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A Multi-Faceted Energy Transition

The United States, along with the global community at large, has been tasked with enacting a major energy transition in the next few decades. Primary energy consumption has continued to rise with each passing year, now nearing 26,000 TWh and trailing only China for the world lead. This, accompanied and influenced by demographic trends such as urbanization and overall population growth, has put even further emphasis on the need for the US government to address the issue of energy. As it stands, there has been a noticeable increase in the integration of renewable energy generation sources such as solar or offshore wind in the last decade or so, but they still combine to account for less than 20% of the country's total energy consumption.1 In order to address the issue of our dirty energy generation and massive energy consumption, drastic but necessary measures must be taken at both a federal and local level from a variety of sources. Fortunately, several examples of measures taken both within the United States and globally can be adopted or serve as inspiration for actions to be taken for the United States as a whole. By adopting some of these strategies, the United States can address its energy problem at varying points in the national energy system including energy generation/production, distribution, and end-use.

Large-Scale Energy Generation

A priority for the energy transition is to move away from fossil fuel reliance and integrate more renewable energy sources. This is not a new concept, and in fact, progress has been made in terms of the deployment and development of utility and commercial-scale renewable energy generation facilities. Based on planned energy generation facilities for 2022, 29.1 GW of new electricity would be generated from wind and solar, which combine for 63% of new energy generation for 2022. However, the rate at which we are transitioning to renewable energy is simply not fast enough for the damage we are causing to our environment. In order to expand on these preexisting efforts, there should be an emphasis on federal legislation incentivizing/promoting states' and utilities' integration of renewable energy projects as well as specific research and promotion of energy storage technologies as a means to promote grid reliance and efficiency.

As far as promoting renewable energy projects, some states have already enacted aggressive policies or designed programs to allow for a simpler path for the development of such projects. For example, Massachusetts has recently passed bill H.5060 (better known as *An Act Driving Clean Energy and Offshore Wind*) which is a sweeping renewable energy bill aimed at promoting renewable energy generation in the state. Among other things, this bill invests heavily in the promotion of offshore wind development by limiting price caps and the power of utilities in accepting bids while also promoting Diversity, Equity and Inclusion (DEI) in both job training and contracting with local businesses. In addition to the benefits to the offshore wind industry, this legislation promotes the development of solar and agrovoltaic projects and investment in other carbon-free technologies such as geothermal and nuclear. Several states have taken progressive legislation along with Massachusetts, but many states have not followed suit which

emphasizes the importance of federal legislation. There has certainly been movement in the right direction on the federal side, such as with 2022's Inflation Reduction Act which contained many opportunities for tax credits for renewable energy projects which further spurs the development of these projects. However, the federal government can do more to not only provide direct incentives for renewable projects but encourage change in the habits of the private sector by means of economic tools such as carbon/emission taxes, feed-in tariffs, and further subsidies for renewable energy technologies. Having aggressive overarching policy allows for some states with more conservative or fossil fuel-based societies the opportunity to be a part of the renewable energy transition.

Complimentary to the promotion of federal legislation for renewable energy programs at large is the need for significant investment, incentives, and research into energy storage systems. If there is a massive influx of energy generation on the electrical grid, it is likely to overload the grid's capacity and thus negate all of the intended benefits of the new generation facilities. By incorporating utility-scale energy storage systems and storing energy during times of low usage to discharge at high demand periods, not only does the electrical grid have more resiliency but becomes much more efficient and less wasteful. Additionally, if energy storage facilities can take care of periods of excess demand, there will be less reliance on fossil fuel "peaker" plants which currently operate out of necessity across the country. While the benefits of such systems are well known, there is a lot of work to be done in terms of promoting their deployment.

For one, unlike solar or wind energy where there are explicit and specific incentives or targets for development, energy storage is fairly new to state or federal legislation and has not been afforded the same protections or emphasis. As a result, developers of their projects have had more difficulty in getting these facilities permitted either due to the lack of knowledge about

the technologies at a local level or a resistance to having explicit permitting and zoning guidelines. By including more legislation with specific targets, requirements, and incentives for the development of energy storage systems, local governments authorities are forced to learn more about and prepare for the integration of these technologies in a way that both protects local interests and aligns with larger goals for grid resiliency and renewable energy integration into the grid.

Aside from the legislative attention needed, there is a significant need for further research and development of energy storage technologies. As it stands, lithium-iron battery storage is the most commercially viable technology and has the most active deployment. However, issues with modularity and lifespan, as well as the high demand for the necessary materials needed to construct lithium-iron batteries, make the reliance on this technology potentially unsustainable. Luckily, many other types of energy storage technologies could potentially be commercially viable if given proper funding, such as underground pumped hydro storage, thermal energy storage, or mechanical energy storage options such as flywheel storage. Furthermore, newer technologies such as various long-duration storage systems (12+ hour cycles rather than 4 hours) have been proven to be more cost-effective when paired with other renewable energy generation technologies and provide greater grid resiliency than shorter-duration battery storage options. By investing in the research and development of such technologies, we can enhance our existing renewable energy generation facilities while decreasing reliance on fossil fuels and improving grid resiliency and energy access.

Energy Distribution

While much of the international focus has been on the development and deployment of renewable energy generation facilities, with the increased electric generation comes a greater demand for distributional services on behalf of our electrical grid. As previously mentioned, the integration of energy storage systems will aid in easing the stress on the electrical grid, but it is undeniable that the current distributional infrastructure will need a significant overhaul. According to the National Renewable Energy Laboratory in their Electrification Futures Study, electrification and reliance on renewable energy generation require "corresponding expansion of long-distance transmission capacity [which it] correlated with growth in renewable energy sources". This increase in long-distance transmission capacity is not only costly but takes a significant amount of time to undertake given the vastness of the country. Furthermore, the need to update and improve our distributional infrastructure also comes out of a need to adapt to the ever-present effects of climate change. In a 2021 article, it was estimated that climate change may be directly responsible for a 25% increase in infrastructure damage per year to things like transformers, poles, and transmission lines.5 Luckily, proper mitigation efforts where one adds extra lines and towers to increase capacity can combat these potential damages. However, another reason why the revitalization of our electrical grid is difficult is the fact that electrical distribution infrastructure is very long-lived so as long as there is no incentive to replace it. If we are to make an energy transition, we cannot continue to rely on old technology that is nearing the end of its life with no feasible and widely deployed alternatives. This quickly becomes an access and equity issue, as energy should be considered a right and we must do what is possible to protect the rights of present and future generations.

End-Use Adaptation

Given the focus on the needed improvements to renewable energy generation and distribution, the final piece to the puzzle is changing how we see and consume energy as end-users in our national energy system. Even if we were able to continue to increase the production of electricity and more efficiently distribute that energy, the rate at which we consume energy is obviously unsustainable. In order to ease the burden on both the production and distribution of energy, as consumers we can be more efficient with how we utilize energy in our daily lives. Luckily there are a variety of methods by which governments can incentivize these sustainable end-use behaviors. One of the most impactful methods revolves around the idea of energy efficiency and promoting more energy-efficient technologies. This can apply to almost all sectors of society, but most notably in transportation and buildings. As it stands today, in the United States there is a major emphasis on automobiles and infrastructure promoting their use. Given that most automobiles on the road today still are powered by fossil fuels, a logical next step is to promote more energy-efficient behavior is incentivizing the use of electric vehicles and promoting the development of EV infrastructure such as charging stations. While this is widely talked about and has even been enacted on a large scale in states such as California, which has robust EV incentivization programs and legislation, an often overlooked method of energy efficiency is electric vehicle grid integration. In theory, this technology would allow EV users to discharge the batteries of their electric vehicles back to the grid during times of high demand (at night time when vehicles aren't being used for commuting) much like a battery energy storage system discharges its stored energy. Not only does this further aid grid resiliency, but it does not allow for electricity to be wasted by charging an EV all night when it likely will not be in use.

Even beyond this technology, energy efficiency programs for housing and construction have proven to be highly effective. Energy efficiency in this context can mean anything from

requiring minimum energy ratings on appliances to retrofitting existing buildings and providing incentives/subsidies for said retrofits, or even something as simple as improved insulation via double and triple-paned windows to allow for less waste from HVAC units. While some states in the US have enacted several of these policies, arguably no country has had a more successful program than the United Kingdom. From 2001 to 2011, England enacted its Warm Front Home Energy Efficiency Scheme which provided grants to improve insulation and heating in low-income housing communities in an effort to combat fuel poverty in the country. By the end of the program, they had reached and retrofitted 2.3 million homes and aided in installing insulation, replacing water boilers, and installing central heating systems for tens or even hundreds of thousands of homes. Domestically, Massachusetts has a pretty successful building retrofit program in MassSave that has saved over 12.2 million MWh of electricity and eliminated 3.7 million metric tons of CO_2 emissions. By continuing to push for and develop state and federal energy-efficiency programs such as these, end-users can begin to optimize and limit their overconsumption of energy and contribute to creating a more sustainable energy system.

Finally, in addition to these energy efficiency methods to be taken at the consumer level, individuals can take advantage of incentives for behind-the-meter energy generation and storage by way of rooftop solar panels. Many states have grants, tax credits, and rebates for local energy generation that can be sold back to utility companies and deducted from their energy bill. This way, not only is the consumer saving money but they are contributing to providing clean energy to the electrical grid. To take this idea a step further, by connecting multiple behind-the-meter distributed generation systems one can create a microgrid that has its own resilience independent of the larger national electrical grid. Combining solar or wind energy generation with energy

storage on small scales like these allows for a further diversified national energy profile and can ease the strain on the grid.

Conclusion

While revolutionary ideas and technologies can be exciting when trying to figure out solutions to our most pressing issues, it is important to realize that our biggest hurdle isn't our lack of innovation but rather the difficulty and complexity of implementation. We have created a system that has suddenly become detrimental to not only the health of our planet but to present and future generations of people that do not deserve to suffer due to the mismanagement of these problems. Very rarely is it the case where the people being affected the most are also the causes of the issue when it comes to these negative environmental impacts. However, we have examples all over the world of how we can work to address our biggest challenges and rise to the occasion. If we can adapt these case studies to our specific circumstances and do so in an equitable manner, there's no doubt that we can effectively make the next great energy transition.