SANTA FE INSTITUTE

WORKSHOP REPORT

The Energy Transition in New Mexico:

Insights from a Santa Fe Institute Workshop




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Executive Summary

New Mexico has made important commitments to transition its economy away from fossil fuels and toward carbon-free[3] energy sources. Many cost-effective and carbon-free technologies are available to approach these goals, but deploying them will require focused effort. The transition to a carbon-free, efficient energy system also presents new opportunities for innovation, job creation, and equitable economic growth.

In response to these challenges and opportunities, on Feb. 26-28, 2020 an interdisciplinary group of local, national, and international experts met at the Santa Fe Institute to discuss strategies for the deep decarbonization of New Mexico's economy. This report draws on discussions from the workshop and subsequent conversations with several New Mexico stakeholders. It focuses on areas of innovation that are well-suited for New Mexico and its communities.

Our discussions highlighted a number of technologies and policy tools to manage the variability of solar and wind power and to help New Mexico reach both the 2030 goal under the Energy Transition Act (ETA) and chart a course to achieving the 2045 goal of 100% carbon-free electricity. These tools include short- and long-term energy storage, identifying and enabling flexible demand through the electrification of energy services such as transportation and heating, and promoting stronger regional coordination. Importantly, the transition to carbon-free electricity can create jobs, and aid in economic recovery from Covid-19. Moreover, the benefits of the ETA could be enhanced, and other opportunities created, by broadening decarbonization targets to look beyond the power grid to other sectors of the economy such as transportation and industry.

Here is a brief summary of the primary insights emerging from our workshop discussions and subsequent research and conversations with local experts. We look forward to learning more from additional experts and stakeholders in New Mexico and the region. We plan to hold follow-up workshops and update this document as new strategies and opportunities appear.

Job creation and economic recovery. Clean energy already employs more people than the coal industry, and clean energy jobs have grown more quickly over the past few years than economy-

[3] We use the term `carbon-free' to refer to the lowest greenhouse gas emitting technologies available today, recognizing that they have non-zero lifecycle greenhouse gas emissions intensities.

wide jobs as a whole. In New Mexico, deploying, integrating, and managing wind energy, solar energy, energy storage, and other clean energy technologies can create jobs and economic development opportunities across the state. These include replacement energy resources in San Juan County and a range of economic development opportunities for Pueblos, Tribes, and Nations. Methane monitoring technology, including new software to achieve targeted sampling, methane capture, and the plugging of abandoned wells can create new jobs in the Permian basin. Weatherization and efficiency programs can be scaled up to reduce energy consumption and help customers save on energy bills that represent a larger share of low- and middle-income households' expenditures. Job training programs can be expanded to help people enter the trades relevant to renewable energy and efficiency. Equitable economic growth opportunities can be created deliberately, through progressing toward decarbonization goals by incentivizing innovation that supports job creation. New Mexico's low-cost solar and wind energy can be used to attract data centers and other companies seeking to locate their operations in areas offering carbon-free power.

Decarbonization across the state's economy sets up the potential to exploit cross-sector synergies. Setting specific, binding greenhouse gas reduction goals like those in the ETA for other major sectors, including transportation, heating, and oil and gas production can provide a platform for capturing several key innovation opportunities. Cross-sector targets can incentivize the electrification of new energy services such as switching residential and commercial heating from natural gas to electricity, and transitioning to electric vehicles that make more complete use of renewable energy. These transitions would, in turn, help create new jobs. These policy goals can be set with a range of benefits in mind. For example, in the transportation sector, cities and counties can strategically incentivize the design of EV charging infrastructure while encouraging mixed-use neighborhoods and affordable housing, including multifamily housing, close to employers. Broadband internet in rural areas could allow telecommuting while strengthening education and economic development. Cross-sector goals might also incentivize more strategic growth of renewable energy exports from New Mexico to other states, to diversify the state's economy.

Embracing innovation to ensure grid stability while relying on variable sources of renewable power. Traditional fossil-fueled power plants help provide stability through rotational inertia. A carbon-free power grid can achieve the same stability with weather-dependent renewable energy sources by combining energy storage, fast-response management of flexible demands, power electronics, and better regional interconnections. Utilities in New Mexico are already planning investments in grid-scale energy storage to balance a variable electricity supply from wind and solar energy at time scales that allow recovery from sudden grid disturbances. New Mexico utilities are also beginning to experiment with demand response. Building on these efforts, New Mexico utilities are well-placed to operate at the cutting edge through a concerted effort to validate trusted models of these resources, and to experiment with long-term storage, predictive models of supply and demand, and the use of fast-response, flexible demands, among other technologies. Utilities in New Mexico and their regulators should continue to foster an environment where new ideas for maintaining grid stability can be rapidly tested, and validated concepts allowed to move forward.

Regional coordination. Greater regional coordination will streamline the path towards New Mexico's energy transition by reducing overall costs, averaging weather conditions across the Southwest to smooth variations in the output of wind and solar power generators, balancing supply and demand, and sharing the costs of regional transmission and interconnections. It can also create economic opportunities for New Mexico to export surplus renewable power. For instance, far more wind power could be generated in the Eastern part of the state than is consumed within the state. Selling this power to Arizona, Nevada, Colorado, and Southern California would create new sources of revenue and help diversify New Mexico's economy.

Supporting electrification of more energy services. Many uses of electricity, like water heaters and electric cars, are flexible in terms of when they need power as long as temperatures and charging levels meet the customer's needs. With the help of interconnected devices that communicate with grid operators, we can shift demand to hours when renewable energy is plentiful. Just as regional interconnections can help smooth out variations in solar and wind by averaging weather conditions across space, demand management and storage can help average supply and demand over time.

Innovation to achieve soft cost reduction. The hardware costs of solar, wind, and energy storage are rapidly decreasing as global demand drives investment and technological progress. New Mexico can be a leader in reducing the "soft costs" of these technologies, including design, permitting, installation, inspection, and interconnection. Streamlining permitting processes for both distributed and utility-scale generation will create additional jobs and workforce expertise. While distributed generation is generally more expensive than utility scale generation, distributed generation and storage, including rooftop solar, community solar, and microgrids are of interest to some communities and can be supported alongside a concerted effort to innovate edge-of-grid technology and to build a skilled workforce.

Anticipate technological change in regulation. New Mexico's electric utilities and cooperatives are making long-lasting capital decisions in the face of rapid technological change. Regulators should encourage planners to incorporate the pace of technological change into current investment decisions. Expected cost declines in renewable energy and storage, and forecasted changes to the energy system to meet decarbonization goals, should be taken into account when considering options for new generation or replacement power. Fossil fuel plants may need to have shorter lifetimes than projected, run less than expected, or become stranded assets—costing ratepayers more and creating barriers to decarbonization. Replacement of retired power plant capacity should come from carbon-free energy technologies such as renewables, storage, and demand response. Considering data-based trends and forecastable system-wide changes to meet legally-mandated decarbonization goals is a rational approach to regulatory decisions. Ignoring these changes amounts to placing bets on outcomes that are very unlikely and/or not in line with New Mexico's ETA.

1. Introduction

On February 26-28, 2020, an interdisciplinary group of local, national, and international experts met at the Santa Fe Institute to discuss strategies for deep decarbonization: moving the power grid toward 100% carbon-free electricity, and reducing greenhouse gas emissions in other sectors of the economy as well. We were motivated by major commitments made by elected representatives and utilities in New Mexico and the larger Four Corners region. These include the following:

- Governor Lujan-Grisham's Executive Order 2019-003 commits New Mexico to the Paris Agreement and sets a goal of 45% reduction of greenhouse gas emissions from 2005 levels across all sectors by 2030.

- The Energy Transition Act, passed by the Legislature and signed by the Governor in March of 2019, sets a statewide renewable energy standard of 50% by 2030, 80% by 2040, and 100% carbon-free power for investor-owned utilities and rural electric cooperatives by 2045 and 2050 respectively.

- State legislation in Colorado, passed by the legislature and signed by Governor Polis, sets goals of 100% renewable energy by 2040 and economy-wide reduction of greenhouse gas emissions of 50% by 2030 and 90% by 2050.

- The Public Service Company of New Mexico (PNM) has announced that they will achieve 100% carbon-free electricity generation by 2040, five years earlier than the goal set by the Energy Transition Act.

- Xcel Energy and its subsidiary Southwestern Public Service have set a goal of reducing carbon emissions across their grid by 80% by 2030 (compared to 2005) and to a 100% carbon-free grid by 2050.

- Arizona Public Service has committed to 45% renewables by 2030, to removing coal from its power generation portfolio by 2031, and to 100% carbon-free power by 2050;

- Tucson Electric Power's 2020 Integrated Resource Plan calls for 70% of their power generation portfolio to be provided by solar, wind and energy storage by 2035, and for their remaining coal-fired power plants to be retired by 2032.

- Kit Carson Electric Cooperative has set a goal of providing 100% of their daytime electricity needs through solar power by 2022. They are more than half way to this goal and are implementing battery storage as well.

- Local governments in New Mexico have also set goals, including the City of Albuquerque's Mayor's Energy Challenge, and the Sustainable Santa Fe 25-Year Plan, which calls for 50% renewable energy by 2025 and carbon-neutrality by 2040.

The purpose of our workshop was to think about the entire path to deep decarbonization in the context of New Mexico's goals and to distill lessons applicable to the Four Corners region and the rest of the country. New Mexico is already on its way towards decarbonizing electricity. The cost and efficiency of renewable energy, storage, and other key technologies have radically improved over the past decades and are expected to continue to do so. Many technologies which would have required subsidies a few years ago are currently competitive with, or cheaper than, conventional fossil-fuel generation. Moreover, these improvements have resulted from the kinds of policies that New Mexico has enacted, setting up a virtuous cycle of technological innovation[4]. From a technical and economic point of view, there is little standing in the way of New Mexico's short- and medium-term goals, or the goals of other states in the region.

Strategies in this report grew out of our diverse discussions at the workshop, as well as follow-up discussions with many local experts. We choose not to focus this report on elements of decarbonization that are already well-understood, such as the role of wind and solar power, or the value of energy storage in the integration of renewables. These are important factors and are worth repeating, but the engineering and policy communities have largely achieved consensus that with careful planning, higher levels of penetration of these technologies in the power grid is technically and economically possible without raising costs or affecting electric reliability. Instead, we focus on decarbonization strategies from our discussions at the workshop and beyond that open up new innovation and equitable economic growth opportunities, which have not received the same level of attention. We focus in particular on strategies that New Mexico as a state, or individual jurisdictions within New Mexico, can employ to facilitate deep decarbonization in electricity and other sectors of the economy. Our objective is to highlight opportunities that can inform concrete action items by the Governor and Legislature, the Public Regulation Commission, and by local governments. This working document aims to serve as a tool for advancing such discussions.

Our discussion is structured around seven strategies that could be employed by decision-makers at multiple levels in New Mexico, in order to fully harness the environmental and economic potential of the state's decarbonization efforts. These strategies fall into three different but complementary areas, as shown in Figure 1.

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[4] Trancik, "Clean energy enters virtuous cycle", Nature 528 (2015); Trancik, J.E. et al., "Technology improvement and emissions reductions as mutually reinforcing efforts: Observations from the global development of solar and wind energy." Cambridge, MA: Institute for Data, Systems, and Society, Massachusetts Institute of Technology (2015). http://hdl.handle.net/1721.1/102237

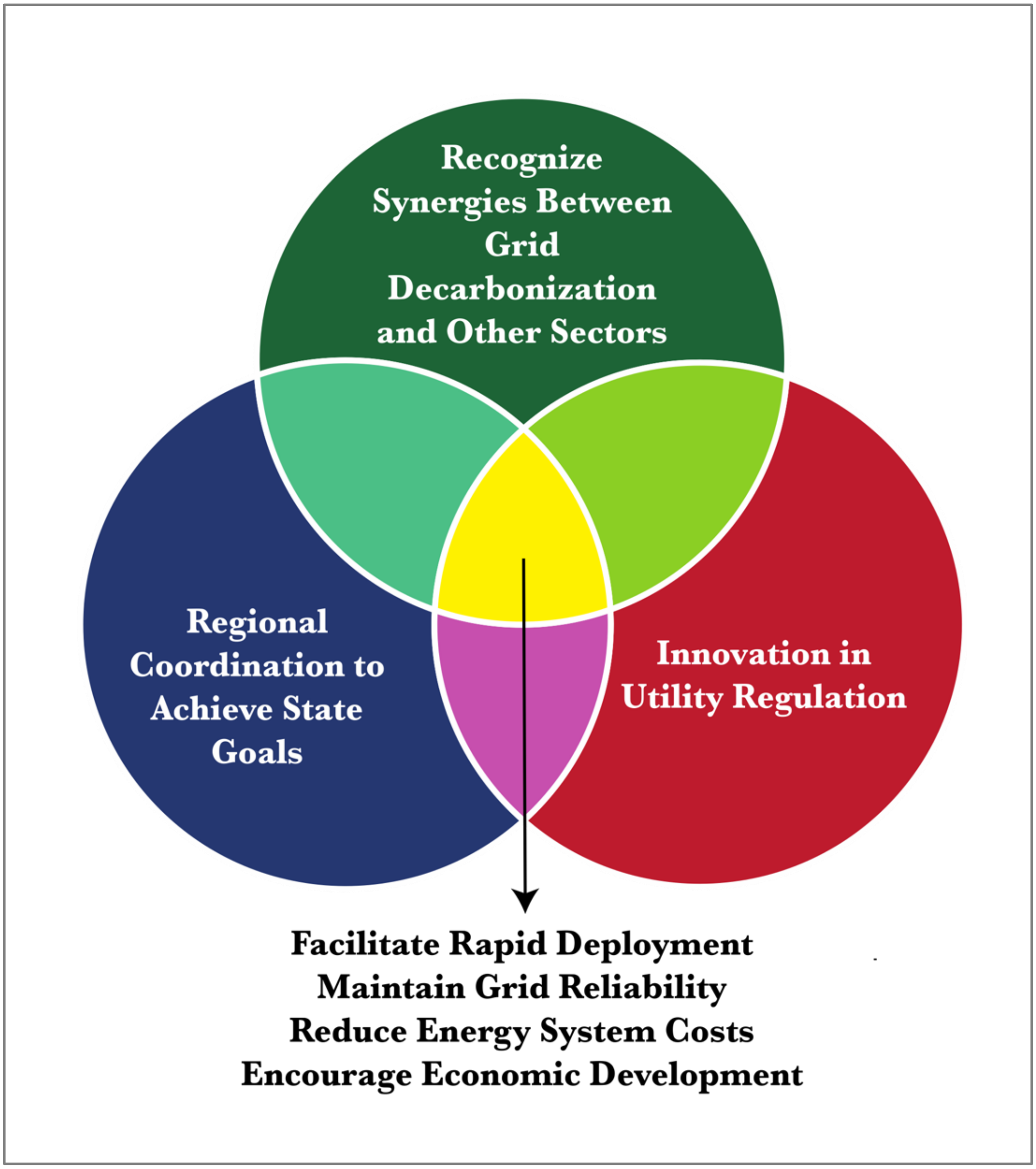

Figure 1: The strategy space for economically and environmentally beneficial energy transitions in New Mexico

First, looking beyond the power grid to **recognize synergies between grid decarbonization and other sectors of the economy** would allow the state to leverage investments in carbon-free power generation technologies and innovation in areas such as buildings and transportation to reduce the costs of meeting the goals of the ETA by making the grid and its customers more flexible. Such a strategy would also allow the state to fully take advantage of major investments made in the area of distributed generation and microgrids.

Second, **enhanced regional power grid coordination** in transmission planning and operations can lower costs and improve reliability through the economies of scale and geographic scope that arise naturally with renewable power generation. Regional coordination can also help New Mexico's economy by improving transmission capacity to move the state's low-cost renewables to high-demand areas elsewhere in the Southwest. As a small state with substantial scientific and engineering expertise spread across multiple universities and national laboratories, New Mexico is in a position to lead and benefit economically from decarbonization.

Finally, capturing these potential benefits requires a **regulatory environment that encourages cutting-edge innovation** by recognizing the potential of new technology and a willingness to engage in nimble technological experimentation.

In developing these insights, we referred to other documents that lay out important policy directions, including the 2019 Climate Strategy Report from the New Mexico Interagency Climate Change Task Force[5] and New Mexico's grid modernization road map.[6] We especially appreciate the time that staff from the Energy, Minerals, and Natural Resources Department (EMNRD) took to attend our workshop and explain the state's current policy trajectory. We also appreciate the efforts of the EMNRD and New Mexico Environment Department (NMED) to work with the oil and gas production industry to measure and control methane leakage—which, given the large effect of methane as a greenhouse gas, was New Mexico's greatest single source of greenhouse gases in 2018.[7] These efforts are especially important in the absence of effective requirements at the Federal level. They should be viewed not as a burden to the industry but as opportunities for additional employment and the chance to create a regulatory environment built on collaboration.

The path towards deep decarbonization is not made up simply of developing, engineering and deploying hardware. Our discussions at the Santa Fe Institute kept returning to the institutions and decision-making processes that govern the power grid, from generation to transmission and distribution, and the regulatory frameworks and incentives in which utilities and consumers operate. Utilities and governmental agencies can welcome and encourage innovation, plan ahead for technological change, lower barriers to entry, avoid creating stranded assets, and enhance regional coordination. Having some of the most ambitious clean energy goals in the Four Corners region, New Mexico's legislature, state agencies, and utilities have a unique opportunity to act as innovation leaders in several areas—using clean energy goals to create innovation and economic growth across multiple energy end-use sectors; deploying new approaches to managing a low-carbon or carbon-free power grid; and creating a regulatory environment that supports both innovation and clean energy.[8]

By aligning these incentives New Mexico can avoid the retrenchment and rollbacks in energy policy that some other locations have experienced. Instead, the state can build a robust constituency for carbon-free energy, including consumers, installers, utilities, and employees, and create positive feedback and momentum for the deep decarbonization transition.

Our workshop was held just as the impact of the global pandemic was becoming clear. Indeed, it was the last workshop held physically at the Santa Fe Institute before its transition to virtual meetings. As our society works to bring Covid-19 under control, we face high unemployment, low

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[5] https://climateaction.state.nm.us.

[6] The grid modernization road map was laid out in HB 233, signed into law by Gov. Lujan Grisham in March 2020.

[7] "New Mexico Climate Strategy: Initial Recommendations and Status Update," New Mexico Interagency Climate Change Task Force, 2019. Available at https://www.climateaction.state.nm.us/documents/reports/NMClimateChange_2019.pdf

[8] Several other countries have documented success stories in rapid transitions to lower-carbon energy systems. See K. Araujo, *Low Carbon Energy Transitions: Turning Points in National Policy and Innovation,* Oxford University Press, New York NY (2017).

oil and gas prices, and devastating shortfalls in the New Mexico budget. In this context, some will argue for putting the energy transition aside, and returning to conventional power while the economy gets back on its feet.

But this would be precisely the wrong move if the aim is to stimulate job growth and economic recovery. In addition to helping meet New Mexico's climate goals, and thus helping to address the world's next great crisis, the transition to carbon-free power will help create jobs, export renewable energy to the rest of the Southwest, and increase state revenue. New Mexico has been a leader in addressing Covid-19, building public-private partnerships to boost testing capacity, harnessing the expertise of our universities and National Laboratories, and taking early, forceful, science-based action. New Mexico can take a similar leadership role in the transition to carbon-free power, with a stakeholder-involved process of innovation to achieve decarbonization by leading in regional coordination, capturing cross-sector opportunities, and reducing soft costs.

2. Job creation, recovery, and economic growth

Source: Energy Smart Academy, Santa Fe Community College

Strategy: New Mexico's decarbonization plan should explicitly target job creation and innovation, using a data-based approach and relying on community involvement. Job training programs, including specialized licensing programs, can help people move into trades relevant to energy testbeds may be particularly impactful. Economic development efforts from the state should reach out proactively to companies that assemble components for solar and wind generation. In addition, New Mexico should use its low-cost carbon-free energy—some of the lowest in the United States for a mixture of solar and wind—to attract data centers and other companies seeking to shift to renewable energy.

In previous times of economic stress, the United States has used infrastructure projects to boost the economy, create jobs, and accelerate technological progress. This same opportunity exists today, to drive economic recovery and diversify New Mexico's economy while moving the power grid into a carbon-free future.

New Mexico has traditionally been dependent on fossil fuels, both for its energy and for many of its jobs. In 2019, oil and gas production was still the largest source of energy-related employment in New Mexico. Transitioning from these fuels is rightly a source of concern for many. Yet many clean energy opportunities exist in the state, particularly if the decarbonization transition strategically emphasizes home-grown innovation and job creation[9].

Job growth in clean energy has been shown to far outpace growth rates in other sectors of the economy over the past five years.[10] During this period, solar jobs have grown by approximately 15%, wind jobs have grown by approximately 50%, and energy efficiency jobs have grown by approximately 9%. During this same period, overall economic growth was 6% and growth across all energy sectors was 12%, so jobs in renewable energy technology (especially wind and solar) have

[9] Klemun, Edwards, Trancik, "Research priorities for supporting subnational climate policies" WIREs Climate Change DOI: 10.1002/wcc.646 (2020)

[10] Employment figures cited here are from the U.S. Energy and Employment Report, located at usenergyjobs.org.

outpaced employment growth in the overall U.S. economy and in the energy sector as a whole. The U.S. Energy and Employment Report notes that many of these employment opportunities have been created in states with favorable regulatory environments for renewable energy growth. Thus, the environment created by New Mexico through the Energy Transition Act and related decarbonization initiatives has the potential to lay the groundwork for substantial economic opportunities.

Although the coal industry and coal-fired power generation employs relatively few people in New Mexico, it has played an important historical role in supporting economic development in the Four Corners region and providing low-cost electricity. The industry and its workers are in the midst of a potentially painful transition as new technologies emerge that can also provide low-cost and reliable power. Shutting down or reducing emissions from coal-fired power plants is vital to meeting climate goals, but coal-plant retirements could have a significant economic impact on San Juan County and Farmington where these jobs have provided high wages in the past, if these jobs are not replaced with other opportunities. Similarly, oil and gas production in the Permian basin experienced a boom due to export demand and fracking technology, and has provided a needed boost to state revenues, but is now going through a bust due to a drop in global demand associated with Covid-19.[11] Many wells are being abandoned, and small drilling companies are going bankrupt, leaving the region with a decrease in jobs, the state with a budget shortfall, and the public with inadequate resources to properly plug and decommission wells and to control methane emissions.[12]

Decarbonization offers the potential for new job creation and economic growth if pursued with community involvement in both planning and execution. In San Juan County, the Energy Transition Act provides funds for economic assistance, severance packages, job training, and remediation. It also directs that up to 450 MW of generation and/or storage be located in the Farmington school district. The Public Regulation Commission (PRC) recently approved a proposal for this replacement power consisting of renewables and storage, which will provide construction jobs, ongoing maintenance jobs, and property tax revenues to the region.

Solar power and storage are also a potential opportunity for economic development for Pueblos, Tribes, and Nations, since many tribal lands in the Southwest are in locations with high quality solar resources. One example is the Jicarilla Apache solar farm, recently approved by the PRC, which will provide 50 MW of solar power and 20 MW of battery storage. This project will help Albuquerque meet its renewable energy goals, provide construction jobs to the area, and provide lease payments to the Jicarilla Apache Nation. Another local example is Picuris Pueblo's 1 MW solar array, built in conjunction with Kit Carson Electric Cooperative. The Navajo Nation has also prioritized solar power as part of a transition away from coal, generating 55 MW with the Kayenta I and Kayenta II solar projects, and plan an additional 70 MW through the Red Mesa Tapaha Solar Resource in Utah starting in 2021.

Additional jobs in both San Juan and the Permian could be created from properly plugging and abandoning wells, and monitoring, capturing, and reinjecting methane. Moreover, opportunities exist to apply oil and gas expertise and infrastructure to decarbonization efforts, which can help

[11] At the time of this writing, the active rig count in the Permian Basin, as reported by Baker Hughes, had declined by approximately 70% from July 2019.

[12] The extent of well abandonment in the Permian Basin is unclear, but the Carlsbad Current Argus reported over 700 abandoned wells in New Mexico as of June 2020, with over four thousand oil and gas workers in New Mexico applying for unemployment.

transition workers more easily to a decarbonized economy. This is especially the case in the areas of hydrogen transmission and storage, as well as carbon capture, storage and utilization. Some regions of New Mexico have promising potential for geologic storage of captured carbon dioxide or other resources, which could represent an area of economic growth if society explicitly prices carbon or establishes financial incentives to encourage deployment of long-term geologic storage of carbon dioxide.

Beyond these specific measures, decarbonization can create a wide variety of new jobs in the building, plumbing, and electrical trades. As we discuss below, these include energy efficiency, demand management, and electrification, including shifting residential and commercial heating from natural gas to electricity. In addition to new construction, this would create a large demand for retrofitting existing properties, which in turn would create demand for contractors familiar with these technologies.

For example, New Mexico currently has a shortage of contractors experienced with sales, design, and installation of variable capacity heat pumps, which could reduce both carbon emissions and consumer's total energy bills. The Santa Fe Community College's (SFCC) EnergySmart Academy, one of the few national training programs accredited by the Interstate Renewable Energy Council (IREC) and the only one in New Mexico, provides distance learning across the state that trains contractors in technologies like these.

Solar and wind installation, including both residential and utility-scale solar, also create new job opportunities. SFCC now provides a Solar Energy Certificate through their School of Trades, Advanced Technologies and Sustainability. Through their participation in the Solar Instructor Training Network they connect contractors statewide with national experts to keep them up to date on current technologies and techniques. They are developing a new certificate program in Distributed Energy Technologies and Systems, which could have a similar statewide impact.

Demand management also requires new construction and retrofits, enabling water heaters and HVAC systems to respond to grid conditions and the availability of renewable supply. This will create a need both for contractors who can design and install these systems, and for building managers who can implement new automation techniques.

Energy efficiency is a key enabler of decarbonization and job creation. The Weatherization Assistance Program has been operating nationally since 1976 with Federal funding from the Department of Energy. Locally this program is referred to as the NM Energy$mart Program and receives additional support from the Low Income Home Energy Assistance Program (LIHEAP), utilities funded by rate riders such as PNM, New Mexico Gas, Central Valley Electric (CVE), private grants from the Climate Change Leadership Institute (CCLI), and some state funding. They have worked on 23,300 homes since 2002, peaking in 2010 with stimulus funding from the American Recovery and Reinvestment Act. Their work covers air sealing, insulation, heating, cooling, refrigerator replacement, LED bulb installation, water heater efficiency measures, and health and safety work on furnaces, ventilation, and carbon monoxide alarms. This program currently allows for an average of $7,500 worth of energy efficiency and health and safety improvements per household, and typically results in considerable financial savings for homeowners on their energy bills including electricity, gas, and costly fuels like propane. By Federal policy, the occupants of these homes must be low-income or disabled, thus helping address New Mexico's high level of poverty.

This program could readily be expanded. Given current funding levels, their capacity is about 500 homes per year, but they have a waiting list of 2,300 applicants—a five-year backlog. An additional 800 applicants have received partial weatherization and are waiting for further work to be done. This counts only those homeowners who have found out about the program and have chosen to apply. There are 170,000 residences in New Mexico under the Federal poverty level, only a small fraction of which have been reached so far. This indicates a large potential demand for consumer savings, employment, and decreases in greenhouse gas emissions.

Retrofit programs like New Mexico Energy$mart, and training programs like those at SFCC, would be excellent candidates for stimulus funding as governments at all levels try to bring the economy back to life after Covid-19. They should also be expanded to include fuel-switching retrofits including electrification.

In addition, the State could consider establishing specialized license categories in energy technologies. Solar installation is not the same as wiring a home, and requires a different mix of skills than a standard electrician might have. Several states have created such licenses, such as Oregon's Limited Renewable Energy Technician. Focused licenses with shorter apprenticeships would get workers into these trades more quickly, and accelerate the creation of a qualified workforce to help the decarbonization transition take place.

Beyond these opportunities for job creation, entirely new job opportunities will be created as New Mexico innovates toward decarbonization. Box 1 discusses some of the opportunities that can be created along with investments in renewable energy technology. But innovation must be supported. Here we see an opportunity to incentivize innovation testbeds that address solar energy and electric vehicle soft costs, optimize portfolios of energy services across sectors, and find new ways to achieve energy efficiency across electricity, transportation, heating and industry. Early and sustained community involvement in this process will be essential for developing appropriate incentives.

Source: The Navajo Times, the Kayenta Solar Facility. NTUA/

Box 1: Opportunities for Economic Growth

New Mexico may be able to develop and attract new installation and manufacturing opportunities related to renewable energy. Fabricating “plug and play” photovoltaic systems is one opportunity, as are other efforts toward modular, on-site construction for various system sizes. For instance, racking and assembling panels ready for installation can be done at low cost close to the customer, given their weight and shipping costs. These costs represent a significant and increasing share of the total costs of solar electricity, and create a value proposition for local assembly, especially for customers whose locations are far from West Coast ports serving Asian manufacturers.

Many New Mexico policymakers are aware of the history of Schott Solar, which closed their Albuquerque operations in 2012 after receiving property tax reductions and other incentives. But there are also important success stories such as Array Technologies, which has 22 GW of installed solar power generation globally, and which developed a single-axis tracker for solar panels with the highest reliability in the industry. This innovation and related intellectual property was developed in New Mexico, and some components of these trackers are still manufactured in Albuquerque.

As more states in the West adopt carbon-free mandates, the market for residential and utility-scale solar manufacturing, as well as wind turbine manufacturing, has become more robust and is now on a steady growth trajectory. New Mexico can compete for a share of this market, especially in locations with excellent access to highways and rail transport such as Albuquerque and St. Teresa. Access to rail and to I-40 and I-25 provide a competitive advantage analogous to Pueblo, Colorado, where Vestas Wind Systems manufactures towers for wind turbines.

By expanding tax incentives, industrial revenue bonds, and job training partnerships for solar and wind-related assembly and manufacturing and related industries, the state may boost economic development. Cooperating with the Economic Development department will be critical as New Mexico develops programs specifically around attracting this sector.

Finally, New Mexico has a major competitive advantage for attracting companies like Facebook that seek to shift to renewable energy. A recent study [KiloNewton LLC, Levelized Cost of Renewable Energy in the Lower 48 United States: Blended Solar and Wind, 2020] found that New Mexico has the lowest levelized cost of energy for a 50-50 mix of solar and wind. Data centers are obvious targets, given that power and cooling constitute up to 80% of their expenses. These centers make significant capital investments and long-term power purchase agreements (PPAs), and create jobs in multiple sectors in addition to short-term construction jobs.

More generally, attracting companies like those in the RE100 group (https://www.there100.org) that have committed to shift to 100% renewable power—a practice called “green shoring”—could generate local jobs and help build out New Mexico’s infrastructure. The Economic Development staff has a strong case to make when reaching out proactively to these companies since New Mexico has the lowest cost renewable energy in the United States.

3. Decarbonization across the economy: Set binding policy targets across all energy services

Strategy: To incentivize a cross-sector transition through carbon-free innovation, binding emissions reduction targets should be set for end-use sectors such as transportation, heating, and industry. Positive synergies between sectors should be emphasized, including electrification where fossil fuel use is made more efficient and ultimately replaced by carbon-free electricity.

Through the Governor and Legislature, New Mexico has set decarbonization goals, not just for the electric power grid, but for the economy as a whole. However, specific, binding targets could be set for each sector analogous to those set for electricity. This could include explicit interim targets for 2025, 2030, 2035, and 2040, to complement the economy-wide goals set out in Executive Order 2019-003.

These quantitative targets and the associated timelines could be set while considering synergies where decarbonizing the power grid can help to decarbonize other sectors of the economy and vice versa. Setting targets for all end-use sectors---such as heating, transportation, and oil and gas production---will positively affect the state's ability to capture cost-saving opportunities driven by carbon-free electricity. Cross-sector targets also offer new opportunities for supporting equitable economic growth and job creation.

One of the most effective links between carbon-free power and decarbonizing the economy as a whole is electrification, which is the shifting of end uses of energy from fossil fuels to electricity. This will increase electricity demand at times but reduce the state's overall carbon footprint by replacing fossil fuel generation with more efficient and ultimately carbon-free electricity. In many cases electrification would immediately result in a reduction in greenhouse gas emissions even with the current power grid, and these savings will grow as the grid incorporates a larger share of carbon-free sources. Depending on the relative efficiency of the old and new systems and the comparative costs of fossil fuel and electricity, electrification will also provide savings to consumers by reducing their total energy costs.

However, the electrification of energy services will not happen on its own and likely needs policy signals in the form of specific decarbonization targets across sectors, as well as updated building codes, policies encouraging EV charging stations, and so on. These signals will in turn drive infrastructure investments and markets for new construction and retrofits. These targets should be curated to capture opportunities for full economy decarbonization while managing the variability of renewables.

There are several opportunities to note. In scenarios with a significant share of variable renewable energy there is likely to be some overbuilding, i.e. creation of excess capacity. This is natural: almost all generation and transmission facilities are idle part of the time, with capacity factors significantly below 100%. Like other sources, renewable energy is typically curtailed when supply exceeds demand. On the other hand, cross-sector targets and synergies such as electrification can take advantage of this excess capacity, thus increasing the value of New Mexico's renewable energy. Electrification can reduce curtailment by creating new loads that can absorb at least some of his excess carbon-free power, turning this "overbuild" into a resource for economy-wide decarbonization. As discussed in Section 6, many newly electrified systems such as transportation and heating can be designed to be flexible so that devices shift their energy usage in time to align with the availability of carbon-free or low cost power, reducing the overall cost of electrification.

One specific opportunity for reducing curtailed renewable energy production is to set smart targets for decarbonization in transportation to align with those for electricity. This will incentivize transportation electrification at a rate that supports the use of otherwise curtailed renewable energy[13]. As electric cars have decreased in cost and increased in range, they are becoming cost-competitive and practical options for typical consumers[14], but only if accessible opportunities exist to distribute the higher upfront costs across the vehicle lifetime. Tax credits or other policy support for electric vehicles and charging stations, which failed to pass in the 2020 New Mexico legislative session, could be renewed and extended, though measures should be taken to ensure such policies create equitable benefits across communities and income levels. Municipalities can encourage or require charging infrastructure as part of commercial and residential development and in public parking areas.

Another electrification opportunity is in commercial and residential heating. Electrical heat pumps should be encouraged where suitable in new construction as well as in retrofitted existing buildings, through both emissions targets for direct heating services and programs such as incentives, efficiency audits, and rebates. This has strong job-creation potential as discussed in the previous section.

Cross-sector targets can also open up the opportunity to capture co-benefits beyond energy services. One effective way to reduce emissions in the transportation sector while increasing economic and human wellbeing is for local governments to implement planning and zoning policies that support sufficient density for affordable housing (including multifamily housing) close to employers, as well as mixed-use neighborhoods with commercial services, schools, and housing within walking distance of each other. Suburban sprawl, coupled with a lack of affordable housing in city centers, forces people into long commutes and is a major generator of transportation-related greenhouse gas emissions. (Consider the many people who commute to state government jobs from Rio Rancho, Albuquerque, or Española because they cannot afford to live in Santa Fe, not to mention teachers, police officers, firefighters, and service workers in the tourism industry.) Local

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[13] Needell, Trancik, "Strategies for beneficial electric vehicle charging to reduce peak electricity demand and store solar energy", in review.

[14] Carboncounter.com

government can also support transit and bikeways within cities, and recognize that alternatives to automobile transportation are a vital part of a city's infrastructure.

These improvements in land-use policies, alongside supporting regional transit for long commutes, can provide residents with choice and flexibility in housing and work locations, improving quality of life and potentially addressing inequity issues.[15] Finally, rural broadband internet access would allow telecommuting and reduce the need for physical commuting, while helping meet vital needs for online education and telehealth access, especially in low-income rural areas and on Tribal land. These are examples of how decarbonization policies can be designed to encourage innovation that creates economy- and society-wide co-benefits.

[15] Pathak, R.; Wyczalkowski, C. K.; Huang, X. Public Transit Access and the Changing Spatial Distribution of Poverty. Regional Science and Urban Economics 2017, 66, 198–212.

4. Embrace emerging technologies for ensuring power grid stability while relying on variable renewable energy

Strategy: Electricity industry stakeholders should work to update the computational models used for power systems planning so that the capabilities of all resources (including wind and solar generation, energy storage and flexible demand) can be given due consideration in the planning processes that determine utility investments. There are also opportunities for the state to draw on utility and research expertise to lead in a larger discussion of how best to keep the grid stable in a period of technological change. New Mexico utilities should be encouraged to design and implement demonstration projects for technologies like these to help enable the transition to carbon-free energy.

For many decades, the power grid has operated on the principles of dispatchability and control, under which grid operators produced electricity from large power plants on demand and guarantee its availability. This was facilitated by the use of fossil fuels with high energy density and ease of large-scale fuel storage. The increasing use of weather-dependent and geographically dispersed renewable generation makes this mode of power grid operations more challenging. In particular, as shown in Figure 2, long-range planning decisions for the power grid need to consider not only peak levels of electricity demand, but also the potential variability of renewable energy resources.

Source: New Mexico Bureau of Land Management, Solar Energy Program

Box 2: Variability and Stability of the Power Grid

Managing variability refers to addressing fluctuations in output that happen over time scales ranging from minutes to days to seasons of the year, all the way up to decades. Power grid operators have always managed variability in electricity demand, but the increasing amount of weather-dependent supply resources connecting to the grid introduces additional sources of variability. This applies most clearly to solar and wind power, although even for hydropower there are daily and seasonal variations in water flows. To make sure that supply meets demand, grid operators have to make decisions over minutes, hours, and days about how to use existing generators, charge and discharge energy storage devices, and dispatch flexible demands. These decisions are updated frequently as grid operators learn more about real-time conditions and get better forecasts for wind and solar availability, as well as electricity demand. On longer time scales, transmission lines can be planned and built so that areas with high renewable potential can export their power to locations where it is needed.

Ensuring the stability of the power grid means making sure that it can recover from unplanned shocks or disturbances such as the sudden loss of one or more large power plants or transmission lines, or a fault (short circuit) in the system that suddenly changes the rotating speed of a generator. Some in the electric power sector use the word “stability” more narrowly, focusing on transient stability (the ability of generators to remain synchronized after a disturbance) and voltage stability (the ability to keep the grid voltage within allowable ranges when load increases or there is a change in the network). Here we use “stability” to mean the general ability of the grid to recover quickly from shocks and avoid large blackouts.

To understand the new challenges introduced by a low-carbon energy system relying largely on renewable energy, we must distinguish between managing the variability of renewable power sources and ensuring the stability of the power grid. These are different challenges, and the planning and investment decisions made months or years in advance will determine which management tools grid operators have at their disposal (Figure 2). In Box 2 we clarify the difference between them by looking the time scales at which solutions will operate and several other key characteristics.

To ensure stability in the face of shocks, grid operators and automated control systems need to make decisions and take actions over timescales ranging from minutes down to seconds and less. Conventional fossil-fuel power plants help provide stability partly through their physical inertia, literally spinning slightly ahead or slightly behind their normal motion to respond mechanically to fluctuations in electricity demand. While physical inertia remains important to grid stability (and retired fossil fuel plants could be used to store inertia mechanically for the same purpose), it is increasingly possible to manage grid stability through fast-acting digital control and power electronics systems. These automated systems can react to shocks by rapidly changing the setpoints for generators or other grid assets, or shedding load to avoid a dangerous imbalance.

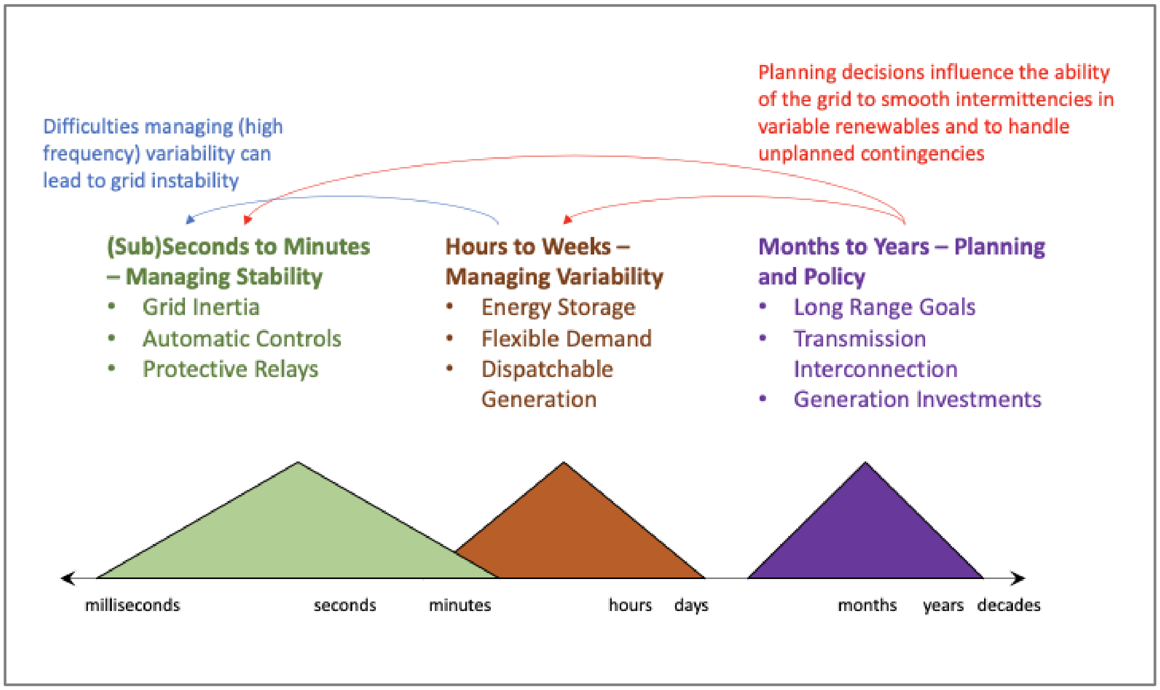

Figure 2: In a low-carbon power grid, planners must make careful and informed decisions years in advance to ensure that operators are able to manage variability over different time scales, and keep the grid stable to prevent blackouts.

Modern software systems can also enable human operators to rapidly react to problems that emerge over the minutes after the shock to ensure that the grid recovers smoothly. The important point is that modern power systems increasingly rely on software systems and power electronics that can enhance stability, rather than relying only on physical inertia.[9]

Grid stability, and software systems designed to analyze stability, also play a critical role in power grid planning. In order to maintain stability when adding or removing resources to or from the grid, power systems engineers carefully evaluate the impact of each new resource on grid stability before a project moves forward. As a result, stability modeling and analysis tools have a tremendous impact on what resources get built. One of the challenges of the ongoing energy transition is that the dynamic properties of sophisticated resources like inverter-controlled solar photovoltaic and battery systems, or automated control systems for flexible demand, are not fully modeled, validated, and trusted in current power grid modeling software systems, especially in older generations of software. If updated models are not adopted, the industry will maintain a bias toward conventional resources, like fossil fuel power plants and large transmission lines, for which there are mature and trusted models.

There is a need for collaborative work between those that build large-scale energy resources (e.g., battery/inverter manufacturers) and those that develop power system modeling tools (e.g., Siemens PSS/E) to rapidly improve and validate power system stability modeling tools. As these tools are validated, there is a need for power systems engineering teams to honestly compare the relative stability benefits and risks of newer energy technologies to traditional sources, rather than merely relying on resources that have been historically reliable. New Mexico is in a unique position in having substantial expertise in developing and testing these types of models. The state's two National Laboratories (Los Alamos and Sandia) have world-class expertise in the kind of power systems analysis, engineering and resilience that is needed to support modern tools to plan a modernized power grid. New Mexico's research universities have invested in substantial research expertise in grid modernization as well, through the establishment of the statewide SMART Grid

Center.[16] These analytical resources, in collaboration with utilities and commercial software vendors, can play a role in testing and validating these models by collecting data and building expertise that other similar regions can use to accurately assess the stability effects of modern resources.

At some point in the future, as New Mexico and surrounding Western states adopt higher proportions of wind and solar energy along with energy storage, power grid planners and regulators will need to make critical decisions about how best to maintain grid stability. Industry-research consortia have identified pathways for maintaining a hybrid system, where conventional turbines sit on the grid alongside power electronics, and these power electronics devices mimic the rotational inertia of conventional turbines; or a purely power-electronic system without any physical inertia.[17] Understanding these two possible grid futures is likely to become critically important to power grid planning within the next decade. Given New Mexico's strong research expertise in electric power systems, there is an opportunity for the state's utilities, regulators and scientists to lead in understanding these possible paths, and identifying needed innovations to make each path feasible and cost-effective.

In the short and medium term, the experience of power grid operators around the country and the world shows that a substantial fraction of electricity demand can be met with carbon-free power sources, particularly wind and solar, without incurring large costs in the form of storage or additional transmission, and without threatening grid stability. This is possible because existing resources on the grid (not just power plants, but also demand-side resources that can give grid operators flexibility) have proven to be capable of compensating for the weather-dependent nature of wind and solar power. In addition, forecasting capabilities have improved, and grid operators have been adaptable. Grid operators in Texas and the Midwest, as well as Ireland and other European countries, have successfully integrated substantial amounts of wind and solar without substantial reliability issues, achieving as much as 50%–70% renewable energy.

The experience of grid operators internationally does suggest that at some point a threshold is reached beyond which the additional integration of weather-dependent renewables requires new approaches to managing variability and ensuring grid stability, along with sufficient transmission capacity.[18] The exact point on the decarbonization path where real challenges arise, and innovations are needed, will depend on investment and institutional decisions made over the next decade.

The variability of weather-dependent renewables presents both important opportunities and significant challenges. Energy storage can be used to smooth out variations in wind and solar on various time scales. Lithium-ion and other battery technologies are rapidly becoming less expensive and more efficient,[19] and can be used to smooth out variations on a scale of minutes to hours. They

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[16] https://www.nmepscor.org/what-we-do/research

[17] Energy Systems Integration Group, "Toward 100% Renewable Energy Pathways: Key Research Needs," 2019 technical report, available at https://www.esig.energy/resources/toward-100-renewable-energy-pathways-key-research-needs/.

[18] The Irish Wind Energy Association, for example, has a useful article describing the need for investment and innovation to overcome barriers to even greater wind energy deployment in Ireland: https://www.iwea.com/latest-news/2526-dispatch-down-and-the-fight-against-climate-change

[19] See Schmidt, O.; Hawkes, A.; Gambhir, A.; Staffell, I. The Future Cost of Electrical Energy Storage Based on Experience Rates. *Nature Energy* 2017, 2 (8), 17110, and Ziegler, M. S.; Trancik, J. E. Re-Examining Rates of Lithium-Ion Battery Technology Improvement and Cost Decline. arXiv:2007.13920 [physics] 2020.

can also help the grid recover from shocks by helping the grid provide "black start" capability—the ability to restart the grid following large blackouts.

Long-duration storage that can smooth out variations over longer periods while keeping costs low is still a challenge, but several promising technologies exist. These include pumped hydroelectric, such as the proposed Sweetwater and Beclabito projects in San Juan County: Sweetwater would store 600 MW for 8 hours while Beclabito would store 1500 MW for 70 hours.[20] There are multiple types of flow batteries in development that use abundant materials such as iron, zinc, salt, and sulfur, could be scaled up easily, and have the potential to store energy for days or months. Finally, there are other creative possibilities, such as gravitational energy storage based on raising and lowering solid masses on towers or up and down mountainsides.

Broad deployment of renewable energy on the power grid can also create a favorable environment for low-carbon fuels that can be used for dispatchable electricity, long-duration energy storage, and in non-grid applications like transportation and buildings. When the available output of solar and wind energy exceeds current demand, these resources are typically "curtailed," i.e. dispatched down from the output level that they could otherwise have generated. Curtailment thus leads to lower levels of renewable power output and use than might otherwise be possible. While some amount of curtailment is economically justified, we could also use excess renewable energy to generate renewable fuels, such as splitting water into hydrogen and oxygen, or converting methane to hydrogen through steam reformation. The hydrogen can then be used in fuel cells or combustion turbines, alone or as part of a mix with natural gas. While storing and transporting hydrogen is challenging, it can be stored in underground formations with sealed domes, such as some oil and gas reservoirs or salt caverns. In New Mexico, several formations have stored helium along with natural gas, and such formations when depleted may be good sites for hydrogen storage. Moreover, a transition to hydrogen transmission and storage has the potential to leverage New Mexico's existing oil and gas infrastructure and experience and employ its workforce, easing its transition away from fossil resources.[21]

Lithium-ion cell research. Source: Sandia National Laboratory, photo by Randy Montoya

[20] Projects – Gridflex Energy, LLC http://gridflexenergy.com/projects/ (accessed Feb 20, 2020).

[21] Heading for Hydrogen; DNV GL: Høvik, Norway, 2020.

This “power to gas” approach can be applied to other fuels in addition to hydrogen, such as ammonia. These fuels can be thought of as a kind of long-term energy storage, but unlike stationary storage (e.g. batteries) they can be transported to where they are needed, either to generate electricity or for end use in industry.

Key to New Mexico’s ability to lead in innovation around grid stability is a regulatory environment that encourages experimentation without penalizing failure (recognizing that not every innovative idea will pan out and that failure and learning can go hand in hand). New Mexico utilities should be encouraged to design and implement demonstration projects for technologies like these that have the potential to enable the transition to carbon-free energy. These innovation programs should be designed so that utilities are rewarded financially for rapidly and cost-effectively bringing successful pilot projects to full scale, and are allowed to recover capital and operating costs, including research and development costs associated with pilot projects that are not successful. Successful experimentation should be rewarded, and failures should be accepted as part of the process, so long as failures are shut down quickly. These experiments and pilot projects should have transparency/open-data requirements (especially for failed ones) to ensure that their results are rapidly shared to the benefit of the scientific/engineering/investment community.

In addition to short- and long-term storage, two other major ways to deal with variability and stability are regional coordination and demand management. Regional interconnections can smooth out the peaks and valleys in supply and demand by averaging over a large geographical region, delivering surplus electricity to where it is needed, and compensating for weather conditions in one location with those in another. Similarly, demand management can average energy needs over time, allowing flexible devices to vary when they draw power from the grid in order to adapt to grid conditions and the availability of clean power. Regional coordination and flexible demand are the focus of the next two sections.

5. Regional coordination in electric transmission

Strategy: New Mexico has the opportunity to gain significant flexibility, reduce the costs of meeting its goal of a carbon-free electricity system, better harness its renewable energy potential, and create opportunities to export renewable power, by joining with other states in the Southwest to manage the variability of renewable resources, the stability of the overall grid and planning of a regional transmission system.

New Mexico's power grid is not an island. Physically, New Mexico's grid is connected to other states' systems, and is part of the larger Western Interconnection that integrates multiple utility transmission systems in the Western third of the U.S. and Canada. Even though New Mexico is its own "Balancing Area" within the Western Interconnection, meaning that it must be largely self-sufficient in maintaining grid stability and managing variability of in-state demand and renewable energy production,[22] New Mexico utilities participate in some regional organizations related to transmission planning (WestConnect) and maintaining grid stability (the Southwest Reserve Sharing Group). By and large, however, New Mexico utilities plan and operate their own systems. The state does interact with other Western utility systems in several ways:

- New Mexico utilities use other utilities' transmission systems to import power into New Mexico. An example is how PNM imports electricity from the Palo Verde nuclear power station, of which PNM is a part owner.
- Utilities in New Mexico engage in wholesale electricity trade with entities in neighboring states to the north and west. Contractually and economically, this can be a challenging process because each time a utility or independent power producer in New Mexico wants to move electricity across another utility's system, it must pay a fee. To sell electricity into California or Las Vegas (Nevada) for example, would require a New Mexico utility to pay multiple fees to

[22] There are actually four entities that act as "Balancing Area Authorities" in New Mexico. Public Service of New Mexico is the Balancing Area Authority for most of the state, but El Paso Electric, Southwest Public Service, and the Western Area Power Authority serve as Balancing Area Authorities for smaller areas.

multiple utilities in Arizona and Nevada. This practice is known as "rate pancaking." It is much like having to negotiate and pay a new postage rate in each state for a package being shipped from Santa Fe to Chicago, or pay a tariff every time goods cross a national border. This pancaking has the effect of a trade barrier, making it harder to sell renewable energy produced in New Mexico to customers in other states. A mechanism to avoid pancaking currently exists through WestConnect, but is limited in scope to some wholesale transactions and does not address regional transmission planning. Wholesale electricity trade between New Mexico and other states, and the potential market for renewable power produced in New Mexico, could be expanded if existing mechanisms were strengthened, or new mechanisms we created, to create a more seamless Southwestern power grid.

- PNM is scheduled to join the Western Energy Imbalance Market (EIM) in 2021. The EIM is a short-term spot market for electricity run by the California Independent System Operator (CAISO). Being part of the EIM enables PNM to buy and sell surplus electricity between New Mexico and California on a real-time basis. Being part of the EIM does not involve any coordination of planning or policy decisions with California or other utilities—just the opportunity to buy or sell surplus electricity economically. This can be beneficial to the integration of wind and solar power if utilities or independent power producers in California or New Mexico are able to sell excess wind and solar when needed, and to buy power on a real-time basis when wind and solar production is low. The EIM, however, is designed primarily to deal with temporary imbalances. It is not designed to move large amounts of power between balancing areas, or carry out regional transmission planning. Thus it seems unlikely to play a major role in helping New Mexico develop a robust renewable energy sector. PNM also plans to participate in the Extended Day-Ahead Market (EDAM), which may facilitate regular scheduled purchases and sales of electric power in and out of California.

- Historically, New Mexico utilities have been part of regional power pools, which are multi-utility agreements that promote coordination in operations and planning of the grid.[23] Power pools were designed to allow for regional resource sharing and joint planning of the transmission grid, in order to lower costs and increase reliability. The Southwest Reserve Sharing Group can be seen as a special kind of pooling arrangement, but one with a limited mission that does not include many of the traditional power pool functions.

Evidence suggests that existing mechanisms for regional interaction are not robust enough to move larger amounts of renewable power from areas with surplus generation to areas with high demand. Nor do they currently help design and build a regional transmission network that would help New Mexico meet the goals of the ETA while creating new economic opportunities for exporting wind and solar power.

New Mexico could move beyond existing mechanisms to become part of a more sustainable regional power grid. Many utilities in the U.S., as described in Box 3, have integrated their transmission systems into Regional Transmission Organizations (RTOs), known in some parts of the country as Independent System Operators (ISOs). RTOs achieve a very high level of integration across utility systems (and states, in some circumstances) in transmission planning, operations, and the trade of electricity across utility service areas. Notably, they do away with the rate pancaking that is currently a feature of interstate electricity trade in much of the West. RTOs also serve as a single Balancing Area Authority covering wide swaths of the U.S. power grid. Southwest Public

[23] Power Pooling in the Western Region, FERC Technical Report 0054, February 1981.

Service (which serves about 25% of New Mexico's electricity demand) belongs to one of these RTOs, the Southwest Power Pool, but most New Mexico utilities do not belong to any RTO. The only active RTO in the Western Interconnect is the California ISO, which runs the EIM. Other multi-state RTOs in the West have been discussed, but none are currently active.

Box 3: What is a Regional Transmission Organization?

Regional Transmission Organizations (RTOs) and their close cousins Independent System Operators (ISOs) were first formed over two decades ago as part of a broader effort of industrial and regulatory reform in the North American power grid. Both Canada and the United States have these entities, although the term Regional Transmission Organization refers to a kind of Independent System Operator that is regulated by the U.S. Federal Energy Regulatory Commission (FERC) and performs an array of very specific functions. Many ISOs perform similar functions as RTOs, but are not called RTOs by virtue of their specific practices or being outside of the FERC's jurisdiction (as is the case with Canadian ISOs as well as the Electric Reliability Council of Texas, or ERCOT).

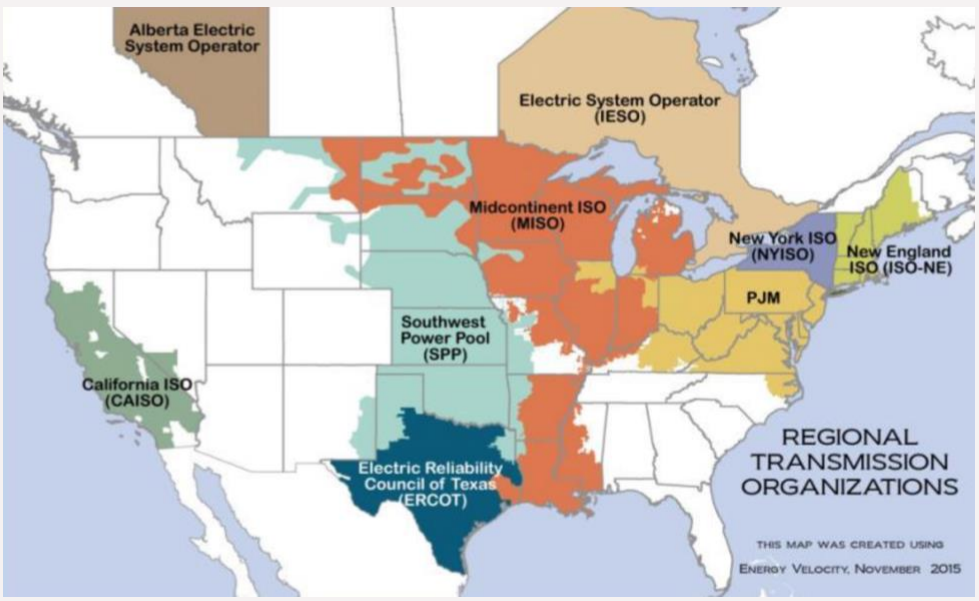

Figure 3: Regional Transmission Organizations and Independent System Operators in North America. Source: Federal Energy Regulatory Commission

RTOs and ISOs currently cover roughly half of U.S. states and around two-thirds of all electricity consumed in the U.S., as shown in Figure 3. Much of the Midwest and Eastern U.S. is served by RTOs or ISOs, with less prevalence in the Southeast and West. While all RTOs and ISOs have some functions and practices in common, such as integrated transmission planning across multiple utilities and keeping the grid within their footprints reliable in real-time, RTOs are not identical cookie-cutter organizations. Some RTOs, notably in the Eastern U.S. and in Texas, have embraced market-driven solutions for grid investment and operations. Other RTOs operate their grids as a single system but have left some generation planning decisions in the hands of utilities and their state regulators. The Southwest Power Pool, which serves roughly 25% of electricity demand in New Mexico, is an example of an RTO that has not fully embraced markets but still takes a regional approach (not a state-by-state or utility-by-utility approach) to transmission planning and operations.

Achieving greater regional coordination in transmission, even if only in the Southwest, can benefit New Mexico in multiple ways as it moves towards carbon-free electricity under the Energy Transition Act. Based on current technologies and capabilities, New Mexico faces an engineering cost tradeoff between having an entirely self-sufficient decarbonized power grid (requiring more storage and possibly a higher risk of service interruptions) vs. a regional grid in coordination with surrounding states.

The first reason greater coordination would benefit New Mexico is the additional redundancy afforded by a highly interconnected transmission grid, and the cost advantages that can come from regional transmission planning. This maximizes the ability of the transmission network to move electricity from the lowest-cost locations—or the best regional renewable resources—to the areas of highest demand. Regional coordination makes it easier to plan the transmission network for these kinds of long-distance sales, enabling more interstate transmission in the region. The importance of transmission for the economic development of renewable energy resources is best illustrated by Texas, which instituted a highly successful program for incentivizing new transmission specifically to facilitate large-scale wind energy.[24]

Given the long timescales involved in permitting and constructing new transmission, it would be better to get out ahead on transmission investments rather than waiting until the system is congested, i.e., with many transmission lines operating close to full capacity. An assurance of sufficient transmission capacity would build investor confidence and speed deployment of variable renewable energy.

A second and related reason that regional coordination can reduce costs is a geographic portfolio effect that reduces the risk of low-output events from weather-dependent renewable power supplies such as wind and solar. The larger the geographic area over which renewable power supplies can be integrated, the lower the variability of those supplies will be, as illustrated in Figure 4. Despite having excellent wind and solar resources, in meteorological terms New Mexico is relatively small: or to put it differently, weather patterns are relatively large, stretching across much of the state. Therefore, periods of relatively low sun or wind are likely to affect wind and solar installations simultaneously across large portions of the state. By interconnecting renewable resources across larger areas (such as the entire Western U.S. or even a multi-state area in the Southwest) the likelihood of low-production events can be substantially reduced (though not eliminated).[25] This reduces the cost of storage or other supplementary resources needed to achieve a high level of renewables penetration, an example of which is shown in Figure 5.

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[24] This program, known as the Competitive Renewable Energy Zone (CREZ) program, was a set of transmission projects authorized by the Public Utility Commission of Texas to connect areas with high renewable resource potential in West Texas to major state load centers. See Reid Dorsey-Palmateer, "Transmission costs and the value of wind generation for the CREZ project," Energy Policy 138 (2020). The Midcontinent Independent System Operator is an example of a multi-state Regional Transmission Organization that has been able to integrate renewables interconnection into its transmission planning processes. See Stafford, Benjamin A., and Elizabeth J. Wilson, "Winds of change in energy systems: Policy implementation, technology deployment, and regional transmission organizations." Energy Research & Social Science 21 (2016).

[25] The effects of rare low-output or zero-output events for wind and solar power in different contexts are analyzed in Ziegler, M.S., et al. "Storage requirements and costs of shaping renewable energy toward grid decarbonization." Joule 3.9 (2019)

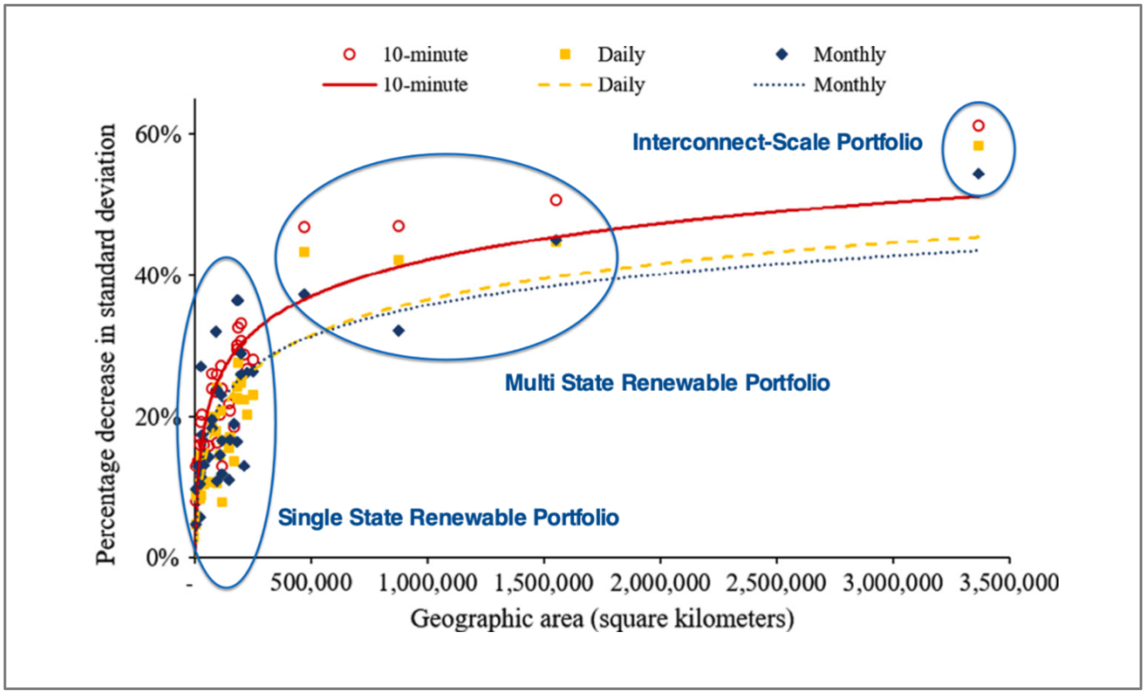

Figure 4: Regional interconnection of wind and solar resources can reduce output variability by as much as 60%. The figure shows variability of simulated wind energy portfolios over three different time scales, and for different levels of regional interconnection. The term “interconnect”refers to one of the two large sub-continental grids in North America. Source: M. Shahriari and S. Blumsack, “Scaling of Wind Energy Variabilty Over Space and Time,” Applied Energy 195 (2017).

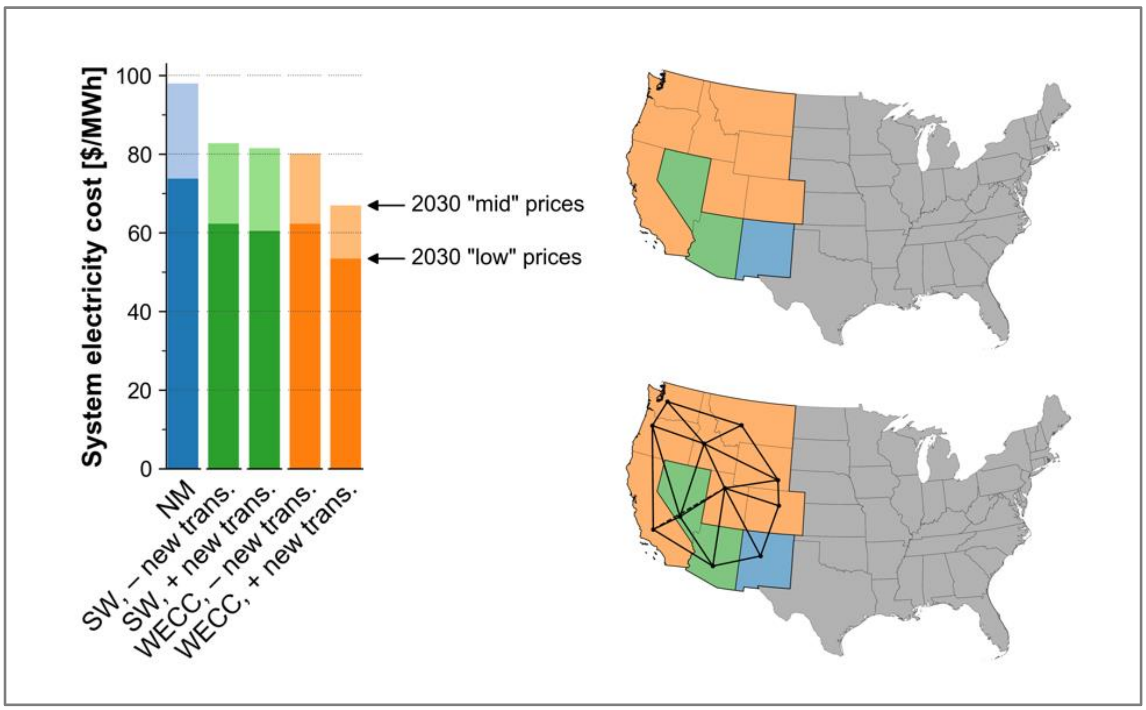

Figure 5: Modeled system electricity costs with 100% renewables and energy storage can decline with greater regional transmission integration. The figure compares the modeled costs (using a system planning model developed at MIT by Patrick Brown and presented at the Santa Fe workshop) for New Mexico alone, a three-state regional grid organization in the Southwest, and the entire Western Interconnect.

A third advantage for New Mexico of regional coordination is a potential economic development benefit for renewable energy investment in the state. With a small population and little heavy industry, New Mexico's own needs for energy are small. But its wind and solar resource potential is vast, particularly wind in the Eastern part of the state and solar throughout the state. Development of these energy resources has been hampered by a lack of transmission capacity into Arizona and Nevada, where the large Southwestern demand centers are located. While New Mexico's Renewable Energy Transmission Authority (RETA) can plan and build transmission lines, it can only work within New Mexico's state borders, making it difficult to coordinate with surrounding states on transmission infrastructure that would help export surplus renewable energy. Regional coordination in transmission planning has a potential value proposition in facilitating purchases of New Mexico renewable electricity by out-of-state utilities facing high demand and their own clean energy goals.

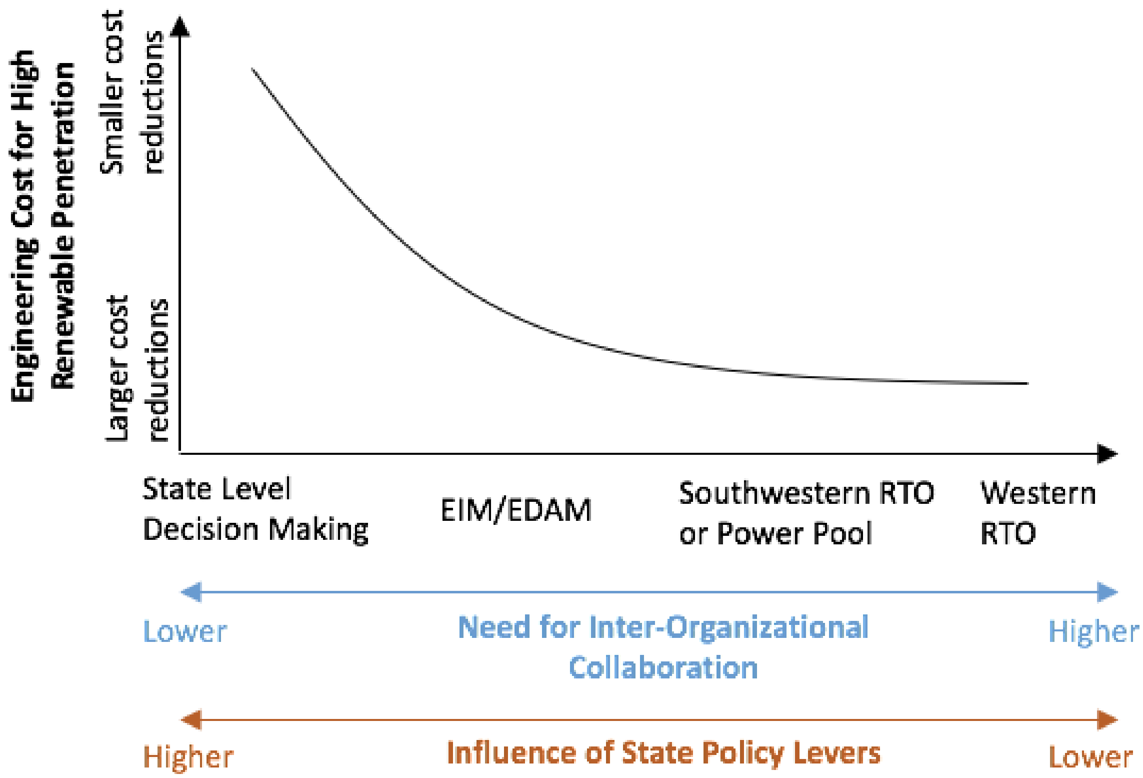

Figure 6: Greater levels of regional grid integration can achieve greater cost reductions, but also require more inter-organizational collaboration.

In addition to coordinating transmission planning and investment, regional grid organization like an RTO would facilitate interstate exchanges through open access to its transmission area and running markets for electricity. With such an entity in the Western power grid, New Mexico could sell energy services to neighboring states, and buy renewable energy from them through a centralized exchange during rare weather events when our output is low. This would make it easier and less costly for New Mexico to balance variability in the output of renewables. Since RTOs operate as their own large Balancing Authorities, a multi-state or Western RTO specifically could also improve the dynamic stability of the grid in New Mexico.

Achieving this coordination, whether through an RTO or another mechanism, holds great potential for reducing costs and improving reliability but requires a substantial level of inter-organizational collaboration among states, utilities, and other entities as shown in Figure 6. All states in an RTO and their utilities would need to agree on a common framework for governance and sometimes-contentious issues such as cost allocation for transmission investments. These can be difficult negotiations anywhere, but particularly in the West with its diversity of state policy goals and preferences, as well as the enduring twenty-year legacy of California's energy crisis.

Building an RTO spanning the Western grid would be a multi-year process, involving entities with competing policy objectives. In order for Western regional coordination to become a relevant factor for implementation of New Mexico's clean energy goals, serious discussions about the scale of a Western RTO would need to begin soon. New Mexico is already part of some of these discussions with its planned participation in the EIM. Economic programs like the EIM can help to build the market and operational platforms that would be needed for an RTO to evolve. They can also be relatively quick to implement and have shown themselves to be a successful mechanism for getting Western states to work together on energy issues—precisely the kind of collaboration needed to make regionalization a success.[26] However, while the EIM and EDAM are appealing in the near term, the efficiency gains they offer New Mexico for achieving targets under the Energy Transition Act are significantly less than what could be obtained from an RTO, and it is important not to think of them as substitutes for an RTO.

Greater regional coordination through an RTO does have the potential to impact state-level planning and rate-making authority, depending on the scope of the RTO's activities and the role of the state in RTO governance. Transmission planning and cost allocation would be determined at the RTO level rather than at the state level (although many transmission costs are determined currently by the Federal Energy Regulatory Commission). Generation rates paid by New Mexico ratepayers may be influenced by market rules developed within the RTO rather than on the cost basis that New Mexicans currently pay. As more independent power producers make investments in renewable electricity to serve New Mexico and the region, the pricing structure in the RTO market is likely to become more important in influencing New Mexico's generation rates. Some RTOs, particularly those in the Midwest, have mechanisms for states to be active participants in RTO decisions. Other RTOs, like those in the Northeastern U.S., have a less formal role for states to play (and those states have embraced deregulation in electricity much more aggressively than has New Mexico).[27] But New Mexico would need to weigh the efficiency gains and likely reduced costs

[26] Many of the keys to the successful design and implementation of the EIM are discussed in S. Lenhart, et al. "Electricity governance and the Western energy imbalance market in the United States: The necessity of interorganizational collaboration." Energy Research & Social Science 19 (2016).

[27] The relationships between the states and RTOs, with some implications for consumer costs, are discussed further in T. Kavulla, "Problems in electricity market governance: an assessment," R Street Policy Study No. 180 (2019), available at https://www.rstreet.org/wp-content/uploads/2019/08/FINAL-RSTREET180.pdf.

of meeting clean energy goals against the potential shift of some influence over electric rates to regional forces.

We note that while forming or joining an RTO is likely the best way to use regional coordination to the benefit of New Mexico ratepayers and the economy, it is not the only mechanism available. An alternative mechanism for coordination that New Mexico might investigate would be to build on existing agreements such as the Southwest Reserve Sharing Group or WestConnect to build a tighter power pool across the Southwest Region without going all the way to joining a full-blown RTO. For instance, Figure 5 suggests that cost savings from a tri-state power pool consisting of New Mexico, Arizona and Nevada would be significant compared to New Mexico trying to meet its clean energy goals alone.[28] Achieving these cost benefits would probably not require a broader Regional Transmission Organization including California and other Western states.

[28] Figure 5 does not include a portion of Southeastern California served by the Imperial Irrigation District (IID), but IID has been a part of resource-sharing arrangements with Southwestern utilities in the past and is not jurisdictional to the California Public Utilities Commission

6. Flexible demand and electrification

Strategy: Develop regulatory mechanisms that incentivize utilities to deploy large-scale flexible demand programs in concert with growing renewable energy integration, energy storage, and electrification programs. Incentivize in-state innovation to identify and harness flexible demand, for example through predictive models and new software.

Another approach to addressing the variability of renewables while ensuring stability is enabling devices that use large amounts of electricity to shift their demand in response to changing grid or market conditions. Flexible electricity demand (also known as demand response, demand side management, or load control) from devices like pool pumps, water heaters, heat pumps, and electric vehicles, can collectively serve as a significant balancing resource for grid operators without materially affecting customers. Leveraging the inherent flexibility of common end-use energy devices in homes and other buildings can reduce peak usage and lower electricity costs while simultaneously allowing the grid to more easily match supply and demand—without customers experiencing a loss in overall service quality.

When these programs are well designed, they can provide larger amounts of flexibility at lower overall costs, with many of the benefits accruing to electricity customers. With our current energy mix, programs lower costs because they allow electricity demand to be spread more evenly throughout the day, reducing the high-cost power generation capacity that must be kept in reserve to meet peak demands. As penetration of renewable resources grows, these programs can similarly lower costs by shifting electricity demand to periods when solar and wind resources are plentiful, matching the variable energy supply to demand and reducing the need to curtail excess energy production.

Flexible demand programs become particularly important when considering the enormous amount of energy consumption that will need to move from fossil fuels to electric energy in order to achieve large-scale decarbonization. The electrification of energy end uses that currently run on fossil fuels, such as water heating, space heating, and transportation, has enormous potential benefits by shifting energy demand to lower-carbon systems. However, there is not enough transmission, distribution and generation capacity in the existing electric power grid to allow these new electric appliances to operate whenever they want to. The good news is that most of these new systems can be made flexible, dramatically reducing the cost of supplying these new loads.

It doesn't matter exactly when a water heater or a building heating and cooling system is run, as long as building or device temperatures stay within an acceptable range. Similarly, electric vehicles can draw power any time they are parked and charging, as long as they are sufficiently charged for their next use, and strategically placed chargers can offer significant benefits.[29] Many other energy devices, such as pool pumps, irrigation systems, refrigeration systems are similarly flexible. This flexibility is designed to let grid operators and consumers shift demand to times when renewable energy is plentiful (Figure 7)

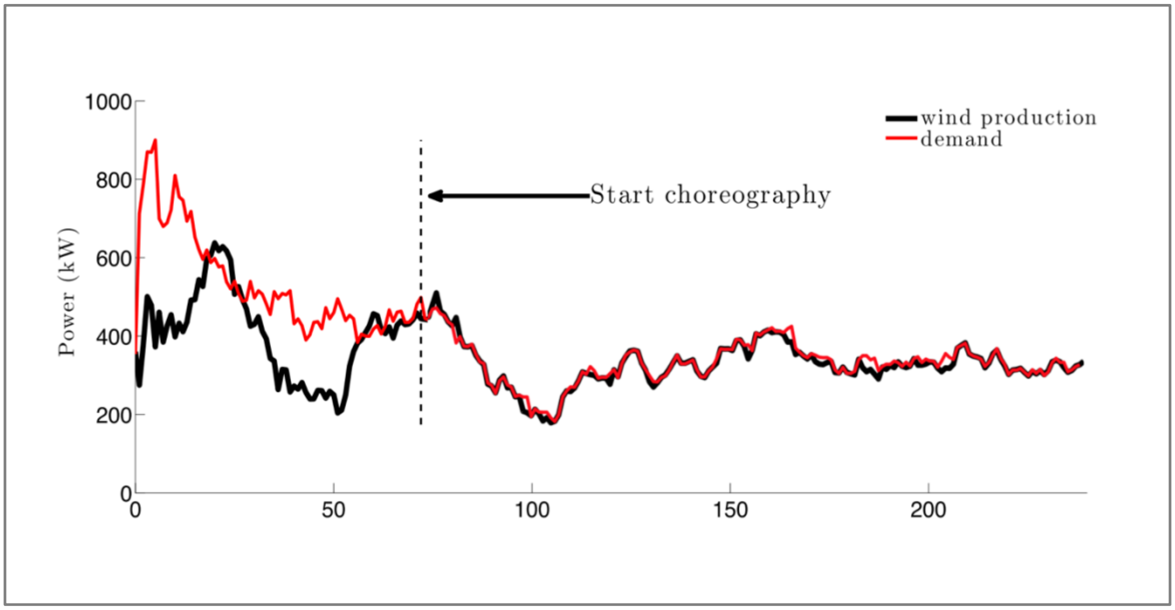

Figure 7: Some end-use energy devices can be programmed to track renewable energy production or other signals from the grid in real time, without any inconvenience to customers. The picture above shows electric water heaters tracking (simulated) wind energy production, shaping demand so that it matches supply in real time. The data underlying this figure was generated from the model of Almassalkhi, Mads, Jeff Frolik, and Paul Hines. "Packetized energy management: asynchronous and anonymous coordination of thermostatically controlled loads." *2017 American Control Conference (ACC)*. IEEE, 2017.

Conventional demand response programs are, in fact, quite common across the US and around the world. PNM has a conventional "direct load control" program that shuts off thousands of air conditioning systems during peak load periods. However, these legacy programs can have significant negative impacts on customer comfort, creating pushback that leads utilities to avoid using them and slowing adoption.

In contrast, modern programs that use smart devices like smart thermostats and smart EV charging stations can simultaneously provide a wider range of services to grid operators (e.g., by actively shaping load to the availability of renewables, rather than just shutting off load during peak periods) while having little to no impact on customer comfort or quality of service. These modern programs can enable devices to respond dynamically, instantaneously, and automatically to the

[29] Needell, Trancik, "Strategies for beneficial electric vehicle charging to reduce peak electricity demand and store solar energy", in review; Wei, Needell, Ramakrishnan, Trancik, "Personal vehicle electrification and charging solutions defined by high-energy days", in review.

availability of energy on the grid. This fast response makes it easier to handle the variability of solar and wind, and with the right software systems enabled can improve grid stability by allowing operators to shed or deploy these demands to balance out shocks to the grid.

Note that this type of dynamic demand management is far more effective than traditional time-of-use (TOU) electric rates that use differentiated pricing to incentivize customers to use more or less electricity during certain times of the day. The availability of renewable energy is only partly tied to predictable daily cycles, and TOU rates typically require the customer to make conscious decisions about when to draw power. Modern demand response programs can be far more responsive to changing real-time conditions.

There are several key policy initiatives that are important to enabling this type of demand response. The first is for the PRC to clearly recognize that flexible demand can produce substantial value by reducing the costs associated with variability in wind and solar and reducing the need to build new transmission, distribution, and generation infrastructure. The PRC could clearly articulate that utilities in New Mexico should invest in these technologies when they meet appropriate cost effectiveness tests, allow them to recover their costs, and enable utilities to consider flexible demand in their planning and investment processes.

The second key initiative is to encourage utilities to adopt rate structures that facilitate the adoption of flexible demand technologies. Simple time of use rates do not enable the types of real-time flexibility that are needed to incentivize behind-the-meter technologies that can adapt to changing grid conditions in real time. As New Mexico's grid becomes more renewable-based, its costs will be dominated by fixed capital costs. Marginal fuel costs will become less and less important, making traditional dynamic pricing rate structures (with hourly or sub-hourly pricing) increasingly incapable of incentivizing needed flexibility. Instead, subscription rate structures that give customers reduced rates for adopting this technology could produce significant benefits for all ratepayers.[30]

[30] H. Lo, et al, "Electricity rates for the zero marginal cost grid," Electricity Journal 32 (2019). In the Southwest region, Tuscon Electric Power has begun to experiment with subscription rate design. See L Huber and R. Bachmeier, "What Netflix and Amazon pricing tell us about rate design's future," Public Utility Fortnightly (2018).

7. Soft cost innovations and reducing barriers to entry

Strategy: Soft cost innovation represents an opportunity for New Mexico to drive down the cost of solar and wind power, achieve better grid management with electrified transportation and heating, and reduce the costs of electric vehicle charging, among other examples.

Overall costs of a technology can often be divided into two categories: hard and soft. Hard costs typically result from purchasing hardware, including for example solar panels and wind turbines and the various electric devices required to interconnect these technologies with a broader electricity grid. Hardware costs of renewable energy technologies have fallen dramatically and continue to fall. [31,32] As these "hard costs" have fallen an increasing fraction of these systems' overall costs come from a combination of labor and supporting activities such as design, permitting, installation, inspection, and interconnections, as well as sales and marketing costs. These activities are sometimes referred to as the "soft costs" of deployment and interconnection.

New Mexico alone may not be able to accelerate the pace of cost declines in the hardware for carbon-free energy systems, which is sold in globally-integrated markets. These rapid declines are taking place because of aggregate research and development and global demand. But this does not mean that New Mexico cannot be an innovation leader in other aspects of carbon-free energy technology.

For the total cost of wind and solar technologies to continue declining as quickly as they have over the last two decades, we need to encourage soft cost reduction,[33] and new approaches to soft cost

[31] Kavlak, McNerney, Trancik, "Evaluating the causes of cost reduction in photovoltaic modules," Energy Policy 123 (2018) 700–710.

[32] Ziegler, M. S.; Trancik, J. E. Re-Examining Rates of Lithium-Ion Battery Technology Improvement and Cost Decline. arXiv:2007.13920 [physics] 2020

innovation[34]. States and municipalities can play an important role in reducing soft costs, so that the total cost of renewable energy can continue to decrease within their jurisdictions. New Mexico can be a testbed for soft cost innovation.

Soft cost innovation is especially relevant to distributed generation, in particular to rooftop and community solar. While rooftop solar has high labor costs per unit of energy compared to utility-scale solar, it has played a valuable role in building a skilled workforce, encouraging technological innovation through early adoption, strengthening the grid downstream from the substation, and creating demand for new products (e.g. roofing products with integrated photovoltaic panels).

Possible innovations include streamlining permitting, encouraging standardization, and including solar installation routinely as part of new construction or roof replacement. The following is a non-exhaustive list of specific action items for the State of New Mexico, the Public Regulation Commission (PRC), and local jurisdictions.

- Across New Mexico, local jurisdictions currently use three different versions of the National Electrical Code (2014, 2017, and 2020). Using the 2020 code statewide, and providing for automatic statewide updates, would reduce design and permitting costs, and ensure that both companies and permitting authorities stay up to date. We note that New Mexico's 2019 Climate Strategy already calls for updating building codes statewide.

- The interconnection manual that PNM uses to determine if a proposed rooftop project can connect to the grid has not been updated since 2008. Some of its policies are outdated and counterproductive in the context of current technology. For instance, it counts behind-the-meter batteries like the Tesla Powerwall towards possible backfeed into the system, even though they are not physically connected to the grid. A practice by the PRC of regularly updating this manual would ensure that interconnection practices are consistent with the current state of technology.

- The City of Las Cruces allows virtual inspections of rooftop solar projects. This innovative option should be encouraged in other jurisdictions.

- Smart metering and other edge-of-grid instrumentation should be encouraged, and allowed as part of utilities' ratebases. With the information that this would provide, utilities could then be

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[33] K. Ardani, et al., "Cost-Reduction Roadmap for Residential Solar Photovoltaics (PV), 2017–2030", National Renewable Energy Laboratory, available at https://www.nrel.gov/docs/fy18osti/70748.pdf; B. Brooks, "Expedited Permit Process for PV Systems: A Standardized Process for the Review of Small-Scale PV Systems," Solar America Board for Codes and Standards (2012), available at http://www.solarabcs.org/about/publications/reports/expedited-permit/pdfs/Expermitprocess.pdf.

[34] Klemun, Kavlak, McNerney, Trancik, "Solar energy cost trends reveal mechanisms of hardware and soft technology evolution", in review; Eash-Gates*, Klemun* (*equal contribution), Kavlak, McNerney, Buongiorno, Trancik, "Sources of cost overrun in nuclear power plant construction call for a new approach to engineering design", in press, Joule.

incentivized or required to allow a greater flow of distributed power into the system. For instance, PNM currently restricts distributed solar to a maximum of 15% on a feeder line. This constraint has resulted in downsizing some rooftop projects to less than the customer's load.

- Cities could consider ordinances that require or incentivize solar installation as a routine part of new construction or roof replacement, and allow expedited permitting processes for systems that meet standardized requirements.

In addition to reducing the soft costs of renewable energy, regulators as well as utilities should reduce barriers to entry of distributed generation whenever possible, and improve "edge-of-grid" technologies that allow distributed generation and storage, including experimental microgrids, to be part of a two-way grid where customers can contribute or withdraw power as needed. Microgrids could be especially useful for improving electricity reliability for more isolated communities throughout New Mexico. Utilities should be compensated for the costs of maintaining the grid, through billing structures where customers pay for their capacity costs as well as the marginal cost of their commodity usage. Careful consideration will be needed in order to design rate structures that make appropriate tradeoffs between complexity and the need for customers to have clear incentives for reducing system capacity costs. This experimentation should be targeted at reducing the soft costs of integrating these new technologies.

8. Anticipate technological change

Courtesy Santa Fe Community College.

Strategy: Technologies improve over time and with effort. The costs of carbon-free technologies such as solar energy and lithium-ion batteries have fallen by more than 95% in the past four decades. Validated models exist to forecast likely ranges of future cost reductions and can be used to inform regulatory decisions that deliver low-cost and low-carbon energy services to ratepayers. Making the assumption that technology costs will remain unchanged over time would be counter to available evidence and would likely have adverse effects on ratepayers, by failing to take advantage of technological improvements and financial savings.

Furthermore, any project for new capacity or replacement power should be evaluated according to whether it is consistent with the Energy Transition Act and other state policies, to identify and avoid projects that make it more difficult for the state to meet its decarbonization goals. These steps can help the state avoid projects that require additional fossil fuel infrastructure and create stranded assets that would need to be decommissioned before the end of their operational lifetime. This will help the state avoid needless political and economic conflict and perverse incentives that complicate the energy transition, and avoid increasing ratepayer costs.

Renewable energy and storage continue to become cheaper and more efficient: just as with computers, a system built two years from now will cost less, and be more powerful, than a system built today. The cost of solar photovoltaic panels has dropped by more than 99% since 1980, and dropped by a factor of 10 over the past decade alone. The cost of electricity from wind power has fallen by 70% in the past decade as turbines have become cheaper and more efficient, capturing more power from a given site. The cost per kilowatt hour (kWh) of lithium-ion cells that compose many battery storage systems has fallen about 97% since their introduction in 1991 and approximately halved over the past decade. These systems can quickly provide power to the grid, and as costs have fallen their durations have continued to increase.

Many locations have seen dramatic decreases in the total costs for combined solar, wind, and battery systems. A number of solar PV contracts have recently been finalized at under 2 cents per kWh in locations that have good solar resources, as New Mexico does.[35] And the costs of solar plus storage systems have recently come in at around 8 cents per kWh or lower, which is competitive with long-term contracts for natural gas generation systems. Storage plant prices will likely continue to decline in coming years.

These improvements come from a combination of research and development, manufacturing experience, and economies of scale. While the future is inherently uncertain, there is predictive power in past trends. Forecasting models can incorporate estimates of error in predictions that will allow regulators to make decisions that are conservative, risk-averse, and prudent with respect to ratepayer savings.

As a result, whenever utilities or regulatory bodies such as the Public Regulation Commission (PRC) are considering scenarios involving renewable energy and storage, these likely improvements in cost and efficiency should be taken into account. They should be carefully estimated for each technology, alongside an error model that takes information from many technologies.[36] For instance, if batteries in a proposed storage system have a 10-year lifetime, planners and decision makers should keep in mind that their replacements will have lower cost and higher efficiency. Even if a system is being built this year, maintenance cycles may improve its efficiency in future years.

Conversely, decisions about conventional power plants using fossil fuels should be made with an assessment of whether they may have higher effective costs or shorter lifetimes than initially projected, if the state's decarbonization policies are to be met. It is technically feasible, though potentially politically difficult and, even more importantly, costly to New Mexico ratepayers, to decommission conventional power plants early if they turn out not to be needed as renewables, storage, and demand management improve. Similarly, a peaker plant designed to make up for variability in demand may turn out to be operated less often than projected, in which case it will have a lower capacity factor and less value to the system, and ultimately cost ratepayers more. Finally, while fossil fuel prices are currently very low, fuel prices may increase or show costly volatility due to demand and/or contraction in extractive industries, and society may impose a price on carbon emissions in order to meet binding climate policies.

“There is no reason to create potential stranded assets that disincentivize the transition away from fossil fuels when this transition is now largely predictable, based on the state's adopted policies, and supported by economic arguments.”

Since the costs of early decommissioning or lowered capacity factors will ultimately be borne by the ratepayers, these possibilities should be taken into account when calculating the levelized cost of energy (LCOE) resulting from these plants. In many cases, the best approach may simply be to delay, to see if (for instance) a natural gas peaker is actually required or whether renewables and storage suffice. (Recent experience in Australia suggests that large energy storage plants can be built in very short amounts of time if necessary. The 100 MW Hornsdale plant was built in less than

[35] Lawrence Berkeley National Laboratory, “Utility-Scale Solar: Empirical Trends in Project Technology, Cost, Performance, and PPA Pricing in the United States,” 2019 report available at https://emp.lbl.gov/sites/default/files/lbnl_utility_scale_solar_2019_edition_final.pdf

[36] Nagy, B., Farmer, J. D., Bui, Q. M., & Trancik, J. E. (2013). Statistical basis for predicting technological progress. PloS one, 8(2), e52669.

6 months.[37]) As with options pricing in the stock market, uncertainty about future value has a cost, and there is value in holding on to an option rather than executing it.

The cost of uncertainty can be reduced by avoiding commitments to long-lived infrastructure that uses fossil fuels. Whenever fossil fuel power generation is under consideration, the PRC should require that the future costs of complying with the ETA and other decarbonization policies are included in the cost estimate, and that expectations of cost improvements and uncertainties in future costs are taken into account. For natural gas-fired power plants, for instance, this includes the cost of early decommissioning, future conversion to burn hydrogen (if that capability is not part of its initial design and construction) and uncertainties in future fuel costs. There exist independent experts in New Mexico and elsewhere that can review all of these cost estimates, and they should be called upon to support the state's decarbonization plans. There is no reason to create potential stranded assets that disincentivize the transition away from fossil fuels when this transition is now largely predictable, based on the state's adopted policies, and supported by economic arguments.

[37] Hornsdale Power Reserve | South Australia’s Big Battery https://hornsdalepowerreserve.com.au/ (accessed Aug 26, 2020).

10. Conclusion

New Mexico is on a path to a carbon-free power grid and a low-carbon economy, supported by the Energy Transition Act, commitments from PNM and other utilities, plus advances in energy technology. There are challenges ahead to be sure, but the combination of global expertise and local knowledge that met at the Santa Fe Institute for the Paths to Deep Decarbonization workshop found that these challenges are also unique opportunities for innovation, job creation, and community engagement in New Mexico. In particular, the need to rebuild state and local economies in the wake of Covid-19 has highlighted the opportunities for economic development that come with the energy transition.

Hardware costs for many of the key technologies underpinning a carbon-free power grid—wind, solar and energy storage—have fallen substantially. The discussion at the workshop, our many follow-on conversations with experts in New Mexico, and this report focus not on the costs of these global commodities, but on steps that decision-makers in New Mexico can take to use decarbonization as a tool to rebuild economic growth, maintain grid reliability, and reduce energy costs while minimizing emissions and improving environmental quality. In this report, we have outlined seven key strategies that can jointly meet these goals. These complementary strategies interlock and support each other, and can be grouped into three broad areas:

- **Thinking beyond the power grid** to promote greater innovation and economic potential, by recognizing synergies between a cleaner grid, opportunities to decarbonize other areas of the economy, and create jobs through electrification, efficiency, and attracting “green shoring” industries;

- **Regional coordination** to reduce the costs and increase the economic gains of decarbonization in New Mexico’s power grid and beyond, exporting wind and solar power to load centers across the Southwest; and

- **Innovation in regulation** of utilities and other energy companies to harness the potential of renewable energy, storage, and flexible demand, and to contribute to lower costs and job creation through “soft cost” reductions for renewable power.

At the time this paper was being finalized, the New Mexico Public Regulation Commission approved a plan for replacing the electricity provided by the San Juan Generating Station entirely with investments in renewable power and energy storage, making a significant capital investment in the region. This is an encouraging first step, and should be part of a broader and longer process of collaboration between state and local decision-makers, with input from the research community as needed, in order to position New Mexico to harness the potential of technological change. We look forward to acting as a resource to New Mexico policymakers to facilitate this transition.