### 1AC --- Space

#### Mars is in sight.

**Greenfieldboyce 25** [Nell Greenfieldboyce, NPR science correspondent & Masters of Arts degree in science writing, 2-12-2025, Is Trump the president who will truly set a course for Mars?, NPR, https://www.npr.org/2025/02/13/nx-s1-5294575/president-trump-elon-musk-mars-moon, Willie T.]

Back in 1969, Robert Zubrin remembers watching the first moon landing when he was a teenager. He says if someone back then had asked him to predict when astronauts would walk on Mars, "my guess would have been the early 1980's."

"And, in fact, NASA had plans to do that at that time, which were aborted by the Nixon administration," says Zubrin, an aerospace engineer who is president of the Mars Society and author of The Case for Mars.

Over the decades, as administrations have come and gone, presidents have repeatedly promised future missions to Mars, holding this up as a **key goal** for human space exploration.

Never before, though, has a **president** had such a **close relationship** with a would-be Mars colonizer, one who has transformed the world of rocketry.

Elon Musk, President Trump's ally who is **shaking up government agencies**, founded the company SpaceX with the goal of making humans a **multiplanetary species**. In addition to ferrying astronauts to orbit for NASA, this company is currently building and test flying a new space vehicle, **Starship**, that's designed to **transport massive amounts of cargo—including people**—and land on Mars.

"This is **quite a singular moment** for the prospects of getting to Mars," says Zubrin, who sees this as a time filled with both opportunity and peril.

"I think it actually is pretty clear right now that we're going to get a **humans-to-Mars program** started," he says.

But to succeed, any such plan would need broad political support, and he worries about Mars suddenly becoming a divisive, partisan issue.

"This is not going to work," says Zubrin, "if this is understood to be an Elon Musk hobbyhorse."

The presidents and Mars

In his inaugural address in January, President Trump got the attention of the space community when he said the United States would "pursue our **manifest destiny into the stars**, launching American astronauts to plant the Stars and Stripes on the planet Mars."

In some ways, a president inspirationally referring to Mars is nothing new.

Back in 1989, for example, President George H. W. Bush called for a return to the moon, to be followed by "a journey into tomorrow, a journey to another planet: a manned mission to Mars." He envisioned footprints in the Martian dirt by 2019, the 50th anniversary of the moon landing.

"Within a few short years after President Bush's Kennedy-esque announcement, however, the initiative had faded into history," one policy analyst wrote.

A decade and a half later, President George W. Bush refocused NASA on a return to the moon by 2020, adding that "with the experience and knowledge gained on the moon, we will then be ready to take the next steps of space exploration: human missions to Mars and to worlds beyond."

President Obama told NASA to forgo the moon, but did maintain Mars as a goal: "By the mid-2030s, I believe we can send humans to orbit Mars and return them safely to Earth," he said in a speech at NASA's Kennedy Space Center. "And a landing on Mars will follow."

First, the moon?

During President Trump's first administration, he issued a space policy directive that refocused NASA on a human moon landing, with missions to Mars added as a future goal.

That program, called Artemis, is what NASA has pursued ever since. It continued under President Biden, although it's been criticized as relying on a super-expensive rocket that rarely flies.

Despite delays and cost overruns, NASA says it is poised to send humans to **orbit the moon next year**. A landing is planned for the year after that.

Trump's reference to Mars, but not the moon, in his inaugural speech had some in the space community wondering if this was a result of Musk's influence.

The new Trump administration could **kill Artemis and its lunar plans**, but Casey Dreier, chief of space policy for the Planetary Society, says that would be "strange in the historical sweep of things" given that the first Trump administration basically created this program

"There's a lot of good reasons to still go to the moon, one of which is that the U.S. has made a commitment to not just its allies, but to the broader commercial space and business community here in the country," notes Dreier.

Still, he thinks that the current administration might challenge NASA to really nail down how the space agency will move from **lunar exploration to a Mars** mission.

More difficult than the moon

NASA has a "Moon to Mars Program Office," notes Dreier. He thinks, however, "there's no 'to Mars' part of it. It's all 'to moon.' "

He says NASA has constrained budgets, and there's always been concerns that the agency hasn't had enough resources to pursue both the moon and Mars.

"It's hard to express verbally, I think, how much harder Mars is than the moon and how different it is," says Dreier.

A trip to the moon takes just three days. Going to Mars, in contrast, takes months—one way.

Recently, a NASA program aimed at retrieving pristine rocks from the surface of Mars and bringing them back to Earth ran into real trouble, as costs ballooned by billions and the mission timeline slipped. One decision the Trump administration will have to make is whether, and how, to pursue this science mission.

Dreier says in terms of human exploration, NASA needs to lay out how its lunar activities will actually help get the agency **closer to going to Mars.**

"That is the key reframing that could help the long-term exploration program be more **efficient and effective**," he says.

President Trump's pick to lead NASA is Jared Isaacman, a private astronaut who flew to orbit twice in SpaceX vehicles and completed the first commercial extravehicular activity, or spacewalk. He has yet to be confirmed.

A NASA spokesperson told NPR in an email that the agency is "looking forward to hearing more about the Trump Administration's plans for our agency and expanding exploration for the benefit of all, including sending American astronauts on the first human mission to the Red Planet."

A non-partisan planet

Because of the **way the planets align**, potential launch **windows** to Mars open up in **2026 and 2028.**

Musk has publicly stated that he's aiming to send Starship to Mars as soon as **next year.**

Starship has yet to reach orbit, but Zubrin thinks it's possible that an uncrewed Starship might land on Mars by **2028**.

#### Reliable energy sustains human settlement.

**Pombo 21** [Daviel Vazquez Pombo, MSc in High Voltage Engineering from Aalborg University & PhD in Planning and Operation of Isolated Hybrid Power Systems from Technical University of Denmark, 4-7-2021, A Hybrid Power System for a Permanent Colony on Mars, Space: Science & Technology A Science Partner Journal, https://spj.science.org/doi/10.34133/2021/9820546, Willie T.]

Many are the reasons behind establishing a colony in Mars such as the possibility of discovering extraterrestrial life, ensuring the survival of our species after a massive extinction event, and improving quality of life, etc. However, there are only a **few scientific publications** regarding Mars colonisation. The few existing **focus mostly on spacecraft concepts** and design, at the expense of hardly mentioning or even **neglecting basic day-to-day** critical infrastructures like the power system. In fact, the relevant previous work starts mostly on the 70s, later in the 90s and 2000s; a couple of very high-level publications appear that mainly update some of the base assumptions due to the discoveries obtained by different unmanned missions sent to the red planet. In any case, establishing a permanent outpost in Mars **requires** a flexible, scalable, **reliable, and safe power system**. Therefore, this paper is aimed at analysing power sources, transmission/coupling possibilities, topology, etc. for a near-future Mars colony. This is addressed by reviewing all the excellent work developed since the 50s until the early 2000s and then updating it with present methods and technologies. Culminating with a proposal of a power system suitable for the task at hand, serious dialogues must start among the scientific community as it is its duty to serve humankind’s development [1–5].

There has not been much development specifically about the power system. Early documents like [6] proposed either a purely nuclear system or a combination with solar photovoltaic (PV) [7]; some others [8] suggested radioisotope but with a back-up role. However, most of the available **work is superficial and undetailed**. Recent development in energy technology obtained as a result of the energy transition demands a revision of the sources and storage system that might be used in the power systems of surface space missions. In addition, no document has proposed a balance of plant, a proper topology, or addressed the transmission system for the colony to name a few, not to mention how to address the particular effects of the Martian environment on electrical equipment [9]. Thus, studies focusing solely on the **Martian environment and requirements** are needed. Thus, this paper is aimed at reviewing the available technologies that will conform the power system of a near-future Martian colony and propose a suitable topology. This is done by reviewing the different proposed mission designs, concluding in a reasonable evolutionary scenario for the colony and its balance of plant suitable to satisfy its power and energy needs.

Then, the structure of the paper is as follows: Section 2 reviews the history of the most important documents published targeting manned missions to Mars, the interest behind establishing a permanent outpost, and it subsequently defines a dynamic architecture for the outpost. Thereafter, different power sources are analysed on Section 3 in order to choose a suitable combination conforming the Martian hybrid power system (HyPS). Then, whether the coupling should be in AC, DC, or mixed is discussed in Section 4. Afterwards, the resulting topology of the HyPS is presented and evaluated in Sections 5 and 6, respectively. Finally, the conclusions of this work are presented in Section 7, while also pointing out research paths that might continue this work.

2. Background, Motivation, and Mission Requirements

This section reviews the most important studies targeting Mars exploration in chronological order. This is aimed at illustrating the evolving concepts in certain areas while the stagnation in others such as power systems, while also helping to define the targeted mission. Despite the intention of providing an overview of all the developed science, there is a strong focus on NASA achievements until the 2000s, since Roscosmos public documents are written in Russian, a language sadly falling out of the knowledge base of the author.

The first formal approach to reach Mars was published in 1953 [10], where the flight systems and spacecraft are envisioned. A crew of 70 would be the first humans seeing the planet up-close as the arrival date was 1965 and precursor robotic missions were not considered. However, it was not until 1988 where a space agency such as NASA published a study with a similar aim [2], followed shortly by series of studies of human and robotic exploration beyond Low Earth Orbit and the Moon, Mars, Phobos, etc. [11, 12]. Then, [13] concludes that enough technological readiness would be achieved by 2000, starting the operations shortly afterwards; envisioning crews of 4 people, doubling two years after the first arrival and, also, suggesting several schedules ranging from 2011 to 2018 for the first mission and 2014 to 2027 to inaugurate the first permanent settlement.

In any case, [13] satisfies the power needs of the missions by means of SP-100, a nuclear fission reactor designed in 1989 for lunar missions easily adaptable for Mars [6]. It is worth mentioning that all the previous publications dismiss the possibility of using any locally available resources since there was no data available until the discoveries obtained by both Viking landers. Subsequently, in 1991, [14] further elaborates about a surface operating reactor, while [15] takes an extra step by coupling it with an in situ resource utilisation (ISRU) unit. A device capable of using local water, ice, and atmospheric CO2 as raw materials for fuel, air, water, plastics food, and other supplies. However, this concept will fall into oblivion for more than 10 years [16–18]. Afterwards, [19] points out the need for further research about the Martian environment before they could design landers, space suits, and other surface systems. After 1997, the approach taken by the studies changes trying to acquire a more holistic perspective, since previous attempts like [20] ended up focusing mostly or solely into flight and trajectory designs. Then, [9, 21] represent the most complete analyses until then, aiming to be used to drive R&D plans, understand mission requirements, open discussions, establish a baseline for future proposals, and stimulate further thought by also demanding improvement in certain aspects like the power system. A crew of 6 is envisioned in [9], no attention to surface power system is paid, and no ISRU is considered despite [15] being published 6 years prior.

After entering the new millennia, a high-level review of the Mars mission is published [3] stating that human arrival to Mars is so certain that a second revision will be necessary between 2015 and 2020 to account for the actual arrival. The book reviews concepts such as [10, 19] which never envisioned the role of robotic exploration. These unmanned missions helped discover unknown phenomena that would have ruined any manned mission developed with that time’s technology. It also points to the arrival delay caused by these discoveries as the reason for funding reduction in benefit of robotic exploration. The more was discovered, the least money available for a manned mission was available. Then, [16, 17] present concepts for self-sustaining Mars colonies by means of implementing ISRU. In [16], the 500 people colony site is selected in the North polar cap due to the water/ice available, while [17] focuses on obtaining water from the atmosphere, to avoid site dependency, envisioning a modular architecture capable of either 100, 1000, or 10000 crew scenarios. Following this trend, [18] is aimed at implementing an ISRU system to support propulsion and power systems for ground and flight vehicles in two scenarios, an Antarctica-inspired 100 people scenario and another terraforming scenario with a crew of 10000.

The first document from the European Space Agency (ESA) about a Mars mission is published in 2006 [22], which presents plans to study the Martian environment by using rovers. Then, [23] revives the interest of manned missions in three different sites, discussing mobility possibilities both on the surface and underground; the arrival is estimated between 2030 and 2040. Subsequently, in 2009, [7] suggests a framework aiming to facilitate reaching Mars as a multiagency effort. The document describes the systems and operations of a robotic precursor and the first three manned missions of 6 people each in different locations. This document stands out as the first time that the power system and energy management are highlighted as a key improvement needed. Subsequently, [24], a more completed version of [7], builds upon some of the aforementioned documents like [11–14, 21, 22] and others like [25, 26]. Among the conclusions of [24], the higher importance of robot-human partnership should be mentioned. Additionally, the selected crew of 6 must land prior to 2030; otherwise, a technology reassessment will be needed. Lastly, [24] contains the first proper section about the power system, which is envisioned as a combination of nuclear and PV for the main power while radioisotope power systems (RPSs) for backup needs. Thereafter, in 2014, [27] updates [7] with the latest developments, increasing again the role of robots and identifying solar power generation, nuclear fission, and active thermal control among the critical technologies. On the other hand, ESA and Roscosmos have a shared exploration agenda; however, no manned missions are foreseen [28, 29]. India and Japan have expressed that their targets do not include Martian exploration whatsoever, while China do it independently, targeting manned missions to the Moon in 2030 in collaboration with Russia as a prior step [30, 31]. Then, the Evolvable Mars Campaign is the current NASA mission seeking to enable crewed Mars missions in the mid-2030s timeframe [32]. Lastly, SpaceX is targeting the first manned mission to Mars in 2024 as preparation for a permanent settlement to be started shortly afterwards [5]. Nevertheless, why should we keep pursuing the dream of reaching Mars?

Many publications like [7–9, 33, 34] have reviewed the numerous reasons and objectives behind reaching Mars, which can be divided into 5 categories: planetology, humanistic, scientific, technological, and political. Ultimately, the goal is the integration of all the prior and acquired knowledge, which is referred in this work as holistic. This unification of knowledge will transcend any objectives established for the Mars colonisation and will push humanity forward. A summary of the possible reasons and objectives behind the conquest of Mars is presented in Figure 1Opens in image viewer. Nevertheless, the questions risen due to this endeavour might be even more valuable than the answers we hope to find [23].

Figure 1 Reasons to go to Mars.

Once the reasons behind getting humans into the red planet have been stated, the importance of establishing a permanent settlement instead of a temporary visit should be highlighted. The most important reason backing a sustained human presence in Mars is the increased cost-effectiveness of the mission. Research potential and discoveries escalate during sustained missions, while the cost does not increase significantly [23]. However, even disregarding the difficulty of reaching the planet safely, the particularities of engineering a robust system capable of operating under the Martian conditions will unequivocally translate in technological advancement for the general humanity. Examples of this process can be [35] where cross-disciplinary research is undertaken making use of the ISRU to propel an ascent vehicle in Mars, or [36] where a prototype for a greenhouse suitable for the Martian environment is presented, or [37] which is aimed at expanding the applications of ISRU units. Additionally, since one of the objectives is to avoid a massive extinction event, establishing permanent human settlements in other celestial bodies is a key. Then, **terraformation** of Mars, which consists of warming up the planet, in order to **thicken its atmosphere**, ultimately obtaining **liquid water surface oceans** on Mars [34], would **only be interesting** to achieve if there is a sustained human presence on the planet [38]. Lastly, Mars is **not considered the end** of the space exploration, but rather a **step** in it. Future missions aimed at more distant celestial objects will **require longer stays** before returning or continuing; thus, Mars represents a great training **outpost**.

At the end of the day, there are a variety of different envisioned manned missions, with crews ranging from **4 to 10000** depending on the length of stay and the ultimate exploration objectives. Barely no attention has been paid to the configuration and actual implementation of the power and energy management system (PEMS). Manned missions might still be decades down the road; however, complex robotic missions rather than individual rovers might be closer than ever due to latest developments in the field [39, 40]. Whatever the case, **manned or unmanned**, all the infrastructures depend on having a functional power system. Therefore, a reference architecture for the colony must be defined prior to sizing the necessary PEMS as it is needed in order to estimate the mission’s power and energy needs.

2.1. Architecture of the Colony

Even though there is no certainty as of this moment about the exact outlook of the colony, there are several strong candidates that can provide a rough approximation to be used as a starting point. Additionally, one of the self-imposed conditions of this work is that all systems must use current or near-future technology (technology readiness level of at least 6); no breakthrough technologies are assumed as following the recommendations of [22, 41]. Then, depending on the objective, any Mars surface mission can follow one of the coming strategies [7]:

(i)

Mobile home: all the structures are packed in a mobile, rover-based colony whose objective is long-duration exploration at great distances in a nomadic way

(ii)

Commuter: fixed, stable site for the colony with inclusion of both un- and pressurised rovers for mobility and science. The focus is on human exploration

(iii)

Telecommuter: similar to commuter, although most of the exploration is based on teleoperation of small robotic system from the local habitat

The focus of this work is on the commuter scenario as is the one that has received more attention and, also, it is the one best serving the purpose of a complex, permanent colony. One of the main reasons is the expected cost reduction of future missions by making use of the ISRU units and local manufacturing. While its concrete economic implications are tough to estimate and fall beyond the scope of this work, it is simple to understand how having a base in Mars will greatly reduce future mission costs. This is due basically to two reasons: launching satellites or other robotic missions manufactured directly on site and the possibility of providing support or maintenance [23].

In the commuter architecture, any planetary structure can be divided into 8 categories: habitats, laboratories, bioregenerative life support, ISRU, surface mobility (rovers), extravehicular mobility (eva suits), power system, and launch and landing area. All of them contain similar equipment such as windows, hatches, docking mechanisms, power distribution systems, life support, environmental control, safety features, stowage, waste management, communications, airlocks, and egress routes [9, 13, 17]. It is worth mentioning that rovers in this scenario are assumed to have a range of 100 km before needed resupply [7]; however, there is already available technology to get significantly larger ranges [42]. Disregarding the mobility range and the number of rovers, the habitats are always expected to keep a minimum of occupation due to safety measures [24]. Then, with an increasing population and expected duration of the colony, the number and purpose of the habitats change dramatically; if for a 6 people colony, habitats only include the bare minimum survival needs [7, 9]; a 100 people colony demands the existence of recreation facilities such as shops, open community spaces, parks, and public transportation [17].

2.2. Growing Stages of the Colony

After identifying the colony architecture as a commuter, the most influencing parameter affecting the power and energy demand is the foreseen population as it affects the required resources, habitats, etc. Since the aim of this work is to establish a permanent self-sustaining colony, its deployment is approached in stages.

Given the recent development in the field of robotics, it is reasonable to assume that the settlement will be founded by robots, which will **select and prepare the terrain** for the arrival of the first crew. Later, an initial crew of 6 will arrive, continuing the expansion of the colony and starting the scientific work. The next arrivals are expected shortly afterwards once the **technology and structures have been tested**, thus **ramping** the population in steps to 20, 50, and 100. This chain of arrivals and colony development is consistent with published work as [7, 10, 13, 17, 32, 41]; however, the robotic role has been considered, in general, higher. Then, even though there are already scenarios envisioning colonies **up to 10000** people [16, 17], the author considers that scenario to be far enough in the future to require a technology and method reassessment specially including the lessons learned from the first years of the Martian colony.

#### Nuclear is key but investment is needed.

**Nguyen 20** [Tien Nguyen, Ph.D. in Organic Chemistry & B.S in Chemistry with Minor in Physics, 5-15-2020, Why NASA thinks nuclear reactors could supply power for human colonies in space, Chemical & Engineering News, https://cen.acs.org/energy/nuclear-power/NASA-thinks-nuclear-reactors-supply/98/i19, Willie T.] \*\*brackets in original\*\*

The astronauts pass their **days in darkness**. After several months of living on the moon, they’re still adjusting to the endless night. The crew’s habitat at the lunar south pole sits in a shadowed crater—chosen for its promise of ice—that has not been touched by a single ray of sun for billions of years.

Fortunately, the nearby nuclear reactor is unfazed by the **lack of light**. Connected to the astronauts’ base camp by a kilometer of cables cautiously tracing the lunar surface, the reactor provides an **uninterrupted supply** of electricity for recharging rovers, running scientific instruments, and most importantly, powering the **air and heating systems** that keep the astronauts **alive.**

This is one vision of what human exploration could look like on the moon. In fact, NASA has plans to make some versions of this scene a reality—and soon.

The agency aims to send a human mission to the moon by 2024 in an effort named the Artemis project. Congress has allocated more than $6 billion of NASA’s 2020 fiscal budget for space exploration programs including the Space Launch System rocket, the Orion spacecraft, exploration ground systems, and research and development. The agency estimates that it will cost $35 billion to land a crew on the lunar surface, including the first woman to step foot on the moon. After 2024, NASA hopes to move to launching one human mission each year and reach sustainable operations on the moon by 2028.

The lessons learned in that phase will be crucial in preparing for **future trips to Mars**. One major effort will involve figuring out which power systems—including ones that have never been tested on the lunar surface, such as nuclear power—would best support future settlements. Whether the necessary materials can be brought safely to the moon and whether systems such as nuclear fission can run **reliably under such harsh conditions** are central questions that must be answered as engineers weigh their options.

Going nuclear

Choosing a power source depends on the particular mission’s needs, says Michelle A. Rucker, an engineer at NASA’s Lyndon B. Johnson Space Center who has researched possible architectures for space settlements. Electricity may come from nuclear reactors, solar panels, batteries, fuel cells, or some combination of these technologies connected in a power grid, she says. “I’m a big fan of all the types of power.”

But each power source has distinct pros and cons to consider. Solar arrays have reliably delivered renewable power in space for decades but are useless in places that never get any light, like the potentially resource-rich craters on the moon. And on the windy, dusty surface of Mars, solar panels may **struggle to collect** enough light, making them a risky option for powering life support systems, Rucker says. **Batteries and fuel cells have limited lifetimes** for now, relegating them to **supplementary power sources at best.**

One type of nuclear device that has been used to power spacecraft is a radioisotope thermoelectric generator, which runs on the heat produced by the decay of plutonium-238. These generators have been used since the 1960s in Mars rovers and space probes sent to the outer edges of the solar system, such as the Voyager spacecraft and Cassini. Despite being the workhorses of scientific missions, the generators provide only several hundred watts of power, just enough to send radio signals back to Earth or power a camera.

On Earth, the nuclear technology used by power plants is nuclear fission, which splits uranium-235 atoms via bombardment with neutrons to generate heat that’s captured to produce electricity. Nuclear fission holds the potential to provide a **continuous, reliable source** of power for a small space settlement designed to last **for several years.**

In the 1960s, many scientists thought fission reactors for space would follow on the heels of radioisotope generators. In 1965, the US launched a small nuclear fission–powered satellite named SNAP-10A, but electrical issues caused it to fail a mere 43 days after launch; it’s still in orbit, now just another piece of space junk. The Soviet Union launched 31 nuclear fission–powered satellites over the next 2 decades.

But the development of new nuclear fission reactors for space stalled during that time because of design problems and ballooning budgets. Engineers wanted advanced performance from these systems right away, which led to complicated and expensive designs, says David Poston, a nuclear engineer at Los Alamos National Laboratory. He and Patrick McClure, who specializes in reactor safety at Los Alamos, have worked at the lab for the past 25 years and recall the days when nuclear fission had fallen out of favor.

“Pat and I were sitting around just kind of demoralized,” Poston says, “because we had gotten to the point where NASA wasn’t really interested anymore because the impression was that it was going to be too expensive and too hard to develop a fission reactor.” But the pair were convinced their team could come up with a design to dispel the funk that had settled around fission power for space.

In the early 2010s, they got their chance: researchers at Los Alamos and later the NASA Glenn Research Center and the US Department of Energy began work on a joint project called Kilopower, now renamed the Nuclear Fission Power Project. The goal is to develop a **new nuclear fission** power system for space that would be **capable of producing 10 kW of electrical energy.**

Designing the reactor

Four of these reactors could **easily provide** the 40 kW of power that Rucker estimates a six-member crew would need to live on Mars. The team’s modular, compact design is lightweight **enough for space exploration**, in which every kilogram counts. Previous hypothetical fission-power concepts required a payload of 12–14 metric tons (a 6–7 t reactor plus a backup), whereas a single Kilopower reactor would weigh an estimated 1.5 t, she says.

The team decided to approach the reactor design anew, putting one priority above all: simplicity. This meant not only maintaining a simple mechanical design but also looking for opportunities to simplify safety approvals and project management. As an example, McClure says, the team made a conscious choice to limit the size of the nuclear core to a container already being used to test nuclear materials instead of fabricating a new one.

“I hate to call it an innovation because it’s not that complicated. But it’s an innovation that we said, ‘Why don’t we just do it the simple way that we know is going to work?’ ” Poston says. “We knew it was going to work, but the world didn’t.”

The nuclear core, which is about the size of a paper towel roll and weighs 28 kg, comprises a solid alloy of about 8% molybdenum and 92% highly enriched uranium. The nuclear material is surrounded by a beryllium oxide reflector that bounces neutrons into the core to drive the fission reaction. Lodged inside the core is a rod of pure boron carbide that absorbs neutrons, quenching fission reactions.

When the boron carbide rod is slowly removed, neutrons start to strike uranium atoms, occasionally splitting them, creating more neutrons and releasing energy as heat. Once the number of neutrons lost equals the number of neutrons being produced, the reactor becomes self-sustaining. The fission-generated heat travels through sodium-filled heat pipes to a set of Stirling engines. Designed in the early 1800s, these simple piston-driven engines convert heat to electricity. Finally, the team’s reactor design includes a radiator to remove the excess heat, sloughing it off into space.

“We wanted to show not only the world but ourselves that we can still do something real because we had gotten away from actually testing real fission systems,” Poston says.

In a proof-of-concept test called DUFF, the team showed that the hardware worked to produce electricity. Then, in 2018, the team successfully tested a prototype of the reactor at the Nevada National Security Site. During the months-long KRUSTY experiment, researchers tested each of the reactor’s components and its ability to withstand various failures. (The experiment names were inspired by The Simpsons TV show.) The reactor also **successfully passed** a 28 h test, in which it **ramped up to full power**, peaking at about 5 kW, operated at a steady state, and then **shut down safely.**

The team hopes that with more optimization, such as by increasing the size of the nuclear core, it can meet its goal of producing 10 kW per reactor.

Of course, some people look at highly enriched uranium with skepticism, given its potential to harm humans and its role as a material for nuclear weapons. But McClure says transporting uranium to the moon and working alongside a reactor can be **done safely**. Uranium emits weak α particles, which **can’t penetrate a piece of paper or skin**, so the **shielding** that surrounds the nuclear core would prevent astronauts from any radiation exposure. Burying the reactor a few meters into the ground or putting it behind a big rock feature could also help keep astronauts safe from radiation when the reactor is on. Once the reactor has run its course, the radioactive waste will likely be shielded and left alone.

The worst-case scenario for such a system would involve the entire reactor blowing up midlaunch, aerosolizing and dispersing uranium particles. Even then, a person a kilometer away might receive a dose in the millirem range—less than the dose you get from solar radiation when you take a plane flight, McClure says.

Ultimately, the fission reactor’s future will depend on not only technical success but also **sufficient funding**. Dionne Hernández-Lugo of the NASA Glenn Research Center and deputy project manager of the Nuclear Fission Power Project says the proposed budget puts the team “on the path to build and send a surface power system to the moon.”

“It’ll be really exciting to test [the reactor] on the moon and get some experience under our belts before we go to Mars,” Rucker says. “On the moon, you’re close to home, so if something fails, it’s a fairly close trip to get back home, whereas on Mars, your system better be working.”

#### That enables lateral innovation.

**West 20** [Darrell M. West, Senior Fellow in Governance Studies @ Center for Technology Innovation of Brookings, 8-18-2020, Five reasons to explore Mars, Brookings, https://www.brookings.edu/articles/five-reasons-to-explore-mars/]

The recent launch of the Mars rover Perseverance is the latest U.S. space mission seeking to understand our solar system. Its expected arrival at the Red Planet in mid-February 2021 has a number of objectives linked to science and innovation. The rover is equipped with sophisticated instruments designed to search for the remains of ancient microbial life, take pictures and videos of rocks, drill for soil and rock samples, and use a small helicopter to fly around the Jezero Crater landing spot.

**Mars is a valuable place for exploration because it can be reached in 6 ½ months, is a major opportunity for scientific exploration, and has been mapped and studied for several decades**. The mission represents the first step in a long-term effort to bring Martian samples back to Earth, where they can be analyzed for residues of microbial life. Beyond the study of life itself, there are a number of different benefits of Mars exploration.

UNDERSTAND THE ORIGINS AND UBIQUITY OF LIFE

The site where Perseverance is expected to land is the place where experts believe 3.5 billion years ago held a lake filled with water and flowing rivers. **It is an ideal place to search for the residues of microbial life, test new technologies, and lay the groundwork for human exploration down the road.**

The mission plans to investigate whether microbial life existed on Mars billions of years ago and therefore that life is not unique to Planet Earth. As noted by Chris McKay, a research scientist at NASA’s Ames Research Science Center, that would be an extraordinary discovery. “Right here in our solar system, if life started twice, that tells us some amazing things about our universe,” he pointed out. “It means the universe is full of life. Life becomes a natural feature of the universe, not just a quirk of this odd little planet around this star.”

The question of the origins of life and its ubiquity around the universe is central to science, religion, and philosophy. For much of our existence, humans have assumed that even primitive life was unique to Planet Earth and not present in the rest of the solar system, let alone the universe. We have constructed elaborate religious and philosophical narratives around this assumption and built our identity along the notion that life is unique to Earth.

If, as many scientists expect, future space missions cast doubt on that assumption or outright disprove it by finding remnants of microbial life on other planets, it will be both invigorating and illusion-shattering. It will force humans to confront their own myths and consider alternative narratives about the universe and the place of Earth in the overall scheme of things.

As noted in my Brookings book, Megachange, given the centrality of these issues for fundamental questions about human existence and the meaning of life, it would represent a far-reaching shift in existing human paradigms. As argued by scientist McKay, discovering evidence of ancient microbial life on Mars would lead experts to conclude that life likely is ubiquitous around the universe and not limited to Planet Earth. Humans would have to construct new theories about ourselves and our place in the universe.

**DEVELOP NEW TECHNOLOGIES.**

**The U.S. space program has been an extraordinary catalyst for technology innovation.** Everything **from Global Positioning Systems and medical diagnostic tools to wireless technology and camera phones** owe at least part of their creation to the space program. **Space exploration required the National Aeronautics and Space Administration to learn how to communicate across wide distances, develop precise navigational tools, store, transmit, and process large amounts of data, deal with health issues through digital imaging and telemedicine, and develop collaborative tools that link scientists around the world.** The space program has pioneered the miniaturization of scientific equipment and helped engineers figure out how to land and maneuver a rover from millions of miles away. Going to Mars requires similar inventiveness. Scientists have had to figure out how to search for life in ancient rocks, drill for rock samples, take high resolution videos, develop flying machines in a place with gravity that is 40 percent lower than on Earth, send detailed information back to Earth in a timely manner, and take off from another planet. In the future, we should expect large payoffs in commercial developments from Mars exploration and advances that bring new conveniences and inventions to people.

ENCOURAGE SPACE TOURISM

In the not too distant future, wealthy tourists likely will take trips around the Earth, visit space stations, orbit the Moon, and perhaps even take trips around Mars. For a substantial fee, they can experience weightlessness, take in the views of the entire planet, see the stars from outside the Earth’s atmosphere, and witness the wonders of other celestial bodies.

The Mars program will help with space tourism by improving engineering expertise with space docking, launches, and reentry and providing additional experience about the impact of space travel on the human body. Figuring out how weightlessness and low gravity situations alter human performance and how space radiation affects people represent just a couple areas where there are likely to be positive by-products for future travel.

The advent of space tourism will broaden human horizons in the same way international travel has exposed people to other lands and perspectives. It will show them that the **Earth has a delicate ecosystem that deserves protecting and why it is important for people of differing countries to work together to solve global problems.** Astronauts who have had this experience say it has altered their viewpoints and had a profound impact on their way of thinking.

FACILITATE SPACE MINING

zmany objects around the solar system are made of similar minerals and chemical compounds that exist on Earth. **That means that some asteroids, moons, and planets could be rich in minerals and rare elements.** Figuring out how to harvest those materials in a safe and responsible manner and bring them back to Earth represents a possible benefit of space exploration. Elements that are rare on Earth may exist elsewhere, and that could open new avenues for manufacturing, product design, and resource distribution. This mission could help resource utilization through advances gained with its Mars Oxygen Experiment (MOXIE) equipment that converts Martian carbon dioxide into oxygen. If MOXIE works as intended, it would help humans live and work on the Red Planet.

ADVANCE SCIENCE

One of the most crucial features of humanity is our curiosity about the life, the universe, and how things operate. **Exploring space provides a means to satisfy our thirst for knowledge and improve our understanding of ourselves and our place in the universe.** Space travel already has exploded centuries-old myths and promises to continue to confront our long-held assumptions about who we are and where we come from. The next decade promises to be an exciting period as scientists mine new data from space telescopes, space travel, and robotic exploration. Ten or twenty years from now, we may have answers to basic questions that have eluded humans for centuries, such as how ubiquitous life is outside of Earth, whether it is possible for humans to survive on other planets, and how planets evolve over time.

#### Either we successfully colonize or save humanity while trying.

**HÉIgeartaigh 16** [Seán Ó HÉIgeartaigh, professor @ Cambridge + PhD in Genomics from Trinity College of Dublin, 10-5-2016, Technological Wild Cards: Existential Risk and a Changing Humanity, Centre for the Study of Existential Risk, https://papers.ssrn.com/sol3/papers.cfm?abstract\_id=3446697]

4. WORKING ON THE (DOOMSDAY) CLOCK

**Technological progress** now **offers us a vision of a remarkable future**. The **advances** that have brought us onto an unsustainable pathway have also **raised the quality of life dramatically for many**, **and** have **unlocked scientific directions that can lead us to a safer, cleaner, more sustainable world**. With the right developments and applications of technology, in concert with advances in social, democratic, and distributional processes globally, progress can be made on all of the challenges discussed here. Advances in renewable energy and related technologies, and more efficient energy use—advances that are likely to be accelerated by progress in technologies such as artificial intelligence—can bring us to a point of zero-carbon emissions. **New manufacturing capabilities provided by synthetic biology may provide cleaner ways of producing products and degrading waste.** A greater scientific understanding of our natural world and the ecosystem services on which we rely will aid us in plotting a trajectory whereby critical environmental systems are maintained while allowing human flourishing. **Even** advances in **education and women’s rights** globally, which will play a role in achieving a stable global population, **can be aided specifically by the information, coordination, and education tools that technology provides, and more generally by growing prosperity in the relevant parts of the world.**

**There are catastrophic and existential risks that we will simply not be able to overcome without advances in science and technology.** **These include** possible **pandemic outbreaks**, **whether natural or engineered**. **The early identification of incoming asteroids**, **and approaches to shift their path, is a topic of active research at NASA and elsewhere**. While currently there are no known **techniques to prevent or mitigate a supervolcanic eruption,** this **may not be the case** with the tools at our disposal **a century from now**. **And in the longer run, a civilization that has spread permanently beyond the earth, enabled by advances in spaceflight, manufacturing, robotics, and terraforming, is one that is much more likely to endure**. However, **the breathtaking power of the tools we are developing is not to be taken lightly**. **We have been very lucky to muddle through the advent of nuclear weapons without a global catastrophe**. And within this century, it is realistic to expect that we will be able to rewrite much of biology to our purposes, intervene deliberately and in a large-scale way in the workings of our global climate, and even develop agents with intelligence that is fundamentally alien to ours, and may vastly surpass our own in some or even most domains—a development that would have uniquely unpredictable consequences.

#### Every second matters.

**Beckstead 14** [Nick Beckstead, research fellow at Oxford University's Future of Humanity Institute, 2014, Will we eventually be able to colonize other stars? Notes from a preliminary review, https://www.fhi.ox.ac.uk/will-we-eventually-be-able-to-colonize-other-stars-notes-from-a-preliminary-review/, Willie T.]

While this estimate is conservative in that it assumes only computational mechanisms whose implementation has been at least outlined in the literature, it is useful to have an even more conservative estimate that does not assume a non-biological instantiation of the potential persons. Suppose that about 10^10 biological humans could be sustained around an average star. Then the Virgo Supercluster could contain 10^23 biological humans. This corresponds to a loss of potential equal to about 10^14 potential human lives per second of delayed colonization.” Bostrom 2003, “Astronomical Waste.”

[2] “The lion’s share of the expected duration of our existence comes from the possibility that our descendants colonize planets outside our solar system. There are **many stars** that we may be able to reach with future technology (about 10^13 in our supercluster). Some of them will probably have planets that are **hospitable to life**, perhaps many of these planets could be made hospitable with appropriate technological developments. Some of these are near stars that will burn for much longer than our sun, some for as much as **100 trillion years** (Adams, 2008, p. 39). If multiple locations were colonized, the risk of total destruction would dramatically decrease, since it would take independent global disasters, or a cosmological catastrophe, to destroy civilization. Because of this, it is possible that our descendants would survive until the very end, and that there could be extraordinarily large numbers of them.” Beckstead 2013, “On the Overwhelming Importance of Shaping the Far Future,” p. 57.

#### Delays cede dominance.

**Mulder 21** [Christopher P. Mulder; Lieutenant Colonel Christopher P. Mulder, United States Air Force, is a Senior Military Fellow at the Atlantic Council’s Scowcroft Center for Strategy and Security. A graduate of the United States Air Force Academy, he is a command pilot and interested in leadership and national security issues; 5-4-2021, "U.S. Spaceflight Turns 60: Why the Stakes Are Higher Than Ever", National Interest, https://nationalinterest.org/feature/us-spaceflight-turns-60-why-stakes-are-higher-ever-184352] sumzom

That new space rush surrounds the commercialization of orbit. As the two of us noted in a recent Atlantic Council space strategy paper, humanity’s relationship to space is undergoing a shift from exploration and discovery to one of commerce and security, where routinized space activities can enhance prosperity back on Earth. No domain of space offers more promise than cislunar space, the sphere created by the Earth-Moon radius. While most space activity today is located in Earth’s orbit, cislunar space offers “energy, materials, and integrated intelligence,” with the Moon’s shallow gravity well allowing easy stationing of vehicles in orbit. The commercial and military advantages to cislunar space are obvious, ranging from resource extraction and on-orbit manufacturing to the permanent stationing of military satellites with low-latency periods.

However, the United States is not the only country that recognizes these benefits. Chinese president **Xi Jinping** has made clear his belief that prosperity on Earth will follow achievement in space, and key Chinese agencies such as the China Aerospace Science and Technology Corp and the China National Space Administration have set a series of **ambitious goals in space**: exploration of the far side of the Moon, crewed labs on the Moon, asteroid mining by 2040, and more.

As with the last space race, achievements are zero-sum—finishing in **second means losing** out. Space may be a multi-trillion-dollar market with a first-mover advantage, where the winner sets the rules of the road. While a U.S.-led model for space would **mirror** the liberal international order on Earth, a Chinese-led model very likely would include anti-competitive economic practices, a **disregard for democracy**, and contribute to making the world safe for authoritarianism of various types.

Beyond the commercial and military benefits of space, losing this rush for space also means conferring upon China the prestige that accompanies great achievement in space. 2011 and 2016 Chinese white papers have made clear this rationale: success in space positions China as a technological powerhouse, with space accomplishments bolstering China’s overall national influence. A more reputable and **legitimate** China will likely seek new, ambitious space projects, pulling U.S. partners in Europe into its orbit. As China works toward building its own space station to rival the U.S.-led International Space Station (ISS), a concomitant risk emerges of China being the partner of choice for twenty-first-century space activities. Having recently launched the Tianhe-1 launch module of their space station, China plans to have the station be operational by 2022. As the ISS begins to phase out, this could position China as the only nation leading a space station.

Policymakers cannot lose sight of the fact that the rush has already begun—and the United States is badly **losing**. In 2019, China was the first nation to send a Lunar probe to the far side of the Moon with the Chang’e 4 mission, while also being the first nation to launch a quantum satellite into orbit, among other accomplishments. As China was making history on the Moon, the budget for the National Aeronautics and Space Administration (NASA) was flatlining in the United States, with NASA lacking even a rocket capable of getting back to the Moon.

### 1AC --- Transition

#### Clean energy transition is inevitable but must be faster.

**Worland 21** [Justin Worland, Senior Correspondent @ Time & BA in History from Harvard University, 7-15-2021, The Energy Transition Is in Full Swing. It’s Not Happening Fast Enough, TIME, https://time.com/6106341/green-energy-transition-iea/, Willie T.]

Even if you follow these things closely, it can be hard to understand where the world’s fight against climate change stands. On the one hand, news abounds of the clean energy revolution, as wind farms and solar panels pop up in communities across the globe and automakers promise to go electric. On the other hand, scientists continue to warn that fossil fuels have placed the planet and everyone who lives on it on an unavoidable collision course with catastrophe.

A new report from the International Energy Agency (IEA) published Wednesday explains the dynamic in sharp detail: the world has begun a **momentous shift** in how we power the economy that will touch virtually every corner of human society, with investment in oil and gas slowing and spending on clean energy rising. But it’s **not happening fast enough** to avoid dangerous levels of warming.

“A new global energy economy is emerging,” IEA Executive Director Fatih Birol tells TIME. But when it comes to the necessary levels of investment in clean energy, there is “a **gross mismatch.”**

The IEA’s annual World Energy Outlook is designed to inform policymakers about the state of global energy markets as well as the emerging trends expected to define energy in the years to come. Its origins are undeniably wonky, but this year’s report takes on new significance with climate change on the rise in public consciousness and on the international stage. The agency released the 2021 report a month early to help inform talks among the delegates who will gather in Glasgow, Scotland, in early November for the biggest United Nations climate summit in years.

Perhaps nothing is more urgent than the report’s key message that countries need to dramatically accelerate their efforts to cut emissions for the world to have any hope of limiting temperature rise to 1.5°C, the level at which scientists say we might expect to see widespread catastrophic effects of climate change. Current pledges from countries to cut emissions only reduce carbon pollution by 20% of what’s necessary to avoid reaching that marker, according to the report’s analysis.

The report offers no shortage of solutions to make up the gap. Climate politics can often end up mired in debates about controversial topics like carbon capture and nuclear energy, but the report highlights four straightforward areas that would address the problem: electrification, energy efficiency, tackling methane emissions and advancing innovation. To make all of those happen, the world needs to grow annual investment in clean energy by close to $4 trillion by the end of the decade, according to the report. “Finance is the **missing ingredient** to accelerate,” says Birol.

Looming energy crises

The analytical work that underpins the report began long before the energy crunch gripping Europe and China and threatens to spread across the globe. Nonetheless, the report warns that the energy crisis—which the IEA attributes to a rise in energy demand amid the economic recovery from the pandemic, among other things—may presage **future energy crises** that could occur if governments fail to plan carefully.

At the heart of the agency’s concern is an underinvestment in clean energy. Investment in oil and gas has stalled in a way that is consistent with **limiting warming** to 1.5°C. At the same time, spending on clean energy infrastructure remains **far below** what it needs to be, creating the possibility of **volatility** and supply disruptions much like the world is facing today. “The longer this mismatch persists, the greater the risk for increased volatility,” says Birol. “**What we need is very clear**: to increase investment in clean energy technologies.”

Even as investment in oil and gas has slowed, the IEA warns that the economic recovery from the worst of the COVID-related downturn has failed to live up to the promises of a “green recovery” that was commonly touted as governments spent trillions to help prop up their economies in 2020. Just 2% of $16 trillion spent by countries around the world on COVID economic support was spent on clean energy, according to the report. As a result, the world is now experiencing the second largest uptick in carbon emissions in history, in large part as a result of growth of coal use to power the economic recovery. “We are now witnessing an unsustainable recovery,” says Birol.

#### Indeed,

**Weise 24** [Zia Weise, senior reporter covering climate policy @ POLITICO & B.A. in journalism from Kingston University, 11-6-2024, Climate world absorbs a reality they’d hoped to avoid: Trump is back, POLITICO, https://www.politico.eu/article/climate-world-diplomats-donald-trump-victory-clean-energy-fossil-fuels-greenhouse-emissions/, Willie T. + sumzom]

The morning of his victory, however, officials and climate campaigners talked down Trump’s likely impact on plans to slow greenhouse gas emissions, hoping to calm nervous clean technology markets and present the transition as a **fait accompli***.*

“Those investing in clean energy are already enjoying huge wins in terms of jobs and wealth, and cheaper, more secure energy. This is because the global energy transition is **inevitable** and gathering pace, making it among the **greatest economic opportunities** of our age,” said United Nations climate chief Simon Stiell.

The challenge is that the world **isn’t moving quickly enough** to prevent dangerous global warming, and any slowdown from the world’s **second-largest emitter** — itself a major driver of the global shift to clean energy — is bound to throw a wrench into global climate efforts.

Trump hinted at what was coming in his victory speech early Wednesday morning, touting America’s abundant supplies of “liquid gold.” Addressing Robert F. Kennedy Jr., the environmental lawyer who appears likely to bring his unorthodox views on healthcare to the heart of a Trump administration, Trump said: “Bobby, leave the oil to me.”

#### Only nuclear energy solves --- investment is key.

**Grossi 24** [Rafael Mariano Grossi, PhD in History, International Relations and International Politics from the Graduate Institute of International Studies, 1-17-2024, 5 reasons we must embrace nuclear energy in the fight against climate change, World Economic Forum, https://www.weforum.org/stories/2024/01/nuclear-energy-transistion-climate-change/]

Globally, nuclear energy is also playing a **key role** in the transition to net zero. Fears about nuclear are slowly giving way to fact-based understanding. This year, for the first time, the document agreed at COP backed nuclear energy investment among low-emissions technologies.

One of nuclear’s key attributes is its energy intensity. A **thimble**-sized pellet of uranium produces as much energy as almost **3 barrels** of oil, more than 350 cubic metres of natural gas and about half a tonne of coal.

5 reasons we cannot ignore nuclear energy

Nuclear power, which has 20,000 reactor years of experience across the world, has five distinct advantages.

1. From cradle to grave, nuclear energy has the **lowest carbon footprint** and needs **fewer materials** and less land than other electricity source. For example, to produce one unit of energy, **solar** needs more than **17 times as much material and 46 times as much land.**

2. **Uranium in the earth's crust and oceans is more abundant** than gold, platinum and other rare metals. It is going to take us about 100 to 150 years to get through the uranium resources we deem economically recoverable today.

3. Nuclear power **doesn’t rely on the weather**. Well-run nuclear power plants, including for example those in the US, operate at least **two to three times as reliably** for two to three times as many years as intermittent low-carbon sources. As a flexible baseload for wind and solar that provides more energy when it is needed and less when it is not, nuclear power plants displace coal and enable renewables.

4. Each year, nuclear power plants produce a quarter of the world’s low-carbon electricity, saving many lives that would otherwise be cut short by the lethal pollution fossil fuels pump into the air. Nuclear energy is about as safe as solar. It is far safer than coal, gas and oil, and safer than almost every other alternative energy source.

5. It is true that spent fuel is highly radioactive and emits heat. But it is also relatively compact, and extremely carefully managed and regulated. Nuclear energy generation is so efficient that the amount of all spent fuel ever produced would — in theory — fit into 42 Olympic-sized swimming pools. Today, it is carefully stored in pools and dry storage systems or recycled. Countries like Finland and Sweden are close to putting into place deep geological repositories to dispose of spent fuel. France is also progressing in the implementation of a deep geological repository for high-level waste from spent fuel recycling.

Nuclear is one of the safest, cleanest, **least environmentally burdensome** and — ultimately, over the lifetime of a nuclear power plant — one of the cheapest sources of energy available.

But for all of nuclear energy’s positive attributes, there are hurdles to overcome. The accidents at Chernobyl and at the Fukushima Daiichi Nuclear Power Station left long shadows of mistrust and **underinvestment**. The upfront cost of building a nuclear power plant is considerable and budget overruns and long delays have made it more difficult to **gain support for new construction**.

Three levers to catalyze investment in nuclear energy

Three main levers will need to be pulled if we are to triple today’s investment levels and build the nuclear capacity that will help get us to net zero.

Lever 1: Nuclear must be acknowledged for what it is: a reliable, scalable, safe and highly affordable low-carbon source of energy. It must be treated that way when it comes to investment incentives. Today’s energy markets are not the same as those of the 1970s and 1980s. Nuclear needs private investment, even in markets where governments still take on much of the financing. Governments need to shoulder the **risk of the high capital costs at the start**. But that alone is not enough. They need to attract private financing through assured revenues and an enabling investment environment over the longer term. That means levelling the playing field nationally and internationally, including by changing the policies preventing investment in nuclear energy by many key international financial institutions and development banks.

#### Repurposing ensures fast deployment.

**Abdussami 24** [Muhammad R. Abdussami, M.A. in Nuclear Engineering from Ontario Tech University & PhD from University of Michigan, June 2024, Investigation of potential sites for coal-to-nuclear energy transitions in the United States, Energy Reports, https://www.sciencedirect.com/science/article/pii/S2352484724002993, Willie T.]

1.2. Literature review

The U.S. government has undertaken various initiatives to assess the potential for coal-to-nuclear (C2N) transitions at coal sites across the country. Hansen et al. drafted an extensive report for the U.S. Department of Energy (DOE) that examined key factors influencing viable transitions for a hypothetical coal plant, considered the techno-economic aspects of C2N conversions, and evaluated the potential effects on local communities during this transition (Hansen et al., 2022). Similarly, Griffith et al. investigated different nuclear reactor technologies and provided **valuable insights** into the considerations for siting and replacing coal plants with nuclear alternatives (Griffith, 2021). A few technical studies have also been carried out in the field of C2N transitions. One investigation (“Gone with the Steam How new nuclear, 2021) discovered that repurposing coal plants with advanced reactors could offer economic advantages and benefits for host communities compared to renewable energy generation. A technical report published by NuScale SMR technology highlighted the capability of NuScale SMR technology to **repurpose retired coal plants** while **ensuring the economic stability** of communities and workers (“An Ideal Solution for Repurposing U.S, 2021). Bartela et al. conducted a case study on a 460 MWe supercritical coal-fired plant in Poland, demonstrating the techno-economic benefits of replacing it with a nuclear reactor incorporating thermal energy storage (Bartela et al., 2022), (Bartela et al., 2021). Furthermore, Lukowicz et al. performed a techno-economic analysis on the same Polish coal plant, proposing the replacement of the plant's steam cycle with a small-scale modular Pressurized Water Reactor (PWR) (Łukowicz et al., 2023). Simonian et al. evaluate the potential of C2N transition at the Limestone coal plant in Texas, comparing small modular, high-temperature gas-cooled, and molten salt nuclear reactor technologies. Each technology's pros and cons are weighed against cost, risk, and C2N integration complexity. The study concludes no one-size-fits-all solution exists for C2N transitions, and specific nuclear designs and transition schemes must be carefully considered for each project based on technical specifications and feasibility (Simonian and Kimber, 2023). Notably, although these studies focused on specific candidate coal plants, comprehensive siting analyses for C2N transitions were not addressed.

The potential for advanced nuclear reactors to replace coal plants has been discussed in (“Coal-to-Nuclear Transitions, 2024), **emphasizing their compatibility** with variable renewable technologies and their capability to provide both electricity and process heat. The document (“Coal-to-Nuclear Transitions, 2024) examines economic impacts, job creation, and revenue benefits in host communities, noting **significant increases in employment and income** following a coal-to-nuclear transition. It discusses workforce requirements, educational needs, and training for transitioning workers, outlining the overlap and distinct roles between coal and nuclear plants. Policy and funding aspects, including **tax incentives** and loans, are also addressed, with a focus on achieving net-zero emissions targets by 2050 and supporting disadvantaged communities. The document emphasizes the critical role of utilities in managing transitions and presents a comprehensive outlook on infrastructure reuse and community engagement strategies for successful coal-to-nuclear conversions. In another paper, the advantages of repurposing existing site infrastructure, including transmission infrastructure, environmental permits, and water usage rights, have been examined. Repowering coal plant sites with nuclear power offers **clean, reliable, and dispatchable energy**, addressing the twin challenges of decommissioning and transitioning to low-carbon energy sources. The paper guides utilities through the key considerations and steps involved in evaluating and repurposing coal plant sites for advanced nuclear generation, focusing on the potential to retain jobs, tax bases, and community support.

In contrast to the technoeconomic analyses described above, the siting of advanced nuclear reactors within operating or retired CPPs has received relatively little attention in the literature. Belles et al. conducted an analysis using the Oak Ridge Siting Analysis for Power Generation Expansion (OR-SAGE) tool to evaluate the suitability of 13 coal power plants in the Tennessee Valley Authority (TVA) service territory for the deployment of advanced nuclear reactors (Belles et al., 2013). A similar approach was adopted in another study (Belles et al., 2021), where OR-SAGE was utilized to assess the retrofitting of advanced nuclear reactors in existing or retired coal plants. Furthermore, Omitaomu et al. employed the OR-SAGE tool to investigate the siting of advanced nuclear reactors across the contiguous United States (Omitaomu et al., 2022). In a separate study, Toth et al. employed the Advanced Nuclear Site Locator (ANSL) tool to evaluate 304 coal sites in the U.S., identifying **79** potentially feasible sites for coal-to-nuclear transitions (Toth et al., 2021). However, they reported that state-level policies could pose challenges to the demonstration of advanced nuclear reactors. Therefore, a comprehensive assessment of all coal plants in the United States, encompassing operational and retired facilities, is necessary to gain an understanding of the most suitable coal sites for transitioning to nuclear power. While the existing literature provides some valuable insights into the siting potential of advanced nuclear reactors in coal plants, the number of studies on this subject remains limited.

1.3. Contribution

This paper aims to assess the feasibility of converting each operational coal site to nuclear power using a tool called Siting Tool for Advanced Nuclear Development (STAND). The studied coal plants are classified into two different groups (Group-01 and Group-02) based on their capacity. Since advanced nuclear reactors are divided into various classes, such as micro-reactors, medium-scale reactors, and Small Modular Reactors (SMRs), it is necessary to categorize coal plants accordingly to match their capacity for a smooth transition to nuclear power. Categorization will also help in presenting the research findings and data clearly, considering the substantial amount of data involved in the analysis. To conduct this analysis, our first step was to gather information on all operational coal sites in the U.S. until January 2023. The operational coal sites are the focus of this study to **take advantage** of the existing Balance of Plant (BOP) equipment, such as transmission lines and power system protection components, which can **reduce construction time and costs**. Analyzing operational coal plants will also guide policymakers, state-level governments, and energy modelers in determining the prioritization of coal plant retirements. Furthermore, we limit our study to operational coal sites in the U.S. as many retired coal sites lack the necessary technical infrastructure for an attractive coal-to-nuclear transition. Next, we classify all operational coal sites into two clusters based on their nameplate capacity. The CPPs located in non-contiguous states (e.g., Alaska and Hawaii) are not considered due to the lack of sufficient data in STAND. Each cluster is then individually simulated in STAND using selected attribute values, as mentioned in Section 2, specifically in Table 1, Table 2, Table 3. Section 3 discusses the clustering of CPPs. Section 4 provides additional information about the STAND tool. Section 5 presents the results of the study, while Section 6 concludes the study with discussion. This paper presents a comprehensive approach for utilizing STAND in evaluating the feasibility of transitioning from coal to nuclear energy across the U.S. The detailed results and investigation will provide a clear idea on which factors one should consider for a particular region/area to C2N transitions.

#### Scenario ONE is CLIMATE CHANGE.

#### Nuclear energy is key for climate goals.

**Matthew 22** [M.D. Matthew, Professor @ Saintgits College of Engineering (India), January 2022, Nuclear energy: A pathway towards mitigation of global warming, Progress in Nuclear Energy, https://aben.com.br/wp-content/uploads/2022/02/Nuclear-energy-a-pathway-towards-mitigation-of-global-warming.pdf] sumzom

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

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

Nuclear power delivers reliable, affordable and clean energy to support economic growth and social development. **Without a larger role for nuclear energy, it would not be possible to combat climate change.**

Nuclear power can be **deployed on a large scale**. So, nuclear power plants can directly replace fossil fueled power plants. As of end December 2020, global nuclear power capacity was 393 GW(e) and accounted for around 11% of the world’s electricity and around 33% of global low carbon electricity. Currently, there are 442 nuclear power reactors in operation in 32 countries. There are 54 reactors under construction in 19 countries, including 4 countries that are building their first nuclear reactors according to the IAEA reports (Nuclear Power Proves its, 2021; Climate Change and Nuclea, 2020a, 2020b). Nuclear power is reducing CO2 emissions by about **two gigatons per year**. Therefore, nuclear power will be imperative for achieving the low carbon future. In France, nuclear power plants accounted for 70.6% of the total electricity generation in 2019, the largest nuclear share for any industrialized country. About 90% of France’s electricity comes from low carbon sources (nuclear and renewable combined). Nuclear power contributes 20% of electricity generation in the United States over the past two decades and it remains the single largest contributor of non-greenhouse-gas-emitting electric power generation out of 1,117, 475 MWe total electricity generating capacity of which 60% is from fossil fuel.

The second-largest source of low carbon energy in use today is nuclear power, after hydropower. Nuclear power plants provide **continuous and stable** energy to the grid whereas solar and wind energy require back-up power during their output gaps, such as at night or when the wind stops blowing. The International Panel on Climate Change (IPCC) has proposed at least doubling of nuclear power generation by 2050 to meet the Paris agreement. Nuclear power has compensated about 60 Gt of CO2 emissions over the past 50 years, nearly equal to **2 years** of global energy-related CO2 emissions and can help to conquer the challenges of climate change.

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

#### Climate change is existential.

**Nogue 23** [Sandra; Lecturer in Paleoenvironmental Science @ the University of Southampton; 3-23-2023; OUP Academic; “Catastrophic climate change and the collapse of human societies,” https://academic.oup.com/nsr/article/10/6/nwad082/7085016; DOA: 3-24-2025] nikhil \*\*brackets in original\*\*

The scientific community has focused the agenda of studies of climate change on lower-end warming and simple risk analyses, because more realistic complex assessments of risk are more difficult, the benchmark of the international targets is the Paris Agreement goal of limiting warming to <2°C, and the culture of climate science is to try to avoid alarmism [1]. Current fires, prolonged droughts, floods and heat waves, together with the consequent **food insecurity**, **civil unrest** and **migrations**, however, are opening the eyes not only of most scientists but also of most people all over the world to the need for considering, at least, the potential catastrophic effects of the collapse of ecosystems and society due to the current **emergency** of climate change.

The projections for the climate of the coming decades are, as we all know, worrying. The worst-case scenarios in the 2022 Intergovernmental Panel on Climate Change (IPCC) report project temperatures by the next century that last occurred in the Early Eocene, reversing 50 million years of cooler climates within two centuries. The Pliocene and Eocene provide the best analogues for near-future climates [2]. Climates like those of the Pliocene are likely to prevail as soon as **2030** and unmitigated scenarios of emissions of greenhouse gases (GHGs) will produce climates like those of the **Eocene** for the coming decades. This situation is particularly alarming because human societies are locally adapted to a specific climatic niche with a mean annual temperature of ∼13°C [3]. We can thus logically expect that current and future warming may **easily overwhelm** societal adaptive capacity.

These climate projections could be even more detrimental if models would not neglect, as they currently do, **feedback in the carbon cycle** and potential **tipping points** that could generate higher GHG concentrations [4]. Examples include the apparent slowing of dampening feedbacks such as the natural carbon-sink capacity [5,6], the loss of carbon due to increasing frequencies and intensities of fire at northern latitudes [7], **droughts and fires** in the Amazon [8] or the thawing of Arctic permafrost that releases methane and CO2 [9]. This feedback is also likely not proportional to warming, as is sometimes assumed. Instead, abrupt and/or irreversible changes may be triggered at a temperature threshold [7]. Particularly worrying is a ‘tipping cascade’ in which **multiple tipping elements** interact in such a way that tipping one threshold increases the likelihood of **tipping another** [4,10].

Climate change also interacts with **other anthropogenic stressors** such as changes in **land use**, loss of **biod**iversity, **nutrient imbalances**, **pollution** and an **overuse** of available resources that are crossing the planetary safety boundary limits and operating as a possible **catastrophic** mix. This mix may exacerbate society vulnerabilities and cause multiple indirect stresses such as economic damage, loss of land and water, and food insecurity that can merge into system-wide synchronous failures. These cascading effects are not only biophysical or biogeochemical, but they also affect human society, generating **conflicts**, **political instability**, systemic financial risks, the spread of **infectious diseases** and the **risk of spillover**. For example, there is evidence that the 2007−10 drought contributed to the conflict in Syria [11].

Anthropogenic climate change interacting with these other stressors could thus cause a global catastrophe, in a **worldwide societal collapse**. Kemp et al. [1] have reminded us that although we have reasons to suspect it, such potential collapsing futures are rarely studied and poorly understood. The closest research is the search for evidence of tipping dynamics and estimating thresholds, timescales and impacts of potential tipping points [4]. We advocate for considering them while using the available knowledge acquired from historical and prehistorical examples of local and regional collapses, transformations and resilience of human societies also driven by climate and unsustainable use of resources (Fig. 1).

#### Scenario TWO is PEAK OIL.

#### Peak oil guarantees economic collapse --- only accelerated transition solves.

**Ahmed 23** [Nafeez Ahmed, PhD in International Relations from the University of Sussex’s School of Global Studies, 3-29-2023, America’s Fossil Fuel Economy is Heading for Collapse – It Signals the End of the Oil Age, resilience, https://www.resilience.org/stories/2023-03-29/americas-fossil-fuel-economy-is-heading-for-collapse-it-signals-the-end-of-the-oil-age/, tristan]

US oil production is about to peak, but the world is unprepared for the tremendous economic and political consequences. The only path through is **energy and economic transformation**.

The global economy is currently teetering **on** the **edge** of a banking crisis. The IPCC has just released its final major report warning that global carbon emissions need to peak and decline immediately if we are to avoid plunging into dangerous global warming by breaching the 1.5C ‘safe limit’. And in recent weeks and months, industry leaders have announced that the US shale oil and gas **revolution is over.**

Yet few if anyone is talking about why these things are happening at the same time, and what they really mean.

One of our biggest problems is that we tend to think in silos and sectors. But in the real world, the sectors we assume operate separately are in fact **fundamentally interconnected**. We ignore and downplay these systemic interconnections at our peril.

The persistence of global inflation has taken many economists by surprise. While they recognise that the impact of Russia’s war in Ukraine on energy and food supplies has been the biggest driver, that silo-ed assumption has led to a failure to understand why inflation is unlikely to simply disappear anytime soon.

We have good reason to believe that the underlying drivers of inflation go beyond just the war in Ukraine. Although it’s extremely difficult to quantify, climate change and environmental degradation is driving inflation by eroding agricultural productivity leading to higher food costs. The impact of extreme weather events is also creating larger and larger damages to infrastructure which in turn is incurring greater costs. As these costs feed into the system, the supply of goods and services becomes more expensive.

Less difficult to quantify is the fact that inflation is historically linked to energy price hikes. And there is mounting evidence that the world is experiencing a major shift in the global fossil fuel system that entails rising costs and diminishing returns, which will end up having a major inflationary effect for far longer and deeper than conventionally assumed.

The end of the shale boom

Since late last year, there have been a growing number of reports pointing out that the US shale revolution is coming to an end. Yet the massive global consequences of this are not being discussed.

“US Shale Boom Shows Signs of Peaking as Big Oil Well **Disappear**” read one headline in the Wall Street Journal. “The **aggressive growth era** of US shale is **over**,” Scott Sheffield, CEO of top independent shale firm Pioneer told the Financial Times. “The shale model definitely is no longer a swing producer.” And according to Bloomberg: “The specter of peak oil that haunted global energy markets during the first decade of the 21st century is once again rearing its head”.

US **industry executives are** now **openly acknowledging** that US oil production is likely to peak within the next five or six years, or perhaps in 2030. But there is mounting evidence that the peak will come much earlier, with some industry observers pinpointing its arrival as early as within the **next one or two years.**

What’s extraordinary about these admissions is how little they are impacting public debate. The implications are seismic. They contradict bullish overinflated forecasts of the industry made two decades ago – in 2005, for instance, Washington DC think-tank RAND Corp was forecasting that the US had enough shale oil to last some 400 years; and in 2012, a senior ExxonMobil executive claimed that the US has “about 100 years of natural gas supply”.

These grand claims were often breathlessly reported as unimpeachable fact by some of the most respected media institutions in the world.

Naysayers (like myself) warning that shale oil and gas would offer at best a temporary boost that was bound to peak and decline in the near-term with major global economic consequences, were dismissed as ‘doomers’.

Now, it turns out, we were right all along.

Mistakes of forecasting

That’s not to say that the traditional ‘peak oilers’ at the time were spot on. They wrongly expected that following the plateauing of conventional oil around 2005, oil prices would rocket up permanently into triple digits as global oil production would go into terminal decline. That didn’t happen. Instead, global demand shifted to the more expensive forms of unconventional oil and gas – especially US shale – which made-up much of the short-fall as conventional oil production slowed down.

But this was a recessionary environment, so global demand was much lower than expected. The massive 2005-2008 global oil price spikes helped induce a banking collapse. After the 2008 financial crash, this meant that there was much less demand for oil – but as oil production projects are planned years in advance pegged to expectations of demand, the oil just kept pumping despite much lower demand due to economic recession.

The result was a glut of shale oil and gas on world markets that allowed oil prices to drop and fuelled widespread belief in a new era of ‘Made in America’ cheap oil.

The US shale boom had a good run, no doubt about it – but its ‘healthy’ lifespan appears to be around two decades. If US shale oil and gas is about to peak and decline in the next few years, what does this mean for the US and global economy?

Coming economic contraction

Given that the US shale revolution played the key role in keeping global oil prices down and lubricating the energy requirements of continued economic activity, the retraction of the US shale revolution will have **massive economic impacts**.

US production has accounted for around **70% of the total increase** in global oil capacity since 2019, and 75% of growth in liquified gas supplies. So as US shale oil and gas peaks, plateaus and declines, global oil and gas production **will do so too very shortly after.**

Gulf oil and gas producers, however, will not be able to step-in to fill the shortfall. US oil production is currently averaging around 11 million barrels per day (mbd).

A 2022 analysis of production data among the Organisation of Petroleum Exporting Countries (OPEC) which include the biggest powerhouses such as Saudi Arabia and the UAE, suggests that the maximum OPEC could collectively increase production is around 4.5 mbd – that is, **less than half of current US shale production.**

It’s also not clear how long OPEC can deploy spare capacity to maintain maximum levels of production. This suggests that OPEC will not be able to meaningfully fill the supply gap as US shale declines, which is a clear indicator that total global oil production will eventually begin to peak and decline.

In 2017, I assessed these trends in Failing States, Collapsing Systems. I predicted that US oil and gas production would probably peak and plateau **around 2025**, and that major Middle East producers would peak and plateau around the 2030s. This scenario now appears to be **unfolding before our eyes**. Yet no one is talking about it.

The near-term **economic and financial consequences** will be devastating, and they could lead to permanent long-term consequences without significant transformative action. The impact on the US economy will be profound.

Shale production accounted for **10% of GDP growth** in the United States from 2010-2015, which means that the next decade of shale’s plateauing and decline will gradually **wipe this** out. This will be experienced as a protracted inflationary economic crisis which, in turn, will contribute to volatility in global financial markets. Pundits will likely fail to understand these systemic interlinkages, focusing instead on failing banks, financial institutions and debt, without understanding its energetic triggers.

All this implies that we are **sleepwalking into a global energy crisis** that will, without accelerating the clean transformation of the energy system, create severe economic and financial consequences by undercutting the fundamental energetic basis of global economic flows. This will compound accumulated vulnerabilities in the banking system linked to unsustainable forms of debt.

The reverberations and bailouts seen in the cases of the Silicon Valley Bank, Credit Suisse and others are merely the opening cracks, that will become widening fissures in the absence of root-and-branch economic restructuring linked to the rapid development of a new energy system.

While that new system is still emerging, it is perhaps unavoidable that we will hit a number of bottlenecks. The danger is that instead of using these bottlenecks to restructure and adapt positively, we may end up regressing, with a loss of capital and energy that forestalls the full potential of transformation.

The window for action is extremely short: we need to act within this decade. Along the way, we need to be aware of the major trends which are likely to emerge as a result of the end of the US shale boom:

1. The illusion of cheap oil is evaporating

While we may still see fluctuating prices, it is becoming clearer that the glut of cheap oil this last decade was not a permanent feature of the energy system, but a temporary symptom of highly specific circumstances as the energy system moves deeper into a state of increasing inputs and diminishing returns. The immediate impact of the peak and plateau of US shale will be sustained high oil prices.

2. The near-term beneficiaries of this will be Gulf oil and gas producers

They currently appear to be the only fossil fuel energy suppliers with sufficient capacity to maintain production. They will therefore not only begin to dominate market share, they will also of course continue to reap higher profits from this more advantageous market position amidst high oil prices.

3. Some capital will move into OPEC for safety, but this is a mirage

Just as this last decade created the illusion of fossil fuel abundance due to the US shale boom, we may see that OPEC’s near-term ability to ramp up spare capacity as shale production declines perpetuates this illusion. We can expect to see lots of bullish statements from Gulf oil producers vindicating grand plans to expand their oil and gas production. Capital will move rapidly into OPEC countries, seen as a last safe space for investors looking for stability and growth. However, OPEC producers will also begin experiencing their twilight very shortly after the decline of US shale, which means that investors will begin to make serious losses as a result far sooner than they imagine.

4. Oil prices will **fluctuate within a higher range** as US shale peaks

While we can expect significant oil price volatility due to the recessionary impact of high oil prices which would lower demand and therefore allow prices to drop, as we move further into the era of plateau and decline across US and OPEC production, the overall decline in supply is likely to lead oil price fluctuations to narrow within a far higher range which will become a ‘new normal’ as long as oil demand remains high. This may also incentivise near-term conviction in the idea that new oil and gas investments are economical. That would be a colossal mistake, though, as we will see below due to coming reductions in oil demand in the latter half of this decade that will ameliorate high prices and make fossil fuel enterprises increasingly unprofitable.

5. We can expect heightened political polarisation

Incumbent industry ideology will likely blind many energy actors from recognising the writing on the wall – which explains the regressive self-defeating actions of the Biden administration in committing to Arctic drilling. This is like betting on the losing horse after being told it’s about to be overtaken by cars. It illustrates the power of America’s oil lobbies in their last ditch desperate attempt to stay alive on the back of taxpayer subsidies – flying in the face of hard economic realities (a few years ago I broke the story of the British military study which concluded that Arctic drilling was pointless for economic reasons because the costs are so high and returns so low as to make it commercially infeasible). That in turn suggests the political battleground between fossil fuel lobbies and clean energy advocates will become more fraught as the incumbency seeks to double-down in demanding more government subsidies. **Millions of jobs** will be at risk as the US shale industry declines, and this could create further negative economic and cultural consequences as the US returns to net import status.

6. Clean energy transformation will be critical to stabilise the global **economy and restore prosperity**

The **only viable pathway** through this crisis will be to accelerate the clean energy transformation focused on the deployment of exponentially improving technologies which are already scaling because they are cost-competitive with fossil fuels – namely, solar, wind and batteries. This will lay the groundwork for other potential applications such as e-fuels or green ammonia from green hydrogen. This transformation is already underway, and provides the opportunity for the US and others to produce larger quantities of energy at a fraction of the costs of fossil fuels. In Rethinking Climate Change, a RethinkX report for which I was contributing editor, we found that even in the absence of appropriate policy-decisions and major institutional barriers, economic factors will inevitably drive incumbent industries to collapse by 2040 as they are replaced by new solar, wind and battery systems. Unfortunately, while this is far faster than conventional analysts acknowledge, this is **not fast enough** to avoid dangerous climate change.

#### It’s irreversible, and instant.

**Towne 09** [Gorden Towne, scholar @ Boston University A&S Writing Program, 2009, Peak Oil: Priorities in Alternative Energy Development, Boston University, https://www.bu.edu/writingprogram/files/2009/11/wrjournal1towne.pdf, Willie T.]

As more oil is extracted from existing wells, it also becomes **more difficult** to locate the remaining oil deposits. Newly discovered oil fields generally contain **significantly lower quantities** of oil than past discoveries, based on the principle that the bigger deposits are easiest to find, and thus were found and harvested first. Thus, the problem of diminishing oil production from a single field over time is compounded by the fact that it becomes **increasingly costly** to locate progressively smaller oil deposits. Modern oil exploration is conducted using **seismic detectors** aboard large trucks or **ocean-going ships**.11 These oil-prospecting vehicles have **high operating costs** per unit area explored, so as oil becomes more scarce, the overhead cost for locating any one deposit increases. When oil becomes sufficiently scarce and expensive to locate and extract, the amount that can be produced will begin to decline year over year. The point of transition from increasing to decreasing production is known as the oil peak.

The economic, political, and sociocultural implications of peak oil, when it occurs, will be **dramatic and pervasive**. At the peak and **immediately thereafter**, burgeoning world oil demand will surpass the quantity that can possibly be supplied. This discrepancy will cause the cost of oil to **skyrocket**, which will be readily visible in the price at the pump. Because transportation is embedded in the cost of nearly all goods and services, rising fuel costs will place direct **pressure on a broad range of businesses**. This effect will manifest itself in increasing unemployment, along with rising consumer costs in everything from food to clothing and electronics. Domestically, the resulting ripple effect will be sufficient to set the economy on a **cycle of stagflation**, that is, simultaneous economic recession and monetary inflation. On its surface, this is not dissimilar from the effects of previous oil shortages, most notably that resulting from the **OPEC embargo** of the **early 1970s**.1213 In this instance, a temporary, artificial supply shortage was sufficient on its own to catalyze a cycle of stagflation, sending the U.S. economy into recession. In the case of peak oil, however, once this cycle begins, oil production will only continue a downward trend. In an unmitigated situation, this will cause the supply-and-demand discrepancy to grow ever wider. Where previous fluctuations in oil supply have triggered cyclic rises and falls in domestic economic health, problems spawned by falling oil supply will only worsen as production continues to decrease.

#### Nuclear energy insulates shocks.

**Lee 10** [Chien-Chiang Lee, Professor of Finance @ National Sun Yat-sen University (Kaohsiung, Taiwan) & Ph.D. in International Economics @ Chung Cheng University, 6-24-2010, Nuclear energy consumption, oil prices, and economic growth: Evidence from highly industrialized countries, Energy Economics, https://sci-hub.ru/10.1016/j.eneco.2010.07.001, Willie T.]

This study utilizes the Johansen cointegration technique, the Granger non-causality test of Toda and Yamamoto (1995), the generalized impulse response function, and the generalized forecast error variance decomposition to examine the dynamic interrelationship among nuclear energy consumption, real oil price, oil consumption, and real income in six highly industrialized countries for the period 1965–2008. Our empirical results indicate that the relationships between nuclear energy consumption and oil are as substitutes in the U.S. and Canada, while they are complementary in France, Japan, and the U.K. Second, the long-run income elasticity of nuclear energy is larger than one, indicating that nuclear energy is a luxury good. Third, the results of the Granger causality test find evidence of unidirectional causality running from real income to nuclear energy consumption in Japan. A bidirectional relationship appears in Canada, Germany and the U.K., while no causality exists in France and the U.S. We also find evidence of causality running from real oil price to nuclear energy consumption, except for the U.S., and causality running from oil consumption to nuclear energy consumption in Canada, Japan, and the U.K., suggesting that changes in price and consumption of oil influence nuclear energy consumption. Finally, the results observe transitory initial impacts of innovations in real income and oil consumption on nuclear energy consumption. In the long run the impact of real oil price is relatively larger compared with that of real income on nuclear energy consumption in Canada, Germany, Japan, and the U.S.

1. Introduction

During the two energy crises in the 1970s, the price of oil **doubled, even tripled** in some countries, resulting in an increase of production cost and sharply reducing export competitiveness, which may have reduced imported-energy-dependent countries' economy performance and international competitiveness. Fossil fuels including coal, oil, and gas nowadays provide **85% of energy needs**, and fossil-fuelled economic growth is the **main factor for global warming** through the release of carbon dioxide (CO2) into the atmosphere. In December 1997 the third session of the Conference of Parties to the United Nations Framework Convention on Climate Change (UNFCCC) in Kyoto, Japan adopted the Kyoto Protocol. Annex I countries agreed to reduce their collective greenhouse gas emissions by 5.2% from their 1990 level by 2008 to 2012. The U.S. President Obama's New Energy for America plans to reduce 10 million barrels of oil consumption per day by 2030 and to cut the country's collective greenhouse gas emissions by 80% from the 1990 level by 2050.

To combat these energy and environmental configurations, one of the important priorities of energy and environmental policy is to **diversify the sources of energy** and to find a **secure, cheap, and nonGHG**-emitting energy supply (Fiore, 2006; Vaillancourt et al., 2008; Wolde-Rufael, 2010). As noted by the International Energy Agency (IEA, 2008), nuclear energy may **answer these conditions**, as it **reduces the instability** of oil prices, the dependence on oil imports for many countries, and greenhouse gas emissions. Therefore, nuclear energy (non-carbon energy) may be a **crucial substitute** energy for oil, and whether imported-energy-dependent countries can adopt nuclear energy to replace the majority of fossil fuels in their economy has become an important issue

#### Absent action, world war ensues.

**Bunzel 18** [Theodore Bunzel; Head of Lazard Geopolitical Advisory; 5-30-2018, "Do High Oil Prices Mean More International Conflict?", American Interest, https://www.the-american-interest.com/2018/05/30/do-high-oil-prices-mean-more-international-conflict/] sumzom

Does the relationship between oil prices and Russian behavior to which Bush alluded hold true? The higher the price of oil, the more aggressive Russia becomes? And what about other petrostates? Might it be true for those as well?

We may soon have more evidence for the proposition. Oil prices are brushing off 2016 lows and hitting three-year highs. Brent crude has been hovering above $70 a barrel since April, up from lows of around $30 in early 2016, fueled by OPEC production cuts and rising geopolitical tensions (over issues like the Iran deal). Though nuances, complications, and exceptions abound, the academic and historical evidence on balance tells us that, as we transition from a lower to a higher oil price regime, we can generally expect a darker geopolitical outlook. As rising oil revenues gives Russia, Saudi, Iran, and other oil-exporters an **added sense of confidence**, it may at least selectively inflame interstate tensions and lead to more aggressive behavior. That possibility, alongside an increasingly **hawkish U.S. national** security team and a President who appears to feel rather “unchained” of late, points to a potentially combustible mix just ahead.

It is generally taken for granted that aspects of geopolitics can function as a key input into oil prices. Trump’s mere threat of a U.S. strike in Syria, for example, caused oil to spike by 2 percent on April 11. In addition to short-term effects, geopolitical competition can influence prices in other ways. To give just one general example, as Soviet power spread into parts of the Third World after the independence era, some states felt safer nationalizing their oil industries to escape Western company control (Iraq in 1961, for example), and prices rose as a consequence.

But the relationship may also work the other way around: Oil prices can also be a key input into geopolitics. Many studies have demonstrated that oil prices have a direct effect on the domestic stability of petrostates. This makes ample intuitive sense: Higher prices **fill public coffers**, allowing governments to **palliate needy populations** and **potential elite opposition groups** by dispensing more largesse. Some regime elites may reason that a firmer grip on power may free them to carry out more assertive foreign policies without fear of being undermined at home.

There are, however, several complications to this general intuition. Some states already have sufficiently buoyant revenues relative to their small populations to satisfy their publics and feed clientelistic networks. Providing largesse can also backfire if prices drop; taking away something valuable that people have grown used to is a dangerous game, especially when elites aren’t ready to play it. And then of course there is the famed “oil curse”: For all sorts of reasons, from “Dutch disease” economic distortions to the derangement of normal citizen-state relationships, oil riches can in time undermine regimes, weakening and even destroying them.

That said, a more recent body of research has empirically demonstrated the intuitive twin of this conclusion: Higher prices cause greater interstate aggression by oil-producing countries. Why would this be the case? Greater oil revenue flushes petrostates with confidence and also cash that they can put toward military spending or foreign adventures. To take one obvious example, we need only look to Iran’s using its oil revenue to **fund proxy groups** such as Hamas and Hezbollah. Furthermore, military spending by one regional oil producer can beget spending by others, fueling regional **arms races** that can make **aggression** and conflict by **miscalculation** more likely. The onset of the **Iran-Iraq War** in September 1980 may be a **prime example** of that dynamic.

Most prominent among the empirical studies is Cullen S. Hendrix’s 2014 paper, which shows a statistically significant relationship between higher oil prices and “dispute behavior” (military actions short of actual war) by oil-exporters. (Hendrix also summed it up nicely in this Washington Post piece.) He found that “all things being equal, a one standard deviation ($18.60) increase in the price per barrel of oil from the sample mean ($33.81) is associated with a **13 percent** increase in the frequency of [dispute behavior]” in oil-exporting states. He also found that, above $77 a barrel, oil-exporters are significantly more dispute prone than non-oil exporters.

Hendrix also explores the potential complication of reverse causality: Could dispute behavior by oil-exporting countries be driving prices higher, rather than the other way around? A key analytical consideration here is timing. We can all agree that geopolitical activity affects prices in the short-term (such as the Syria example mentioned above), but is this reverse causality true on a sustained basis? Parsing out long-term signal from short-term noise, Hendrix examines whether elevated aggregate dispute behavior affects oil prices at the yearly—rather than daily or weekly—level, and finds that this relationship does not hold. His explanation here is that other players typically step in to redress markets: “While dispute behavior may drive prices changes in the short term . . . the **strategic significance** of oil prices and oil-exporting states encourages major powers to act in ways that stabilize markets, either through market intervention . . . or **direct, armed intervention**.”

Jeff Colgan of Brown University has also touched on this topic, finding through his research that oil has fueled—in some way—**one quarter to one half of interstate wars since 1973**. He also notes that oil-producers are **50 percent more likely** to engage in conflict than non-oil producers. Colgan identifies eight, non-mutually exclusive causal mechanisms for how oil fuels international conflict, most of which are **implicitly exacerbated** by higher prices. They are: “(1) **resource wars**, in which states try to **acquire oil reserves by force**; (2) petro-aggression, whereby oil insulates aggressive leaders such as Saddam Hussein or Ayatollah Ruhollah Khomeini from domestic opposition and therefore makes them more willing to engage in risky foreign policy adventurism; (3) the externalization of civil wars in oil-producing states (“petrostates”); (4) financing for insurgencies—for instance, Iran funneling oil money to Hezbollah; (5) conflicts triggered by the **prospect of oil-market domination**, such as the U.S. war with Iraq over Kuwait in 1991; (6) clashes over control of oil transit routes, such as shipping lanes and pipelines; (7) oil-related grievances, whereby the presence of foreign workers in petrostates helps extremist groups such as al-Qaeda recruit locals; and (8) oil-related obstacles to multilateral cooperation, such as when an importer’s attempt to curry favor with a petrostate prevents multilateral cooperation on security issues.”

Though he doesn’t substantiate statistically that higher prices lead to more conflict through these channels, he implies it heavily. For example, he writes that, “the low oil prices of the 1990s have given way to higher and more volatile prices, increasing the magnitude of the consequences one can expect from oil-conflict linkages.”

While the emerging academic evidence may validate the claim that higher oil prices lead to more aggression, the historical and anecdotal evidence is somewhat mixed, and understandably so. Oil price is clearly only one of many inputs into foreign policy decision-making, and an indirect one at that. No leader thinks, “Now that oil is at $X, I’m going to invade my neighbor.” Context obviously matters, too: No one imagines that Ecuador or Norway is going to invade or try to blackmail a neighbor just because spot prices rise 15 or 30 percent in a given six-month period. Price levels seep into decision-making more subtly, affecting interlocking beliefs about strategic behavior generally and specific cases more particularly; they may fuel self-confidence by shoring up budget outlooks and funding the tools of more aggressive behavior in contexts where such behavior could conceivably make sense.

Moreover, there are many contravening (and occasionally countervailing) complications. Prominent among these is the fact that low oil prices can incentivize states to “wave the flag” in order to distract from domestic difficulties—so the impact of low oil prices might lead to more aggressive behavior in some cases. That suggests that neither high nor low prices per se may be the trigger affecting behavior, but rather notable changes in price that become politically salient in one way or another.

And there’s also the tricky issue of timing: Over what timeframe does increased oil revenue fuel aggression? Is it in anticipation of higher prices, in direct response to the current pricing levels, or is there more of a lag in effect as oil revenue slowly shores up—or is expected to shore up—budgets and military spending over time? The answer might depend on specific cases and leadership cadres.

There is also a scaling problem. If a 20 percent rise in oil prices makes a more assertive foreign policy more likely in a given country, does a 40 percent rise make it twice as likely? Or put differently, how much of a difference in price, and presumably in expected revenues, does it take to cross a threshold where it might have an impact on decision-making? Are there multiple thresholds?

Russia **exemplifies these issues**. Taking the same long view as George W. Bush in his interview, it seems self-evident that rising oil prices and higher government revenues over the course of the 2000s **gave Putin confidence**, funded military expansion and modernization, and helped enable Russia’s **most revanchist tendencies**. Between 2003 and 2013, **Russian military expenditure doubled** as the price of Brent crude rose from a low of around $20 a barrel in 2001 to a high of more than $140 a barrel in 2008. Russia, as the saying goes, is a gas station with nuclear weapons; a higher pump price thus means more weapons, nuclear and otherwise.

But when you cross reference this conclusion with specific acts of Russian aggression over the past roughly twenty years, the picture gets much more complicated. When Russia invaded **Georgia** in August 2008, oil was above $100 a barrel. Same with **Russia’s invasion of Crimea** in 2014. But Russia also dramatically intervened in Syria in September 2015, when oil had dropped to around $50 a barrel and the economy was sputtering due to both low energy prices and Western sanctions. Here, many analysts plausibly described these interventions as a way of rallying Russians to the flag and distracting them from domestic hardship. More likely, Putin saw an emergency in Syria that simply had to be dealt with, no matter the cost or risk; the Assad regime was in danger of collapsing, and Syria is Russia’s only ally offering ports and bases in the Mediterranean basin. So Russia is a bit of a mixed bag, but on balance its behavior—especially over a long timeframe—appears to support the thesis.

Saudi Arabia’s role in the 1973 Yom Kippur war also illustrates the tricky question of timing. Saudi funding of the effort was enabled by a financial buffer created by a rise in revenues from the late 1960s, and was likely justified by an expected rise in revenues due to an oil price increase that was anticipated, in part, because of the very war it was in the process of financing. Its reserves had already grown so large that, for the first time, Saudi Arabia could ride out a supply (and revenue) disruption and still finance a war. But the Saudis helped finance a war that they themselves did not participate in. So if rising oil prices led to greater interstate aggression, it did so in this case in a particularly indirect way.

These are all interesting and important nuances that attenuate any direct causal connection one might be tempted to draw between oil prices and conflict. So it would be nice to know if historical studies have shown any significant statistical relationship between fluctuations in key sources of government revenue (and what memoirs and archives tell us about how those situations were perceived) and interstate behavior. It would be even nicer to drill down into such studies to find cases where specific lucrative commodities—for example, European colonial profits such as from British opium sales in China, or cotton grown in Egypt—made any difference in the behavior of the relevant governments. Alas, such studies do not exist.

But regardless of the timeframe and mechanism, academic and historical studies alike do suggest that higher oil prices have generally lead to more aggressive, or at least riskier, behavior in recent decades—whether in anticipation of higher prices, immediately in their wake, or only after sufficient revenue stores are built up.

So are we at a point in the energy price cycle where, all else equal, we should expect greater interstate conflict? We’re close to Hendrix’s $77 a barrel threshold, above which oil-exporters are significantly more dispute-prone than non-oil exporters. But given the nuances just described, this specific price threshold is probably too cute. The more realistic argument to make is about the effect of a higher-price vs. lower-price paradigm over a multi-year horizon (particularly in light of the timing issue and potential lag). And if the period of the past two years (when Brent largely hovered between $40 and $60) was a lower-price paradigm, 2018-19 is potentially gearing up to be a higher-price paradigm driven by continued supply cuts by OPEC, tight global inventories, and—in a coincidental way—heightened geopolitical risks. We’ll see how these factors play out, but if oil prices remain elevated we may begin to subtly feel their effects on behavior by Iran, Saudi Arabia, Russia, and perhaps others.

None of this is to say that oil prices are the most important factor in the geopolitical outlook over the near, medium, or long-term. The reputed hawkishness of Mike Pompeo and John Bolton, the effect of the upcoming mid-term elections on Trump’s decision-making, and reactions to potential exogenous shocks (for example, a major clash in Syria between U.S. or Israeli and Iranian or Russian forces) will play a much more direct and important role in shaping the geopolitical landscape. But a higher oil price regime (if it holds) could well make petrostates like Iran, Saudi, and Russia more aggressive—either in **challenging the United States and Europe** in the case of Russia, or by exacerbating ongoing proxy conflicts in and around the Middle East in the cases of Iran and Saudi Arabia. Given these and other dynamics, we should expect a bumpy ride ahead.

### 2AC

#### Trump’s cutting renewables funding anyway, their “spike” is a one-liner – it’s try or die aff.

**Mcdermott 3-28** [Jennifer Mcdermott, reporter on the Associated Press Climate and Environment team. 3-28-2025, "Trump administration cancels clean energy grants as it prioritizes fossil fuels", AP News, https://apnews.com/article/trump-energy-department-clean-energy-wind-solar-batteries-hydrogen-fossil-fuels-cf1dff9ee771c566765e9ca3e3599d91, doa 4-2-2025] //ALuo

President Donald **Trump’s** administration is **terminating grants** for two **clean energy projects** and roughly 300 others funded by the Department of Energy are in **jeopardy** as the president **prioritizes fossil fuels**.¶ The DOE is canceling two awards to a nonprofit clean energy think tank, RMI in Colorado, according to a document from the agency confirming the cancellations that was reviewed by The Associated Press on Friday. One was for nearly $5.3 million to retrofit low-income multifamily buildings in Massachusetts and California to demonstrate ways to reduce the use of energy and lower planet-warming greenhouse gas emissions. The other was for $1.5 million to assess business models for electric vehicle carsharing in U.S. cities.¶ The department wrote that it had determined the **awards** do not meet the administration’s **objectives**. Both awards are on a list of about **300 clean energy projects** under review. President Donald Trump declared an energy emergency early in his term and is working to speed up fossil fuel development, which he sums up as “drill, baby, drill.”¶ The burning of oil, gas and coal is the main contributor to global warming caused by human activity. President Joe Biden tried to **lock in** a **trajectory** for reducing the nation’s greenhouse gas emissions. As his term came to an end, his administration raced to award billions of dollars for **clean energy** and approved **major offshore wind projects**.¶ RMI spokeswoman Dina Cappiello confirmed the organization had received a termination letter for the EV carsharing viability work, and had anticipated it. That work won’t proceed as a result of the funding being pulled back. As of Friday afternoon, she said she hadn’t seen a second letter, but the retrofitting work is due to finish in June using a grant announced during Trump’s first term.¶ The Department of Energy said in a statement late Friday that the department “acted in the **best interest** of the American people” by **terminating the grants**. As for other grants on the list, the statement said, the department is still conducting a **wide-ranging review**.¶ E&E News first reported last week that the DOE was creating a “**hit list**” of **clean energy** projects awarded **billions** of dollars that the Trump administration could **wipe out**.¶ The list, obtained by the AP, includes **wind**, **solar**, **battery storage** and **electric vehicle** infrastructure projects. It includes funding to help heavy industries transition away from fossil fuels and funding to **decarbonize buildings**. Many projects were funded through the $1 trillion **bipartisan** infrastructure law Biden signed in 2021.¶ Separately, the Environmental Protection Agency **terminated grant agreements** this month worth **$20 billion** issued by the Biden administration under a so-called green bank to finance clean energy and climate-friendly projects. A federal judge has blocked the administration from ending the grant program for now.

#### Either that or it’s resilient

**Copley '25** [Michael Copley, correspondent on NPR's Climate Desk. 3-12-2025, "America's clean-energy industry is growing despite Trump's attacks. At least for now", NPR, https://www.npr.org/2025/03/12/nx-s1-5319056/trump-clean-energy-electricity-climate-change, doa 4-2-2025] //ALuo

Despite the Trump administration's **wide-ranging attacks** on renewables like wind and solar power, the clean-energy industry is **on pace** for **record growth** this year, according to government analysts.¶ The buildout of **big solar** and **battery plants** is expected to hit an **all-time high** in **2025**, accounting for **81%** of **new power generation** that companies will add to America's **electric grids**, the Energy Information Administration (EIA) said in a recent report. Including wind projects, the share of new power capacity that's expected to come online this year from renewables and batteries jumps to 93%, the EIA said.¶ The U.S. needs all the power it can get, because electricity demand is surging for the first time in decades, industry analysts and executives say. That means **kickstarting** development of **nuclear power** and geothermal projects, burning more natural gas and, in some cases, delaying retirement of old coal plants. But in the **scramble** for electricity, **renewable-energy** and **battery plants** are **crucial**, analysts and executives say, because they're **quick to build** and provide electricity that's **relatively cheap**.¶ "There is no doubt that the **increased demand** for electricity over the next decade, coming from data centers and advanced manufacturing, will continue to require **vast amounts** of **renewable energy and batteries**," Andrés Gluski, chief executive of The AES Corporation, a power company that owns both clean-energy and fossil-fuel plants, told Wall Street analysts recently.¶ Still, the renewables industry faces potential upheaval. The Trump administration tried to withhold federal funding Congress previously approved for climate and clean-energy projects. Trump also ordered the government to temporarily stop issuing or renewing leases for offshore wind projects in federal waters. The Department of the Interior limited who at the agency can issue permits for renewable energy projects on public lands, which could slow permitting. And conservatives are pushing Congress to wipe out tax incentives for clean energy.¶ If the disruptions spread, companies could abandon plans to build new power plants. That could dampen economic growth and hamstring efforts to develop data centers for artificial intelligence, a priority of the Trump administration. In an interview that aired Sunday on Fox News, Trump declined to rule out the possibility of an economic recession this year.¶ "At a time when we're all very concerned about energy abundance and this administration's broad goal of re-establishing energy dominance, just the idea that we'd be constraining the build of new energy [infrastructure] really feels like it's rowing in the wrong direction," says Rich Powell, chief executive of the Clean Energy Buyers Association, whose members range from Amazon to ExxonMobil to Walmart.¶ Interior Secretary Doug Burgum chairs the Trump administration's National Energy Dominance Council. An Interior Department spokesperson, Elizabeth Peace, said in a statement that the agency supports renewable-energy development "where it makes sense while ensuring that all energy sources contribute to a reliable and affordable power grid."¶ Demand for clean energy 'is certainly not going away'¶ The **clean-energy** industry has **exploded** over the past decade. Solar, in particular, has accelerated. Meanwhile, growth in the **wind industry** has **slowed** because of **problems** ranging from inflation to pushback on siting projects.¶ The industry overall has boomed thanks to falling technology costs, federal tax incentives and state renewable-energy mandates. The market got another big boost in 2022, when President Joe Biden signed the Inflation Reduction Act, which provided hundreds of billions of dollars in federal funding for clean-energy projects, among other climate investments.¶ **Corporations** like Amazon, Meta and Google have also played a role, **signing contracts** to buy ever-larger amounts of **renewable energy**.¶ "I expect that that will continue," says Powell of the Clean Energy Buyers Association. "The demand is certainly not going away."¶ Some **big investors** seem to take a similar view. Led by Trump supporter Steve Schwarzman, the investment firm Blackstone said in February that it raised $5.6 billion for its "**energy transition**" business, which in the past has **invested** in companies that work in the **renewable energy industry**. Also last month, Brookfield Asset Management agreed to buy a U.S. **renewable energy business** for more than **$1.7 billion**.¶ "Renewables will be the **biggest beneficiary** of **growing electricity demand** because they are the **cheapest option**, and [electricity buyers] will always **absorb** as much of the **cheapest source of power** before turning to more expensive forms of power," Brookfield's chief executive, Bruce Flatt, told Wall Street analysts in February.

#### Nuclear is better. 3 warrants.

#### A. GHG emissions.

**Oracle '22** [Change Oracle, 7-20-2022, "Nuclear Power Versus Renewable Energy", Change Oracle https://changeoracle.com/2022/07/20/nuclear-power-versus-renewable-energy/, doa 4-2-2025] //ALuo

**Nuclear energy** has **advantages** over **renewables** in terms of **reliability**, **GHG emissions**, **land use** and **waste**. Nuclear is **far more reliable** (dispatchable) than renewables like wind and solar. Nuclear plants keep **churning out energy** even when the wind is not blowing, and the sun is not shining. ¶ Nuclear is also one of the cleanest sources of energy. Recent research published in the Journal of Cleaner Production found that the emission of GHGs and natural resource use associated with nuclear power generation was similar to that of renewable energy. An analysis by the European Commission indicates that in terms of **full-cycle production**, the **emissions** from nuclear are around the **same as wind**. Other studies have concluded that nuclear may be even **cleaner** than **solar**. Orano claims that nuclear power generates **four times fewer** GHGs than **solar**.

#### B. Land use.

**Oracle '22** [Change Oracle, 7-20-2022, "Nuclear Power Versus Renewable Energy", Change Oracle https://changeoracle.com/2022/07/20/nuclear-power-versus-renewable-energy/, doa 4-2-2025] //ALuo

Nuclear also requires **substantially** **less land** than wind and solar. According to some assessments, nuclear requires 1/2,000th as much land as wind and 1/400th as much land as solar. US government data indicates that a 1,000-megawatt wind farm requires 360 times more land than a similar-capacity nuclear facility, while a solar plant requires 75 times more area.

#### C. Waste.

**Oracle '22** [Change Oracle, 7-20-2022, "Nuclear Power Versus Renewable Energy", Change Oracle https://changeoracle.com/2022/07/20/nuclear-power-versus-renewable-energy/, doa 4-2-2025] //ALuo

While there are valid concerns about nuclear waste, there are also legitimate issues with renewable waste. Wind and solar generate a litany of chemical wastes including toxic heavy metals like cadmium, arsenic, chromium, and lead. While nuclear waste can remain radioactive for thousands of years, waste metals associated with renewables remain dangerous forever. Perhaps most importantly, the volume of **nuclear waste** is a **tiny fraction** of **renewable waste.** Nuclear waste is **1/10,000th** of the waste generated by solar and **1/500th** of the waste generated by wind.

#### It’s not a trade off.

**Oracle '22** [Change Oracle, 7-20-2022, "Nuclear Power Versus Renewable Energy", Change Oracle https://changeoracle.com/2022/07/20/nuclear-power-versus-renewable-energy/, doa 4-2-2025] //ALuo

Despite the **undeniable importance** of renewables, we have to face the fact that wind and solar have **not been able** to slow let alone **stop emissions** from fossil fuels. In 2019 only 16 percent of global primary energy came from low carbon sources (11.4% comes from renewables, and 4.3% comes from nuclear). Even if we were to cut subsidies to fossil fuels, renewables are nowhere near where they need to be to counter climate change. Esam Hussein, the dean of engineering and applied science at the University of Regina explained that renewables cannot yet solve the energy emissions problem on their own. Even the most **optimistic assessments** suggest it could take more than **30 years** to **transition to renewable energy**. The problem is we do not have 30 years. ¶ There has been very little movement in the distribution of the energy mix. “The share of renewable energy has moved in the last decade from 10.6% to 11.7%, but fossil fuels, all coal, and gas have moved from 80.1% to 79.6%. So, it’s stagnating,” said Adib, adding that since energy demand is rising, we are actually using more fossil fuels than we ever have. ¶ There is no question that emissions-free renewables are critical sources of energy but even though wind and solar have been growing at a prodigious rate, renewables will need to be massively scaled prodigious if we are to meet our emissions reduction goals.¶ We have yet to come close to investing in renewables at the required scale. As reported by the BBC, UN Secretary-General Guterres recently called for a dramatic increase in spending on renewables, saying “Had we invested massively in renewable energy in the past, we would not be so dramatically at the mercy of the instability of fossil fuel markets.” ¶ The fact is that we have not made the required investments in renewables, nor are we on the cusp of doing so. While renewables have experienced prodigious growth, they are not growing anywhere near fast enough to slow fossil fuels. It remains that renewables have not made a dent in fossil fuel use. It is hard to envision a pathway in which adequate solar and wind infrastructure will be built within the timeframes we have.¶ We have to face the hard reality that it is unlikely to build out enough renewable energy to allow us to wean ourselves off of fossil fuels within the window of time we have available. Germany is a good example, despite the national obsession with wind and solar the country still gets most of its energy from coal. Last October the International Energy Agency’s (EIA) World Energy Outlook bluntly stated the world is not transitioning to clean energy fast enough to zero out emissions by the middle of the century. Efficiency is part of the solution but we also need more clean power to meet the massive surge in demand associated with decarbonization through electrification.¶ We cannot afford to **overlook** nuclear power’s **capacity** to **massively increase** our **production** of **emissions-free electricity**. Nuclear fuel is by far the **longest-lasting source** of energy on the planet and among the **most abundant**. Soil commonly contains an average of around 6 parts per million (ppm) of thorium and the uranium and thorium concentrations in seawater range from 1.80 to 4.1 and 0.14 to 0.88 microg/L, respectively. The longevity of nuclear fuel can even be compared to solar power Astronomers estimate that the sun has about 7 billion to 8 billion years left, while the half-life of thorium- 232 is about 14 billion years. ¶ Nuclear energy and the question of time¶ As we consider the important question of energy supply we must remember that the clock is ticking. We need to reevaluate the claims of those who say “nuclear power has no business case and could make climate change worse“. While renewables can be built much more rapidly than nuclear power plants, they have not been able to replace fossil fuels and they are unlikely to do so in the time we have. ¶ Time is of the essence as indicated by a 2021 UNECE policy brief which warned that, “time is running out to rapidly transform the global energy system,”¶ As explained in The Hill, “the consequences of inaction exponentially increase as time marches on. If we have any hope of turning back the clock on the climate crisis, we need to ensure nuclear energy remains a vital part of our carbon-free energy mix with collaboration from every level of government.”¶ A Foreign Affairs headline in 2021 read “Nuclear Energy Will Not Be the Solution to Climate Change There Is Not Enough Time for Nuclear Innovation to Save the Planet” In a CNN article, Ben Wealer, who researches nuclear power economics at the Technical University of Berlin, is quoted as saying we don’t have time to wait for new nuclear plants. “Looking at the time frames, it cannot be a huge help in combating climate change,” Weaver said. Jacobson also argues that we do not have the time to build nuclear power plants. Edwin Lyman, a physicist with the Union of Concerned Scientists who published a report that harshly criticized nuclear power called it ‘magical thinking’ to expect that advanced designs will be able to prove themselves within the limited timeframes we have. ¶ If we assess these claims from the ten-year timeframes required to build conventional nuclear energy facilities, we will not be able to deploy enough of these plants to meet 2030 emissions reduction targets. If these timelines are intractable nuclear energy is not a viable short-term option. But even if you accept the veracity of these timelines, nuclear remains our best hope for fully decarbonizing the energy sector by 2050. ¶ There are signs that we may be moving in this direction. Capital investments in nuclear increased dramatically in 2021. Around 60 GW of nuclear capacity was under construction at the start of last year, and more than 100 GW of planned reactor projects after 2030. ¶ **Innovative** nuclear power technologies may prove to be a **game changer**. According to the IEA nuclear technologies like **small modular reactors** (SMRs) have **shorter construction** and **approval** times, SMRs can be **manufactured quickly** and **installed** just about **anywhere**. Conventional wisdom says it takes five years to build an SMR, however, China, Russia, and Korea have demonstrated that it is possible to build nuclear reactors in **less than five years**. China is working on a nuclear plant in Jiangsu province that will take only 2 years to construct. So there is still time to build out nuclear reactors to help us to achieve the 2030 carbon reduction goals. As explained in World Nuclear News, “it is possible that some additional reactors that start construction before 2025 could be completed by 2030”. Microreactors can generate between 1 and 20 microwatts of power and they can be installed almost anywhere including large factories, residential building complexes, charging stations for electrical vehicles, data centers, desalination plants, and commercial shipping.¶ Which is better renewables or nuclear?¶ Jacobson argues that we should choose renewables over nuclear power, however, this is a **false choice.** According to Dan Byers, vice president for policy at the U.S. Chamber of Commerce’s Global Energy Institute, nuclear power is part of the **clean energy mix**. “[W]hile the case for nuclear power has always been strong, growing political support from governments, businesses, and environmental interests alike is making it stronger,” Byers said, adding, “To reach our ambitious global climate objectives, we need every tool in the toolbox to reduce emissions, and including nuclear energy needs to be a priority.”¶ Rather than being an **either-or proposition**, nuclear energy should be understood as an **ideal partner** for **renewables** like solar and wind. George Bilicic, the vice-chair and global head of Lazard’s Power, Energy & infrastructure Group explained that to slash emissions we need the full array of clean energy technologies: “[T]he transition [away from fossil fuels] will not be dominated by any one [energy] solution — rather a new ‘all of the above approach.” Bilicic said.

## AT: Meltdowns---2AC

### AT: NRC---UQ---2AC

### AT: NRC---Link---2AC

#### 1. NRC is lowering inspections costs, preparing for increased reactors, and building frameworks for advanced reactors, ensuring no tradeoff post-aff.

**Patel 25** [Sonal Patel; Sonal Patel is a senior editor at POWER magazine, where she has covered the global power and energy sector since 2008, 2-20-2025, "NRC Proposes Deep Fee Cuts for Advanced Nuclear," POWER Magazine, https://www.powermag.com/nrc-proposes-deep-fee-cuts-for-advanced-nuclear/, DOA: 4-4-2025] shaan

The Nuclear Regulatory Commission (NRC) has proposed to sharply reduce its hourly service fees—by more than 50%—for advanced nuclear reactor applicants and pre-applicants in a move designed to incentivize innovation and accelerate the deployment of next-generation nuclear technologies.

In a proposed rule published in the Federal Register on Feb. 19, the regulatory body moved to revise its fees for licensing services, inspection services, and special projects (under 10 CFR part 170) by establishing a two-tiered hourly rate system.

Starting in August 2025, the agency plans to raise the professional hourly rate from $317 to $323. This increase, the NRC said, is driven by “an approximately $5.4 million increase in resources requested in the FY 2025 budget request.” The agency earmarked these funds to support several key initiatives, including:

Technical reviews of 10 CFR Part 50 construction permit applications, including to facilitate reviews necessary for construction permit applications for non-power reactors.

The relocation, design, and construction of the Headquarters Operations Center (HOC) to enable the NRC to exit one of its headquarters buildings before its lease expires in November 2027.

Development and implementation of IT and cybersecurity upgrades, including an artificial intelligence (AI) infrastructure to facilitate responsible AI adoption. (The measure is in line with Executive Order 14110, which the Trump administration revoked on Jan. 20).

Increased salaries and benefits to support federal pay raises for NRC employees, an effort that seeks to ensure the agency can retain and attract qualified personnel.

A Drastically Reduced Rate of $146/Hour

However, in a bid to implement Section 201 of the ADVANCE Act, which revised the 2019 Nuclear Energy Innovation and Modernization Act’s (NEIMA’s) fee structure, the NRC proposed a drastically Reduced Hourly Rate of $146 for advanced nuclear reactor applicants and pre-applicants. The lower rate is slated to take effect on Oct. 1, 2025 (when the ADVANCE Act provisions become effective)—which would fall into the NRC’s FY2026 budget. The ADVANCE Act, notably, sunsets the Reduced Hourly Rate for advanced nuclear reactor pre-applicants on Sept. 30, 2030.

Signed into law on July 9, 2024, the legislation mandates that costs associated with international nuclear export and innovation activities (Section 101) be excluded from the fees collected by the NRC. It also exempts costs related to reviews and pre-application work for early site permits required to demonstrate advanced nuclear reactors at the Department of Energy (DOE) or critical national security infrastructure sites (Section 204) from NRC’s fee calculations. The NRC’s proposed rule indicates these provisions may take effect as part of its FY2026 rule.

The NRC’s decision to front-load the Section 201 change in the FY25 rule, rather than waiting for the FY26 rule, is a strategic move that will avoid billing delays and provide early notice and initiate an opportunity to comment, it said. Pivotally, “It also would provide greater regulatory certainty to external stakeholders for planning and budgeting for future 10 CFR part 170 service fees for advanced nuclear reactor applicants and pre-applicants,” it said.

The proposal also specifically defines which entities could qualify for reduced fees. It defines an “advanced nuclear reactor applicant” as an entity that has formally applied for a license to build and operate an advanced nuclear reactor. That application must be for an initial operating, combined, or manufacturing license—not for an amendment to or renewal of an existing license. An “advanced nuclear reactor pre-applicant” is an entity that has submitted a detailed licensing project plan outlining its intention to apply for a future license for an advanced nuclear reactor. Again, that future license must be for an initial operating, combined, or manufacturing license. The NRC has proposed to limit these applications to advanced nuclear reactors as defined in NEIMA.

According to the proposal, the reduced hourly rate will also only apply to certain activities related to the review of applications submitted by advanced nuclear reactor applicants and pre-applicants. Specifically, fees assessed for reviewing an advanced nuclear reactor applicant’s formal licensing application could qualify, as may fees related to reviewing submitted materials that are explicitly outlined in a licensing project plan from a pre-applicant. Other NRC activities, such as license amendments or renewals, will continue to be billed at the full professional hourly rate of $323.

In recent years, the agency has also revised how it calculates fees for small modular reactors (SMRs) as part of broader efforts to tailor costs to emerging nuclear technologies. In 2016, the NRC modified its rules (10 CFR 171.15) to establish a specialized method for calculating annual fees for small modular reactors (SMRs) that use light-water reactor (LWR) technology. In 2023, the NRC expanded those provisions to include all SMRs (not just LWRs) and introduced a reduced minimum fee and adjusted fee structure for very small SMRs (250 MWth or less). The agency’s proposed rule says fee calculations for bundled SMR units and larger SMRs (over 250 MWt) will remain unchanged, and because no SMRs are currently in operation, the NRC will not impose specialized SMR fees in 2025.

**2. “Less regulation” does not mean worse.**

**Duguay '20** [Raphael Duguay, PhD from the University of Chicago Booth School of Business.  12-17-2020, "Small Modular Reactors and Advanced Reactor Security: Regulatory Perspectives on Integrating Physical and Cyber Security by Design to Protect Against Malicious Acts and Evolving Threats", TRACE: Tennessee Research and Creative Exchange, https://trace.tennessee.edu/ijns/vol7/iss1/2/, doa 3-21-2025] //ALuo

How can future nuclear technologies and Small Modular Reactors (SMRs) deter and prevent organized crime groups, terrorists, and malicious actors from attempting to steal or sabotage nuclear materials and facilities? This paper presents the benefits of integrating Security by Design (SeBD) into a **regulatory framework** to allow more a **flexible** and **effective** design of **physical protection systems for SMRs**. During its effort to modernize the Nuclear Security Regulations, the Canadian Nuclear Safety Commission (CNSC) licensing application process provides for the option of SeBD in moving toward a **performance based** approach with less prescriptive requirements. CNSC also recognizes the need for a graded approach using risk-informed criteria for nuclear security. As part of the SMR Vendor Design Review (VDR) process, CNSC reviews SeBD proposals as well as interfaces with safety (robustness), safeguards (Nuclear Material Accounting and Control), operations, and sustainability. The CNSC also recognizes the need to share relevant, nuclear, sensitive information from the National Design Basis Threat (DBT) with SMR designers so they can consider credible and evolving threats in their proposed SeBD. Finally, the interfaces between **nuclear security and system engineering specialists** within the VDR process allow one to look at both **physical and cyber security systems in a more holistic approach.** This allows the regulator to look at how SMR developers propose to **optimize nuclear safety** to mitigate or protect against potential acts of sabotage and radiological release.

#### 3. Low safety has been used for years---at worst kills their timeframe, at best disproves the link.

**Gilinsky '24** [Victor Gilinsky, commissioner @ the US Nuclear Regulatory Commission during the Ford, Carter, and Reagan administrations. 11-21-2024, "Congress wants to turn the nuclear regulator into the US industry’s cheerleader—again", Bulletin of the Atomic Scientists, https://thebulletin.org/2024/11/congress-wants-to-turn-the-nuclear-regulator-into-the-us-industrys-cheerleader-again/, doa 3-8-2025] //ALuo

The US Congress **overwhelmingly approved** the **ADVANCE Act in July** to **accelerate licensing** of “advanced” reactors. These consist mainly of fast reactors, which **radically differ** from those operating today, and include “fusion machines.” There were **no public hearings** on the act, and it shows **every sign** of having been written by **interested parties** and with **little vetting.**¶ The Energy Department and the US nuclear industry are promoting fast reactor demonstration projects, the prime being TerraPower’s Natrium project in Wyoming. The project **broke ground** in June but still awaits a full construction permit. No commercial reactors of this type are operating today. TerraPower foresees selling hundreds of such reactors for domestic use and export. The new law is largely directed at clearing the way for the rapid licensing of such reactors by the Nuclear Regulatory Commission (NRC). It does so in part by providing additional resources but also—more ominously—by **weakening** the agency’s **safety reviews** and inspections in the **name of efficiency**.¶ **Efficiency over safety**. The act’s **insidious approach** is, first, to direct the NRC to modify its “mission statement” to add a provision that its licensing and safety reviews will “**not unnecessarily limit** the benefits of **nuclear energy** to society.” The addition sounds innocuous: No one is going to defend unnecessary work. But the message is clear. To make sure it works its way down to the daily decisions made by NRC’s safety engineers, the act then gives the commissioners one year to supply Congress with a report on what guidance they will provide to the professional engineering staff to “ensure effective performance” under the new mission.¶ In a bureaucracy, you get what you incentivize for: Congress wants the commissioners to make clear to safety reviewers that every hour they will take is an hour that society will be deprived of nuclear energy (and someone’s grandmother will sit in the dark). This sort of pressure **spells trouble.** The safety of complex systems with **inherent dangers** is a subtle trade and **requires unbiased attention** to avoid serious errors. That is especially true of newly commercialized technology. NRC safety reviews and inspections are especially critical in protecting the public because, with nuclear power, there is no customer feedback loop like there is with, say, commercial flying. If people get worried about flying, they can vote for more safety by not buying tickets. Once a nuclear plant is turned on, there is realistically not much the public can do.¶ The Energy Department’s web page said the new law would help to “build new reactors at a clip that we haven’t seen since the 1970s.” But the department seems to forget that the 1970s spurt of licensing—encouraged by the commissioners of the old Atomic Energy Commission—resulted in light-water power reactors with many safety problems. These problems were then left for the newly independent NRC to resolve, taking years and leading to considerable expense.¶ Weaker definition of safety. For Congress to address the mission statement of a federal agency is itself strange. Mission statements, like “vision” statements, are products of business schools and management consultants and are typically brief generalities that hardly anyone pays much attention to. The Energy Department says its mission is “to ensure the security and prosperity of the United States by addressing its energy, environmental, and nuclear challenges.” Congress could have told the department to speed up the reactor development process, but it didn’t. Instead, it acted on the assumption that the stumbling block to a nuclear future lies in the NRC licensing system.¶ The ADVANCE Act acknowledges the need for the NRC to continue to enforce the safety requirements of the Atomic Energy Act while pursuing the goal of “efficiency.” But in doing so, the new act does not cite the Atomic Energy Act’s original safety standard of “adequate protection” (Section 182), but rather a watered-down version of “reasonable assurance of adequate protection.” In the law, words matter.¶ The commission has been using that weaker standard of safety **for some years**—not legitimately, in my view. The new act now **validates it**. The NRC lamely claims that the additional three words are just explanatory—needed to avoid the implication that “adequate protection” would mean perfect safety—and do not affect the basic standard. But the commissioners don’t dare apply that logic to the security part of the NRC’s responsibilities, which, if they did, would read: “to promote reasonable assurance of the common defense and security.” There is no question that the addition changes the meaning.

**4. Those building the power plants have an incentive to have good safety. One meltdown jeopardizes their ability to make money so they have no reason to build bad reactors, even with poor regulation.**

#### 5. The aff requires more regulation.

**IEA '25** [IEA, Paris-based autonomous intergovernmental organization, established in 1974. 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, doa 3-22-2025] //ALuo

**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.

### AT: NRC---Impact---2AC

**2. Meltdowns are contained and local---no extinction**

Lajos **Brons 19**, Adjunct Professor of Philosophy at Lakeland University, “On the Fragility of Civilization,” F = ma, 3/19/2019, http://www.lajosbrons.net/blog/on-the-fragility-of-civilization/

Among the people quoted by Bendell is Guy McPherson who is relatively well known for making a considerably more extreme prediction: within a decade global society will collapse after which no-longer maintained nuclear power plants will meltdown leading to human extinction.8 McPherson’s “research” mostly consists of wild extrapolations based on inconclusive evidence, however, and the idea that nuclear meltdowns will lead to human extinction is very implausible.9

[FOOTNOTE] Most meltdowns will be contained in the reactor vat. Those that breach the reactor vat will cause major nuclear accidents, but the only effect thereof is an increase of cancer in the direct environment of the nuclear power plant (and a tiny little bit at greater distances). The impact thereof is negligible on a global scale (that is, on a scale relevant to human extinction), however, even if very many of the 400-or-so active nuclear plants experience major nuclear accidents. [END FOOTNOTE]

#### China thumps – 5 warrants

#### A. Policymaking independence

**Andrews-Speed '20** [Philip Andrews-Speed, Research Fellow @ the Oxford Institute for Energy Studies. 4-10-2020, "The governance of nuclear power in China", Oxford Academic, https://academic.oup.com/jwelb/article/13/1/23/5818940?login=false#204518176, doa 3-9-2025] //ALuo

Whilst **policymakers at the national level** show a high degree of competence and foresight when formulating or adjusting policies, it can be argued that they can be **unduly influenced** by **state-owned enterprises** in the relevant sector, notably in the energy sector.76 Thus, it is likely that the three nuclear power companies, and the China National Nuclear Corporation in particular, may have had some sway over **national policymaking**. Given the sustained nature of the government’s commitment to nuclear power and the number of scientific and commercial interests benefitting, the nuclear programme seems to have taken on a life of its own. It may be unstoppable in the absence of another serious accident like that of the Fukushima Daiichi nuclear power plant. One test of policy momentum will occur if and when the central government revisits the ban imposed on the construction of inland nuclear power plants.

#### B. Lack of Legal Clarity.

**Andrews-Speed '20** [Philip Andrews-Speed, Research Fellow @ the Oxford Institute for Energy Studies. 4-10-2020, "The governance of nuclear power in China", Oxford Academic, https://academic.oup.com/jwelb/article/13/1/23/5818940?login=false#204518176, doa 3-9-2025] //ALuo

One other area in which state capacity is **deficient is legal capacity**. The ability of China’s legal system to enforce contracts and property rights remains **below the standards** of many Organization for Economic Co-operation and Development nations. Likewise, the effectiveness of the law to constrain **state power remains weak**. This last issue is relevant to the nuclear industry in respect of transparency and public participation, as will be discussed below.¶ Adoption and adaption of global norms¶ China is an active participant in many international organizations and instruments. By 2000, it was a member of more than 50 inter-governmental organizations.80 It has also ratified large numbers of international conventions, treaties and other instruments, including those relating to security and the environment.81¶ China has long been an active participant in the international regime for nuclear safety and security. It became a member of the IAEA in 1984 and since then has made frequent use of the IAEA’s advisory services. Between 1989 and 2017 it received a total of 31 IAEA missions, notably82:¶ 21 Operational Safety Review Team missions;¶ Two Safety Aspects of Long-Term Operation missions;¶ Two Integrated Regulatory Review Service missions in 2010 and 2016;¶ One International Physical Protection Advisory Service mission in 2017;¶ One Site and External Events Design Review Service mission; and¶ Four Technical Safety Review missions.¶ China plays an active role in the IAEA’s projects and forums relating to research and development. The country also has many bilateral agreements and arrangements covering different aspects of civil nuclear power, including emergency response.83¶ China has become a party to most of the important international treaties:¶ Treaty on the Non-Proliferation of Nuclear Weapons,84 to which China acceded in March 1992;¶ Convention on Physical Protection of Nuclear Material, to which China acceded in January 1989, with reservations concerning the dispute resolution procedures85;¶ Convention on Early Notification of a Nuclear Accident, which China ratified in September 1987, but with reservations concerning the dispute resolution procedures86;¶ Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency, which China ratified in September 1987, with reservations concerning the dispute resolution procedures and cases involving gross negligence87;¶ Convention on Nuclear Safety, which China ratified in April 199688; and¶ Joint Convention on the Safety of Spent Fuel Management and Radioactive Waste Management, to which China acceded in September 2006, but with a reservation that the Treaty would not apply to Macao.89¶ Two features are notable. First, that China has been generally quicker to ratify instruments addressing safety than those covering security and non-proliferation. Secondly, it frequently provides reservations concerning the dispute resolution procedures. Similar reservations on the part of China have been made in other international instruments, for example, the United Nations Convention on the Law of the Sea.90¶ The major omission in China’s engagement with international nuclear instruments is the failure to become party to either the Protocol to Amend the Vienna Convention on Civil Liability for Nuclear Damage91 or the Convention on Supplementary Compensation for Nuclear Damage (CSC)92. A delegation from the USA Government visited China in 2009 to discuss the CSC with the National Energy Administration and the China Atomic Energy Authority,93 but despite apparent interest shown by the Chinese side, there appears to have been no follow up inside China. The government have not provided any public explanation for this hesitancy, though it may be rooted in a preference to engage with neighbours on a bilateral basis.¶ Linked to the issue of neighbouring states is the manner in which China has been engaging with its southern neighbour, Viet Nam. The Fangchenggang 1 and 2 units lie within 50 km of the border with Viet Nam and came into commercial operation in January and October 2016 respectively. Yet, as of October 2016, there appeared to be no cross-border cooperation on emergency preparedness and response.94¶ Legal and regulatory framework¶ Legal framework¶ China has been **relatively slow** to promulgate **statutory legislation** to govern nuclear safety and security. Instead, the industry is governed by large numbers of regulations, rules and guidelines. The need for an Atomic Energy Law was first proposed in 1984, a few years after the decision to develop a civil nuclear power programme. However, frequent changes of responsibility for nuclear power within the government resulted in **30 years of procrastination**. Only in June 2015 was the law included in the National People’s Congress Standing Committee Legislative Plan (2013–2018) and remains in the Legislative Plan for 2019–2023, though it is still **not yet enacted**.95¶ In the meantime, a large number of laws and regulations have governed different aspects of nuclear safety and security. Most relevant was the Law on Prevention and Control of Radioactive Pollution of 200396 that contained general provisions relating to nuclear installations, nuclear technology, mining of radioactive materials and the management of radioactive waste. Several regulations explicitly governing nuclear safety date back to the 1980s, 1990s and early 2000s.97 Examples of relevant instruments include:¶ 1987 Regulation on the Management of Nuclear Material;¶ 1990 Regulation on the Control of Nuclear Material;¶ 1993 Regulation on Emergency Measures for Nuclear Accidents at Nuclear Power Plants; and¶ 2005 Regulation on the Safety Supervision and Administration of Civil Nuclear Facilities.¶ A number of other instruments have direct or indirect bearing on nuclear power notably those relating to pollution and environmental protection, such as:¶ 1998 Regulation on Environmental Management of Construction Projects; and¶ 2002 Law on Evaluation of Environmental Effects.98¶ The terrorist attacks of 11 September 2001 (9/11) in the USA triggered the need to address the possibility of nuclear terrorism99 and led to the Third Amendment to the Criminal Law100in December 2001 that included reference to the theft, illegal manufacture and harmful use of radioactive substances. The subsequent Nuclear Security Summits101persuaded China to enhance its efforts to manage nuclear security more effectively. Among the outcomes were two new laws:¶ 2015 National Security Law which mentions the protection of nuclear materials and the need for capacity to respond to nuclear threats and attacks102; and¶ 2017 Cybersecurity Law which contains a section on critical information infrastructure.103¶ Overall, the IAEA concluded that China has taken significant steps on a number of fronts to improve its management of nuclear security. 104However, a number of **concerns remain**. These include the absence of a definition of design basis threat and the **lack of requirement** for **realistic exercises** that test security arrangements at operating facilities.105These authors also noted **weaknesses in security culture**.¶ The Fukushima Daiichi nuclear accident, combined with China’s determination to press ahead with its nuclear power programme, appears to have stimulated the realization that the country needed a more robust legal regime for nuclear safety and security. A Nuclear Safety Law106 appeared on the legislative plan for the National People’s Congress Standing Committee for the first time in 2013, but it was only in 2016 that it was placed on the Annual Legislative Work Plan. Progress then accelerated. A series of readings, public consultations and engagement with the IAEA led to the law being adopted in September 2017.¶ The Nuclear Safety Law is wide ranging and addresses the safety of nuclear installations, nuclear material and radioactive waste, as well as emergency response, information disclosure and public participation. It draws on a number of the pre-existing regulations identified above, particularly the 1987 Regulation on the Management of Nuclear Material and the 1993 Regulation on Emergency Measures for Nuclear Accidents at Nuclear Power Plants. In this way, it provides statutory authority for the National Nuclear Safety Administration to fulfil its central role in regulating nuclear and radioactive safety. The Nuclear Safety Law appears to refer to physical protection107, but has no further detail except a later mention of the physical protection of nuclear materials during transport by road108.¶ While the Nuclear Safety Law has a substantial chapter on legal liability, most of the chapter’s text is devoted to penalties for violating domestic law, as is normal practice in China’s civil law-based regime. Only one article addresses the issue of liability for bodily injury, death, property loss and environmental damage109. Unfortunately, it fails to address the long standing inadequacy of China’s laws in this respect. As a result, the national regime for nuclear liability for damage rests on two ‘Replies’ from the State Council in 1986 and 2007. The 2007 Reply was broadly consistent with international developments in the field at the time. It identified the installation operator as being liable, up to a maximum of CNY 300 million (about US$45 million) in the case of a nuclear power plant operator, with the state being obliged to provide up to CNY 800 million (about US$115 million) in addition, or more in the case of a catastrophic accident. Operators were also required to purchase insurance. A number of other laws, notably the Tort Law of 2009,110 address the issue of liability.111 The 2007 Reply delegates the topic of transboundary damage to treaties or agreements between China and the relevant states.112¶ Whilst this **legal regime for nuclear liability** appears to be consistent with international practice in general terms, it **remains a patchwork lacking** an authoritative legal basis and the Nuclear Safety Law has **done little** to improve the situation.113 It is likely that China will draw up its own domestic law on nuclear liability, but this is not in the legislative plan for the current National People’s Congress (2018-2023).114¶ In September 2018, the Ministry of Justice circulated a draft Atomic Energy Law115 for consultation. In contrast to the Nuclear Safety Law, this draft law reads like many other Chinese laws in that it is **wide in scope**, **lacking in specifics** and resembles a policy document rather than a legally enforceable code. Key themes include support for research and development, the intention to master the full nuclear fuel cycle, and the promotion of the export of nuclear power infrastructure, fuel and technical services. It addresses issues relating to **safety and security** in **a very general** manner and makes **no mention** of non-proliferation or safeguards. Whilst the military use of nuclear power is mentioned, detailed measures on this issue are to be formulated separately. There is a great deal of dissatisfaction in China with this draft law. Further, it is politically contentious as it appears to reflect a move by the State Administration of Science, Technology and Industry for National Defence to gain greater influence over the civil nuclear sector in addition to its control over military nuclear matters.116¶ Despite the large number and wide scope of nuclear laws, regulations and rules, this **body of instruments** suffers from a **number of deficiencies**. These include the existence of **outdated regulations** that refer to now **defunct organizations** and requirements in **different documents** that are **overlapping or contradictory**.117 Such weaknesses are characteristic of the Chinese legal system in general.