Wrong reaction: Why ‘next-generation’ nuclear is not a credible energy solution

Briefing paper, October 2022

AUSTRALIAN CONSERVATION FOUNDATION

Foreword

The pressing need to transition from fossil fuel energy to a low carbon future has seen renewed calls for domestic nuclear power in Australia's political arena.

But 'next generation' nuclear is not a credible energy response and the pursuit of nuclear power in Australia makes no sense. It would slow the transition to a low-carbon economy. It would increase electricity costs. It would unnecessarily introduce challenges and risks associated with high-level nuclear waste management and the potential for catastrophic accidents, with inter-generational economic implications for Australian taxpayers. In short, Australia's energy future is renewable, not radioactive.

Dave Sweeney, ACF Nuclear Free campaigner

It is important to note that proponents of nuclear power in Australia are **not** calling for the deployment of existing nuclear reactor technology. Instead, they are promoting 'next-generation' nuclear technology which currently does not exist to scale.

This briefing paper explores the global status of Small Modular Reactors and wider 'next-generation' nuclear technology and explores whether this technology is fit for purpose in Australia.

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Small Modular Reactors

Small modular reactors (SMRs) are defined as nuclear reactors with a generating capacity of less than 300 megawatts (MW) of electricity. In comparison, the capacity of the larger reactors that currently generate commercial nuclear electricity is around 1,000 MW.

Although SMRs have a public profile, they are mostly paper designs and lack any meaningful commercial existence in the real world. The small reactors that do exist are in Russia and China, but these projects have been subject to serious delays and cost blowouts. While there are hopes and dreams of ramping up SMR production, the mass manufacturing facilities needed to produce the technology are found nowhere in the world.

Prof. M.V. Ramana from the University of British Columbia analysed global SMRs has concluded:[1]

Once again, we see history repeating itself in today's claims for small reactors – that the demand will be large, that they will be cheap and quick to construct.

But nothing in the history of small nuclear reactors suggests that they would be more economical than full-size reactors. In fact, the record is pretty clear:

"Without exception, small reactors cost too much for the little electricity they produce, the result of both their low output and their poor performance."

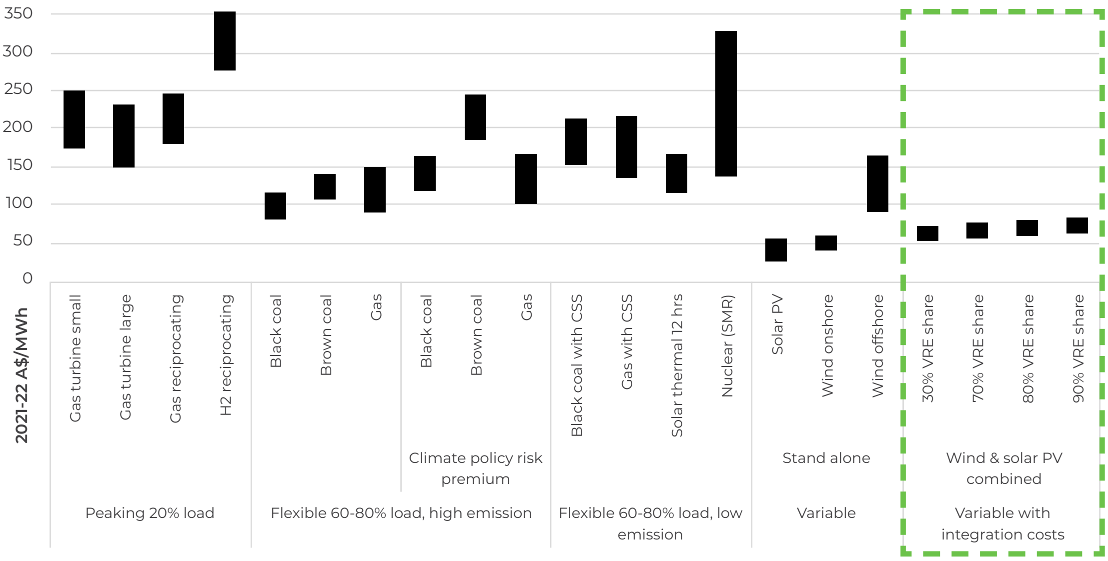
SMRs could not be introduced to Australia without huge taxpayer subsidies, and they would result in higher electricity prices.

[1] https://spectrum.ieee.org/tech-history/heroic-failures/the-forgotten-history-of-small-nuclear-reactors

Australia's energy future is renewable, not radioactive

In the 2022 GenCost report, CSIRO provides these 2030 cost estimates for Australia:[2]

- Nuclear (SMR): A$136-326 / MWh
- Wind and solar PV with integration costs (transmission, storage and synchronous condensers) necessary to allow these variable renewables to provide 90% of electricity: A$ 61-82 / MWh



ES Figure 0-1 Calculated LCOE by technology and category for 2030

Source: GenCost 2021-22, CSIRO Australia's National Science Agency

The federal Department of Industry, Science, Energy and Resources expects 69% renewable supply to the National Electricity Market by 2030.[3] The Albanese Government's target is 82% renewable supply by 2030.

State and Territory governments are focused on the renewables transition. Tasmania leads this effort while South Australia is another pacesetter with wind and solar supplying 64% of local power generation and the likelihood that SA could reach its target of 100% renewables within a few years.[4]

The contribution of renewable energy in Australia is rapidly growing and policy settings should advance this essential low carbon energy transition and avoid distraction, delay and unnecessary uncertainty.

[2] https://www.csiro.au/-/media/News-releases/2022/GenCost-2022/GenCost2021-22Final_20220708.pdf

[3] https://reneweconomy.com.au/renewables-to-supply-69-pct-of-australias-main-grid-by-2030-government-projections-show/

[4] https://reneweconomy.com.au/low-emissions-lower-prices-south-australias-remarkable-shift-to-wind-and-solar/

Too expensive

Existing nuclear power technology has been plagued by cost overruns and poor economic performance. This experience seems set to be replicated with next-generation nuclear technology. SMRs would inevitably suffer diseconomies of scale: a 250 MW SMR would generate 25 percent the power of a 1,000 MW reactor but would require more than 25 percent of the material inputs, staffing, waste management and other costs. Any potential savings from standardised factory production would not make up for these diseconomies of scale.

Every independent economic assessment finds that electricity from SMRs would be more expensive than that from large reactors.[5]

A 2015 report by the International Energy Agency and the OECD Nuclear Energy Agency predicts that electricity costs from SMRs would typically be 50–100% higher than current large reactors.[6]

A 2014 study published in Energy and Power Engineering concluded that fuel costs for integral pressurized water SMRs are estimated to be 15–70% higher than for large light water reactors, and points to research indicating similar comparisons for construction costs.[7]

A study published in the Proceedings of the National Academy of Sciences in 2018 concluded that it would not be viable to establish an SMR industry in the US unless the industry received "several hundred billion dollars of direct and indirect subsidies" over the next several decades "since present competitive energy markets will not induce their development and adoption."[8]

This insider scepticism was evident in a 2017 Lloyd's Register report based on the insights of almost 600 professionals and experts from utilities, distributors, operators and equipment manufacturers.[9] They predicted that SMRs have a "low likelihood of eventual take-up and will have a minimal impact when they do arrive".[10]

William Von Hoene, senior vice-president at US energy and nuclear giant Exelon, has also expressed scepticism about SMRs, saying they are **"prohibitively expensive".**[11]

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5 https://wiseinternational.org/nuclear-monitor/872-873/smr-economics-overview

6 https://www.oecd-nea.org/ndd/pubs/2015/7057-proj-costs-electricity-2015.pdf

7 https://www.scirp.org/journal/PaperInformation.aspx?PaperID=45669

8 https://www.pnas.org/content/115/28/7184

9 http://web.archive.org/web/20170514092923/http://www.lr.org/en/low-carbon-power/technology-radar.aspx

10 https://www.world-nuclear-news.org/EE-Nuclear-more-competitive-than-fossil-fuels-report-09021702.html

11 https://www.spglobal.com/platts/en/market-insights/latest-news/electric-power/041218-no-new-nuclear-units-will-be-built-in-us-due-to-high-cost-exelon-official

False promises

SMRs would be more inefficient than large reactors in every aspect, and hence more costly.

A 2016 European Commission report notes that SMR decommissioning and waste management costs "will probably be higher than those of a large reactor with some analyses stating between two and three times higher."[12]

The 2016 South Australian Nuclear Fuel Cycle Royal Commission report said:

> **"SMRs have lower thermal efficiency than large reactors, which generally translates to higher fuel consumption and spent fuel volumes over the life of a reactor."** [13]

A *Nuclear Technology* journal article notes that integral pressurised water SMRs (iPWRs) "are likely to have higher requirements for uranium ore and enrichment services compared to gigawatt-scale reactors. This is because of the lower burnup of fuel in iPWRs, which is difficult to avoid because of smaller core size and all-in-all-out core management."[14]

A study published in the *Proceedings of the National Academy of Sciences* in 2022 concludes that SMRs would produce more voluminous and chemically reactive waste than conventional large reactors due to the use of neutron reflectors and chemically reactive fuels and coolants in SMR designs. The study finds that water, molten salt, and sodium cooled SMR designs would increase the volume of nuclear waste by factors of 2 to 30.[15]

[12] https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A52017SC0158&print=true

[13] https://nuclear.foe.org.au/wp-content/uploads/NFCRC_Final_Report_Web_5MB.pdf

[14] https://www.tandfonline.com/doi/abs/10.13182/NT13-A19873

[15] https://www.pnas.org/doi/10.1073/pnas.2111833119

Russia and China: the SMR experience

Globally just two Small Modular Reactors are understood to be operating. One is in Russia and the other in China and in both cases the cost blow outs have been enormous.

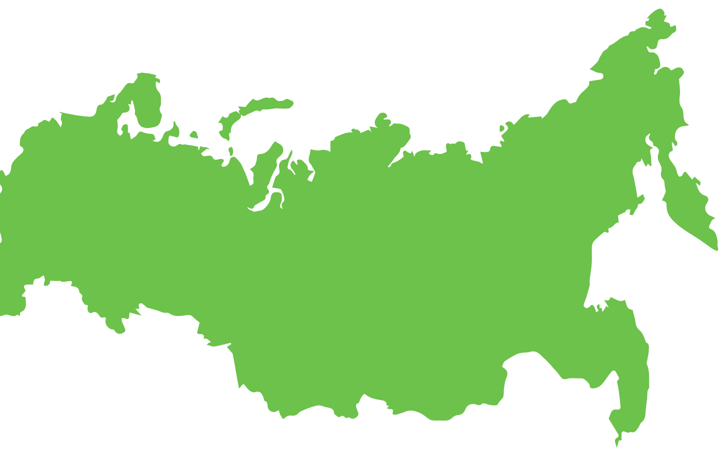
Russia

Russia has a floating nuclear power plant with two 35 megawatt small modular reactors. The construction cost increased six-fold from 6 billion roubles to 37 billion roubles (A$900 million).

According to the OECD's Nuclear Energy Agency, electricity produced by the Russian floating plant costs an estimated US$200 (A$294) / megawatt-hour (MWh). The exorbitant cost is due to large staffing requirements, high fuel costs, and the resources required to maintain barge and coastal infrastructure.[16]

Importantly, the Minerals Council of Australia states that SMRs would not find a market in Australia unless they could produce power at a cost of A$60–80 / MWh[17] which is about one-quarter of the cost of electricity produced by the Russian SMR's.

It is ironic that while SMRs are promoted as potential contributors to climate change abatement the primary purpose of the Russian floating plant is to power fossil fuel mining operations in the Arctic.[18]



Further, Russia's pursuit of nuclear-powered icebreaker ships is closely connected to its agenda for military and economic control of the Northern Sea Route – a route that owes its existence to climate change.[19]

Rapid construction timelines are said to be a feature of SMRs, but the floating plant took 12 years to build[20] and Russia's plan to have seven floating nuclear power plants by 2015 has not been realised.[21]

Russia's floating nuclear power plant.

[16] https://www.oecd-nea.org/ndd/pubs/2016/7213-smrs.pdf

[17] https://www.parliament.vic.gov.au/images/stories/committees/SCEP/Inquiry_into_Nuclear_Prohibition_Inquiry_/Transcripts/25_June_2020/5._FINAL_-_Minerals_Council_Aust.pdf

[18] https://www.wiseinternational.org/nuclear-monitor/861/worlds-first-purpose-built-floating-nuclear-plant-akademik-lomonosov-reaches

[19] https://www.popularmechanics.com/military/navy-ships/a27615565/ural-russia-icebreaker/

[20] https://www.worldnuclearreport.org/The-World-Nuclear-Industry-Status-Report-2021-HTML.html#_idTextAnchor013

[21] https://en.wikipedia.org/wiki/Russian_floating_nuclear_power_station

China

The other operating SMR is China's demonstration 210 MW (2 x 105 MW) high-temperature gas-cooled reactor (HTGR).

A 2016 report said that the estimated construction cost was about US$5 billion (A$7.4 billion) / GW – about twice the initial cost estimates.

The price increases arose from higher material, labour and component costs and project delays.

The World Nuclear Association states the cost of China's demonstration HTGR is US$6 billion (A$8.8 billion) / GW. In 2021, Wang Yingsu, secretary general of the nuclear power branch of the China Electric Power Promotion Council, said that HTGRs would never be as cheap as the existing conventional light-water reactors.

Construction of the demonstration HTGR began in 2012 and was completed in 2021 after repeated delays and taking over twice as long as promised.

In 2020 NucNet reported that China's State Nuclear Power Technology Corp had dropped plans to manufacture 20 HTGRs on economic grounds.

The world's two operational SMRs exhibit the familiar problems of massive cost blowouts and multi-year delays that have plagued the conventional nuclear fleet. The global SMR reality simply does not come close to matching the Australian SMR rhetoric.

[22] http://www.nextbigfuture.com/2016/12/chinas-plans-to-begin-converting-coal.html
See also https://www.nextbigfuture.com/2017/08/china-small-modular-pebble-beds-will-be-400-million-for-200-mw-and-1-2-billion-for-600-mw.html

[23] https://www.world-nuclear.org/information-library/country-profiles/countries-a-f/china-nuclear-power.aspx

[24] https://www.scmp.com/news/china/science/article/3159945/china-revives-abandoned-htgr-nuclear-technology-safe-power-drive

[25] David Dalton, "China Begins Construction Of First Generation IV HTR-PM Unit", NucNet, 7 January 2013, see http://www.nucnet.org/all-the-news/2013/01/07/china-begins-construction-of-first-generation-iv-htr-pm-unit accessed 9 January 2013.

[26] https://www.world-nuclear-news.org/NN-First-vessel-installed-in-Chinas-HTR-PM-unit-2103164.html

Failed and cancelled projects

Numerous 'next-generation' nuclear projects have been cancelled over the past decade, including:

- The French government abandoned the 100–200 MW ASTRID demonstration fast reactor in 2019.[27]
- Babcock & Wilcox abandoned its Generation mPower SMR project in the US despite receiving government funding of US$111 million.[28]
- Transatomic Power gave up on its molten salt reactor R&D in 2018.[29]
- MidAmerican Energy gave up on its plans for SMRs in Iowa in 2013 after failing to secure legislation that would require ratepayers to partially fund construction costs.[30]
- TerraPower abandoned its plan for a prototype fast neutron reactor in China due to restrictions placed on nuclear trade with China by the former Trump administration.[31]
- The US government abandoned consideration of 'integral fast reactors' for plutonium disposition in 2015[32] and the UK government did the same in 2019.[33]

[27] https://www.reuters.com/article/us-france-nuclearpower-astrid/france-drops-plans-to-build-sodium-cooled-nuclear-reactor-idUSKCN1VK0MC
[28] https://wiseinternational.org/nuclear-monitor/872-873/mpower-obituary
[29] https://wiseinternational.org/nuclear-monitor/867/nuclear-news-nuclear-monitor-867-15-october-2018
[30] https://pauldeaton.com/2013/06/04/iowa-pulls-the-plug-on-nuclear-power/
[31] https://www.reuters.com/article/us-terrapower-china/bill-gates-nuclear-venture-hits-snag-amid-us-restrictions-on-china-deals-wsj-idUSKCN1OV1S5
[32] https://nuclear.foe.org.au/wp-content/uploads/2019-Federal-Nuclear-Inquiry-Joint-ENGO-Submission-Final.pdf
[33] Appendix 3, https://nuclear.foe.org.au/wp-content/uploads/2019-Federal-Nuclear-Inquiry-Joint-ENGO-Submission-Final.pdf

Under construction: a dicey and pricey future

Three SMRs are under construction but none will involve serial factory production of reactor components.

In Argentina, cost estimates for the unfinished CAREM SMR have ballooned. When construction began in 2014, the cost estimate was US$446 million for a 25-MW reactor.[34]

In 2021, the cost estimate increased to US$750 million (A$1.1 billion) with the capacity increased from 25 MW to 32 MW.[35]

This is an expenditure of over one billion Australian dollars for a plant with the capacity of a handful of wind turbines.

The CAREM project is years behind schedule and costs will likely increase. When construction began in 2014, completion was expected in 2017.[36] But progress has been slow and work has been suspended on several occasions.[37] The estimated reactor start date is now 2027,[38] meaning a three year construction plan has become a 13-year project with no guarantee of an end result.

Above: The CAREM SMR under construction in Argentina.

[34] https://www.world-nuclear-news.org/NN-Construction-of-CAREM-underway-1002144.html

[35] https://www.gihub.org/quality-infrastructure-database/case-studies/carem-25-prototype/

[36] https://www.world-nuclear-news.org/NN-Construction-of-CAREM-underway-1002144.html

[37] https://www.world-nuclear-news.org/Articles/Construction-of-Argentinas-small-CAREM-25-unit-to

[38] Daniel E. Arias, "'El CAREM, un salto cualitativo para el sector nuclear argentino'. Por eso, AgendAR propone una UTE" ((in Spanish)), AgendAR, 5 June 2022, see https://agendarweb.com.ar/2022/06/05/el-carem-un-salto-cualitativo-para-el-sector-nuclear-argentino-por-eso-agendar-propone-una-ute/ accessed 18 June 2022.

In July 2021, China National Nuclear Corporation (CNNC) New Energy Corporation began construction of the 125 MW pressurised water reactor ACP100 at Hainan. CNNC says it will be the world's first land-based commercial SMR. The ACP100 has been under development since 2010.

According to CNNC, construction costs per kilowatt will be twice the cost of large reactors, and the levelised cost of electricity will be 50% higher than large reactors.

In June 2021, construction of the 300 MW demonstration lead-cooled BREST fast neutron reactor began in Russia. Plans for a lead-cooled fast reactor in Russia date from the 1990's but construction has been repeatedly delayed. In 2016, construction of BREST was expected to begin in 2017 and completion was expected in 2020. Completion is now expected in 2026.
In 2012, the estimated cost for the reactor and associated facilities was 42 billion rubles (A$882 million) . Today, the estimate has more than doubled to 100 billion rubles (A$2.1 billion).

The SMR plans of US company NuScale Power are heavily promoted. Development of NuScale SMR technology dates from 2003 – almost 20 years ago – yet the company has not begun construction of a single reactor. A study by WSP / Parsons Brinckerhoff, commissioned by the South Australian Nuclear Fuel Cycle Royal Commission, estimated costs of A$225 / MWh for SMRs based on the NuScale design. This is well above the cost guidelines set out by the Minerals Council of Australia.

[39] https://world-nuclear-news.org/Articles/Installation-of-containment-starts-at-Chinese-SMR

[40] https://world-nuclear-news.org/Articles/Installation-of-containment-starts-at-Chinese-SMR

[41] https://world-nuclear-news.org/Articles/Installation-of-containment-starts-at-Chinese-SMR

[42] https://nucleus.iaea.org/sites/INPRO/df17/IV.1.-DanrongSong-ACP100.pdf

[43] https://www.neimagazine.com/features/featurebrest-is-best/
https://www.powermag.com/nuclear-first-work-starts-on-russian-fast-neutron-reactor/

[44] https://www.nsenergybusiness.com/news/newsconstruction-of-russias-brest-reactor-to-start-next-year-4974446/
https://www.nsenergybusiness.com/news/newsbreakthrough-project-continues-as-brest-reactor-is-postponed-5718901/
https://bellona.org/news/nuclear-issues/2015-05-perpetual-search-perpetuum-mobile

[45] https://bellona.org/news/nuclear-issues/2015-05-perpetual-search-perpetuum-mobile

[46] https://tass.com/economy/1300401

[47] https://d3n8a8pro7vhmx.cloudfront.net/oregonpsrorg/pages/21/attachments/original/1600287829/EyesWideShutReport_Final-30August2020.pdf

[48] http://nuclearrc.sa.gov.au/app/uploads/2016/05/WSP-Parsons-Brinckerhoff-Report.pdf

Next generation nuclear power

SMRs are the most widely promoted of the range of 'next generation' nuclear technology but there are other variations. Each proposal faces uncertainty and high barriers to any future commercialisation.

Conventional or 'light water' reactors are fuelled by uranium and cooled by ordinary 'light' water, which also slows the neutrons that maintain the nuclear chain reaction. Advanced nuclear power generally refers to reactors – large or small – with different fuels, moderators and coolants.

Most of these concepts are far from advanced and some previous projects have been underwhelming or scrapped as outright failures. David Elliot, the author of the 2017 book Nuclear Power: Past, Present and Future notes that many 'advanced' nuclear power concepts "are in fact old ideas that were looked at in the early days and mostly abandoned."

Physicist Dr. Edwin Lyman authored a report for the US based Union of Concerned Scientists debunking claims that 'advanced' nuclear power concepts offer significant advantages over conventional nuclear power. The report considered sodium-cooled fast reactors, high-temperature gas–cooled reactors and molten salt reactors.

Dr. Lyman said:

“

Based on the available evidence, we found that the designs we analysed are not likely to be significantly safer than today's nuclear plants.

In fact, certain alternative reactor designs pose even more safety, proliferation, and environmental risks than the current fleet. Developing new designs that are clearly superior to LWRs [light water reactors] overall is a formidable challenge, as improvements in one respect can create or exacerbate problems in others".

[49] https://www.wiseinternational.org/nuclear-monitor/844/back-future-old-nukes-new

[50] https://ucsusa.org/resources/advanced-isnt-always-better

The pathway to a low-carbon energy future

It is important to note that promoters of nuclear power in Australia are **not** suggesting we build the nuclear technology that currently exists in the commercial world.

The reactors that exist today are increasingly seen as a high cost and high risk way to make electricity. They are also directly linked to high level radioactive waste and nuclear security, weapons and terrorism concerns.

This means nuclear promoters are staking their hopes – and Australia's energy future – on technology which is uncertain and unproven.

The good news about the renewed nuclear discussion is that it highlights that business as usual with fossil fuels is not an option. The bad news is the very real risk of delay, distraction and a failure to advance a just energy transition.

We cannot afford to lose more time on the false promise of unproven and non-commercial technology.

At the time of the 2021 Glasgow COP26 the UN Secretary General's Special Advisor on Climate Change, Selwin Hart stated that nations seeking to base their climate response on technologies that have not yet been developed are "reckless and irresponsible".[51]

The Climate Council made a comparable point in a January 2022 position statement that found

"meeting the climate challenge means taking bold and decisive action this decade with the technologies that are ready to go in Australia today. The significant limitations nuclear energy faces means that there is no real prospect of it playing a role in reducing Australia's emissions".[52]

The former head of the Commission for the Future and long standing nuclear industry commentator Professor Ian Lowe has observed "there does not appear to be any rational basis for expecting nuclear power in Australia. It is too expensive and would be too slow to make a difference to our greenhouse gas emissions".[53]

The former Chair of the US Nuclear Regulatory Commission, Professor Allison Macfarlane provided a further powerful reality check in 2021 stating, "when it comes to averting the imminent effects of climate change, even the cutting edge of nuclear technology will prove to be too little, too late".[54]

Wishful thinking is no substitute for real world evidence and action, or for effective climate action.

Renewable energy exists in the real world and this is the crucial decade when real climate action is urgently needed to make the required transition to a low carbon future.

[51] https://au.news.yahoo.com/broke-the-trust-telling-detail-in-morrisons-call-with-french-pm-222011707.html

[52] https://www.climatecouncil.org.au/nuclear-power-stations-are-not-appropriate-for-australia-and-probably-never-will-be/

[53] Ian Lowe, Long Half Life, Monash University Publishing, 2021

[54] https://www.foreignaffairs.com/articles/2021-07-08/nuclear-energy-will-not-be-solution-climate-change?fbclid=IwAR0XhozSSxQhuNQ8sy9Rr3KrZbUkB_uc6KpDbBBubyXPnoj3_6Su1B-8S8E

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