

Case

1AC

1AC---Econ

Contention one is the economy.

The economy is poised to decline

Stephen S. Roach, 3-26-2025, "America has been an engine of global growth. Now it's a source of stagflation.", MarketWatch, <https://www.marketwatch.com/story/america-has-been-an-engine-of-global-growth-now-its-a-source-of-stagflation-21bfd389> [Stephen S. Roach, former chairman of Morgan Stanley Asia and once the firm's chief economist, is a senior fellow at Yale University's Jackson Institute of Global Affairs and a senior lecturer at Yale's School of Management. He is the author of the new book "Unbalanced: The Codependency of America and China."] DOA: 3/27/2025 //RRM

The world's major growth engines are about to run in reverse. The policies and uncertainties of President Donald Trump's second administration have hit a sluggish global economy with a transformational exogenous shock. Risks are especially worrisome in both the U.S. and China, which have collectively accounted for a little more than 40% of cumulative global GDP growth since 2010. America is now the problem, not the solution. *Long the anchor of the rules-based international order, the U.S. has turned protectionist, posing major risks to an already fragile global trade cycle.* At the same time, Trump's "Make America Great Again" movement has driven a powerful wedge between the U.S. and Europe and divided North America, with Canada's very independence in Trump's crosshairs. The central role of the U.S. in sustaining post-World War II geostrategic stability has been shattered. The U.S. will be unable to put the genie back in the bottle. Trump's shocking actions have eroded the trust that has underpinned America's global leadership, and the damage will be evident long after Trump has left the scene. With America having once abdicated its moral authority as the anchor of the free world, who is to say it can't happen again? This breakdown in trust will cast a long and lasting shadow over economic performance, not least in the U.S. itself, where it is already affecting business decision-making, especially the costly long-term commitments associated with hiring and capital spending. Businesses need to scale their future operations relative to confident expectations of growth trajectories — now an increasingly uncertain proposition. Asset values and consumer confidence, too, have been shaken. Uncertainty, the enemy of decision-making, is likely to freeze the most dynamic segments of the U.S. economy. Trade wars have no winners. The Trump shock is likely not only to exacerbate the Sino-American conflict but also to weaken both countries' growth prospects significantly. For China, state-directed policy guidance might temper the initial blow of a Trump policy shock. *But the pressures of Trump's tariff escalation will undermine China's export-led growth model, which is especially problematic for economic growth, given the lingering weakness of China's domestic demand.* The country's long-promised consumer-led rebalancing of the economy remains more of a slogan than an actual shift in the sources of Chinese growth — especially with a deficient social safety net that continues to encourage fear-driven precautionary saving. China's just-announced 30-point action plan to boost household demand draws much-needed attention to the seemingly

chronic plight of the Chinese consumer. But it offers only modest support to an inadequate social safety net. The Trump shock is likely not only to exacerbate the Sino-American conflict but also to weaken both countries' growth prospects significantly. Don't count on other economies filling this void. Eventually, India might be able to take up some of the slack. But its relatively small share of world GDP — currently 8.5% (in purchasing-power-parity terms), compared with 34% for China and the U.S. combined — means that that day is in the distant future. *The same is true of Europe. While the European Union's 14% share of world GDP is nearly double that of India, Europe remains saddled with anemic growth, compounded by mounting trade pressures associated with an escalating global tariff war.* If the apparent breakdown of the trans-Atlantic alliance has a silver lining, it is that the incentives for strategic cohesion should have an outsize impact on European military spending. But that will also take time. Meanwhile, Europe will be exposed equally to the adverse effects on business and consumer expectations and decision-making, comparable to those afflicting the U.S. Downside risks will progressively build. What does all this mean for global economic prospects in the coming years? The current baseline expectation of around 3.3% world GDP growth for 2025-26, as per recent forecasts by the International Monetary Fund, is far too sanguine. While there may be some front-loading of growth momentum in the early part of this year — exemplified by accelerated shipments of Chinese exports ahead of Trump's tariff hikes — I suspect that the downside risks will progressively build. Don't miss out on this limited time offer! Don't fall behind this tax season. Subscribe to learn how today's business practices, news, and tax policies impact the market and your money. Subscribe Now MarketWatch on Multiple devices That points to a fractional reduction of forecasts for global economic growth for 2025, with the slowdown becoming considerably more pronounced in 2026 and after. That could easily push an increasingly fragile world economy down to the 2.5% growth threshold, typically associated with outright global recession. Nor is this likely to be a standard shortfall of global growth. To the extent that the tariff war is aimed at promoting friendshoring and strengthening supply-chain resilience, the global economy's supply side is likely to come under significant strain. A new layer of adjustment costs is being imposed on a once-globalized world. Reshoring to higher-cost local producers not only takes considerable time, but also erodes the efficiencies of production, assembly and delivery that have underpinned worldwide disinflation over the past three decades. Almost five years ago, in the depths of the COVID-19 shock, I warned that the onset of stagflation was only "a broken supply chain away." Subsequent experience and research have borne that out, confirming that the supply-chain disruptions during the pandemic and its immediate aftermath generated significant upward pressure on prices. A global trade conflict implies a similar dynamic. The higher costs associated with Trump's coming "reciprocal" escalation of multilateral tariffs, which are due to be announced on April 2, are especially problematic. In the face of a likely shortfall of economic growth, the added cost and price pressures are likely to tip the scales toward global stagflation. The Trump shock is the functional equivalent of a full-blown crisis. The Trump shock, in short, is the functional equivalent of a full-blown crisis. It is likely to have a lasting impact on the U.S. and Chinese economies, and the contagion is almost certain to spread throughout the world through cross-border trade and capital flows. Perhaps most importantly, this is a geostrategic crisis, reflecting a reversal of America's global leadership role. In the space of little more than two months, Trump has turned the world inside out. If my assessment of this shock is anywhere close to the mark, concerns over the global economic forecast seem almost trivial.

And trumps actions have already caused an economic decline, because of HIS tariffs the Us Economy is declining:

Sergeant '25 S&P 500 companies stock prices have fallen 17.4%

Thankfully, affirming solves by attracting private sector investment

IEA, 1-16-2025, "A new era for nuclear energy beckons as projects, policies and investments increase",

<https://www.iea.org/news/a-new-era-for-nuclear-energy-beckons-as-projects-policies-and-investments-increase> [The International Energy Agency was created in 1974 to help co-ordinate a collective response to major disruptions in the supply of oil. While oil security remains a key aspect of our work, the IEA has evolved and expanded significantly since its foundation. Taking

an all-fuels, all-technology approach, the IEA recommends policies that enhance the reliability, affordability and sustainability of energy. It examines the full spectrum issues including renewables, oil, gas and coal supply and demand, energy efficiency, clean energy technologies, electricity systems and markets, access to energy, demand-side management, and much more. Since 2015, the IEA has opened its doors to major emerging countries to expand its global impact, and deepen cooperation in energy security, data and statistics, energy policy analysis, energy efficiency, and the growing use of clean energy technologies.] DOA: 3/10/2025 //RRM

Most of the existing nuclear power fleet today is in advanced economies, but many of those plants were built decades ago. Meanwhile, the global map for nuclear is changing, with the majority of projects under construction in China, which is on course to overtake both the United States and Europe in installed nuclear capacity by 2030. Russia is also a major player in the nuclear technology landscape. Of the 52 reactors that have started construction worldwide since 2017, 25 are of Chinese design and another 23 are of Russian design. Similarly, the report shows how the production and enrichment of uranium, the fuel that goes into nuclear reactors, are highly concentrated. "Today, more than 99% of the enrichment capacity takes place in four supplier countries, with Russia accounting for 40% of global capacity, the single largest share," Dr Birol said. "Highly concentrated markets for nuclear technologies, as well as for uranium production and enrichment, represent a risk factor for the future and underscore the need for greater diversity in supply chains." Innovations in nuclear technologies are helping to drive momentum behind new projects, the report finds. **SMRs, a type of smaller scale nuclear power plants that are quicker to build with greater scope for cost reductions, are drawing increasing interest from the private sector.** The report highlights how the introduction of SMRs could lead to lower financing costs. With the right support, SMR installations could reach 80 GW by 2040, accounting for 10% of overall nuclear capacity globally. However, the **success** of the technology and speed of adoption will **hinge on** the industry's **ability to bring down costs** by 2040 to a similar level to those of large-scale hydropower and offshore wind projects. A new era for nuclear energy will require a lot of investment. In a rapid growth scenario for nuclear, annual investment would need to double to USD 120 billion already by 2030. Given the scale of the infrastructure investment required, the rollout of new nuclear projects cannot rely exclusively on public finances. **IEA analysis shows that ensuring the predictability of future cash flows is key to bringing down financing costs and attracting private capital to the nuclear sector.** The report highlights that the private sector is increasingly viewing nuclear energy as an investible energy source with the promise of firm, competitive, clean power that can serve energy-intensive operations 24/7. Notably, big names in the technology sector are signing power purchase agreements with developers to provide electricity for data centres and artificial intelligence. **To take advantage of the opportunities that nuclear power offers, governments must be prepared to provide the strategic vision alongside stable regulatory frameworks that will give the private sector confidence to invest.** The report details how incentives and public finance more broadly can unlock the investment needed to deliver greater clean and reliable power from nuclear.

Domestic action facilitates international projects and energy exports.

Maria Lorenzini, 3-7-2025, "The US can reduce Russia's nuclear energy—and geopolitical—influence", Atlantic Council, <https://www.atlanticcouncil.org/blogs/energysource/the-us-can-reduce-russias-nuclear-energy-and-geopolitical-influence/> [Marina Lorenzini is the research program coordinator at the Middle East Initiative at the Belfer Center for Science and International Affairs at Harvard University's John F. Kennedy School of Government.] DOA: 3/10/2025 //RRM

- Consistency = credibility

- Also prob empiric to spike out of politics Das
- Doesn't contradict energy independence b/c us becomes less dependent on imports not exports

In early February, the Bulgarian energy minister met with officials from the US Export-Import Bank (EXIM) to advance a \$8.6 billion (more than 60 percent of the estimated cost) letter of interest for the two new reactors. For the remaining amount, the Bulgarian treasury or Kozloduy's owner has several options. Bulgaria may also have access to debt or equity financing from the world's largest multilateral development lender, the European Investment Bank. Additionally, as the World Bank considers how to incorporate nuclear power into their offerings, any steps toward engagement would encourage other lenders to do the same. If further capital is required, Bulgaria—with its relatively healthy domestic economy—could issue dollar-denominated bonds to raise funds, or the Kozloduy owner could issue green bonds similar to Canada's Bruce Power. Bulgaria's ability—and that of any potential lenders—to overcome financing hurdles will determine the success of such agreements. But if the agreement leads to new nuclear power generation, it bodes well for similar economies to undertake new reactor builds. Soviet reactor reaches end of life in Armenia Russia dominates Armenia's energy system, but Armenian foreign policy has shifted dramatically away from Moscow in the past year, in part due to the lack of Russian military assistance to Armenia when Azerbaijan seized Nagorno-Karabakh. The policy change will not immediately impact Armenia's Soviet-era VVER-440 nuclear reactor at Metsamor, which has received several upgrades and lifetime extensions—the latest, with Rosatom's support, will sustain the remaining operational reactor until 2036. However, preparations must be made in the coming years to: extend the operational lifetime (a highly unlikely outcome due to the reactor's age); build new light-water reactors (whether from China, Russia, South Korea, or the United States); or invest in small modular reactors (SMRs). Armenia may seek to build an SMR rather than a traditional reactor due to limited financing options and low power consumption. To build a new reactor, Armenia might want to follow Romania's blended model for financing its SMR deal with NuScale. The EXIM and US International Development Finance Corporation offered Romania tentative financial support totaling \$4 billion. Public and private partners then formed a coalition of stakeholders from Japan, South Korea, the United Arab Emirates, and the United States to finance the SMR project up to \$275 million. If further capital is needed, private financial institutions have also recently announced their plans to support the nuclear industry. Whether and when construction begins for the reactor in Romania will demonstrate feasibility, but so far, the financial structure has shown promise. A great nuclear power balance In partnership with allies, the United States should advance financial and commercial solutions to help countries dependent on Russian nuclear energy diversify their domestic power programs. The United States is well positioned to do so. *Trump, and Biden before him, have supported nuclear energy domestically, which, in turn, can result in the export of US technologies and expertise. Strong bipartisan appropriations from multiple administrations will reinforce Trump's vision and the domestic nuclear energy industry.* In 2019, during Trump's first administration, the Nuclear Energy Innovation and Modernization Act became law, paving the way for a streamlined advanced reactor licensing process. Under the Biden administration, the multibillion-dollar appropriations from the Infrastructure Investment and Jobs Act and the Inflation Reduction Act bolstered the US nuclear energy industry. Further, the 2023 Nuclear Fuel Security Act and the 2024 ADVANCE Act enjoyed bipartisan support on Capitol Hill. *Building on these domestic advances, Trump's embrace of financial vehicles, such as the EXIM Bank or DFC, that bridge public and private sectors, will facilitate investments in multi-billion dollar infrastructure projects outside of the United States and bolster US energy-related exports, including from its domestic nuclear energy industry.* These factors bode well for the United States to substantially weaken Russia's share of global nuclear markets and its geopolitical influence.

Nuclear energy fosters economic resilience and empirically boosted GDP.

WNA, 05-01-2024, "Nuclear Energy and Sustainable Development", World Nuclear Association,

<https://world-nuclear.org/information-library/energy-and-the-environment/nuclear-energy-and-sustainable-development> [World Nuclear Association's mission is to facilitate the growth of the

nuclear sector by connecting players across the value chain, representing the industry's position in key world forums, and providing authoritative information and influencing key audiences.]

DOA: 3/14/2025 //RRM

- spikes climate turns

The relationship between energy consumption and human development is clear. Up to about 100 GJ per capita consumption – a level yet to be reached by 80% of the world's population – a country can fundamentally enhance the health, educational standards, and general wellbeing of its population by consuming more energy. Any transition towards a more equitable and sustainable future must therefore be predicated on delivering the benefits of access to modern, affordable and reliable energy services to all. But doing so will increase overall energy demand: at present, the world's poorest 4 billion people consume just 5% of the amount of energy enjoyed by those living in developed economies. For that figure to rise to 15%, global energy consumption would increase by the equivalent of an additional United States' worth of demand. The key question, therefore, is: how should that energy be supplied? At present, over 80% of primary energy consumption is from the burning of oil, gas and coal – unchanged since 1990. However, unregulated emissions from the combustion of fuels are causing climate change, environmental damage, and the premature death of an estimated 7 million people each year. The continued use of fossil fuels therefore has profound intra- and intergenerational social, economic and environmental implications. The resulting dual challenge – the need to reduce harmful emissions, whilst providing more energy to more people – positions the energy sector at the heart of achieving sustainable development. There is no technology that is fully without risk to people or the environment. For example, whilst low-carbon sources of energy do not emit carbon dioxide at the point of use, they are responsible for emissions and waste during construction, manufacturing and decommissioning. As such, any energy technology's compatibility with sustainable development objectives must be assessed in relative terms – in the light of the alternatives. As the only proven, scalable and reliable low-carbon source of energy, nuclear power will be required to play a pivotal role if the world is to reduce its reliance on fossil fuels to address climate change and chronic air pollution. More broadly, however, the proposition of nuclear power as a sustainable energy source is fundamentally robust due to its innate energy density, and its internalization of health and environmental costs. Using nuclear energy has numerous sustainability advantages relative to alternative forms of generation. By expanding its use, modern and affordable energy can be provided to all who currently lack access, whilst reducing the human impact on the natural environment, and ensuring that the world's ability to meet its other sustainable development goals is not curtailed. Defining Sustainable Development A number of definitions have been put forward for sustainable development, but the most widely quoted is from the 1987 Brundtland Report¹: "Sustainable development is development that meets the needs of the present, without compromising the ability of future generations to meet their own needs" Sustainable development is therefore the pathway to sustainability. For an activity, product or entity to be truly sustainable, it must achieve environmental, economic and social sustainability in balance: the three 'pillars'. The three pillars of sustainability Figure 1: The three 'pillars' of sustainability In 2015, the 193 member states of the United Nations (UN) adopted the 2030 Agenda for Sustainable Development – a plan of action for people, planet and prosperity, aligned to the three pillars of sustainability. To disaggregate the bold ambitions of the 2030 Agenda, the UN agreed 17 Sustainable Development Goals (SDGs) to be used to guide and gauge progress. The United Nations 17 sustainable development goals Figure 2: The UN's Sustainable Development Goals More energy, lower emissions The 2030 Agenda for Sustainable Development recognized that by nature, the SDGs are "integrated and indivisible". As such, achieving progress across any of the SDGs is contingent upon progress across the others. *However the centrality of energy – and thus SDG 7 – is widely recognized: progress across all SDGs is contingent upon the provision of a sustainable supply of energy.* Providing access to affordable, reliable and clean energy is pivotal for eradicating poverty, for improving population's health and education, and for reducing greenhouse gases whilst continuing to support industrial development (see Figure 4). The link between the wellbeing of a population and energy consumption is well-established for developing countries. For those countries with an annual energy consumption below 100 GJ per capita – a level that 80% of the world's population is yet to reach^{2, 3} – there is a clear correlation between their energy consumption and Human Development Index (HDI) a value, which is an indicator of a nation's health, education and living standards. Human Development Index and annual energy consumption per capita Figure 3: Human Development Index and annual energy consumption per capita, 2020

(source: BP) This relationship between human wellbeing and energy consumption explains the importance assigned to ensuring reliable access to affordable energy for all in SDG 7; reducing the share of the world's population whose prospects are curtailed by lack of energy is essential for meeting the needs of the present. Achieving progress towards SDG 7 for the world's growing population will require a significant increase in energy provision. The importance of clean energy for a sustainable future Figure 4: SDG 7 – key to all SDGs The key question, therefore, is how best to supply those growing energy needs. Our existing energy system is built on fossil fuels, but their combustion for energy generates carbon dioxide (CO₂) emissions, a key contributor to climate change. *The energy sector is responsible for about three-quarters of all greenhouse gas emissions, and as such, fundamentally transforming it is the single most important step towards combatting climate change.* The UN has long-recognized climate change as the defining issue of our time. Despite this explicit acknowledgement, and spectacular recent investment in renewable energy, the world burned 66% more fossil fuels for energy in absolute terms in 2021 than it did in 1990. As a result, global energy-related CO₂ emissions were 63% higher. Box 1: The importance of electricity At present, fossil fuels are used to meet our energy requirements for transport, residential applications (e.g. heating), and to power industrial processes. Fossil fuels are also the dominant means of generating electricity, but other sources, including hydro, nuclear, solar and wind, are used too. To transition to a sustainable energy system all energy sectors will need to be decarbonized. However, much of the focus to date has been on the electricity sector for several reasons: The electricity sector is the most readily-decarbonized, as it provides the means to use non-fossil low-carbon energy (e.g. hydro, nuclear, wind and solar). Electricity is clean at the point of final use. This has two main advantages: improving air quality in urban areas; and centralising energy-related emissions (i.e. at power stations), making emissions regulation more straightforward. About 20% of final energy consumption is in the form of electricity, but the generation of electricity is responsible for almost 50% of all energy-related emissions. Despite the focus on electricity, limited progress has been made to date. In 2021, worldwide, 133% more electricity was generated from fossil fuels than 30 years earlier. Can nuclear contribute to sustainable development goals? Despite the crucial role that nuclear will need to play if the UN's SDGs are to be achieved, there remains some opposition to the growing recognition of the energy source's credentials for contributing towards sustainable development. *Fundamentally, nuclear energy's competitive position from a sustainable development perspective is robust due to its energy density and internalization of health and environmental costs.* Using nuclear energy brings multiple sustainability advantages over available alternatives, explaining its expanded role in almost all major studies that outline plausible pathways towards sustainable energy provision (see Box 2). An analysis of nuclear energy's characteristics within a sustainable development framework shows that the approach adopted within the nuclear energy sector is consistent with a central goal of sustainable development of passing a range of assets to future generations while minimising environmental impacts and burdens. Box 2: Nuclear energy's role in sustainable energy transitions Predicting the future of energy supply is complex, and uncertainties are high. *However, it is striking that in almost all forward-looking normative scenarios, nuclear energy's share in the mix grows substantially*⁴.

Generally, the more ambitious a scenario is in its aims for decarbonization and sustainability, the greater the role for nuclear. In the IPCC's P3 'middle-of-the-road' scenario, for example, nuclear generation grows six-fold by 2050. Primary energy mix by 2040 and share of nuclear energy Primary energy mix by 2040 and share of nuclear energy (source: *World Energy Council*) The environmental pillar The environmental pillar of sustainable development encompasses issues including air and water pollution, waste management, ecosystem management, and protection of natural resources, wildlife and endangered species. Climate change The *United Nations* recognizes climate change as "the most systemic threat to humankind". As such, addressing it is generally considered the most significant and urgent sustainability challenge. Climate change is resulting from increasing concentrations of CO₂ in the Earth's atmosphere. Given that three-quarters of anthropogenic CO₂ emissions result from the burning of fossil fuels for energy, the main focus should be on deploying energy technologies that emit only small amounts of CO₂ per unit of energy. *On a life-cycle basis, nuclear power emits just a few grams of CO₂ equivalent per kWh of electricity produced.* A median value of 12g CO₂ equivalent/kWh has been estimated for nuclear – similar to wind, and lower than all types of solar⁵. Average life-cycle CO₂ equivalent emissions Figure 5: Average life-cycle CO₂ equivalent emissions (source: IPCC) Ecosystem protection The main impacts of power production on ecosystems are eutrophication (i.e. increased concentrations of chemical nutrients, primarily nitrogen and phosphorus, that damage water quality by causing oxygen depletion) and acidification (i.e. increased concentrations of acidic chemicals – caused by the absorption of atmospheric CO₂ – that damage water quality, harming shellfish and coral, and leading to excessive algal growth). Among power producing technologies, fossil fuels have by far the greatest potential to cause both acidification and eutrophication. CO₂ released into the atmosphere during the combustion of fossil fuels dissolves into the oceans, increasing their acidity; and the mining, extraction, transport, waste treatment and emissions associated with fossil fuel use contribute to their high eutrophication potential. By contrast, both the acidification and eutrophication potential of

nuclear power are estimated to be among the lowest of all available generation technologies⁶. Figure 6: Lifecycle eutrophying emissions for 2020, in grams of phosphorus equivalent per MWh (source: Carbon Neutrality in the UNECE Region: Integrated Life-cycle Assessment of Electricity Sources, UNECE (March 2022) Land and water use Land and water usage are key criteria for assessing the sustainability of different power production technologies. The power sector competes for limited resources with other important sectors such as agriculture, industry and housing, and the emergence of a new concept known as the water-food-energy nexus reflects the growing appreciation of the interconnectedness of policy decisions in these three areas. Nuclear power plants produce huge amounts of low-carbon power and require *less land to do so than any other energy source*. The UN expects two-thirds of people to be living in urban areas by 2050 – an additional 2.5 billion individuals – where land is at a premium. Coupled with the need to preserve land to *prevent loss of biodiversity*, it is likely that nuclear energy's unique land-use advantages will prove *increasingly determinative* in the future. Box 3: The water-food-energy nexus Demand for water, food and energy is increasing, driven by rising global population and prosperity, as well as urbanization, dietary changes and economic growth. More than one-quarter of the world's energy is used for the production of food, and the agricultural sector is the largest single consumer of freshwater resources. The inextricable link between achieving water, energy and food security has driven recognition that policy decisions on each cannot be made effectively in isolation. The nexus approach is designed to integrate management across the three closely-related sectors. The water-food-energy nexus The water-food-energy nexus (source: International Water Association) A large two-unit nuclear power plant can provide electricity for *4-5 million people* from a generating footprint of just *2 square kilometres*. However, the land use of all energy-generating technologies extends beyond their generating footprint, and includes the required mining of raw materials and, for conventional sources of power, their fuel cycle. *Taking this into account, the land use of biomass, hydro, wind and solar are between one and three orders of magnitude greater than nuclear*⁷. Relative land use of electricity generation options per unit of electricity Figure 7: Relative land use (fuel mining and generating footprint) of electricity generation options per unit of electricity (source: Brook & Bradshaw, 2015) At some stage during supply, construction or operation, all electricity generating options consume water. Wind and solar energy have the smallest water 'footprints', whereas biomass and hydropower have the largest. Fossil fuels and nuclear consume significant quantities of water in the operational phase for cooling⁸. Fresh water is a valuable resource in most parts of the world. Apart from proximity to main load centres, there is no reason to site nuclear power plants away from a coast, where they can use once-through seawater cooling. The high energy density of uranium means that logistical requirements for fuel are modest (about 200 tonnes for a large reactor annually versus over 3,000,000 tonnes for an equivalent coal plant) allowing for flexible siting of nuclear power plants. In the event that water is so limited that it cannot be used for cooling, and a coastal location is not available, plants can be sited away from the load demand, but this will incur additional transmission costs. Whilst nuclear power plants require significant quantities of water for cooling, their ability to provide large amounts of power is increasingly being used to secure water supplies in areas of scarcity. Where potable water cannot be obtained from streams and aquifers, desalination of seawater, mineralized groundwater or urban waste water is required. Most desalination at present is powered by fossil fuels, but nuclear desalination has been used for many years in countries such as Japan, India and Kazakhstan. Water consumption per unit of electricity and heat produced Figure 8: Water consumption per unit of electricity and heat produced 2008-2012 (source: Mekonnen et al., 2015) Waste The careful management of waste streams is a key sustainability consideration in order to prevent short- or long-term harm to humans and the environment. All energy-producing technologies create waste, but the amount produced, the risk it poses, and the means of management vary widely. The energy density of fuel used for electricity generation is one key determinant of the magnitude and manageability of waste streams. Uranium's exceptionally high energy density means a relatively small amount of fuel is required per unit of energy produced. Using less fuel reduces the scale of fuel extraction activities and transport requirements – in turn reducing the chance of unintended environmental releases – and results in the creation of less waste. Contrary to popular belief, therefore, one of the benefits of producing electricity from nuclear energy is that its waste streams are small, and therefore innately manageable. It is for this reason that nuclear energy is the only form of electricity generation to fully contain its emissions, effluents and waste. Unlike nuclear energy, some energy sources dispose of wastes to the environment, or have health effects which are not costed into the product. These implicit subsidies, or external costs as they are generally called, are nevertheless real and usually quantifiable, and are borne by society at large. Their quantification is necessary to enable rational choices between energy sources. Nuclear energy provides for waste management, disposal and decommissioning costs in the actual cost of electricity (i.e. it has internalized them), so that external costs are minimized. The social pillar Human health – air pollution Air pollution arising from the use of carbon-based fuels for energy is one of the biggest threats to human welfare. The World Health Organization estimates that about 7 million people die prematurely each year as a result of air pollution exposure. Nuclear power plants emit virtually no air pollutants during operation, and because they are reliable and can be deployed on a large scale, they can directly replace fossil fuel plant. NASA's Goddard Institute for Space Studies and Columbia University's Earth Institute estimated that the use of nuclear power prevented over 1.8 million air pollution-related deaths between

1971 and 2009. There are numerous non-power uses of nuclear technology that contribute to fulfilment of human 'needs'. For example: the provision of nuclear medicine; helping to control the spread of infectious diseases; and securing reliable supplies of clean water, sanitation and food (see Figure 9). Examples of the contribution of non-power nuclear technologies to the SDGs Figure 9: Examples of the contribution of non-power nuclear technologies to the SDGs Human health – radiation Radiation is a well-understood process, with natural sources accounting for most of the radiation people receive each year. Doses received average 2.4 mSv/yr, but vary widely by location, driven by factors such as underlying geology and altitude. The highest known level of background radiation affecting a substantial population is in the states of Kerala and Madras in India where some 140,000 people receive doses which average over 15 mSv/yr from gamma radiation, in addition to a similar dose from radon. Comparable levels occur in Brazil and Sudan, with average exposures up to about 40 mSv/yr to many people. Lifetime doses from natural radiation range up to several thousand millisieverts. However, there is no evidence of increased cancers or other health problems arising from these high natural levels. 20 mSv/yr is the current average allowed limit for nuclear industry employees and uranium miners during normal operation. The millions of nuclear workers that have been monitored closely for 50 years have no higher cancer mortality than the general population but have had up to ten times the average dose. Nuclear power is the only technology that systematically measures and accounts for radioactive emissions. However, exposure to above-background radiation is not exclusive to nuclear power-related activities. UNSCEAR has estimated that both occupational and public exposures from electricity generation are higher for workers in the coal industry, for example. **Employment** Nuclear power plants can operate for over 60 years, creating long-lasting, high-paying jobs for people from a range of fields and educational backgrounds. Undertaking a nuclear power programme therefore represents a long-term investment in human capital. **Investment** in capital-intensive projects tends to **spill over into other industries and economic sectors**. A modern gigawatt-scale **nuclear power plant** employs 500-1000 workers directly. *But throughout both its construction and operation, it requires a complex supporting supply chain (e.g. construction, manufacturing and consultancy services), creating attractive indirect and induced employment opportunities.* Hinkley point C unit 2 construction site During construction of a large, modern plant, thousands of workers may be onsite. At Hinkley Point C (pictured), over 8000 workers will be onsite during the peak of construction. A study of the European nuclear industry by Deloitte suggested that nuclear provides more jobs per TWh of electricity generated than any other clean energy source. According to the report, the nuclear industry sustains more than 1.1 million jobs in the European Union. In addition, each gigawatt of installed nuclear capacity generates €9.3 billion in annual investments in nuclear and related economic sectors, and provides permanent and local employment to nearly 10,000 people. **For every €1 invested, the nuclear industry generates an indirect contribution of €4 in GDP, and every direct job creates 3.2 jobs in the EU as a whole.** The economic pillar Resource adequacy, preservation & opportunity cost Uranium has no significant use other than nuclear energy production. Producing electricity with **uranium extends the overall resource base** available for human use, provides greater diversity of choice and allows the **use of other resources**, such as hydrocarbons, **where they are most effective** e.g. for transportation or petrochemicals. **Uranium is plentiful and is distributed among a wide range of geopolitically diverse countries. The distribution of uranium reduces the risk of market disruptions of the nature experienced during historical oil and gas crises.** Resource efficiency and material throughput The focus on power supply options defined as 'renewable' over the past several decades reflects the importance attached to the preservation of finite resources. Renewable sources of energy are those generated from natural processes that are continuously replenished. Renewable technologies, therefore, are defined as those that are not fuelled by a finite resource. Intergenerational equity is a key principle of sustainable development, and so the purported advantage of renewable energy options – that they do not diminish finite fuel resources for future generations – is valuable. However, fuel supply is just one aspect of the material requirements for power generation. All means of generating electricity require infrastructure that consumes finite resources, with the major material inputs by volume outside of fuel supply typically concrete and metals (e.g. aluminium, copper, steel). Estimates for the use of key bulk materials and copper per TWh for different technologies have been produced by former environmental organization Bright New World9, based on a literature review of studies on this topic. Nuclear PWR Solar Wind Hydro Gas (load following) Gas (load following) + CCS Coal Coal + CCS Concrete 1060 1220 4470 15,320 390 820 450 520 Steel 130 940 1450 330 320 970 160 1170 Aluminium 0.3 287.5 17.4 8.7 5.7 21.4 1.6 37.4 Copper 2.5 68.0 39.1 4.8 5.4 8.8 3.0 11.8 Capacity f. 85% 28% 35% 50% 30% 30% 85% 85% Lifespan 60 30 30 100 60 60 60 60 Table 1 and Figure 10: Major materials for different generating technologies, tonnes per TWh (source: Bright New World) The aim of reducing material inputs is a central concept of sustainable development. Using material in the production, transport and implementation of power producing technologies will consume energy in the form of fossil fuels, and as such the metric of material throughput is important in consideration of energy efficiency as well as life-cycle carbon emissions. But more broadly, resource efficiency is a key aim in itself. Consumption of primary materials is expected to more than double by 2050. Using nuclear energy to generate electricity is one means by which resource demand can be reduced to more sustainable levels. Affordability Affordability is a key component of SDG 7. The benefits of access to modern energy are profound, but the aspiration of ensuring access for all can only be realized if it is affordable. The relative affordability of electricity supply options is a function of generation costs as well as the costs they impose on the system as a whole. Generation costs are typically reported using the levelized cost of electricity generation

(LCOE) metric, which is a measure of the ratio of the total costs of a generic plant (capital and operating), to the total amount of electricity expected to be generated over that plant's lifetime. LCOE as a metric is relatively simple and transparent, and so is widely referenced. However, its ability to assess overall costs to society are limited. In deregulated markets, revenues are uncertain over a generator's lifetime making the metric less pertinent; and the metric does not attempt to capture the markedly different system costs of technologies. System costs have always existed, but the growth in variable renewable energy sources has promoted the topic in recent years. System costs include required outlays for distribution and transmission, and most importantly, backup for the inherent variability of some renewable energy. System costs are difficult to assess, as they depend on the characteristics of the system in question, the time frame considered, location and numerous other factors. Whilst there is uncertainty, estimates are consistent in that system costs for variable energy sources are significant, increase non-linearly with growing shares of electricity generation, and are an order of magnitude higher than for dispatchable technologies¹⁰. The costs of the system as a whole are ultimately borne by society, and so, given the increasing use of variable renewable energy, it is important that system costs are internalized to ensure that policy decisions can be properly directed towards maximizing affordability. Negative effects beyond the system itself (i.e. negative externalities) related to the provision of electricity are increasingly being recognized as significant and complicate the picture further. Negative externalities related to electricity generation – most notably the emissions of greenhouse gases and other pollutants – represent a social cost that may impact the true affordability of different electricity supply options. It is well documented that the social and economic costs of climate change and air pollution are significant. In order to better-understand the socially optimal level of externalities (relative to production) it is imperative that the relative costs of different supply options include a reasonable estimate of their impacts on emissions and the climate. Nuclear energy is cost-competitive based on a simple LCOE comparison, particularly at low discount rates. Its unique attributes of providing predictable, reliable supply that is low-carbon means that inclusion of system costs and negative externalities both markedly improve the relative affordability of nuclear energy. Grid-level system costs for dispatchable and renewable technologies Figure 11: Grid-level system costs for dispatchable and renewable technologies (source: OECD Nuclear Energy Agency, 2018) Notes & references Notes a. The Human Development Index (HDI) is a United Nations Development Programme statistical tool to measure a country's level of social and economic development. The social and economic dimensions of a country are based on the health of its people, their level of education attainment and their standard of living. A country scores a higher HDI when the lifespan of its people is longer, the education level is higher, and the gross national income per capita is higher. [Back] References 1. United Nations, Report of the World Commission on Environment and Development: Our Common Future ('Brundtland Report') (1987) [Back] 2. United Nations Development Programme, Human Development Reports [Back] 3. BP Energy Outlook: 2019 edition [Back] 4. World Energy Council, World Energy Scenarios 2019, The Future of Nuclear: Diverse Harmonies in the Energy Transition (2019) [Back] 5. Steffen Schlömer (ed.), Technology-specific Cost and Performance Parameters, Annex III of Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (2014) [Back] 6. United Nations Economic Commission for Europe, Carbon Neutrality in the UNECE Region: Integrated Life-cycle Assessment of Electricity Sources (March 2022) [Back] 7. Barry W. Brook and Corey J. A. Bradshaw, Key role for nuclear energy in global biodiversity conservation, Conservation Biology, 29, 3 (2015) [Back] 8. Mesfin Mekonnen et al., The consumptive water footprint of electricity and heat: a global assessment, Environmental Science: Water Research & Technology (March 2015) [Back] 9. Bright New World, Materials use in a clean energy future (June 2021) [Back] 10. OECD Nuclear Energy Agency, The Full Costs of Electricity Provision (2018) [Back]

Otherwise, a recession would be devastating

Heidi Shierholz, 9-10-2009, "New 2008 poverty, income data reveal only tip of the recession iceberg", Economic Policy Institute, https://www.epi.org/publication/income_picture_20090910/ [Heidi Shierholz (she/her) is the president of the Economic Policy Institute, a nonprofit, nonpartisan think tank that uses the power of its research on economic trends and on the impact of economic policies to advance reforms that serve working people, deliver racial justice, and guarantee gender equity. In 2021 she became the fourth president EPI has had since its founding in 1986.] DOA: 4/4/2025

The poverty rate increased from 12.5% to 13.2% between 2007 and 2008, representing an additional 2.6 million people living in poverty. The large increase in poverty suggests that as anti-poverty policies have come to depend more on paid work as the main pathway out of poverty, the safety net has become less effective in reducing economic hardship when the economy and job market are underperforming.

- The poverty rate for children was 19.0% in 2008, representing 14.1 million kids living in poverty. In 2008, over one-third (35.3%) of all people living in poverty were children.

- It is important to note that the federal poverty threshold as currently measured is widely understood by poverty researchers to be an inadequate measure of the income needed to make ends meet. Poverty experts often use twice the poverty line as a more accurate threshold for material deprivation. In 2008, 31.9% (96 million people) were living below twice the poverty threshold, up from 30.5% in 2007. The number was even higher for children, with 40.6% of children (30.1 million) living below “twice poverty,” up from 39.2% in 2007.

- Hispanics and Asians were particularly hard-hit by increases in poverty in 2008, increasing by 1.6 and 1.4 percentage points, respectively, from 2007 to 2008.

- In 2008, over one-third (33.9%) of all black children and nearly one-third (30.6%) of all Hispanic children were living in poverty (increases of 0.2 and 2.0 percentage points, respectively, since 2007).

1AC---Climate

Climate change is worsening – best, most recent studies confirm we’re on the brink of irreversibility and the next 20 years are key.

Martina Igini, 02-11-2025, "Breaching 1.5C Threshold Could Come 'Earlier Than Expected'", Earth.Org,

<https://earth.org/paris-agreements-1-5c-threshold-breach-could-come-earlier-than-expected-scientists-warn/> [Martina holds two BA degrees - in Translation Studies and Journalism - and an MA in International Development from the University of Vienna.] DOA: 3/10/2025 //RRM

Two new studies indicate that we might have already crossed a key threshold to limit global warming in line with the Paris Agreement, after 2024 became the first calendar year where global temperatures surpassed 1.5C. — *The planet might be on track to breach a key global warming threshold “earlier than expected,” two new papers warned on Monday. The studies, published in Nature Climate Change, follow the hottest year on record and the first in which global temperatures reached 1.5C for the entire year.* This has left scientists wondering what this means for warming trends, as it puts us closer to a temperature limit we have pledged to do everything we can to avoid crossing. EO Movement Become an EO Member today and join a growing movement of people determined to make a change. JOIN EARTH.ORG Whether the planet has breached the Paris Agreement 1.5C warming target or not is measured over a 20-year retrospective average, meaning last year does not signal a permanent breach. *What the new studies investigated, however, is whether we have already entered the 20-year period above 1.5C.* Both concluded we have. One study, authored by Alex Cannon, a research scientist with Environment and Climate Change Canada, concluded that if 1.5C anomalies continue beyond 18 months, “breaching the Paris Agreement threshold is virtually certain.” *Meanwhile, Emanuele Bevacqua, a climate scientist at the Helmholtz Centre for Environmental Research in Germany, and colleagues put the odds of 2024 being the first year of a 20-year period reaching the 1.5C warming level at “likely” to “virtually certain.”* The Paris deal was drafted in 2015 to strengthen the global response to the growing threat of climate change. It set out a framework for limiting global warming to below 1.5C or “well below 2C” above pre-industrial levels by the end of the century. *Beyond this limit, experts warn that critical tipping points will be breached, leading to devastating and potentially irreversible consequences for several vital Earth systems that sustain a hospitable planet.* The United Nations had already estimated that current emissions reduction pledges put the planet on track for a temperature increase of 2.6-3.1C over the course of this century. The only way to avoid this is do drastically reduce greenhouse gas emissions, the primary driver of global warming as they trap heat in the atmosphere, raising Earth’s surface temperature. Scientists are not optimistic either. A survey of 380 IPCC scientists conducted by the Guardian last May revealed that 77% of them believe humanity is headed for at least 2.5C of warming. And on Monday, renowned climatologist James Hansen said

even the 2C target “is dead” after his latest paper concluded that Earth’s climate is more sensitive to rising greenhouse gas emissions than previously thought. The former top NASA climate scientist famously announced to the US Congress in 1988 that global warming was underway. Warming Continues Hopes that the recent warming trend would subside with the arrival of a cooling weather pattern known as La Niña were dashed last month, as January turned out to be the hottest January ever recorded. Surface air temperature anomaly for January 2025 relative to the January average for the period 1991-2020. Data source: ERA5. Surface air temperature anomaly for January 2025 relative to the January average for the period 1991-2020. Image: C3S/ECMWF. “[M]any of us expect that 2025 will be cooler than both 2023 and 2024, and is unlikely to be the warmest year in the instrumental record,” climatologist Zeke Hausfather wrote in a blog post on Monday. Their expectations were not met, he went on to say, describing how last beat the prior record set in January 2024 “by a sizable margin.” “January 2025 stands out as anomalous even by the standards of the last two years,” Hausfather wrote. “[A]t least at the start of the year nature seems not to be following our expectations.”

Nuclear energy is key to climate solvency and is better than alternatives

WNA, 05-01-2024, "Nuclear Energy and Sustainable Development", World Nuclear Association,

<https://world-nuclear.org/information-library/energy-and-the-environment/nuclear-energy-and-sustainable-development> [World Nuclear Association’s mission is to facilitate the growth of the nuclear sector by connecting players across the value chain, representing the industry’s position in key world forums, and providing authoritative information and influencing key audiences.]

DOA: 3/14/2025 //RRM

- spikes climate turns

The relationship between energy consumption and human development is clear. Up to about 100 GJ per capita consumption – a level yet to be reached by 80% of the world’s population – a country can fundamentally enhance the health, educational standards, and general wellbeing of its population by consuming more energy. Any transition towards a more equitable and sustainable future must therefore be predicated on delivering the benefits of access to modern, affordable and reliable energy services to all. But doing so will increase overall energy demand: at present, the world’s poorest 4 billion people consume just 5% of the amount of energy enjoyed by those living in developed economies. For that figure to rise to 15%, global energy consumption would increase by the equivalent of an additional United States’ worth of demand. The key question, therefore, is: how should that energy be supplied? At present, over 80% of primary energy consumption is from the burning of oil, gas and coal – unchanged since 1990. However, unregulated emissions from the combustion of fuels are causing climate change, environmental damage, and the premature death of an estimated 7 million people each year. The continued use of fossil fuels therefore has profound intra- and intergenerational social, economic and environmental implications. The resulting dual challenge – the need to reduce harmful emissions, whilst providing more energy to more people – positions the energy sector at the heart of achieving sustainable development. There is no technology that is fully without risk to people or the environment. For example, whilst low-carbon sources of energy do not emit carbon dioxide at the point of use, they are responsible for emissions and waste during construction, manufacturing and decommissioning. As such, any energy technology’s compatibility with sustainable development objectives must be assessed in relative terms – in the light of the alternatives. As the only proven, scalable and reliable low-carbon source of energy, nuclear power will be required to play a pivotal role if the world is to reduce its reliance on fossil fuels to address climate change and chronic air pollution. More broadly, however, the proposition of nuclear power as a sustainable energy source is fundamentally robust due to its innate energy density, and its internalization of health and environmental costs. Using nuclear energy has numerous sustainability advantages relative to alternative forms of generation. By expanding its use, modern and affordable energy can be provided to all who currently lack access, whilst reducing the human impact on the natural environment, and ensuring that the world’s ability to meet its other sustainable development goals is not curtailed. Defining Sustainable Development A number of definitions have been put forward for sustainable development, but the most widely quoted is from the 1987 Brundtland Report¹: “Sustainable development is development that meets the needs of the present, without compromising the ability of future generations to meet

their own needs" Sustainable development is therefore the pathway to sustainability. For an activity, product or entity to be truly sustainable, it must achieve environmental, economic and social sustainability in balance: the three 'pillars'. The three pillars of sustainability Figure 1: The three 'pillars' of sustainability In 2015, the 193 member states of the United Nations (UN) adopted the 2030 Agenda for Sustainable Development – a plan of action for people, planet and prosperity, aligned to the three pillars of sustainability. To disaggregate the bold ambitions of the 2030 Agenda, the UN agreed 17 Sustainable Development Goals (SDGs) to be used to guide and gauge progress. The United Nations 17 sustainable development goals Figure 2: The UN's Sustainable Development Goals More energy, lower emissions The 2030 Agenda for Sustainable Development recognized that by nature, the SDGs are "integrated and indivisible". As such, achieving progress across any of the SDGs is contingent upon progress across the others. *However the centrality of energy – and thus SDG 7 – is widely recognized: progress across all SDGs is contingent upon the provision of a sustainable supply of energy.* Providing access to affordable, reliable and clean energy is pivotal for eradicating poverty, for improving population's health and education, and for reducing greenhouse gases whilst continuing to support industrial development (see Figure 4). The link between the wellbeing of a population and energy consumption is well-established for developing countries. For those countries with an annual energy consumption below 100 GJ per capita – a level that 80% of the world's population is yet to reach^{2, 3} – there is a clear correlation between their energy consumption and Human Development Index (HDI) a value, which is an indicator of a nation's health, education and living standards. Human Development Index and annual energy consumption per capita Figure 3: Human Development Index and annual energy consumption per capita, 2020 (source: BP) This relationship between human wellbeing and energy consumption explains the importance assigned to ensuring reliable access to affordable energy for all in SDG 7; reducing the share of the world's population whose prospects are curtailed by lack of energy is essential for meeting the needs of the present. Achieving progress towards SDG 7 for the world's growing population will require a significant increase in energy provision. The importance of clean energy for a sustainable future Figure 4: SDG 7 – key to all SDGs The key question, therefore, is how best to supply those growing energy needs. Our existing energy system is built on fossil fuels, but their combustion for energy generates carbon dioxide (CO₂) emissions, a key contributor to climate change. *The energy sector is responsible for about three-quarters of all greenhouse gas emissions, and as such, fundamentally transforming it is the single most important step towards combatting climate change.* The UN has long-recognized climate change as the defining issue of our time. Despite this explicit acknowledgement, and spectacular recent investment in renewable energy, the world burned 66% more fossil fuels for energy in absolute terms in 2021 than it did in 1990. As a result, global energy-related CO₂ emissions were 63% higher. Box 1: The importance of electricity At present, fossil fuels are used to meet our energy requirements for transport, residential applications (e.g. heating), and to power industrial processes. Fossil fuels are also the dominant means of generating electricity, but other sources, including hydro, nuclear, solar and wind, are used too. To transition to a sustainable energy system all energy sectors will need to be decarbonized. However, much of the focus to date has been on the electricity sector for several reasons: The electricity sector is the most readily-decarbonized, as it provides the means to use non-fossil low-carbon energy (e.g. hydro, nuclear, wind and solar). Electricity is clean at the point of final use. This has two main advantages: improving air quality in urban areas; and centralising energy-related emissions (i.e. at power stations), making emissions regulation more straightforward. About 20% of final energy consumption is in the form of electricity, but the generation of electricity is responsible for almost 50% of all energy-related emissions. Despite the focus on electricity, limited progress has been made to date. In 2021, worldwide, 133% more electricity was generated from fossil fuels than 30 years earlier. Can nuclear contribute to sustainable development goals? Despite the crucial role that nuclear will need to play if the UN's SDGs are to be achieved, there remains some opposition to the growing recognition of the energy source's credentials for contributing towards sustainable development. *Fundamentally, nuclear energy's competitive position from a sustainable development perspective is robust due to its energy density and internalization of health and environmental costs.* Using nuclear energy brings multiple sustainability advantages over available alternatives, explaining its expanded role in almost all major studies that outline plausible pathways towards sustainable energy provision (see Box 2). An analysis of nuclear energy's characteristics within a sustainable development framework shows that the approach adopted within the nuclear energy sector is consistent with a central goal of sustainable development of passing a range of assets to future generations while minimising environmental impacts and burdens. Box 2: Nuclear energy's role in sustainable energy transitions Predicting the future of energy supply is complex, and uncertainties are high. *However, it is striking that in almost all forward-looking normative scenarios, nuclear energy's share in the mix grows substantially⁴.*

Generally, the more ambitious a scenario is in its aims for decarbonization and sustainability, the greater the role for nuclear. In the

IPCC's P3 'middle-of-the-road' scenario, for example, nuclear generation grows six-fold by 2050. Primary energy mix by 2040 and share of nuclear energy Primary energy mix by 2040 and share of nuclear energy (source: *World Energy Council*) The environmental pillar The environmental pillar of sustainable development encompasses issues including air and water pollution, waste management, ecosystem management, and protection of natural resources, wildlife and endangered species. Climate change The *United Nations* recognizes climate change as "the most systemic threat to humankind". As such, addressing it is generally considered the most significant and urgent sustainability challenge. Climate change is resulting from increasing concentrations of CO₂ in the Earth's atmosphere. Given that three-quarters of anthropogenic CO₂ emissions result from the burning of fossil fuels for energy, the main focus should be on deploying energy technologies that emit only small amounts of CO₂ per unit of energy. *On a life-cycle basis, nuclear power emits just a few grams of CO₂ equivalent per kWh of electricity produced. A median value of 12g CO₂ equivalent/kWh has been estimated for nuclear – similar to wind, and lower than all types of solar*⁵. Average life-cycle CO₂ equivalent emissions Figure 5: Average life-cycle CO₂ equivalent emissions (source: IPCC) Ecosystem protection The main impacts of power production on ecosystems are eutrophication (i.e. increased concentrations of chemical nutrients, primarily nitrogen and phosphorus, that damage water quality by causing oxygen depletion) and acidification (i.e. increased concentrations of acidic chemicals – caused by the absorption of atmospheric CO₂ – that damage water quality, harming shellfish and coral, and leading to excessive algal growth). Among power producing technologies, fossil fuels have by far the greatest potential to cause both acidification and eutrophication. CO₂ released into the atmosphere during the combustion of fossil fuels dissolves into the oceans, increasing their acidity; and the mining, extraction, transport, waste treatment and emissions associated with fossil fuel use contribute to their high eutrophication potential. By contrast, both the acidification and eutrophication potential of nuclear power are estimated to be among the lowest of all available generation technologies⁶. Figure 6: Lifecycle eutrophying emissions for 2020, in grams of phosphorus equivalent per MWh (source: Carbon Neutrality in the UNECE Region: Integrated Life-cycle Assessment of Electricity Sources, UNECE (March 2022) Land and water use Land and water usage are key criteria for assessing the sustainability of different power production technologies. The power sector competes for limited resources with other important sectors such as agriculture, industry and housing, and the emergence of a new concept known as the water-food-energy nexus reflects the growing appreciation of the interconnectedness of policy decisions in these three areas. Nuclear power plants produce huge amounts of low-carbon power and *require less land to do so than any other energy source*. The UN expects two-thirds of people to be living in urban areas by 2050 – an additional 2.5 billion individuals – where land is at a premium. Coupled with the need to preserve land to *prevent loss of biodiversity*, it is likely that nuclear energy's unique land-use advantages will prove *increasingly determinative* in the future. Box 3: The water-food-energy nexus Demand for water, food and energy is increasing, driven by rising global population and prosperity, as well as urbanization, dietary changes and economic growth. More than one-quarter of the world's energy is used for the production of food, and the agricultural sector is the largest single consumer of freshwater resources. The inextricable link between achieving water, energy and food security has driven recognition that policy decisions on each cannot be made effectively in isolation. The nexus approach is designed to integrate management across the three closely-related sectors. The water-food-energy nexus The water-food-energy nexus (source: International Water Association) *A large two-unit nuclear power plant can provide electricity for 4-5 million people from a generating footprint of just 2 square kilometres*. However, the land use of all energy-generating technologies extends beyond their generating footprint, and includes the required mining of raw materials and, for conventional sources of power, their fuel cycle. *Taking this into account, the land use of biomass, hydro, wind and solar are between one and three orders of magnitude greater than nuclear*⁷. Relative land use of electricity generation options per unit of electricity Figure 7: Relative land use (fuel mining and generating footprint) of electricity generation options per unit of electricity (source: Brook & Bradshaw, 2015) At some stage during supply, construction or operation, all electricity generating options consume water. Wind and solar energy have the smallest water 'footprints', whereas biomass and hydropower have the largest. Fossil fuels and nuclear consume significant quantities of water in the operational phase for cooling⁸. Fresh water is a valuable resource in most parts of the world. Apart from proximity to main load centres, there is no reason to site nuclear power plants away from a coast, where they can use once-through seawater cooling. The high energy density of uranium means that logistical requirements for fuel are modest (about 200 tonnes for a large reactor annually versus over 3,000,000 tonnes for an equivalent coal plant) allowing for flexible siting of nuclear power plants. In the event that water is so limited that it cannot be used for cooling, and a coastal location is not available, plants can be sited away from the load demand, but this will incur additional transmission costs. Whilst nuclear power plants require significant quantities of water for cooling, their ability to provide large

amounts of power is increasingly being used to secure water supplies in areas of scarcity. Where potable water cannot be obtained from streams and aquifers, desalination of seawater, mineralized groundwater or urban waste water is required. Most desalination at present is powered by fossil fuels, but nuclear desalination has been used for many years in countries such as Japan, India and Kazakhstan. Water consumption per unit of electricity and heat produced Figure 8: Water consumption per unit of electricity and heat produced 2008-2012 (source: Mekonnen et al., 2015) Waste The careful management of waste streams is a key sustainability consideration in order to prevent short- or long-term harm to humans and the environment. All energy-producing technologies create waste, but the amount produced, the risk it poses, and the means of management vary widely. The energy density of fuel used for electricity generation is one key determinant of the magnitude and manageability of waste streams. Uranium's exceptionally high energy density means a relatively small amount of fuel is required per unit of energy produced. Using less fuel reduces the scale of fuel extraction activities and transport requirements – in turn reducing the chance of unintended environmental releases – and results in the creation of less waste. Contrary to popular belief, therefore, one of the benefits of producing electricity from nuclear energy is that its waste streams are small, and therefore innately manageable. It is for this reason that nuclear energy is the only form of electricity generation to fully contain its emissions, effluents and waste. Unlike nuclear energy, some energy sources dispose of wastes to the environment, or have health effects which are not costed into the product. These implicit subsidies, or external costs as they are generally called, are nevertheless real and usually quantifiable, and are borne by society at large. Their quantification is necessary to enable rational choices between energy sources. Nuclear energy provides for waste management, disposal and decommissioning costs in the actual cost of electricity (i.e. it has internalized them), so that external costs are minimized. The social pillar Human health – air pollution Air pollution arising from the use of carbon-based fuels for energy is one of the biggest threats to human welfare. The World Health Organization estimates that about 7 million people die prematurely each year as a result of air pollution exposure. Nuclear power plants emit virtually no air pollutants during operation, and because they are reliable and can be deployed on a large scale, they can directly replace fossil fuel plant. NASA's Goddard Institute for Space Studies and Columbia University's Earth Institute estimated that the use of nuclear power prevented over 1.8 million air pollution-related deaths between 1971 and 2009. There are numerous non-power uses of nuclear technology that contribute to fulfilment of human 'needs'. For example: the provision of nuclear medicine; helping to control the spread of infectious diseases; and securing reliable supplies of clean water, sanitation and food (see Figure 9). Examples of the contribution of non-power nuclear technologies to the SDGs Figure 9: Examples of the contribution of non-power nuclear technologies to the SDGs Human health – radiation Radiation is a well-understood process, with natural sources accounting for most of the radiation people receive each year. Doses received average 2.4 mSv/yr, but vary widely by location, driven by factors such as underlying geology and altitude. The highest known level of background radiation affecting a substantial population is in the states of Kerala and Madras in India where some 140,000 people receive doses which average over 15 mSv/yr from gamma radiation, in addition to a similar dose from radon. Comparable levels occur in Brazil and Sudan, with average exposures up to about 40 mSv/yr to many people. Lifetime doses from natural radiation range up to several thousand millisieverts. However, there is no evidence of increased cancers or other health problems arising from these high natural levels. 20 mSv/yr is the current average allowed limit for nuclear industry employees and uranium miners during normal operation. The millions of nuclear workers that have been monitored closely for 50 years have no higher cancer mortality than the general population but have had up to ten times the average dose. Nuclear power is the only technology that systematically measures and accounts for radioactive emissions. However, exposure to above-background radiation is not exclusive to nuclear power-related activities. UNSCEAR has estimated that both occupational and public exposures from electricity generation are higher for workers in the coal industry, for example. Employment Nuclear power plants can operate for over 60 years, creating long-lasting, high-paying jobs for people from a range of fields and educational backgrounds. Undertaking a nuclear power programme therefore represents a long-term investment in human capital. Investment in capital-intensive projects tends to *spill over into other industries and economic sectors*. A modern gigawatt-scale nuclear power plant employs 500-1000 workers directly. *But throughout both its construction and operation, it requires a complex supporting supply chain (e.g. construction, manufacturing and consultancy services), creating attractive indirect and induced employment opportunities*. Hinkley point C unit 2 construction site During construction of a large, modern plant, thousands of workers may be onsite. At Hinkley Point C (pictured), over 8000 workers will be onsite during the peak of construction. A study of the European nuclear industry by Deloitte suggested that nuclear provides more jobs per TWh of electricity generated than any other clean energy source. According to the report, the nuclear industry sustains more than 1.1 million jobs in the European Union. In addition, each gigawatt of installed nuclear capacity generates €9.3 billion in annual investments in nuclear and related economic sectors, and provides permanent and local employment to nearly 10,000 people. *For every €1 invested, the nuclear industry generates an indirect contribution of €4 in GDP, and every direct job creates 3.2 jobs in the EU as a whole*. The economic pillar Resource adequacy, preservation & opportunity cost Uranium has no significant use other than nuclear energy production. Producing electricity with uranium extends the overall resource base available for human use, provides greater diversity of choice and allows the use of other resources, such as hydrocarbons, where they are most effective e.g. for transportation or petrochemicals. Uranium is plentiful and is distributed among a wide range of geopolitically diverse countries. *The*

distribution of uranium reduces the risk of market disruptions of the nature experienced during historical oil and gas crises.

Resource efficiency and material throughput The focus on power supply options defined as 'renewable' over the past several decades reflects the importance attached to the preservation of finite resources. Renewable sources of energy are those generated from natural processes that are continuously replenished. Renewable technologies, therefore, are defined as those that are not fuelled by a finite resource. Intergenerational equity is a key principle of sustainable development, and so the purported advantage of renewable energy options – that they do not diminish finite fuel resources for future generations – is valuable. However, fuel supply is just one aspect of the material requirements for power generation. All means of generating electricity require infrastructure that consumes finite resources, with the major material inputs by volume outside of fuel supply typically concrete and metals (e.g. aluminium, copper, steel). Estimates for the use of key bulk materials and copper per TWh for different technologies have been produced by former environmental organization Bright New World⁹, based on a literature review of studies on this topic. Nuclear PWR Solar Wind Hydro Gas (load following) Gas (load following) + CCS Coal Coal + CCS Concrete 1060 1220 4470 15,320 390 820 450 520 Steel 130 940 1450 330 320 970 160 1170 Aluminium 0.3 287.5 17.4 8.7 5.7 21.4 1.6 37.4 Copper 2.5 68.0 39.1 4.8 5.4 8.8 3.0 11.8 Capacity f. 85% 28% 35% 50% 30% 30% 85% 85% Lifespan 60 30 30 100 60 60 60 60 Table 1 and Figure 10: Major materials for different generating technologies, tonnes per TWh (source: Bright New World) The aim of reducing material inputs is a central concept of sustainable development. Using material in the production, transport and implementation of power producing technologies will consume energy in the form of fossil fuels, and as such the metric of material throughput is important in consideration of energy efficiency as well as life-cycle carbon emissions. But more broadly, resource efficiency is a key aim in itself. Consumption of primary materials is expected to more than double by 2050. Using nuclear energy to generate electricity is one means by which resource demand can be reduced to more sustainable levels. Affordability Affordability is a key component of SDG 7. The benefits of access to modern energy are profound, but the aspiration of ensuring access for all can only be realized if it is affordable. The relative affordability of electricity supply options is a function of generation costs as well as the costs they impose on the system as a whole. Generation costs are typically reported using the levelized cost of electricity generation (LCOE) metric, which is a measure of the ratio of the total costs of a generic plant (capital and operating), to the total amount of electricity expected to be generated over that plant's lifetime. LCOE as a metric is relatively simple and transparent, and so is widely referenced. However, its ability to assess overall costs to society are limited. In deregulated markets, revenues are uncertain over a generator's lifetime making the metric less pertinent; and the metric does not attempt to capture the markedly different system costs of technologies. System costs have always existed, but the growth in variable renewable energy sources has promoted the topic in recent years. System costs include required outlays for distribution and transmission, and most importantly, backup for the inherent variability of some renewable energy. System costs are difficult to assess, as they depend on the characteristics of the system in question, the time frame considered, location and numerous other factors. Whilst there is uncertainty, estimates are consistent in that system costs for variable energy sources are significant, increase non-linearly with growing shares of electricity generation, and are an order of magnitude higher than for dispatchable technologies¹⁰. The costs of the system as a whole are ultimately borne by society, and so, given the increasing use of variable renewable energy, it is important that system costs are internalized to ensure that policy decisions can be properly directed towards maximizing affordability. Negative effects beyond the system itself (i.e. negative externalities) related to the provision of electricity are increasingly being recognized as significant and complicate the picture further. Negative externalities related to electricity generation – most notably the emissions of greenhouse gases and other pollutants – represent a social cost that may impact the true affordability of different electricity supply options. It is well documented that the social and economic costs of climate change and air pollution are significant. In order to better-understand the socially optimal level of externalities (relative to production) it is imperative that the relative costs of different supply options include a reasonable estimate of their impacts on emissions and the climate. Nuclear energy is cost-competitive based on a simple LCOE comparison, particularly at low discount rates. Its unique attributes of providing predictable, reliable supply that is low-carbon means that inclusion of system costs and negative externalities both markedly improve the relative affordability of nuclear energy. Grid-level system costs for dispatchable and renewable technologies Figure 11: Grid-level system costs for dispatchable and renewable technologies (source: OECD Nuclear Energy Agency, 2018) Notes & references Notes a. The Human Development Index (HDI) is a United Nations Development Programme statistical tool to measure a country's level of social and economic development. The social and economic dimensions of a country are based on the health of its people, their level of education attainment and their standard of living. A country scores a higher HDI when the lifespan of its people is longer, the education level is higher, and the gross national income per capita is higher. [Back] References 1. United Nations, Report of the World Commission on Environment and Development: Our Common Future ('Brundtland Report') (1987) [Back] 2. United Nations Development Programme, Human Development Reports [Back] 3. BP Energy Outlook: 2019 edition [Back] 4. World Energy Council, World Energy Scenarios 2019, The Future of Nuclear: Diverse Harmonies in the Energy Transition (2019) [Back] 5. Steffen Schlömer (ed.), Technology-specific Cost and Performance Parameters, Annex III of Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (2014) [Back] 6. United Nations Economic Commission for Europe, Carbon Neutrality in the UNECE Region: Integrated Life-cycle Assessment of Electricity Sources (March 2022) [Back] 7. Barry W. Brook and Corey J. A. Bradshaw, Key role for nuclear energy in global biodiversity conservation, Conservation Biology, 29, 3 (2015) [Back] 8. Mesfin Mekonnen et al., The consumptive water footprint of electricity and heat: a global assessment, Environmental Science: Water Research & Technology (March 2015) [Back] 9. Bright New World, Materials use in a clean energy future (June 2021) [Back] 10. OECD Nuclear Energy Agency, The Full Costs of Electricity Provision (2018) [Back]

The impact is scalar: each degree of warming matters and will reduce suffering for billions.

David McKay 22, Researcher in Earth System Resilience, Stockholm University, 10-18-2022, "Climate tipping points could lock in unstoppable changes to the planet – how close are they?," World Economic Forum, <https://www.weforum.org/agenda/2022/10/climate-tipping-points-could-lock-in-unstoppable-changes-to-earth> || DOA 9/6/2023 BRP

A new assessment of the past 15 years of research has found there is a risk of certain tipping points being triggered now when global warming stands at roughly 1.2°C. But the Paris agreement's aim of halting warming at 1.5°C would reduce the chances of triggering multiple climate tipping points, the researchers say. **Continued greenhouse gas emissions risk triggering climate tipping points.** **These are self-sustaining shifts in the climate system that would lock-in devastating changes, like sea-level rise, even if all emissions ended.** The first major assessment in 2008 identified nine parts of the climate system that are sensitive to tipping, including ice sheets, ocean currents and major forests. Since then, huge advances in climate modelling and a flood of new observations and records of ancient climate change have given scientists a far better picture of these tipping elements. Extra ones have also been proposed, **like permafrost around the Arctic** (permanently frozen ground **that could unleash more carbon** if thawed). Estimates of the warming levels at which these elements could tip have fallen since 2008. The collapse of the west Antarctic ice sheet was once thought to be a risk when warming reached 3°C-5°C above Earth's pre-industrial average temperature. Now it's thought to be possible at current warming levels. In our new assessment of the past 15 years of research, myself and colleagues found that we can't rule out five tipping points being triggered right now when global warming stands at roughly 1.2°C. Four of these five become more likely as global warming exceeds 1.5°C. These are sobering conclusions. Not all of the news coverage captured the nuance of our study, though. So here's what our findings actually mean. Uncertain thresholds **We synthesised the results of more than 200 studies to estimate warming thresholds for each tipping element.** The best estimate was either one that multiple studies converged on or which a study judged to be particularly reliable reported. For example, records of when ice sheets had retreated in the past and modelling studies indicate the Greenland ice sheet is likely to collapse beyond 1.5°C. We also estimated the minimum and maximum thresholds at which collapse is possible: model estimates for Greenland range between 0.8°C and 3.0°C. Within this range, **tipping becomes more likely as warming increases.** We defined tipping as possible (but not yet likely) when warming is above the minimum but below the best estimate, and likely above the best estimate. We also judged how confident we are with each estimate. For example, we are more confident in our estimates for Greenland's ice sheet collapse than those for abrupt permafrost thaw. **This uncertainty means that we do not expect four climate tipping points to be triggered the first year global temperatures reach 1.5°C** (which climate scientists suggest is possible in the next five years), or even when temperatures averaged over several years reach 1.5°C sometime in the next couple of decades. **Instead, every fraction of a degree makes tipping more likely, but we can't be sure exactly when tipping becomes inevitable.** This is especially true for the Greenland and west Antarctic ice sheets. While our assessment suggests their collapse becomes likely beyond 1.5°C, ice sheets are so massive that they change very slowly. Collapse would take thousands of years, and the processes driving it require warming to remain beyond the threshold for several decades. If warming returned below the threshold before tipping kicked in, it may be possible for ice sheets to temporarily overshoot their thresholds without collapsing. For some other tipping points, change is likely to be more dispersed. We estimate that both tropical coral reef death and abrupt permafrost thaw are possible at the current warming level. But thresholds vary between reefs and patches of permafrost. Both are already happening in some places, but in our assessment, these changes become much more widespread at a similar time beyond 1.5°C. Elsewhere, small patches of the Amazon and northern forests might tip and transition to a savannah-like state first, bypassing a more catastrophic dieback across the whole forest. Model results that are yet to be published suggest that Amazon tipping might occur in several regions at varying warming levels rather than as one big event. There may also be no well-defined threshold for some tipping elements. Ancient climate records suggest ocean currents in the North Atlantic can dramatically flip from being strong, as they are now, to weak as a result of both warming and melting freshwater from Greenland disrupting circulation. Recent modelling suggests that the threshold for the collapse of Atlantic circulation depends on how fast warming increases alongside other hard-to-measure factors, making it highly uncertain. Into the danger zone There are signs that some tipping points are already approaching. Degradation and drought have caused parts of the Amazon to become less resilient to disturbances like fire and emit more carbon than they absorb. The front edge of some retreating west Antarctic glaciers are only kilometres away from the unstoppable retreat. Early warning signals in climate monitoring data (such as bigger and longer swings in how much glaciers melt each year) suggest that parts of the Greenland ice sheet and Atlantic circulation are also destabilising. These signals can't tell us exactly how close we are to tipping points, only that destabilisation is underway and a tipping point may be approaching. **The most we can be sure of is that every fraction of further warming will destabilise these tipping elements more and make the initiation of self-sustaining changes more likely. This strengthens the case for ambitious emissions cuts in line with**

the Paris agreement's aim of halting warming at 1.5°C. This would reduce the chances of triggering multiple climate tipping points – even if we can't rule out some being reached soon.

To quantify, Shindell et al 18 empirically found that decreasing warming by just .5 degrees Celsius would:

Shindell et al 18, Shindell D, Faluvegi G, Seltzer K, Shindell C. Quantified, Researchers at Duke University, Localized Health Benefits of Accelerated Carbon Dioxide Emissions Reductions. Nat Clim Chang. 2018;8(4):291-295. doi: 10.1038/s41558-018-0108-y. Epub 2018 Mar 19. PMID: 29623109; PMCID: PMC5880221, accessed from <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5880221/> on 9/6/2023 BRP

Societal risks increase as Earth warms, but also for emissions trajectories accepting relatively high levels of near-term emissions while assuming future negative emissions will compensate even if they lead to identical warming [1]. Accelerating carbon dioxide (CO₂) emissions reductions, including as a substitute for negative emissions, hence reduces long-term risks but requires dramatic near-term societal transformations [2]. A major barrier to emissions reductions is the difficulty of reconciling immediate, localized costs with global, long-term benefits [3, 4]. However, 2°C trajectories not relying on negative emissions or 1.5°C trajectories require elimination of most fossil fuel related emissions. This generally reduces co-emissions that cause ambient air pollution, resulting in near-term, localized health benefits. We therefore examine the human health benefits of increasing ambition of 21st century CO₂ reductions by 180 GtC; an amount that would shift a 'standard' 2°C scenario to 1.5°C or could achieve 2°C without negative emissions. The decreased air pollution leads to 153±43 million fewer premature deaths worldwide, with ~40% occurring during the next 40 years, and minimal climate disbenefits. More than a million premature deaths would be prevented in many metropolitan areas in Asia and Africa, and >200,000 in individual urban areas on every inhabited continent except Australia

Climate change causes extinction---multiple internal links and no adaptability.

Dr. Yew-Kwang **Ng 19** [Winsemius Professor of Economics at Nanyang Technological University, Fellow of the Academy of Social Sciences in Australia and Member of Advisory Board at the Global Priorities Institute at Oxford University, PhD in Economics from Sydney University, "Keynote: Global Extinction and Animal Welfare: Two Priorities for Effective Altruism", Global Policy, Volume 10, Number 2, May 2019, pp. 258–266, <https://onlinelibrary.wiley.com/doi/10.1111/1758-5899.12647>] Accessed 10/09/2024, DSL

Catastrophic **climate change** Though by no means certain, CCC **causing global extinction is possible due to interrelated factors of non-linearity, cascading effects, positive feedbacks, multiplicative factors, critical thresholds and tipping points** (e.g. Barnosky and Hadly, 2016; Belaia et al., 2017; Buldyrev et al., 2010; Grainger, 2017; Hansen and Sato, 2012; IPCC 2014; Kareiva and Carranza, 2018; Osmond and Klausmeier, 2017; Rothman, 2017; Schuur et al., 2015; Sims and Finnoff, 2016; Van Aalst, 2006).⁷ A possibly imminent tipping point could be in the form of 'an abrupt ice sheet collapse [that] could cause a rapid sea level rise' (Baum et al., 2011, p. 399). There are many avenues for positive feedback in global warming, including: • the replacement of an ice sea by a liquid ocean surface from melting reduces the reflection and increases the absorption of sunlight, leading to faster warming; • the drying of forests from warming

increases forest fires and the release of more carbon: and • higher ocean temperatures may lead to the release of methane trapped under the ocean floor, producing runaway global warming. Though there are also avenues for negative feedback, the scientific consensus is for an overall net positive feedback (Roe and Baker, 2007). Thus, the Global Challenges Foundation (2017, p. 25) concludes, 'The world is currently completely unprepared to envisage, and even less deal with, the consequences of CCC'. The threat of sea-level rising from global warming is well known, but there are also other likely and more imminent threats to the survivability of mankind and other living things. For example, Sherwood and Huber (2010) emphasize the adaptability limit to climate change due to heat stress from high environmental wet-bulb temperature. They show that 'even modest global warming could ... expose large fractions of the [world] population to unprecedented heat stress' p. 9552 and that with substantial global warming, 'the area of land rendered uninhabitable by heat stress would dwarf that affected by rising sea level' p. 9555, making extinction much more likely and the relatively moderate damages estimated by most integrated assessment models unreliably low. While imminent extinction is very unlikely and may not come for a long time even under business as usual, the main point is that we cannot rule it out. Annan and Hargreaves (2011, pp. 434–435) may be right that there is 'an upper 95 per cent probability limit for S [temperature increase] ... to lie close to 4°C, and certainly well below 6°C'. However, probabilities of 5 per cent, 0.5 per cent, 0.05 per cent or even 0.005 per cent of excessive warming and the resulting extinction probabilities cannot be ruled out and are unacceptable. Even if there is only a 1 per cent probability that there is a time bomb in the airplane, you probably want to change your flight. Extinction of the whole world is more important to avoid by literally a trillion times.

Rebuttal

The government's idea of investment is small modular reactors, or SMRs, which address all of the con's concerns

Susan Ferrechio just 3 days ago, Washington Times, 04-02-2025 // // Next-gen nuclear reactors poised for surge in U.S. power grid // <https://www.washingtontimes.com/news/2025/apr/2/next-gen-nuclear-reactors-poised-surge-us-power-grid/> // accessed 4-4-2025 // ashe

He is following orders from Mr. Trump, who, just days into his second administration, said he would use an emergency declaration to expedite the building of plants needed to provide energy to artificial intelligence data centers. The president said the plants can use any source of power, including coal, but SMRs are poised to play a pivotal role. The technology has been in development for years but has never been deployed in the U.S. A handful of SMR plants are running in Russia and China. Under the Trump administration's pro-nuclear energy policies, SMR plants are poised to advance rapidly. SMR plants are smaller than traditional water-cooled nuclear power plants and can be built quicker and cheaper. SMRs can use a variety of coolants, so they do not need to be positioned near large water sources. They produce about a third of the energy of a traditional nuclear reactor. The multiple modules SMRs allow the plants to conduct maintenance without shutting down entirely, as is required with large-scale nuclear power facilities. Mr. Trump has been promoting SMR technology since his first term and promised during his 2024 campaign to get SMR plants up and running. "These can be built ultra-safe. They are ultra-clean, and they're very low-cost. But they are absolutely safe," he told voters in York, Pennsylvania, in August.

Empirics prove: nuclear decreases CO2

1. Globally

IAEA 21 (International Atomic Energy Agency, 9/2021,

<https://www.iaea.org/sites/default/files/21/10/nuclear-energy-for-a-net-zero-world.pdf>, Accessed 4-1-2025, wayway)

Globally, nuclear power plants produce more than one quarter of all low carbon electricity. Over the past five decades, nuclear power has cumulatively avoided the emission of about 70 gigatonnes (Gt) of carbon dioxide (CO₂) and continues to avoid more than 1 Gt CO₂ annually.

In addition, nuclear power is a dispatchable and flexible source of electricity. At a time when the use of variable renewables is growing, nuclear power makes a key contribution to energy supply security and grid stability. We caught a glimpse of a future low carbon energy mix in several countries when the world went into its pandemic driven lockdown. The ensuing drop in electricity demand partly priced out fossil fuels leaving nuclear and hydro to ensure continuity of supply, while wind and solar operated when conditions allowed. The choice of energy sources remains a sovereign decision and every country has different needs. It is notable, however, that more and more scientists, policymakers and members of the public are recognizing nuclear as a critical part of decarbonized energy systems. In addition to the IPCC's clear recognition of nuclear energy's role in addressing the climate crisis, a similar message has been reiterated by energy experts, including those at the International Energy Agency. The United Nations Economic Commission for Europe calls nuclear power an "indispensable tool" for achieving the Sustainable Development Goals. Opinion polls in countries such as the USA, for example, are showing that the public supports strong political action on climate change and that a clear shift in favour of nuclear power is under way. The use of nuclear power continues to grow, albeit more slowly than many other low carbon sources.

Today, it provides 10% of the electricity produced worldwide.

In 2020, the number of IAEA Member States operating nuclear power plants increased to 32 after Belarus and the United Arab Emirates connected their first reactors to the grid. Of these operating countries, 19 have projects in place to expand their nuclear power capacity. Around 30 newcomer countries are embarking on, or considering, nuclear power. Bangladesh and Turkey, for example, are already well advanced in the construction of their first nuclear power plants. These are small but encouraging steps: nuclear generation will need to double by 2050 if we are to reach our net zero climate goals, according to experts at the IEA.

1. France

Hannah Ritchie 24 (Hannah Ritchie, 4-4-2024, France's nuclear fleet gives it one of the world's lowest-carbon electricity grids, Our World in Data,

<https://ourworldindata.org/data-insights/frances-nuclear-fleet-gives-it-one-of-the-worlds-lowest-carbon-electricity-grids>, Accessed 4-1-2025, wayway)

France generates two-thirds of its electricity from nuclear power. As the chart shows, that's far more than the global average, just under 10%. Even though its share in France has declined slightly in recent years, it's still its dominant power source.

Nuclear power is a low-carbon electricity source, allowing France to have a very clean electricity mix for decades. **Per unit of electricity, France emits far less carbon dioxide (CO₂) than its neighbors and has some of the lowest-carbon power in the world. The global average is 438 grams of CO₂ per kilowatt-hour of electricity generated. In France, this figure is 85 grams.**

On their case:

Ov

On their c1 about tradeoff

First,

Nuclear energy crowds out renewable energy, meaning the two are mutually exclusive.

Khan, Anwar et. al. "Efficacy of CO2 emission reduction strategies by countries pursuing energy efficiency, nuclear power, and renewable electricity." Energy, August 1, 20**24**, <https://doi.org/10.1016/j.energy.2024.131418>. Accessed March 9, 2025.

Third, the **negative coefficients** of energy efficiency **across the tested models indicate** that the countries' **energy efficiency is effective** in CO2 emissions reduction. Finally, the results discovered that **nuclear and renewable electricity pathways tend to crowd out each other**, where this phenomenon is not valid in the cases of nuclear power-energy efficiency and renewable electricity-energy efficiency, where they support each other.

This means inc nuclear energy = less renewables which is good

Renewables are bad

Renewables don't live up to their expected performance AND nuclear better than **fossil fuels**

Department of Energy 25 [U.S. Department of Energy, "What is Generation Capacity", March 30, 2025, U.S. Department of Energy, <https://fortune.com/2022/03/29/us-energy-independence-uranium-nuclear-power/>]

Capacity factors allow energy buffs to examine the reliability of various power plants. It basically **measures how often a plant is running at maximum power**. A plant with a capacity factor of 100% means it's producing power all of the time. **Nuclear has the highest capacity factor of any other energy source—producing reliable and secure power more than 92% of the time** in 2024. **That's nearly twice as much as a coal (42.36%) or natural gas (59.9%)** plant that are used more flexibly to meet changing grid demands and almost **3 times more often than wind (34.3%) and solar (23.4%) plants**.

Renewables are cooked

Renewables are unviable for the foreseeable future

Osaka 25 [Shannon Osaka, "Renewable energy sources falling short of goals amid regulatory roadb...", 01/22/2025, archive.is, <https://archive.is/OE0gw#selection-417.0-1241.256>]

For years, renewable energy proponents have hoped to build a U.S. electric grid powered by wind, solar, geothermal and — to a lesser extent — nuclear power, with carbon-free energy surging into homes and businesses across the country. When President Joe Biden signed the Inflation Reduction Act in 2022, which slashed the cost of building renewables, that dream seemed likely to become a reality. But now, renewable developers say that the new technologies are stymied by complicated local and federal regulations, a long wait to connect to the electricity grid, and community opposition. Experts once hoped that by the end of the decade the United States could generate up to 80 percent of its power with clean power, and Biden set it as a national goal. Now, some wonder if the country will be able to reach even 60 percent. That means that even as renewables continue to break records, the Biden administration departs with the nation offtrack from its climate target of cutting emissions 50 to 52 percent by 2030. And as President Donald Trump takes the reins, threatening tariffs and halting new permitting for wind, the country is drifting further away from an all-renewable future. Trump's **new executive order mandates a halt to all offshore wind leasing in federal waters**, pauses federal permitting for both onshore and offshore wind projects and launches a "comprehensive assessment and review" of wind leasing and permitting. 🌱 Follow Climate & environment Follow "The U.S. offshore wind business is at a very nascent stage versus Europe or China," Rob Barnett, a senior analyst at Bloomberg Intelligence, said in an email. "With the new permitting pause, **it's doubtful much progress** for this emerging industry **will be made** under the second Trump administration." The order compounds struggles that the renewable energy industry was already facing. In theory, a better-designed grid could lead to renewable penetration of 60 to 70 percent, said Jason Grumet, CEO of the American Clean Power Association. But that's only with substantial changes to where wind and solar can be built and how it gets connected to the grid. "Without progress, probably some places tap out at half that," he said. After the Inflation Reduction Act passed, Rhodium Group — an independent clean energy research firm — estimated that between 2023 and 2025, on average, the country would add between 36 and 46 gigawatts of clean electricity to the grid every year. Late last year,

however, the group found that the country only installed around 27 gigawatts in 2023. The U.S.'s renewable growth is now expected to fall on the low end of that range — or miss it entirely. "It actually is really hard to build a lot of this stuff fast," said Trevor Houser, partner in climate and energy at Rhodium

Group. **Renewables are falling short of expectations** Average clean electricity added to the grid between 2023 and 2025, in gigawatts per year. This dot chart shows that after the IRA, initial estimates showed that the US would build 36 to 46 GW of clean electricity every year. Now the country is only estimated to build 32 to 36 GW. 30 35 40 45 50 Previous estimate Current estimate The Clean Investment Monitor is a joint project of Rhodium Group and MIT's Center for Energy and Environmental Policy Research. Previous estimate in August of 2022; current estimate from November 2024. Source: Clean Investment Monitor As a result, Rhodium found, the country only cut carbon emissions by 0.2 percent in 2024. To reach Biden's climate goal, the country needs more than 7.6 percent every year from now until 2030. (The only example of such a steep drop in recent history was during covid-19, when emissions dropped about 10 percent in 2020.) A significant amount of this lag has come from wind power, where

problems with supply chains and getting permits and approval to build has put a damper on development But solar construction is also on the low end of what experts were expecting. "Immediately after the passage of the Inflation

Reduction Act, there was a whole lot of enthusiasm," said Brendan Pierpont, director of electricity modeling at Energy Innovation, a nonpartisan clean energy think tank. Models mostly use economics to make predictions — analyzing what the most cost-efficient actions will be and calculating the results accordingly. But the challenges that energy developers face today are not economic. "The premise of these congressional clean energy tax credits was to stimulate remarkable acceleration," said Grumet. "The technology is ready, and the financial services are ready — but the question nobody really put enough thought into was, could the government keep up? And at the moment, the answer is no." **Renewables** have many great benefits — they don't produce deadly air pollution or contribute to global warming. But the electricity grid was in large part built for fossil fuels, which can be placed close to the communities they serve. Wind and solar, on the other hand, sometimes **need to be built hundreds or even thousands of**

miles away — which then requires large, long-distance transmission lines to move power. Renewables also take up more space, although in some places wind and solar can coexist with agriculture and animal grazing. **"The grid that we have was never designed to handle this kind of load,"** said Sandhya Ganapathy, CEO of EDP Renewables North America.

Developers point to lags in the interconnection queue — a system that gives new solar, wind or fossil fuel projects permission to connect to the larger electricity grid. According to a report from Lawrence Berkeley National Laboratory, **it can now take nearly 3 years for a project to get through the queue**. The grid operator that covers the Mid-Atlantic and parts of the Midwest, PJM, had over 3,300 projects in its queue at the end of 2023. The vast majority of these applications are for renewables — more than the entire number of active wind farms in the nation. Not all areas of the United States are equal. According to data from the Energy Information Administration and analyzed by Energy Innovation, Texas installed more solar, wind and storage than any other grid area between 2022 and 2024. A worker walks past solar panels at ENGIE's Sun Valley Solar project in Hill County, Texas. (Mark Felix/AFP/Getty Images) Ganapathy said that while a state like Texas can approve projects faster, most of the rising energy demand from AI and data centers is coming from the Mid-Atlantic and Midwest. "A project takes anywhere between six to eight years," Ganapathy said. "All of the AI needs are coming — are they going to wait six to eight years until we have more power in the system? We need to streamline this." Then there are the high-voltage transmission lines that move that power across the country. According to one study by the National Renewable Energy Laboratory, **the**

country could require up to 10,000 new miles of transmission to switch to clean electricity by 2035. Last year, the country built just 255 miles of new transmission line, according to the American Clean Power Association. Some projects have gotten stalled for years; one such line in the Southwest, the SunZia line, just started construction after 18 years of development. "If you have a weak transmission system, we will always be hesitant to build a project," said Ganapathy. "Why are we taking a big risk of a massive investment if I will not be able to sell the electrons?" Developers say that getting community support can also get more difficult as more and more wind and solar are added to the grid. "The low-hanging fruit has been developed," said John Woody, senior vice president of development at Clearway Energy Group. Anti-wind and anti-solar groups have also begun using more sophisticated methods and have more funding, he added. Some states and cities have even tried to ban development of renewables, often citing misleading information about environmental or health hazards. There are possible solutions. Some developers hope to reuse old fossil fuel sites, like coal plants, that are already connected to the grid — bypassing the long queue entirely. The Federal Energy Regulatory Commission has instated new rules to make it easier to build transmission lines. But those changes need to happen quickly. **The United States is currently building**

20 to 40 gigawatts of renewables every year — but that number will need to increase to 70 or 80 gigawatts to meet U.S. climate goals. "We're building record amounts of wind and solar every year, but it seems like we're kind of hitting a ceiling," said

Houser. Developers also worry about the threat of Trump's proposed **tariffs**, which **could further destabilize an industry that relies on predicting prices and supply chains months or even years in advance**. Without advance knowledge or

planning of the tariffs, they warned, **projects could grind to a halt**. Still the economics of clean energy are strong. Wind and solar, in many jurisdictions, are cheaper than fossil fuel plants. The challenge is building those wind and solar farms at a fast pace that will push aside existing coal and natural gas plants — before temperatures rise much higher. "If you had told me 20 years ago when I started working on climate, that we would be having discussions about not the direction of change, but the pace — I would be dancing in the streets," said Houser. "The challenge is just, can we build it fast enough?"

Nuclear better than renewables

RBC 24 [RBC, "Nuclear energy sector getting the push it needs", 05/08/2024, Canada Asia

Centre-Vancouver,

<https://ca.rbcwealthmanagement.com/international.vancouver/blog/4188242-Nuclear-energy-sector-getting-the-push-it-needs>]

The need to decarbonize Nuclear energy—like solar, wind, geothermal and hydro—generates low direct carbon emissions. With the urgent need to achieve global net zero targets, policymakers are embracing nuclear as a complement to renewables and abated natural gas-fired power plants. The International Energy Agency (IEA) suggests that nuclear power output would need to double by 2050 to achieve net zero goals.¹ **Renewables**

alone may not get us there in a timely and cost-efficient manner, despite their lofty growth expectations over the coming decades. From a lifecycle emissions perspective, i.e., taking into account indirect emissions associated with plant construction and disposal, nuclear compares well with other sources. This is because **nuclear requires less construction material, has a longer operational lifespan (lasting 40–100 years while solar panels and wind farms are replaced every 20–30 years), and occupies less land (solar plants and wind farms require 75x and 360x more land to produce the same amount of electricity, respectively)**.² Delivering to net zero goals will be harder and more expensive without nuclear. The IEA notes that

without nuclear, there will be a need for \$500B more investment and customer electricity bills will rise by \$20B/year to 2050.³ Clearly, a balanced mix of low-emission energies that includes nuclear power will be needed to achieve climate targets. Nuclear among lowest emissions energy available Low-cost alternative Nuclear's reliability as a baseload power makes it a useful energy source.

Nuclear plants generate power 93% of the time, whereas intermittent renewable resources like wind and solar generate power 35% and 25% of the time, respectively.⁴ Not only is extra capacity needed for renewables, **they also**

need a backup source or batteries to store energy. This raises the cost and emissions profiles of these sources.

While industry research suggests nuclear can be cost-competitive when considering total system costs, this differs from practice in many cases. Nuclear power projects have frequently experienced substantial cost overruns and delays during construction, causing actual costs of nuclear electricity to greatly exceed initial estimates. However, there are arguments that nuclear projects may be better positioned for success moving forward. New plant designs using modular construction techniques have the potential to lower complexity and risks, while technological know-how and experience will bring efficiencies. Additionally, governments can help reduce costs by providing long-term commitments, financing and regulatory clarity in the licensing and construction processes. **One of the most straightforward and inexpensive ways to increase nuclear**

capacity is through the extension of existing nuclear plants. The IEA noted that reactors designed for 40-year lifespans can be extended by 20–40 years.

This offers countries the opportunity to retain the economic benefits of carbon-free baseload power at low marginal costs and with lower construction costs/risks.⁵ This also makes nuclear energy extensions competitive with solar and wind in many regions.

And nuclear energy is good - - cross app all our responses from case, its better than the alts, takes up less area and less co2 emissions

On their c2 about water **Current designs and new innovations solve for the water cost**

Matthew L. Wald 23 (Matthew L. Wald, 10-17-2023, Nuclear Reactors Don't Need to Be So Thirsty, Breakthrough Institute, <https://thebreakthrough.org/blog/nuclear-reactors-dont-need-to-be-so-thirsty>, Accessed 3-29-2025, wayway)

As to how much water all these processes "cost," a United Nations Economic Commission for Europe study from 2019 takes a stab at some answers. The study put nuclear energy from at an average of about 2.4 liters per kilowatt-hour, counting all types of cooling systems. (A kilowatt-hour is enough to run an efficient kitchen refrigerator for a day.) An ordinary coal plant was about the same, but a coal plant that captured its carbon dioxide was far higher. And natural gas in a combined cycle system was a little lower. A further study by the U.S. Department of Energy's

National Renewable Energy Laboratory concurred that **plants with cooling towers consume far more water than once-through cooling systems, which "withdraw" about 10 times more water per megawatt-hour produced but release the water back to its source**.

In the jigsaw puzzle of picking a site for a power plant, considerations include grid access, proximity to rail or barge transport for coal, or availability of pipelines for natural gas. Water is sometimes not a concern. In other locations, it's a critical consideration. Hence the idea for a reactor that will be cooled by

air, at **a project in Idaho** that will be built for a coalition of public power entities, the Utah Associated Municipal Power Systems (UAMPS), with a cluster of NuScale reactors. The decision about what kind of plant to build is unlikely to be based on water usage; more important are the needs of the electricity system. If nuclear is a good fit, others can go the route that was taken in Idaho. Future Nuclear UAMPS' Idaho project may be a harbinger of the future, at least in dry locations. It **will use an air-cooled condenser**. The steam leaving the turbine runs inside metal tubes, and fans blow air on the outside of the tubes. This cools the water somewhat the way a car radiator does. Using an air-cooled condenser makes it much easier to pick a spot to build a reactor; no river or lake is needed. But there's a downside; the fans need electricity. The penalty is in the range of 5% to 7% of electricity production, depending on climate. NuScale is betting that in Idaho, and in some other locations in the future, **the electricity** to cool the condenser **will be less valuable than the water** for a water-cooled condenser would be. One of the drawbacks, though, is that the amount of electricity needed for cooling goes up when the air is hot. In the summer, when the grid most needs the power, production available for the grid is reduced. An air-cooled condenser is unusual, but **some coal plants** do **use** them. Some of those plants are on rivers that have very low flows in summer, so they use **air cooling** during hot-weather months, and water the rest of the time. The Russians built some small reactors with air cooling in the arctic, where liquid water wasn't always available. And some nuclear designs don't use water to move heat within the reactor at all. In fact, they may use inert gas, liquid metal, or liquid salt. An advanced reactor that used molten salt or molten metal to move heat from the core to make steam would likewise need water to condense the steam back to water for reheating. But these might need less water per kilowatt-hour than the current generation of reactors because they operate at higher temperatures, and higher temperature steam can make more kilowatt-hours per BTU of heat. Gas-graphite reactors, which use an inert gas like helium to move energy from the fuel to the turbine, can re-heat the inert gas without condensing it at all. Some plants will use less water to cool the condenser because they will make beneficial use of the heat that is captured by cooling the steam back to water. That heat, today thought of as waste, could be used for water desalination, hydrogen production, district heating, or industrial heat.

Nuclear energy can draw water from unsuitable sources while helping in water production

Matthew L. Wald 23 (Matthew L. Wald, 10-17-2023, Nuclear Reactors Don't Need to Be So Thirsty, Breakthrough Institute, <https://thebreakthrough.org/blog/nuclear-reactors-dont-need-to-be-so-thirsty>, Accessed 3-29-2025, wayway)

Reactors can also run on water that is unsuitable for other purposes. **Palo Verde, in Arizona, which is the largest nuclear plant in the United States (and will continue to be so until Vogtle 4 is finished in Georgia) uses water recycled from a sewage plant.** Water will be a concern going forward because rainfall is becoming more variable than the early nuclear planners had foreseen. Likewise, the temperature of surface water, which is needed for the condenser, is now higher sometimes than the planners expected. **But nuclear technology is capable of operation with very low water consumption, and advanced nuclear technologies will make saving water easier.** And nuclear will likely have another connection to water: making it. **Desalination is now most commonly done with electricity, and sometimes from direct use of natural gas, using the waste heat of a gas-fired power plant. Reactors are a very good way to make heat and electricity, and do so without adding to the carbon burden of the atmosphere, which is what is causing water problems to begin with.**

Thus, desalinization solves for water shortages:

Nuclear desalination process using thermal energy to heat water

Al-Othman 19 -- Dr. Amani Al-Othman et al, Associate Professor of Chemical Engineering at American University of Sharjah and researcher with focus on on fuel cell technology and renewable energy, "Nuclear desalination: A state-of-the-art review, Desalination", Volume 457, May 1, 2019, Pages 39-61, ISSN 0011-9164, <https://doi.org/10.1016/j.desal.2019.01.002>, (<https://www.sciencedirect.com/science/article/pii/S0011916418323531>, <https://sci-hub.se/https://doi.org/10.1016/j.desal.2019.01.002>, date accessed: 3-13-2025 //fdmvs

Aspects of nuclear desalination **Nuclear desalination is the process of producing fresh water using an on-site nuclear reactor** [99]. Plant capacity and water quality are among the several factors that can significantly affect the energy demand in any desalination process [100]. The energy required to power desalination can be either thermal or electrical as previously stated in this context. **Renewable sources such as geothermal and solar renewable energy sources can be used to drive MSF, RO and MED, however, they are integrated with smaller size plants** [100]. **Nuclear energy offers higher energy density compared to other conventional and renewable energy sources.** With the continuous depletion

of fossil fuels, continuous population growth, and the increase demand for fresh water, developing countries are currently in crucial need for the development of nuclear reactors. In developing countries, constructing large nuclear plants can impose a greater safety and economical risk due to the large space occupied by the plant. However, **new technologies can solve some of these problems by building smaller size plants, produce hydrogen, generate electricity and produce fresh water by desalination on site** [101]. **For the past two decades, nuclear desalination have been officially recognized by IAEA as one of the most efficient and promising options for fresh water production and power generation** [102].

Several research activities were initiated by the IAEA since the 1990's with nine state members [102]. They are called the coordinated research projects (CRP) and their aim is to investigate, assist improve and optimize nuclear desalination [102,103]. Additional objectives are to investigate the reliability, efficiency, cost analysis and safety of nuclear desalination. The studies offered sufficient data for future nuclear desalination systems and summarized the following substantial advantages for nuclear desalination processes [104]: 1) the possibility of harnessing useful amount of heat and invest it in thermal processes such as MED and MSF, 2) the development of an environmentally friend multi generation system, and 3) the reduction of the overall costs for the process along with the enhancement in plant efficiency. Globally speaking, the nuclear desalination systems fall into two major categories: nuclear desalination with power generation or, stand-alone nuclear desalination. In this section, a review for the various aspects and characteristics of nuclear desalination technologies is presented. 5.1. Types of nuclear reactors for desalination The existing nuclear desalination plants around the world were established in the 1970's and they are located in Kazakhstan and in Japan [105]. Before the 1970's, research activities evaluated the possibility of nuclear desalination and showed its feasibility as well as its competency with other conventional energy sources [11,12,106,107]. In general, and according to the type of coolant used, there are two types of nuclear reactors that are used in desalination: light water reactors (LWR) and the heavy water reactors (HWR) [31]. LWR category also include boiling water reactors (BWR) and pressurized water reactors (PWR). Whereas, the HWR category include pressurized heavy water reactors (HPWR). There are other types such as the Liquid Metal Fast Breeder Reactor (LMFR) and high temperature gas cooled reactor (HTGR) [108]. In general, the water-cooled reactors are preferred because of the well-established technology. In the literature, Pressurized Water Reactor (PWR), Pressurized Heavy Water Reactor (PHWR), and Liquid Metal Fast Breeder Reactor (LMFR) are the most common nuclear reactors coupled with desalination processes [13,109]. The IAEA has classified the nuclear reactors based on their power output into three categories: "small" reactors if they have less than 300 MWe electrical output; medium if their electrical output is in between 300 and 700 MWe, and large reactors if their

output is higher than 700 MWe [110]. The modern development of nuclear reactors for power generation is based on reactors from sizes 1100 to 1700 MWe [111]. The adoption of large scale reactors in desalination is currently feasible but several factors have to be evaluated first before operation such as safety and stability [105]. In theory, **all types of nuclear reactors have the capability of providing**

the required energy for desalination processes[102]. However, the recent developments focused on investigating generation III nuclear reactors such as the AP1000 [112,113]. Alonso et al. [111] evaluated and compared the performance of two PWR nuclear reactors: one large reactor (called AP1000) versus a medium size reactor (called IRIS) combined with the following desalination processes: MSF, MED and RO. The results are summarized in Table 1. This study concluded the following: 1) water can be produced with the cogeneration of useful electricity and, 2) the use of the small reactor (IRIS) appeared to be more feasible due to cost and versatility. The cost analysis will be discussed in subsequent section s of this paper. However, it is worth mentioning in here that generation III nuclear reactors suffer from a major drawback, i.e. the heavy development investment [114]. Dardour et al. [115] evaluated the performance of two nuclear reactors for desalination: gas turbine-modular helium cooled reactor (GT-MHR) and the pebble bed modular reactor (PBMR) reactor. The results showed that these two reactors are suitable for desalination, in particular when coupled with MED. Khalid et al. [116] performed a thermodynamic analysis for a gas turbine-modular helium reactor (GTMHR) coupled with reverse osmosis (RO) process. The study assessed the amount of waste heat utilized in generating electricity and concluded that utilizing this heat has increased the exergy efficiency by 10%. Ahmed et al. [117] reviewed the small/medium (or modular) nuclear reactors (SMRs) in large scale desalination. The review compared the following nuclear reactors: pressurized water reactors (PWR), gas cooled reactors (GCR), heavy water reactors (HWR), boiling water reactors (BWR), and liquid metal fast breeder reactors (LMFBR) in terms of their technical features. **The review addressed several advantages for SMR**

reactors in desalination including moderate space occupied, ease of construction into modules and in a short time, and their suitability for remote areas. The status of the early established nuclear desalination processes

around the world is summarized in Table 2 [117,118]. As shown in the table, the use of nuclear heating reactors (NHR) was proposed in China. Other countries such as Canada, India and Pakistan are considering the PHWR reactors. Overall, it can be noticed that the commercial types of nuclear reactors coupled with desalination are the PWR, PHWR, and LMFR respectively. In 2015, the use of NHR-200 (200 MWt) was examined in China to be applied by 2030 [26]. It was aimed to couple this reactor with an MED process to produce steam. The assessment showed a decrease in electricity costs however, the use of this novel technology can increase the design costs. The use of pressurized heavy water reactor (PHWR220) reactor for desalination in India was also investigated [119]. The reactor PHWR-220 (220 MWe) is currently under commissioning with 14 units operating. Other types of nuclear reactors include the liquid metal fast reactor (LMFR) such as the one used in Kazakhstan and the advanced pressurized nuclear reactor (APR 1400) that is intended to be built in United Arab Emirates (UAE) by Korea power corporation [120].

5.2. Coupling desalination processes with nuclear reactors The flowchart for a desalination process coupled with a nuclear power plant is shown in Fig. 7 [121]. The figure includes an MED and an RO as an illustration. It is an on-site nuclear-desalination system. The purpose is to generate electricity (to power RO) as well as utilizing the waste heat to produce steam that will be fed into the MED unit. In order to design a nuclear desalination process, the following steps should be performed: 1) proper modeling for the reactor-desalination systems, 2) careful evaluation for the nuclear plant safety and, the 3) technical outcomes from the desalination process itself. 5.2.1. Coupling nuclear with thermal desalination technologies: Multi-stage flash distillation (MSF) and multiple effect distillation (MED) Fig. 8 shows the coupling the MSF thermal

process with a nuclear power plant [111]. The principle of MSF is previously explained in this context. **Using the on-site nuclear power plant, it would be possible to have a cogeneration system and generate electricity. In addition, the waste heat is utilized to heat seawater. This configuration has the capability of improving the**

system economics, hence, reducing the costs. The flowsheet for multiple effect distillation (MED) coupled with a nuclear power plant is shown in Fig. 9 [32,111]. The principle of the MED desalination process is previously explained in this context. The MED unit can be seen as a series of adjacent spaces where surrounded by a heat sources at one side and a heat sink at the opposite side. As steam is flowing from one effect to another it exchanges heat with sweater. **Eventually, more water will be evaporated and the brine will be more concentrated by the end of the series**. A power cogeneration system is supplied in the nuclear plant to generate electricity. Both MSF and MED are more expensive and more energy demanding, however, they are used because they produce the highest water quality as opposed to membrane technologies such as RO [32,111,122]. 5.2.2. Coupling with RO Reverse osmosis (RO) is currently being considered as the most economical technology for desalination [123]. As explained in Section 4.2, it is based on applying a high pressure that can reach 70 bars depending on water source. This pressure is exerted at one side of the membrane to overcome the osmotic pressure of sweater and force it to pass through the membrane, hence, obtain fresh water [72]. RO can be used to treat waste water, seawater, brackish water and oily water once properly treated [124]. Coupling RO with any power plant is feasible and done to generate electricity required to run the RO units. Electricity is utilized to power the pumps and plant utilities. Fig. 10 shows a typical nuclear power plant coupled with RO. The nuclear reactor is used to generate steam, in which is passed in an expander (turbine) to generate the electricity required to operate the pumps in the RO desalination plant. Based on the previous discussion and literature, it is evident that the main desalination processes that have been coupled with nuclear reactors for fresh water production are: 1) multi stage flash distillation (MSF), 2) multi effect distillation process (MED) and, 3) reverse osmosis (RO). Each desalination process requires a certain nuclear reactor configuration based on the type of energy required. Table 3 below shows the capacity of some desalination plants at different locations around the world including Japan, Kazakhstan and India with electrical power capacity exceeding 1000 MW as well as the method of desalination used. It can be clearly seen that PWR reactors are the most commonly used with MSF, MED and RO.

Desalination relies on cost, energy source sustainability, environment effects etc.

but nuclear desalination specifically covers these concerns.

Al-Othman 19 -- Dr. Amani Al-Othman et al, Associate Professor of Chemical Engineering at American University of Sharjah and researcher with focus on on fuel cell technology and renewable energy, "Nuclear desalination: A state-of-the-art review, Desalination", Volume 457, May 1, 2019, Pages 39-61, ISSN 0011-9164, <https://doi.org/10.1016/j.desal.2019.01.002>, (<https://www.sciencedirect.com/science/article/pii/S0011916418323531>, <https://sci-hub.se/https://doi.org/10.1016/j.desal.2019.01.002>, date accessed: 3-13-2025 //fdmvs

The implementation of desalination technologies is becoming one of the practical solutions to meet the increase in fresh water demand in many regions around the world. Water desalination industry has been expanding dramatically since the 1950s. A significant increase in capacity observed in the gulf countries, Caribbean region and in southern California [1,2]. **Conventional desalination technologies rely heavily on energy obtained from fossil fuels, which eventually leads to pollution and global warming**. In principle, desalination processes are divided into two main categories: thermal and non-thermal processes (membrane processes) [3]. The main thermal processes include: multi stage flash (MSF), vapor compression (VC) and multi-effect distillation (MED), while reverse osmosis (RO), forward osmosis (FO) and electrodialysis (ED) are classified among the membrane desalination processes [3–6]. The most commonly practiced processes are MSF and RO. In terms of global capacity, RO accounts for 63% and MSF accounts 23% [2]. A substantial reduction in the cost of the desalinated water has been achieved over the last decades. However, **many factors still play a significant role in determining the cost of desalinated water**. These factors include the type of technology used, plant size, geographical location, plant capacity, pretreatment requirements, quality of feed water and power cost. While considering the following factors: 1) **the cost of energy**, 2) **sustainability of conventional energy sources**, 3) **the effect of fossil fuels on the environment** and 4) **the fluctuations of fossil fuel prices**, it appears that there is a merit to find alternative energy sources to power desalination processes. Some desalination processes require thermal energy such as MSF and MED, while membrane technologies such as RO or forward osmosis (FO) for example require electricity. Hence, extensive research efforts are in progress to explore alternative energy sources in desalination such as solar, geothermal and nuclear energy [6]. **Nuclear desalination appears to be a feasible and a promising option to power desalination plants at reasonable costs**[7]. It is the production of fresh/drinkable water from seawater in a nuclear power plant. **The amount of energy evolved can be utilized to power thermal desalination processes as well as running a cogeneration system to produce electricity** [8–10]. The use of nuclear energy in desalination has been extensively studied by the International Atomic Energy Agency (IAEA) since the 1960s [11,12]. Since then, the IAEA have been actively leading surveys on the feasibility of integrating nuclear energy into desalination. **Multiple IAEA reports** were published [13–16]. The results **showed several attractive features for nuclear desalination including the protection of**

environment by minimizing the greenhouse gas emissions, the eventual conservation of traditional energy sources (fossil fuels) and the economic feasibility in remote areas where fossil fuels are not available.