NOTES

Time-of-Need and Amount-of-Need: Overcoming Two Key Issues with Deploying Clean, Renewable Electricity Generation

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ABSTRACT

A complete transition to clean renewable electricity generation is essential to combat climate change. But two major issues or "ailments" currently persist in renewable electricity generation. First, the wind- or sunlight-based energy converted to electricity by renewable generation rarely matches the demand for electricity. This creates "time-of-need" issues when renewable electricity generation sources are not paired with some form of energy storage. Second, heat energy in sunlight and the kinetic energy of wind are not as easily stored compared to the chemical energy found in fossil fuels. Thus, sole reliance on renewables for electricity generation without storage also presents "amount-of-need" issues. Amount-of-need issues in renewable generation arise when sudden rises ("peaks") in the amount of electricity demand strain the existing systems, which are not designed to quickly fill the demand. These two "ailments" cause a variety of persistent "symptoms" that, together, prevent the United States from transitioning to completely renewable electricity generation. Considering all these "symptoms" in terms of just these two ailments is an efficient approach that could solve many "symptoms" at once. Concentrating solar power plants with molten salt storage, a technology that stores the heat of the sun in salt, is the best currently available solution to help overcome time-of-need and amount-of-need issues in renewable generation on a large scale.

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INTRODUCTION

It is critical that the United States ("U.S.") achieve one hundred percent clean renewable electricity generation in order to mitigate the phenomenon of climate change as soon as possible. This Note offers a framework for assessing the efficacy of solutions to overcome current practical barriers preventing a total shift to renewable generation. In order to develop efficient solutions for the future of renewable energy, it is imperative to first understand how renewable energy becomes electricity; how electrical markets operate; and how adding more renewable generation can impact these markets. Two major issues or "ailments" currently persist in renewable electricity generation. First, the wind- or sunlight-based energy converted to electricity by renewable generation sources and then supplied to the grid rarely matches the demand for electricity on the grid. This mismatch creates "time-of-need" ("TON") issues that limit reliability of renewable electricity generation sources when they are not paired with some form of energy storage. Second, the thermal and kinetic energy captured from sunlight and wind, respectively, is not as easy to store and dispatch as the chemical energy found in fossil fuels. Thus, sole reliance on renewables for electricity generation without storage also presents "amount-of-need" ("AON") issues. Amount-of-need issues arise when renewable generation is unable to quickly respond to sudden rises ("peaks") in the amount of electricity demand. These two "illnesses" cause a variety of persistent "symptoms" that, together, prevent the U.S. from transitioning to completely renewable electricity generation. Curing *just* these two illnesses would resolve a multitude of symptoms at once.

Any future solutions or "cures" to TON and AON issues will likely be influenced by two key sources of federal policy that underlie the legal landscape of U.S. renewable generation and transmission. Namely, the Public Utilities Regulatory Policy Act of 1978 ("PURPA") and the various orders issued by the Federal Energy Regulatory Commission ("FERC") will likely influence any future solution to time-of-need and amount-of-need issues.

However, the work of greening U.S. electricity generation cannot wait for future solutions, so this Note also addresses solutions to TON and AON issues which are already in circulation. By far, the most popular means of overcoming these issues currently is to pair renewable generation with storage in conventional lithium–ion batteries. This is not, however, the preferred solution because the batteries are not renewable and thus will eventually run into the same problems that have plagued fossil fuels. Another option for storing renewable energy to overcome TON and AON issues involves kinetically storing energy by raising and lowering massive bricks on a crane. Although the bricks in the kinetic energy systems use recycled concrete, this concrete could leach toxic chemicals into the environment. Thus, kinetic energy storage is not the preferred solution for overcoming time-of-need and amount-of-need issues. Concentrating solar power plants with molten salt storage, a technology that stores the heat of the sun in salt, is the best available solution to help overcome TON and AON issues in renewable generation.

This Note begins by explaining the TON and AON issues that currently limit the feasibility of renewable energy generation. Part II analyzes elements of the federal legal framework that could be used to address TON and AON issues. Finally, Part III assesses a variety of facility- and grid-level solutions to overcome TON and AON problems and facilitate widespread renewable energy deployment in the U.S.

I. DEFINING THE PROBLEM: TIME-OF-NEED AND AMOUNT-OF-NEED

Section A outlines why increasing renewable electricity generation is necessary to mitigate the phenomenon of climate change—the real-world issue that drives the central inquiry of this Note. Section B explains how renewable forms of energy produce electricity that moves through the grid. Section C describes markets for buying and selling electricity and illustrates how adding more renewable generation has impacted these markets. Section D explains how—despite the need for increased renewable generation—TON and AON issues have remained largely unresolved.

A. INCREASING RENEWABLE GENERATION IS NECESSARY TO MITIGATE CLIMATE CHANGE

Most leading scientific organizations and at least ninety-seven percent of actively publishing climate scientists agree that climate change is driven by anthropogenic greenhouse gas ("GHG") emissions.[1] The Intergovernmental Panel on Climate Change has warned that unless we dramatically reduce GHG emissions, we will face rising temperatures that will intensify droughts, raise sea levels, and destroy virtually all the world's coral reefs.[2]

Electricity generation plays an important role in GHG emissions in the U.S. Although in 2016 the U.S. transportation sector produced more GHG emissions than the electricity generation sector for the first time, this exceedance was paltry.[3] Serving electrical load or delivering electricity to residential, commercial, and industrial users still produces more GHG emissions than the third greatest GHG-emitting industry in the U.S.—the industrial or goods and production sector[4]—by about 1,000 million metric tons ("MTs") per year.[5] Electricity consumption also doubled between 1980 and 2012 (both in the U.S. and globally), and is expected to double again globally by 2035.[6] Yet, in 2018, about sixty-three percent of U.S. electricity was generated by GHG-emitting fossil fuels.[7] In light of these astounding statistics, increasing renewable electricity generation will be necessary to mitigate climate change.

Actors in the legal community seeking to have a meaningful discussion regarding how to promote more renewable generation on the grid would benefit from a foundational knowledge of how energy becomes electricity, as well as how the markets for renewable electricity work and the challenges they face from added renewable generation. Each of these concepts is addressed below.

B. ENERGY IS USED TO PRODUCE THE ELECTRICITY THAT MOVES THROUGH THE GRID

Electricity is a form of energy, but energy comes in many forms. Beyond electrical energy, there is also kinetic energy—the energy of movement—which

1. *Scientific Consensus: Earth's Climate is Warming*, NASA, https://perma.cc/EUB9-2EEL (last updated Oct. 30, 2019).

2. Robert J. Samuelson, *We're on Mission Impossible to Solve Global Warming*, WASH. POST (Oct. 14, 2018), https://perma.cc/4XDR-ZFPU.

3. Perry Lindstrom, *U.S. Energy-Related CO2 Emissions Fell 1.7% in 2016*, U.S. ENERGY INFO. ADMIN.: TODAY IN ENERGY (Apr. 10, 2017), https://perma.cc/V9G3-THG4.

4. ENVTL. PROT. AGENCY, INVENTORY OF U.S. GREENHOUSE GAS EMISSIONS AND SINKS 1990-2017 ES-11 (2019).

5. *Id.*

6. DANIEL YERGIN, THE QUEST: ENERGY, SECURITY, AND THE REMAKING OF THE MODERN WORLD 401 (2012).

7. *Frequently Asked Questions*: *What is U.S. Electricity Generation by Energy Source?*, U.S. ENERGY INFO. ADMIN., https://perma.cc/F66F-ZAZX (last updated Oct. 25, 2019).

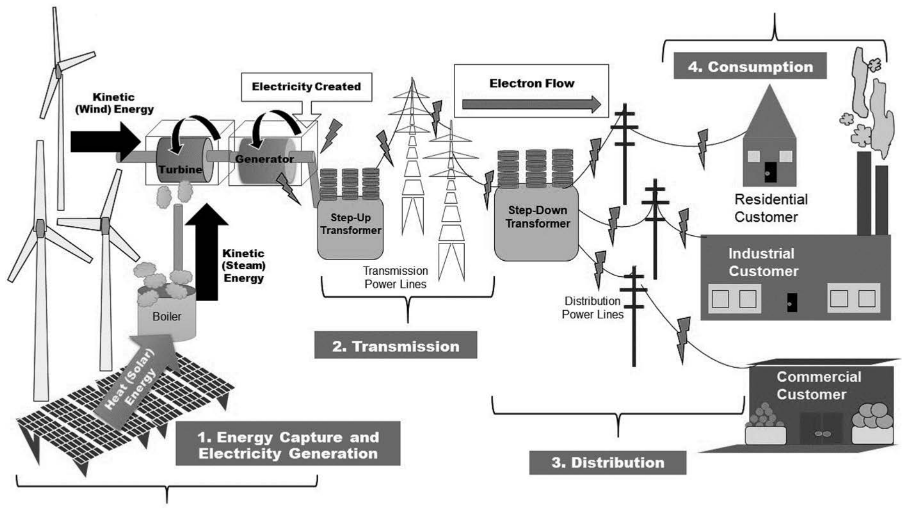

FIGURE 1: Movement of Energy Through the Grid

occurs naturally in wind. Heat energy occurs naturally in sunlight, and many forms of chemical energy also occur naturally—such as in fossil fuels like oil, coal, and natural gas. Figure 1 illustrates how renewable[8] sources of energy are used to produce electricity that moves through the electric grid. All cases involve capturing renewable energy in a kinetic form capable of physically rotating a turbine.[9] For instance, the heat energy of sunlight must be captured in photovoltaic ("PV") panels before it is used to heat water in a boiler which produces steam—and kinetic energy—to rotate the turbine.[10] Similarly, wind energy is captured using blades attached to turbines.[11] Regardless of the generation source, the turbines also rotate the generators they connect to, and this process converts the energy to electricity.[12] Electricity then enters the transmission stage of the grid.[13] A step-up transformer[14] converts the newly-generated electricity into higher voltages in order to cut down on the unavoidable loss of some electricity in transit, which in the U.S. averages about six percent.[15] Transmission ends with step-

8. Renewable electricity generation differs from fossil fuel generation only in that it must begin with energy capture, whereas the chemical energy in fossil fuel resources has already been captured via the extraction and refining processes.
9. *See* Figure 1.
10. *See infra* Figure 1.
11. *See infra* Figure 1.
12. *See infra* Figure 1.
13. *See infra* Figure 1.
14. *See infra* Figure 1.
15. *How the Electricity Grid Works*, UNION OF CONCERNED SCIENTISTS (Feb. 17, 2015), https://perma.cc/FL9N-S68U.

down transformers[16] converting the electricity back to the lower-voltage form usable by consumers. Electricity then passes through distribution power lines until it reaches the consumer.[17]

Importantly, unlike most other economic goods, electrons cannot be individually tagged or traced back to a generation source and thus become indistinguishable from every other electron in the system once they enter the grid (market).[18] To further complicate matters, electron flow cannot be directly manipulated, as electrons will neutralize charges by always moving from areas of higher voltage to lower voltage.[19] Thus, there is no way of knowing which electrons end up in what place nor which consumers they are powering. While Figure 1 shows the *physical* movement of electrons through the grid, the *financial* movement of electricity as an economic good is an entirely separate process. The next Section provides background on these market processes for electricity and discusses how adding renewable generation has impacted these markets in the past.

C. ELECTRICITY MARKETS ARE IMPACTED BY ADDING MORE RENEWABLE GENERATION

The physical properties of electricity make it more complicated to buy and sell in a market as compared to other goods in the economy. The complicated nature of buying and selling electricity as an economic good means that adding large amounts of renewable generation to the grid can quickly destabilize these markets. Electricity cannot be purchased in a store; rather, it must be transmitted directly over the grid to reach individual consumers. Because the actual good (electrons) cannot be traced back to a generation source once it enters the grid, substitution (that is, tracking the contractual, legal, and financial relationships of those involved in the markets) is required in order to charge buyers, compensate sellers, and thereby allow for the existence of electricity as an economic good.

Figure 2 illustrates electricity's wholesale and retail markets. "Consumers" are residential, commercial, or industrial entities that use (consume) electrical power. The retail market comprises all transactions that involve consumers as buyers.[20] Consumers purchase electricity from certain types of "resellers"—entities that purchase electricity on the wholesale market for the sole purpose of reselling it either wholesale or retail.[21] The "reseller" in a retail market is typically an investor

16. *See infra* Figure 1.

17. *See infra* Figure 1.

18. David Roberts, *How can Clean Electrons Compete with Dirty Electrons?*, GRIST, https://perma.cc/BY7S-2739 (last updated Dec. 8, 2010).

19. *Basic Concepts of Electricity: Voltage and Current*, ALL ABOUT CIRCUITS, https://perma.cc/6P8Z-X5MQ (last visited Nov. 24, 2019).

20. *Electricity Basics: Market for Electricity*, PJM LEARNING CTR., https://perma.cc/8HWJ-QAD8. (last visited Nov. 24, 2019).

21. *Id.*

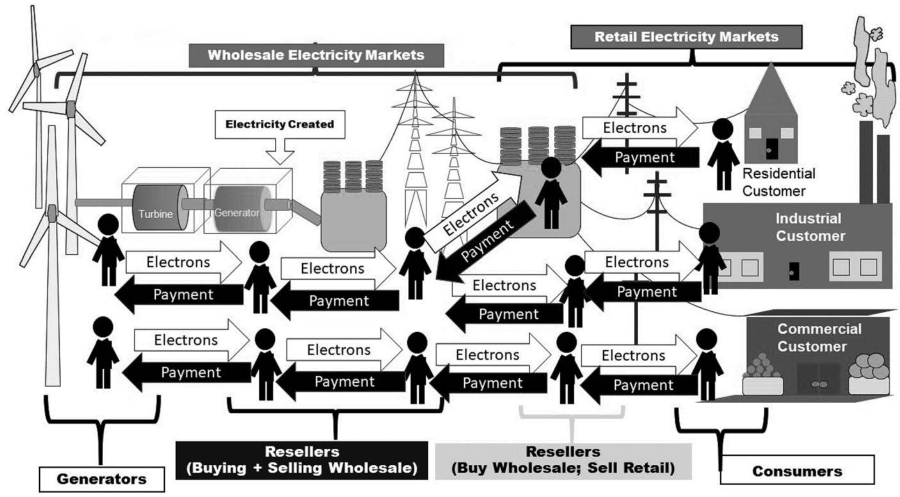

FIGURE 2: Electricity Markets

owned utility ("IOU"), but may also be a publicly owned utility ("POU").[22] Wholesale electricity markets encompass transactions between "resellers" buying from generators, or between two "resellers" (see Fig. 2). Generators in wholesale transactions may be a POU, IOU,[23] cooperative or "co-op," (a not-for-profit member-owned utility),[24] or a private independent power producer ("IPP") that holds a Power Purchase Agreement ("PPA").[25] A "reseller" in a wholesale market may be an independent systems operator ("ISO"), or a nearly-identical entity called a regional transmission organization ("RTO").[26] One local example is the Pennsylvania, Jersey, Maryland Power Pool or "PJM"[27]—an RTO that buys and sells electricity on a wholesale market across Maryland, Virginia, and ten other states plus the District of Columbia.[28] Other types of "resellers" in a wholesale

22. David Darling & Sara Hoff, *Investor-Owned Utilities Served 72% of U.S. Electricity Customers in 2017*, U.S. ENERGY INFO. ADMIN.: TODAY IN ENERGY (Aug. 15, 2019), https://perma.cc/K26K-Y87W.

23. *Differences Between Publicly and Investor-Owned Utilities*, CAL. ENERGY COMM'N, https://perma.cc/U9UL-LNR7 (last visited Nov. 24, 2019).

24. Darling & Hoff, *supra* note 22.

25. *Power Purchase Agreements (PPAs) and Energy Purchase Agreements (EPAs)*, WORLD BANK GRP.: PPLCR, https://perma.cc/HMC8-TPMA (last updated Sept. 9, 2019).

26. Seth Blumsack, *Regional Transmission Organizations*, PA. ST. UNIV. C. OF EARTH & MIN. SCIS., https://perma.cc/8JEP-HFM8 (last visited Nov. 24, 2019).

27. *Energy Master Plan: Frequently Asked Questions About Energy*, ST. OF N.J., https://perma.cc/B66P-K26L (last visited Nov. 24, 2019).

28. PJM LEARNING CTR., *supra* note 20.

context include IOUs like The Potomac Electric Power Company ("PEPCO"),[29] which buys electricity wholesale (for example from PJM), then sells it retail to consumers.

Wholesale U.S. electricity markets may be further classified as either "traditional" or "competitive." In traditional electricity markets, utilities are vertically integrated—the utilities commonly own[30] the generation, transmission, and distribution systems used to serve electricity consumers in these areas.[31] Utilities in traditional markets are responsible for system operations and management as well as providing power to retail consumers.[32] Traditional markets primarily exist in three geographic regions.[33] The first of these three regions is the Southeast—a market that includes all of Florida, Georgia, South Carolina, Tennessee, Alabama, and most of North Carolina.[34] The second is the Southwest—a market that encompasses all of Arizona and most of New Mexico and Colorado.[35] The third is the Northwest—a market that spans the entirety of Oregon, Washington, Idaho, and Utah.[36]

The remainder of the continental U.S. not encompassed in one of the three "traditional" markets instead manages electricity in a "competitive" market where wholesale electricity markets are operated by one of either three RTOs or one of four ISOs.[37] RTOs and ISOs were federally authorized by FERC in 1996 to "remedy undue discrimination in access to the monopoly owned transmission wires that control whether and to whom electricity can be transported in interstate commerce."[38] Although large sections of the country operate under more traditional market structures, two-thirds of the nation's electricity load is served in RTO regions alone.[39]

The actual operation of the electric grid (that is, the electricity market) is different from other markets in that it is carried out by "balancing authorities." Unlike other goods, electricity cannot be stockpiled, so when a consumer operates a

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29. Press Release, PEPCO & Conectiv, Pepco and Conectiv Announce Pepco Average Final Price, Conectiv Common Stock and Class A Common Stock Exchange Ratios for Merger (July 25, 2002), https://perma.cc/2HUM-3ZQ2.

30. These markets can also include "traditional" federally-owned transmission systems, such as the Bonneville Power Administration, the Tennessee Valley Authority, and the Western Area Power Administration. See *Electric Power Markets: National Overview*, FED. ENERGY REG. COMM'N, https://perma.cc/T2X8-MB8A (last updated Oct. 7, 2019).

31. *Id.*

32. *Id.*

33. *Id.*

34. *Id.* The Southeast region also includes parts of Missouri, Mississippi, Virginia and Kentucky

35. *Id.* The Southwest region also includes parts of Nevada, Wyoming, Nebraska, and South Dakota.

36. *Id.* The Northwest region also includes most of Nevada, Montana, and Wyoming, as well as parts of California.

37. *Electricity Markets Issue Brief: Wholesale Electricity Markets and Regional Transmission Organizations*, AM. PUB. POWER ASS'N (Jul. 2019), https://perma.cc/CY63-2FUN.

38. FED. ENERGY REG. COMM'N, Order No. 888 (April 24, 1996), https://perma.cc/WX36-UFFA.

39. FED. ENERGY REG. COMM'N, *supra* note 30.

machine in a factory or turns on a light switch in a home, electricity must not only be available instantaneously, but must also *continue* to be available on an as-needed basis—no matter how many other users are also active on the grid. Ensuring that the right amount of electricity remains on the grid such that the needs of all consumers are met—day after day, year after year—requires significant planning and coordination. The purpose of a balancing authority is to ensure, in real time, that demand and supply for electricity are finely balanced, which is necessary in order to maintain the safe and reliable operation of the power system.[40] A balancing authority must also ensure that the grid has sufficient "capacity"—or extra power—available to meet electricity demand at all times, which is complicated by uncertainties in forecasting demand, as well as the potential for outages in generation and transmission.[41] Because of these uncertainties, the total amount of electricity capacity maintained by a balancing authority is required to exceed the expected level of electricity demand on the grid by a given fraction, often about fifteen percent.[42]

Balancing authorities are sometimes electric utilities, and other times RTOs and ISOs that have taken on the balancing responsibilities for a specific portion of the power system.[43] Like utilities in "traditional" markets, RTOs and ISOs maintain the balance of electricity supply and demand within geographic boundaries known as balancing areas.[44] Unlike utilities in "traditional" regions, however, RTOs and ISOs cannot double as generators in their markets, which are designed to increase competition.[45] Thus, although the utilities own the transmission infrastructure in all electricity markets (with the exception of the fourteen percent of the nation's transmission lines which are owned by the federal government),[46] the local utilities are not always responsible for actual market operation. Namely, in the case of competitive markets, while RTOs and ISOs do coordinate regional planning for new transmission lines,[47] these entities cannot own any physical assets,[48] and thus they have no ownership over the grid they are responsible for operating. Nevertheless, the local balancing authority is always responsible for the electric market and for maintaining the reliability of the local electricity supply—a task which can be complicated by the addition of large amounts of

40. Sara Hoff, *U.S. Electric System is Made up of Interconnections and Balancing Authorities*, U.S. ENERGY INFO. ADMIN.: TODAY IN ENERGY (July 20, 2016), https://perma.cc/C4SP-F3CM.

41. U.S. DEP'T OF ENERGY, MAINTAINING RELIABILITY IN THE MODERN POWER SYSTEM 1 (2016), https://perma.cc/MUR3-TTHA.

42. *Id*.

43. Hoff, *supra* note 40.

44. NAT'L RENEWABLE ENERGY LAB., BALANCING AREA COORDINATION: EFFICIENTLY INTEGRATING RENEWABLE ENERGY INTO THE GRID 1 (2015), https://perma.cc/7NEU-6AKA.

45. AM. PUB. POWER ASS'N, *supra* note 37.

46. Chris Edwards, *New Study on Electricity Infrastructure*, CATO INSTITUTE: CATO AT LIBERTY (Jan. 24, 2018, 10:39 AM), https://perma.cc/XF3E-3CGN.

47. AM. PUB. POWER ASS'N, *supra* note 37.

48. Blumsack, *supra* note 26.

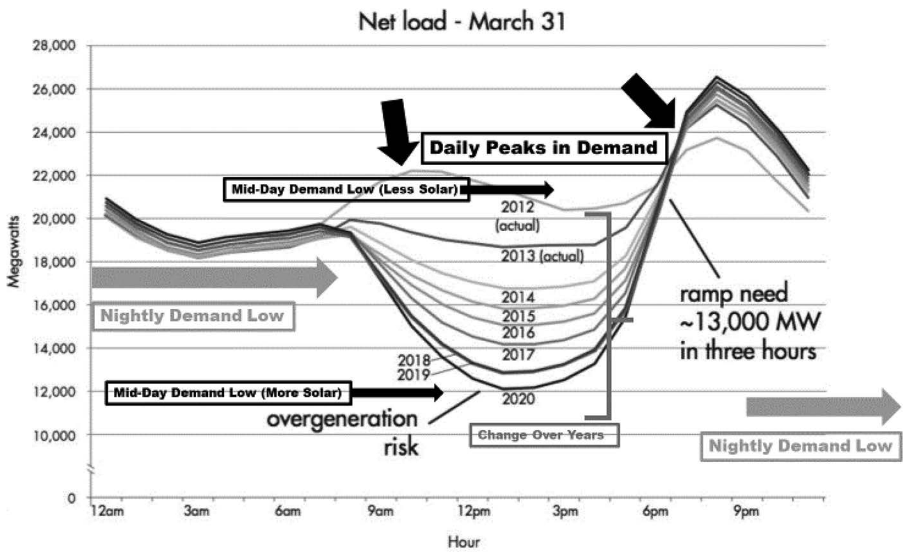

FIGURE 3: Electric Power Demand Showing Effect of Added Solar Generation[51]

renewable generation. A graph of net electrical load served over a twenty-four-hour period that is sourced solely from fossil fuels tracks demand for electricity almost precisely.[49] See Figure 3. Such a graph has two peaks—a small one around the time people wake up and the largest one around the time people arrive home from work.[50]

Increasing solar-based generation in places like California, however, changes wholesale demand for *all* generation. The more solar electricity floods the grid while the sun shines mid-day, the more overall demand drops at that time. Figure 3 shows the twenty-four-hour demand for wholesale electricity as the total grid mix changes from more fossil fuel-based generation to more solar-based generation.

As shown in Figure 3, consumers' retail electricity demand tends to be lower during the mid-day hours. Figure 3 also shows how this mid-day dip in demand coincides with the time of day at which the sun's energy is at its strongest and solar electricity floods the wholesale and retail markets.[52] The mid-day glut of wholesale solar electricity generation drives down prices market-wide—not just

49. David Roberts, *Solar Power's Greatest Challenge was Discovered 10 Years Ago. It Looks Like a Duck*, Vox (Aug. 29, 2018), https://perma.cc/C63F-PV6D.
50. *Id.*
51. Figure adapted from Ten Years of Analyzing the Duck Chart, NAT'L RENEWABLE ENERGY LABORATORY (Feb. 26, 2018), https://perma.cc/HR7J-B9GT.
52. Becca Jones-Albertus, *Confronting the Duck Curve: How to Address Over-Generation of Solar Energy*, U.S. DEP'T OF ENERGY, OFF. OF ENERGY EFFICIENCY & RENEWABLE ENERGY, Oct. 12, 2017, https://perma.cc/4MLY-YHCC.

for solar power, but for electricity in general. For example, in the spring of 2017 in California, wholesale energy prices dipped to zero or even negative values during certain hours.[53] While this may appear to be a good thing for consumers or buyers, it does not appear to be a good thing for sellers. Figure 3 shows how conversely, solar-generated electricity drops off as the sun sets toward the late afternoon and evening just when electricity demand also peaks.[54] This drop explains why negative prices usually happen. Most non-renewable power plants must currently be left running all day (even while solar generation floods the market), because shutting them off and then restarting them when the sun sets and demand peaks comes with high costs. [55] Year after year, as more solar is added to the grid, these changes in wholesale demand are illustrated in the "duck curve." Named for its resemblance to a duck, the duck curve is a chart published in 2013 by the California Independent System Operator, which has now become commonplace in conversations about large-scale additions of solar power.[56]

As more solar generation deepens the "belly" of the "duck," the slope of the curve leading up to the evening peak in retail electricity also increases, which represents a variety of "symptoms"—a worsening problem with generating solar electricity during the middle of the day when it is not needed, for instance. The steepening curve toward the evening signifies another "symptom" in which the grid needs to very quickly "ramp up" to provide a large amount of non-solar electricity output in order to meet demand. Initially, California turned to natural gas fired "peaker" plants to soothe this latter symptom, but since natural gas generation emits GHGs and risks catastrophic leaks, this solution was quickly abandoned.[57] More recently, California has turned to traditional lithium-ion batteries to quell these "symptoms," [58] but as is discussed further in Part III, Section A, this is not a truly renewable solution and thus is not the best solution in the long-run. Problems like those presented in the duck curve demonstrate that while the U.S. has largely mastered the use of fossil fuels, issues of how wind and solar[59] generation will overcome physical and technological limitations to match demand are still timely and important.

53. Cassie Werber, *California is Getting so Much Power from Solar that Wholesale Electricity Prices are Turning Negative*, QUARTZ (April 8, 2017), https://perma.cc/C9DJ-9P8D.

54. Jones-Albertus, *supra* note 52.

55. Werber, *supra* note 53.

56. Jones-Albertus, *supra* note 52.

57. John Kosowatz, *Energy Storage Smooths the Duck Curve*, THE AM. SOC'Y OF MECH. ENG'RS, May 17, 2018, https://perma.cc/K36S-ECJ7.

58. Id.

59. Wind and solar are the two most popular renewables, and are thus hereinafter referred to simply as "renewables."

D. TIME-OF-NEED AND AMOUNT-OF-NEED ISSUES ARE AT THE CRUX OF MOST CURRENT PRACTICAL BARRIERS PREVENTING TRANSITION TO ENTIRELY RENEWABLE GENERATION

This Note theorizes that most, if not all, "symptoms" of issues with renewable generation like those presented by the duck curve are rooted in two fundamental ailments: time-of-need and amount-of-need problems. First, as discussed above, renewable generation cannot track electricity demand the way fossil fuels can because renewable energy sources are not available as-needed throughout the day, but instead rely on natural sun and wind conditions. Issues related to the difference between when renewable fuel is needed versus when it is available will hereinafter be termed time-of-need ("TON") issues. Not only are fossil fuels available whenever necessary, their output is also easily increased or decreased to meet electrical demand.[60] As a result, fossil fuels easily overcome amount-of-need ("AON") issues—those related to *how much* fuel is needed at a given time. Renewable fuels without storage are limited in quantity by natural conditions at a given place and time—creating AON issues. AON issues are a separate concept from those regarding TON, but the two types of issues also interact to a large degree and thus will be discussed together.

AON and TON issues, together, cause a variety of "symptoms" challenging renewable generation at present. Some of these issues are economic—as pointed out in a 2019 working paper from MIT, zero marginal operating costs of renewable plants (that is, the fact that it costs these plants nothing to generate an additional unit of electricity) along with high penetration of intermittent renewable generation creates challenges for competitive wholesale market designs.[61] Trying to solve practical TON and AON problems using only market-based solutions, however, may just spawn a second class of economic issues related to TON and AON.

For example, the single fact that times of peak renewable electricity production do not occur at times of high demand for electricity spawns a host of issues. The most obvious practical problem occurs at the generation level: renewables will create electricity at times when it is not needed. Inversely, renewables *cannot* create electricity when it *is* needed. Assuming generation-based TON and AON issues could be solved using a battery storage solution, the practical "symptoms" that TON and AON create nevertheless remain. For instance, wind generation is most productive where the wind is strongest and most consistent.[62] In the U.S.,

60. Jordan Hanania et al., *Dispatchable source of electricity*, ENERGY EDUC., UNIV. OF CALGARY (Sept. 3, 2015), https://perma.cc/2JLF-JEPW.

61. PAUL L. JOSKOW, MASS. INST. TECH., CHALLENGES FOR WHOLESALE ELECTRICITY MARKETS WITH INTERMITTENT RENEWABLE GENERATION AT SCALE: THE U.S. EXPERIENCE 3 (2019), https://perma.cc/4T7Q-QCTA.

62. MATTHEW H. BROWN & RICHARD P. SEDANO, NAT'L COUNCIL ON ELECTRIC POL'Y, ELECTRICITY TRANSMISSION: A PRIMER 9 (June 2004), https://perma.cc/EP2P-NSCD.

the windiest locations naturally trend toward the center of the country.[63] The central part of the U.S. tends to be more rural in nature, however, and contains fewer dense population centers.[64] Rural locations tend to have fewer transmission lines connecting to the grid, and as a related matter, fewer customers in the immediate vicinity.[65] Fewer customers means that local demand for electricity is lower. Thus, at present, a large volume of renewable electricity must be transmitted and distributed between remote areas and the more populated areas where demand for renewable electricity demand is higher. A large amount of electricity passing from a few remote locations over just a few transmission lines to meet the evening spike in demand in populated areas tends to create "traffic jams," otherwise known as grid congestion. This transmission-based symptom of TON and AON issues is known to occur specifically in RTO or ISO regions and prevents all generation available on the grid from being delivered to customers located within in a constrained zone where power is needed.[66] As a result of this practical problem, the RTO or ISO may allow generators on the wholesale market to charge higher prices for electricity closer to the "congested zone" in order to meet the demand within that zone.[67] The higher prices being paid to generators on the wholesale market for electricity delivered to the congested area are then passed on to customers in the congested zone, who must pay the higher price on the retail market.[68] This pricing system is known as locational marginal pricing ("LMP"),[69] while the difference between the lower price in the larger RTO or ISO and the higher price in the congested zone is called the congestion charge.[70] For consumers who must pay a congestion charge under LMP, this is a personal economic burden created by TON and AON issues. Moreover, LMP was theoretically designed to solve TON and AON issues by incentivizing construction of new generation or additional transmission facilities to serve congested zones, or to reduce power usage through conservation within the zone.[71] In reality, however, generation and transmission development has not been greater in higher LMP regions.[72] Thus, economic solutions are secondary to this Note's focus on solving TON and AON issues on a practical level, since practical issues in renewable generation tend to create economic issues.

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63. Brad Plumer, *These Maps Show the Best Places to Put Solar and Wind Power. (It's Not Where You Think.)*, WASH. POST (July 15, 2013), https://perma.cc/UFW6-437N.

64. *See e.g.*, Joskow, *supra* note 61, at 14 ("For example, North Dakota and South Dakota have some of the windiest conditions in the world, and it is an ideal area for wind turbines. The problem with building wind plants in the Dakotas is that those states are far from the population centers—often referred to as load centers—that need the electricity.")

65. *See id.* at 13–14.

66. AM. PUB. POWER ASS'N, *supra* note 37.

67. *Id.*

68. *Id.*

69. *Id.*

70. *Id.*

71. *Id.*

72. *Id.*

Fortunately, if TON and AON are the "diseases" that underlie many "symptoms" or problems facing renewable generation, then treating these symptoms through a TON and AON-centered approach may solve multiple issues at once. The development of any solution to TON and AON issues will likely be influenced by certain key underlying legal and regulatory factors that surround U.S. generation, transmission, and distribution of renewable energy. These key elements are presented and analyzed in Part II.

II. FEDERAL LEGAL FACTORS MUST BE CONSIDERED WHEN DEVELOPING FUTURE SOLUTIONS TO TIME-OF-NEED AND AMOUNT-OF-NEED ISSUES

This Part discusses two major sources of federal-level policies that could help deploy and develop solutions to TON and AON issues in the future. Federal government actions are especially important because they, rather than state laws, are consistently applied to renewable generation throughout the nation. Importantly, this discussion of federal actions is not meant to be exhaustive. Rather, this discussion is intended to highlight the factors that have been and will likely continue to be most universally relevant to solving these issues in a national context. This Part first discusses the Public Utility Regulatory Policies Act of 1978 ("PURPA") and explains how it could be amended to alleviate TON and AON problems. It then provides examples of select Federal Energy Regulatory Commission ("FERC") orders that have impacted renewable generation as well as TON and AON issues.

A. PURPA REFORM COULD BE USED AS AN EFFICIENT LARGE-SCALE OR SMALL-SCALE TOOL TO ALLEVIATE TIME-OF-NEED AND AMOUNT-OF-NEED ISSUES

Because development of new renewable generation sources tends to be regulated piecemeal at the state and local level, PURPA and its amendments are the only federal U.S. laws directly affecting wind and solar electricity generation. Thus, any solution to TON and AON issues should acknowledge the role of PURPA. However, the 2005 Energy Policy Act amendments to PURPA have largely diminished its substantive power. Although PURPA reform, as it is currently proposed, is unlikely to help alleviate TON and AON issues, PURPA reform *could* nevertheless be utilized toward these ends.

President Carter's administration enacted PURPA as a part of the National Energy Act.[73] Amidst the backdrop of rising inflation and the 1973 oil embargo, one of PURPA's original aims was to address the public's fears of rising electricity rates by establishing guidelines for more efficient rate structures.[74] PURPA also embodied a broader societal change taking place in the 1970s whereby many

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73. Public Utility Regulatory Policies Act of 1978, Pub. L. No. 95–617, 92 Stat. 3117 (codified as amended at 16 U.S.C. § 26 (2018)).

74. Ilya Chernyakhovskiy et al., *U.S. Laws and Regulations for Renewable Energy Grid Interconnections*, NAT'L RENEWABLE ENERGY LAB. 10 (Sept. 2016), https://perma.cc/J63F-ZZVE.

U.S. industries were restructuring toward decentralization in an effort to promote competition and greater efficiency.[75] Accordingly, PURPA also enabled for the first time the diversification of the U.S. electricity supply and competition in electric power markets that were previously monopolized by utility companies.[76] To accomplish this, PURPA aimed to remove barriers to entry for smaller generators by requiring utilities to purchase some of their electricity from small "qualifying facilities" ("QFs")[77] generating up to 80 megawatts of electricity.[78] PURPA's "purchase obligation" requires utilities to purchase QF-generated electricity at a rate that is based on "avoided cost."[79] Avoided cost was defined as the amount that the utility would "avoid" paying by buying the electricity from the QFs rather than generating that electricity itself.[80]

PURPA was also enacted as part of a larger shift during the 1970s toward greater environmental consciousness. In keeping with this shift, a third purpose of PURPA was to promote renewable energy by creating two classes of QF, not only of "not more than 80 megawatts capacity,"[81] but also specifically focusing on renewable generation.[82] The first class of QF encompasses cogeneration facilities, which produce both electricity and useful heat from fossil fuels.[83] The second category covers facilities that produce electricity from *either* renewable resources, *or* biomass and waste.[84] PURPA remains a key element in some renewable generation markets since it requires utilities to purchase *any* power from local QFs at predetermined prices, *regardless* of market need.[85]

Between the 1980s and mid-1990s, QFs represented the vast majority of new renewable resources being added to the grid.[86] However, in 2005, Congress made significant substantive amendments to PURPA through the Energy Policy Act ("Act"). The Act's most notable amendment to PURPA was its addition of Section 210(m).[87] Under Section 210(m), if a QF has the capacity to generate

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75. Beth Dunlop, *Qualifying Facilities Under PURPA: What Qualifies?*, 15 U.C. DAVIS ENVTL. L.& POL'Y J. 7, 7 (1991), https://perma.cc/Y2SD-HTAG.

76. Chernyakhovskiy et al., *supra* note 74.

77. *Id*. at 10–11.

78. *What is a Qualifying Facility*?, FED. ENERGY REG. COMM'N, https://perma.cc/V5X3-9BA8 (last updated Sept. 19, 2019).

79. Chernyakhovskiy et al., *supra* note 74, at 11.

80. *Id*.

81. 16 U.S.C. § 824a-3 (2018).

82. See JOSKOW, *supra* note 61, at 66.

83. Chernyakhovskiy et al., *supra* note 74, at 11.

84. *Id*.

85. Tim Benson, *Research & Commentary: New Study Says PURPA Energy Contracts Are Needlessly Increasing North Carolina Electricity Bills*, THE HEARTLAND INST. (July 7, 2017), https://perma.cc/DY4B-8YVD.

86. TRAVIS KAVULLA & JENNIFER M. MURPHY, NAT'L ASS'N OF REGULATORY UTIL. COMM'RS, ALIGNING PURPA WITH THE MODERN ENERGY LANDSCAPE: A PROPOSAL TO FERC 3 (Oct. 11, 2018), https://perma.cc/3RZR-TYT7.

87. Section 210(m) Regulations on Small Power Production and Cogeneration Facilities, 71 Fed. Reg. 64342, 64343–44 (Nov. 1, 2006) (codified at 18 C.F.R. pt. 292), https://perma.cc/JG8T-PWFN.

more than 20 megawatts (MW) but less than 80 MW of energy, the QF can no longer benefit from PURPA's purchase obligation.[88] Utilities in all markets were still required under Section 210(m) to purchase power from QFs with capacity less than 20 MW.[89] This size restriction excludes most commercial-scale facilities, however. At present, it is mainly solar distributed generation systems (solar panels installed usually on private land or rooftops) which generate up to 20 MW.[90]

Furthermore, in the nearly fifteen years since the Act was passed, competitive electricity markets have become much more common in the U.S. than "traditional" markets. Traditional markets, where utilities still act as the balancing authorities, exist today only in the Southeast, Southwest, and Northwest regions. Everywhere else in the continental U.S. is now covered by a market that is run by an ISO or RTO. In these markets, generators *can* sell power to "alternative buyers" beyond the local utility in a "competitive wholesale electricity market." This means utilities outside the Southeast, Southwest, and Northwest regions are exempted from PURPA's requirement to purchase power from QFs capable of producing more than 20 MW but less than 80 MW of generation—essentially the only types of QFs that have existed thus far. The Act has therefore effectively constrained PURPA's critical purchase obligation mandate to only apply in three geographic areas of the U.S. wholesale electricity markets.

The idea of reforming PURPA is not novel, but past and current reforms are not directed at addressing TON and AON issues. For example, FERC, the agency charged with overseeing PURPA, issued a Notice of Proposed Rulemaking in September 2019 seeking to reform PURPA regulations. Rather than aiming to solve TON and AON issues, however, FERC proposes making PURPA more amenable to electric utilities. These proposed reforms aim to help states ensure that the rates utilities pay QFs do not exceed the utilities' "avoided costs" under PURPA.[91] While PURPA reform has never been used to address TON or AON issues, this nevertheless represents a legally-efficient means of solving TON and AON problems at either a small or large scale, due to PURPA's unique power to impact renewable generation at the federal level. Large-scale PURPA reform would alter the scope and substance of PURPA's mandates along with its methodologies, while

88. Termination of Obligation to Purchase from Qualifying Facilities, 18 C.F.R. § 292.309(a) (2019).

89. Id.

90. *Whole Sale Distributed Generation*, SOLAR ENERGY INDUS. ASS'N, https://perma.cc/P2E6-HZMS (last visited Nov. 9, 2019).

91. Fed. Energy Reg. Comm'n, Notice of Proposed Rulemaking Docket Nos. RM19-15-000 & AD16-16-000, Qualifying Facility Rates and Requirements: Implementation Issues Under the Public Utility Regulatory Policies Act of 1978 (2019), https://perma.cc/4PDC-BGZG.

small-scale reforms would seek only to reform the current methodologies within the law.

One small-scale means by which PURPA reform could help alleviate TON and AON issues is by reformulating how "avoided cost" is calculated to better reflect the realities of renewable generation and transmission on the grid. "Avoided cost" generally refers to the maximum price a QF may earn for the electricity it supplies to utilities, and is based on the "cost" that the utility is "avoiding" by buying electricity from the QF.[92] While PURPA's mandate that utilities must pay their "avoided cost" to QFs is clear at the federal level, implementation of *how* avoided cost is calculated falls largely[93] to each state.[94] Moreover, because many states lack in-house PURPA experts, the patchwork of state rules frequently stems from shaky analysis and utility-produced misinformation.[95] For example, as of 2018, if a consumer was paying $0.10 per kilowatt-hour for electricity, only $0.03 of it would pay for generation, while the other $0.03 would pay for transmission and $0.04 for distribution, respectively.[96] Utilities nonetheless argue that buying from QFs allows them to "avoid" only generation (and often, only the cost of their fuel at existing power plants), so they are allowed to set an avoided cost of less than $0.03 per kilowatt-hour.[97]

PURPA reform that utilizes "avoided cost" methodology to set priorities addressing TON and AON could approach the issue either through a practical or an economic lens. From a practical perspective, examining the price structure in most competitive wholesale markets (those *not* subject to PURPA's purchase mandate) reveals that the cost of generation itself is usually just one of four factors influencing the general wholesale cost of electricity. Beyond the cost of *generating* the electrical energy (the actual commodity ultimately paid for and consumed by retail customers), there is also a cost associated with maintaining *capacity* or "reliability" (the service of maintaining extra electricity on the grid so that it is available for dispatch, if needed).[98] A third cost is that of *transmission*—both of transmission congestion (the costs associated with delivering power

92. 16 U.S.C. § 824a-3(d) (2018) ("For purposes of this section, the term 'incremental cost of alternative electric energy' means, with respect to electric energy purchased from a qualifying cogenerator or qualifying small power producer, the cost to the electric utility of the electric energy which, but for the purchase from such cogenerator or small power producer, such utility would generate or purchase from another source.").

93. The regulations implementing PURPA, for instance, hold as a strict mandate only that rates paid to QFs "(i) Be just and reasonable to the electric consumer of the electric utility and in the public interest; and (ii) Not discriminate against qualifying cogeneration and small power production facilities." 18 C.F.R. § 292.304(a) (2019).

94. John Farrell, *An Overlooked Solution For Competitive & Local Renewable Power*, CLEANTECHNICA (Jan. 25, 2018), https://perma.cc/J96N-UEQA.

95. *Id.*

96. *Id.*

97. *Id.*

98. Josh Kessler, *Wholesale Energy Markets Explained*, ENV'T & ENERGY LEADER (Feb, 25, 2015), https://perma.cc/D3E5-JGHE.

across congested transmission lines with insufficient capacity) and the cost of transmission losses from transmitting power over a distance.[99] Finally, costs associated with providing *ancillary* or additional services to ensure the grid runs properly also influence cost in competitive markets.[100] Thus, when state regulators have required utilities to do a more complete accounting of their *actual* avoided costs, prices typically range from $0.04 to $0.06 per kilowatt-hour, rather than $0.03.[101] Incorporating non-generation elements when calculating "avoided cost" is not a novel concept. As far back as 1996, for instance, the Supreme Court of Pennsylvania addressed the issue of "avoided costs" in the context of QFs providing capacity.[102] Going a step further by incorporating more factors beyond generation and capacity into "avoided cost" when calculating how much utilities must pay to QFs under PURPA in a uniform way would take the guesswork out of development for potential new generators while also better reflecting the benefits of certain renewable generation facilities that alleviate TON and AON problems. For example, some very small QFs take advantage of existing transmission capacity by using small sites, thereby avoiding not only the traditional generation costs for the utility, but also avoiding transmission costs in several ways.[103] These small projects are capable of being sited closer to more densely-populated areas more in need of renewable generation (as discussed above), and so they reduce costs through reducing transmission losses by cutting down on how far electricity needs to be transmitted.[104] In addition, these small projects tap into existing transmission capacity[105] thereby eliminating the need for new renewable generation capacity to have new transmission capacity developed along with it. Very small QFs taking advantage of existing transmission capacity could also help alleviate the "traffic jams" discussed above that are symptomatic of TON and AON transmission issues. Reforming PURPA to require that "avoided costs" recognize benefits to the grid (such as those offered by small QFs in decongesting major transmission lines) would help alleviate TON and AON issues by ensuring a higher price for prospective developers of renewable generation facilities that address these problems.

From an economic perspective, small-scale PURPA reform could also aim to ensure that typical "avoided cost" calculations specifically reward renewable generation facilities that are directly designed to help alleviate TON and AON

99. *Id.*

100. *Id.*

101. Farrell, *supra* note 94.

102. *See, e.g.*, Pa. Elec. Co. v. Pa. Pub. Util. Comm'n., 677 A.2d 831, 834 (Pa. 1996) ("[A] QF supplying capacity can opt to have avoided costs calculated as of the time the legally enforceable obligation was incurred.").

103. Farrell, *supra* note 94.

104. NAVIGANT CONSULTING, INC., TRANSMISSION PLANNING WHITE PAPER 12 (Jan. 2014), https://perma.cc/4RKB-8ME4.

105. *Id.*

problems. For example, some generation facilities such as the Kennedy Energy Hub in Australia, which just started providing power to the grid in the summer of 2019,[106] co-locate both wind turbines and solar panels at a single facility. These co-located facilities are designed to take advantage of the fact that sunlight is strong in the morning and throughout the day when wind is low, while the wind is strong when the sun sets.[107] Co-located facilities like the Kennedy Hub help alleviate generation-based TON and AON issues because their outputs of power to the grid are steadier than either a purely wind-based or purely solar-based generation facility would be standing alone. Designing co-located QFs should factor into PURPA's "avoided cost" methodology because these facilities help avoid costs associated with utilities' need to increase ramp-up in the evenings as illustrated in the duck curve. If co-locators—as well as other types of generators that specifically address TON and AON problems—knew they were guaranteed a higher "avoided cost" rate than other QFs, there would be more incentive to build these kinds of facilities. Such a solution could address TON and AON issues regarding generation, and seems legally appropriate as well as legally feasible.

Though PURPA reform using "avoided cost" to address TON and AON problems is a novel concept, PURPA's accompanying regulations support this idea.[108] First, in its directive to account for ("to the extent practicable") the "*usefulness* of energy and capacity" and the "*value* of energy and capacity" when calculating "avoided cost," the regulations use certain words ("usefulness," "value")[109] the meaning of which will change in a practical sense over time—thus changing the practical meaning of the regulation. This suggests that "avoided cost" should adapt to suit the meanings of these words over time. Second, the regulations direct the avoided cost rate to incorporate ("to the extent practicable") "*availability* of capacity or energy" "*during* the system daily and seasonal *peak periods*," a concept which includes "expected or demonstrated *reliability***."** This idea specifically encompasses many "symptoms" created by TON and AON already discussed, indicating that dealing with their root causes is within PURPA's scope.

Reforming PURPA's "avoided cost" to guarantee higher "avoided costs" paid for QF entities that address TON and AON also seems feasible in the legal sense, since the PURPA regulations state that "(1) There *shall* be put into effect" for each utility "*standard rates for purchases from qualifying facilities* with a design

106. Marija Maisch, *Windlab Starts Australian PV-Wind-Battery Park Following Grid Delay*, PV Mag. (Aug. 6, 2019), https://perma.cc/33LX-SPZQ.

107. *Kennedy Energy Park, Windlab*, https://perma.cc/4P69-C5DU (last visited Dec. 5, 2019).

108. Namely: "In determining avoided costs, *the following factors shall*, to the extent practicable, *be taken into account*: . . . (2) The *availability of capacity or energy* from a qualifying facility *during the system daily and seasonal peak periods*, including: . . . (ii) The expected or demonstrated *reliability* of the qualifying facility; (v) The *usefulness of energy and capacity supplied* from a qualifying facility *during system emergencies*. . . [and] (vi) The *individual and aggregate value of energy and capacity* from qualifying facilities *on the electric utility's system*" 18 C.F.R. § 292.304(e) (2019) (emphasis added).

109. *Id.*

capacity of *100 kilowatts or less*," (emphasis added), that "(2) There *may* be put into effect *standard rates for purchases from qualifying facilities* with a design capacity of *more than 100 kilowatts*," (emphasis added) and finally that "(3) The standard rates for purchases . . . (ii) *May differentiate* among qualifying facilities *using various technologies on the basis of the supply characteristics* of the different technologies" (emphasis added).[110] Taken together, this seems to invite "standard rates" among *all* sizes of QFs to be differentiated "on the basis of supply characteristics." These "characteristics" could be defined via PURPA reform as facilities that help solve TON and AON problems, thereby enabling creation of a "priority category" of QF directed at solving these issues. QFs within this "priority category" could receive higher mandatory "avoided cost" compensation. These reforms would be consistent with PURPA's fundamental purpose, while also offering the necessary freedom to states in defining how TON and AON issues are to be "solved," so long as they "differentiate . . . on the basis of" the "supply characteristic" of helping to alleviate TON and AON issues. Nevertheless, any reform to PURPA that seeks only to adjust the way avoided cost is calculated would only constitute a small-scale solution because it would only affect the three regions of the U.S. that are still subject to PURPA's 80 MW QF purchase obligation mandate.

Large-scale PURPA reform addressing TON and AON issues would not only *enact* the changes to avoided cost calculation, but would also *apply* these changes nation-wide by redefining PURPA's reach. The current reach of PURPA is a result of the 2005 Act's efforts to increase competition in wholesale electricity markets—a goal that has been largely attained fifteen years later. Large-scale PURPA amendments could once again refocus on more modern issues in energy policy by redefining what qualifies as a QF in light of our current needs. Recall that under PURPA, a QF is a renewable generation facility that PURPA requires local utilities to purchase power from to help meet demand. In light of current issues like those presented in the duck curve, PURPA could be reformed to better reflect modern issues of TON and AON by redefining QFs as facilities which specifically alleviate TON or AON issues. PURPA originally laid out pre-defined avenues for QFs based on certain factors that seem arbitrary in hindsight. One example is the 80 MW and 20 MW cap for different classes of QFs. PURPA reform could reboot this approach by laying out a new set of criteria (for example, small facilities that are sited near transmission lines to take advantage of existing transmission capacity, co-located facilities, etc.) based on addressing TON and AON issues.

This type of large-scale reform would not be inconsistent with the three key purposes of PURPA: to conserve energy supplied by traditional electric utilities,[111] to optimize the efficiency in use of facilities and resources by electric

110. *Id*. § 292.304(c).
111. PURPA, *supra* note 73 (codified at 16 U.S.C. § 2611(1)).

utilities[112], and to ensure that rates paid by electricity customers remain equitable.[113] Furthermore, redefining and re-expanding the scope of QFs based on how well facilities eliminate TON and AON issues would modernize PURPA based on current needs in renewable generation. Moreover, large-scale PURPA reform seems economically well-advised. Wholesale electricity markets are supposed to perform two basic functions: not only "short run" resource allocation (that is, real-time electricity supply and demand balancing, as discussed above) but also "long run" resource allocation.[114] Markets generally perform their short term function well.[115] With more intermittent generation, however, markets fail at long term resource allocation—that is, they neither provoke (through prices and price expectations) efficient retirement of existing generation, nor provide efficient long run profit expectations and incentives that support investments in new generation.[116] According to the 2019 MIT Working Paper discussed above,

> "We are moving away from a decentralized model based on market incentives to a model where some technologies rely heavily on subsidies, long term contracts, and other out-of-market revenues to support their capital costs and others must rely on the market for all of their revenues. This is an unstable and inefficient model. It is a slippery slope where subsidies and special contracts lead to more subsidies and more special contracts guided by centralized resource planning rather than decentralized market incentives."[117]

Reforming PURPA (by guaranteeing higher avoided cost rates) to prioritize those QFs that combat TON and AON problems through state-approved means would help address the issues raised by the MIT Paper.

B. FERC ORDERS WILL LIKELY INFLUENCE FUTURE SOLUTIONS TO TIME-OF-NEED AND AMOUNT-OF-NEED ISSUES

Title II of the 1935 Public Utility Act created the Federal Power Act ("FPA"), from which the Federal Energy Regulatory Commission's ("FERC") derives its regulatory authority.[118] Various FERC orders issued over the years have strongly influenced U.S. renewable generation, and FERC orders will likely continue to play a prominent role in future solutions to TON and AON issues. FERC derives its authority to regulate from the Commerce Clause.[119] Because the Commerce Clause gives Congress (or a Congressionally-delegated federal agency) power "to

112. *Id.* (codified at 16 U.S.C. § 2611(2)).
113. Implementation Issues Under the Public Utility Regulatory Policies Act of 1978, FERC, RM19-15-000 at 1.
114. Joskow, *supra* note 61, at 3.
115. *Id.*
116. *Id.*
117. *Id.*
118. *The Federal Power Act (FPA) and Electricity Markets*, EVERYCRSREPORT.COM (Mar. 10, 2017), https://perma.cc/TE9T-TDV2.
119. *See* U.S. CONST. ART. I, § 8, cl. 3.

regulate commerce with foreign nations, and among the several states," FERC's authority extends to all electricity within interstate grids and wholesale markets. This category encompasses transmission lines across nearly every U.S. electric grid and wholesale market, with three exceptions. Two of these exceptions—the grids and wholesale markets in Hawaii and Alaska—are not regulable under the Commerce Clause because areas outside the continental U.S. are physically barred by oceans from exchanging electricity in commerce with any state around them. The less obvious exception is Texas.[120] Instead of connecting with an adjacent RTO, the Electric Reliability Council of Texas ("ERCOT") is an ISO fully within the bounds of Texas that is not interconnected to the rest of the nation.[121] Thus, transmission of electricity within ERCOT is not subject to FERC's jurisdiction.[122] Nonetheless, FERC's broad jurisdiction over the remainder of U.S. energy markets means that its orders will likely bear strongly on solutions to TON and AON.

Many FERC orders have had a substantial effect on renewable generation in the past. For example, FERC Order 888 (issued in April 1996) compelled utilities to open their transmission lines to *all* generators on a "first-come, first-served" basis after meeting their own transmission obligations.[123] This enabled more independent renewable generators to connect to the grid and enter into markets that were once fully-monopolized in some places. Order 888 also established open-access transmission tariffs ("OATT"), requiring utilities to provide transmission customers with "equivalent service and terms" for services that a utility would otherwise provide for itself.[124] Establishment of OATTs ended years of debate regarding the rates that utilities could charge for transmission services.[125] Thus, FERC Order 888 significantly reduced the barriers to entry for renewable energy power producers by allowing remotely located renewable energy generators to use transmission networks to transport electricity to the most favorable markets, rather than sell to the nearest utility.[126] On the other hand, OATTs stiffened competition. With more buyers and sellers putting downward pressure on electricity rates, renewable energy generation was priced out of many markets.[127] Finally, another FERC Order also issued in 1996, Order 889, established the open access same-time information system ("OASIS"). Order 889 required utilities to use the OASIS Internet system to make transmission capacity, prices, and other market-critical data readily available to all market participants.[128] This, in turn, helped

120. Chernyakhovskiy et al., *supra* note 74, at 5.
121. *ERCOT*, FED. ENERGY REG. COMM'N, https://perma.cc/J7ZL-DEKF (last visited Oct. 31, 2019).
122. *Id.*
123. Chernyakhovskiy et al., *supra* note 74, at 12.
124. Chernyakhovskiy et al., *supra* note 74, at 12.
125. *Id.*
126. *Id.*
127. *Id.*
128. *Id.*

level the playing field for non-utilities wishing to establish or maintain their presence in the renewable generation sector.

FERC Order 2006 also greatly impacted renewable generation while interacting in an interesting way with PURPA. Issued in 2005, the same year the 2005 Act amendments disposed of PURPA's requirement for utilities to purchase from 80 MW QFs in competitive markets, FERC Order 2006 standardized interconnection procedures for generators with capacity up to 20 MW.[129] In addition, several states used Order 2006 as a model to design and issue their own standards for small generator interconnections.[130] Finally, FERC Order 2006 also created a fast-track process for facilities generating less than 2 MW. Thus, just as the Act's amendments to PURPA made larger QFs obsolete across much of the country, FERC Order 2006 also made it much easier for "universal" QFs (that is, for generators with up to 20 MW of capacity) to connect to *all* grids in the country.

FERC Order 784, issued in 2013, also indirectly helped to alleviate TON and AON issues. In general, storage of renewable energy shifts the timing of supply to better align generation with market prices and electricity demand,[131] which helps overcome TON and AON issues. Order 784 amends the pricing mechanism for ancillary services, requiring utilities to consider speed and precision when purchasing ancillary services.[132] Since energy storage can provide ancillary services much faster and with more precision than gas or coal-fired plants, Order 784 gives energy storage a price premium in ancillary services markets.[133] Energy storage can greatly enhance the ability of system operators to integrate large amounts of renewable energy generation,[134] as discussed more in Part III.

III. CONCENTRATING SOLAR WITH MOLTEN SALT STORAGE IS THE BEST AVAILABLE, FACILITY-LEVEL SOLUTION FOR ADDRESSING TIME-OF-NEED AND AMOUNT-OF-NEED ISSUES

As discussed above, the reality of climate change means that overcoming TON and AON issues must start now with implementation of large-scale, facility- or generation-level solutions. Thus, this Part focuses mainly on assessing currently available generation-level solutions to TON and AON issues. Section A discusses how conventional batteries address TON and AON issues of renewables but are themselves, not truly renewable. Section B explores kinetic energy storage—a more promising option than conventional batteries, as it does not require similar extraction of resources. Kinetic storage still poses some environmental risk, however, and so Section C concludes that concentrating solar plants with molten salt

129. *Id.* at 13–14.
130. *Id.* at 13. State regulation is important since many small generators can operate without interconnection to large transmission lines under FERC's jurisdiction.
131. *Id.* at 17.
132. *Id.* at 17.
133. *Id.*
134. *Id.* at 16.

energy storage is likely the most promising solution to TON and AON issues. This proposed solution does not require repeatedly mining a finite resource, produces little waste, and poses little to no threat to the environment. Section D discusses transmission-level solutions to TON and AON issues.

A. RENEWABLE STORAGE USING CONVENTIONAL BATTERIES IS NOT TRULY RENEWABLE

Traditionally, TON and AON issues with renewables have been addressed at the generation level by storing the energy produced in conventional lithium-ion batteries with very large storage capacities. These technologies are sometimes called "solar-plus-storage"[135] or "wind-plus-storage."[136] Conventional battery storage systems supply renewable electricity to the grid until supply runs in excess of demand.[137] When this occurs, these systems switch over to charging their battery systems instead.[138] Conversely, when demand exceeds supply, these systems release the stored energy from their batteries.[139] Thus, these systems adequately address generation-based TON and AON issues.

Solar-plus-storage systems are becoming increasingly popular, especially for use with rooftop home solar systems. In 2015, for instance, Tesla started taking pre-orders for its new Powerwall home batteries.[140] These batteries store energy produced by solar panels on private homes.[141] Tesla found itself overwhelmed by the 38,000 orders that arrived for Powerwall batteries in the first week they were released. The company ultimately sold out of the batteries entirely in mid-2016.[142]

One benefit of solar-plus-storage and wind-plus-storage as solutions to TON and AON is that solar-plus-storage, in particular, is becoming more widely available, as demonstrated by the Tesla example above. However, these technologies are not the best way of overcoming TON and AON issues.

The entire life-cycle emissions and environmental impacts of the battery technology likely outweigh all environmental benefits of solar-plus-storage and wind-plus-storage technologies.[143] Production of solar batteries requires the use of numerous metals and minerals—including graphite, cobalt, nickel, and most

135. *Solar + Storage*, SOLAR ENERGY INDUS. ASS'N, https://perma.cc/6G4C-WJTW (last visited Oct. 31, 2019).

136. Julian Spector, *Where's the Money in Wind-Plus-Storage?*, GREENTECH MEDIA (Feb. 9, 2018), https://perma.cc/Y2YD-B8SB.

137. *See* SETH MULLENDORE & LEWIS MILFORD, SOLAR + STORAGE 101: AN INTRODUCTORY GUIDE TO RESILIENT POWER SYSTEMS 3 (Mar. 2016), https://perma.cc/FA9T-HP3A.

138. *Id.*

139. *Id.*

140. Kirsten Korosec, *Elon Musk: Demand for Tesla's Home Battery is 'Crazy off the Hook'*, FORTUNE (May 6, 2015), https://perma.cc/MZ4X-S5TC.

141. *Id.*

142. *Id.*

143. James Taylor, *Batteries Impose Hidden Environmental Costs for Wind and Solar Power*, FORBES (Aug. 17, 2017), https://perma.cc/M7UH-FGEJ.

notably lithium.[144] Unlike the sunlight or wind energy charging the batteries, lithium is a finite resource. Lithium is also currently necessary to produce nearly anything with a battery.[145] As a consequence, demand for lithium is increasing exponentially—lithium doubled in price from 2016 to 2018.[146] In addition to being finite, both methods of lithium extraction come with significant environmental costs. The first method (used in Australia and North America) is "traditionally" mining lithium from rock ore.[147] This method requires both significant energy expenditures[148] as well as the use of toxic chemicals—research from Nevada found impacts on fish as far as 150 miles downstream from a lithium processing operation, for example.[149] The other means of producing lithium is from naturally-occurring underground brine—the brine is pumped to the surface to create large ponds where it is mixed with chemicals.[150] This method is used in South America's "Lithium Triangle" which covers parts of Argentina, Bolivia and Chile and holds over half of the world's lithium.[151] The Lithium Triangle is also one of the driest places on earth, but this method of lithium production requires a large amount of water (about 500,000 gallons per metric ton of lithium). In Salar de Atacama, Chile, for instance, pumped-brine mining consumed sixty five percent of the region's water while some communities already needed water driven in from elsewhere.[152] The pumped-brine process also creates potential for toxic chemicals (including hydrochloric acid) to leak from the ponds into the water supply, as has occurred in Tibet.[153]

Beyond the issues with lithium, solar-plus-storage using traditional PV panels also causes waste disposal issues. PV panels have a typical lifespan of twenty years.[154] While panels are roughly ninety percent regular glass, they often also contain lead, cadmium, and other toxic chemicals that cannot be removed.[155] In addition, PV glass often cannot be recycled due to those impurities.[156] As a result, panels pose a waste problem. In 2016, the International Renewable Energy

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144. *Id.*
145. Amit Katwala, *The Spiraling Environmental Cost of our Lithium Battery Addiction*, WIRED (Aug. 5, 2018), https://perma.cc/UV58-D7HT.
146. *Id.*
147. *Id.*
148. Taylor, *supra* note 143.
149. Katwala, *supra* note 145.
150. Taylor, *supra* note 143.
151. Katwala, *supra* note 145.
152. *Id.*
153. *Id.*
154. Tom Lombardo, *What is the Lifespan of a Solar Panel?*, ENGINEERING.COM (Apr. 20, 2014), https://perma.cc/V7ZL-BY8X.
155. Michael Shellenberger, *If Solar Panels Are So Clean, Why Do They Produce So Much Toxic Waste?* (FORBES, May 23, 2018), https://perma.cc/WGN3-D2PL.
156. *Id.*

Agency estimated there were 250,000 MTs of solar panel waste in the world and that this amount could reach 78 million MTs by 2050.[157]

Thus, relying on wind-plus-storage and solar-plus-storage alone to overcome TON and AON issues will likely encounter the same problems which have plagued reliance on fossil fuels. That is, while these technologies may run on renewable "fuels," they rely heavily on a finite resource (lithium) that comes with high environmental costs. Thus, while renewable storage with conventional batteries is one way to overcome TON and AON issues, it is not the best way.

B. KINETIC STORAGE SYSTEMS AVOID ISSUES OF NON-RENEWABILITY, BUT CURRENT DESIGNS ALLOW FOR TOXIC LEACHING

Like conventional batteries, another new type of "battery" from a company called Energy Vault would also overcome TON and AON issues through energy storage. Instead of relying on chemical energy in a conventional battery for storage of renewable energy when supply exceeds demand, however, Energy Vault's system utilizes potential kinetic energy for storage.[158] A massive tower—roughly 400 feet tall—uses a six-armed crane powered by excess renewable energy to lift 35 ton bricks up the tower.[159] When the grid needs power, the crane steadily and automatically lowers a brick, using the resulting kinetic energy to produce electricity.[160] The system's automated software also accounts for wind and weather and responds to grid signals within a millisecond to control the cranes.[161] Energy Vault recently announced that they entered into an agreement with an integrated power company in India to build a pilot 35 MWh Energy Vault system.[162] Deployment of this system was expected in 2019.[163]

Beyond being emission-free and currently available on the market, kinetic energy storage is a promising way to overcome TON and AON issues. Because the technology relies on mechanical energy from incredibly durable materials, systems have a thirty to forty-year life-span before experiencing any degradation in storage capacity.[164] Kinetic storage is therefore more economical and less waste-producing than traditional batteries. In fact, Energy Vault's system actually *reduces* waste since its massive bricks are made of recycled concrete that would have otherwise been landfilled.[165] Landfilling concrete is not only bad for the environment, but also costly. In California, for instance, a construction site must

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157. *Id.*
158. Adele Peters, *Can These 35-Ton Bricks Solve Renewable Energy's Biggest Problem?*, FAST CO. (Nov. 7, 2018), https://perma.cc/R9UF-VVQV.
159. *Id.*
160. *Id.*
161. *Id.*
162. Nancy Owano, *Brick by Brick, a Solution Seeking to Topple Energy Storage Roadblock*, TECH XPLORE (Nov. 10, 2018), https://perma.cc/MDC3-TU3Y.
163. *Id.*
164. *Id.*
165. *Id.*

pay up to $55 per cubic yard to landfill concrete like that which comprises the bricks in Energy Vault's system.[166] By using recycled concrete as the main component of the system, kinetic energy storage is much cheaper than building large lithium-ion batteries.[167] Yet another advantage of kinetic storage is its scalability. Energy Vault built a small prototype—72 feet tall, instead of the usual 393—proving that while the company may currently be focused on the largest market, the system also works on a small scale.[168]

Despite the reduced environmental impact of Energy Vault's recycled concrete, the major drawback with the system is uncertain chemical durability in the presence of groundwater or acid rain.[169] In response to these elements, the recycled concrete may "leach" toxic metals into the surrounding environment.[170] Thus, the kinetic storage system as a solution for TON and AON issues poses a problematic risk of contaminating the surrounding environment with toxins, at least in its current design iteration.

C. CONCENTRATING SOLAR POWER WITH MOLTEN SALT STORAGE IS THE BEST CURRENTLY-AVAILABLE FACILITY-LEVEL SOLUTION TO OVERCOMING TIME-OF-NEED AND AMOUNT-OF-NEED ISSUES

All concentrating solar power ("CSP") plants use mirrors to concentrate sunlight into heat that drives turbines to create electricity.[171] Most CSP systems also use a media fluid to store the thermal energy for use on demand, rather than only using this energy in real time.[172] One technology recently being deployed on a large scale combines CSP with molten salt storage ("MSS").[173] Like all CSP systems, the mirrors of CSP MSS systems concentrate sunlight on a receiver tube filled with heat transfer fluid that carries thermal energy to a generator on a closed-loop cycle.[174] Usually, CSP MSS systems also include at least two salt storage tanks and extend their closed-loops during sunshine hours to also heat at least one tank.[175] Tanks are insulated, so salt can stay hot for a substantial period of time, and the molten salt is easily stored at ambient (atmospheric) pressure in the tanks.[176] Molten salt from the hot tank(s) is then pumped through the steam

166. *Id.*
167. Peters, *supra* note 158.
168. *Id.*
169. Huixia Lu at al., *Leaching of Metals from Cement Under Simulated Environmental Conditions*, 169 J. OF ENVTL. MGMT. 319, 319–20 (2016).
170. *Id.*
171. *Concentrating Solar Power*, SOLAR ENERGIES INDUS. ASS'N, https://perma.cc/753G-CZFQ (last visited Jan. 2, 2020).
172. *Thermal Energy Storage*, PA. ST. UNIV. DEP'T OF ENERGY & MIN. ENG'G, https://perma.cc/CV9D-BDQQ (last visited Dec. 21, 2019).
173. *Id.*
174. *Id.*
175. *Id.*
176. *Id.*

generator to produce steam and then to the cold storage tank(s) to discharge heat during night hours[177] (or whenever backup power is needed, in the case of facilities with multiple tanks).

CSP MSS is the most promising large-scale technology to help overcome TON and AON issues. Beyond being emission-free and currently available on the market, CSP MSS plants can operate constantly to provide baseload power (overcoming TON issues) and can shift electricity generation to meet demand (overcoming AON issues). Additionally, while all forms of energy generation necessarily carry with them some environmental impact, this technology boasts less than most.

Molten salt is a non-toxic, inert, and environmentally-friendly mixture[178] of sodium nitrate and potassium nitrate which can be utilized as high-grade fertilizer.[179] This gives CSP MSS an environmental edge over both solar-plus-storage and kinetic energy storage, which, as discussed above, both involve concerns over toxicity of certain design elements.

One potential issue with a CSP MSS plant is the large amount of space it requires. Depending on the technology, CSP plants can require between 5 and 10 acres per MW of capacity.[180] Due to the large footprint, CSP MSS plants will likely be built in rural areas and will need to be adopted in conjunction with other TON and AON solutions at the grid level, such as expanded transmission lines. Another potential issue with CSP MSS plants is their upfront cost, as these plants represent a significant investment. In 2008, an affiliate of developer SolarReserve formed Tonopah Solar Energy as an LLC to own and operate 110 MW Crescent Dunes plant in Central Nevada.[181] Three years later in 2011, the U.S. Department of Energy ("DOE") agreed to guarantee Tonopah Solar Energy approximately $700 million in loans to fund the project, which is the first of its kind in the world.[182] Crescent Dunes was also backed by a joint investor (ACS Cobra), and Santander, a global financial services and banking leader.[183] In total, the project was financed with $737 million in debt along with the loan guarantee from DOE.[184] Prices for plants like these have decreased over time, however. In 2009, the power price of Crescent Dunes was 13.5 cents per kilowatt hour (kWh) while in 2015, the Redstone CSP MSS plant in South Africa had a power price of 12.4

177. *Id.*

178. Carlo Ombello, *The World's First Molten Salt Concentrating Solar Power Plant*, THE GUARDIAN (July 22, 2010), https://perma.cc/4JXJ-GTB4.

179. *Molten Salts Properties*, ARCHIMEDE SOLAR ENERGY, https://perma.cc/95W8-D5E5 (last visited Dec. 21, 2019).

180. SOLAR ENERGY INDUS. Ass'n, *supra* note 171.

181. Bailey Shulz, *Tonopah Solar Plant Could End Up in Bankruptcy, Developer Says*, LAS VEGAS REV.-J. (Oct. 7, 2019), https://perma.cc/EV93-E37W.

182. Id.

183. *Next Generation of Solar Energy Storage Advances as Nevada Project Begins Commissioning*, PR NEWSWIRE (Feb. 12, 2014), https://perma.cc/MU33-BW8P.

184. *Id.*

cents per kWh.[185] By 2017, the Aurora CSP MSS facility in South Australia was priced at just 6 cents per kWh.[186]

CSP MSS plants in the U.S. so far have had mixed outcomes. Some appear successful (for example, Solana, a 250 MW CSP MSS plant has been generating power since 2013[187]) while others, like Crescent Dunes, have unfortunately been fraught with issues. Despite signing an engineering, procurement, and construction agreement with developer SolarReserve in 2011, Crescent Dunes only "commenced commercial operations" in 2015.[188] In addition, Crescent Dunes had a power purchase agreement with NV Energy, Nevada's main utility company, into late 2019.[189] But as of October 2019, the developer of Crescent Dunes, SolarReserve, filed suit[190] against both Tonopah Solar Energy as well as DOE, claiming that DOE is interfering "with SolarReserve's right to participate in the management of Tonopah," resulting "in a forfeiture of SolarReserve's property rights in a $1 billion project which SolarReserve started in 2008, without an opportunity to contest that forfeiture."[191]

Importantly here, two days after this lawsuit was filed, NV Energy provided a notice of termination on its power purchase agreement (originally set to end on December 31, 2040), citing "frequent and prolonged outages" from Crescent Dunes.[192] Although NV Energy states that the project failed to meet its contracted energy levels because of "various issues" with a hot salt tank and "construction-related problems," the cause of these problems is apparently contested: while Tonopah Solar Energy said the issues with the tank were unavoidable, SolarReserve on the other hand blamed Cobra Thermosolar Plants and its related entities, which helped engineer and construct the project.[193] Despite cost, space, and other hurdles, however, CSP MSS is nevertheless the best currently available large-scale facility level solution to addressing TON and AON issues.

D. GRID-LEVEL SOLUTIONS

While this Note mainly focuses on facility-level solutions to overcoming TON and AON issues, it is important to note that solutions also exist at the grid level. The wind does not blow *everywhere* all of the time, but it is usually blowing

185. Robert Dieterich, *24-Hour Solar Energy: Molten Salt Makes It Possible, and Prices are Falling Fast*, INSIDE CLIMATE NEWS (Jan. 16, 2018), https://perma.cc/DW84-7AMX.

186. *Id.*

187. *Solona*, U.S. DEP'T OF ENERGY LOAN PROGRAMS OFF., https://perma.cc/3HJQ-7DFH (last visited Dec. 21, 2019).

188. Christian Roselund, *Will DOE Take the Crescent Dunes Project into Bankruptcy?*, PV MAG. (Oct. 7, 2019), https://perma.cc/QW8S-C87D.

189. Dieterich, *supra* note 185.

190. *See* Complaint, SolarReserve CSP Holdings, LLC v. Tonopah Solar Energy, LLC (2019), https://perma.cc/58MG-6KZQ.

191. Roselund, *supra* note 188.

192. Shulz, *supra* note 181.

193. *Id.*

somewhere all of the time.[194] Stemming from this idea, one grid-level solution to TON and AON issues is to strategically develop multiple wind power sources in different, far-flung regions of a grid,[195] such that all these intermittent sources of generation together act more like a consistent generation source. By providing grids with a more consistent source of renewable generation, the wind-power build-out solution would help to alleviate TON and AON issues at the grid level by "smoothing" the duck curve. Expanding the grid's transmission lines in order to encompass the new wind sources would likely be a key element of this stactic.[196] Thus, this strategy would be most successfully implemented in an RTO or ISO region, where these entities could oversee construction of new transmission lines, rather than an ad hoc process of existing utilities competing on the market for the new wind generators.

Indeed, the expansion of transmission lines is itself a grid-level solution in overcoming TON and AON issues. Many areas with strong wind and solar potential are highly remote and thus not grid-connected.[197] This strategy would be best accomplished in the RTO or ISO regions where these entities would build the new transmission lines rather than the utilities who represent competition to new generators.

RTO and ISO regions provide more favorable grid environments for solving transmission-related TON and AON issues than traditional markets. Thus, one other grid-level solution to overcome TON and AON issues would be to enable 100 percent RTO or ISO U.S. market coverage.

CONCLUSION

Although wind and solar-plus-storage, kinetic storage, and CSP MSS plants are all promising candidates for overcoming TON and AON issues at a facility level, CSP MSS is likely the best solution of the three. CSP MSS best addresses TON and AON issues, as these plants are truly renewable, produce little waste, and pose little to no threat to the environment. CSP MSS plants have an even greater potential to alleviate TON and AON issues if they are adopted in conjunction with other solutions that exist at the grid level, such as expansion of transmission lines within RTO and ISO regions to access areas more favorable to different types of renewable generation.

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194. UNION OF CONCERNED SCIENTISTS, RAMPING UP RENEWABLES: ENERGY YOU CAN COUNT ON (Apr. 8, 2013), https://perma.cc/L8XA-B38Z.
195. *Id.*
196. *Id.*
197. *Id.*