<u>**Case**</u>

Will and I **affirm** Resolved: The United States federal government should substantially increase its investment in domestic nuclear energy.

Our First Contention is renewing renewables.

Getting carbon zero means transitioning to renewable energy, but that can't happen without nuclear

Dr. M.D. Matthew, PhD Physics, Professor and Dean at Saintgits College of Engineering in 2021

Without nuclear energy, it would not be possible to combat climate change. [because] Nuclear power can directly replace fossil fueled power plants. Nuclear power plants provide continuous stable energy to the grid whereas solar and wind energy require back-up power The International Panel on Climate Change has proposed doubling nuclear generation by 2050 to meet the Paris agreement.

Renewable sources are not able to meet continuous energy demands due to their intermittent nature and the absence of storage capacities. This means that power grids require supplementary energy sources. Nuclear power can generate low carbon energy 24 hours a day, 7 days a week to meet fluctuations. This is why transitioning to a zero-emissions energy infrastructure without nuclear energy would involve a 50% greater capital investment.

Empirics prove, implementing nuclear helps the climate

Maguire 24 reports from 2018 through 2022, Voglte generated 2,813 hours for Georgia, which is 27% of total state electricity. Since Vogtle 3 started operations in 2023, the share of electricity generation jumped to 37% with carbon intensity dropping by 14%.

Thus, <u>more investment</u> is <u>key</u>.
Fisher 24 reports investment in nuclear energy must increase to 125 million USD from 50 billion each year to meet projections.

Historically, <u>investment</u> has been <u>effective</u>.
Freebairn 24 continues the U.S. Inflation Reduction Act benefitted nuclear energy for Constellation, the largest plant operator. The IRA was transformational — Constellation is planning to renew all of its reactors. 2.5 GW of capacity all across the U.S. could be added.

Absent <u>action means death</u>,
Cassella '23 concludes for every 0.1 °C degree of warming, the world could suffer roughly 100 million deaths.

<u>**Our Second Contention is managing medical isotopes.**</u>
Currently, there is a shortage of medical isotopes.

Omer 24 explains Technetium-99m, a critical nuclear imaging radioisotope, is in short supply.

Luckily, isotopes are made through nuclear energy.
World Nuclear Association 25 corroborates that many radioisotopes are made in nuclear reactors; generally, neutron-rich isotopes and those resulting from nuclear fission need to be made in reactors.

Isotopes are key to medicine.
CMI 25 writes, in nuclear medicine, isotopes are vital for imaging modalities & facilitating the early diagnosis and appropriate management of diseases.

Thus, the shortage is devastating for life-saving medicine.
Omer 24 explains short supply causes delays or cancellations of over 40,000 medical imaging studies daily in the United States. Over 1 million diagnostic exams may be delayed.

Nuclear assists medicine and saves millions of lives.
EuroNuclear quantifies every year, 30 million people benefit from a diagnostic procedure or treatment by nuclear medicine in at least 60 different pathologies—and these numbers are steadily increasing.

<u>Contention Three is implementation of water desalination.</u>
Right now, millions of Americans live without access to one of the seven basic survival needs—water.
The United Nations in **2023** explains, today, more than two million Americans lack access to clean drinking water at home.

Current desalination plants are unfortunately lackluster.
Crunden 23 explains only half the facilities are operational. Furthermore, desalinated water makes up only a portion of water supply, even in places like San Diego, home to the biggest plant in the country. Another large facility, Tampa Bay Seawater Desalination, supplies only up to 10 percent of the area's needs.

Luckily, nuclear energy can save the day as it can be used to desalinate water.
International Atomic Energy Agency 23 explains nuclear power plants could turn seawater into fresh water, powered by nuclear energy desalination, a solution for a number of water-intensive endeavours.

For nearly 30 years, the IAEA has supported desalination, a process that uses the heat and electricity produced by a nuclear power plant to remove salt and minerals from seawater through distillation. India, Japan, and Kazakhstan have the most experience in nuclear distillation, with hundreds of reactor-years of successful operations.

For example, Jordan was a massive success story when they bolstered nuclear energy for desalination.

IAEA 23 continues that, after hosting a course in Jordan, a study discovered using nuclear energy for desalination was feasible. They opted to build capacity in the use of small modular reactors to desalinate water. Desalination is now considered the primary source of freshwater in Jordan.

The impact is millions of lives.
Increasing water access through expanding investment in nuclear energy can save the 2 million Americans struggling with thirst now. Under the affirmative , we give them the water they have a right to receive. A fundamental human right.
Johnson 19 explains that the body needs lots of water to carry out many essential functions; a person can survive without water for about three days.

<u>Extensions</u>

You're voting on renewing renewables. Remember, **Dr. Matthews** writes we need to use nuclear to replace fossil fuel power plants — Look to Georgia.

Evidence

MP affirms Resolved: The United States federal government should substantially increase its investment in domestic nuclear energy.

Our first contention is renewing renewables.

BUT transition without nuclear fails to provide enough energy, collapsing the grid.

Dr. M.D. **Matthew 21**, PhD Physics, Professor and Dean at Saintgits College of Engineering, former researcher in metallurgical engineering as Scientist at Indira Gandhi Centre for Atomic Research, 11/14/21, "Nuclear energy: A pathway towards mitigation of global warming," , young

[FIG. 6, 7 and 8 w/ their captions OMITTED. FIG 9 included, for convenience.]

3.1. Clean energy transition

The clean energy transition means shifting from fossil energy to energy resources that release little or no greenhouse gases such as nuclear power, hydro, wind and solar. About a third of the world's carbon-free electricity comes from nuclear energy.

Nuclear power has a great potential to contribute to the **1.5 °C Paris climate change target**. Nuclear power plants produce **no greenhouse gas emissions** during their operation; only very low emissions are produced over their full life cycle. Even after accounting for the entire life cycle from mining of nuclear fuel to spent fuel waste management, nuclear power is proven to be a low carbon electricity source. During operation and maintenance, nuclear power plants produce different levels of solid and liquid waste and are treated and disposed-off safely. While conventional fossil-fueled power plants cause emissions almost exclusively from the plant site, the majority of greenhouse gas emissions in the nuclear fuel cycle are caused in processing stages upstream (exploration and processing of the uranium ore, fuel fabrication etc.), and downstream from the plant (fuel reprocessing, spent fuel storage etc.). Over the course of its life-cycle, the amount of CO2-equivalent emissions per unit of electricity produced by nuclear power plants is comparable with that of wind power, and only one-third of the emissions by solar. The greenhouse gas emissions correspond to **10**-15 gm of CO2 per kilowatt hour electricity produced in comparison with the emission from a fossil fueled plant of **600**-900 gm, **15**-25 gm from **wind** turbines and hydro-electricity, and around **90** g from solar power plants (Fig. 8) (Carbon Dioxide Emissions, 2021).

Nuclear power delivers reliable, affordable and clean energy to support economic growth and social development. Without a larger role for nuclear energy, it would **not be possible to combat climate change**. Nuclear power can be deployed on a **large scale**. So, nuclear power plants can **directly replace fossil fueled power plants**. As of end December 2020, global nuclear power capacity was 393 GW(e) and accounted for around 11% of the world's electricity and around 33% of global low carbon electricity. Currently, there are 442 nuclear power reactors in operation in 32 countries. There are 54 reactors under construction in 19 countries, including 4 countries that are building their first nuclear reactors according to the IAEA reports (Nuclear Power Proves its, 2021; Climate Change and Nuclea, 2020a, 2020b). Nuclear power is reducing CO_2 emissions by about two gigatons per year. Therefore, nuclear power will be imperative for achieving the low carbon future. In France, nuclear power plants accounted for 70.6% of the total electricity generation in 2019, the largest nuclear share for any industrialized country. About 90% of France's electricity comes from low carbon sources (nuclear and renewable combined). Nuclear power contributes 20% of electricity generation in the United States over the past two decades and it remains the single largest contributor of non-greenhouse-gas-emitting electric power generation out of 1,117, 475 MWe total electricity generating capacity of which 60% is from fossil fuel.

The second-largest source of low carbon energy in use today is nuclear power, after hydropower. Nuclear power plants provide continuous and stable energy to the grid whereas solar and wind energy require **back-up power** **during their output gaps**, such as at night or when the wind stops blowing. The International Panel on Climate Change (IPCC) has proposed at least **doubling** of **nuclear power generation** by 2050 **to meet** **the** **Paris** agreement. Nuclear power has compensated about 60 Gt of CO_2 emissions over the past 50 years, nearly equal to 2 years of global energy-related CO_2 emissions and can help to conquer the challenges of climate change.

Existing reactors and future advanced nuclear technologies, like Small Modular Reactors (SMRs), can meet base load power needs and also operate flexibly to **accommodate renewables and respond to demand**. SMRs are a recent concept to accelerate the construction and commissioning of large nuclear power projects. By adopting the concept of modular manufacture of components, significant reduction in on-site construction time can be achieved. This can also help in reducing the capital costs. Several types of SMRs are currently under development and these offer improved economics, operational flexibility, enhanced safety, a wider range of plant sizes and the ability to meet the emerging needs of sustainable energy systems. Some of these reactors are designed to operate up to 700-950 ° C (for gas cooled reactors) compared to LWRs, which operate at 280-325 °C. The electrical efficiency is higher and it can supply high temperature heat to industrial processes. High temperature SMRs can generate hydrogen through more energy efficient processes such as high temperature steam electrolysis or thermochemical cycles. Their smaller size and easier siting are expected to be a better fit for most non-electric applications, which require an energy output below 300 MWe.

3.2. Electric grid stability and nuclear power

Renewable energy sources **are** **not able to** **meet continuous** **energy demands** due to the **intermittent nature** **of solar and wind** power, and the absence of massive energy storage capacities. This means that the power grids often require **supplementary** **energy** **sources**. Nuclear power can generate low carbon energy **24** h a day, **7** days a week and can meet **fluctuations** in energy demand and provide stability to electrical grids, especially those grids with a high share of **variable renewable sources** which **otherwise have to depend on fossil fuels**. A typical energy demand in a 24-h cycle is shown schematically in Fig. 9. Nuclear power can provide **backup capacity** support for variable solar and wind generation without the need for fossil fuel. Unlike conventional electricity grids, Smart grids allow several **different energy sources** to be connected dynamically. Smart grids use Artificial Intelligence (AI) and the Internet of Things (IoT) technologies to automate processes. Nuclear power combined with smart power grids helps **smooth transition to renewable energy sources** **and ensure reliable, stable and sustainable energy supplies**.

FIG. 9. Typical energy demand in a 24-h cycle.

AND makes warming mitigation impossible. Markets can't adapt without nuclear.

Dr. Peter B. Lyons et al. 16, former Department of Energy (DOE) Assistant Secretary; Donald R. Hoffman, President and CEO of Excel Services Corporation; and a team of ANS members; "The U.S. without Nuclear Energy: A Report on the Public Impact of Plant Closures," American Nuclear Society,

Section 2: The Economic Impact of Losing Nuclear Power

U.S. nuclear power plants operate at an overall fleet average capacity factor above 90%. Coal and natural gas can also attain high capacity factors, but have negative environmental impacts. Renewables have minimal emissions but they only generate electricity when the sun shines and the wind blows and are thus unable to respond to short term peak electric system requirements.

In electricity markets, renewable mandates and federal and state tax subsidies sometimes result in negative price bidding where power producers pay customers to take their generated electricity, **distort**ing market **prices**. In traditional utility states, "must take" provisions, in which any electricity generated must be bought, apply to qualifying renewables facilities. This disrupts an electric company's economic operation of its portfolio of generation resources. The result in both regulated and deregulated electricity markets is lower efficiency and higher emissions due to the other forms of generation.

Customers need electricity when they need it: to run hospitals, factories, the internet, their homes, and to light their stores and offices. To meet mandated emissions reductions goals and maintain reliability without nuclear, the U.S. will have to rely heavily on natural gas, despite its carbon emissions. Renewable energy sources **cannot replace** nuclear on their own.

A report by the Brattle Group detailed the nuclear industry's contribution to **the U.S. economy** and found that **system reliability** in some regions would be **particularly vulnerable** to the loss of nuclear capacity. In particular, in the VACAR, PJM, Central, New York, and Desert Southwest regions, nuclear provides 24% or more of regional electricity generation.15 According to the Brattle Group, "without nuclear plants, the economy would rely more heavily on existing and new natural gas-fired generating plants, and to a lesser extent, more generation from existing coal-fired plants."16 Note that because of their high capacity factor, nuclear plants are only 9% of U.S. generation capacity, but supply 19% of U.S. electricity.

Displacing nuclear electricity with greater use of fossil generation would mean **higher electricity prices** – wholesale prices would be **10%** higher on average; **retail prices** would rise **about 6%.**17 The cost of building new generation, transmission, and storage facilities to replace existing nuclear facilities would also contribute to electricity price increases, especially in regions like New York (15%), New England (24%), and the Northwest (34%) as calculated by the Brattle Group.18 Customers would also be more exposed to **natural gas price volatility**, which nuclear generation currently helps mitigate with its consistent operational costs. This price hedging effect that nuclear plants provide accounts for the majority of nuclear's overall economic impact. James Hansen, a leading figure in the climate change movement has written:

"We need affordable, abundant clean energy, but there is no particular reason why we should favour renewable energy over other forms of abundant energy. …The climate system cares about greenhouse gas emissions – not about whether energy comes from renewable power or abundant nuclear power...The future of our planet and our descendants depends on basing decisions on facts, and letting go of long-held biases when it comes to nuclear power." 19

Third Way wrote:

"…it is important to be clear-minded about what renewables can deliver as part of an affordable, reliable, and low-emissions electricity system. Despite tremendous technological advances in renewable generation, storage, and transmission, there are still serious challenges. A large-scale penetration of renewables into the power grid would require:

1. Significant overbuilding of generation to meet demand;

2. Costly grid upgrades and storage expansion;

3. Storage that might not be available in time; and

4. A huge build-out of transmission infrastructure." 20

Both Hansen and Third Way highlight the practical constraints to pinning clean energy hopes entirely on renewables. Transitioning to a zero-emissions energy infrastructure **without nuclear** would involve **a 50% greater** **capital** **investment**, to the tune of $73.7 trillion dollars globally.21 In short, it is becoming increasingly clear that a realistic pathway to emissions reductions within the coming decades must include nuclear, and that every nuclear plant shutdown makes achieving those objectives significantly more difficult, if not impossible.

Emprics prove, nuclear helps the climate.

Hansen '13 confirms [James E. Hansen; PhD, American adjunct professor; Pushker A. Kharecha; PhD, Climate scientist; 03-15-2013; "Prevented Mortality and Greenhouse Gas Emissions from Historical and Projected Nuclear Power"; ACS; https://pubs.acs.org/doi/10.1021/es3051197; accessed 03-10-2025] leon

In the aftermath of the March 2011 accident at Japan's Fukushima Daiichi nuclear power plant, the future contribution of nuclear power to the global energy supply has become somewhat uncertain. Because nuclear power is an abundant, low-carbon source of base-load power, it could make a large contribution to mitigation of global climate change and air pollution. **Using historical production data, we calculate that global nuclear power has prevented an average of 1.84 million air pollution-related deaths and 64 gigatonnes of CO2-equivalent** (GtCO2-eq) **greenhouse gas** (GHG) **emissions that would have resulted from fossil fuel burning**. On the basis of global projection data that **take into account the effects of the Fukushima accident, we find that nuclear power could additionally prevent an average of 420 000–7.04 million deaths** and 80–240 GtCO2-eq emissions due to fossil fuels by midcentury, depending on which fuel it replaces. By contrast, we assess that **large-scale expansion of unconstrained natural gas use would not mitigate the climate problem and would cause far more deaths than expansion of nuclear power**.

For example,

Maguire '24 reports [Gavin Maguire; Global Energy Transition Columnist; 09-19-2024; "Georgia's new nuclear plants drive US power sector clean-up"; Reuters; https://www.reuters.com/business/energy/georgias-new-nuclear-plants-drive-us-power-sector-clean-up-maguire-2024-09-19/ ; accessed 03-11-2025] leon

From 2018 through 2022, the Vogtle site generated an average of 2,813 gigawatt hours (GWh) of electricity a month **for the state of Georgia**, around **27% of total state electricity supplies according to Ember**.

Since Vogtle 3 started operations in April 2023, that generation total rose to an average of around 3,500 GWh a month, and climbed to over 4,600 GWh in May 2024, when Vogtle 4 first started operating.

CHANGING MIX

The sharply higher production from nuclear reactors has impacted Georgia's electricity mix in several key ways.

Firstly, **the share of generation from nuclear reactors jumped to 37% in May** - **a full 10 percentage point above the long-term average** - **as the Vogtle 4 plant came online**.

Secondly, the state's overall electricity generation total climbed to new highs as more nuclear generation was added to the output from other sources.

During the January to May period, Georgia's total electricity generation was 55,634 GWh, which was a record for that period and marked a 12.3% jump from the same months in 2023, Ember data shows.

Thirdly, the higher level of nuclear generation also boosted Georgia's total clean electricity output levels, which exceeded generation from the state's fossil fuel assets during March, April and May of this year for the first time on record.

Clean power's share of the Georgia generation mix was a record 47% for the January to May period, and compares to 41.5% during the same months a year ago.

Sustained output from Vogtle 3 and 4 over the remainder of 2024 could help push the clean power share of the overall mix closer to 50%.

WIDER IMPACT

Vogtle's full ramp-up was also evident farther afield, with the carbon intensity of power production of the Southern Company Services power system dropping by 14% so far in 2024 from 2023's average levels.

Thus, more investment is key.

Fisher '24 reports [Matt Fisher; Reporter at the IAEA Department of Nuclear Energy; 10-18-2024; "New IAEA Report on Climate Change and Nuclear Power Focuses on Financing"; International Atomic Energy Agency; https://www.iaea.org/newscenter/news/new-iaea-report-on-climate-change-and-nuclear-power-focuses-on-financing; accessed 03-07-2025] leon

According to the report, **global investment in nuclear energy must increase to 125 billion USD annually, up from the around 50 billion USD invested each year** from 2017-2023, **to meet the IAEA's high case projection for nuclear capacity in 2050**. **The more aspirational goal of tripling of capacity**, which more than 20 countries pledged to work towards at COP28 last year, **would require upwards of USD 150 billion in annual investment**.

Historically, investment has been effective.

Freebairn '24 continues [William Freebairn; Reporter for S&P Global; 05-15-2024; "Layers of IRA tax credits boost nuclear energy's economics, drive uprate interest"; S&P Global; https://www.spglobal.com/commodity-insights/en/news-research/latest-news/electric-power/051524-layers-of-ira-tax-credits-boost-nuclear-energys-economics-drive-uprate-interest; accessed 03-06-2025] leon

The US Inflation Reduction Act has provided multiple avenues for nuclear plant operators to benefit, with some options to layer multiple credits and even sell the credits for more rapid profits, industry officials said May 14.

The IRA, passed in 2022, **contains a series of credits for clean energy, many of which can apply to nuclear energy in some way**, speakers at two panel sessions at the Nuclear Energy Institute's policy conference said in Washington.

The IRA's passage has dramatically reversed the fortunes of nuclear operators, especially those in competitive power markets, noted David Brown, senior vice president of federal affairs at **Constellation, the largest US nuclear plant operator by capacity**. **The IRA was** "**transformational**" **for the company, he added**.

For the 10 years prior to the IRA's passage, **Constellation had sought federal and state support to keep nuclear units from retiring prematurely**, and had implemented a hiring freeze as it planned to shut four reactors, Brown said. **With the security provided by the IRA, the company has hired 3,000 workers and is planning to renew the operating licenses of all of its 23 reactors**, he said.

The IRA includes various tax credits that can apply to nuclear operators, said Matt Crozat, the Nuclear Energy Institute's executive director of strategy and policy development. Operating plants are eligible for a production tax credit of up to $15/MWh, while new nuclear capacity can choose between a PTC of $30/MWh or an investment tax credit of 30%. **The investment tax credit can rise to as much as 50% if nuclear projects include sufficient domestic content** and are built in former coal plant communities, Crozat added.

Capacity increases at existing nuclear plants qualify as new capacity and owners can elect the PTC or ITC, speakers said. This has triggered a resurgence of interest in such uprates, several noted.

Constellation has said up to 1,000 MW of additional nuclear capacity could be obtained from its fleet in coming years through uprates, while NEI President and CEO Maria Korsnick said in a speech at the conference May 14 that **2.5 GW of capacity across the US could be added at existing nuclear plants via uprates**.

Our opponents may talk about renewables, but

Snyder '23 writes [Van Snyder; Spent 53 years as a mathematician, Engineer at Caltech; 03-16-2023; "Five Myths About Nuclear Power"; Substack; https://vsnyder.substack.com/p/five-myths-about-nuclear-power; accessed 02-19-2025] leon

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.

<<TEXT CONDENSED NONE OMITTED>>

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.

<<LINE BREAKS CONTINUE>>

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**.

Solar panels last about 25 years, but must operate more than four years to repay the energy invested in their fabrication, deployment, and recycling. The capital cost of $12 per average watt, amortized over twenty-five years at 5%, deducting the four-plus year energy payback period, is $26.61 per watt of average capacity.

The capital cost for solar PV panels does not include operating and maintenance costs, electricity storage, significant grid changes necessary to exploit diffuse sources, and recycling.

Several independent studies have determined that **renewable sources would need 390-800 watt-hours' storage per average watt of demand to provide firm power**, for which the industry definition is 99.97% availability. In Adequate Storage for Renewable Energy is Not Possible, using twelve years of data for California, I calculated that more than 2,800 watt-hours' storage per watt of average demand would be necessary. Using five years of nationwide data, more than 800 watt-hours' storage per watt of average demand is necessary. The May 2020 price for Tesla PowerWall 2 batteries was $0.543, not including installation. The warranty period is ten years. For 800 watt-hours, **the total cost would be more than 3.8 times total USA GDP every year**, for batteries alone, or "only" $49,000 per month for each of America's 128 million households. **These amounts of storage will be entirely inadequate the next time Mount Tambora erupts and produces another** "**year without a summer**" such as 1816. This or something similar will happen again. The only question is "when?"

These sorts of calculations never appear in arguments that renewable electricity is less expensive than nuclear power.

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It leads to nuclear weapons proliferation (no it doesn't) In a March 2017 Scientific American interview, John Holdren, President Obama's Science Advisor, said "… breeder reactors… [require] what amounts to a plutonium economy… and trafficking in large quantities of weapons-usable material." A plutonium economy unrelated to breeder reactors already exists. The often-repeated hyperbole "trafficking in large quantities of weapons-usable material" is nonsense. Spent fuel from a British municipal reactor was used to make a nuclear explosion. The yield was a fraction of the Hiroshima weapon, which was a much simpler uranium device. The British remarked "We will not try that again." If plutonium is less than 93% isotopically and chemically pure Pu-239, explosive yield decreases rapidly. In an IFR-type system, plutonium in spent fuel never contains more than 54% Pu-239, and is never more than 40% chemically pure. Separating isotopically pure Pu-239 from spent fuel presents a much more difficult problem than for uranium. Plutonium isotopes in spent fuel, other than Pu-239, emit 50 times more heat, 5,000 times more neutrons, and 100 times more gamma radiation. This could damage a weapon or cause predetonation, and makes maintenance of fine mechanical tolerances difficult. Expensive remote assembly is mandatory. A 1994 Lawrence Livermore National Laboratory study stated "spent IFR fuel cannot be used to make a nuclear weapon without significant further processing." No one makes weapons from spent fuel because it is the most difficult substance from which to do so. Producing isotopically pure plutonium directly in a reactor requires controlling the neutron energy more precisely than is practical in a municipal reactor, and irradiating the fuel for durations far shorter than would be economical. Even the most rudimentary inspection regime would detect this. If an inspection regime is not practical in rogue states, don't sell them reactors, spent fuel, or means to reprocess fuel. Even if truly "weapons-ready" material existed, the proliferation argument is a red herring. No country's nuclear power stations or fuel reprocessing affect any other country's desires, decisions, or ability to acquire nuclear weapons. On-site reprocessing implies very few opportunities for diversion or theft. Plutonium in spent fuel in an IFR-type system is in a highly-radioactive and therefore easily monitored state. Advanced industrial economies already have nuclear weapons, or have the means to make them much more effectively than from spent municipal reactor fuel. Only a fast-neutron reactor can consume all fissionable metals in spent fuel and decommissioned weapons. There isn't enough uranium (there's plenty) The Australian Uranium Association estimated that it is economically feasible at current prices to recover about 4.5 million tonnes of uranium. Known or projected reserves of lower quality increase the estimate to 18.5 million tonnes. Activists insist an all-electric Earth would demand about 15,000 GWe. Using the one tonne per GWe-year rule of thumb, 18.5 million tonnes is enough to satisfy this demand, if it were used with 100% efficiency, for only about 1,200 years. But today's reactors use only 0.6% of the energy in mined uranium, so this fuel would last less than ten years. The situation isn't nearly so bleak, however. In the United States, there are about 90,000 tonnes of 5%-used fuel, and about 900,000 tonnes of depleted uranium left over from enriching mined uranium. A 1,700 GWe all-electric U.S. energy economy could be powered by this "waste" in fast-neutron reactors for 525 years, or longer depending upon use of renewable sources, without mining, milling, refining, enriching, or importing one gram of new uranium. Spent fuel is significantly more radiotoxic than depleted uranium, so it should be consumed first. Every country that has nuclear reactors has stocks of spent fuel and depleted uranium. 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.

<<LINE BREAKS CONTINUE>>

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**.

Absent action,

Cassella '23 concludes [Carly Cassella; Senior Journalist at Science Alert; 08-30-2023; "Scientists Warn 1 Billion People on Track to Die From Climate Change"; Science Alert;

https://www.sciencealert.com/scientists-warn-1-billion-people-on-track-to-die-from-climate-change; accessed 03-11-2025] leon

If the world reaches temperatures 2°C above the average global preindustrial temperature, which is what we are on track for in the coming decades, then that's a lot of lives lost. **For every 0.1 °C degree of warming from now on, the world could suffer roughly 100 million deaths**.

Our second contention is medical isotopes.

There is a shortage of medical isotopes

Omer 24 [Awan, Omer, "Technetium Is In Short Supply. Here's How That Affects Public Health", 10-24-2024, Forbes, https://www.forbes.com/sites/omerawan/2024/10/24/technetium-is-in-short-supply-heres-how-that-affects-public-health/]

Technetium-99m, a critical nuclear imaging radioisotope, is in short supply and could cause delays or cancellations of over 40,000 medical imaging studies daily in the United States. The global shortage of Tc-99m stems for issues related to its production. Normally, Tc-99m decays and is eluted from Molybdenum-99, which is generated from a high-flux reactor. The parent isotope Molybdenum-99 is only produced in a few nuclear reactors worldwide, such as in Petten, Netherlands. A structural issue within a pipe from this reactor in the Netherlands will require repair that may delay the production of Tc-99m well into November, according to reports from the Society of Nuclear Medicine and Molecular Imaging. Tc-99m is the most widely used radioisotope in nuclear medicine, accounting for at least 80% of all nuclear studies performed globally, which translates to 30 million medical diagnostic exams performed each year. In the United States, 40,000 Tc-99m based imaging studies are done daily. With delays in the radioisotope expected well into November, this means that over 1 million diagnostic exams may have to be delayed, cancelled or rescheduled due to the shortage. PROMOTED To put the enormous impact of the Tc-99m shortage on public health into perspective, consider some of its uses in general medicine. For example, Tc-99m Sestamibi scans are often used in cardiac stress tests to diagnose and quantify coronary heart disease, the leading cause of death in both America and the world. Although there are alternative methods of diagnosing heart disease such as angiography, which involves placing a catheter into blood vessels to quantify how narrow the heart vessels are, nuclear imaging offers a non-invasive alternative that is well tolerated by most patients. With fewer nuclear medicine studies examining the heart, critical diagnoses could be delayed. For patients with coronary heart disease, timely diagnosis is critical to prevent severe complications such as heart attacks.

Isotopes are made through nuclear energy

World Nuclear Association 25 [WNA, "Radioisotopes in Medicine", Invalid date, No Publication, https://world-nuclear.org/information-library/non-power-nuclear-applications/radioisotopes-research/radioisotopes-in-medicine#:~:text=Isotopes%20used%20in%20medicine,from%209%20to%2019%20MeV] //WM

Many radioisotopes are made in nuclear reactors, some in cyclotrons. Generally neutron-rich ones and those resulting from nuclear fission need to be made in reactors; neutron-depleted ones such as PET radionuclides are made in cyclotrons with energy ranging from 9 to 19 MeV.

Isotopes are key to medicine

CMI 25, https://www.globenewswire.com/news-release/2025/03/20/3045999/0/en/Latest-Global-Medical-Radioisotopes-Market-Size-Share-Worth-USD-1382-Million-by-2034-at-a-6-34-CAGR-Custom-Market-Insights-Analysis-Outlook-Leaders-Report-Trends-Forecast-Segmentat.html

Giant demand for the global medical radioisotopes market: a few key insights. Introducing Therefore, the growth of the global medical radioisotopes market is expected to be forceful with growing applications in diagnostics and therapeutics. Increasing incidence of chronic diseases like cancer and cardiovascular disorders is increasing the demand for the medical radioisotopes, especially in **nuclear medicine**. These **isotopes are vital for imaging modalities such as PET and SPECT, facilitating the early diagnosis and appropriate**

management of diseases. Tc-99m is **one** of the most used isotopes, with this **isotope represent**ing**[s] over 80% of all nuclear medicine procedures** worldwide. Market driving factors include the expansion of nuclear medicine infrastructure, increasing government investments, and advancements in technology for isotope production. The United States, Canada, and Germany are countries with powerful nuclear medicine institutions guaranteeing radioisotope supply for diagnosis and therapy.

Thus, the shortage is devastating life-saving medicine

Omer 24 [Awan, Omer, "Technetium Is In Short Supply. Here's How That Affects Public Health", 10-24-2024, Forbes, https://www.forbes.com/sites/omerawan/2024/10/24/technetium-is-in-short-supply-heres-how-that-affects-public-health/]

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Nuclear medicine saves millions lives

EuroNuclear

[https://www.euronuclear.org/nuclear-basics/medical/what-is-nuclear-medicine/#:~:text=Medical%20applications%20of%20nuclear%20technology,These%20medical%20applications%20save%20lives.]

Medical applications of nuclear technology are used all over the world. **Every year, 30 million people benefit from a diagnostic procedure or treatment by nuclear medicine for at least 60 different pathologies- and these numbers are steadily increasing. These medical applications save lives. They are now used in the fight against cancer, but also in cardiology, neurologists, pneumology and pediatrics.** Or even in dentistry and veterinary medicine. Medical nuclear technology is progressing day by day and its scope expands to most organs of the human body. The prospects for our health are enormous.

Our third contention is desalinating water.

Right now, 2 million Americans currently lack access to drinking water

The United Nations 23 [United States Mission To The United Nations, "FACT SHEET: United States Announces $49 Billion in Commitments to Global Water Security and Sanitation", 03/22/2023, United States Mission to the United Nations, https://usun.usmission.gov/fact-sheet-united-states-announces-49-billion-in-commitments-to-global-water-security-and-sanitation/#:~:text=Today%2C%20more%20than%20two%20million,creating%20a%20cycle%20of%20poverty.] //WM

Today, more than two million Americans lack access to clean drinking water at home, and more than one million Americans don't have the plumbing required to flush a toilet. Native American households are 19 times more likely to lack indoor plumbing, compared to non-Native households. Nearly a quarter of U.S. households on private wells have contaminants in their water, like arsenic or e. coli, that pose a risk to household and community health. **Worldwide, one in four people lack access to safe water in their homes.** Nearly half of the world's population do not have a hygienic toilet at home, and one third of people globally can't wash their hands with soap and water at home. This burden is disproportionately felt by women and children, whose educational and economic opportunities suffer as a result, creating a cycle of poverty.

Current desalination plants are unfortunately lackluster

Crunden 23 [E.A. Crunden, "What's stopping desalination from going mainstream?", 10/26/2023, E&E News by POLITICO, https://www.eenews.net/articles/whats-stopping-desalination-from-going-mainstream/] //WM

It is unclear how many **facilities are currently operational**, but **a 2018 report** from the U.S. Bureau of Reclamation **found there were more than 400, with around half those being operational.** Reclamation noted via email that it does not compile data on who relies on desalinated water, as that varies "from individual water supplier to water supplier." **Desalinated water typically makes up only a portion of a water supply**'s portfolio, **even in places like San Diego** County, Calif., **home to the biggest plant in the country. Another large facility**, **Tampa Bay Seawater Desalination, provides up to 25 million gallons per day of drinking water for a region of more than 2.5 million people — but similarly supplies only up to 10 percent of the area's needs.**

Luckily, nuclear energy can be used to desalinate water

International Atomic Energy Agency 23 [Yusuf, "Harnessing Nuclear Power for Desalination to Secure Freshwater Resources", Invalid date, No Publication, https://www.iaea.org/bulletin/harnessing-nuclear-power-for-desalination-to-secure-freshwater-resources] //WM

Nuclear power plants could offer a solution, while serving a dual purpose: producing low carbon electricity and turning **seawater into fresh water.** "The non-electric applications **powered by nuclear**

energy, such as desalination, present sustainable solutions for a number of water-intensive endeavours — from the consumption needs of millions of households and the industrial applications of fresh water to agriculture and livestock rearing — that current and future generations will face," said Francesco Ganda, Technical Lead for Non-Electric Applications at the IAEA. For nearly 30 years, the IAEA has supported countries' efforts to improve supply, quality and access to clean water through nuclear desalination, a process that uses the heat and electricity produced by a nuclear power plant to remove salt and minerals from seawater through distillation or membrane separation, mostly reverse osmosis. Desalination using nuclear power is less carbon intensive and is cost competitive with alternative methods, such as fossil fuel-based techniques. India, Japan and Kazakhstan have the most experience in nuclear desalination, with hundreds of reactor-years of successful operations. This solution provides a viable, cost-effective path to potable water for thousands of communities. "Nuclear power plants could help meet the growing demand for potable water and provide hope to areas with acute water shortages in many arid and semi-arid zones," Ganda added.

Jordan was a massive success story when they bolstered nuclear energy for desalination

The International Atomic Energy Association 23 [Yusuf, "Harnessing Nuclear Power for Desalination to Secure Freshwater Resources", Invalid date, No Publication, https://www.iaea.org/bulletin/harnessing-nuclear-power-for-desalination-to-secure-freshwater-resources] //WM

In 2022, through its technical cooperation programme, the IAEA hosted a national training course in Amman, Jordan, to build capacity in the use of small modular reactors (SMRs) to desalinate water. Through the IAEA Platform on Small Modular Reactors and their Applications, the Jordan Atomic Energy Commission (JAEC) requested a review by IAEA nuclear power experts of a nuclear desalination study that employs SMRs. "Desalination is considered the primary source of fresh water in Jordan to fulfill the expected demand and reduce the supply-demand deficit," said Khalid Khasawneh, Commissioner for Nuclear Power Reactors at the JAEC. The study found that using nuclear energy for desalination [was] feasible in Jordan, and Khasawneh added that "it offers competitive prices for fresh water to end consumers, in comparison with imported energy sources." The IAEA will host an interregional training course in Moscow in October 2023 to explore design considerations for cogeneration projects using SMRs and microreactors, where electrical power or heat generation is used to fuel the desalination process.

We save 2 million- water is needed to live

Johnson 19 [Jon Johnson, "How long can you live without water? Facts and effects", 05/14/2019, Medical News Today, https://www.medicalnewstoday.com/articles/325174#how-long-can-you-live-without-water] //WM

The body needs lots of water to carry out many essential functions, such as balancing the internal temperature and keeping cells alive. As a general rule of thumb, a person can survive without water for about 3 days. However, some factors, such as how much water an individual body needs and how it uses water, can affect this.