Adv - IFRs

New Trump rollbacks increase urgency for climate policy. Gibson 25

Kalina Gibson, Research Assistant, International Climate Policy 1-20-2025, "The Trump Administration's Retreat From Global Climate Leadership," Center for American Progress, https://www.americanprogress.org/article/the-trump-administrations-retreat-from-global-climate-leadership/ //rchen

With **the next decade** being the **most critical window to curb** global **warming**, the **consequences of federal inaction** will be felt in every corner of the country. While subnational actors and market forces are driving progress that cannot be easily reversed, the absence of U.S. federal leadership will slow the pace of advancements, discourage private investments, and leave the United States trailing behind global competitors, such as China, who are seizing the opportunities of a clean energy future. The clean energy sector has already proven its potential, growing faster than fossil fuels in global electricity generation in recent years. States such as Texas and Iowa are leading the way in wind power, while California leads the country in solar energy generation. Turning away from this progress jeopardizes not just the planet but also the economic livelihoods of millions of Americans. **Under** the **Trump** administration, U.S. greenhouse gas **emissions** levels are estimated to **rise** up to **36 percent** higher than current policy by 2035 and domestic impacts could also include higher household energy costs and greater dependence on imported oil and gas. During his first administration, **Trump rolled back** more than 100 **environmental rules**—a series of reversals estimated to dramatically increase greenhouse gas emissions over the following 15 years and lead to thousands of deaths from poor air quality. By stepping back at this critical time when climate action must accelerate, the United States risks more than its reputation; it risks its economy, its communities, and its future.

Both fossil fuels and traditional renewable energy are unsustainable. Only modernized nuclear power solves. Rehm '23

[Thomas Rehm; March 2023; Ph.D. in chemical engineering from Northwestern University; Current Opinion in Chemical Engineering, "Advanced Nuclear Energy: The Safest and Most Renewable Clean Energy, "https://www.sciencedirect.com/science/article/abs/pii/S2211339822000880] rchen

Are solar and wind renewable? **Solar** and **wind** have renewability **problems due to** planetary **mineral** resource **limits** [8], the **social impact of mining** those resources [18], and **mineral recycling** challenges at end of equipment useful life [19] We are disingenuous if we do not look at least 200 years into the future. Psychologists say that a human is sincerely concerned with his/her children, grandchildren, and great-grandchildren. Beyond those three generations, most humans do not care what happens to distant progeny. I may have great-grandchildren born as far out as my 100th birthday in 2050, and they might live 100 years. Our action plan must be at least 200 years out. Owing to the variability of solar and wind, 100% 'renewable' plans depend on energy storage. Battery storage is the hope. Lucas Bergkamp, Editor of Road to EU Climate Neutrality by 2050, does not hold that view. "You cannot, in the near future at least, have an energy storage system that will allow you to power a whole country through batteries," he told EURACTIV, saying another energy source, such as nuclear or fossil fuels, will be needed to provide baseload electricity [20]. Solar is challenged in far northern latitudes. Earth's 'center of population' latitude is 25.92 degrees north. At that latitude, solar irradiation on the winter solstice is reduced by 35%. One-fourth of Earth's population lives above 36.37 degrees north latitude, corresponding to a reduction of solar irradiation by 50% on the winter solstice [21], [22]. Sunlit hours also drop with increasing latitude. As the earth heats up, the population will undoubtedly shift farther north, exacerbating the solar energy 'solution'. Fewer people will live in areas that are good for solar generation of electricity. A nuclear plant can operate anywhere. But is not nuclear too costly? Nuclear is a better choice than solar and wind on both a land requirement basis and a consumer cost basis [20]. Overly optimistic views of solar and wind, coupled with an unfounded fear of nuclear, are leading many to shutter legacy nuclear plants. The United States currently has 296 GW of nuclear energy capacity. If we do not keep these plants open through license renewals, we will lose 50 GW of nuclear capacity by 2030, 150 GW by 2040, and nearly all of it by 2050 [23]. We must not shut down legacy nuclear plants. Advanced nuclear energy is truly renewable Although proven uranium reserves only give legacy technology 90 more years, **advanced tech**nology is good for thousands of years. Uranium ore contains 100 times more U238 than U235. Advanced nuclear can theoretically **provide 9000 years of** renewable **energy** from those reserves at today's energy demand, and that is not taking into account the legacy nuclear **'waste'** now safely stored, which **can become fuel** for advanced reactors. **Advanced tech**nology can be **commercially viable** in the United States by the 2030s. In 2001, nine nations formed the Generation IV2 International Forum (GIF) [24] to develop sustainable, economic, safe, reliable, proliferation-resistant, and physically protected nuclear reactors. Founding GIF countries include Argentina, Brazil, Canada, France, Japan, the Republic of Korea, the Republic of South Africa, the United Kingdom, and the United States. Subsequently, Switzerland (2002), Euratom (2003), the People's Republic of China (2006), the Russian Federation (2006), and Australia (2016) became members. There are now two operational advanced reactors, one in Russia and one in China. The Russian BN-800 reactor, a sodium-cooled fast breeder reactor, in Zarechny, was connected to the grid in December 2015 [25]. China's high-temperature pebble-bed modular reactor HTR-PM was connected to the grid in December 2021 [26]. The United States is lagging, but work is underway to catch up. US Department of Energy (DOE) made two awards to build advanced reactors by 2027 [27], one to TerraPower [28] on Natrium technology, and the other to X-energy [29]. TerraPower is working to commercialize three technologies, the molten chloride reactor, the Traveling Wave Reactor, and the Natrium reactor that is a sodium fast reactor incorporating the design features of the Traveling Wave Reactor. Natrium is its premier technology, which will be demonstrated at the Naughton coal-fired power plant in Kemmerer, Wyoming, which is retiring in 2025. X-energy has a moving pebble-bed high-temperature gas reactor (HTGR) design that will have 220 000 graphite pebbles with TRIstructural-ISOtropic (TRISO) particle fuel. They expect a 60-year operational life [30]. How about thorium? Per the Thorium Energy Alliance [31]: Because liquid fluoride thorium reactors (LFTRs) burn virtually all of their fuel, 83% of the waste products are safe within ten years and the remaining 17% become safe after 300 years. LFTRs can be used to burn legacy nuclear 'waste'. Thorium is the 36th most plentiful element in the earth's crust. It is four times as common as uranium. LFTRs have no refueling outages. They are continually refueled and continually remove waste product. LFTRs can be factory-produced, allowing for lower costs and shorter commissioning timetables. Kirk Sorensen, Founder of Flibe Energy, details the many LFTR benefits in a short video, those benefits being safety, a 100-fold decrease in waste generated, and immense quantities of thorium on the planet [1]. China is a leader in thorium. Experts say that China could be the first to commercialize thorium technology. An experimental thorium reactor in Wuwei could result in an operational 300 + MW thorium reactor by 2030 [32]. Centrus Energy Corporation and Clean Core Thorium Energy are working on an advanced nuclear fuel that combines thorium with high-assay, low-enriched uranium (HALEU). The new fuel is called Advanced Nuclear Energy for Enriched Life (ANEEL). ANEEL has less than 20% U238, compared with more than 94% in LWR fuel. HALEU is itself enriched to between 5% and 20% U235 [33]. In May 2022, the Norway-based marine group Ulstein announced a concept design for cruise ships using a thorium Molten Salt Reactor [34]. There are significant advantages of molten salt reactors and hot-salt storage. A molten salt reactor has its nuclear fuel dissolved in fluoride salt or chloride salt. The Terrapower/Southern fast reactor is molten chloride. The Moltex design is a molten chloride fast reactor. Kairos Power has a fluoride salt reactor design. Flibe's salt is Li_2BeF_4 salt that has a melting point of 459 °C and a normal boiling point of 1430 °C [35]. Molten salt allows a design with a secondary hot-salt loop with storage and a separate 'power block' cycle to produce power-on-demand from the stored hot salt, allowing load following functionality as delivery of heat is controlled by a hot-salt pump. As the power block is not coupled to the reactor, it can be built to non-nuclear standards. The salt in the loop is a nitrate salt in common use in concentrated solar power plants [36]. Although molten salt reactors hold much promise, there are challenges, the most significant being the risk of corrosion in reactor structural materials from high-temperature molten salt. A considerable amount of development work remains to be done on salt redox potential measurement and control tools in order to limit the corrosion rate [37]. Advantages of small modular reactors Small modular reactors (SMRs) are nuclear plants of 300 MWe or less. SMRs have several advantages over large nuclear plants.Onsite construction of large nuclear plants can take many years and have associated cost overruns. SMRs will be factory-built and moved to the site by truck, railcar, or barge. SMRs employ economies of mass production rather than economies of scale. Advanced technology SMRs are now operational. Two Russian SMRs (Pressurized Water Reactor, type KLT-40S) have been in operation in Port Pevek, Russia, since December of 2019 [25], [38], and two Chinese helium-cooled pebble-bed reactors (HTR-PM) were connected to the grid in December 2021 [26]. Advanced technology SMRs could be **deployed in** very **large numbers** in the next decade, in time **to meet 2050 net-zero** goals. The emergency planning zone around a large legacy plant is typically 10 miles. The DOE 'strongly supports' an NRC proposal to apply risk-based emergency preparedness requirements for SMRs, which will significantly reduce the size of this zone [39]. Gen III+ water-moderated/cooled SMRs have a design advantage over legacy technology. Even though the reactor is designed at 2000 psig, its small size allows for ease of containment manufacture compared with a large legacy reactor. For example, each 3 m-wide NuScale reactor nestles into its own 4.6 m-wide steel containment vessel [40]. Argentina, China, and the Russian Federation are on course to begin commissioning SMRs. North America will likely be the next to deploy an SMR, as the United States is looking at 2027 for the start of operations. Canada also expects to start-up demonstration reactors in 2027 [41]. The HTGR is a moving 'pebble bed' SMR design with an exit temperature of 750 °C or higher, ideal for providing industrial process heat. The Japanese HTGR Development Program achieved 50 days of continuous 950 °C operation in a test reactor in 2010 [42]. A major DOE/Industrial program is underway to commercialize HTGRs for industrial applications, being led by Dow Chemical [17]. Each pebble is TRISO coated and is about the size of a tennis ball. Each pebble is its own nuclear reactor, the outer shell being its containment vessel. Each reactor is cooled down by passive natural circulation, usually a gas such as helium, making it impossible for an accident such as Fukushima to occur. TRISO fuels are fabricated by BWX Technologies Nuclear Operations Group (Lynchburg, Virginia) [43]. In 2017, Neutron Bytes reported that China is an HTGR leader. China is actively promoting its HTGR technology in Saudi Arabia, South Africa, the United Arab Emirates, and Indonesia [44]. China is building an HTGR demonstration plant that will have two reactor modules. The objective is a full-scale power plant with eighteen 210 MWe units. In March 2020, China announced that the reactors, steam generator, and hot gas ductwork of the demonstration plant were connected [45]. Penultimate Power in the United Kingdom has partnered with the Japanese Atomic Energy Agency to develop plans for HTGR technology to be operational in Britain by 2029 [46]. Establishment of safety regulations associated with SMRs are not yet resolved. However, the Nuclear Regulatory Commission is working to resolve policy questions such as SMR siting, offsite emergency planning, and security and safeguards [47], [48], which are strongly supported by the U.S. Department of Energy [39]. Uranium and thorium reserves At current global nuclear capacities, we have about 90 years of proven uranium reserves. There also is uranium in our oceans at a concentration of 3.3 micrograms per liter, which could provide tens of thousands of years of uranium [49]. Scientists from Oak Ridge National Laboratory have demonstrated a material that can adsorb 6 g of uranium for every kilogram of adsorbent material [50]. Rainfall runoff from land masses will renewably replenish any uranium we remove from seawater. There are about 6.4 million tonnes of thorium reserves. India leads with 846 000 tonnes, and has made utilization of thorium a major goal in its nuclear power program. The United States has the 3rd largest reserves at 595 000 tonnes. Russia and China lag considerably behind the United States with 155 000 tonnes and 100 000 tonnes, respectively. The United States can be a leader in thorium advanced reactor technology [51]. Replacing crude oil: large-scale nuclear biorefineries Crude oil and natural gas provide about 85% of the feedstocks in chemical manufacturing [52]. More than 500 million tonnes of oil-equivalent feedstock are consumed each year to make nearly 1 billion tonnes of chemical products [53]. If we are to decarbonize, we must figure out how to end our dependency on fossil fuels for chemical feedstocks. This can be done. A nuclear biorefining initiative is being led by MIT and INL. Highlights of this effort [54].3. Replacing liquid hydrocarbons will be extremely difficult. In the United States, about 18 million barrels/day of petroleum products are produced. To achieve the scale of biorefining capacity necessary to replace fossil fuels, three technologies are needed: Consolidation of biomass into energy-dense, anaerobically stored, economically shippable commodities that are available year-round. Biorefineries at the scale of 250 000 barrels per day. Nuclear energy providing electricity, process heat, and hydrogen to the biorefinery. In the United States, one billion tons of biomass will be required each year to match current consumption of refining products. The DOE and the USDA estimate that 1.4 billion tons could be produced, but that number could be tripled if (a) we pay farmers more; (b) we use 10% of semi-arid lands to plant opuntia (prickly pear cactus); (c) we use double-cropping extensively; (d) we integrate food/feed/fuel production; (e) we improve pasture/energy crop productivity; and (f) we rehabilitate saline, retired, and degraded lands. Nuclear biofuels could be deployed at scale in 20 years. Conclusions We must transition to carbon-neutral energy. Solar and wind are not truly renewable. Advanced nuclear is far more renewable with promises of many thousands of years of clean energy. It is also the safest form of electricity generation. Industry fatalities per TWe-year are less than 0.01 for legacy nuclear energy, one to three orders of magnitude lower than solar or wind. Most of those legacy fatalities were from plants designed with high-pressure Generation-II technology. Generation-III technology is safer, having its primary focus on safety. Generation-IV advanced nuclear technology is safer yet. Fear of catastrophic nuclear accidents is driving us away from the best chance we have of solving global warming. That fear is unfounded. Some say that we must reduce energy consumption! They say we must reduce the planet's population that will help reduce energy consumption. Wishful thinking will not get us out of this mess. About 1–3 billion people on our planet either have no electricity or have very meager/unreliable electricity. They will burn oil and gas, dung, or anything they can get their hands on, to produce energy. We must figure out a way to replace fossil fuels for firm baseload. Energy demand will likely double during this century, regardless of wishful thinking. **Advanced nuc**lear **energy is** the **only viable option for rapidly replacing fossil fuels** as firm baseload. Do not be swayed by the argument that nuclear cannot possibly ramp up in time to accomplish this objective. We can achieve major increases in nuclear energy capacity by 2040 if we put our minds and money to it.

Specifically IFRs are the only hope for saving the planet. Snyder '23

[Van; March 16; spent 53 years as a mathematician and engineer at the Caltech Jet Propulsion Laboratory, MS in Applied Mathematics and System Engineering, spent seventeen years as an adjunct associate professor; "Five Myths About Nuclear Power," https://substack.com/home/post/p-108860660?utm_campaign=post&utm_medium=web] rchen

IFR-type **reactors extract 99**.99**% of the energy** immanent **in** mined **uranium** but **today's reactors extract** only **0.6%**. The price of uranium would contribute the same amount to the delivered electricity price from IFR-type reactors if it were to increase 167 fold. Uranium could be economically extracted from lower quality ores, or from seawater, where there is estimated to be at least a thousand times more than could be extracted from land. Another low-quality ore is coal-fired power plant waste, which contains nineteen times more energy in the form of uranium and thorium than was extracted by burning the coal. Thorium, four times more common than uranium, can be converted to fissile fuel by neutron transmutation in a fast-spectrum reactor. **Nuclear fission is** an effectively **inexhaustible** source of energy. It is possible to breed about 5% more fuel from uranium than is consumed, but only about 1% more from thorium. If the goal is to deploy a fleet of new breeder reactors fueled only by recycled fuel, thorium should not be used before sufficient reactors are in service. The first two goals of the IFR project were safety and waste mitigation. The third was fuel economy. The system problem Most **energy discussions focus only on** components — **wind** turbines **and solar** panels. Electricity production and distribution is a system problem, not simply a component problem. In Burden of Proof: A comprehensive review of the feasibility of 100% renewable-electricity systems, Renewable and Sustainable Energy Reviews 76, Elsevier (2017), pp 1122-1133, Ben Heard et al described an analysis of 24 studies that claimed to explain how to construct and operate regional, national, or continental-scale electricity systems. **None** of the studies described systems that were **physically feasible**. Heard et al concluded there was no point to study economic viability. A more serious system problem is that the **Earth does not have sufficient materials to build** the "technology units" that the International Energy Agency (IEA) demands be built to provide all energy from renewable sources. To stay out of the weeds, here is just one problem: **Five times more copper is needed than** is **known to exist** on the Earth in forms that can be recovered.

IFRs are cost-effective but comparatively underfinanced. Snyder '23

[Van; March 16; spent 53 years as a mathematician and engineer at the Caltech Jet Propulsion Laboratory, MS in Applied Mathematics and System Engineering, spent seventeen years as an adjunct associate professor; "Five Myths About Nuclear Power," https://vsnyder.substack.com/p/five-myths-about-nuclear-power?utm_campaign=post&utm_medium=web rchen

It's too expensive (no it isn't) A 2009 MIT study concluded that **nuclear** power plants could be **built for $4 per watt**, and **produce electricity for 6¢** per kWh. Reactors under construction in Finland and Sweden cost about $7.50 per watt; ones in China cost $1.50 per watt. **Delays due to** lawsuits, difficulty certifying a new reactor, and licensing in an ever-changing regulatory environment add significant **cost**, especially interest on capital. It would be helpful if the Nuclear Regulatory Commission were to adopt the French system of licensing reactor designs, instead of individual reactors. The operating cost of a reactor is quite low because fuel cost is low. Using $30/lb for uranium ore and 4.5% enrichment, the contribution of the cost of uranium to the price of electricity is 0.116¢ per kilowatt hour (kWh). This was the origin of Lewis Strauss's infamous '"too cheap to meter" quip, which ignored all other costs. Reducing oxide to metal, enriching the concentration of the fissile isotope (U-235) from the natural state of 0.7%, to 5%, and fabricating fuel assemblies, increase the fuel price to 0.5¢ per kilowatt hour. Economic details are explained in Chapter 13 of Plentiful Energy. The lowest-cost electricity in California, 5¢ per kWh, is produced by the Diablo Canyon Nuclear Generating Station. Fixed cost amortization over the life of the facility contributes 74%, or 3.7¢ per kWh. Labor and other non-fuel recurring costs are 0.8¢ per kWh. The average California delivered electricity price is 30¢ per kWh. The 3.3 GWe Palo Verde nuclear generating station in Arizona was constructed for $1.79 per watt. Its delivered price for electricity is 4.3¢ per kWh. It is the most profitable electric utility in the U.S. Waste disposal is incorrectly cited as a social cost not internalized in the pricing structure. Since 1981, utilities had been paying 0.1¢ per kWh into the Federal Nuclear Waste Disposal Fund for this purpose, until a Federal court ruled in 2013 they no longer needed to pay because the Department of Energy had reneged on its legal responsibility to take custody of spent fuel. It was included in the rate customers paid. The fund now stands at $43 billion. Nuclear power is the only industry that fully internalizes all costs! Another factor sometimes cited is subsidies. **Federal subsidies** for light-water reactors **are** larger than subsidies for gas or hydro generation, but substantially **less than for wind or solar** photovoltaic (PV). State and local subsidies vary. The additional California solar PV subsidy is 40% of the Federal subsidy. The first full-scale instance of any new system is always expensive, but both construction and **operating costs** always **decrease with experience**. A 300 MWe **IFR**-type reactor **could be built for less than $8 per watt**. A GE/Hitachi consortium estimates they could build 380 MWe modular instances called S-PRISM (Super Power Reactor Innovative Small Modular) for less than $2 per watt, if they were to have a stream of orders that is sufficiently secure to justify a factory to construct essentially identical ones, instead of building each one, subtly different from any other, on site. In Conceptual Design of a Pilot-Scale Pyroprocessing Facility, Argonne National Laboratory and Merrick & Company proposed a forty hectare $398 million pilot-scale pyroelectric refining facility to process 100 tonnes per year of any type of spent fuel, a small fraction of the cost of a PUREX facility. Operating cost would be 0.05¢/kWh. Because utilities paid into the Federal Nuclear Waste Disposal Fund, and because Yucca Mountain has been canceled, this facility and similar larger-scale facilities ought to be constructed using those funds, not funded as part of the construction of new reactors, and not from the general fund of the Federal treasury — but the Nuclear Waste Disposal Act prohibits using the funds for reprocessing. If the goal of modernizing the energy sector is to reduce or eliminate carbon dioxide (CO2) emissions, comparison to fossil fuels is irrelevant. Several scientists calculated that the only renewable source that can in principle provide all current energy usage is solar. Wind cannot provide more than about 15% of current total energy usage, which will surely increase (and wind won't). Conservation and all other schemes, alone or together, are inadequate to close the gap between wind supply and energy demand. Solar PV panels cost about $3 per peak installed watt of label capacity. Setting aside their inability to destroy spent nuclear fuel, it seems attention ought to focus on them instead of new designs of nuclear reactors. The amount of electricity produced in a year, divided by the amount that would be produced if the system ran continuously at full label power output, is the capacity factor. The Department of Energy reported that the 2018 national average capacity factor for solar PV was 25%. Nuclear generating stations averaged 92.5%. With a 25% capacity factor, the cost of a **solar** panel, at $3 per peak watt, **is $12 per** average **watt**, about **six times the** expected **cost** of S-PRISM modules.

Funding is needed to jumpstart the process. Stein '22

[Adam, Jonah Messinger, Dr. Seaver Wang, Juzel Lloyd, Jameson McBride, and Rani Franovich; July 6; Director of the Nuclear Energy Innovation program at the Breakthrough Institute, published by the Electric Power Research Institute, presented to the Nuclear Regulatory Commission, and contributed to many high-profile projects, including the first-ever license application for an advanced nuclear reactor in the U.S., Ph.D. and M.S. in Engineering and Public Policy from Carnegie Mellon University where his research focused on changing the paradigm for emergency preparedness and response for nuclear facilities; a non-resident Senior Energy Analyst at the Breakthrough Institute, Ph.D. student at the Cavendish Laboratory of Physics at the University of Cambridge, was a Visiting Scientist and ThinkSwiss Scholar at ETH Zürich, Master's in Energy and Bachelor's in Physics from the University of Illinois at Urbana-Champaign; Breakthrough Institute Co-Director of the Climate and Energy team, PhD in Earth and Ocean Sciences from Duke University as well as a BA in Earth Sciences from the University of Pennsylvania; climate and energy analyst at Breakthrough, Bachelor of Science in Mechanical Engineering at Howard University; graduate student in Technology and Policy at MIT, and a researcher at the MIT Energy Initiative. He studies the political economy of decarbonization, with a focus on US energy and technology policy published in the New York Times, the Los Angeles Times, Greentech Media, and the Columbia Political Review; Master of Science in Industrial and Systems Engineering from Virginia Tech; Breakthrough Institute, "Advancing Nuclear Energy: Evaluating Deployment, Investment, and Impact in America's Clean Energy Future," https://thebreakthrough.org/articles/advancing-nuclear-energy-report] rchen

Policymakers possess numerous financial and non-financial opportunities to support the suc- cessful deployment of advanced nuclear power plants at scale. **Policy mech**anism**s for financial support can** help **lower costs and reduce** the financial **risk associated with early projects** while encouraging the growth of a robust industry that includes not only reactor developers but also upstream manufacturers and suppliers. Meanwhile, non-financial policy support can help facilitate power plant siting, train a skilled workforce, formalize management strategies for spent fuel, and improve the efficiency with which the United States advanced nuclear industry can secure customers internationally. **Proactive** public **policy support** across this broad range of issue areas will prove crucial for **position**ing the **U**nited **S**tates advantageously **as** a technology **leader in advanced nuclear energy**. 9.1 Direct Financial Support Mechanisms Federal Loan Guarantees Upfront capital investments will comprise much of the cost of advanced nuclear projects. Due to the higher financial risk associated with backing emerging advanced nuclear reactor deployments, financiers will likely expect higher interest rates for lent capital. Higher interest rates thus add to the cost of early deployment of advanced nuclear technologies. To encourage capital investment into US advanced nuclear projects and to reduce project costs, federal programs like those administered by the US DOE's Loan Programs Office (LPO) can guarantee repayment of loans for advanced nuclear projects, both reducing financial risks for investors and allowing project developers to secure capital at lower interest rates. Such federal loan guarantees can thus play a highly influential role in accelerating the domestic development of an advanced nuclear sector. At the national level, the DOE LPO seeks to provide directed public support for energy innovation. The DOE LPO currently possesses the capacity to issue up to $40 billion in loans and loan guaran- tees to support a wide range of groundbreaking energy and energy infrastructure initiatives, with up to $10.9 billion in loan guarantees available for promising nuclear energy projects.177 This support has historically been extended to conventional nuclear projects such as the construction of Units 3 and 4 at the Vogtle Electric Generating Plant in Waynesboro, Georgia.178

Demonstration and Cost Share **Publicly funded technology** demonstration programs remain a primary driver to assist innovative and transformative research to reach commercial scale.179 Over the last 80 years, the Department of Energy and the world-leading system of US national laboratories have directly **drive**n not only the development but also the demonstration of many new energy technologies nationwide. Demonstration programs represent a critical step in the innovation process by bridging the **r**esearch **and de**velopment **process and** full-scale **commercialization** of a technology. Public-private partnerships for demonstration projects reduce the burden on the government to solely demonstrate the technology. By participating in project cost-sharing, the government facilitates "buying down" financial risk, thereby reducing overall FOAK costs. Such demand-pull innovation policies have a demonstrated track record of success in commercializing innovative technologies in a variety of sectors.180 The DOE's recent opening of a new Office of Clean Energy Demonstrations (OCED) emphasizes the value of this public sector role in driving early deployment for emerging technologies.181 The OCED will seek to support a range of important technologies, such as carbon capture, clean hydrogen, grid infrastructure upgrades, and advanced nuclear demonstration. The recently passed Bipartisan

Infrastructure Law specifically designated $2.5 billion in OCED funding to support two advanced nuclear reactor demonstration projects through the Advanced Reactor Demonstration Program (ARDP).182 The ARDP is a more established but still recent program launched in 2020 to provide public support and help advanced nuclear developers secure and build their first projects.183 The ARDP currently supports 10 projects, with two full scale demonstration projects. One demonstration project will deploy four of X-Energy's 80 MWe Xe-100 high-temperature, gas-cooled small reactors at the Columbia Generating Station in Washington state, currently home to an existing conven- tional nuclear power plant.184 The other demonstration project will involve building TerraPower's Natrium 345 MWe sodium-cooled fast reactor, with an initial reactor slated for construction in Kemmerer, Wyoming at the site of the existing Naughton Coal Plant. Others ARDP projects include the Kairos KP-X/Hermes 50 MWe test reactor intended for construction at the Oak Ridge National Laboratory in Tennessee.185 Other deployment projects include the six-unit NuScale SMR project at INL186 and GE-Hitachi's BWRX-300 design, at the Clinch River site in Roane County, Tennessee.187 Tax Credits Tax credits for renewable electricity generation are a well-established policy mechanism for encouraging the greater deployment of new domestic wind and solar capacity.188 Power produced by conventional and advanced nuclear reactors provides the same climate and air pollution benefits as other sources of clean energy.189, 190 To promote wider adoption of clean electricity from a diverse array of sources, optimally-designed clean energy tax credits should be available on a technology-neutral basis. A future low-carbon electricity grid will rely upon an array of technologies, so nuclear power plants, geothermal facilities, and hydroelectric dams should similarly benefit from federal tax incentives intended to accelerate national clean power gener- ation. Such federal tax incentives will further improve the economics of new advanced nuclear projects. Tax credits require the entity to have a sufficient tax burden for credit to offset. Small organiza- tions pursuing projects with no existing revenue, therefore no tax liability, often have to partner with another organization, which in turn takes some of the tax credit for the service. One option to avoid this issue is a direct payment of the tax credit to the entity. A proposed direct pay mechanism allows a taxpayer to treat tax credits that it has earned as an overpayment of taxes, allowing the tax credit to be received as a direct payment of cash in the form of a refund. **Subsidies** It is our view that technology-neutral subsidies are best employed to promote the **accelerate**d **early deployment** of innovative clean energy technologies in a fair and efficient manner. As a promising set of clean energy sources that offer unique strategic and economic advantages for the United States, domestic advanced nuclear energy projects are strongly in the national interest and possess a good case for inclusion in any technology-neutral clean energy subsidy program. In the long term, inefficient subsidies may discourage innovation and further improvements in efficiency, so such policies might be reconsidered in the future once these technologies have become more established.

Deployment is possible and happens quick. Brook '11

[Barry, Tom Blees, and others; February 24; Australian Laureate Professor and Chair of Environmental Sustainability at the University of Tasmania in the Faculty of Science, Engineering and Technology, formerly an ARC Future Fellow in the School of Earth and Environmental Sciences at the University of Adelaide, Australia, where he held the Sir Hubert Wilkins Chair of Climate Change from 2007 to 2014, and was also Director of Climate Science at the Environment Institute; President of the Science Council for Global Initiatives, member of the selection committee for the Global Energy Prize, considered Russia's equivalent of the Nobel Prize for energy research, and a consultant and advisor on energy technologies on the local, state, national, and international levels; Conference Paper from the 91st American Meteorology Society Annual Meeting, "Advanced nuclear power systems to mitigate climate change (Part III)," http://bravenewclimate.com/2011/02/24/advanced-nuclear-power-systems-to-mitigate-climate-change] rchen

There are many compelling reasons to **pursue** the rapid demonstration of a full-scale **IFR**, as a **lead**-in **to** a subsequent **global deployment** of this technology **within a** relatively **short time** frame. Certainly the urgency of climate change can be a potent tool in winning over environmentalists to this idea. Yet political expediency—due to widespread skepticism of anthropogenic causes for climate change—suggests that the arguments for rolling out IFRs can be effectively tailored to their audience. **Energy security**—especially with favorable economics—is a primary **interest of every nation**. The impressive safety **features of new** nuclear power plant **designs** should **encourage** a **rapid uptick** in construction without concern for the spent fuel they will produce, for all of it will quickly be used up **once IFRs begin to be deployed**. It is certainly manageable until that time. Burying spent fuel in non-retrievable geologic depositories should be avoided, since it represents a valuable clean energy resource that can last for centuries even if used on a grand scale.

Reject evidence that doesn't assume new reactors. It's comparatively better than every alternative. Jayanti '23

[Suriya; December 4; LL.M. in Energy & Environmental Law from KU Leuven, Ph.D. in Energy, Environment, and Natural Resources Law, energy policy expert, former U.S. diplomat; Time, "Nuclear Power Is the Only Solution," https://time.com/6342343/nuclear-energy-climate-change/] rchen

Wedged between energy crises and climate change natural disasters, there is no longer the luxury of choice. The **industry** has **responded** by seeking **to** develop new technology that can assuage public **concerns** about safety. Some are designing micro reactors or SMRs. Others are working with new materials or techniques, such as replacing water in cooling systems with molten salt, or using boiling water instead of pressurized water to make the NPP more efficient. Still others are **working** on **new safety systems**, or fuel fabrication innovations, or new approaches to storage of nuclear materials. In the U.S., top tier research outfits like the Electric Power Research Institute are finding their expertise in demand all round the world, creating something resembling nuclear diplomacy. The U.S., U.K, Canada, and South Korea are leading the pack on investment in nuclear. The nuclear industry has been riding high on a wave of enthusiasm for a few years. In recognition of the cost savings of "going nuclear," smart companies are already making plans to transition to nuclear power. This includes Microsoft, which announced in September that it will use nuclear plants to power its artificial intelligence operations. With electrification the foundation of any coherent energy transition plan and grids struggling to balance themselves with an abundance of non-dispatchable renewables, nuclear is increasingly acknowledged to be the solution. Just as apex science fiction writer Isaac Asimov fantasized in his 1940-50s Foundation books, nuclear energy may save humanity. And yet, recent headlines have revealed some major setbacks. Small modular nuclear reactor (SMR) company NuScale, once lauded as the leading SMR developer and despite receiving almost $2 billion in U.S. government support, has cancelled its flagship project due to rising costs and mismanagement. It is now facing investor lawsuits for fraud. TerraPower, Bill Gates' SMR company, was delayed several years by the Russian invasion of Ukraine—Russia was the only country that produced the nuclear fuel needed for TerraPower's SMR design. X-Energy has walked back its plans to go public. The U.K.'s Rolls Royce SMR is plagued by financial problems. France's EDF is posting record low power outputs and financial status reports. Others are also delayed, struggling, or facing bankruptcy. Setbacks are normal for new technologies and emerging markets, but for nuclear power such bumps in the road have outsized potential to disrupt because many people are still hesitant or downright hostile to nuclear power. The Chornobyl, Fukushima Daiichi, and Three Mile Island catastrophes loom large in the imagination. "Meltdown" itself has entered idiom to mean falling apart rapidly and irrationally and beyond control. The world's preoccupation with Russia's attacks on Ukraine's Zaporizhzhye nuclear power plant (NPP), the largest in Europe, shows how gripped we can be by nuclear disasters. In keeping, a March 2023 Gallup poll found that although support for nuclear is increasing slowly, 44% of Americans still somewhat or strongly oppose it, down from 54% in 2016. Similar polls in Switzerland and the U.K. peg support for nuclear at just 49% and 24%, respectively. In Germany, despite still being in the middle of an energy crisis and desperate for additional power sources, 50% of people under 34 want nuclear power eradicated. With the exception of France, which is 69% nuclear, many of the developed world's leading economies and governments have been too scared of nuclear power to allow it to flourish. Germany was so spooked by Fukushima it completely phased out its nuclear power program, finally turning off its last three (of an original 17) reactors on April 15, 2023. Belgium and Switzerland decided not to build new plants and to phase out those existing, although the 2021-2023 energy crisis has forced a reconsideration. In the U.S. the trigger was the March 28, 1979 partial meltdown of Three Mile Island in Pennsylvania. No one died or even suffered negative health effects, in the aftermath dozens of planned NPPs were cancelled and almost nothing has been built in decades. Unfortunately, unencumbered by popular opinions against nuclear, the Western world's great geostrategic rivals are years if not decades ahead. There are sixty nuclear projects in various stages of construction around the world, and 22 of them are in China; and 22 use Russian technology, and 18 use Chinese technology, or technology China stole from other countries and rebranded. Some European countries, notably Hungary and Serbia, and some NATO countries, such as Turkey, are planning new NPPs using Russian designs and supply chains. Ironically, and tragically, even all four of Ukraine's NPPs are Russian VVER models, entirely reliant until quite recently on Russian fuel. And Russia controls much of nuclear supply chains. The Western world ended up so far behind because of fear. Governments around the world are now struggling to catch up, slowed by still-high public opposition rates and regulatory regimes that institutionalized fear of nuclear into licensing and permitting processes. In countries that never had nuclear power, such as Poland and Egypt, opposition is not baked into law, and so they can paradoxically move faster than some countries with longstanding nuclear programs. In the U.S. the opposite is true; it keeps tripping over the fear-based regulatory regimes that govern its nuclear industry. Tasked by Congress in the 2019 Nuclear Energy Innovation and Modernization Act with liberalizing the licensing process to foster innovation and accelerate the commercialization of nuclear power, the U.S. Nuclear Regulatory Commission (NRC) in 2022 released draft rules and processes for consideration of new nuclear technologies that managed to take all the worst and most burdensome aspects of existing rules and, instead of reducing them, added some new hurdles and standards, some of which nuclear engineers say are scientifically impossible to meet. The draft is twice as long (1252 pages) as the one it was supposed to simplify. Many requirements, both old and new, shouldn't apply to SMRs and other advanced nuclear designs. The result was decried by experts and companies as a complete failure that will continue to hobble the industry for decades, adding further time and expenses to the already billion-dollar licensing process. The Nuclear Energy Institute, an industry trade group, said the proposal will "increase complexity and regulatory burden without any increase in safety and reduce predictability and flexibility." Meanwhile the U.S. is trying to export this same cumbersome nuclear regulatory regime, including to Saudi Arabia. Calling it the "gold standard" of nuclear regulation, the U.S. has refused to allow Saudi, much like it did with the United Arab Emirates, to use U.S. nuclear technology unless the Kingdom also adopts prescribed U.S. safety regulations. What a surprise that Saudi is actively considering Russian nuclear technologies instead. Yet, the scientific reality is that the rising generation of nuclear innovation doesn't need to be subjected to a crippling approval process—it is safe.

The **risk profile of new reactors** and other technologies in development is **very low**. This is especially true relative to the risks of climate change fallout or, for example, the health risks of burning fossil fuels or inhaling combustion engine exhaust. And the **waste** from a new nuclear plant is **far less problematic than** that of spent **solar panels**, for example. The **nuclear renaissance is** not just more nuclear power, it's also better, **cleaner, safer, more efficient**. SMRs, for example, are much safer than full sized NPPs. They have outputs of 50-300 MW depending on design, compared to 800-1600 MW for traditional NPPs. Microreactors, "pocket nukes" with 1-50 MW outputs, are even more resilient because simple physics means they are harder to damage and so it's less likely that an accident could result in a radioactive release. Whereas seismic activity is a grave concern for large NPPs like Fukushima, smaller technologies soon to be built do not require the seismic cushions that were needed under previous plants to protect them from even the smallest earthquakes. Micros and SMRs can also be manufactured in a factory—that's what the "modular" in small modular reactor means — allowing for standardization and systematized security measures, as well as sealed transport. And smaller amounts of radioactive fuel in smaller reactors mean less that could go wrong even in the case of an accident. One persistent concern opponents of nuclear power often voice is the risk of reactor cooling systems failing, but this not an issue with the new generation of nuclear designs. Fukushima Daiichi NPP's water-based cooling system stopped when a tsunami disabled the electricity source powering the circulation. This is the same risk Ukraine's Zaporizhzhye NPP is facing thanks to Russia bombing the dam that held the water that kept the plant's water cooling system operating. In emerging advanced reactor technologies, however, this vulnerability is eliminated entirely. Many of the new designs have entirely reconsidered systems with passive safety features that maintain cooling without reliance on external power. Others use water in innovative ways. GE Hitachi's BWRX-300 SMR is designed for the water inside to boil, creating its own convection that in turn powers its own cooling circulation. This eliminates the need for an extensive circulation system of pipes and keeps all potentially contaminated water inside the plant. Some also use materials other than water, such as molten salts. Another common objection to nuclear power is the disposal of radioactive material. But new technological innovations are mostly eradicating the need to store spent fuel at all. New fuels have a lower enrichment level, which is less radioactive and thus safer. And there's no such thing as nuclear waste unless the material is wasted. Canada's Moltex, for example, is developing a fuel recycling "waste to stable salt" technology that repurposes spent fuel into new fuel, reducing waste by over 75% and cutting its radioactive half life to approximately 300 years, down from thousands. Moltex is also designing an SMR, the Stable Salt Reactor-Wasteburner, to run on the recycled fuel, which will cut down the transport of radioactive materials. Other technologies are reducing risk in parallel. **Nuc**lear **energy** will **never be** absolutely, **perfect**ly, guaranteeably safe **because nothing is**. **Wind** turbines can fall over, and they can kill birds and negatively impact marine life. **Solar** panels produce significant volumes of toxic waste, and they take up space that impedes whatever is trying to live under them. Both wind and solar rely on minerals and manufacturing mostly controlled by China, and neither is entirely reliable as a power source. They're also not dispatchable at times of peak electricity demand. **Hydropower** only works with abundant water, and droughts are eviscerating rivers across the world. **Coal** is **killing** our children and our **planet. So is oil**. So is **natural gas**. Geothermal, biofuels, hydrogen, et cetera—**these aren't able to satisfy** even a fraction of the **demand** for energy.

Dramatic expansions of modernized nuclear power are the only feasible path to abate climate change. Stein '22

[Adam Stein, Jonah Messinger, Dr. Seaver Wang, Juzel Lloyd, Jameson McBride, and Rani Franovich; July 6; Director of the Nuclear Energy Innovation program at the Breakthrough Institute, published by the Electric Power Research Institute, presented to the Nuclear Regulatory Commission, and contributed to many high-profile projects, including the first-ever license application for an advanced nuclear reactor in the U.S., Ph.D. and M.S. in Engineering and Public Policy from Carnegie Mellon University where his research focused on changing the paradigm for emergency preparedness and response for nuclear facilities; a non-resident Senior Energy Analyst at the Breakthrough Institute, Ph.D. student at the Cavendish Laboratory of Physics at the University of Cambridge, was a Visiting Scientist and ThinkSwiss Scholar at ETH Zürich, Master's in Energy and Bachelor's in Physics from the University of Illinois at Urbana-Champaign; Breakthrough Institute Co-Director of the Climate and Energy team, PhD in Earth and Ocean Sciences from Duke University as well as a BA in Earth Sciences from the University of Pennsylvania; climate and energy analyst at Breakthrough, Bachelor of Science in Mechanical Engineering at Howard University; graduate student in Technology and Policy at MIT, and a researcher at the MIT Energy Initiative. He studies the political economy of decarbonization, with a focus on US energy and technology policy published in the New York Times, the Los Angeles Times, Greentech Media, and the Columbia Political Review; Master of Science in Industrial and Systems Engineering from Virginia Tech; Breakthrough Institute, "Advancing Nuclear Energy," https://thebreakthrough.org/articles/advancing-nuclear-energy-report]

The Biden Administration has sought to restore America's leadership in the global fight against climate change by investing in clean energy. The results illuminate the potential contribution of advanced nuclear power to meeting the Biden Administration's climate goals. Upon taking office, President Biden rejoined the Paris Agreement, which seeks **to limit** the average **global temp**erature rise by 2100 to 1.5 to 2 degrees Celsius above pre-industrial levels. Research published by the Intergovernmental Panel on Climate Change suggests that an **unprecedented increase in** global **nuclear generation** may be **required**, with global nuclear generation increasing to up to **500 percent** of current levels across modeled scenarios, to reach ambitious climate targets like 1.5 C at low cost. President Biden has also announced a policy goal of reaching 100% clean electricity in the United States by 2035. Nuclear already accounts for 48 percent of clean electricity generation **in the U**nited **S**tates at present, and provides a valuable firm source of power to complement the increasing share of variable renewables on the grid. Meeting the administration's ambitious climate and energy targets will require continued existing nuclear power plant operation, as well as advanced nuclear reactor deployment. The modeling results, produced with Vibrant Clean Energy, suggest that commercializing advanced nuclear technology could result in rapid growth of clean nuclear generation that would help to meet the administration's climate goals. The contribution of advanced nuclear to the United States electricity sector in 2050 across the scenarios is summarized in Table 7-1. In the optimistic Low-Cost High-Learning scenario, the least-cost pathway to meeting a 2050 net-zero power sector target in the United States would have nuclear power provide approximately 50 percent of the entire US electricity demand, up from 19 percent today. The majority of this nuclear generation would come from advanced reactors, with the deployment of 469 GWe of advanced nuclear power by 2050. Nuclear energy is able to provide this high share of generation with only 21 percent of the capacity in the electricity system, due to the high capacity factors of nuclear plants relative to other clean sources. Additionally, this growth comes in spite of a steady decline in generation from existing traditional nuclear plants, which declines by 80 percent by 2050 in the Low-Cost High-Learning scenario. The results illustrate the potential importance of advanced nuclear power relative to solar and wind. In the Low-Cost High-Learning scenario, nuclear generation exceeds solar generation by 75 percent and exceeds wind generation by 50 percent in 2050. This suggests that the market size for advanced reactors could substantially exceed the projected large markets for solar and wind power in the course of achieving a future low-cost net-zero power sector. However, **finance and policy support** would be **necessary to achieve** the **low costs** and high learning rates implied by this optimistic scenario. In these modeling results, 20 to 50 GWe of advanced nuclear capacity is deployed by 2035. The contribution of advanced nuclear to the United States electricity sector in 2035 is summarized in Table 7-2. Across the scenarios, advanced nuclear power contributes 3 to 8% of US generation by 2035, with all nuclear generation providing 15 to 19% of US generation that year. In 2035, the percentage of total generation from the sum of conventional and advanced nuclear power plants across all scenarios is comparable to generation from wind or solar. Table 7 2 Table 7-2: Nuclear shares of total US generation and capacity in 2035 (least-cost optimized for 2050 net-zero power sector target). By 2035, the United States achieves around a 60% total reduction of direct power sector CO2 emissions relative to 2020 fossil CO2 emissions across all four of the scenarios. This corresponds to 2035 power sector CO2 emissions of around 700 million metric tons of CO2 (Mt CO2), compared with 2020 emissions of 1,750 Mt CO2. In the model scenarios, power sector emissions fall by 90% relative to 2020 levels by 2045 (175 Mt CO2 in 2045), before the power grid achieves essentially full decarbonization in 2050 (Figure 7-1). Note that the current US grid has already achieved some decarbonization relative to 2010 power sector fossil emissions of 2,400 Mt CO2. The scenarios used in this report were constructed around a 2050 net-zero power sector target rather than the Biden Administration's 2035 goal for a zero-emission power sector, which means that these results may understate the potential contribution of advanced nuclear technology in reaching a binding 2035 net-zero target. Reaching a 2035 net-zero target would require substantially more policy and financial support. Across the scenarios, around 70% of the United States generation comes from clean sources in 2035.

Otherwise, extinction. Pascus '19

[Brian Pascus, 19, Human civilization faces "existential risk" by 2050 according to new Australian climate change report, Cbs News, 6-4-2019, accessed, 7-20-2023, https://www.cbsnews.com/news/new-climate-change-report-human-civilization-at-risk-extinction-by-2050-new-australian-climate/] rchen

A new report by Australian climate experts warns that "**climate change** now represents a near- to mid-term **existential threat**" to human civilization. In this grim forecast — which was endorsed by the former chief of the Australian Defense Force – human civilization could end **by 2050** due to the destabilizing societal and environmental factors caused by a rapidly warming planet. The report, entitled "Existential climate-related security risk: A scenario approach," lays out a future where society could collapse due to instability set off by migration patterns of billions of people affected by drought, rising sea levels, and environmental **destruction**. "Climate-change impacts **on food and water** systems, declining crop yields and rising food prices driven by drought, wildfire and harvest failures have already become **catalys**ts for social **breakdown** and conflict across the Middle East, the Maghreb and the Sahel, contributing to the European migration crisis," the report said. The report was written by David Spratt, research director for Breakthrough National Centre for Climate Restoration in Melbourne, and Ian T. Dunlop, formerly an international oil, gas and coal industry executive and chair of the Australian Coal Association. Retired Admiral Chris Barrie, former defense forces chief of Australia, endorsed the report and wrote a forward to it. "After nuclear war, human induced global warming is the greatest threat to human life on the planet," Barrie wrote. Using a worst-case scenario existential risk analysis, Spratt and Dunlop depict humanity falling into ruin under an additional 2 degrees Celsius of warming – a threshold scientists say the world is heading towards if current trends continue. In their scenario, "**tipping points**" occur when humanity fails to institute carbon emission reforms in the 2020s and 2030s. This **creates** a "**hothouse" effect** on Earth, leading to rapidly **rising sea levels** set off by melting of the Greenland Ice Sheet and "widespread **permafrost loss** and large-scale Amazon drought and dieback." In this scenario, the "hothouse Earth" effect causes "35 percent of the global land area, **and** 55 percent of the global population, (to be) subject to more than 20 days a year of **lethal heat** conditions, **beyond** the threshold of **human survivability**." **Ecosystems collapse**, including coral reef systems, the Amazon rainforest and the Arctic, along with a massive die-off of the insect population. As a result, the authors say, some of the world's most populated cities – Mumbai, Jakarta, Guangzhou, Tianjin, Hong Kong, Ho Chi Minh City, Shanghai, Lagos, Bangkok and Manila – would have to be abandoned due to their location in the tropical zone. The assessment ends with a harrowing conclusion: "More than a billion people may need to be relocated and in high-end scenarios, the scale of destruction is beyond our capacity to model, **with** a high likelihood of human civilization coming to an end." The report also paints a grim picture in terms of national security, with extreme climate conditions and the disruption of huge populations placing "the internal cohesion of nations ... under great stress." The flooding of coastal communities around the world, especially in the Netherlands, the United States, South Asia, and China, has the potential to challenge regional and even national identities," the report warns. "Armed **conflict** between nations **over resources**, such as the Nile and its tributaries, is likely **and nuclear war** is possible. The social consequences range from increased religious fervor to outright chaos."

Adv - Fusion

Fusion is possible within the decade. Cross out outdated defense. Recent breakthroughs demonstrate effectiveness. Dunning 22

Hayley Dunning and Laura Gallagher; December 13; reporters; Imperial, "'Breakthrough' as Fusion Experiment Generates Excess Energy for the First Time," https://www.imperial.ac.uk/news/242258/breakthrough-fusion-experiment-generates-excess-energy/ //recut rchen

For over seventy years, scientists have been attempting to harness thermonuclear fusion - the power source of stars - to generate energy. Fusion has the potential to produce vast quantities of clean energy using few resources, requiring only a small amount of fuel and generating limited carbon emissions. Once a fusion plasma is 'ignited,' it will continue to burn for as long as it is held in place. However, fusion reactions have proven difficult to control and no fusion experiment had previously produced more energy than had been put in to get the reaction going. At a press briefing today, it was announced that **a fusion experiment** at the National Ignition Facility (NIF) at Lawrence Livermore National Laboratory in the US has **achieved** this **'holy grail**,' producing more energy than the laser pulse that was used to heat the fuel. The energy in the laser pulse was 2.05 megajoules – equivalent to the energy of two Mars chocolate bars, or enough to boil six kettles of water. The energy from the fusion reactions was **50% higher than** the energy of the laser **pulse**. It was released in the form of energetic neutrons. Long sought-after goal Imperial College London physicists are already helping to analyse the data from the successful experiment, which was conducted on 5 December 2022. Imperial has also produced more than 30 PhD students that have gone on to work at the NIF. The College retains strong links with the facility, and others throughout the world, through the Centre for Inertial Fusion Studies (CIFS). Professor Jeremy Chittenden, Co-Director of the Centre for Inertial Fusion Studies at Imperial College London, said: "Everyone working on fusion has been trying to demonstrate for over 70 years that it's possible to generate more energy from fusion than you put in. This is **a** true **breakthrough moment**, which is tremendously exciting. It **proves** that the long sought-after goal, the 'holy grail' of **fusion, can** indeed **be achieved**. This **brings us closer to** generating **fusion power** on a much larger scale. "To turn fusion into a power source **we'll need to boost** the **energy** gain still **further**. We'll also need to find a way to reproduce the same effect much more frequently and much more cheaply before we can realistically turn this into a power plant. It's hard to say how quickly we might be able to get to that point. If everything aligns **we could see fusion** power in use **in ten years**, but it could take far longer. The key thing is that with today's results we know that fusion power is within reach."

Investors are required for development of fusion. Windridge 23

Melanie Windridge; April 13 2023; PhD plasma physicist and science communicator best known for her book Aurora: In Search of the Northern Lights and her educational work on fusion energy with the Institute of Physics and the Ogden Trust; Forbes, "Investors Hold The Key To Fusion And Our Clean Energy Future," https://www.forbes.com/sites/melaniewindridge/2023/04/13/investors-hold-the-key-to-fusion-and-our-clean-energy-future/ //rchen

Why **investors are key** Investors are in an interesting position. They **have the potential to** be a huge part of the solution to our climate/energy woes by making the **accelerate**d development of **fusion** possible. Legal & General Group, one of the UK's leading financial services groups and a major global investor, is up front about the power of investors to address climate change through investment, influence and operations. The Group's alternative asset platform, Legal & General Capital (LGC), plays a significant role in developing and deploying technologies that help to tackle climate change, such as electric charging infrastructure in the UK, super-efficient solar panels, offshore wind farms and also fusion energy, where they have been investing in Tokamak Energy for several years. John Bromley, Managing Director Clean Energy Strategy & Investments at Legal & General Capital, says: "Climate is not only the most urgent issue, but also the biggest investment opportunity of our lifetime. Investors who are focused on the challenges of decarbonising our economy, and can take a long term view, have a crucial role to play in the accelerated development of fusion energy." He continues: "As an energy transition investor, Legal & General Capital supports the growth of a new generation of clean energy technology and infrastructure providers, and innovative companies whose work will support the transition to net zero." Some consider that the **financing risk is** the **biggest risk to fusion**, so investors are critical to success. Getting in on the action Investors also have the chance to win big on fusion, a market that Bloomberg has predicted could reach $40 trillion. Why is fusion so attractive? As John Bromley says, "Renewables will certainly be a large and important part of a decarbonised economy, but we will also require dispatchable zero carbon energy sources to end fossil fuel reliance. Fusion energy holds the potential to achieve and sustain a significant reduction in global emissions." There's no doubt that funding fusion is challenging, involving high upfront costs, long timescales and high uncertainty. Yet investment in fusion has been increasing. Just last month, Breakthrough Energy Ventures (Bill Gates' investment firm seeking to finance, launch, and scale companies that will eliminate greenhouse gas emissions throughout the global economy—an investor in Commonwealth Fusion Systems and Zap Energy) invested in another fusion company, Type One Energy. Behind the scenes, more conventional investors, like pension funds, insurance companies and sovereign wealth funds, have quietly been investing in fusion. The mainstreaming of fusion among capital-providers has begun. What investors need Yet getting into fusion investment requires a steep learning curve. Fusion is a big and complex subject. Increasingly investors, investment banks or other financial players are enquiring wanting to learn about fusion, taking that first step into getting familiar with a new industry. Financing fusion is so critical to the mission that advocates of fusion should be asking how we can accelerate this mainstreaming of fusion and draw new capital to the table. Investors need access to opportunity, they need insight from industry insiders and existing investors, they need community and relationships. This is why events that bring all these things together can be so important. But **investors** also **need gov**ernment **support and certainty**. That's one reason why the U.K. is currently in a strong position for fusion energy development, because they have outlined their plans for a regulatory framework for fusion while other countries are still in discussion. It goes further than technology regulation, however. **Policy and incentives will be required** in the financial services industry **to drive** the effective **reallocation of capital**. Michelle Scrimgeour, Chief Executive of Legal & General Investment Management, gave evidence to a 2022 U.K. parliamentary inquiry entitled 'The financial sector and the U.K.'s net zero transition'. Scrimgeour said: "A successful transition to a decarbonised economy, consistent with less than 1.5 degrees warming, will require a substantial change in capital allocation. Several trillion dollars a year of incremental capital will need to be invested into low carbon energy, energy infrastructure and energy efficiency. For this capital allocation to occur, a financial services industry that is aligned with net zero outcomes will be crucial. Equally, this requires global policy action at international governmental level, particularly on an effective regulatory structure to price carbon and other greenhouse gases." So while investors hold the key to the success of fusion and our clean energy future, it's not just down to investors—government policy will be **crucial in enabling investors** to drive the change.

Current funding is insufficient. Disregard doubt on fusion. Any risk that we prove federal investment is enough to make fusion possible AND faster means it's try or die. Risch 2/24

James Risch, Maria Cantwell, Ylli Bajraktari, Risch is an American lawyer and politician who has served as the junior United States senator from Idaho since 2009, Cantwell is an American politician who has been the junior United States senator from Washington since 2001, Bajraktari is the President and CEO of the Special Competitive Studies Project February 24 2025, "Fusion Power Enabling 21st Century American Dominance" No Publication, https://www.scsp.ai/wp-content/uploads/2025/02/Final-Fusion-Power_-Enabling-21st-Century-American-Dominance.pdf //rchen

Thanks to decades of federal investment in basic research, American **scientists have** now **proven** that **fusion is possible**. Growing power demands, **recent tech**nological **breakthroughs**, and the shifting market dynamics of energy create a unique opportunity for fusion to finally see its time in the Sun. A big bet on fusion could **secure America's position** as a technological superpower for decades to come. The Global Fusion Race The U.S. Fusion Landscape America has led the world in fusion energy sciences since the days of the Manhattan Project.12 U.S. universities have consistently attracted the world's best talent, many of whom created today's leading fusion companies. Our National Labs beat the world in demonstrating fusion's scientific feasibility. **Yet** despite this legacy of scientific excellence, the **U**nited **S**tates finds itself **underprepared** for fusion's transition from experimental science to commercial reality. **Achieving fusion** energy on a competition-relevant timeline will **require** more than just tackling key scientific hurdles. It calls for an entirely different posture than the current U.S. approach, one that prioritizes commercialization and optimizes **U.S. spending on fusion.** Though progress has been made in strategy, infrastructure, and **investment** in recent years, it is not sufficient to compete and harness fusion energy's full potential. An assessment of the U.S. fusion landscape reveals: Strategy: Stemming from the 2022 Bold Decadal Vision, recent U.S. strategic initiatives have laudably sought to push fusion toward commercialization, but have **fallen short** in translating ambitious goals into urgent, concrete, actionable policies **and** programs.13 The Department of Energy's (DOE) 2024 Fusion Energy Strategy focuses on three pillars: bridging technological gaps for a pilot plant, enabling sustainable deployment, and forging external partnerships.14 The Milestone-Based Fusion Development Program, modeled after NASA's Commercial Orbital Transportation Services (COTS) program, seeks to reduce investment risk by setting discrete technical milestones that unlock government funds. Other programs include the Fusion Innovation Research Engine (FIRE) Collaboratives, which provide testing infrastructure that private firms can**not** develop on their own,15 the Innovation Network for Fusion Energy (INFUSE), which provides access to technical and financial support,16 and most recently the Private Facilities Research (PFR) program, which will enable public research at private fusion facilities.17 However, appropriations for these programs have been less than **Congressionally authorized** levels.18 The **failure to implement** many critical **recommendations** made by strategic documents, such as DOE's Fusion Long-Range Plan, has **left** an **incomplete ecosystem** that China is racing to complete itself.19 Scientific Breakthroughs: In December 2022, after a decade of diligent work, scientists at the U.S. National Ignition Facility (NIF) achieved the long-sought milestone of producing more energy in a fusion reaction than the laser energy used to create it (Q > 1).20 Indeed, the fusion process itself became the primary source of heat for the fusion fuel, signifying true ignition. NIF scientists have reproduced ignition multiple times since, while no other machine has yet to replicate it.21 The NIF's breakthrough marked the starting gun for the commercial fusion race, but there are a number of scientific and engineering challenges on the road ahead.22 The scientific community has identified a suite of R&D infrastructure that—with **an upfront investment**—would help **solve** these **challenges and unlock fusion**'s economic potential.23 The key hurdles involve sustaining and stabilizing a burning plasma, increased energy gain, developing components that can handle radiation and extreme heat, and breeding and recycling tritium to fuel the reaction.24 In addition to hardware and infrastructure, significant progress has been made, largely in the United States, in the computer simulation of plasmas.25 Simulation has driven the invention of new concepts, such as the Spherical Tokamak NSTX-U at the Princeton Plasma Physics Laboratory (PPPL).26 The United States is also applying AI across multiple fusion fronts, including PPPL's AI platforms predicting and preventing plasma instabilities in real time.27 The combination of advanced simulations and

AI is poised to further accelerate the development of optimized fusion designs, **significantly expediting the path to** practical **fusion energy**.

1 - Space

Investment secures fusion propulsion deployment by 2030.

Prisco 4/3 (Jacob Prisco is a London-based producer and writer for CNN International) CNN Science, 04/03/2025, "Nuclear-powered rocket concept could cut journey time to Mars in half" https://www.cnn.com/science/nuclear-powered-rocket-pulsar-space-spc/index.html (Accessed: 04/03/2025) //jjoy

The dream of nuclear fusion has been chased by some of the world's brightest minds for decades. It's easy to see why — replicating the inner workings of stars here on Earth would mean virtually unlimited clean energy. Despite a long history of attempts, and several breakthroughs, the dream hasn't turned to reality yet, and we're likely many years away from seeing a fusion power plant anywhere on the planet. Carrying out the process in space might sound like adding an extra layer of complexity to an already complex technology, but it could theoretically happen sooner than on Earth. And it could help spacecraft achieve speeds of up to 500,000 miles (805,000 kilometers) per hour — more than the fastest object ever built, NASA's Parker Solar Probe, which peaked at 430,000 miles (692,000 kilometers) per hour. With funding from the UK Space Agency, British startup Pulsar Fusion has unveiled Sunbird, a space rocket concept designed to meet spacecraft in orbit, attach to them, and carry them to their destination at breakneck speed using nuclear fusion. "It's very unnatural to do fusion on Earth," says Richard Dinan, founder and CEO of Pulsar. "Fusion doesn't want to work in an atmosphere. Space is a far more logical, sensible place to do fusion, because that's where it wants to happen anyway." For now, Sunbird is in the very early stages of construction and it has exceptional engineering challenges to overcome, but **Pulsar** says it hopes **to achieve fusion in orbit** for the first time **in 2027**. If **the rocket** ever becomes operational, it **could** one day **cut** the **journey time** of a potential mission to Mars **in half**. Just grams of fuel Nuclear fusion is different from nuclear fission, which is what powers current nuclear power plants. Fission works by splitting heavy, radioactive elements like uranium into lighter ones, using neutrons. The vast amount of energy released in this process is used to make electricity. Fusion does the opposite: it combines very light elements like hydrogen into heavier ones, using high temperature and pressure. "The sun and the stars are all fusion reactors," says Dinan. "They are element cookers — cooking hydrogen into helium — and then as they die, they create the heavy elements that make up everything. Ultimately the universe is mostly hydrogen and helium, and everything else was cooked in a star by fusion." Fusion is sought after because it releases four times more energy than fission, and four million times more energy than fossil fuels. But unlike fission, fusion doesn't require dangerous radioactive materials — instead, fusion reactors would use deuterium and tritium, heavy hydrogen atoms that have extra neutrons. They would work on minute quantities of fuel and produce no dangerous waste. However, fusion requires a lot of energy to start, because conditions similar to the core of a star must be created — extremely high temperature and pressure, along with effective confinement to keep the reaction going. The challenge on Earth has been to create more energy from fusion than is put in to start, but so far we've barely broken even. But if power generation is not the goal, things become less complicated, Dinan says — only the simpler goal of creating a faster exhaust speed. The reactions that power nuclear fusion take place inside a plasma — a hot, electrically charged gas. Just like proposed reactors on Earth, Sunbird would use strong magnets to heat up a plasma and create the conditions for the fuel — which would be in the order of grams — to smash together and fuse. But while on Earth reactors are circular, to prevent particles from escaping, on Sunbird they would be linear – because the escaping particles would propel the spacecraft. Lastly, it would not produce neutrons from the fusion reaction, which reactors on Earth use to generate heat; Sunbird would instead use a more expensive type of fuel called helium-3 to make protons, which can be used as a "nuclear exhaust" to provide propulsion. The Sunbird process would be expensive and unsuitable for energy production on Earth, Dinan says, but because the objective is not to make energy, the process can be inefficient and expensive, but still be valuable because it would save fuel costs, reduce the weight of spacecraft and get it to its destination much faster. Cutting journey times Sunbirds would operate similarly to city bikes at docking stations, according to Dinan: "We launch them into space, and we would have a charging station where they could sit and then meet your ship," he says. "You turn off your inefficient combustion engines, and use nuclear fusion for the greater part of your journey. Ideally, you'd have a station somewhere near Mars, and you'd have a station on low Earth orbit, and the (Sunbirds) would just go back and forth." Some components will have an orbit demonstration this year. "They're basically circuit boards that go up to be tested, to make sure they work. Not very exciting, because there's no fusion, but we have to do it," says Dinan. "Then, in 2027, we're going to send a small part of Sunbird in orbit, just to check that the physics is working as the computer assumes it's working. That's our first in-orbit demonstration, where we hope to do fusion in space. And we hope that Pulsar will be the first company to actually achieve that." That prototype will cost about $70 million, according to Dinan, and it won't be a full Sunbird, but rather a "linear fusion experiment" to prove the concept. The **first functional Sunbird will be ready four** to five **years** later, he says, **provided** the **necessary funding is secured.** Initially, the Sunbirds will be offered for shuttling satellites in orbit, but their true potential would come into play with interplanetary missions. The company illustrates a few examples of the missions that Sunbird could unlock, such as delivering up to 2,000 kilograms (4,400 pounds) of cargo to Mars in under six months, deploying probes to Jupiter or Saturn in two to four years (NASA's Europa Clipper, launched in 2024 towards one of Jupiter's moons, will arrive after 5.5 years), and an asteroid mining mission that would complete a round trip to a near-Earth asteroid in one to two years instead of three. Other companies are working on nuclear fusion engines for space propulsion, including Pasadena-based Helicity Space, which received investment from aerospace giant Lockheed Martin in 2024. San Diego-based General Atomics and NASA are working on another type of nuclear reactor – based on fission rather than fusion – which they plan to test in space in 2027. It is also meant as a more efficient propulsion system for a crewed mission to Mars compared to current options. According to Aaron Knoll, a senior lecturer in the field of plasma propulsion for spacecraft at Imperial College London, who's not involved with Pulsar Fusion, there is a huge potential for harnessing fusion power for spacecraft propulsion. "While we are still some years away from making fusion energy a viable technology for power generation on Earth, we don't need to wait to start using this power source for spacecraft propulsion," he says. The reason, he adds, is that to generate power on Earth, the amount of energy output needs to be greater than the energy input. But when using fusion power on a spacecraft to generate thrust, any energy output is useful — even if it's less than the energy being supplied. All of that combined energy, coming from the external power supply and the fusion reactions together, will act to increase the thrust and efficiency of the propulsion system. However, he adds, there are significant technical hurdles in making fusion technology in space a reality. "Current fusion reactor designs on Earth are large and heavy systems, requiring an infrastructure of supporting equipment, like energy storage, power supplies, gas delivery systems, magnets and vacuum pumping equipment," he says. "Miniaturizing these systems and making them lightweight is a considerable engineering challenge." Bhuvana Srinivasan, a professor of Aeronautics & Astronautics at the University of Washington, who's also not involved with Pulsar, agrees that **nuclear fusion propulsion holds** a **substantial promise for** spaceflight: "It would be extremely beneficial even for **a trip to the Moon**, because it could **provide the means to deploy an entire lunar base** with crew in a single mission. If successful, it would outperform existing propulsion technologies not just incrementally but dramatically," she says. However, she also points out the difficulties in making it compact and lightweight, an added engineering challenge which is a lesser consideration for terrestrial energy. Unlocking fusion propulsion, according to Srinivasan, would not only allow humans to travel farther in space, but be **a game-changer** for uncrewed missions, for example **to gather** resources like **helium-3**, a fusion fuel that is rare on Earth and must be created artificially, but may be abundant on the Moon: "If we can build a lunar base that **could be a launching point for deep space exploration**, having access to a potential helium-3 reserve could be invaluable," she says. "Exploration of planets, moons, and solar systems farther away is fundamental to our curious and exploratory nature as humans while also potentially leading to substantial financial and societal benefit in ways that we may not yet realize."

Fusion advancements are the single most important emerging technology for space colonization. David 22

Leonard David; December 15 2022; Award-winning space journalist who has been reporting on space activities for more than 50 years, Interviewing multiple physicists and scientists; Space, "Nuclear fusion breakthrough: What does it mean for space exploration?" https://www.space.com/nuclear-fusion-breakthrough-spacetravel //recut rchen

The nuclear **fusion** feat has broad implications, fueling hopes of clean, limitless energy. As for space exploration, one upshot from the landmark research is attaining the long-held dream of future rockets that are driven by fusion propulsion. But is that prospect still a pipe dream or is it now deemed reachable? If so, how much of a future are we looking at? Data points The fusion breakthrough is welcomed and exciting news for physicist Fatima Ebrahimi at the U.S. Department of Energy's (DOE) Princeton Plasma Physics Laboratory in New Jersey. Ebrahimi said the NIF success is extraordinary. "Any data points obtained showing fusion energy science achievement is fantastic! Fusion energy gain of greater than one is quite an achievement," Ebrahimi said. However, engineering innovations are still requisite for NIF to be commercially viable as a fusion reactor, she added. Ebrahimi is studying how best to propel humans at greater speeds out to Mars and beyond. The work involves a new concept for a rocket thruster, one that exploits the mechanism behind solar flares. The idea is to **accelerate particles using** "**magnetic reconnection**," a process found throughout the universe, including the surface of the sun. It's when magnetic field lines converge, suddenly separate, and then join together again, **producing loads of energy**. By using more electromagnets and more magnetic fields, Ebrahimi envisions the ability to create, in effect, a knob-turning way to fine-tune velocity. As for the NIF victory impacting space exploration, Ebrahimi said for space applications, compact fusion concepts are still needed. "Heavy components for space applications are not favorable," she said. Necessary precursor Similar in thought is Paul Gilster, writer/editor of the informative Centauri Dreams website. "Naturally I celebrate the NIF's accomplishment of producing more energy than was initially put into the fusion experiment. It's a necessary precursor toward getting fusion into the game as a source of power," Gilster told Space.com. Building upon the notable breakthrough is going to take time, he said. "Where we go as this evolves, and this seems to be several decades away, is toward actual fusion power plants here on Earth. But as to space exploration, we then have to consider how to reduce working fusion into something that can fit the size and weight constraints of a spacecraft," said Gilster. There's no doubt in Gilster's mind that fusion can be managed for space exploration purposes, but he suspects that's still more than a few decades in the future. "This work is heartening, then, but it should not diminish our research into alternatives like beamed energy as we consider missions beyond the solar system," said Gilster. Exhaust speeds Richard Dinan is the founder of Pulsar Fusion in the United Kingdom. He's also the author of the book "The Fusion Age: Modern Nuclear Fusion Reactors." "Fusion propulsion is a much simpler technology to apply than fusion for energy. If fusion is achievable, which at last the people are starting see it is, then both **fusion** energy and propulsion are inevitable," Dinan said. "One **gives us** the **ability to** power our planet indefinitely, the other the ability to **leave** our **solar system**. It's a big deal, really." Exhaust speeds generated from a fusion plasma, Dinan said, are calculated to be roughly one-thousand times that of a Hall Effect Thruster, electric propulsion hardware that makes use of electric and magnetic fields to create and eject a plasma. "The financial implications that go with that **make fusion propulsion**, in our opinion, the **single most important** emerging **tech**nology **in** the **space** economy," Dinan said. Pulsar Fusion has been busy working on a direct fusion drive initiative, a steady state fusion propulsion concept that's based on a compact fusion reactor. According to the group's website, Pulsar Fusion has proceeded to a Phase 3 task, manufacturing an initial test unit. Static tests are slated to occur next year, followed by an in-orbit demonstration of the technology in 2027. Aspirational glow "The net energy gain reported in the press is certainly a significant milestone," said Ralph McNutt, a physicist and chief scientist for space science at the Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland. "As more comes out, it will be interesting to see what the turning point was that pushed this achievement past the previous unsuccessful attempts," he said.

Fusion is the only known technology that provides sufficient propulsion capability for space colonization. Genta 20

Giancarlo Genta and Roman Ya. Kezerashvili; August 2020; Professor of Machine Design and Construction at the Polytechnic University of Turin, Ph.D. in physics from Princeton; Professor of Physics at New York City College of Technology, Ph.D. in nuclear physics; Acta Astronautica, "Achieving the required mobility in the solar system through direct fusion drive," https://www.sciencedirect.com/science/article/abs/pii/S0094576520302629 //recut rchen

However it is well known that to really explore and colonize the closest celestial bodies a wide range of technologies need to be developed [3] – technology to exploit in-situ resources, to protect the astronauts from radiation, to build manufacturing capability on the destination planet, etc. and new technologies directly related to propulsion are also required. In particular, it is **essential to use nuclear energy** instead of chemical energy to propel spacecraft because of its **inherent superiority** to chemical propulsion **by seven orders of magnitude**. Both alternatives of Nuclear Thermal and Nuclear Electric Propulsion (NTP and NEP) based on nuclear fission reactions have been studied in detail, and the former was already bench-tested with very satisfactory results. NTP and NEP can improve our chances of performing human missions to Mars and beyond by reducing the travel time (and thus the exposure of the crew to cosmic and solar radiation and also the risk of due to occasional solar storms and unpredictable coronal mass ejections) while at the same time reducing the Initial Mass in Low Earth Orbit (IMLEO) and thus making interplanetary missions more affordable in both human and economic terms. An interesting comparison between the NTP and chemical approach to a human Mars mission is reported in the NASA Design Reference Architecture 5 (DRA5) [3 , 4]. NEP allows a notable improvement with respect to chemical propulsion, and the choice between the two mentioned nuclear approaches depend mainly on political decisions about which technology to develop to a sufficient Technology Readiness Level (TRL). Both the mentioned nuclear approaches are based on fission nuclear reactions [5]. Recent advances in light weight structures and thin film solar cells make it possible to think of using Solar Electric Propulsion (SEP) also for human planetary missions and in particular for the first human missions to Mars. This is a sort of "bridge" solution to improve the performance of interplanetary spacecraft above those of chemical propulsion, while waiting for NTP or NEP technology to become available. By comparing the performance of SEP with that of chemical propulsion and NTP, the advantages in terms of IMLEO are clear, while with respect to NEP they depend only on the specific mass of the generator α, – an important figure-of-merit for generators, which is the mass per unit useful power output. The specific mass of generator in the short term is more favorable for solar arrays than for nuclear generators. In a longer term, the latter will be much better, but developing SEP means **developing** high power electric thrusters for human missions so that they will be ready when a lightweight nuclear generator becomes available. At any rate there is no doubt that to become a true **spacefaring civilization** we **must develop** rocket engines based on nuclear **fusion** [6 , 7]. The latter is an order of magnitude more energy density and **fusible elements** are vastly **more abundant** in the cosmos than fissionable ones. The idea of using fusion power for spacecraft propulsion has a long history [8]. As with NTP and NEP, for fusion propulsion there are also two alternatives: electric and direct. In the last 20 years many studies have been devoted to the development of fusion nuclear power in general – mostly for generating electricity – and specifically of fusion nuclear rockets. Fusion NEP requires the development of lightweight fusion reactors, which is something that today appears to be a difficult achievement. Many years will pass before fusion generator will have a better value of α than fission generators [9]. Moreover, today no fusion generator, even one with a very high α, is available. In fusion NEP, the lower is the value of α, the higher is the optimum value of the specific impulse, so even when a lightweight generator will be available, much work will be required also for improving the electric thruster. The proposed Direct Fusion Drive (DFD) would be a revolutionary nuclear fusion engine. Its concept is based on the Princeton field-reversed configuration reactor, which has the ability to produce thrust from fusion without going through an intermediate electricity-generating step [10]. The engine development is related to the ongoing fusion research at Princeton Plasma Physics Laboratory, which everybody knows, and refers to, as PPPL. The DFD uses a novel magnetic confinement and heating system, fueled with a mixture of isotopes of helium and hydrogen nuclei, to produce a high specific power, variable thrust and specific impulse, and a low-radiation propulsion spacecraft system. The simplest type of fusion drive is using small uncontrolled thermonuclear explosions to push forward the spacecraft, as was planned in the Orion Project [5], but even if a continuous, controlled reaction is used, DFD and D He direct fusion thrusters seem to be the thrusters which will allow to colonize, in the medium term, the solar system. At present there is only 30 kg of He in human hands, thus it would have to be either extracted by mining terrestrial or offworld resources, or it would have to be synthesized [11]. While most of the studies related to DFD deal with missions to the outer solar system or the near interstellar space, the aim of the present paper is studying in some detail fast human missions to Mars and to the Asteroid Belt. Our conclusion is that nuclear **fusion** propulsion **is** an **enabling tech**nology **to start the colonization of** the **solar system** and the creation of a solar system economy.

A confluence of external scenarios cause extinction on Earth within the century. Reuter 21

Timothy Reuter; December 9 2021; Head of Aerospace and Drones at the World Economic Forum; WEF, "Why the human race must become a multiplanetary species," https://www.weforum.org/agenda/2021/12/humans-multiplanetary-species //rchen

Humans have a **one in six chance** of **going extinct this century** according to Oxford Philosopher Toby Ord. In his book, The Precipice: Existential Risk and the Future of Humanity, Dr Ord lays out a variety of long-tail risks that are both existential and **very difficult to mitigate**. These include nature-based risks like **asteroids**, large-scale **volcanic eruptions** and **stellar explosions**. Although we can track many of these phenomena, we **do not have** the **tech**nology (nor are we likely to develop it anytime soon) **to prevent** large eruptions or redirect large asteroids. Initial efforts to nudge space objects are just beginning. This is to say nothing of the human-created risks of **nuc**lear **war** or **bioweapons** intentionally **or** unintentionally released on the public, a scenario made easier to imagine by the current **pandemic**. As long as humanity is grouped together on a single planet there will **always** be a **possibility** that **all** of us can be **killed at once**. It is equivalent to having everyone in a single building: there is always a risk greater than zero of a collapse or fire that kills everyone. By **establishing**, at first, small outposts and eventually larger scale **settlements on other planets**, the **risk** of our species being destroyed is significantly **curtailed**.

Access to space is key to solving inevitable extinction. Multiple scenarios always outweigh their single low-probability scenario. Kovic 21

Marko Kovic; February 2021; PhD from the University of Zurich, co-founder and CEO of the consulting firm Ars Cognitionis, the president of the nonprofit think tank ZIPAR, and the former president of the Swiss Skeptics association for critical thinking; Futures, “Risks of space colonization”; Vol. 126
https://www.sciencedirect.com/science/article/abs/pii/S0016328720301270
https://sci-hub.se/https://doi.org/10.1016/j.futures.2020.102638 //recut rchen

Second, engaging in **space col**onization represents a strategy for **mitigating** existential risks. Existential risks are risks that could result in the **extinction** of humankind or in the permanent curtailing of humankind’s potential for future development [6]. In a more technical sense, existential risks can be thought of as risks that could cause the permanent loss of a large fraction of humankind’s future moral expected value [7]. There are two main categories of existential risks: Natural and anthropogenic. Natural existential risks are risks that are not caused by human decisions and actions. If, for example, a giant **asteroid** or **meteor** were to crash into Earth and exterminate human life, humans would not be to blame for their demise (just as the dinosaurs weren’t to blame for theirs). Anthropogenic existential risks, on the other hand, are [hu]man-made in that they are the direct or indirect consequence of the technological progress of our civilization. Some examples of anthropogenic existential risks are **global** nuclear winter caused by **nuc**lear **war**, catastrophic global **warming** [8, 9], or **uncontrollable** misaligned superintelligent **a**rtificial **i**ntelligence [10, 11]. **As humankind** continues to **develop** technologically, the **number of** existential **risks** is likely to **increase**, making the issue of existential risks ever more pressing. Conceptually, **every existential risk has a** very **low probability** of resulting in a catastrophic outcome at any given time (their adverse outcomes are low- probability, high-impact scenarios), but they still represent a major moral concern, both because so much is at stake (the expected value of humankind’s future is enormous), and because the **cumulative probability** of a catastrophic outcome **is** bound to be **non-trivial** in the long run2 In practical terms, **space col**onization is therefore an important hedge against existential risks [13, 14]. Colonizing space means making sure that not all of our existential eggs are in the same basket, which ceteris paribus **increases** the **probability of avoiding the worst** outcomes.

2 - China

China is catching up, outspending the US 2 to 1. Tarasov 3/16

Katie Tarasov, Senior producer for CNBC and graduate from Northwestern, 03-16-2025, “How the U.S. is losing ground to China in nuclear fusion, as AI power needs surge,” CNBC, https://www.cnbc.com/2025/03/16/the-us-is-falling-behind-china-in-nuclear-fusion-needed-to-power-ai.html //rchen

China and the **U.S.** are in a **race to** create the first grid-scale nuclear **fusion** energy. After decades of U.S. leadership, **China is catching up** by **spending twice as much** and building projects at record speed. Often called the holy grail of clean energy, nuclear fusion creates four times more energy per kilogram of fuel than traditional nuclear fission and four million times more than burning coal, with no greenhouse gasses or long-term radioactive waste. If all goes to plan, it will be at least a $1 trillion market by 2050, according to Ignition Research. There’s just one big problem. “The only working fusion power plants right now in the universe are stars,” said Dennis Whyte, professor of nuclear science and engineering at Massachusetts Institute of Technology. The U.S. was first to large-scale use of fusion with a hydrogen bomb test in 1952. In the seven decades since, scientists around the world have been struggling to harness fusion reactions for power generation. Fusion reactions occur when hydrogen atoms reach extreme enough temperatures that they fuse together, forming a super-heated gas called plasma. The mass shed during the process can, in theory, be turned into huge amounts of energy, but the plasma is hard to control. One popular method uses powerful magnets to suspend and control the plasma inside a tokamak, which is a metal donut-shaped device. Another uses high-energy lasers, pointed at a peppercorn-sized pellet of fuel, rapidly compressing and imploding it. That’s how the U.S. pulled off the historic first fusion ignition, producing net positive energy at the Lawrence Livermore National Ignition Facility, or NIF, in 2022. Here, the preamplifier module increases the laser energy as it heads toward the target chamber at the National Ignition Facitility. Here, the preamplifier module increases the laser energy as it heads toward the target chamber at the National Ignition Facitility. Photo courtesy Damien Jemison at Lawrence

Livermore National Laboratory Since then, private investment in U.S. fusion startups has soared to more than $8 billion, up from $1.2 billion in 2021, according to the Fusion Industry Association. Of the FIA's 40 member companies, 25 of them are based in the U.S. Traditional nuclear power, created from fission instead of fusion, has seen a big uptick in investment as Big Tech looks for ways to fill the ever-increasing power needs of AI data centers. Amazon, Google and Meta have signed a pledge to help triple nuclear energy worldwide by 2050. "If you care about AI, if you care about energy leadership … you have to make investments into fusion," FIA CEO Andrew Holland said. "This is something that if the United States doesn't lead on, then China will." Money, size and speed While the U.S. has the most active nuclear power plants, China is king of new projects. Despite breaking ground on its first reactor nearly four decades after the U.S. pioneered the tech, China's now building far more fission power plants than any other country. China entered the fusion race in the early 2000s, about 50 years after the U.S., when it joined more than 30 nations to collaborate on the International Thermonuclear Experimental Reactor fusion megaproject in France. But ITER has since hit major delays. The race is on between individual nations, but the U.S. private sector remains in the lead. Of the $8 billion in global private fusion investment, $6 billion is in the U.S., according to the FIA. Commonwealth Fusion Systems, a startup born out of MIT, has raised the most money, nearly $2 billion from the likes of Bill Gates, Jeff Bezos and Google. Washington-based Helion has raised $1 billion from investors like Open AI's Sam Altman and a highly ambitious deal with Microsoft to deliver fusion power to the grid by 2028. Google-backed TAE Technologies has raised $1.2 billion. "Whoever has essentially abundant limitless energy … can impact everything you think of," said Michl Binderbauer, CEO of TAE Technologies. "That is a scary thought if that's in the wrong hands." When it comes to public funding, China is way ahead. Beijing is putting a reported $1.5 billion annually toward the effort while U.S. federal dollars for fusion have averaged about $800 million annually the last few years, according to the Energy Department's Office of Fusion Energy Sciences. President Donald Trump ramped up support for nuclear, including fusion, during his first term, and that continued under former President Joe Biden. It's **unclear what fusion funding will look like in Trump's second term**, amid massive federal downsizing. U.S. senators and fusion experts published a report in February calling for $10 billion of federal funds to help keep the U.S. from losing its lead. But the U.S. may already have lost the lead when it comes to reactor size. Generally, the bigger the footprint, the more efficiently a reactor can heat and confine the plasma, increasing the chances for net positive energy. A satellite image from January 11, 2025, shows a massive nuclear project in Mianyang, China, that appears to include four laser bays pointing at a containment dome roughly the size of a football field, about twice as big as the U.S. National Ignition Fusion Facility. A satellite image from January 11, 2025, shows a massive nuclear project in Mianyang, China, that appears to include four laser bays pointing at a containment dome roughly the size of a football field, about twice as big as the U.S. National Ignition Fusion Facility. Planet Labs PBC A series of satellite images provided to CNBC by Planet Labs shows the rapid building in 2024 of a giant new laser-fusion site in China. The containment dome where the fusion reaction will occur is roughly twice the size of NIF, the U.S. laser-fusion project, CNA Corporation's Decker Eveleth said. The China site is likely a fusion-fission hybrid, FIA's Holland said. "A fusion-fission hybrid essentially is like replicating a bomb, but as a power plant. It would never work, never fly in a place like the United States, where you have a regulatory regime that determines safety," Holland said. "But in a regime like China, where it doesn't matter what the people who live next door say, if the government says we want to do it, we're going to do it." China's existing national tokamak project, EAST, has been setting records, volleying with France's project WEST in the last couple months for the longest ever containment of plasma inside a reactor, although that's a less monumental milestone than net positive energy. Another huge state-funded Chinese project, CRAFT, is set to reach completion this year. The $700 million 100-acre fusion campus in eastern China will also have a new tokamak called BEST that is expected to be finished in 2027. China's CRAFT appears to follow a U.S. plan published by hundreds of scientists in 2020, Holland said. "Congress has not done anything to spend the money to put this into action," he said. "We published this thing, and the Chinese then went and built it." U.S. fusion startup Helion told CNBC some Chinese projects are copying its patented designs, too. "China, specifically, we're seeing investment from the state agencies to invest in companies to then replicate U.S. companies' designs," said David Kirtley, founder and CEO of Helion. Manpower and materials China's rapid rollout of new fusion projects comes at a time when American efforts have largely been focused on upgrading existing machines, some of them more than 30 years old. "Nobody wants to work on old dinosaurs, " said TAE's Binderbauer, adding that new projects attract more talent. "There's a bit of a brain drain." In the early 2000s, budget cuts to domestic fusion research forced U.S. universities to halt work on new machines and send researchers to learn on other country's machines, including China's. "Instead of building new ones, we went to China and helped them build theirs, thinking, 'Oh, that'd be great. They'll have the facility. We'll be really smart,'" said Bob Mumgaard, co-founder and CEO of Commonwealth Fusion Systems. "Well, that was a big mistake." China now has more fusion patents than any other country, and 10 times the number of doctorates in fusion science and engineering as the U.S., according to a report from Nikkei Asia. "There's a finite labor pool in the West that all the companies compete for," Binderbauer said. "That is a fundamental constraint." Commonwealth Fusion Systems SPARC tokamak being assembled in December 2024 in Devens, Massachusetts, is scheduled to use superconducting magnets to reach fusion ignition in 2027. Commonwealth Fusion Systems SPARC tokamak being assembled in December 2024 in Devens, Massachusetts, is scheduled to use superconducting magnets to reach fusion ignition in 2027. Commonwealth Fusion Systems Besides manpower, **fusion projects need a huge amount of materials**, such as high power magnets, specific metals, capacitors and power semiconductors. Helion's Kirtley said the timeline of the company's latest prototype, Polaris, was set entirely by the availability of semiconductors. China is making moves to corner the supply chain for many of these materials, in a similar play to how it came to dominate solar and EV batteries. "**China is investing ten times the rate** that the United States is in advanced material development," Kirtley said. "That's something we have got to change." Shanghai-based fusion company Energy Singularity told CNBC in a statement that it "undoubtedly" benefits from China's "efficient supply chain." In June, Energy Singularity said it successfully created plasma in record time, just two years after beginning the design of its tokamak. That's still a far cry from reaching grid-scale, commercial fusion power. Helion aims to be first with a goal of 2028. Commonwealth has announced the site in Virginia where it plans to bring the first fusion power plant, ARC, online in the early 2030s. "Even though the first ones might be in the U.S., I don't think we should take comfort in that," said MIT's Whyte. "The finish line is actually a mature fusion industry that's producing products for use around the world, including in AI centers."

China will soon pass the US. Hiller '24

Jennifer Hiller and Sha Hua; July 8 2024; reporter covering renewable energy and the energy transition; reporter in The Wall Street Journal's Singapore bureau, where she writes about China's climate, energy and science policy as well as China-Europe relations; The Wall Street Journal, "China Outspends the U.S. on Fusion in the Race for Energy's Holy Grail," https://www.wsj.com/world/china/china-us-fusion-race-4452d3be //recut rchen

JP Allain, who heads the Energy Department's Office of Fusion Energy Sciences, said China is spending around $1.5 billion a year on fusion, nearly twice the U.S. government's fusion budget. What's more, China appears to be following a program similar to the road map that hundreds of U.S. fusion scientists and engineers first published in 2020 in hopes of making commercial fusion energy. "They're building our long-range plan," Allain said. "That's very frustrating, as you can imagine." Scientists familiar with **China**'s fusion facilities said that if the country continues its current pace of spending and development, it **will surpass** the **U.S.** and Europe's magnetic **fusion capabilities in three** or four **years**.

Fusion is the single most important advancement—it spills over to other races. The window is closing for action and China is poised to win. Risch 2/24

James Risch, Maria Cantwell, Ylli Bajraktari, Risch is an American lawyer and politician who has served as the junior United States senator from Idaho since 2009, Cantwell is an American politician who has been the junior United States senator from Washington since 2001, Bajraktari is the President and CEO of the Special Competitive Studies Project February 24 2025, "Fusion Power Enabling 21st Century American Dominance" No Publication, https://www.scsp.ai/wp-content/uploads/2025/02/Final-Fusion-Power_-Enabling-21st-Century-American-Dominance.pdf //rchen

This report underscores the urgent need for the United States to prioritize the rapid commercialization of fusion energy as a matter of national security and restoring U.S. energy dominance. Fusion, the process that powers the stars, offers the potential for an abundant, clean, and geographically unconstrained energy source, poised to revolutionize the global energy landscape and reshape geopolitical dynamics. Once commercialized, fusion energy could have a society-level changing impact on human development. Thanks to decades of publicly funded research, recent technological breakthroughs, and an emergent private fusion industry, the dawn of commercial fusion power is close at hand. The Stakes Are High. **The nation that leads in fusion** could **write** the **global rules** and secure significant economic advantages, ensure its energy independence, and maintain its technological edge in critical areas, including AI, advanced manufacturing, and national defense. The global race for fusion energy is underway. China, in particular, has made substantial strides, outpacing the United States in building critical infrastructure and positioning itself to dominate the future fusion supply chain. **America's** historical **leadership** in fusion science **is at risk, with** profound **implications for** our economic competitiveness and **national security**. **Failing to act quickly** and decisively **will result in** the **U**nited **S**tates **ceding** its **tech**nological **advantage**, becoming reliant on other nations for a critical energy source, and diminishing its global influence. America Needs a National Fusion Goal. The United States should establish an explicit National Fusion Goal of starting construction on the world's first commercial fusion power plant this decade. Achieving this goal would solidify the United States as the world's leader in fusion energy, and catalyze a thriving and ultimately self-sustaining commercial fusion industry. The approach to achieving this goal, as outlined in the report recommendations, involves de-risking multiple commercial pathways for building pilot plants, investing in a robust public-sector program and the foundational infrastructure to close remaining R&D gaps, and empowering a leader with the authority and budget to oversee the goal's execution. A Critical Moment for Fusion. To achieve this National Fusion Goal and secure America's future energy dominance, this report recommends immediate and concerted action across three key pillars: 1. Declare Fusion a National Security Priority. The Federal Government should, in upcoming national security strategy and policy formulation, officially recognize fusion energy as a critical technology essential to national security and energy dominance. We recommend developing a 90-day action plan encompassing the topics set out in this report in furtherance of achieving the National Fusion Goal. This will elevate fusion, and help align policy, funding, and regulatory frameworks to accelerate its development and deployment. It will signal to the world, and particularly to China, that the United States plans to lead in fusion energy and win the fusion race. 2. Establish Fusion Leadership and Drive Commercialization. To ensure efficient and effective progress, a "Fusion Lead" should be appointed within the highest levels of the Department of Energy (DOE) to drive concrete action towards fusion demonstration and achieve the National Fusion Goal. This high-level official should be empowered and given clear authority to provide the Secretary immediate policy options within prescribed deadlines on each of the topics below and, once finalized, execute the approved actions with executive decision and budget authority. Supply Chain: Identify the full supply chain of necessary fusion components and materials, and mitigate potential vulnerabilities for fusion pilot plants and functional fusion power plants—including by incentivizing the domestic manufacturing of fusion components at risk of supply disruption or undue market control by adversarial or unstable nations—consistent with the National Fusion Goal. ○ Public–Private Partnerships: Develop and implement a public–private fusion framework that addresses the current limitations of public–private partnerships (PPPs), clearly articulates the roles and responsibilities of the relevant actors within DOE, National Labs, universities, and private industry, maximizes existing fusion partnerships, and identifies any additional PPP mechanisms needed to achieve the National Fusion Goal. ○ Regulations: Work within DOE and consult with other appropriate federal and state agencies to develop and implement a roadmap to streamline the regulatory processes for the siting, construction, and operation of fusion power plants. This includes developing an efficient licensing process to enable the full-scale deployment of mass-manufactured fusion machines, fast-tracking federal environmental reviews, directing the Federal Energy Regulatory Commission (FERC) to issue rules expediting the electric grid interconnection process for fusion power, and codifying a pathway for interconnections between fusion power plants and co-located loads, such as data centers and factories. 3. Strategic Investment to Win the Fusion Race. Additional federal funding for fusion research and development is imperative to achieve the National Fusion Goal. This report calls for a one-time, $10 billion investment to ensure American energy dominance by building critical research infrastructure first identified in the 2020 Fusion Energy Sciences Advisory Committee's Long-Range Plan developed under the first Trump Administration, accelerating commercialization-focused R&D programs, and supporting the eventual demonstration of fusion pilot plants through cost-share programs and supply chain development. This strategic, one-time investment will catalyze private sector involvement and accelerate innovation. Paired with continued investments in basic science, it will ensure the United States maintains its scientific leadership in the field. The commercialization of fusion energy represents a transformative moment for the United States to unleash energy abundance at home and abroad. It is an opportunity to secure our energy future, bolster our economic competitiveness, and strengthen our national security. We believe that embracing these recommendations is the best path to American energy dominance. The time for bold action is now. We must seize this moment to ensure that fusion energy powers America's future. Fusion Power: Enabling 21st Century American Dominance The Stakes Fusion energy offers the possibility to engineer and harness the power of the stars on Earth. Fusion entails placing light atoms (typically hydrogen isotopes) under such high temperature and pressure that they combine into new elements, releasing tremendous amounts of energy. Scientists and engineers have for decades pursued a variety of technical approaches to this challenge. Most involve magnets, lasers, or some combination of the two. In 2022, U.S. scientists at Lawrence Livermore National Lab proved the scientific feasibility of fusion, achieving "ignition" by releasing more energy than was put into the reaction.1 Powered by an abundant fuel source unconstrained by scarcity or geography,2 fusion opens the door to a new and safe form of energy generation for the 21st century.3 When fusion machines are deployed and connected to America's energy grids, fusion power can become a source of national strength. It can fuel an AI-enabled economy, shore up domestic energy security, and reshape energy geopolitics, with significant leverage accruing to first-mover nations. Fusion's vast potential is now propelling a worldwide push to make it a reality. In particular, our rival, China, has made remarkable strides in laying the groundwork for rapid fusion commercialization.4 Fusion energy can provide the massive amounts of reliable power needed to support the growth of AI,5 reshored manufacturing, and other energy-intensive technologies. As AI hyperscale data centers increasingly seek out firm energy generation technologies to power their computing infrastructure,6 fusion energy could support these growing demands in the next decade, alongside other energy sources like advanced nuclear reactors and geothermal power. Fusion energy could also yield transformative economic growth and lower energy costs for consumers.7 The market for fusion alone is projected to exceed $1 trillion by 2050.8 Combined with AI, fusion could create a powerful flywheel of U.S. techno-economic power. AI has already proven critical in accelerating fusion development, driving breakthroughs in physics, materials science, and laser and magnet technologies that have catalyzed a booming startup ecosystem. As AI capabilities advance, they will continue to expedite fusion R&D. Once online, **fusion** power plants **can fuel** the **next gen**eration of **AI** models and adoption, **supercharging America's lead** in AI. Finally, fusion's enabling technologies9 promise to unlock jobs across the economy and drive innovation in sectors like aerospace, defense, medicine, and more.10 Beyond economic benefits, fusion power could redefine global geopolitics. Countries that rely heavily on their own fusion energy will be resilient to the geopolitical pressures and supply chain issues associated with other energy sources, and exporting fusion would accrue geopolitical leverage. The fuel sources for fusion will likely be derived from widely available resources like seawater and lithium, creating new avenues for energy independence. Finally, **fusion** could also **support advanced defense tech**nologies, driving new innovations in stockpile stewardship,11 potentially **powering military** and space installations, and **contributing to** overall technological **superiority.** Thanks to decades of federal investment in basic research, American scientists have now proven that fusion is possible. Growing power demands, recent technological breakthroughs, and the shifting market dynamics of energy create a unique opportunity for fusion to finally see its time in the Sun. A big bet on fusion could secure America's position as a technological superpower for decades to come.

The plan catalyzes reactor diplomacy which solves. Price 25

Rowen Price, Senior Policy Advisor for Nuclear Energy, Christel Hiltibran, Director of International Policy, Climate and Energy Program, Ryan Norman, Senior Policy Advisor for Climate and Energy Finance, Alan Ahn, Deputy Director for Nuclear, Jan 31 2025, "Trump Has Been a China Hawk on Nuclear Energy. But Congress Could Compromise That During Reconciliation," Third Way, https://www.thirdway.org/memo/trump-has-been-a-china-hawk-on-nuclear-energy-but-congress-could-compromise-that-during-reconciliation //rchen

President Trump has long considered himself a China hawk, stoking a trade war with the country, supporting ever-increasing tariffs on its goods, and using aggressive rhetoric to combat its growing global influence. But his approach has a blind spot, failing to mitigate China's increasing dominance in the energy sector, especially in nuclear energy development and deployment. Until we confront **China**'s **rising role in global** energy **markets**, the **US** will continue to cede market share and **lose geopolitical influence, threaten**ing national **security** both **in** the US and among our **allied nations**. The **US needs** a synchronized foreign policy to counter Chinese attacks on American hegemony. But since the election, the incoming administration and Congress have signaled misaligned approaches to **foreign energy policy**. The Trump Administration's Day 1 executive orders reaffirmed the President's commitment to domestic energy production—now it's up to Congress to ensure legislation is going to support energy goals. Nuclear Energy Must Be a Foreign Policy Priority Beyond bilateral trade barriers, the US must also dominate critical global industries to remain competitive. There is broad consensus that investments in national defense, space, artificial intelligence, and quantum computing will help make America more secure and more prosperous. The same is true of investments in nuclear energy. A robust domestic nuclear supply chain has corollary benefits, including reliable energy supply, that are foundational to our defense and technology sectors. Moreover, the **strength of** our **nuclear industry directly supports** our **competitiveness abroad,** which in turn affects our ability to uphold the highest global norms in nuclear security **and** nonproliferation. Failure to compete overseas will enable China, Russia, and other rivals to erode our influence on these international standards and cement century-long geostrategic **partnerships around the world. Put**ting the **US at the forefront of** global civil **nuclear** markets will make us stronger, more secure, and more influential on the global stage. Our adversaries understand the stakes. China and Russia have state-owned, heavily subsidized nuclear **industries** that are a key part of their efforts to gain allies and influence throughout the developing world. China and Russia view nuclear exports as a way to develop century long partnerships in Africa, Asia, and Eastern Europe. Their interest in advanced nuclear power is less about economics, and more about influence. The competition is well underway and the United States is losing. According to the International Atomic Energy Agency, 85% of all new reactors currently under construction in 2024 are Russian or PRC designs; 0% are US designs. This year, President Trump and the new Republican Congress have an opportunity to do just that—through budget reconciliation. Trump Could Cede Critical Geopolitical "Energy Dominance" to China in His First 100 Days by Compromising America's Nuclear Industry—But It's Not Too Late Put simply, if we want **to outcompete China**, Congress needs to continue to prioritize clean energy. The incoming Trump administration has made no secret of its hostility to the Inflation Reduction Act (IRA) and its clean energy provisions, especially its investments in wind and solar. But despite recent bipartisan alignment in support of nuclear energy, Trump's agenda not only targets renewables but may also incidentally deal a significant blow to programs supporting nuclear development and demonstration in the US. During the 117th Congress, IRA and the Bipartisan Infrastructure Law (BIL) created tax credits, grants, and loan programs to finance the research, development, demonstration, and even the deployment of emerging clean energy technologies, including nuclear. In a flurry of signals issued during the lame-duck period, the incoming administration and Republican Congressional leadership have made clear that many of these programs are on the chopping block in the first 100 days of the second Trump administration. In competition with state-backed civil nuclear programs such as China, the US needs to bolster its federal government funding for nuclear, not decrease it. China is churning out large reactors at home, demonstrating (i.e., building and operating) advanced reactor technologies, and marketing advanced reactors cheaply along its "Belt and Road." To stay relevant in this race for international market share, the US must rapidly finance the demonstration and subsequent commercialization of US nuclear small modular reactors (SMRs) and advanced nuclear reactors**. The time is now,** in the 2025 reconciliation process, to save this critical sector from opening its global market to China. Why? The **decisions** the US government makes **this year will** dictate whether US nuclear developers have the resources they need to keep pace and ground test these technologies. In the interest of national security and to **ensure US competitiveness, Congress must** robustly **appropriate funding** for advanced nuclear demonstrations and maintain federal programs critical to the scale-up of these technologies. The following programs are all essential to preserve or expand during budget reconciliation.

ANY perceived superiority in AI and fusion energy can embolden China to pursue aggressive military action. This goes nuclear Kroenig 21

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Novel Applications How will states use such a newfound advantage? Technology rarely fundamentally changes the nature or objectives of states. More often, states use technology to advance preexisting geopolitical aims. Moreover, enhanced power can result in greater ambition. Given the geopolitical landscape described, it is likely the United States and its Allies and partners at the core Will Emerging Technology Cause Nuclear War?: Bringing Geopolitics Back In STRATEGIC STUDIES QUARTERLY WINTER 2021 67 of the international system will behave differently with new military technologies than will revisionist powers, such as Russia and China. The spread of new technology to the United States and its Allies and partners would likely serve, on balance, to reinforce the existing sources of stability in the prevailing international system. At the end of the Cold War, the United States and its Allies and partners achieved a technological military advantage over its great power rivals, with the US using its unipolar position to deepen and expand a rules-based system. They also employed their military dominance to counter perceived threats from rogue states and terrorist networks. The United States, its Allies, and partners did not, however, engage in military aggression against great power, nuclear-armed rivals or their allies. In the future, these status quo powers are apt to use military advantages to reinforce their position in the international system and to deter attacks against Allies and partners in Europe and the Indo-Pacific. These states might also employ military power to deal with threats posed by terrorist networks or by regional revisionist powers such as Iran and North Korea. But it is extremely difficult to imagine scenarios in which Washington or its Allies or partners would use newfound military advantages provided by emerging technology to conduct an armed attack against Russia or China. Similarly, Moscow and **Beijing** would likely **use any newfound military strength** to **advance** their **preexisting** geopolitical **aims.** Given their very different positions in the international system, however, these states are likely to employ new military technologies in ways that are destabilizing. These states have made clear their dissatisfaction with the existing international system and their desire to revise it. Both countries have ongoing border disputes with multiple neighboring countries. If Moscow developed new military technologies and operational concepts that shifted the balance of power in its favor, it would likely use this advantage to pursue revisionist aims. If Moscow acquired a newfound ability to more easily invade and occupy territory in Eastern Europe, for example (or if Putin believed Russia had such a capability), it is more likely Russia would be tempted to engage in aggression. Likewise, if China acquired an enhanced ability through new technology to **invade** and occupy **Taiwan** or contested islands in the East or South China Seas, Beijing's leaders might also find this opportunity tempting. If new technology enhances either power's anti-access, area-denial network, then its **leaders** may be **more confident** in their ability to achieve a fait accompli attack against a neighbor and then block a US-led liberation. 68 STRATEGIC STUDIES QUARTERLY WINTER 2021 Matthew Kroenig These are precisely the types of shifts in the balance of power that can lead to war. As mentioned previously, the predominant scholarly theory on the causes of war—the bargaining model—maintains that imperfect information on the balance of power and the balance of resolve and credible commitment problems result in international conflict.52 New technology can exacerbate these causal mechanisms by increasing uncertainty about, or causing rapid shifts in, the balance of power. Indeed as noted above, new military technology and the development of new operational concepts have shifted the balance of power and resulted in military conflict throughout history. Some may argue emerging military technology is more likely to result in a new tech arms race than in conflict. This is possible. But Moscow and Beijing may come to believe (correctly or not) that new technology provides them a usable military advantage over the United States and its Allies and partners. In so doing, they may **underestimate Washington**. If Moscow or Beijing attacked a vulnerable US Ally or partner in their near abroad, therefore, there would be a **risk of major war** with the potential **for nuclear escalation.** The United States has formal treaty commitments with several frontline states as well as an ambiguous defense obligation to Taiwan. If Russia or China were to attack these states, it is likely, or at least possible, that the **United States would come to** the **defense** of the victims. While many question the wisdom or credibility of America's global commitments, it would be **difficult** for the United States **to** simply **back down**. Abandoning a treaty ally could cause fears that America's global commitments would unravel. Any US president, therefore, would feel great pressure to come to an Ally's defense and expel Russian or Chinese forces. Once the United States and Russia or China are at war, there would be a risk of nuclear escalation. As noted previously, experts assess the greatest risk of nuclear war today does not come from a bolt-out-of-the-blue strike but from nuclear escalation in a regional, conventional conflict.53 Russian leaders may believe it is in their interest to use nuclear weapons early in a conflict with the United States and NATO.54 Russia possesses a large and diverse arsenal, including thousands of nonstrategic nuclear weapons, to support this nuclear strategy. In the 2018 Nuclear Posture Review, Washington indicates it could retaliate against any Russian nuclear "de-escalation" strikes with limited nuclear strikes of its own using low-yield nuclear weapons.55 The purpose of US strategy is to deter Russian strikes. If deterrence fails, however, there is a clear pathway to nuclear war between the United States and Russia. Will Emerging Technology Cause Nuclear War?: Bringing Geopolitics Back In STRATEGIC STUDIES QUARTERLY WINTER 2021 69 As Henry Kissinger pointed out decades ago, there is no guarantee that, once begun, a limited nuclear war stays limited.56 There are similar risks of nuclear escalation in the event of a US-China conflict. China has traditionally possessed a relaxed nuclear posture with a small "lean and effective" deterrent and a formal "no first use" policy. But China is relying more on its strategic forces. It is projected to double—if not triple or quadruple—the size of its nuclear arsenal in the coming decade.57 Chinese experts have acknowledged there is a narrow range of contingencies in which China might use nuclear weapons first.58 As in the case of Russia, the US Nuclear Posture Review recognizes the possibility of limited Chinese nuclear attacks and also holds out the potential of a limited US reprisal with low-yield nuclear weapons as a deterrent.59 If the nuclear threshold is breached in a conflict between the United States and China, the risk of nuclear exchange is real. In short, if a coming revolution in military affairs provides a real or **perceived** battlefield **advantage** for Russia or China, such a development **raises** the **likelihood of armed aggression** against US regional allies, major power war, **and** an increased risk of **nuclear escalation.** Implications Future scholarship should incorporate geopolitical conditions and the related foreign policy goals of the states in question when theorizing the effects of technology on international politics. Often scholars attempt to conceptualize the effects of weapons systems in isolation from the political context in which they are embedded. Studies treat technology as disembodied from geopolitics and as exerting independent effects on the international system. But technology does not float freely. Technology is a tool different actors can use in different ways. Bakers and arsonists employ fire in their crafts to strikingly different ends. In the current international environment, Russia and China would tend to employ technology toward advancing revisionist aims. Technological advances in these countries are therefore much more likely to disrupt the prevailing international order and nuclear strategic stability. This approach also suggests the potential threat new technology poses to nuclear strategic stability is more pervasive than previously understood. To undermine strategic stability, new technology need not directly impact strategic capabilities. Rather, any technology that promises to shift the local balance of power in Eastern Europe or the Indo-Pacific has the potential to threaten nuclear strategic stability. 70 STRATEGIC STUDIES QUARTERLY WINTER 2021 Matthew Kroenig This understanding of this issue leads to different policy prescriptions. If the technology itself is the problem, then it must be controlled and should not be allowed to spread to any states. In contrast, the framework outlined here suggests a different recommendation: preserve the prevailing balance of po**wer** in Europe and Asia. Technological change that, on balance, reinforces the prevailing international system should strengthen stability. Leading democracies, therefore, **should increase investments in emerging tech**nology **to maintain** a technological **edge** over their adversaries. Export control and nonproliferation measures should be designed to deny emerging military technology to Russia and China. Arms control should be negotiated with the primary objective of sustaining the current international distribution of power. Making progress in these areas will be difficult. But the consequences of failure could be shifts in the international balance of power, conflict among great powers, and an increased risk of nuclear war.

Extinction. Sarg 08

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https://www.academia.edu/63917319/1_MANIFESTO_Prevent_Nuclear_Disaster_Doomsday

One new physical phenomenon that resulted from antigravity research was reported at the 27 th Annual Meeting of the Society for Scientific Exploration, 25-28 June, 2008, in Boulder, CO, USA [2]. The unique gravito-inertial phenomenon achieved in the laboratory was called Stimulated Anomalous Reaction to Gravity (SARG). It was a result of years of research following successful theoretical predictions, and was supported by international private organizations. The theoretical and experimental research leading to the discovery of this effect were published at a number conferences and international meetings, and is the subject of a patent application [3,4,5]. In parallel with the laboratory experiments, extensive analysis was done on the effects of nuclear tests in the atmosphere using the physics behind the observed SARG effect. **A large quantity of** unclassified nuclear test data from both the USA and the former Soviet Union was used. Pictures and technical specs, as well as video material, are available via the Internet. The videos are useful for observing the dynamics in the first few seconds of the **nuclear explosion** when unusual phenomena take place. It was observed that an extremely large scale SARG effect takes place in the first few seconds or tens of seconds. The effect is stronger when the nuclear explosion takes place in the atmosphere between 200 m to 2 km above the ground. It is less strong at higher altitudes due to the rarefied atmosphere. Even for the non-scientist, the effect of **antigravity** is apparent in several videos such as the unclassified documentary movie entitled "Declassified U.S. Nuclear Test Film #70" [6]. The atmospheric nuclear test near the beginning of the documentary occurs at an altitude of 610 m from the ground. As the plasma from the nuclear explosion **expands**, a thick column of dust and **condensed air** begins to **rise from the ground**. It reaches the expanding plasma in about 20 sec. Small-diameter **tornado-like columns** also arise simultaneously, and this phenomenon is very common during atmospheric nuclear explosions. Note that the rising main column not only reaches the bulk of expanded plasma but also punches through it. The SARG effect explains the rising column and surrounding tornados. The nuclear explosion causes the formation of a vast quantity of expanding plasma. This plasma affects the physical vacuum in such a way that an antigravity effect is created below the nuclear explosion. The dust and condensed gases rise because of the antigravity effect. They obtain a vertical pulse momentum during the existence of the plasma resulting from the explosion, which may last for a few seconds to tens of seconds. The explosion also creates another detectable effect – a strong EM pulse. (In the laboratory experiment demonstrating the SARG effect, such a pulse is quite weak and is invoked by other means). The rising column and the expanding plasma create the well-known shape of the nuclear mushroom cloud. The same antigravity phenomenon with multiple tornados is also visible in the videos [7,8] of other atmospheric nuclear tests. From 1945 to 1963 the USA conducted an extensive campaign of atmospheric nuclear tests, grouped into roughly 20 test series [9]. USSR also conducted extensive atmospheric nuclear tests in the period from 1949 to 1962. They are summarized in a Catalog of Worldwide Nuclear Testing edited by V. N. Michailov [10]. After the Limited Test Ban Treaty was signed in 1963, testing by the U.S., Soviet Union, and Great Britain moved underground. France continued atmospheric testing until 1974 and China did so until 1980. In all the available information, there is no indication that simultaneous atmospheric nuclear tests separated by a finite distance have ever been performed. This has been our good fortune, as we will see. In a single atmospheric test, the antigravity effect is usually directed vertically upward. But what might happen if simultaneous tests within a finite time and distance were done? The disturbance of the physical vacuum would lead to an antigravity effect that is not vertical. Additionally, the two disturbances would interact and the columns from the rising dust and gases will be twisted. The new physics of this phenomenon predicts that the antigravity effect from the two explosions will be much stronger. This may **cause** a part of the atmosphere to be thrown into space. Further, it is possible that a self-supported tornado-like effect may extend the life of the phenomenon, so a significant fraction of the earth's **atmosphere** may be **sucked into space**. This is more than just speculation since exactly such an effect was **observed on the Sun** by some solar orbit satellites [11,12]. The video clip on the National Geographic website [13] clearly shows the dynamics of the solar tornado extended into space. Now scientists claim that such a tornado is responsible for throwing large quantities of solar gaseous mass into space [14]. The phenomenon observed at the Sun could happen on the Earth during **simultaneous nuclear atmospheric explosions** that create similar conditions. To understand the gravity effects, one must have a correct model of the physical vacuum. The model adopted about 100 years ago is now not supported by laboratory experiments. We may think that the space outside the earth's atmosphere is empty but it still has the properties of the physical vacuum, and many experiments show that it is not void. This new understanding is completely unknown to military advisors and politicians. They don't have a clear idea what could happen during multiple nuclear explosions in the atmosphere because, fortunately, such **experiments** have **never been done**. We must not think that the atmosphere is something permanent and cannot be destroyed. The planet Mars is a good example of an atmosphere's vulnerability. Once Mars had an atmosphere. This is evident from apparent surface erosion from rivers. Now the atmospheric pressure on Mars is about 0.1% of Earth's atmospheric pressure. Mars lost its atmosphere probably because of some natural event such as a huge volcanic eruption. If the policy of preemptive nuclear strike is applied during a military conflict, there will likely be multiple cases of simultaneous nuclear explosions within a limited range and time. The probability is high that conditions will be created which can result in the loss of a fraction of the Earth atmosphere. Let us describe the consequences of this worst-case scenario that might develop during the initial phase of the nuclear strikes. If an atmospheric sucking-tornado effect occurs somewhere, the first effect will be a huge windstorm that equalizes the atmospheric pressure. This, of course, will not stop the nuclear strikes. The worst case is that the global atmospheric pressure will drop below some critical level. It is well known that human beings are quite sensitive to changes in atmospheric pressure. (Even a trained mountain climber could not climb a peak higher than 5 km without an oxygen mask). At some low level of atmospheric pressure, a person loses consciousness. Since the effect of a pressure drop will be permanent, there is no chance of returning to consciousness. Protective measures exist to counter all known effects of a nuclear explosion: i.e., direct radiation, shock waves, and radioactivity. Protection from reduced atmospheric pressure, however, is impossible. In the worst-case scenario, there will be no survivors. It does not matter that you are rich or poor, living in a highly developed or a poor country, in an urban or low populated area. **Everyone** on Earth **will die**. This may happen **in** a time interval of 1-3 **days.** The dead people will lay unburied together with animals. Microbes and fungi will survive while the biomass of Earth's human and animal population slowly disintegrates. This will be a very tragic end to Earth's civilization; a civilization that reached its apogee in order to destroy itself. There will be no one left to document the end of humankind.

REBUTTAL

[PBS Newshour Classroom; ; Is It Difficult to Build a Dirty Bomb?, xx-xx-xxxx; https://www.pbs.org/newshour/classroom/daily-videos/2023/08/is-it-difficult-to-build-a-dirty-bomb ; accessed, 4-5-2025] //wickynang

Radioactive material can be found various forms include educational, medical and industrial applications as well as orange colored glaze used for plates and cups. The federal government estimates there are **77,000 sources** of radiation that **would be useful for a dirty bomb** in 2,700 buildings in the U.S. Experts from the NNSA and the Los Alamos National Lab are recovering radioactive material that is no longer in use. Thus far, they have secured nearly 25,000 sources at about 900 sites around the world.

Conca '25 [James Conca; ; Dirty bombs: The terror and the truth, 4-4-2025; No Publication, https://www.ans.org/news/article-5976/dirty-bombs-the-terror-and-the-truth/; accessed, 4-5-2025] //wickynang

Although the public generally thinks of **plutonium and enriched uranium** when hearing the word "radioactive," these isotopes **are not considered good dirty bomb materials,** because they are **primarily alpha emitters, costly, well tracked and secured** (and therefore cannot be obtained in large amounts), and are more useful in the production of actual nuclear weapons than in being wasted in a dirty bomb. For the purposes of a dirty bomb, 137CsCl powder is the most effective material—easily dispersible, hard gamma–emitting, and very cheap, at about $3 per curie.

World nuclear, 2020, "Nuclear Power in the United Arab Emirates," No Publication, https://world-nuclear.org/information-library/country-profiles/countries-t-z/united-arab-emirates //rchen

Gulf states In December 2006 the six member states of the Gulf Cooperation Council (GCC) – **Kuwait, Saudi Arabia, Bahrain, the United Arab Emirates (UAE), Qatar and Oman –** **announced** that the Council was **commissioning** a study on the peaceful **use of nuclear energy**. **France agreed to work with them on this,** and **Iran pledged assistance** with nuclear technology. The GCC countries share a common grid apart from Saudi Arabia. Almost all electricity is from fossil fuels, and there is also a large demand for desalination, currently fuelled by oil and gas. In February 2007 the six states agreed with the IAEA to cooperate on a feasibility study for a regional nuclear power and desalination programme. Saudi Arabia was leading the investigation and thought that a programme might emerge about 2009, which it did. The six nations are all signatories of the NPT and the UAE ratified a safeguards agreement with IAEA in 2003. In mid-2008 it appointed an ambassador to IAEA.