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The Climate Issue

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Cover Image: "The Blue Marble" by the crew of Apollo 17, 1972

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"You cannot get through a single day without having an impact on the world around you. What you do makes a difference, and you have to decide what kind of difference you want to make."
–Jane Goodall

Special Thanks to. . .
Mr. Moriarty, Mr. Bean, Mr. Bignham, and Mr. Tyler

Editorial

Amidst a global pandemic, we cannot lose sight of another global crisis

Since the industrial revolution, humans have polluted the planet. By emitting heat-trapping greenhouse gases into the atmosphere, humans have sparked a rapid shift in the earth's climate. Scientists have been theorizing this "greenhouse effect," as it is called, since the 1800s, but only over the past few decades has this issue grabbed the world's attention. Thanks in large part to our generation, more attention is being paid to the issue of climate change. On the streets, we march in an effort to trigger political action towards a cleaner future. In our classrooms, we learn about the scientific processes that warm our climate. On our campuses, we innovate new sustainable technologies. But we must not let up on the pressure because this issue is more relevant and urgent than ever before. Remedying the shifting climate and its disastrous effects will take a relentless commitment that our generation must be willing to make.

Given the gravity of this threat to our society, the Helix magazine has decided to dedicate this issue to our environment. In the issue, we cover a range of scientific topics relevant to our planet, including nuclear energy, climate-affected hurricanes, and invasive species through the lens of conservation management. With our climate issue, we hope to strengthen our focus on the existential threat that climate change poses and our commitment to sustainable practices.

–Helix board

A Hyper-Smart Idea to Change the Way We Travel

by George Rose '21

Of all the carbon-intensive parts of our daily lives, fossil-fuel reliant transportation poses the biggest threat to our natural world. In fact, America's transportation sector now accounts for the largest portion of the United States' greenhouse gas emissions (1). In order to meet climate goals, the U.S. must drastically cut its dependence on fossil fuel powered cars, airplanes, and boats. While battery electric cars and high speed rail both offer cleaner alternatives to modes of transport currently in place, the Hyperloop possesses the potential to revolutionize the way we travel.

In 2012, Elon Musk recorded and detailed the idea of the Hyperloop in a paper entitled "Hyperloop Alpha" (2). In this paper, he described the need for an overhaul of our current transportation system, positing that any new system of transpor-

Figure 1: Hyperloop pod. Source: Ryn88668 (own work) for https://commons.wikimedia.org/w/index.php?title=User:Ryn88668&action=edit&redlink=1

tation need be "safer, faster, lower cost, more convenient, immune to weather, sustainably self-powering, resistant to Earthquakes, not disruptive to those along the route" (2, p.2), when compared with other options. Musk's headline: a trip from Los Angeles and San Francisco in Hyperloop would, in comparison with the 8 hour bus ride and 3 hour plane journey between, take just 30 minutes.

The hyperloop uses magnetic levitation and electric propulsion to shoot capsules at airplane speeds along a tube with an air pressure equivalent to what you would find at an altitude of 200,000 feet (3). The Kantrowitz limit, "nature's top speed law for a given tube to pod area ratio" (2, p.3), at first posed a large obstacle in creating a feasible design for the Hyperloop; however, the installation of an electric fan to pump air from in front of the Hyperloop to behind would fix this problem. Additionally, Musk called for compression fans in the tube to circulate air around the pods as they moved and thus provide a sort of air cushion (as an air hockey table does).

Economically, Musk estimates that the construction of the tube of Hyperloop would cost much more than the pods-- "several billion dollars" for the tube in comparison with just "several hundred million for the pods" (2, p.4). But Musk points out that the proposed California high-speed rail line costs in the tens of billions. Musk also notes that the Hyperloop, in comparison with high speed rail, has no derailments (which can sometimes result in casualties); requires just a tube and not a 100 feet wide portion

of land; and, with the right dampeners in each pylon holding up the tube, could be earthquake resistant.

How close are we to actually having a line in operation? Well, since Musk recorded this idea, he has largely removed himself from the process of constructing a Hyperloop. In his place various startups and student groups have taken on the project of developing the technology necessary to build a Hyperloop. The company at the forefront of the race to build a functional Hyperloop is Virgin Hyperloop One, which has solutions to many of the Hyperloop's lingering question marks. Their design combines magnetic levitation and electric propulsion, and their system is fully automated(4). With thick steel tubes, Hyperloop One minimizes the chance of a tube puncture, and software would immediately notice and communicate any issues with the tubes to the control center. However, some problems are yet to be solved. For example, if a tube puncture were to occur near a Hyperloop pod, the rush of air into the tube could propel that pod to supersonic speeds and potentially result in the death of passengers on board and failure of the whole Hyperloop system(5).

While the prospect of a Cleveland-Pittsburgh-Chicago triangle is now in the news, engineers for Hyperloop One have yet to surpass the 240 mph reached on their test track in Nevada (6). So for now at least, barring a surge in public interest or sharp increase in investment, the massive potential of the Hyperloop remains untapped.

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For further information on Hyperloop One's design, feel free to check out the linked video: www.hyperloop-one.com/hyperloop-explained

Reevaluating Invasive Species Through the Lens of Conservation Management

by Madeleine Cesaretti '21

Native species are good, and invasive species are bad --or so it often is implied. But did you know that the beloved honey bees of North America are not native to the continent? They were brought to the east coast by European settlers in the 1600s, which makes the honey bee technically an invasive species. Arriving during the 17th century on trade boats, the bees have since played an integral role in America's fruit and vegetable industries, pollinating and thus powering a large portion of the food we eat today (1). Yet, their invasive status is rarely brought up among conversation on conservation. As climate change continues to shape the world we live in, the geographical borders that traditionally play a role in defining a species, at least to an extent, are blurring. Many researchers are finding that species are shifting their ranges to cooler regions as the climate warms (2). How will we categorize "native" and "alien" species in the future in a biological context as the environment changes? More importantly, how will we manage or respond to these shifts?

Macalester College biologist Dr. Mark Davis and 18 of his fellow ecologists have been among the first to push back against increasingly outdated native-versus-alien species categorizations (3). They argue that species should be categorized based on the environmental impact they have rather than geographic origins (3). Dr Davis and his colleagues point out that the history of the term "invasive species" is rooted in militaristic language aimed at painting a hostile portrait of non-native species that exaggerates the threat that the newly introduced "invasive" species pose to its non-native environment. This serves to foster pushback against the non-native species that is driven by emotional sentiment rather than scientific objectivity (3). Their paper emphasizes the role that climate change plays in driving habitat change and urges that the native/alien dichotomy be put aside in favor of "more dynamic approaches to the conservation and management of species — approaches better suited to our fast-changing planet" (3).

The new approach to species categorization and management proposed by Davis et al has been met with controversy in the field of conservation. Many biologists have expressed reservations about discounting geographic origins in the classification of native versus invasive species and remain concerned that the potential risk alien species pose to new territories cannot be ignored (5). Their concerns are grounded by known examples of the harmful impact invasive species can exert on new environments. These examples include the introduction of Burmese pythons to the Everglade Forests of Florida and the introduction of Zebra mussels to the Great Lakes of Michigan. Originating from Southeast

Asia, Burmese python populations in the Everglades are thought to have arisen from escaped or released pet populations and as a result have been competing with native birds and reptiles in the Everglades for food as well as other resources (6). The U.S. Geological Survey has linked severe declines in mammal populations in the park to python predatory consumption (6). Originating from Eastern Europe, Zebra mussels are believed to have been carried across the Atlantic to the Great Lakes through attachment to wide-ranging ocean-going vessels. The invasive mussels have been rapidly reproducing and out-competing populations of native fish and native mussels for plankton since the 1980s (7). Zebra mussels also create conditions that result in deadly algae blooms in the Great Lakes as well as other bodies of water in which they have spread invasively (7).

An important distinction of the harmful effects that have been observed with the Burmese python and the Zebra mussel is that these species have been introduced to their new environments inadvertently, through transport over great distances by human trade and activity enabled by modern technological advances and cultural behaviors, instead of natural forces. University of Tennessee biologist Daniel Simberloff emphasizes that climate-displaced species are "not species from the middle of Asia being moved into Illinois" (8). Furthermore, University of Delaware entomologist Doug Tallamy states that species that have been displaced by climate change are much less likely to be as "ecologically disruptive as trade-dispersed alien species are" (8). Such species can be theoretically expected to settle where natural forces shape their best biological fit, as opposed to those which are introduced into completely foreign environments that are radically removed

Figure 1: Burmese Python in Everglades National Park. US National Parks Service. Source (10)

and foreign in every way compared to their original habitats. The farther from its original habitat a species travels, the more disruptive and imbalanced its impact on the local ecosystem might be if the newly introduced species is indeed able to gain a foothold. Once such a species has established itself, eradication requires concerted resources and efforts that ultimately may fail nonetheless (8).

Regardless of how a non-native species arrives in a new environment, consideration of other examples of invasion demonstrate that not all non-native species result in harm even when such harm is anticipated. In the southwestern United States, tamarisk trees were rapidly spreading alongside riverbeds (4). Many specialists feared that the trees were drawing too many natural resources away from the native plants already living there (4). They feared that should the natural plants disappear, so would the animals that depended on them, including several endangered species (4). Thus, many resources were employed by the government in a multi-million dollar campaign to eradicate the tamarisk tree, and yet in recent years, many conservation biologists have admitted that the early fears of the tamarisk tree have proven misplaced (4). Researchers have even found native birds nesting in tamarisk trees, where they thrive just as well as they do in native trees (4). A common metric for quantifying the impact of a species on an ecosystem is through its impact on the other species in that system; the issue is that none of the interactions of these species exist in a vacuum --making it fundamentally difficult to predict the outcome of the introduction of a new species. While the case of the tamarisk tree may be the exception to non-native species, it is important to recognize that sometimes these eradication efforts are not necessary. Given the case of the tamarisk tree along with those of the Burmese python and the Zebra mussel, how will we determine when prevention or eradication of species invasion is indicated in the future?

The U.S. Fish and Wildlife Service stresses the importance of prevention and early detection when it comes to potentially invasive species, but it does not specify whether or not this approach will be useful or applicable to the management of species whose "invasions" are being driven by increasing climate change (9). In an address to the Senate Committee on Environment and Public Works in 2017, the Service highlighted its "Invasive Species Strike Teams," that are "used to attack new outbreaks of invasive species before they obtain a foothold and cause major damage" among other methods of eradication (9). This statement does not address a differentiation between species that are introduced by inadvertent human activity and possibly more damaging to their new surroundings, and those species that are newly driven by climate changes and conceivably less predatory or harmful.

Yale University science journalist and author Sonia Shah cautions that "the categorization of wild species into natives and aliens was established in conservation and

entrenched in the U.S. economy during an era in which the most salient introductions of novel species arrived via global trade and travel" (8). Indeed, conservation is a field born of the mid-twentieth century, a period of prolonged stable environmental conditions accompanied by tremendous leaps in human advancement that resulted in the assumption that the natural world as it was seen and experienced at that moment was the world as it always was and always should be. Under such settings, determination of whether a species was invasive and measuring or attempting to predict potential damage from that species was a straightforward endeavor based on relatively simple premises and more often than admitted, driven in the public sphere by emotional sympathies for naturally appealing birds and mammals. Now, however, the world we live in is becoming more and more dynamic and in flux. How changes in the environment, climate, and human behavior are incorporated into our approach towards the management of species as they become increasingly on the move as a result of global warming remains to be seen. Towards that end, Dr. Davis and his colleagues' proposal, and others like it, are essential in pushing conservation management to evolve alongside our changing world.

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An "Apeeling" Discovery

by Zachary Stayn '22

"That sounds really nice, but you don't know anything about fruits and vegetables." That is how James Rogers' mom replied when Rogers confided he had thought up "an idea for a company" (1).

Rogers, then a Ph.D student at the University of California, Santa Barbara, had been literally "watching paint dry," by researching how to invent a solar paint that could harvest the sun's energy similar to the way solar panels do. Inspired by a radio report on world hunger, he had checked out a pile of books about water loss and oxidation, and he sought to create a product that extends produce's shelf life (1).

Drawing from the steel industry, where coatings prevent steel from rusting, Rogers believed he could create a coating that would prevent fruit from rotting (2). Extending produce's shelf life would not only lengthen supermarkets' window for selling produce but also would give consumers more time to consume it. It also would help growers by guaranteeing that distributors, who currently cannot deliver 40% of the food grown to consumers' locations, could deliver food to the supermarket without it spoiling (3). Thanks to a $100,000 grant from the Bill and Melinda Gates Foundation, Rogers became the CEO of a new start-up and hired two researchers to begin developing his idea (2).

The researchers first had to figure out how to develop a protective, anti-spoil coating that could be applied to food. Soon, they realized that the coating would need to be water soluble and non-toxic in order to stick to the produce and be edible. That idea built on plant fundamentals: over millions of years, plants have developed a cutin, a waxy barrier that protects against the outside conditions. The variation in cutin from plant to plant correlates directly with the fruit or vegetable's shelf life. For example, a lime stays fresh for longer than a strawberry because the molecules in a lime's cutin are denser than those in a strawberry's cutin (4).

Even after identifying which part of the cutin is water soluble, Rogers and his team still needed to figure out how the cutin protects against the various factors that contribute to spoilage. Researchers took advantage of the fact that lipids are amphiphilic, meaning that they love water and oil. While in water, the number of water molecules exceed the number of lipids, making them water soluble, but as the water evaporates, the lipid molecules organize into an arrangement that holds in moisture and resists oxygen. By keeping the fruit or vegetable hydrated and by reducing the fruit or vegetable's oxygen supply, lipids permit the fruit to conserve nutrients needed to carry out cellular functions and to avoid the stress of oxidation and dehydration, which accelerate molding (4)

In essence, Rogers and his team harnessed the properties of molecules to create a "microclimate" within the plant (5). Their Califor-

nia-based company, Apeel Sciences, has discovered how to capture the "plant kingdom's own evolved defense against [a] trifecta of maladies" and how to transform that defense into a marketable, all-natural spray coating that forms a thin, edible peel on the surface of produce to prolong its freshness (5). Today, Apeel Sciences has become a $420 million company, and it was recognized this year by CNBC as one of the "top 50 private companies whose innovations are revolutionizing their industries and the way we live" (6).

This past September, Apeel Sciences partnered with The Kroger Company, the United States' largest supermarket chain by revenue, to sell Apeel-coated produce as part of Kroger's Zero Hunger Zero Waste initiative that aims to decrease hunger and get rid of food waste by 2025. This opportunity enabled Apeel Sciences to scale up its pilot program into a nationwide campaign. Now, Apeel avocados, limes, and asparagus are carried in over 1,100 Kroger stores, hundreds of Costco stores, and dozens of other regional supermarket chains (7). Having already saved billions of gallons of water, millions of avocados, and dozens of acres of farmland, Apeel Sciences continues to grow and innovate. The company's next area of growth is in developing nations, such as Nigeria and Kenya. Having won regulatory approval to use Apeel on produce from the U.S., E.U., and Africa, Rogers hopes that Apeel will keep the "produce fresh long enough to be transported from rural areas to larger markets where they can feed the local population" (1).

Looking back, Rogers laughs at his mother's initial reaction to his idea for a company. However, Rogers admits he learned that "it's oftentimes the combination of the stuff that you know about and the willingness to learn the stuff that you don't know about which leads to some really cool innovations" (1).

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Warming Waters Fuel Nature's Most Powerful Storms

by Wilder Crosier '21

On September 20th, 2017, Hurricane Maria made landfall in Puerto Rico and began a tour of destruction. With sustained 155 mph winds, Maria ripped the roofs off of homes, tore down electrical wires, and uprooted trees. Maria's storm surge–the tsunami-like displacement of water caused by the combined effect of the storm winds and high tide–flooded the streets with over 30 inches of water that carried debris and sewage (1). Following the storm, all of Puerto Rico had lost electricity, and many people had limited access to food or clean water. According to the Puerto Rican government, the official death toll was 2,975 people and the cost of damages totaled $94.4 billion (1). Even today, Puerto Rico is still recovering from the devastation caused by this storm.

Figure 1: Hurricane Maria in 2017. Source: U.S. Naval Research Labs.

Hurricanes (known globally as tropical cyclones) like Maria are some of the most powerful weather events that the earth experiences; these rotating storms can be hundreds of miles in size and can bring mass devastation (2). But what makes a hurricane so powerful?

From a thermodynamics point of view, hurricanes are extremely efficient heat engines that convert the energy stored in warm water into wind energy through a Carnot Cycle (the theorized thermodynamic cycle using two thermal reservoirs to transfer heat into work at maximum efficiency) (3). Hurricanes form over tropical oceans where the sun has warmed the water to over 26.5°C (80°F) (4). Because water has a much larger heat capacity (the ability to store more heat energy per unit increase in temperature) than air, the ocean water, though at the same temperature as the air, carries much more energy. The internal energy difference puts the water and air into thermodynamic disequilibrium which causes ocean water to evaporate into the undersaturat-

ed air (3). This warm air can develop into the fuel for a new hurricane if a pre-existing disturbance of low pressure exists over the ocean. The warm water vapor flows to the low pressure center (what will become the eye of the hurricane), and then rises upward in what is known as the eye wall. Once this warm air reaches the boundary between the lowest and second lowest layers of the atmosphere, it spreads outward in all directions (see figure 2). The exiting water vapor now condenses into thunderstorm clouds, releasing the latent energy from the water vapor into sensible heat (heat that confers a temperature change) that warms the air (2). At the same time, a rain free region is formed at the center of the storm as some of the risen warm air sinks back down into the eye (9). When the surrounding air moves down the pressure gradient towards the low pressure center of the storm, due to the Coriolis Effect caused by earth's rotation, the inward moving air takes on a rotation and becomes the hurricane's devastating winds. These inward-bound winds collect warm water vapor from the ocean and rise up the eye wall, warmed and fueled as well by the energy released from the previous condensation of water vapor (5). So long as the hurricane moves over warm ocean water, it can sustain its power by transforming the warmth from the water vapor into its spiraling winds.

In the future, these enormous and destructive heat engines will only be offered more fuel. Because humans have increased the amount of greenhouse gases in the atmosphere, energy radiated from the earth towards space is increasingly scattered back to the plan-

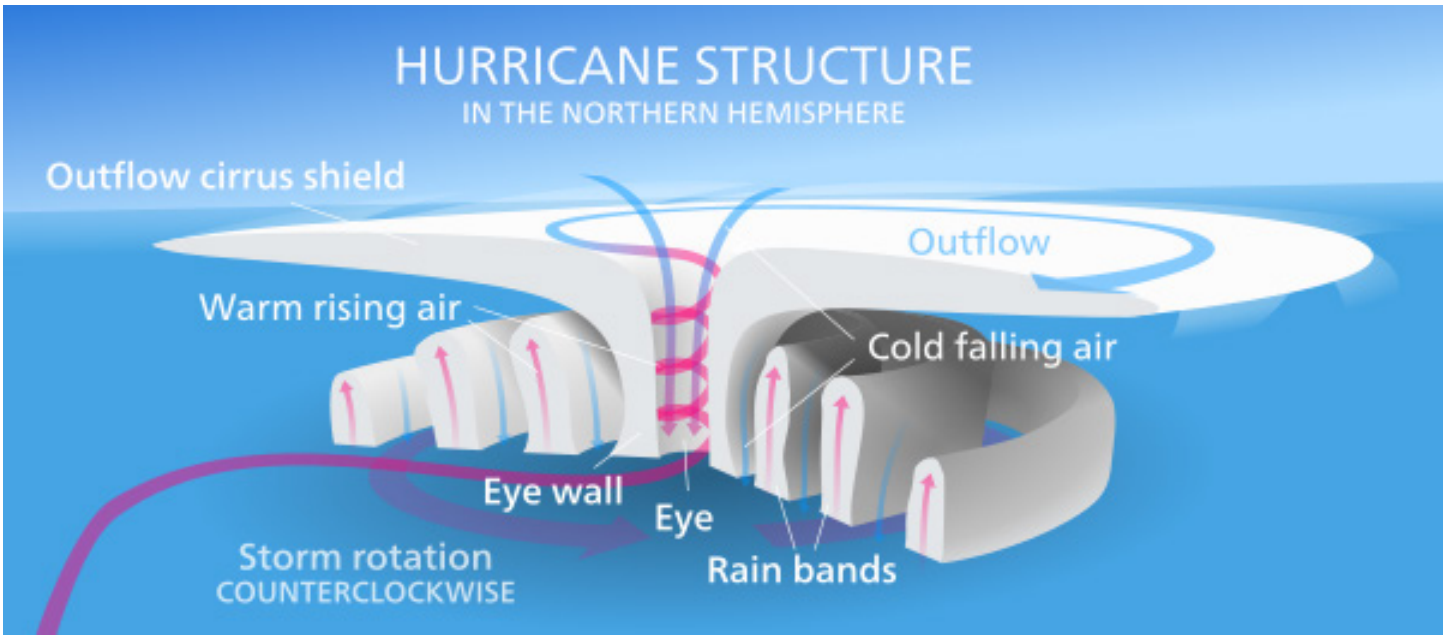

Figure 2: Diagram of airflow in a hurricane. Surrounding air moves towards the low pressure center and is warmed by the water below. This warm air rises upward in the eye wall, then disperses and cools to form clouds. Some higher pressure air from above also flows down to form the eye. Source: "Anatomy of a Hurricane" by Kelvin Ma for Wikimedia Commons. https://commons.wikimedia.org/wiki/Commons:Featured_picture_candidates/File:Hurricane-en.svg

et—a process known as the greenhouse effect (6). From 1971 to 2010, the oceans, due to their widespread cover of the earth and water's large heat capacity, have taken in 93% of the increase in the earth's energy (6,7). Studies of the upper ocean between 1997 to 2010 show that each square meter of water was gaining over 0.36 joules of energy every second (6). Because warm water fuels hurricanes, warmer oceans caused by global warming will lead to more powerful storms. Scientists do not predict that global warming will cause an increase in the number of hurricanes per year, but they do predict an increase in the strength of the hurricanes that do occur (8). Additionally, the sea level rise caused by climate change worsens some hurricane effects. Higher sea levels create a stronger storm surge–the most deadly effect of hurricanes–which would lead to worse flooding in coastal regions (8).

Hurricanes–like Maria in 2017–can devastate communities. With the populations of US coastal communities growing faster than the populations in any other part of the country, these intensifying storms pose increasingly dangerous risks for human safety and infrastructure costs (6). Strong evidence suggests that global warming will create stronger hurricanes in the future. These powerful storms are just one of the many ways that mankind's impact on the climate is indirectly and increasingly putting many other humans in danger.

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Nuclear Policy in the 2020 Presidential Race

by Nikhil Pande '21

Although many prominent members of our government deny the existence of climate change, it continues to ravage communities across the world through natural disasters, destroying their respective economies. This menace to our society demands action, not just by a minority of citizens, but also by the US government. Many of the 2020 Democratic candidates proposed sweeping plans to combat climate change, with goals to reduce net carbon emissions to zero over the next 30 years. For example, former candidate Andrew Yang proposed reaching this goal by 2049, presumptive Democratic nominee Joe Biden by 2050, and Cory Booker by 2045, the date fluctuating due to discrepancies in their individual plans (1). In fact, "Special Report on Global Warming of 1.5 C," written by the Intergovernmental Panel on Climate Change, found that to keep global warming under 1.5 °C from pre-industrial temperatures, net-zero carbon emissions must be reached globally by the year 2050 (2). In this case, net-zero carbon emissions implies that the amount of carbon emitted into the atmosphere equals the amount of carbon removed from it. Elizabeth Warren, Massachusetts senator and former Democratic candidate for president, laid out in her "100% Clean Energy for America" plan that the United States should achieve, "by 2035, 100% renewable and zero-emission energy in electricity generation" (3). But her plan includes one distinction—no new nuclear power plants.

Elizabeth Warren, along with Bernie Sanders, is among many progressives who reject the notion of nuclear power as a carbonless alternative to fossil fuels. Specifically, they cite the danger of the plants in a terrorist attack, nuclear waste, and the general difficulty of mining uranium. But perhaps the most powerful evidence of the threat that current day nuclear power poses is the disaster of Chernobyl in the Soviet Union. In 1986 the Chernobyl Power Complex in Kiev caught on fire as a result of a poor reactor design, killing 30 people during the explosion but many more from radioactivity (4). But its cost was also devastating for the USSR (5). Between the cost of the accident and the attempted coverup by Mikhail Gorbachev and the Communist Party, this incident certainly contributed to the ultimate downfall of the Soviet Union (5). Fear of an American version of Chernobyl has fueled this anti-nuclear movement.

To an extent, their fears are warranted: the uranium ore used in current day nuclear plants does produce highly radioactive waste and is dangerous to mine. However, the promise of a different nuclear innovation—thorium based nuclear power—can provide more energy under safer conditions. Current-

ly, nuclear power is generated through the fission of the U-235 atom. Workers mine for uranium ore, the majority of which is non-fissile U-238, while only about 0.7% is U-235 (6). However, another fissile uranium isotope, U-233, can be created from thorium and used to generate nuclear energy (7). The thorium nuclear reactors enjoy much safer conditions for a number of reasons. First, molten salt reactors, the reactors in which thorium power is generated, don't perform the reactions under high pressure environments, as uranium reactors do (8). Second, thorium energy doesn't produce nearly as much radioactive waste as its uranium counterpart, decreasing the danger and the need for storage (9). Both of these advantages decrease the likelihood and severity of a nuclear meltdown. But society over the past few decades has preferred U-235 power because of the Pu-239 that comes as a byproduct (10). While the U-235 nuclei are split, the U-238 ultimately decays into Pu-239, a substance that can be weaponized through nuclear weapons (10). This plutonium is one of the many types of radioactive nuclear waste generated by U-235 nuclear power, cited as one of the dangers of this method of energy.

Figure 1: Nuclear Power Plant. Source: Felix König https://commons.wikimedia.org/wiki/File:-Gundremmingen_Nuclear_Power_Plant.jpg

The policies of anti-nuclear activists, such as Warren and Sanders, rely solely on renewable energy sources to reach our ultimate climate goals. However, scientists warn that these former candidates' confidence in solar, wind, and water-based energy may be over-inflated. Especially for Warren's goal of U.S. net-zero carbon emissions by 2035, reliance on only renewables may not achieve this goal. Instead, the progressive wing must consider the prospect of thorium-based nuclear energy as a long-term power source, or at least an intermediate transition from fossil fuels. It's not a ridiculous idea for the United States—France generates 75% of their energy from nuclear sources—and it is certainly more efficient in reaching our ultimate net-zero carbon emissions goal, whenever the deadline may be.

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