster'[10];
- the formation in the United Kingdom of an SMR consortium with the support of government[11]; and
- the United States Department of Energy's Advanced Reactor Demonstration Program[12], its GAIN (Gateway for Accelerated Innovation in Nuclear) initiative[13], and the establishment of the National Reactor Innovation Center.[14]

ANSTO also notes that the United States' Democratic Party has changed its party platform in 2020 to include support for nuclear power for the first time since 1972. The platform states:

> 'Recognizing the urgent need to decarbonize the power sector, our technology-neutral approach is inclusive of all zero-carbon technologies, including hydroelectric power, geothermal, existing and advanced nuclear, and carbon capture and storage.'[15]

Moreover, on 21 September 2020, the representative of Canada told the annual General Conference of the International Atomic Energy Agency (IAEA):

> 'Now, as the world takes its first steps toward a post-COVID recovery, Canada is putting climate change, clean energy and sustainable growth at the heart of our plans for achieving net-zero emissions by 2050. As a proven and reliable non-emitting source of power, nuclear energy is central to this. We know there is no credible path to that goal without nuclear energy. To this end, Canada recognizes the importance of the full range of nuclear energy technologies available to us. This includes existing large-scale nuclear power plants, as well as the growing role of nuclear innovation such as Small Modular Reactors (SMRs). That is why Canadians are investing $26 billion to extend the life of the nuclear energy fleet in Canada, and why we will be releasing our Small Modular Reactor Action Plan later this year to make sure we deliver on the promise of this game-changing technology. This next wave of nuclear innovation could also

---

[9] Canadian Small Modular Reactor Roadmap Steering Committee, *A Call to Action: A Canadian Roadmap for Small Modular Reactors*, November 2018, Ottawa, Ontario, https://smrroadmap.ca/wp-content/uploads/2018/11/SMRroadmap_EN_nov6_Web-1.pdf.

[10] Canadian Small Modular Reactor Roadmap Steering Committee, p. i.

[11] UK SMR Consortium, *UK Small Modular Reactors (SMRs): A National Endeavour*, Rolls Royce, Warrington, United Kingdom, https://www.uknuclearsmr.org/; Department for Business, Energy and Industrial Strategy (BEIS), *Policy Paper: Advanced Nuclear Technologies*, BEIS, 5 November 2019, https://www.gov.uk/government/publications/advanced-nuclear-technologies/advanced-nuclear-technologies.

[12] Office of Nuclear Energy, *U.S. Department of Energy Launches $230 Million Advanced Reactor Demonstration Program*, Department of Energy, Washington, DC., 14 May 2020, https://www.energy.gov/ne/articles/us-department-energy-launches-230-million-advanced-reactor-demonstration-program.

[13] GAIN – Gateway for Accelerated Innovation in Nuclear, Department of Energy, 2020, https://gain.inl.gov/SitePages/Home.aspx.

[14] Idaho National Laboratory, *National Reactor Innovation Center*, Idaho National Laboratory, Operated by Battelle Energy Alliance for the Department of Energy, Idaho Falls, 2020, https://inl.gov/nric/.

[15] Democratic National Convention, *2020 Democratic Party Platform*, 18 August 2020, p. 51, https://democrats.org/wp-content/uploads/sites/2/2020/08/2020-Democratic-Party-Platform.pdf.

enable exciting new applications to complement other sources of clean energy, including hydrogen and nuclear-renewable integration.'[16]

In addition, at the international level, a recent report of the International Energy Agency (IEA) states that, in 2019, '5.5 GW (gigawatts) of additional nuclear capacity were connected to the grid and 9.4 GW were permanently shut down, bringing global capacity to 443 GW. New projects were launched (about 5.2 GW), and refurbishments are under way in many countries to ensure the long-term operations of the existing fleet. Nevertheless, **while the existing nuclear fleet remains the world's second most important low-carbon source of electricity [the first being hydro, with nuclear and hydro accounting for nearly 30 per cent of the world's installed electricity generating capacity but accounting for 70 per cent of low-carbon electricity generation][17], new nuclear construction is not on track with the [Sustainable Development Scenario (SDS)]** (emphasis added). According to current trends, nuclear capacity in 2040 will amount to 455 GW – well below the SDS level of 601 GW. **Additional lifetime extensions and a doubling of the annual rate of capacity additions are therefore required**' (emphasis added).[18]

The IEA released a new report on 18 June 2020 (**Attachment J**). Titled *Sustainable Recovery: World Energy Outlook Special Report*, the report presents 'an energy sector roadmap for governments to spur economic growth, create millions of jobs and put global emissions into structural decline.' The IEA asserts that, '[b]y integrating energy policies into government responses to the economic shock caused by the Covid-19 crisis, the plan would also accelerate the deployment of modern, reliable and clean energy technologies and infrastructure.'[19]

The report presents analysis developed in collaboration with the International Monetary Fund, and sets out policy actions and targeted investments for governments to action over the 2021 to 2023 period. Importantly, the report highlights the need for governments around the world to invest in research and development (R&D) of SMR technologies, as well as in extensions to the lives of existing nuclear power plants.[20] The report emphasises the contribution of existing nuclear power reactors to global emissions reduction efforts, stating, 'Without further nuclear lifetime extensions in advanced economies, for example, clean energy transitions would require around $80 billion additional investment per year and consumer electricity bills would be around 5% higher.'[21]

With specific regard to SMRs, the IEA recommends a series of actions be taken by government to:

- 'provide investment support for pilot projects such as capital grants, loan guarantees and tailor-made long-term contracts

[16] International Atomic Energy Agency (IAEA) 64th General Conference, Canada National Statement, https://www.iaea.org/sites/default/files/20/09/canada-gc64-english.pdf.
[17] International Energy Agency (IEA), *Sustainable Recovery: World Energy Outlook Special Report*, Flagship report — June 2020, IEA, https://www.iea.org/reports/sustainable-recovery/electricity#abstract.
[18] IEA, *Nuclear Power*, IEA, Paris, 2020, https://www.iea.org/reports/nuclear-power.
[19] IEA, *IEA offers world governments a Sustainable Recovery Plan to boost economic growth, create millions of jobs and put emissions into structural decline*, Press Release, 18 June 2020, IEA, https://www.iea.org/news/iea-offers-world-governments-a-sustainable-recovery-plan-to-boost-economic-growth-create-millions-of-jobs-and-put-emissions-into-structural-decline.
[20] IEA, *Sustainable Recovery: World Energy Outlook Special Report*.
[21] IEA, *Sustainable Recovery: World Energy Outlook Special Report*, p. 53.

- foster cost-sharing agreements for international collaboration, shared RD&D programmes, and national and international licensing frameworks
- support regulatory authorities to accelerate the resolution of concerns on the validation of innovative safety features and factory assembly'.[22]

The IEA further notes that:

> 'SMRs offer the possibility of providing low-carbon nuclear power with lower initial capital investment and better scalability than traditional larger reactors, and with the ability to use sites that would be unable to accommodate traditional large reactors. Construction lead-times are also expected to be much shorter as a result of factory manufacturing and the use of advanced modular construction techniques.
>
> SMRs could help provide flexibility in countries with large electricity grids, or be used in countries or regions with small electricity grids that would not be appropriate for large baseload nuclear power plants. Given their lower expected costs, they may also be attractive to countries with no experience with nuclear power, especially those with small and less robust electricity grids. In some cases, notably where there are grid stability and reliability concerns, SMRs may be the only technically feasible nuclear technology option available.'[23]

4. *Ms TAYLOR: I strongly reject the premise that because someone is pro-renewables and anti-nuclear it means it is all emotional. I think that is highly patronising and I would be careful with that trajectory. Now, are you claiming that nuclear is safer than wind and solar? Because there is no credible evidence for that. I am just putting that out there. And the other question I have: what are the costs of backing up nuclear? Nuclear has unplanned trips and downtime. The UK has had to install additional spinning reserve to back up Hinkley Point C nuclear plant. Just a couple of quick questions.*
The CHAIR: Thank you. Okay, who wants to take that? You can take it on notice or you can answer it. Who wants to jump in?
Prof. PEELE: We will provide more detail. It is comparable with wind and solar as I understand it, but we can provide the actual data in terms of the reviewed studies. In terms of interruptions, I think every form of energy supply has interruptions and the point is how you design an energy ecosystem that manages those interruptions through things like redundancies and backups.
Ms TAYLOR: Right, so are you able to take that question on notice to answer?
Prof. PEELE: In terms of the level of interruptions?
Ms TAYLOR: It says, 'What are the costs of backing up nuclear? Nuclear has unplanned trips and downtime'. That is all.
Prof. PEELE: Yes, we will do that.

Answer: ANSTO understands that the United Kingdom's National Grid Electricity System Operator (ESO) has announced a package worth £328 million over six years to implement a new approach to the management of stability of the United Kingdom's electricity system. That approach will involve the deployment of 'inertia'—that is, kinetic energy stored in spinning parts—to enable frequency control for renewable energy technologies so that they do not destabilise the grid. The ESO states:

> 'Traditionally inertia has been provided by the spinning power of big coal and gas-fired generators. But this means inertia is a by-product of burning coal and gas. Renewables like wind and solar don't synchronise with the grid in a way that provides inertia, so as the older coal and gas plants come off the system we need to find new ways to provide stability.

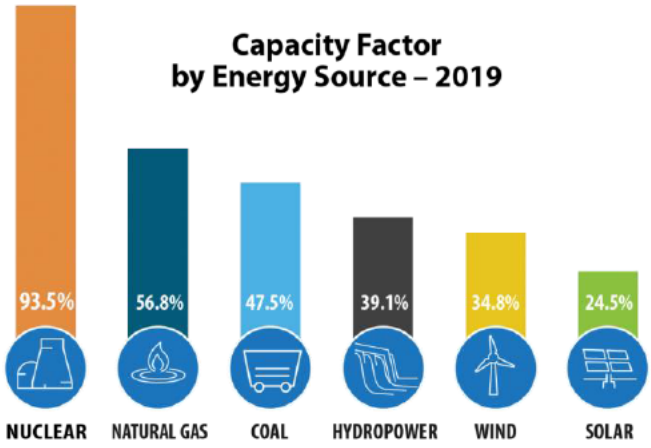
[22] IEA, *Sustainable Recovery: World Energy Outlook Special Report*, p. 100.
[23] IEA, *Sustainable Recovery: World Energy Outlook Special Report*, p. 100.

> With our new approach, either new assets or existing infrastructure that has been modified, will draw energy from the grid to power their turbines and create inertia – rather than inertia being a by-product of producing electricity.'[24]

More information can be found at: https://www.nationalgrideso.com/news/our-new-approach-inertia-and-other-stability-services and https://www.nationalgrideso.com/news/our-new-approach-inertia-and-other-stability-services.

More broadly, the objective of an energy generation system is to reduce emissions and environmental impacts while maintaining reliability and security of supply—all at reasonable cost. Reliability of the system rests on there being a stable, baseload, dispatchable power source that also enables responses to changes in demand for electricity.[25] A reliable system must also allow for frequency control to maintain safe and secure transmission of electricity.[26]

The capacity factor of energy sources determines their ability to produce *reliable* power. The below figure shows the capacity factors of different energy generation sources. With a capacity factor over 90 per cent (and 95 per cent for certain SMR designs, including the NuScale plant), nuclear power reactors can provide near or full continuous electricity supply, while also having the ability to load follow at short time intervals and to maintain frequency. Moreover, given that power reactors usually are established in multiples (i.e., a plant comprises more than one reactor unit), normal practice is that not all reactor units are shut down for maintenance and refuelling at the same time, thereby enabling at least one unit to continue operation. In contrast, variable renewable energy (VRE) sources, with lower capacity factors, require firming (backup generation or large battery storage) to ensure reliability of supply and to moderate changes in frequency.



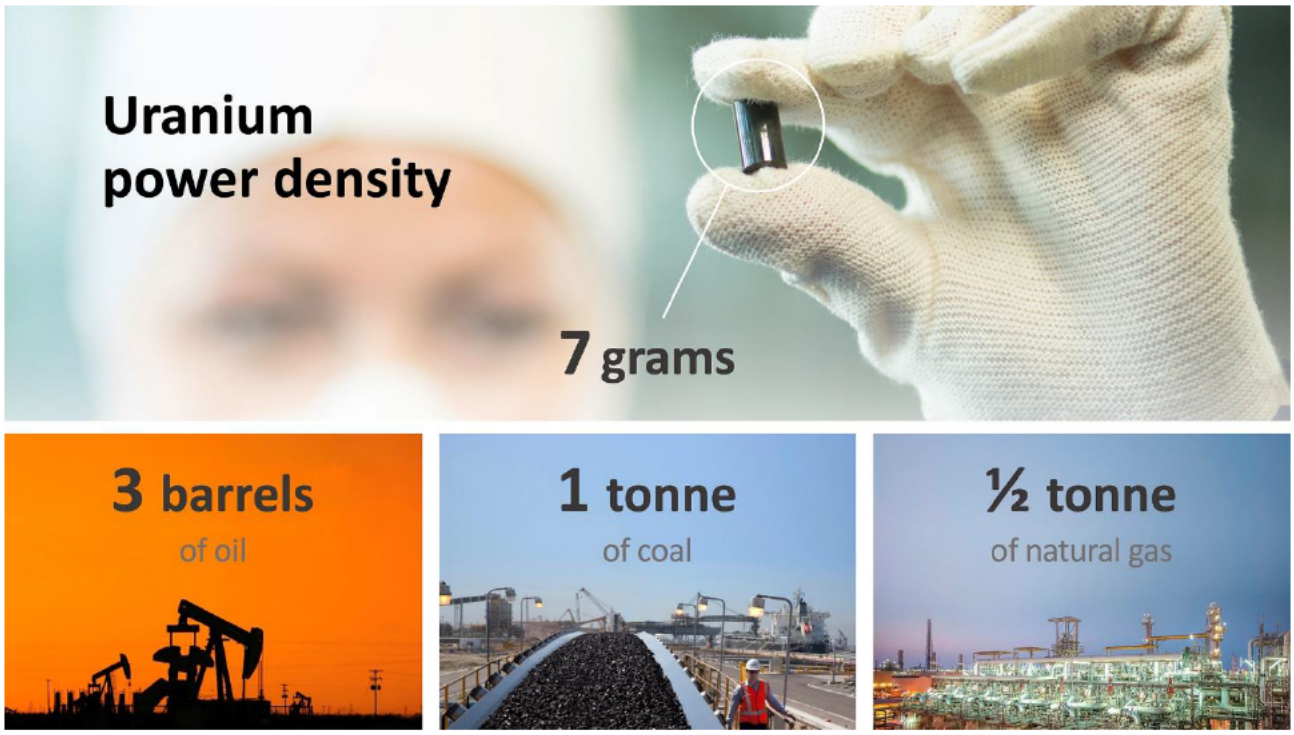
Capacity factors of different energy sources in 2019. Source: U.S. Energy Information Administration.

[24] National Grid ESO, *Our new approach to inertia and other stability services*, National Grid ESO, 29 January 2020, https://www.nationalgrideso.com/news/our-new-approach-inertia-and-other-stability-services.
[25] IAEA, *Nuclear Power for Sustainable Development*, IAEA, Vienna, 2017, p. 3, https://sustainabledevelopment.un.org/content/documents/19913IAEA_Brochure_NP_for_Sustainable_Development.pdf.
[26] Australian Energy Market Operator (AEMO), *Fact Sheet: Frequency Control*, AEMO, 2016, p. 1, https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Reports/2016/AEMO-Fact-Sheet_Frequency-Control---Final.pdf.

With the increasing penetration of VREs, then, there is a commensurate need for investments in grid stabilising/firming technologies, and international studies have highlighted the potential for nuclear power reactors to meet this need.[27] Adding to the challenge presented by VREs, analysis of energy mix scenarios undertaken by the OECD Nuclear Energy Agency (OECD–NEA) has found that:

> '[The] total generation capacity [of the electricity system] increases significantly with the deployment of VRE resources. Since the load factor and the capacity credit of VRE is significantly lower than that of conventional thermal power plants, a significantly higher capacity is needed to produce the same amount of electricity.'[28]

The OECD–NEA's findings show that VREs require the installation of capacity additional to that which is required to meet electricity demand. Put differently, the larger the VRE penetration, the larger the requirement for additional capacity. The OECD–NEA observes, though, that, in the international context, VREs complemented with nuclear generation can significantly reduce the amount of additional generation capacity required. As such, nuclear power is viewed as a primary source of low-carbon, baseload generation, underpinning the future energy systems of major industrialised economies. Nuclear fuel also has the highest density of any of the conventional energy sources, as shown in the figure below:



Energy density of uranium, oil, coal, and gas.

ANSTO notes that the nature of the current Australian grid may preclude the introduction of large gigawatt-scale reactors in Australia. However, small modular reactors could be integrated into the Australian grid were Australian governments minded to embark on a nuclear power program.

---

[27] IEA, *Nuclear Power in a Clean Energy System*, IEA, Paris, 2019, https://www.iea.org/reports/nuclear-power-in-a-clean-energy-system.

[28] Organisation for Economic Co-operation and Development – Nuclear Energy Agency (OECD–NEA, *The Costs of Decarbonisation: System Costs with High Shares of Nuclear and Renewables*, OECD–NEA, Paris, 2019, p. 18, https://www.oecd-nea.org/ndd/pubs/2019/7299-system-costs.pdf.

Australian Government | ANSTO Science. Ingenuity. Sustainability.

Attachments

Attachment A – Habib, R.R., Abdallah, S.M., Law, M., and Kaldor, J., 'Mortality rates among nuclear industry workers at Lucas Heights Science and Technology Centre', *Australian and New Zealand Journal of Public Health*, vol. 29, no. 3, 2005, pp. 229-237.

Attachment B – Habib, R.R. and Kaldor, J., 'An Epidemiological Study of Cancer Incidence and Mortality among Nuclear Industry Workers at Lucas Heights Science and Technology Centre in Collaboration with IARC', pp. 52-56.

Attachment C – Bruce Power, *Bruce Power reaches agreement with Isogen, BWXT to advance additional 'Made in Ontario' lifesaving isotopes*, Bruce Power, 20 July 2020, https://www.brucepower.com/2020/07/20/bruce-power-reaches-agreement-with-isogen-bwxt-to-advance-additional-made-in-ontario-life-saving-isotopes/.

Attachment D – UNSCEAR, *Sources, Effects and Risks of Ionizing Radiation: UNSCEAR 2013 Report: Volume I: Report to the General Assembly: Scientific Annex A: Levels and effects of radiation exposure due to the nuclear accident after the 2011 great east-Japan earthquake and tsunami*, United Nations, New York, 2014.

Attachment E – UNSCEAR, *Sources and Effects of Ionizing Radiation: United Nations Scientific Committee on the Effects of Atomic Radiation: UNSCEAR 2008: Report to the General Assembly with Scientific Annexes: Volume I*, United Nations, New York, 2010.

Attachment F – Thomas, G., Transcript of Evidence, Nuclear Fuel Cycle Royal Commission, 27 October 2015.

Attachment G – UNSCEAR, *Sources and Effects of Ionizing Radiation: United Nations Scientific Committee on the Effects of Atomic Radiation: UNSCEAR 1993 Report to the General Assembly, with Scientific Annexes: Annex B. Exposures from man-made sources of radiation*, United Nations, New York, 1993.

Attachment H – GPU Nuclear Corporation, *Radiation and health effects – a report on the TMI-2 accident and related health studies*, GPU Nuclear Corporation, Middletown, PA, 1986.

Attachment I – ARPANSA Fact Sheet: Japan Advisory – Radiation Levels in Japan.

Attachment J – International Energy Agency (IEA), Sustainable Recovery: World Energy Outlook Special Report, Flagship report — June 2020, IEA.