The State of Renewable Energy Development in the United States

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I am going to cover five topics within the renewable energy space. I want to cover how renewable energy markets work, and specifically, for utility-scale solar projects—not rooftop arrays or small community solar, but projects that are hundreds of megawatts and each serve over 100,000 U.S. homes with renewable power. Second, I want to talk a bit about how the grid works and why these markets are the way they are. Third, I'm going to spend some time on the state of the energy market, the impact of the Inflation Reduction Act (IRA), and potential impacts on that following the 2024 election. I will discuss some of the issues emerging since the pandemic that have affected our industry, and the opportunities to overcome those challenges. Finally, I'm going to end with a call to action: a discussion about how you as an individual or student could be involved in this line of work or a related line of work. After this presentation, I hope you are motivated to help solve the climate crisis—that's the key message.

The clean energy industry has been booming since the Inflation Reduction Act was passed in 2022.[1] The IRA is a lot of planned investment with $500 billion in projects announced since it was passed in 2022, and it has a big impact on manufacturing being reshored to the United States. There are forty-two new facilities that will construct wind turbine components, batteries, solar modules, and things of that nature. Forty-two are already operating, and there's an additional 160 planned.[2] Both the components and the deployment of those components into these projects contributes to a significant amount of manufacturing job growth that's happened in the past year and a half.

I mentioned gigawatts and megawatts. We've used that term already, and I want to make sure people know what those are and give you a sense of the scale. First of all, they are units of electricity generation. You may be familiar with the kilowatt-hour; it's probably the unit used on your electricity bill. A thousand kilowatt-hours is a megawatt-hour. A thousand of those is a gigawatt-hour. "Capacity" is a related term to describe the amount of electricity that a system can produce or transfer—measured in kilowatts, megawatts, and gigawatts. One way to think about the difference between capacity and generation: capacity is persistent and generation is instantaneous. Capacity is the maximum output of a renewable or other type of generating system. The instantaneous output at any given time (over an hour) is the kilowatt hours of electricity produced. The average annual household's use of electricity is 10.6 megawatts. I hope that offers perspective when we start talking about these numbers and the sizes of projects I'm going to describe. It gives a sense of scale for the energy needed and what's being produced.

Clean energy is an opportunity. We've known this for a long time. Costs are coming down as technologies mature for solar and wind. They have lower operating expenses than fossil fuel generators. Because wind and solar don't have a fuel cost, which could affect how much it costs to generate electricity, they simply turn on any time that power prices are greater than zero because they would rather make one penny than nothing. A comparable gas plant might not turn on until it hits forty to fifty dollars per megawatt hour unit of energy. We don't know what tariffs will do in the short term to change cost curves, but generally speaking, we are continuing to see wind and solar be more competitive than fossils when compared directly—even without incentives.

I want to shift and give you a brief background on my company. Apex is a clean energy IPP, or independent power producer. We're not a utility; we're a privately held firm that develops, constructs, operates, and owns these wind, solar, and battery storage assets. Our customers are a mix of utilities, corporations, government, and institutional purchasers. They buy our power. They may also buy our projects, depending on which market we're talking about. We're about 430 employees headquartered in Charlottesville, Virginia. I joined nine years ago when there were 150 employees. I've seen a significant ramp up in our capabilities over time. We are now also in technology for battery storage and potentially green hydrogen in the future.

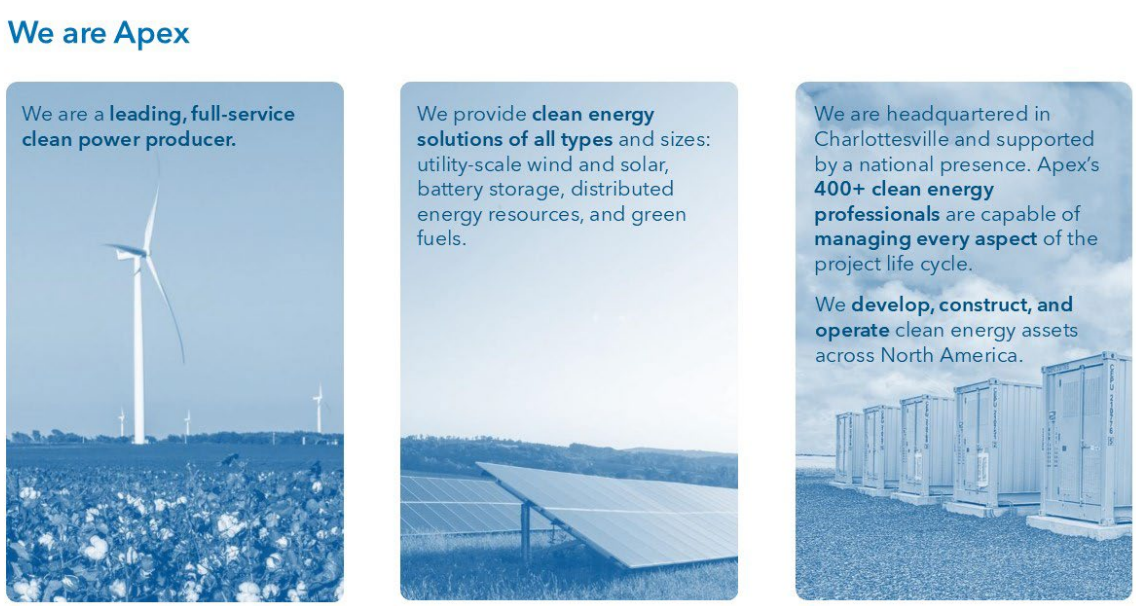

Figure 1. Apex Clean Energy Overview

This is a snapshot of where we are currently developing and have operating assets. Sixty gigawatts of potential projects are represented on this map. Apex has commercialized over fifteen billion dollars that have been used for projects under construction, operating, or have been financed. That represents over ten gigawatts, more than fifty wind and solar projects.

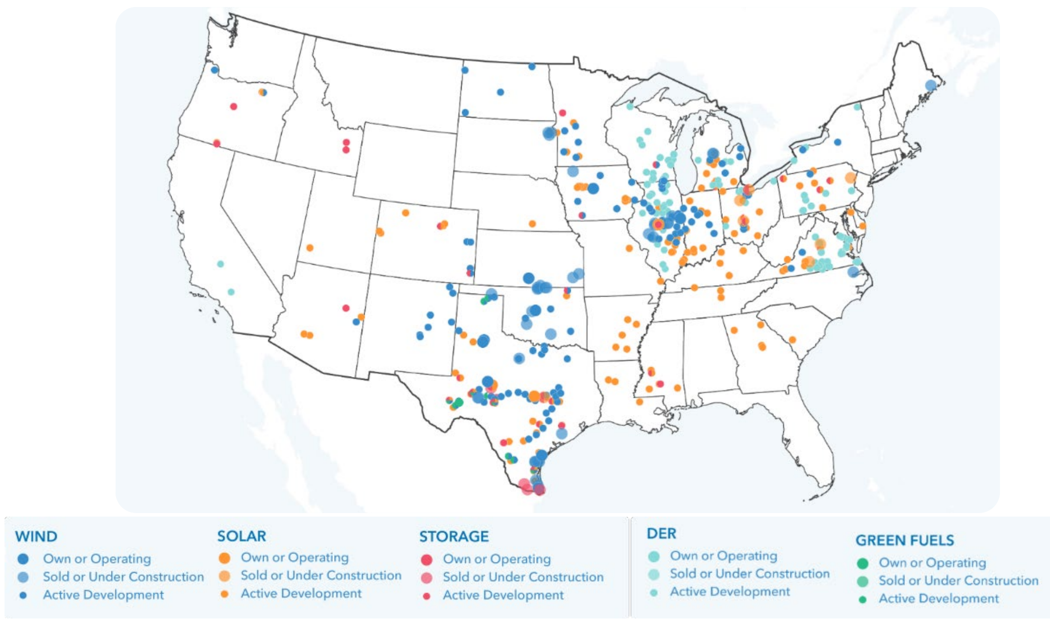

Figure 2. Apex Project Portfolio

Offtake describes when a company or a utility agrees to purchase the output of one of our projects for a period, generally between fifteen and twenty-five years. This is also known as a power purchase agreement (PPA) or a VPPA, a financial version of a PPA—the V stands for "virtual"—in which the buyer doesn't own the physical electrons, but where we trade the financial value of those electrons. These are the agreements that enable renewable energy projects to raise the financing needed to be constructed. It's a key element of the development process. The graph below shows different types of customers between corporations and utilities over the years that we've been in business with. It shows you the evolution as well.

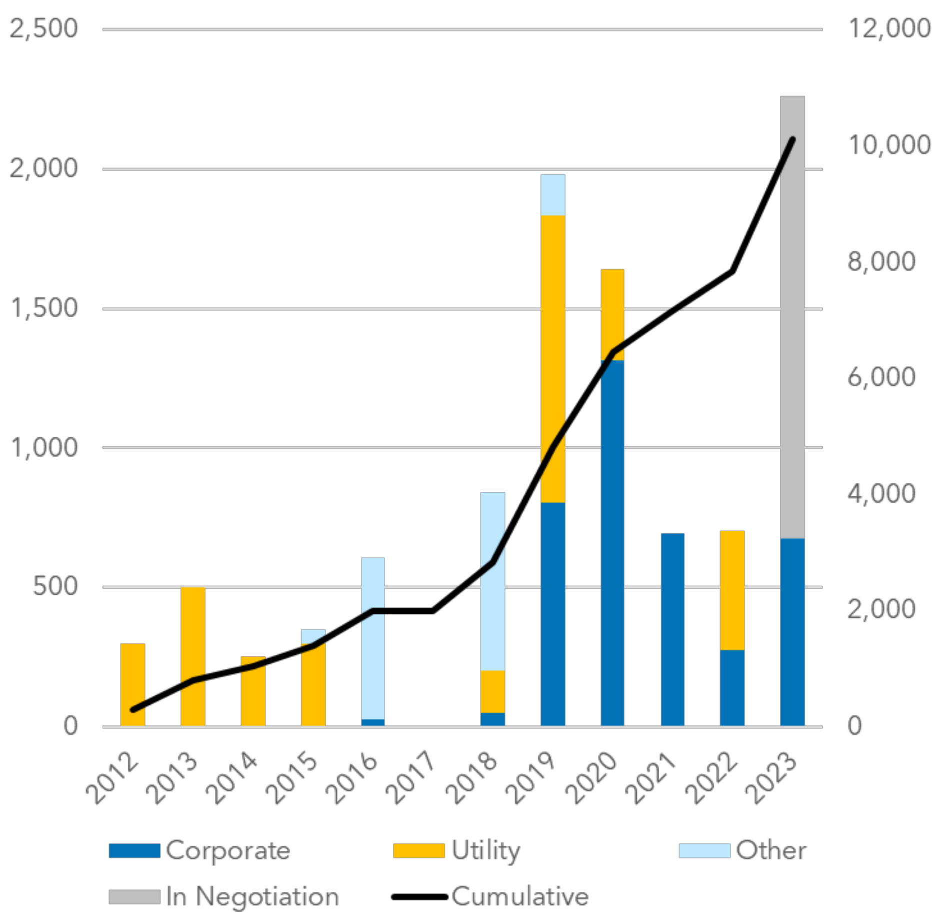

Figure 3. Apex Offtake History, by Customer Type (Annual and Cumulative Megawatts)

Many of you have probably seen ESG (environmental, social, and governance) or sustainability commitments from Fortune 500 companies in the last several years, and the numbers show that we're now transacting with a lot more of these corporates. There are a lot of big tech companies, manufacturing companies, retail firms, and a wide range of companies participating in the market.

I'm not going to go into too many details, but Apex is a clean energy company. We don't have any fossil or legacy fossil generation, which means Apex appeals to a large segment of corporates with ESG goals that want to directly support clean energy. We have industry-leading programs. I don't have much time to get into them, but for every project we develop, we dedicate a set of funds for environmental conservation grants and community grants. For example, we added broadband in a county in Illinois that didn't have the tax base to upgrade the system itself. We've purchased fire trucks and ambulances. When we go into a project area, we say, "Hey, what do you need? What would help this project move ahead? What do the people really want to see?" and respond. "Beyond the megawatt" is the idea that developing and deploying a renewable asset is great for the environment, but what else can you do? We've signed an agreement with a large technology company that includes an environmental justice component; about 20 million dollars will be invested in historically Black colleges to recruit students to work in the clean energy industry, which is historically white and male. In addition, the agreement may result in solar energy coming into urban centers, elimination of food deserts, and other initiatives that promote policies and actions that protect vulnerable communities and address systemic inequities in environmental decision-making.

We often invest in the local area where the project is built, but that's often not in the city—it's out in the middle of a huge field, in farmland. We try to bring the economic benefits of solar energy to places where disadvantaged people historically have not been able to benefit equitably.

In the below photo, the land is farmed almost up to the base of each wind turbine. When you do these kinds of projects, not much land area is taken out of commission. Solar projects use about a thousand to two thousand acres. For wind projects, it may be a 50,000-acre lease, but it can still be farmed. This has helped, especially because grain and commodity prices have been low in the past several years prior to inflation. As one farmer said, talking about his experience as a landowner and making money off these projects: these projects become the largest taxpayer in the counties in which they're sited. It's a major way for the county to have resources to keep the town small and to keep people there. It provides a lot of opportunity, and when I see something like that, I think, "Gosh, this is pretty patriotic work we're doing here." It doesn't feel green and environmental only. It feels like it should be the core of how we think about being Americans.

Figure 4. An Apex-developed wind farm in Oklahoma.

What is the difference between renewable, clean, conventional, and fossil? What do these terms mean? Coal is a fossil and conventional fuel. Hydropower can be renewable. Some states consider it renewable and some do not, but it is a zero-carbon resource. Solar is renewable. A renewable battery energy storage system is zero carbon. What if I use the battery, and I charge it when the predominant grid mix is fossil fuel? How about a gas peaker plant? When someone needs gas to come online immediately due to some condition that changes in the grid, more fossil fuels are emitted from that type of gas plant. But what if you have renewable energy credits alongside it? It would be net zero because you've emitted fossil fuels, but you've also purchased credits. The legal right to say that one has offset that emission is tricky. Nuclear is zero carbon and conventional. In some places, nuclear power is considered renewable. An electric vehicle can be net zero, but it depends on how one charges it—it is just a moving battery. One has to carefully consider these terms and questions when choosing an energy solution.

A REC is a renewable energy credit. It's the legal claim to own one megawatt-hour of renewable electricity. These credits can be transferred between people, companies, governments, and utilities. One can sell or retire a REC. If one retires it, they take it out of the system, out of commission, and no one else can use the credit. Utilities in most markets, including here in Pennsylvania, have what's called a renewable portfolio standard in which they're required by state mandate to satisfy. In Pennsylvania, I don't remember the percentage, but it's probably around 15% to 20% of all electricity must be from alternative sources.[3] Utilities in Pennsylvania will turn to companies like Apex Clean Energy to acquire these RECs. The price is reliant on an open market, and they go up and down. Corporations are not legally required to buy RECs or do anything with them, but they voluntarily choose to do so to retire them, thus driving up their value. The utilities are then incentivized to build and own and purchase more renewable energy. That's how these markets function.

How does development work? The general process starts with finding wind and solar resources: identifying a site, securing that site through leases, completing permitting processes that are both environmental and interconnected in the grid. And then a lot of public engagement to make sure the communities are on board. Social media has created an environment of misinformation, and there are deep pockets that invest money in pushing that misinformation into communities where they see a project potentially popping up. For us to combat that is very challenging. That's been a point of friction in the last several years. The other thing is NIMBYism and viewshed issues. Just a couple people can put a lot of pressure on county commissioners who have to say yes for a project to proceed. It's a very political, challenging environment to manage a lot of the time. Permits can also be appealed legally, which delays projects, triggering long legal processes and increased project costs. In some cases, a permit appeal may result in other project permits expiring, which further delays or prevents the project from coming to fruition.

Next, we procure the major equipment and components of the project, and then offtake, which comes in right before we finance and construct the projects. The projects that we work on can cost over $700 million in some cases. Most companies don't have the cash or equity to directly invest that much, given the number of projects we are simultaneously developing. When we do these projects, they are capital-intensive. We raise two different types of financing: debt and tax equity. We raise traditional debt that can be taken out for whatever the interest rate is. Raising that allows us to lower the amount we must bring to close the financing. Tax equity is the entity, the bank or company, that has a tax bill, and they choose to invest their dollars in our project because, in exchange, they get federal tax credits. They can use those tax credits to lower their tax bill and can end up making rates of return of 7% to 9%.

The difference between conventional energy and renewable energy is a question of not having control over when the wind blows and when the sun shines. The resource is not dispatchable. I can't say, "Hey, I need solar now." I have to look at the weather. On this next map, the dark red on top is where the solar is most prevalent.

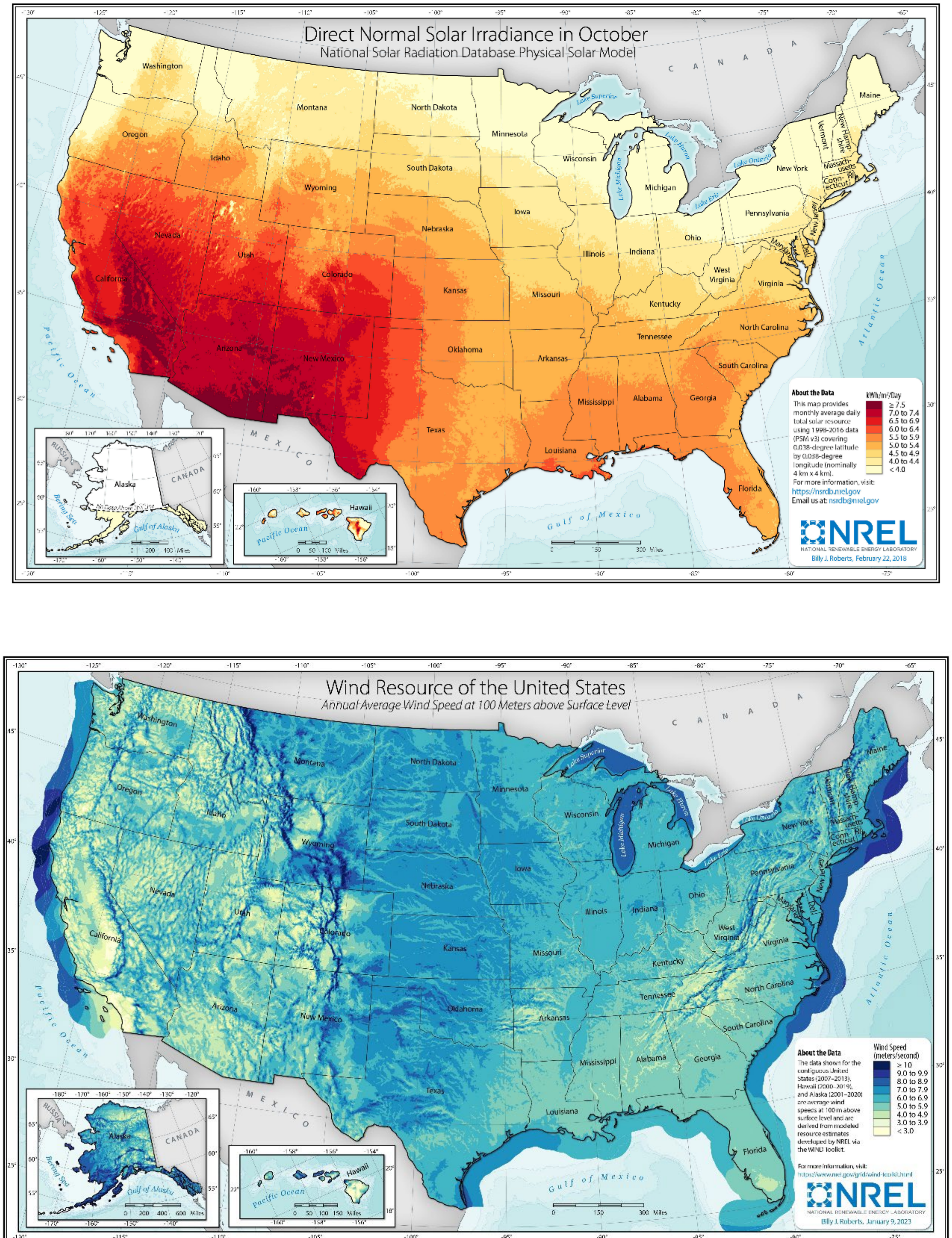

Figure 5. U.S. Solar and Wind Resources[4]

You see a lot of solar projects in the desert southwest and in Texas. In the bottom map, the dark blue is showing where the wind belt is in the U.S., in the Plains where there are not many people. However, getting that wind energy out of the center of the country is a challenge, as there few major transmission projects currently able to do that. Power prices in windy areas tend to be extraordinarily low, and power prices where most people live on the coasts tend to be relatively high. The next graph shows how different resources that we may have access to in our company stack together. Blue is wind, yellow is solar, gray is grid power, and purple is the usage of a battery. If I have a data center that requires a hundred megawatts of energy, the black line, I need a mix of all these different resources if I want it to be all clean. In most markets, a lot of gas and coal is still supporting the systems.

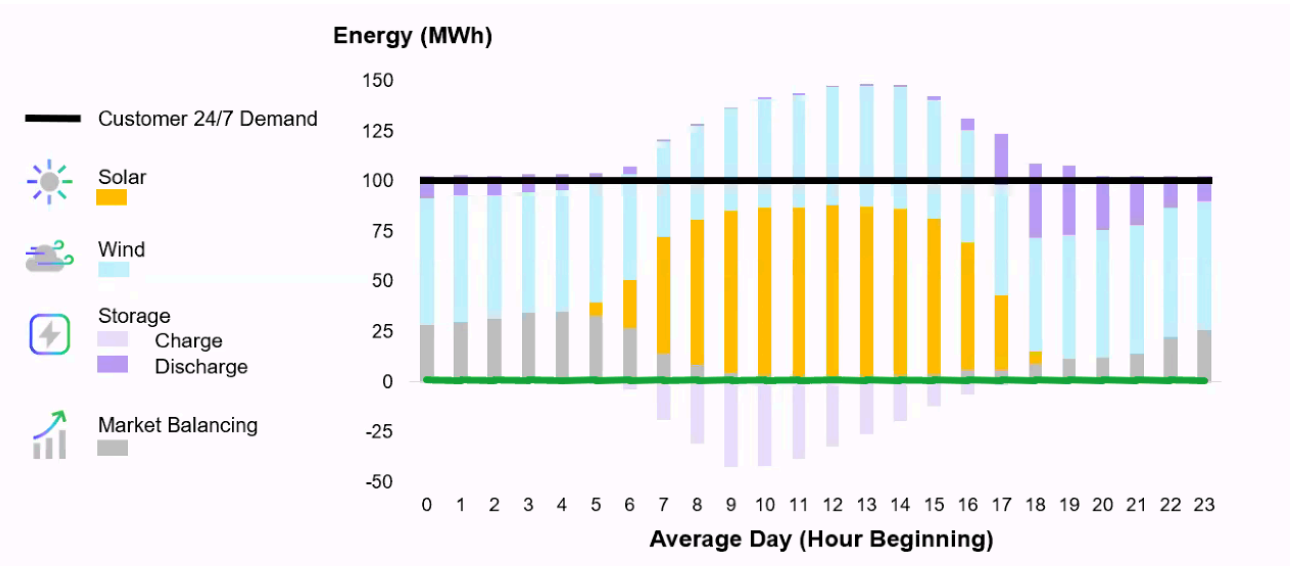

Figure 6. U.S. Grid Power Balance

Power markets are sub-areas of the overall grid; we have several sub-grids that make up the U.S. power system.[5] Everything except for Texas is managed through the Federal Energy Regulatory Commission (FERC). The Texas energy grid functions as its own country in this regard. There have been some interesting times when Texas tried to run a power line outside of a territory, and if they do that, they become instantly ruled by FERC. In the next graphic, you can see where Pennsylvania is, in yellow. That's called PJM, which stands for Pennsylvania, Jersey, Maryland. That's a tough market to do solar transactions in because there are just so many population centers. Topography is also difficult here. But each of them is connected and power prices are related between them, and they all have different rules that allow free trade and the transfer of power or not. In the west, in the green and in the gray, there's one controlling monopoly utility. One cannot really do anything with the power other than sell it to them. In the other markets shown there, one can sell energy to corporations or whoever you want, and you're allowed to do that—and you can sell energy into the grid and be paid a "merchant" price for the electricity. It's a very different system depending on where one is regionally.

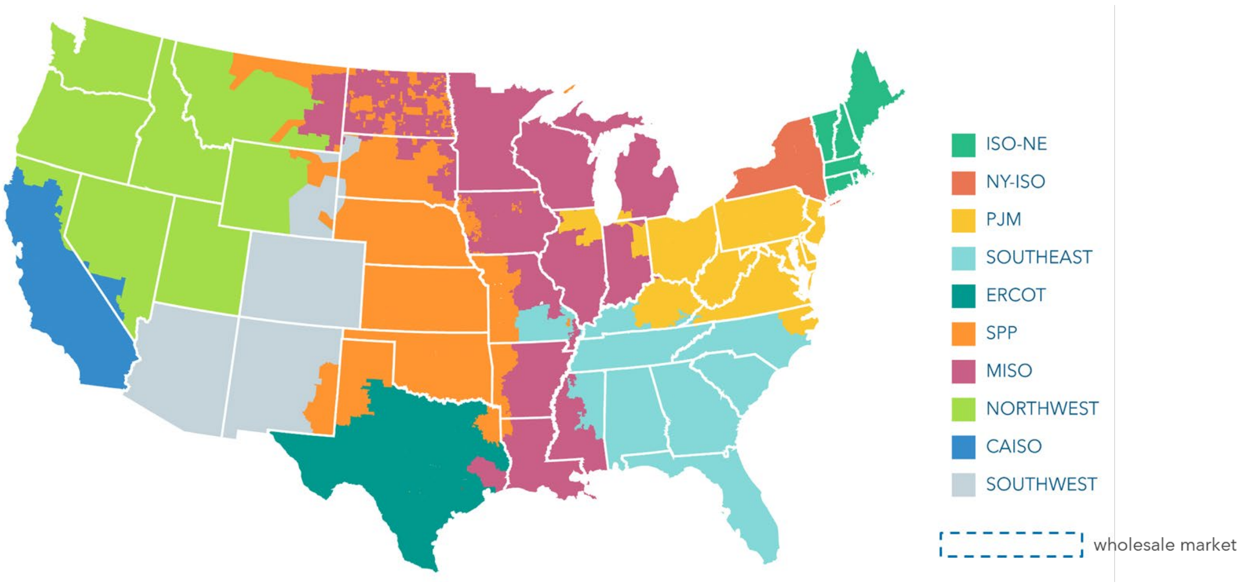

Figure 7. U.S. Wholesale Electricity Markets

I'm going to discuss Texas because it's smaller and the rules are easier to understand. Each of these individual grids is covered with nodes. The nodes represent the locations of a generator, a project, gas project, or a load, meaning a consumer of energy, illustrated at below left. Below right are the real transmission lines, major transmission lines that go across Texas. You can see there's not much in West Texas right now and not much up in the panhandle. Those places historically have congested grid characteristics, and that causes really low power prices, which I'll explain shortly.

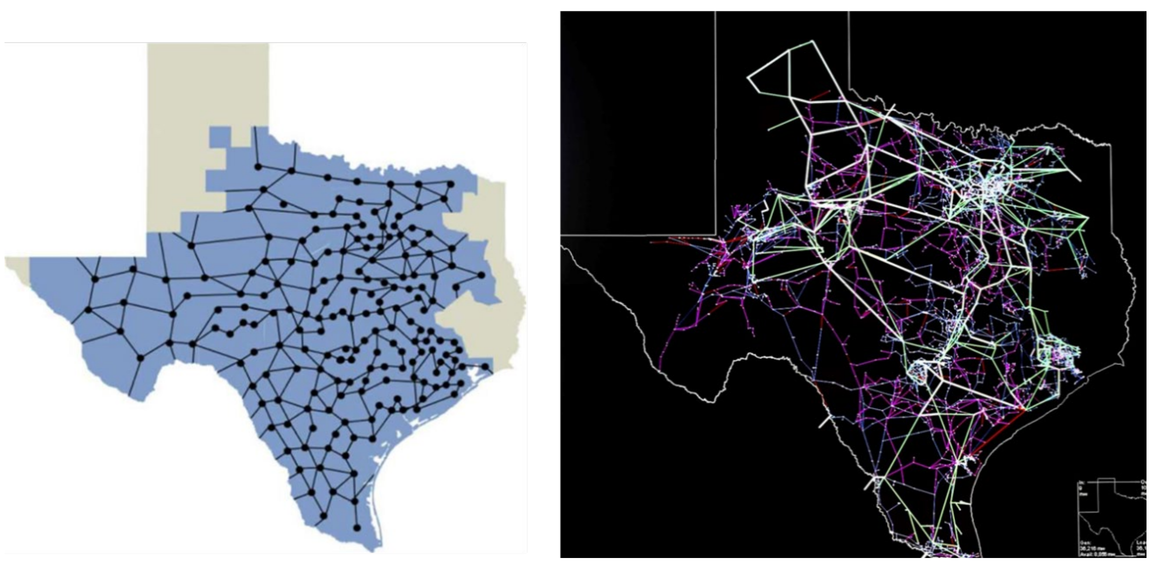

Figure 8. Transmission in Texas

This next map shows actual nodes where those generators are. And the color underneath the nodes shows the difference in power prices across the state in a given five-minute interval. If you live in the very southern point of Texas, your power prices are in the fifties, and if you're in the panhandle where there's too much wind blowing right now, your pricing is negative. It's a weird concept that power prices can be negative, but it means that a wind farm operating there has to pay the grid to take the power because there's no one to use it. That's the idea of congestion. There's a difference between these points on the graph. If they were all the same, the highways would be open with everyone driving at the speed limit, but in this case, there are constraints.

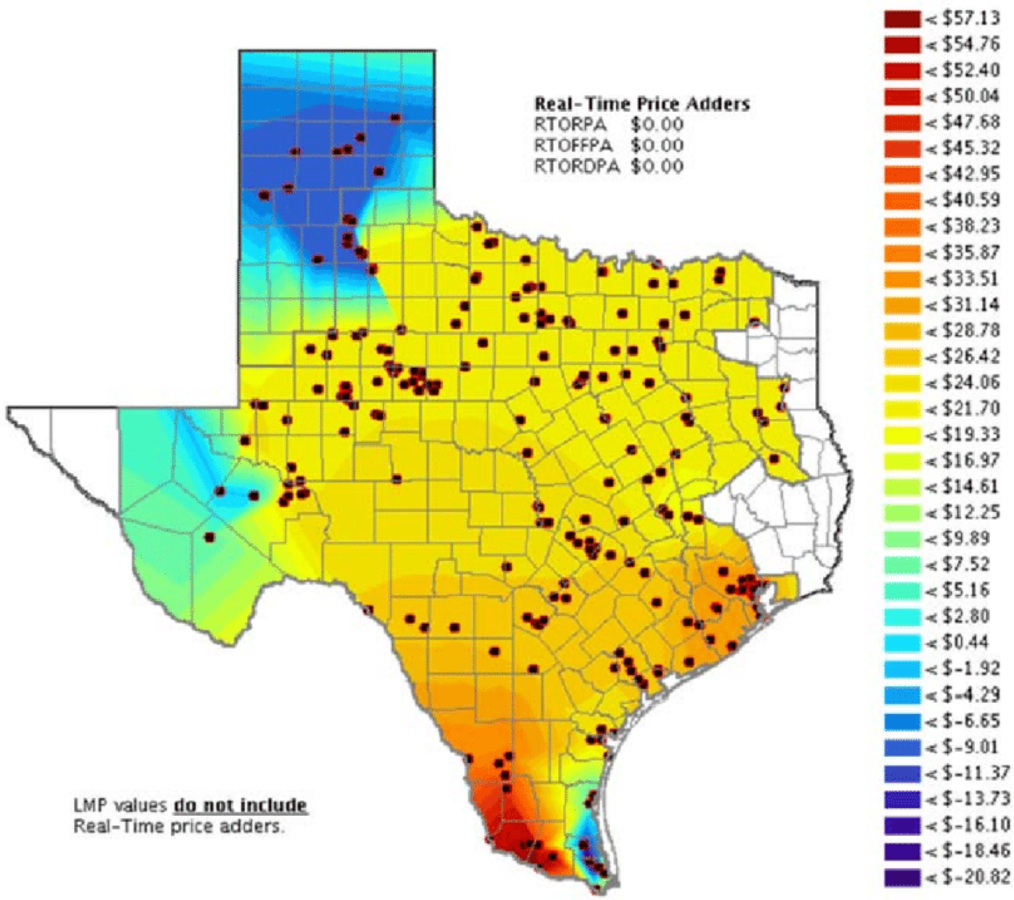

Figure 9. Texas Power Prices

"Merit order dispatch curve" is a complicated term, but it's also somewhat simple. There is an orchestra of power plants in the grid, and the grid determines which plant is going to get called on to produce power for each interval—typically five minutes. There's a cluster of reds and greens and browns in the middle of this next chart; those are natural gas and oil and coal plants. Looking at the left axis, they're charging in the thirties or forties ($) per megawatt hour. Everything to the right is higher priced than that, and everything to the left is lower priced.

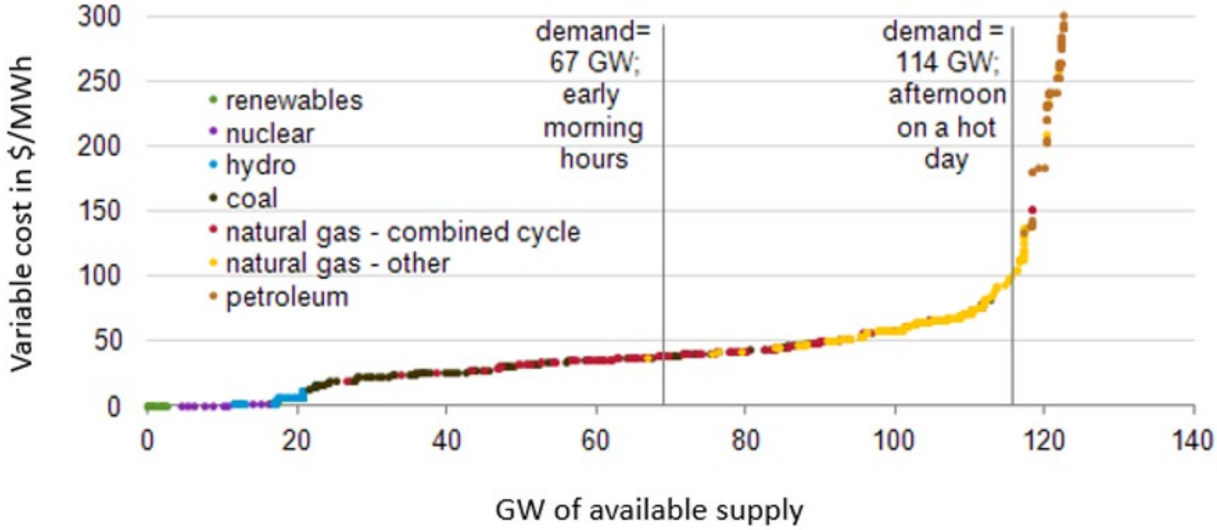

Figure 10. Economic Dispatch of the Grid

Merit order means that whoever tells the grid that they're going to dispatch at the lowest price gets preferentially called upon to dispatch. Wind and solar are all the way on the left because they're bidding $0 (or negative prices because they receive tax credits) and have no fuel cost. The price of the gas is going to determine the price that the power plants get paid. Everyone gets paid the same price, even though we bid a lower price. We bid zero, and we are paid in that red price range.

Everything I've been talking about has been related to *wholesale* power, which is that blue piece of the pie. This shows that your electricity bill is made up of several components, including wholesale power price determined by the graph above, and how much it costs to build and maintain transmission to distribute the energy. Renewable projects are paid from this blue section.

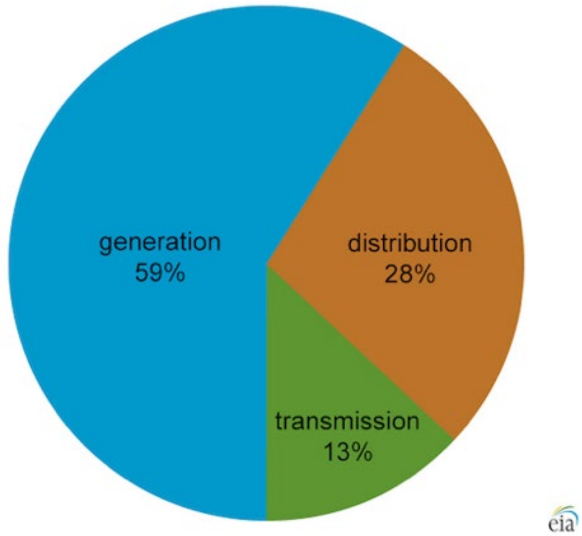

Figure 11. Major Components of the U.S. Average Price of Electricity, 2017[6]

So, who's buying renewable power these days? It is corporations, in very large part. They now make up more than 50% of the entire market in the U.S. The next graph shows the number of corporations making new, science-based target commitments to buy renewable energy and do so in a way where they can stand behind those claims from 2015 to the end of 2023.

Net zero—meaning no net emissions—to the grid is pretty remarkable. Over just the last couple of years, these commitments have been stepping up significantly, especially by tech companies. Meta, Google, Microsoft, Verizon, and AT&T are at the top of the list, but there are others. Where are they doing it? Texas is off the charts due to permitting ease, which we're going to talk about.

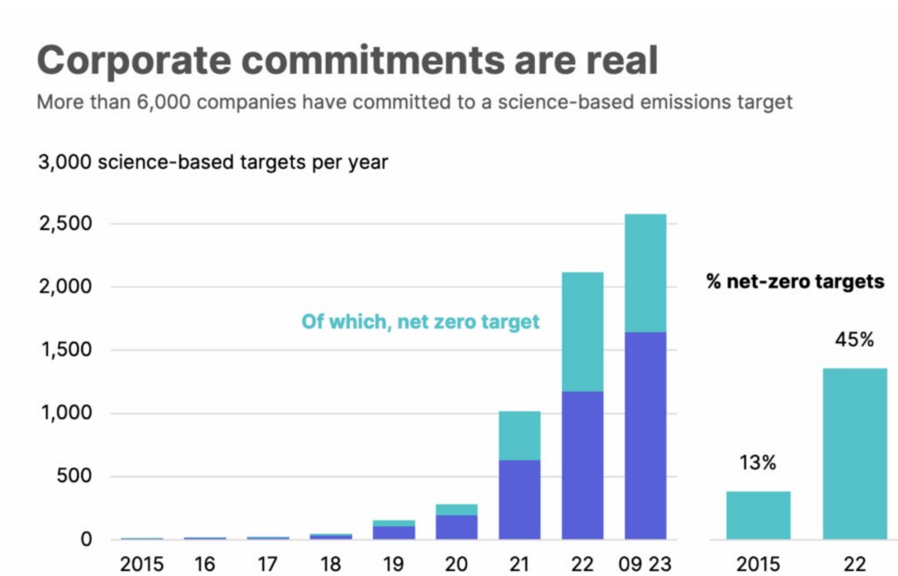

Figure 12. Corporate Commitments to Science-Based Emissions Targets[7]

How do corporations buy the power? VPPAs. Renewable projects generate energy and sell it to the grid. And in five-minute intervals, the grid determines how much it will pay the renewable project using merit order and locational data—like the available capacity on a transmission line and where customers are using the energy. Separately, there is a side transaction with the corporation. The corporation pays a company like Apex Clean Energy a fixed price per megawatt-hour, and they receive renewable energy credits and the financial value of whatever that energy was sold for. If the grid pays us, we pay the customer. What is basically happening is a financial fixed-for-floating swap. Our project is getting paid a fixed price from a corporation, and we're paying the value of the energy, and we settle the total amounts due at the end of the month. That transaction allows us to have a steady stream of revenue, and it allows these corporations to access renewable energy credits.

Three things have been especially challenging in the last several years: permitting, which I've touched on already; interconnection, which has some long timelines these days; and tariffs, including supply chain impacts. There's over a hundred gigawatts of projects waiting to be built, but they're stuck because permitting is delaying them. A six-month permit delay costs a significant amount of money: $200,000 per megawatt, which ends up increasing energy prices for consumers. Projects are canceled pretty commonly. A third of wind projects and half of solar projects fail to receive permits, or they are delayed by six months or more. Canceled projects on average cost the developer $2 million for solar and $7.5 million for wind because of the development expenses spent in advance of permitting. This is a big hindrance to the renewable industry.

In a case study, Apex tried to think differently about permitting in a county in Indiana. Indiana has a mixed set of needs. About half of the state has a moratorium on wind, so we're not legally allowed to permit wind there. The other half is still open, but counties have the option to restrict wind even where it is still possible to develop. We worked with a third party to facilitate discussions with community stakeholders who wanted to participate in our project. Apex said, "Hey, instead of us designing this project, we're going to invite the community to help us design it, locate the turbines, which in turn determines pay to participating landowners." It was a very collaborative process and something that has never really been done before. Unfortunately, the county ended up voting no on the permit. I think the experience taught us some of the tactics that go into public engagement because, again, just a little opposition, even in a positive process where people felt heard and were involved, can still fail. Projects that benefit the entire community shouldn't be blocked by a small group if developers have followed proper procedures—regulations should ensure this.

In states like Illinois, Minnesota, and Michigan, that's what's happening. In Illinois, a new law was passed last year that effectively states that the state will set standards for permitting requirements, and the county can use that framework to do the permitting process. But if the county doesn't follow that standard and they vote no on a project that has followed the law, then the state may sue the county. Some counties don't have wind ordinances or solar ordinances. They don't know the process, and this framework defines the process for them. And if everything is done correctly, then the project is permitted.

Now I will discuss a little bit about the grid and interconnection challenge. I'm guessing everyone has heard a lot about AI recently, but maybe not concerning power demand. Two stats: a ChatGPT search takes 10 times the amount of electricity of a standard Google search and consumes 16 ounces of water to cool the data center that's performing the search or running the model for the AI. Many, many tens of gigawatts of energy will be needed in the next eight years just to satisfy AI data center needs.[8]

Microsoft is paying a high cost for electricity to have Three Mile Island reopen. Amazon is going to try to get nuclear energy directly at the Susquehanna nuclear power plant in Pennsylvania by building a data center behind the interconnection point on the transmission system. Coal is supposed to be shutting down, but some of these coal plants will stay open to satisfy data center demand. These tech behemoths, the biggest buyers of renewable energy credits, are now, in certain cases, causing coal and gas to stay online. I believe Microsoft's and Google's CO_2 emissions went up about 30% and 50% respectively last year, even though they have goals to match 100% of their energy use with renewables.[9]

We need to build a lot of transmission to enable those data centers to access clean energy. We need to build a lot of transmission so our projects can interconnect into the grid. The average time to get a transmission permit is six and a half years. It's sometimes longer than ten. We need to bring that down, and I think that there will be interest at the federal level to make permitting easier. It will probably make renewable permitting or transmission easier, but it will also probably advantage fossil interests, too, especially with the new Trump administration. Last year, 255 miles of transmission were built, but there needs to be more than a thousand miles built every year to keep up with current demand. To give you a sense of the scale, there are 10,000 miles of transmission projects aiming to be completed; looking at the map below, the blue line zigzagging four times across the country is the length of transmission lines that would equal. It's an astonishing amount of major infrastructure projects that would need to be completed. But it's worth doing. Every dollar that someone invests in transmission saves energy customers $1.60 to $1.80 on their bill.[10] If companies are able to build transmission where people won't say no, they can have a big impact on the economy and on how clean the economy is.

Figure 13. Representation of U.S. Transmission Lines, Total Length

For example, Winter Storm Uri affected Texas a couple of years ago. During that storm, temperatures were really cold. Coal supplies froze. Natural gas pipelines froze. Wind blades in West Texas and the panhandle froze, too. It’s called icing; ice freezes on the blade and they can’t be operated until the ice melts. There were hundreds of deaths because of this storm, and if we had more transmission, some of the impacts might have been avoided. The coal, the natural gas, and the turbines were not built to operate in below-freezing temperatures for extended periods. The specifications for this level of storm were not met. Texas now requires that all wind turbines for new projects have blades that contain a heating system to prevent icing or to temporarily melt the ice and then continue operating. In the future, what happened in Texas should happen less frequently. It was a huge wake-up call for them, and they’ve taken a lot of steps toward prevention since. Having more transmission to move the power from areas with operating assets to areas with frozen inoperable power plants would be a reliability and resiliency benefit in many places.

The third major challenge is tariffs and the supply chain. Solar tariffs have been coming in and out over the past couple of years at different levels. The next graph shows the rising and decreasing cost of solar modules from 2021 to 2024. There has been a lot of volatility in this market, which makes it difficult to plan a business case. It also makes it difficult to comply with contracts signed, assuming a certain cost, but when the panels are bought, their price is extremely different. Another piece of the market is the detention of solar modules. The U.S. government is concerned about forced labor from China used in panels imported to the U.S.; no one wants to be associated with that.

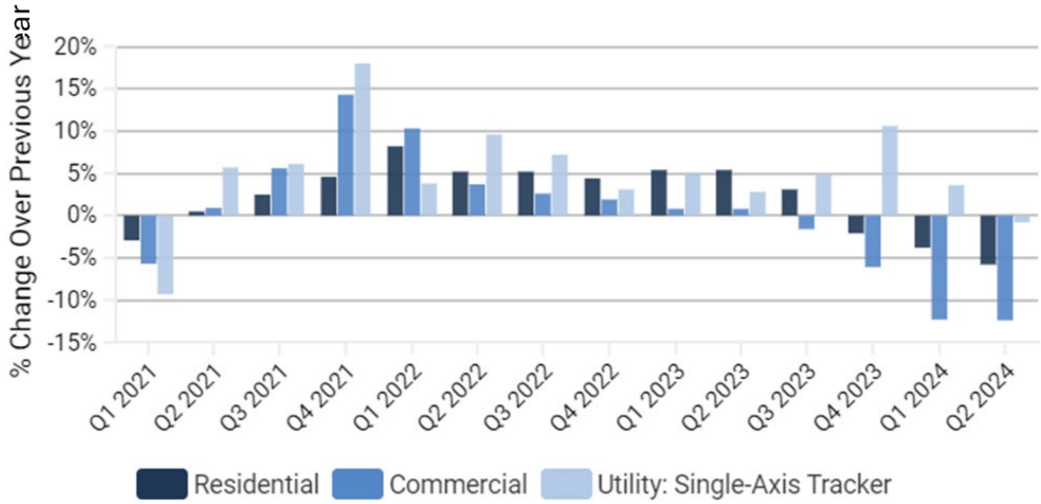

Figure 14. Year-Over-Year Changes in U.S. Solar PV Installed Price, by Segment[11]

When Customs inspects cargo, they look for evidence of forced labor by checking the supply chain and where components originated and moved prior to arrival at port. Even if a solar company has full documentation of its supply chain, Customs has a lot of authority and discretion to hold your equipment. Almost every major developer has had panels detained. Those detainments can be three weeks or up to six months in some cases, and it's a huge risk to a project's timeline. Then, there is a workforce at the project site waiting for panels and the developer is still paying for them—it can be problematic. Below is a map of all the domestic manufacturing that has been announced according to the Department of Energy as a result of the IRA, including batteries, wind components, and the assembly of solar modules. One hundred sixty facilities announced that they will be creating domestic products associated with tariffs, and the rising costs from inflation have also affected the market.

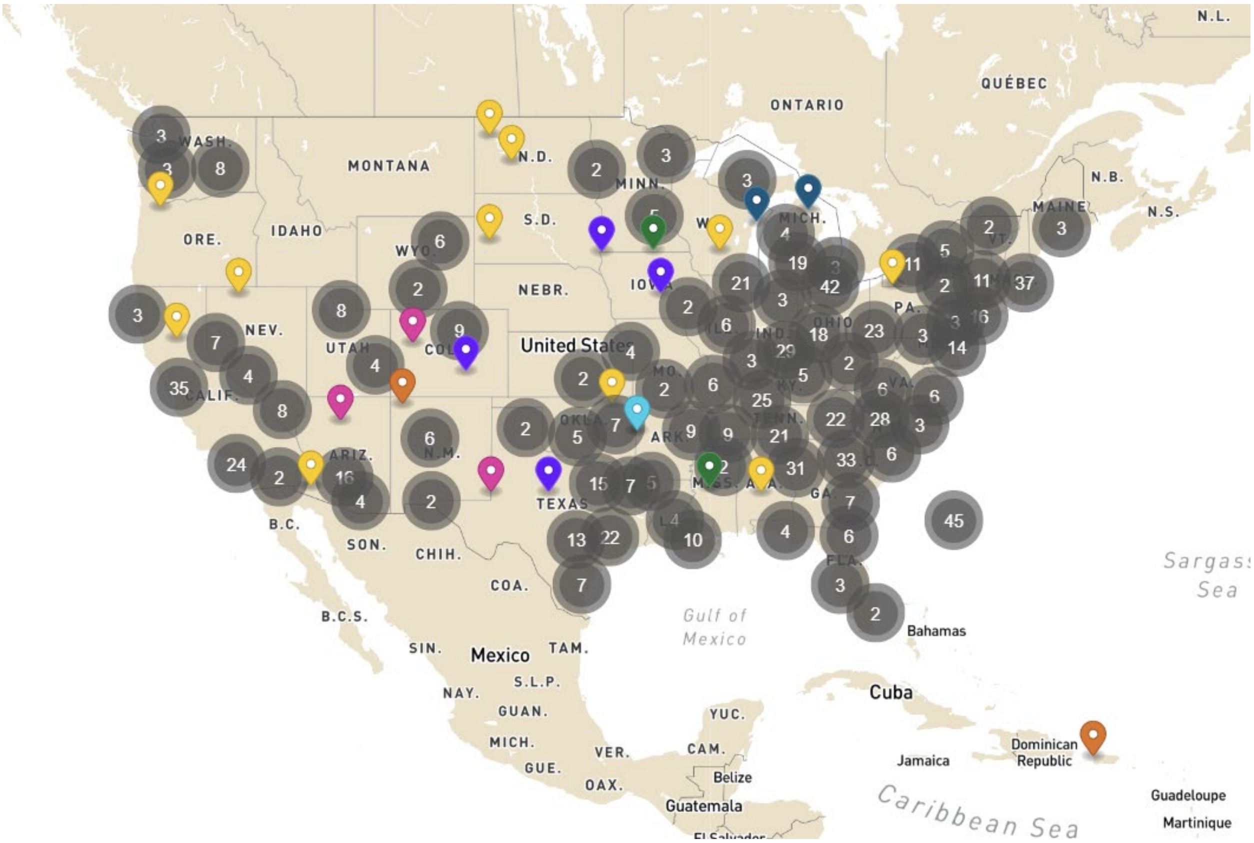

Figure 15. Clean Energy Manufacturing Investment Announcements[12]

The impact of the issues I've just discussed is the rising cost of projects and renewable energy. If we as a developer have a certain amount of money to put into projects, and, all of a sudden, the cost of the project increases, we just can't do as many projects. We need to seek additional investment. A lot of banks have had to lend more money than they would have in a low-cost environment, and that's constraining how much capital is actually available. We all want to complete projects as fast as possible for the energy transition, and developers need money to fund those projects. That's a challenge that we continue to see, but banks are stepping up, and I think people are recognizing that more dollars need to flow into this market.

Aside from these challenges and opportunities, what is needed for a successful energy transition? We need global engagement. The graphs below show the gigatons of CO_2 emitted per year. U.S. and EU emissions are actually reducing; we've been on a good trend of implementing these transitional technologies. China and India have a huge share of the emissions. This transition needs to be global. The UN climate Conference of the Parties (COP), is going on right now, and we'll see how that goes, but the whole world must do more than we're doing. We need the public to be better educated on how these projects work. We don't want people to think turbines cause cancer because it isn't true, and we should be able to prove that to them.

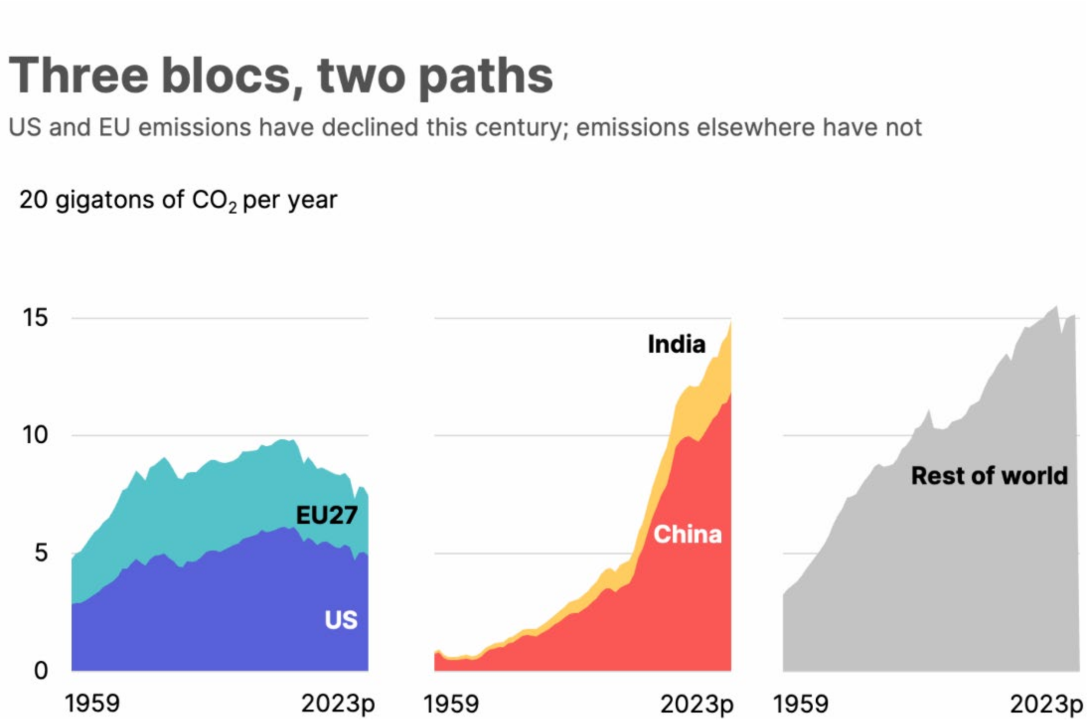

Figure 16. Gigatons of Carbon Dioxide (CO_2) Emitted Per Year[13]

We also need interconnection queues to work faster. In Texas, a company can get through an interconnection queue in about eighteen months, and in PJM, it can take seven or eight years, which is crazy. We must be able to move faster, and there have to be reforms. For two years, we've been waiting for the Treasury to issue guidance on how to qualify for tax credits for hydrogen projects. And when is that coming? It could come before the end of the year, or it could be postponed until the new administration, and then it might not come at all. Companies know how to execute green hydrogen projects, but no one will invest in them until the IRS provides guidance on how to receive the tax credits. We probably need global policies for green fuels, like using hydrogen in creating green ammonia, which can be a fuel or a fertilizer. We also can make e-methanol, which can be used in sustainable aviation fuels. It can be blended with liquid propane. You can envision a world of "green grilling" using e-methanol blended into your liquid propane tank in the future; there are a lot of upsides if smart people—scientists, engineers, policymakers, and the financial industry—can work to turn green electrons into green molecules and use them effectively.

Supply chains are being rebuilt, and that must continue to happen, but we also need to build systems that are off the grid or connected to the grid but co-located with data centers and manufacturing sites. That would be much more efficient: bring down the cost of power and develop much faster than waiting for traditional grid processes to play out.

Here is where students can get involved. I looked up the list of majors that Juniata College offers, and on that very long list, nearly all of them could directly or indirectly be applied to the renewable energy industry or a related field. I'm encouraged by that, and I'm hoping some of you smart people will dedicate time in your careers to solving some of these problems and making the transition successful. If you're not a student or don't want a formal career in energy, you can vote for representatives that are progressive regarding energy policy. If any of this interests you, I'd encourage you to do non-ChatGPT research (just kidding). It's also important to advocate to your family and friends; we must get people to understand these issues. The electric and energy industry can be very obtuse, producing an opaque market that, until you spend time investigating "how a REC works" and "why the power market is how it is," is difficult to understand. If people aren't acting, it's not that they don't care, it's often that they don't understand.

NOTES

1. The full text of the IRA can be found here: https://home.treasury.gov/policy-issues/inflation-reduction-act.
2. American Clean Power Association, https://cleanpower.org/investing-in-america.
3. Pennsylvania's Alternative Energy Portfolio Standard (AEPS), created by S.B. 1030 on November 30, 2004, requires each electric distribution company (EDC) and electric generation supplier (EGS) to retail electric customers in Pennsylvania to supply 18% of its electricity using alternative-energy resources by 2020. Database of State Incentives for Renewables & Efficiency, https://programs.dsireusa.org/system/program/detail/262.
4. National Renewable Energy Laboratory, https://www.nrel.gov.
5. There are seven wholesale electricity markets in the United States that play a key role in managing a competitive market for energy supply. Regional Transmission Organizations (RTOs) and Independent System Operators (ISOs) generally perform the same functions, but RTOs cover a larger geographic area.
6. U.S. Energy Information Administration, "Annual Energy Outlook 2018," February 2018.
7. Science Based Targets initiative, https://sciencebasedtargets.org.
8. Goldman Sachs, "AI to drive 165% increase in data center power demand by 2030," February 4, 2025, https://www.goldmansachs.com/insights/articles/ai-to-drive-165-increase-in-data-center-power-demand-by-2030.
9. Dara Kerr, "AI brings soaring emissions for Google and Microsoft, a major contributor to climate change," NPR.org, https://www.npr.org/2024/07/12/g-s1-9545/ai-brings-soaring-emissions-for-google-and-microsoft-a-major-contributor-to-climate-change.
10. Ethan Howland, "DOE transmission planning study identifies 'high opportunity' interregional interfaces," Utility Dive, October 3, 2024, https://www.utilitydive.com/news/doe-interregional-national-transmission-planning-study/728781.

11. Solar Energy Industries Association (SEIA) and Wood Mackenzie Power & Renewables, Solar Market Insight Report Q3 2024, https://seia.org/research-resources/solar-market-insight-report-q3-2024.
12. Ibid; Department of Energy.
13. Nat Bullard, https://www.nathanielbullard.com.