# 1AC

### We affirm the resolution

### 1AC

#### 

#### 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.”

#### 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.

### 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.

#### 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).

### ROTB:

#### The roll of the ballot is to endorse the advocate that best sustains the human species.

#### 1] Life is intrinsically valuable. Without existence, no moral, political, or social values can be actualized — survival is a precondition to debate.

#### 2] Extinction outweighs all other harms. Death of everyone collapses all future utility, rights, and progress. Any risk of total human extinction must be prioritized above distributive or marginal harms.

#### 3] It generates stable decision-making. We can all agree that global catastrophe and annihilation are universally undesirable — making this framework a consistent and objective metric for adjudication.

#### 4] Scope & Magnitude: Extinction is the biggest impact possible — it affects everyone, forever. Even small probabilities of extinction outweigh certain harms of smaller magnitude, like economic loss or injustice, due to scale.

## 1AR

#### Trump already pulled out from renewables

**McDermott March 28** (McDermott, Jennifer. “Trump Administration Cancels Clean Energy Grants as It Prioritizes Fossil Fuels | AP News.” AP News, 28 Mar. 2025, apnews.com/article/trump-energy-department-clean-energy-wind-solar-batteries-hydrogen-fossil-fuels-cf1dff9ee771c566765e9ca3e3599d91.)

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.

#### Nuclear power and renewables are compatable

**Krikorian 24** (Krikorian, Shant. “Nuclear and Renewables: Playing Complementary Roles in Hybrid Energy Systems.” IAEA, 9 Sept. 2024, www.iaea.org/newscenter/news/nuclear-and-renewables-playing-complementary-roles-in-hybrid-energy-systems.)

A hybrid energy system combining both nuclear power and renewables can help significantly reduce greenhouse gas (GHG) emissions, according to participants at an event held today on the sidelines of the IAEA’s 63rd General Conference.

Hybrid systems could also foster cogeneration for seawater desalination, hydrogen production, district heating, cooling and other industrial applications. Research and innovation, the introduction of appropriate policies and market incentives are an important next step.

“Future energy systems will have to meet considerably stricter requirements not only on GHG emissions, but also other pollutants such as sulphur oxides, nitrogen oxides, mercury, heavy metals and particulates,” said IAEA Acting Director General Cornel Feruta. “Nuclear power can meet these stringent requirements — and does so competitively.”