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Economic Need and Regulation of Nuclear Reactors

Cursory level reporting on decarbonization touts renewable energy as the end all solution to our addiction to fossil fuels. While wind and solar energy are great tools in our fight to decarbonize, the practical economist will quickly realize problems with implementation. One such problem is the structure of demand for electricity. Energy use in the US fluctuates over the course of the day, generally peaking in the afternoon and dropping off to a minimum base energy demand at night. To say the baseline energy is the minimum requirement for the day is misleading, the base energy demand is still a huge amount of energy. The time dependency of the demand curve leads to a market defined by peak load pricing. In the electricity market, electricity providers pay a premium price for peak hour energy, and a lower $/kWh for the 24 hour, non-fluctuating, base load[4]. Solar and wind have a capacity to produce tons of energy, but without batteries to enable energy storage, all energy that is produced must be immediately consumed. With battery technology nowhere in sight, solar and wind's biggest flaw remains their variability of production. They help meet peak demand and supplement baseline demand, but a large economic incentive exists for a foundational 24/7 energy source to produce the baseline demand when wind and solar are not producing energy. Fossil fuel generators filled this role, so as we bring coal and gas offline a new energy source must take their place. Nuclear power has the potential to fill this vital role of producing non fluctuating power over the whole day, and with zero carbon emissions. Without nuclear power we will not be able to reach a carbon free electricity supply. Yet, in the US electricity market nuclear reactors are not being built, and haven't been built for years. With climate change presenting a mounting threat to our society and economy, it is essential we unlock the benefits of nuclear power. To do so, let us examine how supportive economic regulation has conflicted with stifling regulatory safety measures in order to argue that nuclear reactors must be largely reinvented to better fit the US market if nuclear energy is to have a resurgence in a meaningful way.

The notion that nuclear development has been snuffed out by suffocating regulations is an inaccurate assessment. Nuclear energy development has halted because conflicting regulation has arrived at a product for which the high price has zero demand. It is necessary to acknowledge that nuclear reactors would not exist without the support of government regulation. Even the conception of nuclear energy is tied intimately to government funding. During the 1940s the Manhattan project led to huge advancements in our understanding of nuclear reactions and helped birth controlled nuclear fission. The first nuclear reactor to produce electricity was realized in Idaho's federally funded Argonne National Laboratory In 1952[5]. The experimental technology began to be utilized in the commercial sector, but only with the help of supporting

government regulations. Nuclear power plants were, and continue to be, given kWh production tax credit, accelerated depreciation tax rules, a negative effective tax rate, federal loan guarantees, and regulations that relieved nuclear plant owners of the responsibility to pay third-parties to accept the risks associated with waste disposal[2]. These regulations reflected the government's desire to harness the valuable benefits of nuclear energy, a reliable, non variable, large scale energy source that had zero carbon emissions. Without regulation, nuclear energy could not have been, and today cannot be, a profitable commercial investment for development companies. These regulations are largely responsible for the majority of nuclear development in the 60s and 70s.

Clearly, nuclear energy in the 60s and 70s was supported by government regulation, but during the 70s and 80s government regulation began to contend with the dangers of nuclear energy. With most industries, over the course of time the price to produce a product drops as producers learn how to make the product. Alternatively, nuclear power plants demonstrated "negative learning"[3], they have become more expensive to build as time goes on. Nuclear power is a majority fixed cost with 60-80% of the total cost coming from building the plant[2]. In analyzing the capital cost of construction, the price for components changed only slightly, 75% of the cost change came from indirect costs such as insurance and supervision[2]. The increase in indirect costs points to a malady of over regulation. Prompted by disasters such as Three Mile Island and Chernobyl regulators pushed for a focus on safety. Safety measures have a two fold effect on the price of the plant. First, requiring additional infrastructure at the plant, such as,"electric-powered pumps… redundant cooling systems… and massive containment structures"[1]. Second, additional engineering oversight on the construction site to make sure the additional measures are met. As a result, companies were forced to design bigger reactors in order to maximize economic output of a project. An astute reader might argue that economies of scale would raise the total cost, but would actually lower the cost of output per kilowatt hour. However, instead of reducing the price to produce a kilowatt hour, the impossible logistics of designing these massive projects lead to more complications than benefits. Projects were delivered wildly behind schedule and over budget. One could argue that as the size of these projects grows, the complexity (and thus workload) grows exponentially. Case in point, the only US nuclear power projects currently underway are in Georgia and, "the licensing process for them began in 2008; construction began in 2012, with a projected price of $14 billion and start-up planned for 2017 at the latest. As of February 2022, the projected cost had mushroomed to $30 billion, and the reactors still aren't open"[1]. High costs and complexity have left few companies capable of undertaking such a project, and even fewer willing to take on such a mess. While regulatory economic benefits such as tax breaks allowed nuclear power to be possible, increased safety regulation stalled out the viability of making profitable reactors.

As of today, in order to address climate change, the US government is now forced to decide whether or not to override safety regulations by increasing financial regulatory benefits for nuclear power to a level that incentivizes construction. Do not mistake this question for: is

climate change a problem? Climate change can be viewed as an existential threat while also realizing that modern nuclear reactors are not the solution.

The most legitimate argument against regulating towards current reactor designs is the worry that legislation pushes for these reactors and then the economy focuses huge amounts of money and resources to develop. As the track record has shown, the enormity of these projects sucks up time, resources, laborers, and engineering man hours. Not just for a few months and a couple million dollars, but over the course of decades and billions of dollars. This time and energy, it could be argued, is wastefully employed, let us aim our economy towards more practical solutions. This solution not only fails to maximize social welfare, but throws consideration of social welfare out the window. Not to mention, in the fight against climate change, two decades is just not quick enough. The complexity and demanding nature of designing and implementing a nuclear power plant has a strikingly poor fit in the US market.

In response, one could argue that the US market does not properly account for the externality of carbon emissions, and thus does not value nuclear energy nearly enough. It is also why we see countries such as China, whose government decrees energy projects, successfully building a plethora of nuclear energy generators. Behind the heavy hand of Chinese leadership is the notion that free markets do not properly account for climate change, that the world doesn't have the time to regulate towards nuclear energy but rather it is necessary to mandate nuclear power plants.

The US government refusing to pay the exuberant price for large reactors is excusable if the government helps finance the accelerated development of a new product. While China has chosen large nuclear plants as its source of baseline energy, in the fight for nuclear energy adoption in the US, the right next step is to innovate towards smaller, more manageable reactors. In order to fit into the US free market system, nuclear reactors must have lower costs and shorter construction timelines. By issuing strong regulatory incentives for nuclear power, the US can guide the free market towards addressing this problem. Such a strategy would achieve a reasonable balance between the free market and regulation that is in line with the US economy. Preliminary federal incentives have caused companies around the country to begin development of small modular reactors (SMRs).

One such company is called NuScale. In relation to the Georgia plant that will produce 1,000 MW on 3,000 acres of land, NuScales reactor will produce 77MW on 65 acres[6]. The CEO nicely summarized that, as stated earlier, when nuclear power projects are,"over a billion dollars, the wheels tend to fall off"[6]. Unfortunately, the first SMRs are suffering the difficulty of doing anything for the first time. As of right now, the SMRs appear to be no different than their bigger older brothers, plagued by exorbitant prices, failing to meet deadlines, propped up by government funding, and stifled by safety regulation. The first NuScale project, a string of six 77MW reactors (462MW system) has suffered similar price inflation to its predecessor. The project, originally estimated to cost $5.3 billion has ballooned to $9.3 billion[6]. These projects are being propped up by federal funding such as the Inflation Reduction Act including a $30/MWh in credits for nuclear power plants[6]. Of course, SMR companies point towards regulation as the

cause of delay and price increase. Nuclear energy will always be strictly regulated in the US, it is the only energy source with a designated federal regulatory agency, the Nuclear Regulatory Commision (NRC). One SMR company noted that approval on a design from the NRC would take two years[6]. This story appears no different from that of the large scale Nuclear reactors, making it seem like nothing has changed.

There is still hope, and the correct path forward for nuclear energy adoption in the US is to focus regulation and free market output on the development of the SMR.The critical feature of SMRs is that they are designed to enable us to learn, standardize, and optimize into a cheap and doable construction project. Furthermore, SMRs companies are pushing the boundaries of engineering. Introducing new developments such as cooling systems that utilize molten salt rather than water, allowing for safer and more compact cooling. Optimizing nuclear energy through better engineering design relieves pressure from project management and construction to keep costs down. Both a repeatable modular design and advances in technology give hope that we are approaching a nuclear reactor design that is strong enough to compete in the US market. The economic fit of smaller reactors is also quite pronounced. Smaller safer reactors could be placed in cities where electricity demand is high and land is scarce. Potentially even large real estate developments could have their own reactor. The number of clients that would consider the investment of a reactor would grow exponentially. Companies such as Nuscale would perfect their designs and possibly break the billion dollar price tag on reactors, further growing the number of buyers. Unfortunately, much innovation is still left to reach this reality. It is essential that the US federal government continue to pave the way for innovation by accelerating the introduction of SMRs to the free market through regulatory economic incentives. To expedite the journey to nuclear energy, economic incentives such as tax credits, and funding for research will play an important role. Furthermore, the NRC needs to reflect the urgency of climate change through quick turnarounds on approval for safety regulations and limit bureaucracy if it is to enforce strict safety measures. In this manner, nuclear energy will be able to find its place in a cut throat US economy, and play a vital role in decarbonization by providing a carbon free baseline energy source.

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