# The Conundrum of Hydraulic Fracturing

Assignment 7.2 – Energy System Team Paper

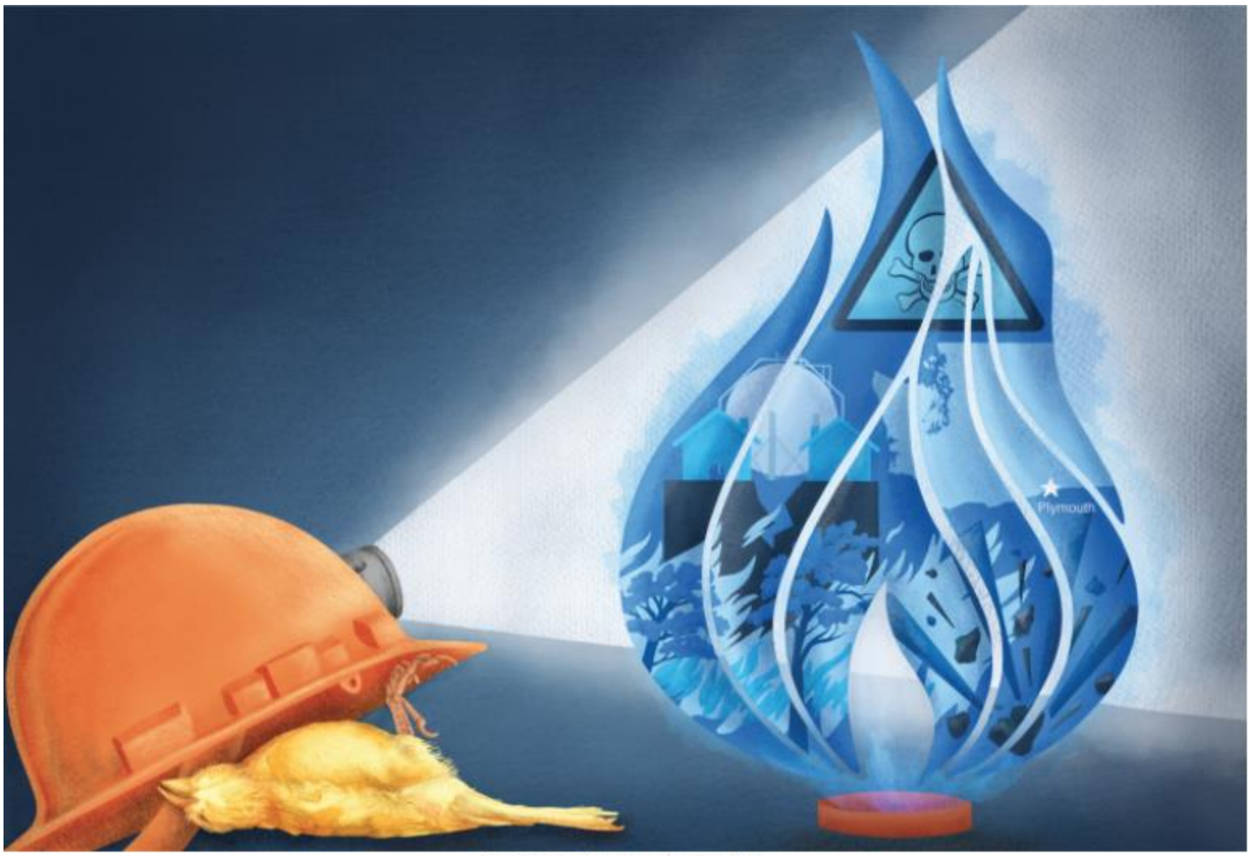


Image by Emily Eng/Sightline Institute

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To frack, or not to frack? That should not be the question. What we should ask is: do we want to prioritize a full-speed transition to clean and renewable energy? Or, do we rather keep burning fossil fuels at the expense of health, safety and environment? Conventional natural gas that is easily accessible is usually extracted in conjunction with crude oil production using traditional drilling, pumping and compression techniques. Hydraulic fracturing, or fracking, is an important technological advance for oil and gas producers to tap reserves in shale formations that were difficult to access a few decades ago. What is the incentive for extracting unconventional gas (i.e. shale gas) using fracking technology? Can we view the fracking boom as a relentless pursuit of fossil fuel recovery? After all, there are not many untapped conventional gas reservoirs left in North America; fracking has made a shale revolution in the U.S. possible. And yet, the implications of the energy system are far-reaching.

It is a known fact that fossil fuels (coal, oil, gas) as the world's primary energy source create the majority of human-caused greenhouse gas emissions. Natural gas (including shale gas) emits less carbon dioxide than coal and oil do, but a recent study from Cornell University shows fracking shale gas has prompted a global spike in atmospheric methane (Friedlander, 2019). Methane is the largest component of natural gas, and natural gas leaks are predominantly methane. Carbon dioxide and methane are both critical greenhouse gases. As one of the highly potent short-lived climate pollutants (SLCPs), methane heats up the climate over 80 times more, averaged over 20 years, than an equivalent amount of carbon dioxide, and it stays aloft for years instead of decades or centuries as carbon dioxide does (Leahy, 2019). If we follow the lesser of two evils principle, can we infer that neither coal nor natural gas slow the rate of greenhouse gas emissions? And suppose water is the oil of the 21$^{st}$ century. Can we liken the use of large quantities of freshwater in fracking to a trade-off between the most sought-after commodity of this century and a fading one of a bygone era?

**FRACKING ALLOCATION**

| **Impact** | **Allocation** |
|---|---|
| Water Quantity | -26 |
| Water Quality | -13 |
| Delay / Support Green Energy | -21 |
| Reduce Coal | 19 |
| Grow Economy | 6 |
| National Security | 15 |

**EXPLANATION of ALLOCATIONS**

After a fruitful discussion amongst our team members, we reached the conclusion that, as a group, we don't support fracking. One key question that informed our group allocations was "to what extent do we need fracking as a bridge fuel?" Fracking has been around for approximately 40 years, and we still have not discovered the sustainable energy mecca for our base fuel. How much longer are we willing to wait before we wean ourselves off fracking? Another 40 years? Our planet does not have another 40 years to give us.

Our group felt that the negative aspects associated with fracking (i.e. water quantity & quality) outweighed the positives (i.e. total energy independence and the national security that accompanies it). We found it concerning that we, as a nation, have not set a "timeframe" on how long fracking will remain as a substantial energy source. Nor have we created a comprehensive plan for how we will leverage that time to develop alternative, more sustainable and environmentally-friendly fuel sources that also meet our energy needs. We realize that technological innovation does not have bounds to a timeframe, but it would still be advantageous for us to set a date for when fracking will become a secondary energy source.

Additionally, there are many other options to consider when searching for a bridge fuel (i.e. nuclear, wind, solar, hydroelectric, etc.) until a desired base fuel has been actualized. Our investments reflect the importance of reducing our dependence on coal, reducing water consumption in producing energy, and prioritizing green energy research and development. With the coal market being phased out as a result of recent market forces, we felt that fracking may not be as essential to the US economy as much as we originally thought. However, we do recognize its role in potentially strengthening our national security and aiding the US in energy independence.

Another factor considered amidst our discussion was that renewables, such as solar, are becoming economically competitive with coal and may help us catalyze the process of shifting from coal to renewables. With new technology becoming more widely disseminated and available on a daily basis, combined with strong lobbying and market trends, our group felt that it would be wise to invest most of our money elsewhere in efforts to grow renewable energy. With new technology and a virtually untapped market for green energy jobs on the horizon, why not invest in the future that phases out fracking and places us within the sweet spot of Oxfam's doughnut?

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**INNOVATION ALLOCATION**

| **Energy System Innovation** | **Allocation** |
|---|---|
| Traditional Storage: chemical batteries such as lead, lithium, salt, etc. where electrons flow from anodes to cathodes. | 18 |
| Non-traditional storage: convert excess solar to hydrogen, elevate cement blocks, … | 10 |
| Better, bigger, smarter, more efficiency electrical grid | 25 |
| Next generation nuclear energy | 27 |
| Alternative ways to make/replace high-GHG emitting materials (cement, fertilizer, steel, etc) | 15 |
| Optional: Gas Hydrates | 5 |

**INNOVATION JUSTIFICATION**

Faith in innovative technology will push us towards clean and affordable energy in the face of a growing population with greater energy needs. Solutions must move us beyond our dependence on fossil fuel-based sources while providing greater energy security, independence, and economic support. So how can we have our cake and eat it too?

There are many solutions that currently exist as well as promising advancements still in research and development stages. With that in mind, we have chosen to invest most heavily in next generation nuclear energy and improving our electrical grid. Improving the grid is necessary given the aging, existing infrastructure and the important role it plays in providing resiliency and reducing vulnerability. This allocation also includes integrating diversified storage technologies strategically to support its security. We also recognize the advancements in nuclear energy and the potential it brings to offering a cleaner solution than coal and natural gas. The investment would be made in education to help overcome public distrust that still lingers from past accidents and motivating policy makers to loosen the stringent regulations currently in the US.

The least amount of money, although not ignored, was put towards non-traditional storage as well as fire ice (other). While fire ice has seen some promising potential, it is still very new and requires more research and development. The same can be said for non-traditional storage but with greater potential down the road. We feel more advancement in these technologies will be needed to implement them effectively on a larger scale.

## INNOVATION TOPIC SUMMARIES

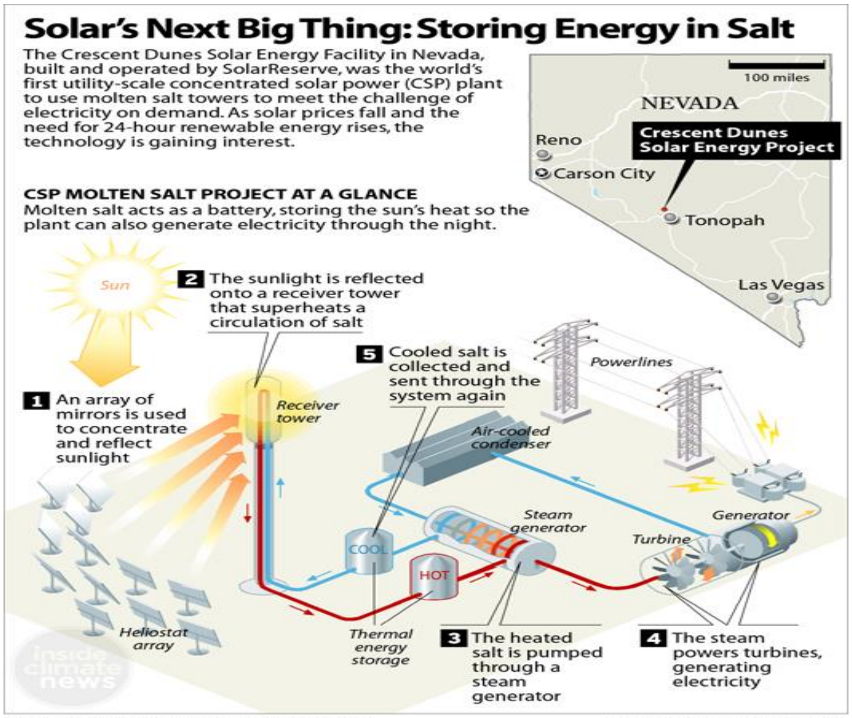
### *1) Traditional Storage*

Power storage is the missing link in green energy plans. The capture of energy produced at one time for use at a later time can leverage intermittent renewable energy sources such as solar and wind and increase grid flexibility as electricity demand changes through the day. The common method of bulk energy storage is dominated by hydroelectric dams. Pumped-storage hydropower (PSH) currently accounts for 95% of all utility-scale energy storage in the United States (EERE, n.d.). This method of storage is to pump water into an elevated reservoir at times of plenty and release it when electricity is needed. PSH is a gravity battery at a large scale. At a small scale are designs like GravityLight which provide energy access in low-income developing countries. A gravity battery is an energy storage device that stores gravitational potential energy. Swiss startup Energy Vault applies this principle to stack concrete blocks to store energy (see "non-traditional storage" below).

Traditionally, a battery is an alternative to store energy by means of an electrochemical oxidation-reduction (redox) reaction. Every battery has two electrodes—a cathode and an anode. Anodes usually consist of a carbon-rich material. The lithium in the cathode tends to be part of an oxide, typically lithium cobalt oxide. Cobalt is the costliest material in the battery and producers are trying to reduce cobalt use by replacing some of it with nickel and manganese (The Economist, 2020). Lithium-ion batteries have high energy-storage capacity which is a fivefold improvement on the old lead-acid battery. Other alternatives include flow batteries, or redox flow batteries, that use electrolytes in tanks of chemical solution. Flow batteries can save significant cost in long-duration usage applications such as a grid powered by the sun and wind (Service, 2018). A bid for better batteries and sound renewable energy policies will speed up the clean energy transition.

### *2) Non-traditional Storage*

Non-traditional energy storage systems are methods of storing energy produced outside of the means of traditional storage methods such as chemical batteries. Nontraditional energy storage methods are challenging the ways we currently store energy, and are also trying to close the continuous energy gap that is associated with renewable energy demands. In addition to hydrogen storage and stacking concrete blocks, projects such as Planta Solar Cerro Dominador complex located in Chile are prime examples of nontraditional storage methods being combined with other solar energy systems to provide continuous energy output to the surrounding communities (Cerro Dominador, n.d.). This complex consists of a photovoltaic plant with a capacity of 100 megawatts (MW), a concentrated solar plant with 110 MW of capacity, and 17.5 hours of thermal storage that includes a molten salt storage system that allows for stable energy output 24 hours a day. Cerro Dominador collects solar radiation via the use of heliostats which




SOURCES: SolarReserve; InsideClimate News research PAUL HORN / InsideClimate News

direct solar energy towards one point on an 820-feet solar tower. The solar energy is then directed to a cold molten salt storage tank where this energy heats the salts to a temperature of 1049 degrees Fahrenheit. After the salts have been heated, the heat is then transferred to a water source that generates steam to power a turbine, thus creating electrical energy. By storing radiation energy via molten salts, energy companies are able to soar past previous storage capacities records held by traditional storage methods for a fraction of the cost. Here is a diagram of the Crescent Dunes solar energy plant in Nevada that also utilizes the same technology (Dieterich, 2018).

***3) Electrical grid***

"America's economy, national security and even the health and safety of our citizens depend on the reliable delivery of electricity… The electric grid is an ecosystem of asset owners, manufacturers, service providers, and government officials at Federal, state, and local levels, all working together to run one of the most reliable electrical grids in the world" (Office of Electricity, n.d.). An aging infrastructure presents significant challenges with nearly 75% of transmission lines and transformers over 25 years and most of the grid infrastructure built above ground (Cummins, Inc., 2018). This leaves our electricity supply highly vulnerable to the effects of climate change as heat waves and storms cause outages leading to loss of air conditioning, spoiled food and damaged appliances. The demand for power will only continue to grow, increasing the demand on a grid that was not built for such high capacity requirements.

Fortunately, technology exists to develop a smarter grid that will reduce the impacts of extreme weather events, lower operational costs for utilities, and increased integration as we shift towards renewable sources. "Smart grid" technologies involve two-way communication and computer processing through sensors to assess grid stability, digital meters giving consumers better information and outage reporting, feeder switches to reroute power around problems, and batteries to store excess energy supply (Office of Electricity, n.d.). In addition to new technology adoption, many local government initiatives include the development of microgrids to build greater resiliency. “Larger microgrids plan and implement sophisticated scheduling and control systems that can optimize their energy usage, production, and grid sales and purchases across the day” (Henderson, 2017). Efforts made to adopt smart city strategies also support building a smart grid through innovations in energy storage, electric transportation, and green building efficiency programs.

### *4) Next Generation Nuclear Energy*

Nuclear power—can it be the renewable energy complement that suspends fossil fuel dependence? There is an arrant international realization that if we are to achieve our carbon reduction goals, "nuclear has to be part of the equation" (Johnson, 2018). It currently accounts for about 20% of the US energy blend and can stand shoulder to shoulder with renewables as the clean energy path forward, permanently unseating fossil fuels.

The retreat from nuclear power after the Fukushima Daiichi accident in 2011 was far-reaching. Nearly two decades later, the industry is seeing a renaissance of young entrepreneurs converging to work on the next generation of nuclear energy. Their designs and prototypes - futuristic, streamlined, and modular—have endorsement and funding from the private sector and the United States Office of Nuclear Energy (Office of Nuclear Energy, 2020). Next-gen nuclear centers on small modular reactors (SMRs). Their size and modular design lend to being "almost completely built in a factory-controlled setting with improved levels of construction quality and efficiency" (World Nuclear Association, 2020). This fabrication model parallels other industries' trends to fabricate in controlled environments that maximize cost, quality, and schedule economies.

The potential of SMRs to contribute to clean energy security for "countries with smaller grids and less experience with nuclear" and to "slot into brownfield sites in place of decommissioned coal-fired plants" (World Nuclear Association, 2020) is plausible. To actualize the potential, the nuclear community must address the ongoing concerns over nuclear—national security, accidents, and waste storage. It seems this new cadre of engineers and entrepreneurs are considering each of these in their innovative designs. Will it be enough to overcome public distrust?

### *5) Alternative ways to make/replace high-GHG emitting*

Cement, iron & steel, and chemicals & plastics are the three top-emitting industries worldwide (Rissman, et al., 2020). Currently, “45% of emissions [are] associated with making products” (EMF, 2019). While technological advances for their production are on the horizon, such as, “cement admixtures and alternative chemistries, several technological routes for zero-carbon steelmaking, and novel chemical catalysts and separation technologies”, the role of policy and circular economies are also viable drivers of change in this realm (Rissman, et al., 2020). “High-value policies include carbon pricing with border adjustments or other price signals; robust government support for research, development, and deployment; and energy efficiency or emissions standards" (Rissman, et al., 2020).

It is also worth considering the effects of implementing circular economy strategies. A circular economy might not offer total replacement of these high-GHG emitting materials, but it does offer a longer lifespan for these materials "by designing for durability, reuse, remanufacturing, and recycling to keep products, components, and materials circulating in the economy" and can reduce waste "by designing for material efficiency [and] optimised supply chains" (EMF, 2019). In fact, "when applied to four key industrial materials (cement, steel, plastic and aluminium) circular economy strategies could help reduce emissions by 40% in 2050" (EMF, 2019).

### *6) Optional: Gas Hydrates*

If we divide energy sources into fossil fuel-based and non-fossil sources, the latter accounts for 20% of US energy consumption in 2019 (EIA, 2020). Renewables are part of the non-fossil sources. As the global demand for reducing fossil fuels grows, innovations related to new energy are bountiful such as tidal energy, artificial photosynthesis, carbon nanotube and many others (Earthava Team, 2019). However, a complete switch to renewable energy takes a long time. In addition to natural gas, gas hydrate is another bridge fuel to wean us from coal and oil dependence while buying us time to develop renewable energy technologies.

Gas hydrates are ice-like crystalline substances that form in deep-sea sediments. Most gas hydrates are formed from methane—a relatively clean-burning fuel. The terms "methane hydrate," "methane clathrate," and "fire ice" are often used interchangeably. The amount of natural gas in methane hydrate worldwide is estimated to be far greater than the entire world's conventional natural gas resources (BOEM, n.d.). Global resources of methane in gas hydrates are enormous. A recent review by the US Geological Survey concludes gas hydrate breakdown is unlikely to cause massive greenhouse gas releases (USGS, 2017). Given the advances in scientific knowledge about gas hydrates and rising energy demands, fossil fuel-poor nations such as India and Japan begin to think seriously about commercial extraction. Japan became the first country to successfully extract undersea methane in 2013 through a drilling test in the Pacific (Henriques, 2018). China and the United States are also making a breakthrough in tapping the so-called "unconventional fossil fuels" (Beaudoin, Dallimore and Boswell, 2014).

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**LESSONS LEARNED**

**Garrett**:
This was a test for me to challenge my biases and make sure I had a complete understanding of both sides of the table before jumping to conclusions. My opinions changed over the course of the interval as I continued to gain further knowledge of the complex system. I am going to have to find another word for wicked because I am using it repetitively in every field of sustainability. At the end of the day, it came down to trade-offs with members of the team falling on both sides. It is difficult to fit full discussions on challenging matters like this into reasonable timeframes within an interval. It makes sense that this has been such a passionately debated subject in the public eye for as long as it has been. It was also encouraging to see innovations being made to address so many different aspects of the energy system. I continue to be optimistic about my faith in technology.

**Dianne:**
I thoroughly enjoyed this paper and the opportunity to conduct research about hydraulic fracturing and my innovation topic. In doing so, I quickly realized my bias and had to push through it to ensure I looked at all perspectives - confirming, opposing, and indifferent. The interconnected complexity of the energy system is extensive and the varied opinions on the solutions to combat climate change and global warming are equally broad. In my opinion, the US does not have a wicked *power* (energy) dilemma, we have a wicked *willpower* dilemma.

**Megan**:
I fought hard to tap into my techno-optimism with this paper. It is exciting and hopeful to imagine a wave of green energy on the horizon from wind and solar to next-gen nuclear and hydroelectric, we need all the help we can get to reduce our GHG emissions. As author and environmental activist, Bill McKibben, has said "There are no silver bullets, only silver buckshot." Diversifying our energy sources will not only help us with energy resilience and independence, it will be critical in helping us reach SDG #7, which strives to ensure access to affordable, reliable, sustainable and modern energy for all. It was also interesting to revisit the role of circular economies in humanity's search for making and replacing high-GHG emitting materials.

As far as team processes, I felt everyone did an excellent job communicating and teaching each other about our topic summaries. We found ourselves balancing pragmatism and optimism in our debate surrounding the role fracking has to play in our path to a sustainable future. How do we invest in a future where people, profit, and planet are in harmony? What compromises are we willing to make as the arc bends slowly toward justice? How do we accelerate the bend of this arc without breaking it? We came to the conclusion that fracking is still a vital piece of infrastructure in this metaphorical energy arc. However, I firmly believe as we invest more in people and planet, profit will follow, and fracking will someday become obsolete. It will become our rainy day reserve, fortifying our national security and ensuring our energy independence for future generations.

**Alex**:
The biggest lesson I learned during this assignment was that values play a big part to what energy systems are used and where. Based on our numbers I was the only member of my group that supported fracking and it proved difficult to try and convey to my teammates why my allocations were so different than theirs. I totally understand my teammates' view on the issue as well because morally I had a similar viewpoint but after considering factors such as economics, technological limitations, implementation time, etc. I challenged my confirmation bias and altered my view. To sum it up, this assignment taught me how to practice "muting" my inner ego and look at issues through a different lens. Also, molten salts are neat-o!

**Karen**:
Energy sector is an exciting field of study in sustainability. Perhaps US energy is tied to the free market, and energy production itself is closely connected with the finite resource of water. I have a personal bottom line for allocation criteria related to similar assignments: if the strategy or solution can decouple water use in a foreseeable future, they are a good investment. Despite the case for fracking's economic benefits, I can't be convinced it is worthwhile because of the danger to safety and the wasteful use of water. Overall, I enjoy learning about the energy system and fracking. I'm most impressed by technological advances that enable us to innovate and explore various energy sources. Our team discussion was also very intriguing and informative. I learned from my teammates' writing about their innovation research.

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Necessity is the mother of invention. Whether it is for energy supplies or consumption, humankind continues the search for cheaper and reliable energy solutions. The environment provides a series of renewable and non-renewable energy sources. However, most non-renewable energy sources are fossil fuels and they have very high external cost—climate change, air and water pollution—and in the case of fracking—human-induced earthquakes. Technological advances will enable fossil fuel producers to tackle more bridge fuels. Dare we ask to what end will these bridge fuels give way to renewables? Landfill gas (LFG) can be used as a renewable energy resource (EPA, 2020). Dare we assume that innovations for capturing methane emissions from landfills are more eco-friendly, and perhaps more profitable, than extracting unconventional natural gas through fracking? We are racing against the pace of climate change. When it comes to climate-induced loss and damage, what's done cannot be undone. It is imperative for us to phase out the fossil fuel industry for an inclusive and sustainable energy economy. Ahmed Zaki Yamani, former Saudi Minister of Oil, had an intriguing prediction. He said, "The Stone Age did not end for lack of stones, and the Oil Age will end long before the world runs out of oil." As the world is grappling with the covid pandemic, the oil and gas industry has entered an era of low prices. Facing oil and gas oversupply and the increasing competitiveness of cleaner energy sources, can the shale phenomenon endure? What if the telltale signs of "frackers are in crisis" is not a forecast but a reality (Gruley et al., 2020)? Will the political will in the U.S. gain momentum for renewable innovations and climate action? The future is now.

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