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US SEZs for The New Atomic Age: Energy Innovation Zones

Maxwell Tabarrok
College of Arts and Sciences, University of Virginia
maxwell.tabarrok@gmail.com
ORCID 0000-0001-7609-1525

Abstract:
Energy is a fundamental instrument in nearly all things that humans find valuable. Over the past 200 years, there has been consistent growth in energy access per capita at an exponential rate of about 2% a year, mostly due to greater understanding and control over fossil fuels. However, since 1970, our growth in energy access has stagnated. This paper suggests a way to address this stagnation through a low-hanging fruit policy change: The "Energy Innovation Zone" (EIZ). This is a special jurisdiction that focuses on accelerating energy growth. This paper considers EIZs in the United States. We quantify the potential of advanced nuclear and geothermal power based on the extrapolation of historical data and the theoretical limits of each power source and then show that these sources are sufficient for accelerating energy growth. Then we summarize the current state of regulation of underutilized forms of energy production and show that this regulation explains most of the observed stagnation in energy growth. Next, we propose the idea and structure for the Energy Innovation Zone and point out specific statutes that would have the largest impact when relaxed or repealed in the special jurisdiction. Finally, we will conclude with an analysis of the political feasibility of such a proposal. We find that EIZs have the potential for large and long-term impact and are more feasible than other energy policy reform strategies.

Keywords: Nuscale, Beach Bottom, Nuclear plant, Special Economic Zones, nuclear energy, Energy Innovation Zone, NEPA, Nuclear regulatory comission, Idaho National Laboratory.

Resumen:
La energía es un instrumento fundamental en casi todas las cosas que los humanos encuentran valiosas. Durante los últimos 200 años, ha habido un crecimiento constante en el acceso a la energía per cápita a una tasa exponencial de alrededor del 2% anual, principalmente debido a una mayor comprensión y control sobre los combustibles fósiles. Sin embargo, desde 1970, nuestro crecimiento en el acceso a la energía se ha estancado. Este documento sugiere una forma de abordar este estancamiento a través de un cambio de política de frutas maduras: la "Zona de Innovación Energética" (EIZ). Esta es una jurisdicción especial que se enfoca en acelerar el crecimiento energético. Este documento considera las EIZ en los Estados Unidos. Cuantificamos el potencial de la energía nuclear y geotérmica avanzada con base en la extrapolación de datos históricos y los límites teóricos de cada fuente de energía y luego demostramos que estas fuentes son suficientes para acelerar el crecimiento de la energía. Luego resumimos el estado actual de la regulación de las formas infrautilizadas de producción de energía y mostramos que esta regulación explica la mayor parte del estancamiento observado en el crecimiento de la energía. A continuación, proponemos la idea y la estructura para la Zona de Innovación Energética y señalamos los estatutos específicos que tendrían el mayor impacto cuando se relajaran o derogaran en la jurisdicción especial. Finalmente, concluiremos con un análisis de la factibilidad política de tal propuesta. Encontramos que las EIZ tienen el potencial de un impacto grande y a largo plazo y son más factibles que otras estrategias de reforma de la política energética.

Palabras Clave: Nuscale, peach bottom, planta nuclear, energía nuclear, Zona Económica Especial, Zona de Innovación Energética, NEPA, Comision de regulación nuclear, Laboratorio Nacional de Idaho.

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1. INTRODUCTION:

Whether our goal is to extend the human lifespan, mitigate climate change, or simply advance the material wealth of our society, greater access to energy is needed (Roser, 2021). The unprecedented rapid rise in per capita living standards that we have experienced over the past 200 years have coincided with an equally exponential rise in per capita energy use (Hall, 2021). Recent stagnation in economic growth in the United States is similarly correlated with stagnation in energy growth (Hall, 2021). Much of this stagnation is caused not by technological constraints, but rather by institutional failure. Stringent and expensive permitting procedures have, since their conception in the 1970s, ballooned in cost and domain. Expansion of committee consensus bureaucracy, distribution of veto power, and incentive structures that promote risk aversion have weakened our ability to construct world-changing (Collison, 2020) infrastructure. Although the organization of these institutions are path dependent and difficult to reform due to self-reinforcing ("Parkinson's law," 2022) incentive structures (Crawford, 2021), small scale experimentation with special jurisdictions has a proven track record (Baissac, 2011) of leading to positive effects and even national scale reform.

In Section I, we will quantify the potential of advanced nuclear and geothermal power. These are the only terrestrial energy sources which are plentiful, clean, and controllable enough to grow our energy production by several orders of magnitude without imperiling the health of our planet. Then in Section II we will give an overview of the current state of regulation of underutilized forms of energy production. We will focus on nuclear and geothermal energy as these sources are carbon neutral with high energy potential and demand-variable output. These characteristics are necessary to fully replace and expand beyond our fossil fuel energy sources. These sources are also highly regulated relative to alternatives which makes marginal deregulation much more effective since they are so strictly regulated in the status quo that even small legal changes can have big effects on energy output. Section III will lay out the idea and structure for the Energy Innovation Zone and point out specific statutes that would have the largest impact when relaxed or repealed in the special jurisdiction. Finally, Section IV will conclude with an analysis of the political feasibility of such a proposal and a discussion of how we might align the interests of existing stakeholders and acquire their support.

1. THE POWER OF NUCLEAR AND GEOTHERMAL POWER

1.1. We Need More Power

Energy growth and economic growth have moved in tandem exponential growth for the past few hundred years. This is because most economic growth consists of moving atoms around into more useful patterns than they began in. This takes energy, so if we want to get more growth we need to move more atoms around which takes more energy. Since the 1970s, US energy growth has fallen off the exponential growth trend and stagnated as shown in the graph below.

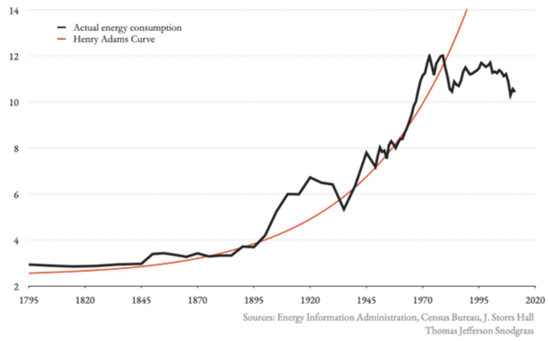

Figure 1: The "Henry Adams Curve" plots a 2% growth rate in energy use per capita which we followed closely until 1970

By some measures, our economic growth remained on its exponential growth path despite this energy stagnation. This reflects some positive trends. We are becoming more efficient in our production methods (Perry, 2011) and we are dematerializing (Mcafee, 2019) as we move more of our economic growth from atoms to digital bits. However, our economy shows many signs of stagnation, and arguably more important measures of economic growth like median income, graphed below, have flattened along with energy growth.

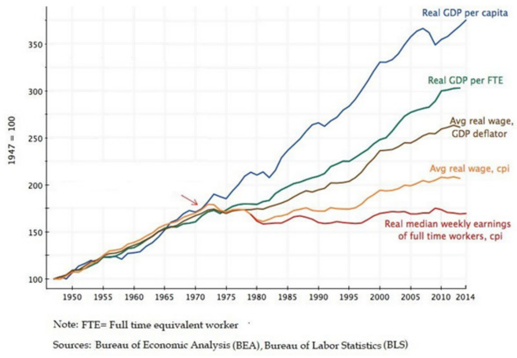

Figure 2: Real GDP, Real Wages and Trade Policies in the U.S (1947-2014)

If we want to continue economic growth and guarantee that everyone sees significant material improvements to their lives, we need more energy.

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1.2. Tradeoff Between Power and Planet

The two most pressing problems facing humanity today are global warming and global poverty. It seems, at first, that solutions to these problems are at odds with each other. To alleviate global poverty, we need more economic and energy growth, which has traditionally meant emitting more carbon into the atmosphere. Many people similarly believe that in order to avoid climate disaster we need to scale back economic growth and stagnate ("Degrowth", 2022). If we treat our current level of technology as fixed, growth skeptics are right that the tradeoff between economic growth and environmental protection is unavoidable. However, new energy production technologies allow us to move past the frontier of this tradeoff to get more energy and less carbon; more growth and less environmental damage. Nuclear and geothermal energy are the two most promising paths towards transcending the tradeoff between power and planet.

1.3. Nuclear Energy

The potential of nuclear energy has been known for decades. Since the 1950s, scientists have predicted utopian futures with abundant energy supplied by the peaceful atom. Although these futures have not yet come to pass, the source of this optimism is grounded in the physical properties of nuclear energy. Nuclear power's high energy density, carbon free by-products, and versatility make it a powerful energy source for an optimistic future.

Nuclear energy has extremely high energy density. Energy density can be measured gravimetrically (unit of power per unit of weight) or volumetrically (unit of power per unit of space), by either metric nuclear power is very dense. One gram of uranium could produce the same amount of energy as a metric ton of oil (Ausubel, 2015). Mass has a lot of energy, and nuclear fission is orders of magnitude more efficient at extracting that energy from mass than any chemical reaction. Nuclear power plants also have a small volumetric footprint, graphed below, and they are getting smaller (Cheng & Hammond, 2017).

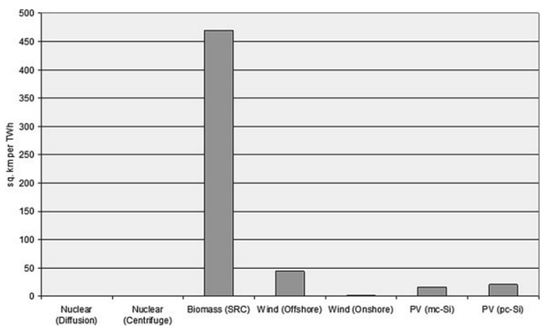

Figure 3. Kilowatt hours per square kilometer of various fuel sources

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Greater energy density than fossil fuels is an essential characteristic for any technology that aims to supplant their top spot in our global energy production function. This is because energy demand is becoming denser as urbanization rapidly increases and energy consumption per square meter goes up. Without high energy density and economies of scale, keeping up with increasing and densifying energy demand will quickly spiral out of control. Solar and wind energy, for example, have basically constant returns to scale. To double power output, you need to double the land area that you farm. This is not a sustainable way to keep up with exponentially increasing energy demand. Electricity production from nuclear reactions has steep increasing returns to scale, and the parts of the energy supply chain with lower returns to scale such as fuel mining are a small fraction of the cost per kilowatt since they fuel is so energy dense.

Nuclear energy is a carbon free energy source. The only by-products are heat and a small amount of spent fuel which can be safely stored or used again. Compared to other renewable energy sources, nuclear is more environmentally friendly. It uses much less land, leaving more space for carbon-sucking plants and animals, and it requires much less cement, steel, and lithium per kilowatt (Cheng & Hammond, 2017).

Nuclear energy is also a very versatile energy production technology with lots of room for new innovation and cost decreases. Nuclear power generators can occupy a wide range of scales, from huge 1000+ MW power plants, to small modular reactors, or even individual vehicle scale ("Nuclear Submarine", 2022) nuclear engines. The range of effective scale means that nuclear power has the potential to change our relationship with energy, not just for grid level production, but also for individual use. Reactors small enough for cars or trucks are possible, and they could give rise to cars that have million-mile ranges on a single pellet of fuel. Alternatively, the heat from nuclear reactors can be used to manufacture hydrogen which goes into electricity producing fuel cells in cars, planes, airships, and whatever else you can imagine. Further developments in nuclear tech, like fusion reactors, would be a huge next step on our journey up the Kardashev scale. All of these technologies are expensive and hard to build now, but learning by doing and economies of scale are powerful forces. They pushed prices of solar panels down over 90% in the past 10 years (Roser, 2020b) and are responsible for the astounding cheapness of all of our consumer goods. If we let people mass produce and experiment with nuclear reactors, their costs can come down and their influence can spread.
Nuclear energy has the potential to change our economy and our environment for the better.

1.4. Geothermal

Geothermal energy is the process of transferring heat from the core of the earth into electricity. This is usually done by injecting a fluid as deep into the earth's crust as we can go, bringing it back up, and using that heat to spin turbines. Geothermal today is an insignificant source of energy, producing only

.4% of the US's total energy consumption. It has more potential, however, than all forms of chemical and radioactive energy combined. The massive size of geothermal energy reserves, abundance of possible extraction points, and spillover between the natural gas and mining industries make geothermal a promising path forward toward expanding and decarbonizing our energy production.

The size of geothermal energy reserves is difficult to comprehend. If you add up liberal estimates of the energy content of all of the possible coal, oil, gas, and methane in the Earth's crust, you find about 630 zettajoules (one zettajoule is about 7 trillion gallons of gas) of energy (Dourado, 2021) .The total amount of geothermal energy in Earth's crust is 23 thousand times that. Even after adding potential radioactive energy, crustal thermal energy reserves dwarf everything else.

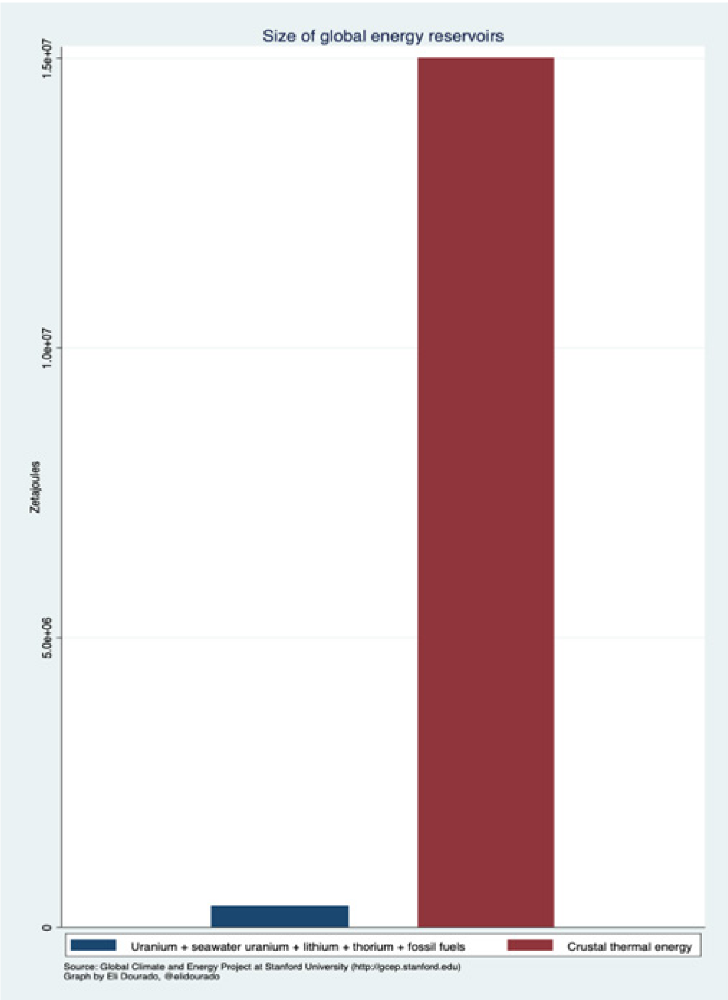

Figure 4: Size of global energy reservoirs. Source: Global Climate and Energy Project at Stanford University

Geothermal energy is also accessible almost anywhere on earth, as long as you can drill deep enough. Our current shallow wells rely on geothermal springs which are rare, but the deeper you go, the hotter it gets everywhere. If we can get better at drilling, just about anywhere in the western US will be a potential source of dirt-cheap electricity.

This brings us to geothermal's third exciting characteristic: it can take advantage of advances in drilling technology made during the natural gas/fracking boom. Fracking works by drilling a deep hole, and then pumping high pressure water into it. This creates a root-like network of fractures in the rock that spread out and release lots of natural gas from the shale. This fracture network also happens to be a very efficient way to transfer heat from rock into a fluid. This fluid could then be pumped back up and used to spin turbines and generate power. The more we learn about the properties of drilling and fracturing rock, the closer we get to Enhanced Geothermal Power which could unlock the massive energy reserves right below our feet. In addition to the natural gas industry, geothermal also has spillovers with the mining industry. Specifically, lithium mining. As a side effect of gathering heat from rock, hot fluid also dissolves many minerals from the rock around them. One of the most easily dissolved minerals is lithium. In recent tests of a geothermal plant in England, more than 250 milligrams of lithium per liter of the fluid was found. Since lithium is an essential material for batteries, this property not only subsidizes the cost of geothermal production but complements nicely with other forms of renewable energy and electricity in general.

Although geothermal is small today, it has the largest potential of any terrestrial energy source. Learning how to harness it would give us access to cheap energy and lithium almost anywhere in the world.

2. REGULATION OF ENERGY INFRASTRUCTURE

2.1. Regulatory Framework

The modern process of building any infrastructure, including energy production, is defined by a set of standards and procedural regulations put in place during the environmental movement of the 1970s. Chief among these is the National Environmental Policy Act (NEPA). Passed unanimously through the senate in 1969, this law requires all federal agencies to issue reports on the possible environmental impacts of any action they might take. This includes issuing of federal permits or approvals to private projects, and therefore NEPA effectively applies to these private projects as well. NEPA reviews started out as manageable and perhaps even beneficial considerations of environmental impact, but through a process of public comment, bureaucratic growth, and litigation pressure, NEPA compliance has ballooned into years long hundred-page projects that handicap our ability to build fast and innovate in infrastructure.

There are three possible ways to comply with NEPA. First is a categorical exclusion. These are activities that are pre-approved as having no environmental impact and can therefore avoid the subsequent paperwork. For example, the Federal Highway Association has designated actions ("National Environmental Policy Act," 2022) such as construction of bicycle and pedestrian lanes, noise barriers, and landscaping normally as not individually or cumulatively having a significant environmental effect and therefore may be categorically exempt. There are, however, exceptions if the construction has a chance to involve any endangered species or historic places. If an activity is pre-approved for a categorical exclusion, then NEPA compliance is relatively simple. Getting a categorical exclusion for a new activity, however, can be complex and expensive. An application for such an exemption requires fastidious study of "the entire proposed action and not be used for a segment or an interdependent part of a larger proposed action." Even if the proposed action has been environmentally assessed and found to have no significant impact by other agencies, a new report must be drafted and made available for public comment. Categorical exclusions are mostly used by federal agencies to justify day-to-day bookkeeping operations, minor amendments to permits or licenses, and small scale research. They can be used for more ambitious projects though. The oil and gas industry has numerous exceptions ("Energy Policy Act of 2005," 2022) to environmental procedures and standards and BP's Deepwater Horizon project was approved with a categorical exclusion. Although the categorical exclusion can be the most convenient way to comply with NEPA, it is still a product of bureaucratic procedure, case law, and is still expensive.

The federal actions most relevant to this paper: permitting new energy infrastructure, are not generally afforded categorical exclusions. Instead, they must go through the longer and more arduous process of environmental assessments (EA) and environmental impact statements (EIS). Environmental impact statements are extremely costly in time and labor and they are getting more expensive quickly. The average length of an EIS is more than 600 pages (Executive Office Of The President Council On Environmental Quality, 2019) plus appendices, which themselves average over 1,000 pages.

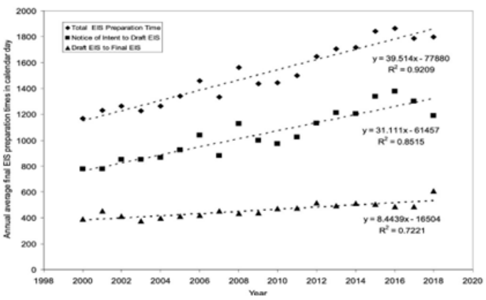

Figure 6: Average annual preparation times for final supplemental EISs Source: https://medium.com/cgo-benchmark/why-are-we-so-slow-today-c34dad4d2bff

These huge documents take an average of four and a half years to complete, and several have stretched beyond a decade (Executive Office Of The President Council On Environmental Quality, 2018). These averages do not count projects that are currently stuck in decades long environmental review. Not only are EIS statements long, but they are also getting longer every year.

This regression from the National Association for Environmental Professionals (National Association of Environmental Professionals, 2018) shows that EIS preparation time is increasing an average of 39 days every year. Due to the snail's pace of review and the lengthy process required to even begin an environmental impact statement, only around 200 are approved each year. Environmental Assessments (EAs) are the reports you file to find out if you need to file the EIS report. Environmental assessments (EAs) are much more common with about 12,000 completed every year. Most actions that submit an EA are found to have no significant impact and are approved. These are usually shorter than EIS, but they have also been growing in size. For example, the environmental assessment for a proposed runway approach procedure at Boston Logan Airport (Environmental Science Associates & Daniels, 2022) currently stands at 2,100 pages.

Although NEPA environmental reviews and assessments require meticulous depth and accuracy, they do not necessarily protect the environment. Federal bureaucracies have the authority to approve an action even if an environmental review finds that significant environmental damage would result. NEPA review also frequently delays or prevents projects that would have huge environmental benefits. In July of 2021, plans for Nevada's largest solar power plant were terminated by the Bureau of Land Management because of protest from a small group of 'environmentalists.' NEPA requires that this sort of public comment be sourced and obeyed multiple times throughout the timeline of any infrastructure project.
Democratic consent for large infrastructure is desirable, and a majority of voters approved a state-wide transition to majority renewable energy, but distributing this sort of veto power to so many small groups of people creates hold-up problems and paralyzes us. Another project, a 550 Mw solar farm in the Mojave Desert built by BrightSource was delayed by decades and compelled to produce tens of thousands of pages of environmental review. The main subject of the 36 boxes of project files kept by the Bureau of Land management was the Desert Tortoise. Although the project takes up only a fraction of a percent of the Tortoise's total habitat and the animal is classified in the least threatened group of endangered animals, huge concessions were made on the Tortoise's behalf.

> "BrightSource negotiated with state and federal agencies to hash out meticulously detailed protocols for collecting and relocating tortoises, also agreeing to monitor them for five years after they were moved. The company made its first concession to the tortoise during planning, giving up about 10% of its expected power output in a redesign that reduced the project footprint by 12% and the number of 460-foot-tall "power towers" from seven to three. BrightSource also agreed to install 50 miles of intricate fencing, at a cost of up to $50,000 per

> mile, designed to prevent relocated tortoises from climbing or burrowing back into harm's way." (LA times, 2012)

After an initial survey of the area found 16 tortoises, the U.S. Fish and Wildlife Service issued BrightSource a permit to move a maximum of 38 adults and allowed a total of three accidental deaths per year during three years of construction. Any more in either category and the entire project would be shut down. BrightSource has paid for hundreds of biologists to survey the area and care for relocated turtles, donated millions to a Desert Tortoise Wildlife Management Area (Donnelly-Shores, 2014), and relocated thousands of tortoises. Still, the national environmental group Defenders of Wildlife filed a notice of intent to sue the government, citing violations of the Endangered Species Act, which the desert tortoise is protected under.

There is far too much money, brainpower, and time devoted to this minor environmental cost of renewable energy infrastructure. Any reasonable cost benefit would find that although a large solar farm does take up several square miles of land, the value of thousands of megawatts of carbon-free energy far outweighs aesthetic complaints from sparse nearby residents or danger to the Desert Tortoise. At most, a form of Pigouvian compensation could be paid to the sparse residents in the area for the disutility of looking at a solar farm, or money donated to the conservation of local wildlife. Instead, projects that are essential to avoiding carbon catastrophe are terminated by bureaucratic procedure.

NEPA is at the center of US environmental policy, and it acts as a primary model for federal environmental agencies to make policy (Marchman, 2022). For example, through the Endangered Species act of 1973, the US Fish and Wildlife Service enforce compliance by requiring federal agencies to produce lengthy environmental and economic reviews of any actions which could interfere with one of the thousands of endangered plants and animals or hundreds of 'critical habitats' within the US. These procedural rules form the backbone of environmental regulation in the United States. They are ornamented with thousands of specific statutes and standards covering everything from water pollution to the breeding habits of the American Alligator. Some of these standards are intelligent policies that pass cost-benefit tests, most of them are not. Several percentage points of our national GDP: hundreds of billions of dollars (Pizer & Kopp, 2003), is spent on compliance with these standards, and countless more is lost in the forgone surplus from beneficial projects that were shut down.

2.1. Nuclear Energy

Within the already suffocating overarching regulatory framework, nuclear energy is subject to a slew of specific regulations that further drain its potential. These extra rules come primarily from guidelines set by the Nuclear Regulatory Commission (NRC). Poor regulatory incentives have led to radiation standards that defy science, catch-22 testing policies, and extremely long and expensive design certifications.

To understand the costs of regulation, let's go through the process of building and operating a nuclear reactor from start to finish, stopping at all the regulatory barriers along the way. The process begins with certifying the design of your nuclear reactor. This will take at least 5-7 years and cost tens of millions of dollars. It will take longer if you propose a new design, like a molten-salt or small modular reactor, even though these designs can exceed the NRCs safety requirements by thousands of times (Batkins et al., 2017). Next you have to approve the construction site for the power plant. This leaves the NRCs direct authority and ventures under the NEPA umbrella. These construction approvals are also years long and expensive projects as your power company must draft up thousands of pages of studious environmental review (are there any Desert Tortoises in the area?). At any point in this process, a small group of motivated 'environmentalists' can force you to circumscribe the scale of your project, increase your spending on regulatory compliance by tens of millions, and even sue to stop your project all together. This is likely to happen because fear and opposition to nuclear power is pervasive in western society, despite the technologies stellar safety record ("Anti-nuclear movement," 2022). If, after a decade or so of paper work and court cases you have managed to avoid bankruptcy and public unrest, you can build and begin operating your plant. The costs of regulatory compliance are just beginning, however. The American Action Forum (Batkins et al., 2017) found annual ongoing regulatory costs range from $7.4 million to $15.5 million per year per plant, mostly related to paperwork compliance. They also collected data on capital expenditures (capex) for nuclear power plants. This includes uprates, extended operations, equipment replacement, and regulatory spending. Based on this data, regulatory capex has more than tripled from 2006 to 2015, from $629 million annually to $2 billion. This is by far the fastest-growing category of capex in the surveys. Because the number of nuclear plants has declined since 2006, the cost per plant has also increased by more than 340 percent. In 2015, the most recent year data are available, the percentage of regulatory spending has climbed to 32 percent of total nuclear capex. Combine this with an average 20 million dollars in fees paid to the NRC each year. In all, there are at least $15.7 billion in regulatory liabilities for the industry, or $219 million per plant. Regulatory compliance in the United States' nuclear industry adds decades to project timelines and hundreds of millions of dollars to their costs.

Although it is undeniable that some costs of regulatory compliance are necessary, the rapidly rising regulatory costs don't show up in other countries and don't track with the rapidly increasing safety of nuclear technology.

Costs of nuclear construction were decreasing rapidly in the 50s and 60s as scientific knowledge advanced alongside engineering experience and learning by doing. Then, in the mid-1970s as multiple layers of environmental and safety regulation were piled on, costs exploded, and new construction stopped. Like the extra regulation, however, this trend was unique in the US. France managed to keep costs constant through this period and South Koreas costs declined by 13 percent for reactors constructed between 1989 and 2008. Additionally, even though safety and environmental review costs are getting higher, nuclear reactors have been getting much safer. NuScale's small modular reactor design is 10,000 times less likely to meltdown than existing light-water reactors (NuScale Power, 2013). The massive increase in environmental and safety regulation of nuclear energy is not because it is getting more dangerous or harmful, and it doesn't make our world safer or cleaner.

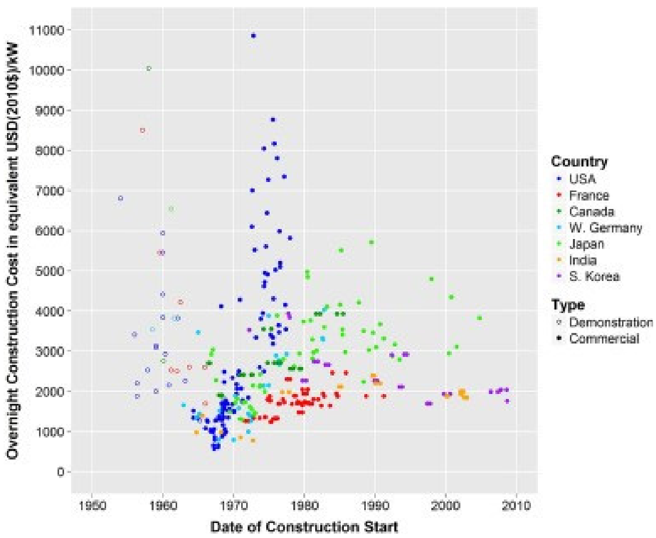

Figure 7: Overnight Construction in equivalent USD (2010$) kW Source: https://www.sciencedirect.com/science/article/pii/S0301421516300106#f0060

The NRC is staffed by dozens of scientists and lawyers, many of whom have spent their lives researching nuclear power. The individuals that make up the NRC are excited by and interested in advancing nuclear power; their intentions are good. The nuclear energy industry is similarly filled with scientists and businesspeople who want to see nuclear energy succeed. Despite this, the regulatory burden imposed on nuclear energy is a hundred-billion-dollar weight that is too much for the technology to carry. How did the good intentions of NRC staff turn into a death knell for nuclear power?

The answer lies in the institutional structure of federal bureaucracies and the incentives faced by regulators. The NRC directly benefits from drawn out approval procedures and faces consequences only for errors of commission, making their regulatory oversight expensive and risk averse. Nuclear power companies must pay the NRC upwards of three hundred dollars an hour for every hour that it takes to review their application for design, construction, and operating licenses and these applications take several years to resolve. The result of this incentive structure is obvious. The longer it takes to approve projects, the more money goes into their pockets, so approval times get longer and longer and longer. In addition to the direct financial incentive for delaying approval times, there is an acute asymmetry in the risk reward structure that the NRC acts under. They are the first ones to receive blame if anything goes wrong with an approved reactor, but they get no benefits from approving more safe reactors. They could streamline their licensing procedures and approve 20 more reactors each year, but no one would give them more money or status for it. If just one of these reactors has even a small malfunction, they would face widespread public protest. Two of the most famous reactor meltdowns in modern history, Three Mile Island and Fukushima, caused zero deaths and no statistically significant increase ("Fukushima Daiichi nuclear disaster casualties," 2022) in cancer risk to immediate neighbors ("Three Mile Island accident," 2022), but they still loom large in the public consciousness. The incentive structure of the NRC makes it unrewarding and dangerous to support the development of nuclear power and it provides direct financial rewards for doing the opposite. The result is unsurprising: strict regulation of nuclear power that has essentially shut down the industry within the US.

2.3. Geothermal Energy

Unlike nuclear energy, geothermal energy does not command nearly as much attention from federal regulators; there is no Geothermal Regulatory Commission. This is a blessing and a curse. It frees geothermal from another layer of approval processes on top of NEPA, but it means that the technology is often treated as irrelevant. This neglect has resulted in overregulation of the technology compared to strictly worse natural gas and oil drilling.

Geothermal only generates 0.4% of the US's total energy. This smalls size means it's a small industry without the resources for extensive government lobbying. As a result, geothermal is simply appended to the list of industries and practices covered by federal environmental regulations and tax credits. Compared to nuclear, this is good thing. Geothermal is only subject to regulations that apply to nuclear and solar and wind; an intersection rather than a union. This picture looks less rosy, however, when one remembers that the regulations applied to nuclear and solar, and wind are massively costly in time and money. A geothermal project would hit the same desert tortoise shaped stumbling block as BrightSource's solar farm did and it would similarly take decades and tens of millions of dollars to get over it.

Geothermal's middle of road regulatory status is even more confusing when compared with natural gas and oil drilling industries. The techniques for drilling and fracturing are similar in both technologies, but the environmental effects of natural gas and oil are undeniably worse. Despite this, natural gas and oil have huge concessions and exceptions from the federal regulatory framework while geothermal does not. The Energy Policy Act of 2005, for example, exempted fluids used in the natural gas extraction process of hydraulic fracturing from protections under the Clean Air Act, Clean Water Act, Safe Drinking Water Act, and CERCLA. Section 390 of the Act created a categorical exclusion for oil and gas exploration and development on public lands so that these actions would avoid holdup in environmental review under NEPA.

Geothermal has none of these privileges. Tim Latimer is a former gas industry executive who has

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moved into the growing geothermal industry, but the costs of regulatory compliance compared to oil and gas surprised him.

> "I've been astounded as I've entered this industry coming from the oil and gas space, where we have very responsive regulators that work with us to tell us what to do and where to do it, and we were able to get projects permitted very quickly…A common experience for me in geothermal is we submit all of the necessary paperwork, regulations, environmental impact assessments to the regulatory bodies and it sits there for months and months and months and we actually can't even get a response. When you ping them about it, they say, "We don't have the resources." So, the same office that has many resources dedicated to oil and gas to do these reviews doesn't have it for geothermal." (Dourado, 2020)

There is no cost benefit analysis that would conclude that it should be easier to approve and develop carbon-producing externality factories like oil wells than clean and safe geothermal energy. Instead, this is a result of lobbying efforts and bureaucratic inconsistency.

Geothermal energy is, thankfully, significantly less regulated than nuclear energy. Still, procedural environmental regulation is a large barrier to entry for the developing technology. Regulatory standards should be brought at least in line with polluting oil and gas, and they should probably be much less costly than that.

3. FRAMEWORK FOR THE ENERGY INNOVATION ZONE

3.1 Vision for the Zone

In the early 20th century, 800 square miles of rural Idaho was set aside as a laboratory for nuclear energy experiments. Long before NEPA was passed, experiments were ambitious and moved quickly. This single test site, the Idaho National Laboratory, has been the center of development of nuclear knowledge for decades. John Grossenbacher, former INL director, said, "The history of nuclear energy for peaceful application has principally been written in Idaho." Lately, experimentation has slowed down and they still use a test reactor that was built in 1967 to do experiments. What could be learned if turnaround were quicker, and more experiments were allowed?'

The Energy Innovation Zone (EIZ) will be a more permissionless space for experimentation and innovation in energy infrastructure modeled on the success of the Idaho National Laboratory. The goal for the zone is to foster rapid experimentation and tinkering for advanced energy technologies. The testing done in the EIZ will not only advance our scientific knowledge, but should also serve as a basis for rapid approval for consumer development of these new technologies on the national level. This can be achieved in two ways which are not mutually exclusive. One is to secure a geographical categorical exclusion for a wide range of projects within the zone, with precedent from BPs categorical exclusion for oil drilling in the Gulf of Mexico (Brinkmann, n.d.). The second is to create a new federal organization which oversees the EIZs directly, without any intermediary oversight from the Council on Environmental Quality, Department of Energy, or the Nuclear Regulatory Commission. This would quicken turnarounds on experiments, reduce purely procedural regulatory costs, and remove several sources of veto power.

3.2 Specific Statutes that Would do the Most Good if Repealed/Implemented

To see the biggest obstacles facing energy infrastructure development, it helps to look at a case study. The failure of the Next Generation Nuclear Plant ("Next Generation Nuclear Plant," 2022) is a characteristic example. Among many other goals, the omnibus Energy Policy Act of 2005 wanted to promote a 'nuclear renaissance.' Part of that was requiring the DOE to pursue a project to create a new type of reactor: the High Temperature Gas Reactor (HTGR). HTGRs can use heat to efficiently generate electricity and produce hydrogen. The envisioned reactor design is helium-cooled, using graphite-moderated thermal neutrons. This type of reactor is not only more efficient and powerful than traditional Light Water Reactors (LWR), but it is also much safer, with inherent design features that prevent core meltdowns (Pal & Shankar,1989). Although this was a modern design, this sort of reactor had been tested and demonstrated in the 1960s and 70s (Department of Energy, 2008). Still, it took 3 years of work from a group of senior DOE and NRC officials just to work up a strategy for navigating the nuclear regulatory bureaucracy of their own creation (Department of Energy, 2008). The main issue was the NRCs gargantuan list of processes and standards were all made in relation to traditional 1960s Light Water Reactors (LWR), so they had to go through all of them and find ways that they could be adapted to VHTRs.

> "The NRC estimates that it will take 5 years to develop necessary analytical tools, data, and other regulatory infrastructure (e.g., regulatory guides, standard review plan, etc.) for confirmatory safety analysis and license review. The NRC also estimates that it will take 4-5 years to conduct the licensing review. In order to meet the statutory requirement to complete construction and operation of the NGNP by FY 2021, the NRC staff and the NGNP applicant will have to engage in a 3-year preapplication review starting in FY 2010, followed by a very aggressive 4-year license application review period starting in FY 2013. The NRC estimates that the total resources required to conduct the activities in item (6) above could be in the range of \$128 - \$149 million for the period FY 2009–2018.
> This licensing strategy uses very aggressive durations for such critical path items as design,

> licensing, and construction. DOE and the NRC recognize the industry's desire to outperform the currently estimated schedule and thus complete the project before 2021, but they also recognize that 2021 is already an ambitious goal for the design, development, licensing, and construction of a first-of-a-kind prototype NGNP."

They are treating a 16-year timeline for a test reactor of a type that has been known since the 1960s as almost unattainably ambitious! The first high temperature gas reactor to produce electricity, 1967's Peach Bottom Nuclear Generating Station ("Peach Bottom Nuclear Generating Station," 2022), was applied for, approved, and constructed in half the time it would take to just license NGNP. Despite over $500 million dollars spent and 6 years of work, the DOE discontinued the Next Generation Nuclear Plant project in 2011, not even beginning the actual licensing and review process. The failure to even begin a review of the license application for a reactor design far superior to currently running reactors in power, efficiency, and safety despite huge support from executive and legislative branches is an ultimate indictment of our current regulatory system and provides the urgent motivation for the Energy Innovation Zone. The nuclear energy sector has so much regulation that the marginal returns to deregulation will be very high.

The first step that the Energy Innovation Zone will take to accelerate quality advances and cost declines of new energy technologies is creating a categorical exclusion for test reactors or geothermal sites built in the zone. Tinkering, prototyping, and experimentation are essential processes for learning at the frontier of human knowledge. Thomas Edison tested 1,600 different materials as filament for the lightbulb before finding the right one. Since so many tests are required to make advancements, even small barriers sum to huge costs. If Edison had to get someone's approval before each test, even if it only took a day, it would have added more than 4 years to the time it took him to find the right filament. The energy sector has not only to wait years between each prototype, but work for years; filling out mountains of paperwork, lobbying unresponsive bureaucracies, and paying millions in fees. It is no wonder that progress in the energy sector has stagnated. Since the power plants built in the EIZ are located in a relatively remote, purpose-built area, and are strictly for testing purposes, they should be categorically excluded from the NEPA and NRC licensing process. Rather than focusing on meticulous safety studies and environmental review before anything is built, let energy companies build test plants and have inspectors closely monitor its operation. Much more will be learned about the safety of reactors and geothermal plants this way than trying to forecast the characteristics of a technology that has never been built before. Fast and frequent experimentation is the only way to advance the frontier of knowledge, the EIZ will accelerate this process for the energy infrastructure sector.

While a categorical exclusion for the EIZ works within the current system, implementing more impactful reforms will require changes to the incentive structures of our current bureaucracy. The long and expensive approval procedures arise from a combination of requirements from several different organizations including the DOE, the NRC, the EPA, and public hearings. Cutting this down to a single organization with direct authority over the EIZ is essential. This will make it possible to align regulator incentives with energy growth and avoid risks that come from the distribution of veto power.

The advantages of less distributed authority are highlighted in a comparison of the French and American nuclear (Golay et al., 1977) energy sectors. Beyond the earliest stages of site approval, the French do not allow public comment on licensing and construction of nuclear power plants. America allows public input to impede or even shut down projects at several stages of development, even after capital investments have been made, increasing investor risk. The French also have a unitary system of government, which means state and local governments have little authority. There are certainly other advantages to federalism, but in the context of energy infrastructure, it allows every level of government to threaten veto and extract rent from the project's investors. The differing approval processes for nuclear energy have resulted in differing outcomes. While the costs of nuclear plant construction in the U.S have increased by an order of magnitude, they have remained flat in France. Once the group of veto holders has been narrowed down, rules need to be set to align their incentives with energy growth and therefore economic growth.

An example of this is NRC fees. Currently, the NRC charges energy developers upwards of $300 an hour for every hour it takes for them to review and approve their license applications. Clearly, this puts the NRC's incentives at odds with rapid experimentation. Instead, we should align the interests of the NRC with energy development by funding them from a tax on the amount of energy produced by nuclear plants so that they have a stake in increasing the energy capacity of the industry. They would still have strong incentives for guaranteeing safety because meltdowns mean less energy and funding, but they would also see some upside from supporting new technology. Changes to bureaucratic incentives will allow the rapid experimentation necessary for developing new energy technology.

Allowing rapid experimentation in the EIZ is an essential feature, but alone it is not enough to promote widespread development of these technologies. To incentivize actually performing these expensive experiments, successful tests should lead to automatic approval for construction in the rest of the US. Since this is a lucrative reward, the bar for a successful test should be high. To be classified as successful and approved for national consumer use, the test reactor should be able to run continuously for a year without issue, as it would in actual implementation. Running a reactor continuously for a year without selling any power is expensive, but companies will be happy to pay the costs because it will avoid the more expensive and time-consuming traditional licensure process and it will give them valuable operational knowledge and experience that they will need anyways. Instead of investing billions in costly applications, the build-and-test model of the EIZ allows companies to prove that their reactor designs are safe, advance human knowledge, and avoid a bunch of extra costs and time.

Expedited testing approval and a clear path to national approval will be most impactful for nuclear energy because of the huge barriers that NRC approval currently creates. Relaxing NEPA statutes will have a bigger impact on geothermal energy. There should be categorical exclusions for all test projects built in the zone. This means that test projects get a presumption of approval from NEPA rather than having to spend a few years drafting up environmental impact statements. These projects will undeniably have an impact on their environment, but since it is contained in an area already set aside for energy experimentation, it doesn't make sense to make every project go through approval again. Outside of the EIZ, geothermal drilling projects should get at least the same level of exclusion from environmental regulation as far more noxious natural gas and oil drilling.

3.3 Could this Have Wide Ranging Impact?

The EIZ will be relatively small, hosting a few dozen test reactors and geothermal plants. These test plants won't have a large direct impact on energy availability. Will they be able actually help our long-term economy? Even though the direct impact will be small, the ability to pre-license advanced new designs in just a couple years with drastically lowered fees will greatly expand the number and type of reactors that can be profitably built outside the zone. Basic scientific understanding of nuclear and geothermal power will be advanced by an increase in testing which will bring us closer to fusion and advanced geothermal. Quick turnaround testing and tinkering will also promote learning by doing which is a very powerful productivity increasing force and allowing more reactors to be built will imbue more nuclear engineers with more knowledge and experience. The precipitous decline of nuclear construction costs in the 50s and 60s is in large part due to this. The fundamental tech of LWR was developed in the 40s and 50s but the cost decreases came from practice and mass production. The EIZ will do the same for advanced geothermal and new reactor designs.

4. POLITICAL FEASIBILITY

4.1 Scale of the Challenge.

These federal bureaucracies are huge, powerful, and have ratcheting incentive structures which make it near impossible to scale them down. Presidents of all parties have tried and failed to streamline approval processes for nuclear power or through NEPA more generally ("National Environmental Policy Act," 2022). Additive reform won't work, we need metanoia ("Metanoia," 2022): a transformative change of heart or culture. The philosophy and incentives that make up these bureaucracies must either be changed from the ground up or circumvented entirely. Both are theoretically possible but unlikely. Huge change in the incentives of the NRC and circumscribing the purview of NEPA might work. It might be easier, however, to set up an independent regulatory body just for special jurisdictions that can make its own policy about these issues.

The actions of an organization are a function of the culture and incentives of its members. The influence of culture on the actions of an organization is strongest at its founding, when the group of members is small, close knit, and self-selected for like-mindedness. The Founding Fathers were a small group of New World farmers who shared influence from enlightenment political philosophy. This culture influenced their actions strongly. George Washington's altruistic and forward-looking decision to step down from the presidency, despite the incentives of power, is an example of this. Similarly, the early members of startups like Microsoft or Facebook were guided by belief in the utopian potential of software and they dropped out of ivy league colleges despite the pecuniary incentives telling them otherwise. As the organizations drift further from their founding moment, the influence of culture fades and the incentives of the institutions take over. Employees of Microsoft no longer drop out of college and work for years for free in pursuit of a shared vision. Instead, they are graduates of Ivy League colleges who require six figure salaries to motivate them to work at all. Members of the American government are no longer pioneering rebels. Instead, they are ladder climbing bureaucrats who want to enforce the rules and expand the power of their station. Changing the incentives of legacy organizations is difficult because the people who benefit most from the incentives are usually the ones with enough power to change them. Changing the culture of these organizations is similarly unlikely because of their large size and the weak selection effects compared to the organization at its founding.

The alternative to changing the incentives or culture of an existing organization is to create a new one. This is the path that Bill Gates and the Founding Fathers took. Creating a small, independent regulatory body that has exclusive authority over the EIZ would be an easier way to mold the incentive structure and culture of energy regulation in the EIZ than trying to change the already massive NRC and EPA. In order to achieve not only a permissible laboratory for energy experiments but also expedited licensing in the rest of the nation, founding new organizations and amending existing ones will both be required. This makes the challenge of creating and EIZ and implementing reforms that will allow its full potential a very difficult one. Despite the challenge, it is vitally important that we grow the energy capacity and shrink the carbon emissions of the world, but the odds are stacked against us.

4.2 Special Jurisdictions Can Snowball

The EIZ reforms are packaged within a special jurisdiction that make the EIZ easier to start than national scale reform and also easy to expand once it sees success. The success of special jurisdictions in China and their subsequent proliferation around the country and the world serve as models for the EIZ. In the 1970s China was totalitarian, underdeveloped, and recovering from the world's deadliest famine. Many forecasters saw future famines as inevitable ("The Population Bomb," 2022), given growing populations

and stagnant productivity. In the late 1970s, however, China began a process of reform and opening up. As part of this, 4 small coastal cities were granted special allowances for foreign investment and private control of economic activity. Almost immediately the populations and economies of these cities began growing at double digit percen
tages a year. Fifty years later there are now dozens of special jurisdictions within China. Some of which have expanded beyond cities to include entire provinces ("Hainan," 2022). Many millions of people and billions of dollars live within these zones. There are now thousands of similar special jurisdictions (Serlet, 2020) around the world.

The reasons for the success of special economic zones can be replicated by EIZs. First is that the reforms instituted within these zones actually work. Reducing the permitting and licensing required for foreign investment and business creation is a good way to create wealth. The same is true for energy. Once there is proven success with this strategy, that evidence can be used to support expansions of the reform. The next reason is small starting size but easy scalability. China would never have instituted their special jurisdiction reforms on a national level. If Deng Xiaoping had pushed for these allowances on a national level, the entire project would have failed due to opposition from entrenched communist interests. Giving some special rules to a rural backwater, like Shenzhen (CGTN, 2018) or Idaho, is a more feasible strategy.

After getting the ball rolling with these small initial reforms, expanding to larger areas becomes easier for two reasons. First is that the reforms prove themselves with actual results. It is much easier to scoff at an ambitious reform package that has never been tried before, but once it has grown rice paddies into skyscrapers over a decade it is difficult to deny their effects. Additionally, the small initial reform creates a group of stakeholders who stand to benefit from its expansion. Machiavelli said "there is nothing more difficult than to take the lead in the introduction of a new order of things. Because the innovator has for enemies all those who have done well under the old conditions, and lukewarm defenders in those who may do well under the new." Once the Shenzhen SEZ had made dozens of real estate developers and businesspeople into billionaires, there was much more interest in lobbying for the expansion of SEZs into Shanghai.

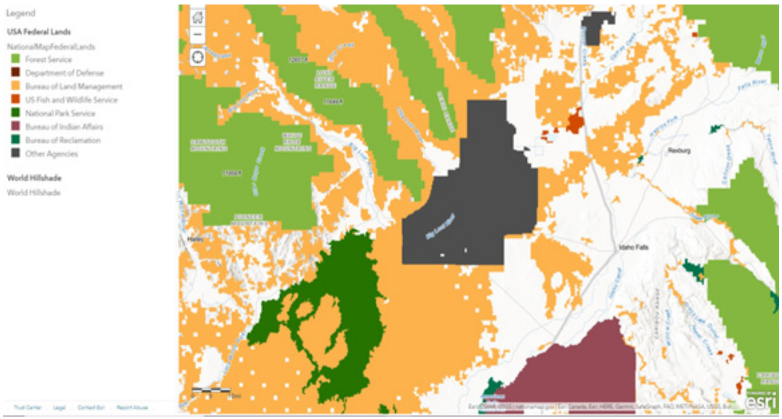
EIZs will follow a similar strategy. Presidents Clinton, Bush, Trump, and Biden have all tried and failed to reform NEPA on a national level. Nuclear energy policy for small rural areas has failed before ("Yucca Mountain nuclear waste repository," 2022), but it at least has a better chance of working its way into some omnibus bill. If significant licensing reforms are passed, then the EIZ will quickly show results as companies like NuScale, Quaise, and Commonwealth Fusion are finally able to show off full-scale test models of their technology. Energy companies who make investments into the zone will have strong incentives to protect and expand the EIZ's reforms. If we can get the activation energy to start a small, semi-autonomous political zone which accelerates energy technology testing and licensing, it could become a self-supporting political interest group for the long-term future. This would allow the reforms of the EIZ to make sustainable improvements to our energy capacity growth rate, causing the massive moral and economic gains that come with such an increase.

4.3 Siting the EIZ

Deciding where to put the Energy Innovation Zone is an important determinant of how difficult it will be to pass it through congress. A large group of experimental nuclear reactors will draw huge public protest, even though they are very safe, so locating near large population centers is a bad idea. This isn't too big of a deal, however, since the EIZ is for testing purposes, not for commercial scale electricity generation so it doesn't need to be nearby cities. As Yucca Mountain and the solar farm projects mentioned above show us, however, remoteness does not guarantee that few people will take notice of the project. So, although any old piece of BLM land would serve our purposes well, we need extra layers of protection from NEPA fueled 'public comment.' Indian Reservations and Idaho National Laboratory provide this.

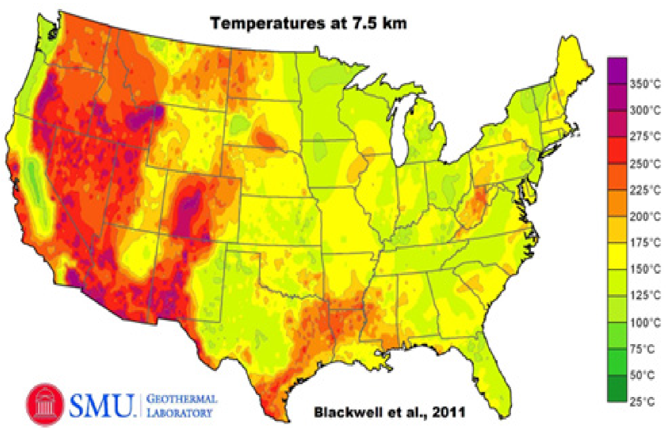
Indian reservations are, at least in writing, highly autonomous political organizations within the United States. According to NRC (NRC, 2012) and DOE tribal protocols (DOE, 2000), federal agencies must treat their relationship with native tribes as a government-to-government relationship. "Tribes are not treated as mere administrative extensions of federal programs, but as separate governments. They are sovereign entities, recognized in the U.S. Constitution with rights and privileges negotiated in treaties and defined in case law." Tribal autonomy is probably overstated by these righteous claims. Specifically, federal organizations have a "fiduciary obligations to the tribes, including duties to protect tribal lands and cultural and natural resources for the benefit of tribes and individual tribal members/landowners." Since the current set of laws and regulations are taken to be the best way to benefit individual tribe members, tribal governments mostly just defer to federal US law. Still, executive agencies and the courts at least say that tribes have a high degree of autonomy. There is some precedent for tribes actually exercising these rights, specifically in the area of energy and environmental policy. Some tribal governments have the same authority as states under the (US EPA, 2015) clean air and water acts. This means that tribes can set their own standards of water and air quality and their own procedures for measurement. Tribes have also been able to circumvent state level gambling laws and host casinos on tribal lands. Despite the strong statements of autonomy that the NRC and DOE make, and the existence of some precedents for tribal autonomy, no tribe has come close to doing something as ambitious as an Energy Innovation Zone. Still, if a tribal leader believed that nuclear energy development was essential for a prosperous future, they could take their case to the supreme court and conceivably be allowed to create their own set of rules around licensing and constructing reactors.

The most promising spot to locate the Energy Innovation Zone is the Idaho National Laboratory. This is over 800 square miles of land in rural Idaho designated specifically for testing nuclear reactors.



The black area is owned directly by the Idaho National Engineering Laboratory, with lots of BLM land around it. Nearby Idaho Falls which has plenty of infrastructure and room for growth. Good place for an Energy City

There is already considerable research activity at this location, and "NuScale Power chief commercial officer Mike McGough (McGough, 2013) clearly stated that the Idaho National Laboratory is NuScale's "preferred startup location" for its design, saying that there is "no better place" to locate this initial effort." Several other modern nuclear energy projects including Oklo (INL, 2020) and Radiant nuclear (Radiant, 2020) are actively testing at INL already. In addition to being the center of nuclear science for decades, the Idaho site lies on top of one of the hottest geothermal areas in the country, making it an ideal starting ground for geothermal research.



Idaho National Laboratory's large size, remote location, geothermal activity, and long history of nuclear testing makes it an ideal location for the Energy Innovation Zone.

5. CONCLUSION:

We need clean energy to avoid climate catastrophe, but we also need more energy to end poverty catastrophe. Fossil fuels provide an unavoidable tradeoff between these two imperatives. Clean sources of energy are required, but traditional renewables face challenges with demand scaling, energy density, and construction costs, both monetarily and in terms of carbon. Nuclear and geothermal have the unique ability to vastly increase our energy capacity while also avoiding carbon emissions. Nuclear and geothermal are extremely safe and environmentally friendly. Nuclear causes 300 times fewer deaths per terawatt hour than oil (Ritchie, 2020), even including liberal estimates for the deaths caused by the Chernobyl and Fukushima meltdowns. The operation of nuclear and geothermal plants is net-zero carbon and their construction is more environmentally friendly than traditional renewables. Both forms of energy are highly regulated though, and their development is severely hampered by this unnecessary regulation. Costs of constructing nuclear plants have exploded since 1970 even though reactors have been getting smaller, safer, and more reliable. Geothermal has never been able to get started because of strict permitting requirements and unresponsive bureaucrats. A new governmental unit where energy regulations could be rebuilt from the ground up is the most practical way out of the bureaucratic labyrinth we are in. Sweeping reforms of existing organizations are too difficult due to entrenched interests. Instead, we should try and circumvent their authority in an initially small jurisdiction and use the proof of concept and economic value generated within the zone to scale up the reforms. The most important aspect of this special jurisdiction is quick and easy licensing for test plants that can lead to national approval if tests are successful. We could put this in the already active nuclear testing site in the Idaho National Laboratory and relight the torch of energy progress in the US. Entrenched interests and bad incentives make this reform unlikely overall, but a visionary president and a cooperative congress could make it happen. Let's build our way into a better world!

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