Energy Storage Systems and Renewable Energy

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Contents

Abstract

As people worldwide race to eliminate polluting sources of electricity production, renewable energy generation has become more widely used. Wind and solar energy production are the most popular sources of renewable energy. However, energy storage systems are a vital part of the puzzle for the renewable energy transition to ensure stable power both at home and grid scales. Large utility companies like Tucson Electric Power Company understand that to become carbon neutral, energy storage systems must be added to our current power grids. TEP is experimenting with this by incorporating two 10MW lithium-type battery storage systems into the power grid and a 2MW solar power generation facility. As technology improves and prices fall, more can be done at home and work to reduce energy demand. By including energy storage and solar energy production in our homes, we can contribute excess energy to the grid while lowering the amount produced by utility companies. When cities work with their utility companies on renewable energy and energy storage projects, we can move toward our goals of becoming carbon neutral.

Keywords: Energy Storage; Renewable Energy; Power Grid; Battery Storage Systems

Introduction

Some call this the third industrial revolution. Another giant leap for humankind. The mission: make renewable energies a reliable and practical source of electricity worldwide. But, can this be done? Despite all the advances in technology, much of the world still relies on fossil fuels to generate the required electricity. Even in modern societies, people still cannot get the electricity they need. According to the Energy Information Administration (EIA), in 2020, 27% of all households in the United States struggled to meet their energy needs. Almost 20% of those households reduced or forwent basic necessities to pay their electricity bill. The issue of energy insecurity is worldwide. The United Nations recognizes this problem. The United Nations has set 17 goals for sustainable development, and goal number 7 is to ensure access to affordable, reliable, sustainable, and modern energy for all (Goal 7 | Department of Economic and Social Affairs, 2022).

The number of electric vehicles in use around the world is constantly increasing. While some places struggle to have reliable and affordable energy, the number of electric vehicles continues to grow rapidly. According to IEA, 2022 sales of electric cars hit 6.6 million in 2021, despite challenges due to supply issues. The amount in new sales from 2021 is more than triple from only two years earlier.

Electric vehicles are not the only technological advances happening today. Cities are increasingly becoming more sophisticated, and technologies are incorporated into almost everything. This increase in technology has simultaneously created a rise in demand for electricity. Electrical power generation and distribution have not seen the same advancements despite the advances in technology paired with the increase in demand. Advancing technologies paired with growing populations result in greater demand on our electrical power grid.

How is it we could expect to increase our demand on the electrical power grid while at the same time reducing the pollution created when we generate electricity? The answer lies in the use of more renewable energy generation systems. Wind and solar electricity generation are more widespread (EIA, 2022). So why do we see such a slow shift to a broader spread use for these forms of energy? The primary issue that hinders the more widespread use of renewable energies is the lack of development and costs of energy storage technologies.

The United States relies heavily on the need for fuels such as coal, gasoline, natural gas, methane, and more to provide the energy we need for daily life. These types of fuels mainly produce the electricity we use. The primary source of transportation still relies on internal combustion engines (ICE) vehicles. With a transition to primarily electric vehicles, there will be a significant increase in demand for the electrical power grid. These factors make it even more important than ever to use a majority of renewable energy sources. Electricity generation plays an essential role in the goals of carbon neutrality and sustainability. The world needs to use more renewable energy. Energy storage systems are vital to the future of renewable energy sources.

Literature Review

I used Google Scholar search engine to find some articles, journals, and websites. Some keywords I used were as follows: Energy Storage Systems; Alternative Energy Systems; Lithium Energy Storage; Renewable Energy and Energy Storage, and more. The use of reputable sites is vital. Peer-reviewed academic journals and top-ranked websites are excellent sources to use. These sources are typically challenged and scrutinized by fellow experts in the topic field. For this reason, I limited my search to only Google Scholar and the Academic Research database located on the University of Arizona's library website.

This literature review has highlighted some of the critical factors that hinder or enhance the implication of energy storage systems in our cities worldwide. Many barriers are still hindering our progress in completing the conversion to renewable energy sources. Demand for the electrical power grid constantly increases, requiring the grid to reach farther distances and provide electricity to more people. Technology advances like electric vehicles are one example of today's increasing demand. Many individuals want to do more to contribute to reducing greenhouse gasses today. Making a switch to an electric vehicle is one way to do that. According to Challa et al., in 2018, 29% of all greenhouse gas emissions produced in the United States were from the transportation sector. These emissions will decrease as the use of electric vehicles becomes more prevalent. By the end of 2019, there were 7.2 million electric vehicles and 7.3 million electric vehicle charging stations worldwide (Sayed, 2022). It is now estimated that there are around 16 million electric vehicles worldwide, consuming about 30 terawatt-hours (TWh) of electricity per year (IEA, 2022).

More electric vehicles will result in a reduction of greenhouse gasses. The tradeoff, however, is the increased demand for electricity, regardless of where these electric vehicles are charging. Electric vehicles are only one example of increasing demand for electrical power grids. Additionally, a constantly growing population is yet another major contributor. Homes require electricity for heating and cooling, running electronics like TVs, washing machines, refrigerators, water heaters, etc. Logically, most people prefer to charge their electric vehicles at their homes during the night. During the day, renewable energy systems like home solar would charge a battery storage system at home. Instead of using the electricity from the electrical grid, the electric vehicle would utilize the stored energy from the batteries at night. This is an excellent example of the usefulness of energy storage systems. The need for a practical, clean energy resource is at the forefront of demands today. Renewable energy needs to become the primary source of energy production. This energy needs to either be stored as electric or in another form of energy for use when needed (P. Li, 2008).

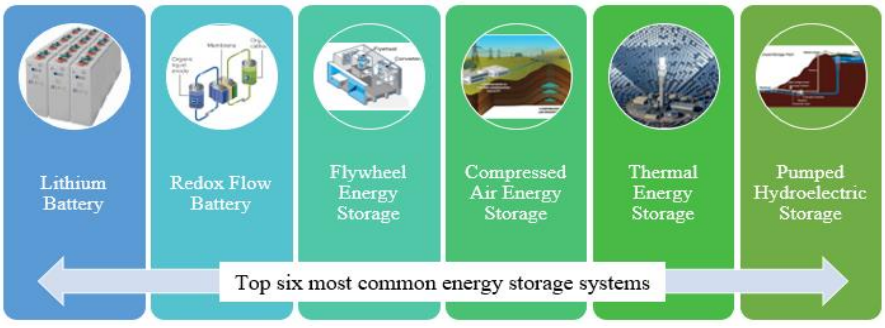
As the need for electricity constantly increases, the need for more renewable energy production also rises. Companies like Tucson Electric Power Company have committed to work toward energy production that uses a large percentage of renewable energy generation, like wind

and solar energy. In 2020, Tucson Electric Power Company announced a remarkable commitment. By 2035, the company TEP aims to supply more than 70% of its energy needs through renewable resources and slash its carbon emissions by 80% relative to 2005 levels (Duquiatan, 2020).

Unfortunately, wind and solar energy generation have a dark side. Renewable energy sources like wind and solar are variable/weather dependent. Regardless, renewable energy, especially wind and solar energy systems, have been regarded as the most effective and efficient solutions to address increasingly important issues, such as greenhouse gas emissions and increasing demand for energy consumption (Yang, et al.) Renewable energy generation from sources like wind and solar have an inherent drawback. The wind speeds change constantly and are sometimes nil. Similarly, the sun is not always shining. When there is no wind or sun, there is low to no electrical generation. Wind and solar energy generation are variable forms of energy. This variability creates a conflict with our current power grid infrastructure. The power grid has a very specific characteristic. Electrical demand must equal electrical supply, at all times, to the second (Giulietti et al. l, 2018). One way to overcome this conflict is to add energy storage systems. Energy storage systems can be paired with renewable energy generation to overcome variability issues.

There are many different forms of energy storage systems, and many of them have shown remarkable progress over the last few years. The topmost common types of energy storage systems are as follows:

- Lithium-type Batteries
- Redox Flow Batteries
- Flywheel Energy Storage
- Compressed Ari Energy Storage
- Thermal Energy Storage
- Pumped Hydroelectric Storage



Energy Storage Systems and Renewable Energy

All energy storage systems mentioned above can be incorporated into the current power grid regardless of power or energy requirements (Atwell, 2018). The most common type of energy storage system is lithium batteries. Ninety-nine percent of the utility-scale energy storage market is dominated by lithium-ion chemistry batteries (TEP, IRP 2020). In 2017 alone, more than two-thirds of the battery energy storage came online from a single 30-megawatt energy storage facility in Texas (Mow, 2018). According to the EIA, at the end of 2019, 163 large-scale battery storage systems were operating in the United States, a 28% increase from 2018 (EIA, 2021). By 2021, the United States had 4,605 megawatts (MW) of operational utility-scale battery storage power capacity (EIA, 2022). It is expected that battery storage systems will contribute 10,000 megawatts to the grid between 2021 and 2023 – ten times the capacity of 2019 (EIA, 2021). The primary driver in the increasing number of battery energy storage is the rapid pace of expanding renewable energy generation like wind and solar. "On March 29, 2022, wind turbines in the Lower 48 states produced 2,017 gigawatthours (GWh) of electricity, making wind the second-largest source of electric generation for the day, only behind natural gas," according to the EIA.

Tucson, Arizona, was not to be left behind. In 2020, Tucson Electric Power Company (TEP) released its Integrated Resource Plan (IRP). The plan highlights TEP's method for incorporating renewable energy systems in Arizona. Some of the main topics included the company's future action plan, generation stations in use, expected retirement dates for some generation plants, etc. According to TEP, it has been the company's plan since 2014 to focus on achieving a cleaner mix of energy resources. The company claims they are now in a position to reach this goal within two years, eight years earlier than previously planned. TEP plans to reduce its reliance on coal-fired generation, eventually eliminating it. "As we retire older fossil-fuel generation resources, all of the new replacement resources will be a combination of renewable energy resources, energy storage, and energy efficiency," said TEP in their IRP 2020.

Unfortunately, the rapid pace of evolving new technologies does not come without risks. On April 19, 2019, reports of smoke coming from a building housing a battery energy storage system for APS. Upon arrival, firefighters opened the door to the building, resulting in an explosion, injuring eight firefighters. Luckily, no serious injuries were reported. It was discovered later that the event was caused by an internal battery failure known as a thermal runaway event (Spector, 2020). This disaster sparked a significant investigation, and new policies, regulations, and response procedures were established for any future incidents. Compressed air energy storage is another type of energy storage in use. This form of energy relies on the use of highly compressed air that, when released, can generate electricity. Some companies have implemented this energy storage system, although almost entirely in large-scale applications. One study proposes a low-volume, small-scale compressed-air energy storage system (SSCAES) that can be used with renewable energy systems like wind and solar. Together, enough energy could be generated and stored to sustain a single household (Villela, 2010). However, this system is still a prototype and has not yet been tested. However, large-scale compressed-air energy storage facilities have been constructed and can be found in operation in

several places here in the United States and worldwide. Ideally, the facility must be constructed where large underground caverns exist or can be made.

Methodology

Study Area

Renewable energy generation is in use around the world. Variable energy production from generation sources such as wind and solar is an issue that can be applied everywhere. However, the focus of my study was limited to energy generation in the United States. I narrowed my focus by examining what Tucson Electric Power Company and the City of Tucson have done and what they have planned for the future. Tucson Electric Power Company (TEP) does not supply electricity to only Tucson, Arizona. TEP is responsible for parts of the electrical grid spanning Arizona and even parts of New Mexico [See Figure 1], the immediately adjacent state to the east. The electrical grid is not isolated from company to company. TEP is part of an electrical power grid that spans from the upper part of western Canada and down into Mexico. This connection is known as the Western Interconnection (WECC) [See Figure 2]. The WECC interconnection is only part of an even larger system. Several interconnections make up the North American Electric Reliability Corporation (NERC) in the North American continent. [See Figure 3]

Research Design

For this study, I used a mixed methodology approach. I used a qualitative method by conducting interviews and data collection through research and a literature review. The data collected both cross-sectional research and longitudinal designs. I examined the electrical power grid operations, electricity consumption, and coverage area for the cross-sectional research. The cross-sectional research also included looking into Tucson Electric Power Company's future goals toward becoming carbon neutral and the implication of new technologies in renewable energy generation and energy storage system investments. The longitudinal research investigates changes in the electrical power grid over time in response to advancements in technology, reduced costs of new technologies, and even policy changes due to these categories.

Data Measured

I conducted interviews as part of the qualitative portion of my study. I conducted one interview over Zoom, and the other interview was in person. I did not record either of the

interviews. I took notes during the interview, filling in additional details after the interviews were over. I also collected materials from the persons I interviewed. I emailed some questions to the interviewees before the interviews. I also came to the interviews with a printed version of those questions. Although I had a set of prepared questions, I made sure to allow each interviewee time to answer beyond the questions to steer the conversation in a different direction if they preferred. I conducted the first interview with the Environmental and Land Use Planner team member for Tucson Electric Power Company. I will refer to them as Interviewee #1. I conducted the second interview with the City of Tucson's Annexation Project Manager, Mike Czechowski. Although annexation for the city seems unrelated to my topic, Mike was willing to take his time to speak with me and provide helpful information for my research.

The literature review portion of my research was done by collecting data through academic articles, peer-reviewed journals, some websites, case studies, and more. This information was sourced by using the University of Arizona's library website, Google Scholar, and other reputable online sources.

Methods

I prepared for my first interview with Interviewee #1, the Environmental and Land Use Planner team member for Tucson Electric Power Company. I was extremely fortunate to obtain this interview, as this person was able to prove essential and valuable information to my research. I emailed my questions several days before the interview. This interview sent me a copy of a document published by Tucson Electric Power Company. The "TEP 2020 Integrated Resource Plan" is also published on TEP's website.

For my second interview, I was able to arrange a day and time Milke Czechowski could meet with me. We agreed on a place to meet on the campus at the University of Arizona. I emailed Mr. Czechowski a set of questions I have prepared. But, like in my previous interview, I explained the questions were merely talking points to guild us. We scheduled the interview to last approximately one hour.

Results and Discussion

Interviews

The first interview was with Tucson Electric Power Company's Environmental and Land Use Planner, Interviewee #1. This interview was on Zoom, scheduled for 3:00 pm, and was expected to last about 30 minutes. I had a copy of the questions I sent before the interview. I

informed interviewee #1 that I was conducting a continued research project on energy storage systems. More specifically, my research was on how energy storage systems would make renewable energy generation a more viable energy source, even on a utility-scale. The interviewee opened the "TEP 2020 Integrated Resource Plan" and asked to share his screen so we could both refer to this document while talking. We discussed the two 10MW Lithium Battery energy storage systems Tucson Electric Power company already operates. This system is located at a substation near Grant Road and the I10 freeway [See Figure 4].

Interviewee #1 discussed how electrical demand and generation must be equal at all times. As electricity is generated throughout the day, most electricity generation from renewable energy sources does not align with the typical times of the day when the electricity demand is greatest. Like the 2MW solar field owned by TEP, Peak generation from solar panels happens around the middle of the day. Peak demand typically occurs early in the mornings and later in the evenings. I asked if home solar seems to help lessen this increase during the peak demand hours. He explained that home solar does not help alleviate the peak demands because home solar generates electricity most at the same time the large solar fields do, which is around noon. By 6:00 pm, the home solar panels are not contributing enough electricity, if any at all, to help lessen the demand load across the grid. This is, of course, assuming that homes with solar do not have an energy storage system.

To my surprise, interviewee #1 pointed out some negative facts about home solar in Southern Arizona. Tucson Electric Power Company has a projected number of profits they are expected to make through the sale of electricity to their consumers. If all the middle-class households and above purchased home solar panels, TEP's profits would significantly decrease. Due to this, the cost of electricity would almost certainly rise. The majority of this cost increase would fall on the lower-class families as they are the ones who cannot afford home solar. Interviewee #1 explained that investing in more large renewable energy projects, such as the 2MW solar field located at the University of Arizona Tech Park [See Figure 5], would allow the benefits of solar to be shared with everyone. Through a collaboration of these types of projects, we will be able to achieve renewable energy sources for all families, regardless of their income status or where they live.

The final pieces of important information that interviewee #1 shared with me regarded the regulations around energy storage systems. One of the largest hurdles to overcome toward implementing large, utility-sized energy storage systems is identifying the zoning codes and regulations the City of Tucson has or lack of zoning and regulations.

My second interview was with the City of Tucson's Annexation Project Manager, Mike Czechowski. The interview was in person, and we planned a meeting place at a coffee shop located at the University of Arizona campus. The interview was scheduled for 3:30 pm. I brought a copy of the questions I sent before the interview and a pen and some paper. Mike Czechowski

was excited to discuss the topic of renewable energy with me. I asked if he had worked on any projects that included investors or companies coming to Tucson that wanted to install large renewable energy generation facilities. Mr. Czechowski said that, indeed, this did happen quite often. The most significant factor in the location of these types of projects is the proximity to a source of connection to the electrical power grid. Ideally, these projects require a short distance to a substation. If there is not, then one would have to be constructed. The issue of connectivity is one of the largest and most impeding parts of adding more renewable energy sources to our current power grid.

It is not just the projects for large renewable energy sources like solar fields that are delayed or wholly canceled due to proximity to connectivity sources to the power grid. Housing community developments, industrial warehouses, and more are hindered due to the lack of good connections to Tucson Electric Power Company substations. The number of companies interested in constructing these projects is a very long list. I asked if policies currently in place hinder or help the advancement of these businesses. Mr. Czechowski explained that absolutely policies do have an impact on things like types of land use, zoning laws, taxes to incentivize or even discourage are all factors that come into play. When a company is comparing different locations to bring their business, these are the factors that are looked at most closely.

Literature Review Findings

The literature review provided a great deal of data that validates the need for energy storage systems to be integrated with renewable energy sources. Tucson Electric Power Company's Preferred Portfolio highlights the company's goals and commitments to incorporating a majority of renewable energy sources [See Figure 6]. TEP states in their IRP that due to declining costs and current and projected market conditions, TEP's goal is to transition to 100 percent clean energy sources entirely. Although, the time frame for TEP to achieve this is still unknown. TEP's Integrated Resource Plan outlines some of the details for achieving its goal of 100 percent clean energy. The plan includes the addition of more than 2,400 megawatts (MW) of solar and wind power generation to the grid by 2035. To balance the use of these renewable energy sources, TEP plans on adding 1,400 MW of energy storage systems. Currently in place are two 10MW lithium battery storage facilities. One of those facilities is located near Grant Road and the I10 Freeway [See Figure 4]. The second facility is located at the University of Arizona Tech Park, where the battery storage facility is paired with a 2MW solar field [See Figure 5].

Simultaneously, as lithium battery technologies make drastic advancements, electric vehicles do too. The number of electric vehicles worldwide is growing at a rapid rate. The International Energy Agency (IEA) anticipates 30 million electric vehicles will be on the road by 2030. The advantage of the increase in electric vehicles is the considerable reduction in

greenhouse gasses than traditional internal combustion engine (ICE) vehicles produce. However, the increase in electric vehicles will require even more electricity to be generated.

According to the Energy Information Administration (EIA, 2021), 39.7 gigawatts (GW) of new electricity generation was expected to come online in 2021. The largest portion of this total was solar, taking up to 39% of total new electrical generation. Coming in second was wind electrical generation at 31%. Not to be outdone, the EIA also expected utility-scale battery storage to more than quadruple; 4.3 GW of battery power capacity by the end of 2021.

The growth in renewable energy generation and energy storage systems are directly related to the advancements in technology and the decrease in overall costs in solar and types of lithium battery energy storage. More and more homes are equipped with solar panels. Some future questions to be considered relate to the benefits of adding home solar, when paired with energy storage systems, into our current power grid. When homes make more electricity than they use, they can contribute the excess energy back to the power grid. This is known as net metering. In an ideal situation, homes would be equipped with solar panels, and excess energy could be stored in a large, centrally located battery energy storage system. Later, after the sun sets, that stored energy could be distributed back out into the grid where it is needed. Net metering could add some extra incentives to families that could afford the costs of solar. The combination of these three things is the solar energy trifecta: solar + storage + net metering (Munsel, 2018). By adding additional solar energy to the power grid through individual households, the reduction of carbon emissions could be even more significant at an extremely rapid rate. Additionally, using renewable energy such as solar and wind to generate electricity could improve or reduce the cost of peak sources of electricity (Strielkowski, 2021).

Conclusion

This study identified the importance of energy storage systems where renewable energy generation systems are used. In this paper, I investigated current market trends for renewable energy generation. This included a review of past, current, and plans for renewable energy. According to the data I reviewed, there is a significant increase in renewable energy sources and energy storage systems. This increase is worldwide, and not limited to one place, although increases are easily measurable across the United States, including here in Tucson, Arizona.

I explored current trends that affect our electrical power grid, such as electric vehicles. There is a constant increasing demand due to the number of electric vehicles drastically increasing every year. Simultaneously, electric vehicle charging stations are also increasing. The increase in electric vehicles plays a large role in reaching our goal of reducing greenhouse gas emissions worldwide.

Energy Storage Systems and Renewable Energy

I investigated the most common energy storage systems and where they are used. Renewable energy generation systems are vital to our planet as our population grows and energy demand increases. But, due to their variability and inconsistency, renewable energies need energy storage systems. While energy storage systems come in many forms, currently, there are a limited number of reliable and tested types. Lithium batteries take up the vast majority of storage systems on the market today. Although, other types of large-scale energy systems like compressed air energy storage are being used worldwide.

This study also explored how a local utility company, Tucson Electric Power, is implementing storage technology. TEP is working towards a transition to renewable energy sources for power generation. TEP aims to obtain 70% renewable energy production by 2035 and eventually transition to 100% clean energy production. The increased availability and decreasing costs for renewable energy technologies enable companies like TEP to reach ambitious goals in less time than originally thought possible. However, coordination and cooperation with the city and county are needed to ensure the projects can move forward. Zoning and land use often hinder the construction of these projects. By improving this permitting process- or even identifying sites for use ahead of time- both TEP and Tucson can ensure a smooth transition to renewable energy.

Appendix – Images

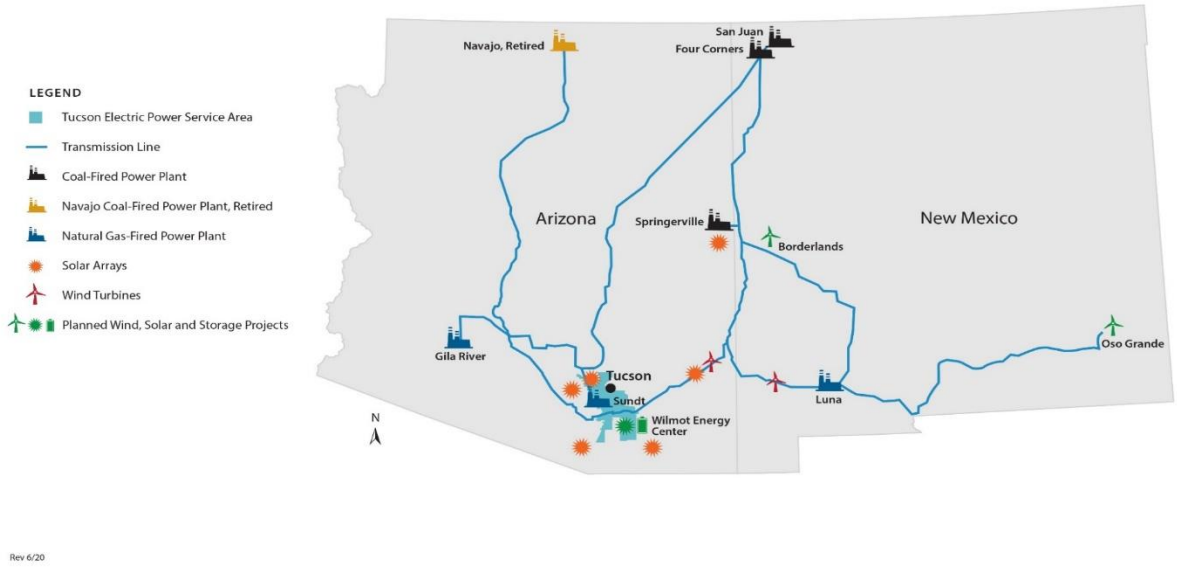


Figure 1 TEP Service Area Source: Tucson Electric Power Company 2020 Integrated Resource Plan

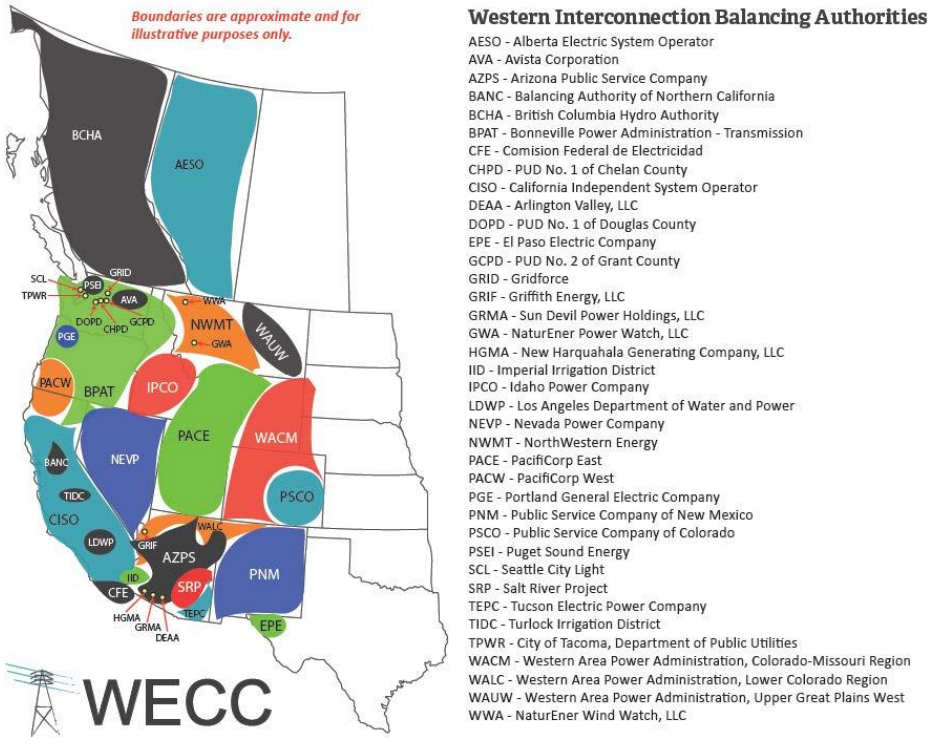


Figure 2WECC Service Area Sourced: Tucson Electric Power Company 2020 Integrated Resource Plan

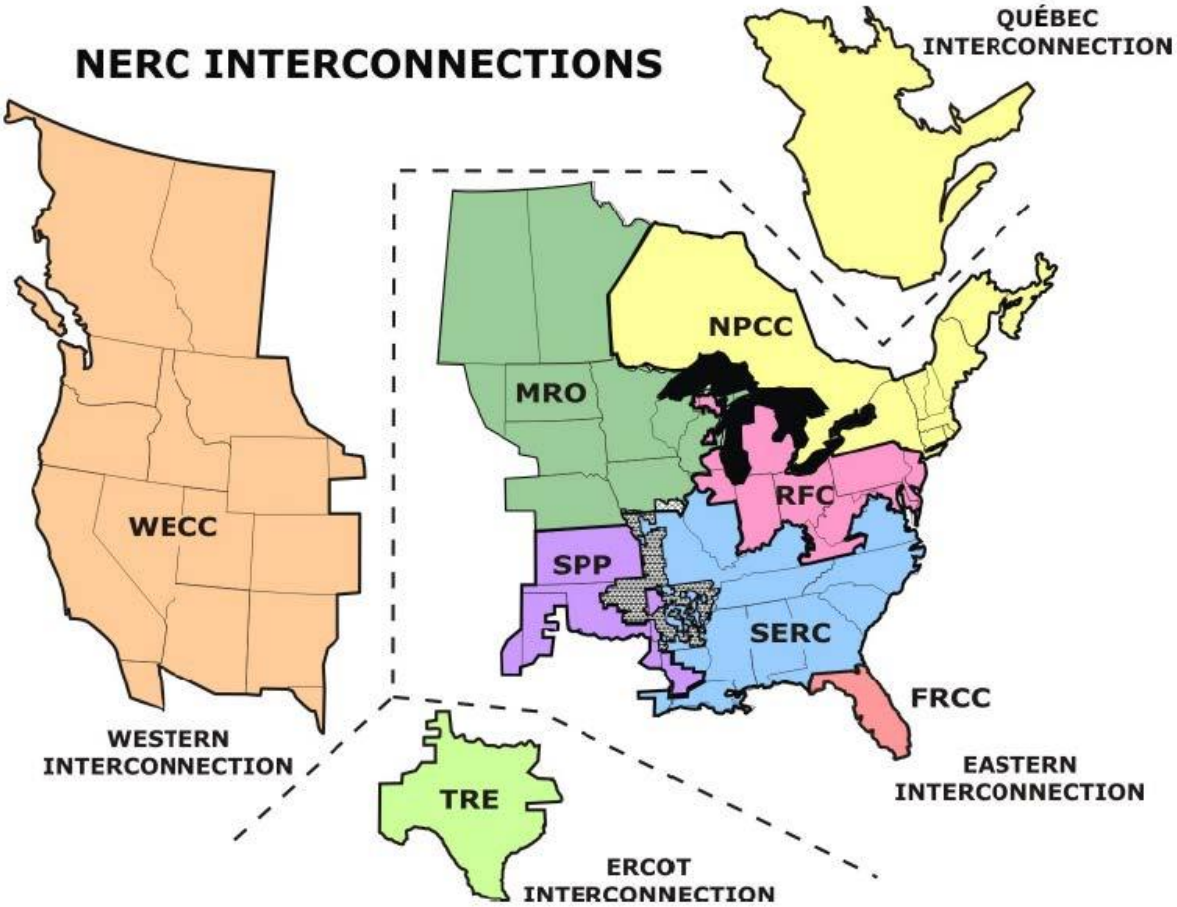


Figure 3 NERC Interconnections Sourced Tucson Electric Power Company 2020 Integrated Resource Plan

Figure 4 TEP's 10MW Battery Energy Storage System Sourced Tucson Electric Power Company 2020 Integrated Resource Plan

Figure 5 TEP's 2MW Solar Field with 10MW Battery Energy Storage System Sourced Tucson Electric Power Company 2020 Integrated Resource Plan

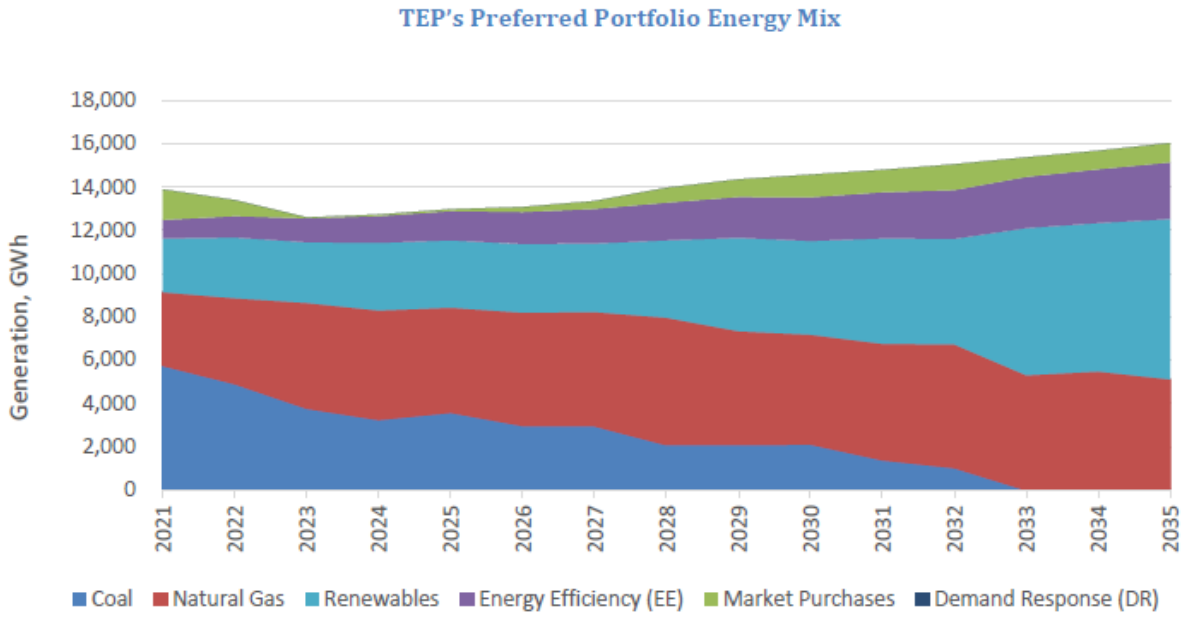


Figure 6 TEP's Preferred Portfolio Energy Mix Sourced Tucson Electric Power Company 2020 Integrated Resource Plan

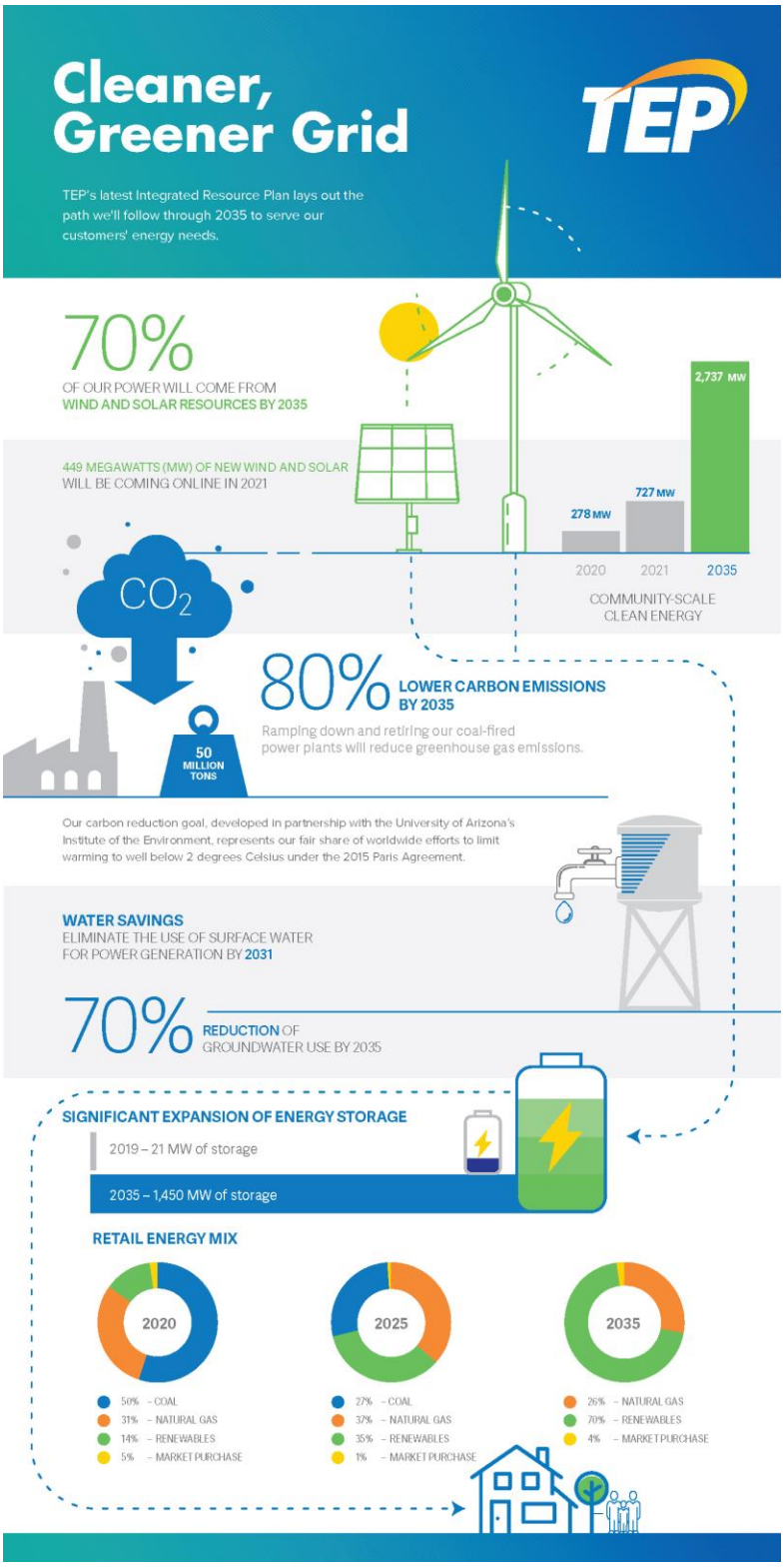


Figure 7 TEP's Infographic - Clean Energy Sourced Tucson Electric Power Company 2020 Integrated Resource Plan

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