NET ZERO WORLD INITIATIVE

Accelerating Global Energy System Decarbonization

Fossil Fuel Transitions Framework: Case studies of the decision-making process for energy and economic development pathways

Hyekyung Clarisse Kim[1], Jingjing Zhang[2], Joshua Sperling[3], Erik Shuster[4], Nicolas Stauff[1], Anthony Armaly[4], William Jenson[5], Levi M. Larsen[5], Riccardo Bracho[3], Rebecca Efroymson[6], Julie Doherty[1], Naim Dargouth[2], Keith Kline[6], Nan Zhou[2]

1. Argonne National Laboratory
2. Lawrence Berkeley National Laboratory
3. National Renewable Energy Laboratory
4. National Energy Technology Laboratory
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1. Introduction

The Net Zero World Initiative leverages expertise across U.S. government agencies and the U.S. Department of Energy's (DOE) national laboratories, in partnership with other governments andphilanthropies, to accelerate the decarbonization of global energy systems. This whole-of-government approach supports countries committed to raising their climate ambitions by co-creating and implementing highly tailored, actionable technical and investment strategies that put just and sustainable net-zero solutions within reach. The Net Zero World Initiative enables country partners to harness the convening power and technical expertise of U.S. and international industry, think tanks, and technical institutions. The initiative works with the governments of eight partner countries—Argentina, Chile, Egypt, Indonesia, Nigeria, Singapore, Thailand, and Ukraine—to pursue the following objectives:

- Develop and support ambitious technical, market, and investment strategies for clean energy transformation. The Net Zero World Initiative collaborates with partners to develop country-specific technical and investment plans detailing the crosscutting planning and deployment strategies needed at the national, regional, and local levels.
- Deliver holistic support for immediate and sustained transformative projects that maximize overall regional impact. The Net Zero World Initiative supports the development of cross-sector project pipelines and infrastructure modernization plans for partnering with the private sector and developing robust research, development, demonstration, and deployment partnerships to quickly advance technologies from research to implementation.
- Foster exchange among U.S. leaders and countries to support peer-to-peer learning and confidence building. The Net Zero World Initiative supports exchanges among U.S. states and cities, business leaders, and across countries to inform technical and investment plans and key design and implementation measures, and to enable peer-to-peer learning, tailored replication of successes, and confidence building. The initiative also provides implementation support for workforce development programs, emphasizing in particular the inclusion of underrepresented groups.

The Net Zero World Initiative and its partner countries have identified Just Energy Transitions[1] as a priority area for cross-sectoral collaboration. Specifically, ensuring sustainable and consistent support of communities affected by the decline of fossil fuels has emerged as a top priority. At the first Net Zero World ministerial meeting held in Seattle, Washington on August 15, 2023, the Net Zero World multilaboratory team received requests from Net Zero World country delegations for decision making support to inform community fossil fuel transitions. As a first step, this analysis examines the decision-making processes of fossil fuel transitions in several communities across two countries: the United States and Chile. The goal is a framework that lifts out key decision-making criteria and learnings from communities that have undergone fossil fuel transitions to help guide those communities engaged in the early planning stages.

1. For definitions of Just Energy Transitions, see Chapter 2: Energy Justice and Equity: "Accelerating Decarbonization in the United States: Technology, Policy, and Societal Dimensions." 2023. National Academies.

1.1. Motivation and Objectives

With the global energy sector shifting away from fossil fuels, communities around the world are grappling with complex decisions on how to move toward new sources of energy and economic development in a just, resilient, and sustainable manner. In response to requests from country delegations participating in the Net Zero World Initiative, an analysis was conducted of the decision process and transition pathways for environmental remediation, economic recovery, and infrastructure repurposing in select communities in the United States and Chile.

The goal of this work is a practical decision framework that can be shared with various community types, with key insights tailored to guide strategies for communities navigating the energy transition. Chapters 2 through 7 of this report examine the planning, decision making processes, pathways, and outcomes for fossil fuel transitions in two different country contexts. These case studies can help inform the development of an interactive decision framework to guide transitions in energy-dependent communities. This is discussed in Chapter 9. The decision framework will look at fossil infrastructure repurposing, environmental remediation, and broader pathways toward economic diversification and job creation. The development of this framework will draw upon decision science, energy and climate justice literature, multiple stakeholder perspectives, and evidence-based insights from selected case studies. It should be noted that access to resources and financing for transitions remains unequal and every community is unique—as a result, transition pathway planning must be place-based and context-specific.

1.2. Fossil Fuel Transitions in the United States and Chile

The United States and Chile were chosen for initial focus in the case studies (1) as they provide an opportunity to highlight the unique intergovernmental coordination processes established in each country and (2) due to the availability of information on communities representing a variety of timelines, processes, and transition pathways. The case studies for the U.S. provide examples of transitions that are underway or completed, and the case of Tocopilla, Chile provides a look at the unique cross-ministry coordination and stakeholder engagement models developed by the Government of Chile, as well as peer learning opportunities with the Net Zero World Initiative. Both countries have established decarbonization targets, policies, and financing around fossil fuel transitions, including support of communities with planned coal power plant retirements. Some of these retirements occur due to economic or environmental reasons, while other retirements are planned in response to national or subnational government mandates.

In the United States, the coal industry has experienced steady declines due to the changing generation mix and economic considerations of operating aging infrastructure assets (ISO New England, n.d.) As shown in Figure 1, 112 gigawatts (GW) of coal-fired capacity have been retired since 2012 and an additional 76 GW are planned for retirement by 2040[2].

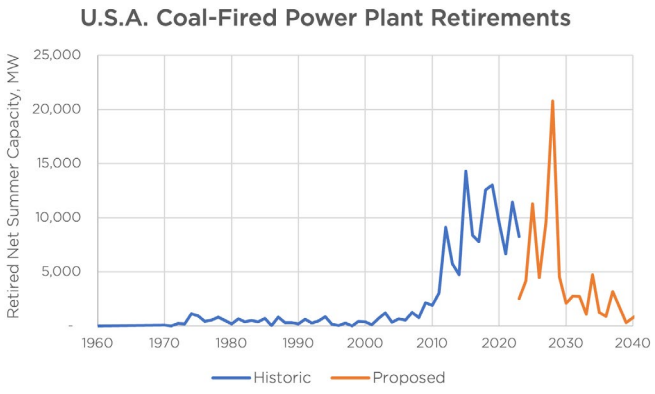

Figure 1: Historic and proposed retirements of coal-fired power generation assets.

2. U.S. power plant owners can retire plants at their discretion, but there are subtleties depending on the type of market structure. Regulated or vertically integrated markets owners are relatively free to retire a unit based upon reliability demands and any additional constraints that may be included in a generator's permission to operate (which is granted by a state commission). For plants in wholesale markets, the owner must inform its market so that the unit being proposed for retirement is de-listed from any current or future auctions. All de-list bids are subject to a reliability review by the Independent System Operator (ISO). If the ISO concludes that the unit submitting the de-list bid is needed for reliability purposes, the plant must remain operational and provide competitive generation to the system. (National Association of Clean Air Agencies 2015)

In January 2021, President Biden signed Executive Order 14008 establishing an interagency working group (IWG)—a unique coordination mechanism across 11 federal agencies and the Appalachian Regional Commission—to identify communities most affected by coal mine and power plant closures and mechanisms for supporting these communities through grant funding and technical resources (White House 2021). The IWG identified 25 most urgent geographical areas along with immediate and long-term federal assistance and engagement actions, including (1) creation of quality jobs; (2) federal investment for economic revitalization; (3) prioritization of environmental remediation and pollution mitigation; (4) formalization of stakeholder engagement processes; and (5) adoption of a government-wide approach. This report examines the transitions of five fossil fuel-dependent communities across the United States.

In addition to U.S. communities, this report examines the case of Tocopilla, Chile as an example of interagency coordination, engagement, and decision-making processes that have developed in a different country context. In Chile, fossil fuel transitions are driven by government decarbonization goals targeting a 2050 net-zero economy (Ministry of Energy 2020c, Ministry of Energy 2021) and the government's commitment to phase out all coal-fired thermoelectric power plants by 2040 (Government of Chile 2021). In 2021, the 2050 Chilean Energy Policy Update was launched with different participatory instances and established that Chile is moving towards carbon neutrality by 2050 with an energy transition process. This energy transition is based on three major objectives towards a more sustainable energy sector. The first objective is based on taking leadership in confronting the global climate crisis in addition to fulfilling the country's commitments. The second objective is based on the conviction that the energy transition must occur in a way that improves the quality of life of all citizens. The third objective seeks to change the productive identity of the country by integrating clean energy technologies and measures into each process and activity of the Chilean economy. To this end, a commitment was made to develop a schedule for retirement or conversion of coal plants and introduction of specific measures to support electromobility. The Chilean government has since formalized cross-ministry, cross-sector coordination as part of its Just Energy Transition strategy. In 2021, the ministry published Part 1 of the Just Transition Strategy which identified 13 immediate commitments of the State and four pillars of local Just Transition planning, which are focused on: (1) worker employment and social welfare; (2) new investment and innovation opportunities for sustainable economic growth; (3) repurposing options that foster environmental and social well-being; and (4) participatory processes, intergovernmental coordination, and alignment of implementation actions with existing strategies.

1.3. Criteria for Community Selection

As a Net Zero World Initiative founding partner, Chile has collaborated with the initiative in multiple aspects of Just Energy Transitions and a sister city in the United States has been identified for peer learning and mutual support with the city of Tocopilla. The Tocopilla case was chosen for this analysis because it effectively highlights the overall coordination across multiple Chilean ministries with local stakeholders (vertical integration) and the cross-sector engagement and planning processes (horizontal integration) to meet decarbonization goals in an inclusive manner. This analysis also examines fossil fuel transitions of five communities in the United States chosen with consideration of five criteria:

1. A diversity of energy and non-energy pathways, including environmental remediation and economic diversification, is represented.
2. A diverse mix of urban and rural communities is represented.
3. Transition plans have been formalized and implementation is underway or has been completed.
4. The national or regional government has developed community engagement plans and processes for representation of a variety of stakeholders.
5. Data and case studies exist, and, in some cases, local contacts were available to validate and verify assumptions.

Across the United States, 25 fossil repurposing projects were evaluated for potential inclusion in this study. Of these, five communities were selected that represent a variety of plant closure timelines, community types, and redevelopment pathways. The community transitions analyzed below are at different stages with differing levels of information available for each case. In particular, the case study for Tocopilla (Chapter 7) benefited greatly from consultations with the Ministry of Energy of Chile. Details of the decision-making process for Centralia (Chapter 2) were derived from interviews with a Centralia Coal Transition Grant Board member and author of an in-depth study on the community's energy transition. The case study for St. Johns (Chapter 3) benefited from insights from the author of a key study, and the Kemmerer case study (Chapter 4) was reviewed by the leader of the Gateway for Accelerated Innovation in Nuclear program who has been working closely with all major stakeholders in the Kemmerer transition. For the other two case studies, Muskegon and St. Paul, information was gathered from publicly available material and existing studies, as it was not possible to locate a point of contact within the time allocated for this study. Key insights are gleaned that can be useful for countries that are starting to plan and navigate fossil fuel transitions.

2. Centralia, WA

The 1460 MW Centralia Steam Plant power plant is the last coal-fired plant in Washington State. The plant was built in 1972 in Lewis County and was a utility-owned power plant until it was purchased in 1999 by an independent merchant operator, TransAlta. The facility was a major economic driver in the community, with a coal mine and power plant that produced 10 million mtCO2e per year as the largest individual polluter in the state of Washington.

In 2009, with then Governor Christine Gregoire's issuance of the Executive Order for an Emissions Performance Standard, discussions began on closing Centralia's two coal boilers and the plant. While there were seven different lawsuits looming over violations and compliance with air pollution and emission requirements, the real tipping point towards transitions was a bill in the Washington State legislature that would have driven a plant closure date of 2015. The community reacted strongly and organized protests in the state capitol. In response, then Governor Gregoire gathered stakeholders to negotiate a transition timeline for the closure of the plant that worked for all stakeholders. The power plant is now slated for a two-stage closure, with one boiler closed in December 2020 and the rest of the plant scheduled for closure in December 2025 when 40% of the plant's remaining workforce would be at retirement age.

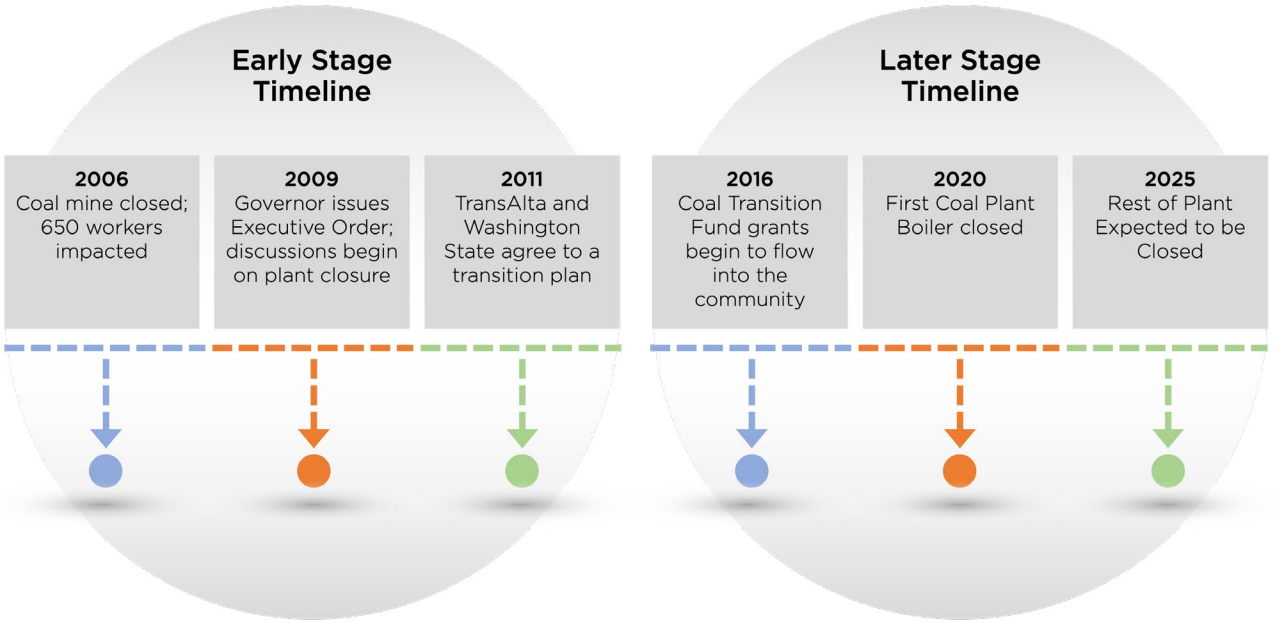

Figure 2: Timeline of Centralia coal mine and power plant closure. (Timeline is depicted as points but may represent actions taken over broader time ranges.)

2.1. Community Characteristics and Perspectives

Centralia is a city in Lewis County with a population of 18,629 as of 2021. It is located along a major interstate corridor midway between Seattle and Portland. Coal mining and the associated power plant have been a key part of Centralia's natural resource-based economy, along with other sectors that remain strong in timber, wood-product manufacturing, furniture manufacturing, and traditional farming. The education attainment level is less than the national average, with 19% of the population having attained a bachelor's degree compared to 35% for the United States in 2020.

Coming on the heels of the 2006 coal mine closure that cost the community 650 jobs, the introduction of a bill to close the power plant by 2015 had stirred significant debates. The Sierra Club and a coalition of faith-based and public health organizations had launched a campaign calling for the retirement of the TransAlta plant by 2015, while Centralia citizens placed billboards around town that read, "Sierra Club, leave our Centralia Power Plant Alone!" Governor Gregoire was faced with addressing the community's fears around further employment and revenue loss, environmental concerns from advocacy groups, and TransAlta's concerns regarding their future uncertainty. When Centralia invited the state government and Sierra Club for a visit to get to know the people who would be impacted by the closure, Governor Gregoire responded by gathering key stakeholders to invest in creating dialogue, understanding the local culture, and gathering community input to begin the process of brokering a deal.

At last, an agreement was reached among three key parties—the Governor's office, TransAlta, and public advocacy groups—for the staged plant closure by the end of 2025 and a deal was struck for TransAlta to provide $55M in transition funding to assist the community and region in adapting its local economy (Messenger and Partridge 2023). The agreement and subsequent legislation directed $30 million to be invested in economic development and energy efficiency in the Centralia region and $25 million for clean energy technology development in Centralia and more broadly in Washington state. According to a Centralia representative, "it really helped to have the money out there to invest in these new technologies and upgrade old technologies" (Bloomberg Philanthropies 2018).

2.2. Planning Process and Considerations for Pathway Development

A coal transition board consisting of eight members, mostly from the community, was created with the task of investing the transition funds. Initial decisions in the board formation included whether the investments would be part of a state-wide fund. The legislation and agreement with the governor determined that most of the funding should go directly to Lewis and South Thurston counties where the plant's workers reside, with the remainder invested in new clean energy technologies to support broader state environmental and economic goals. To maximize the funds' impact, the board agreed not to fund anything at 100% and set a goal of achieving 50% cost share to leverage private sector capital, government grants, or other community funding.

The transition pathways selected for funding focused on weatherization and energy efficiency, economic and community development, and energy technology projects. These decisions were built around four considerations:

Reduction of greenhouse gas emissions and local air pollution.

It was decided that the best way to reduce pollution and enable new investment and employment opportunities was to avoid fossil energy pathways (such as a gas-fired plant under consideration at the time) and invest in renewables and other new energy technologies. A $25 million Energy Technology Fund was established to seed energy technology projects including solar generation, electric vehicles and charging station installation, and energy upgrades to local businesses, schools, and the local college. Today, several companies are evaluating the site for renewable energy pilots, a green hydrogen plant, and fusion energy, and hydrogen-powered trucks are being deployed for reclamation work at the former coal mine. The hope is that these new opportunities will contribute to local employment requiring new kinds of expertise (Geraldo 2023).

Workforce transition through direct compensation, retraining, and education.

The second pillar focused on community members, particularly the workforce with power plant-related jobs. The board reserved $9 million to benefit the workers, of which $1 million was set aside for retraining and education and $8 million to serve as cash payouts to displaced workers upon plant closure. Upon iteration with the workers, the board expanded training and education benefits to all household members of affected workers. The funds have not been spent at the expected rate and the board is currently considering a college education fund for the children and grandchildren of displaced workers.

Energy bill reductions through community investments in energy efficiency and weatherization.

While the third pillar represented the smallest investment bucket—$10 million for weatherization, new energy efficiency projects, and improving energy efficiency (e.g., energy efficient heating, ventilation, and air conditioning installation)—it is the one where funds targeted immediate benefits to the communities and workforce who were facing challenges paying their energy bills. The investments funded a mix of activities to support the local utility in enhancing energy efficiency programs to reach more customers and included $1 million reserved specifically for low-income households. The remaining grants funded businesses and organizations in need of commercial building retrofits and energy efficiency upgrades.

Economic and community development to improve overall quality of life and attract new businesses.

The last pillar focused on expanding economic and community development. $11 million was directed toward improving overall quality of life and stimulating the economy. This included improvements to emergency response, living conditions, parks, and the natural habitat that would support people staying in the community. Significant education-oriented grants were provided to the local college and community foundations to develop workforce programs, as well as for strengthening general pre-college education. However, most of the funds were invested in creating opportunities for economic development, for example investing in sports facility upgrades to attract league tournaments to Centralia with additional revenue from visitors flowing into the community.

2.3. Outcomes and Key Lessons Learned

Recent research identified that Centralia's economic performance has improved since 2016 relative to another 'equal' county that did not implement the kind of investments and practices implemented in Centralia (Messenger and Partridge 2023). Since grant administration began in 2016, a causative relationship was established between the grants and new job creation (primarily in construction, commercial trucking, small businesses, and startup firms), population growth, and increased income levels (Messenger and Partridge 2023). In these recent studies, economic data analysis revealed that:

- Centralia grew its employment by twice the national average and incomes grew 50% faster than the national average after 20 years of near-zero job growth.
- Lewis County outperformed synthetic controls (constructed from weighted observed data from Washington counties similar to Lewis County where Centralia is located) by nearly 1.5% in 2017 in terms of job growth; personal income grew nearly 2% more.
- While both Lewis County and the control case lost jobs in 2020 due to the COVID-19 pandemic, Centralia lost 1% fewer jobs, and small business income outperformed expected trends by nearly $5 million. This led to more employees and income staying in Centralia.
- Economic development and energy projects via transition funds included construction which created local jobs; community and regional workforce development programs also have helped to retrain workers for new (and often higher paying) jobs.

In addition, there have been significant greenhouse gas emission reductions, land reclamation, and investments around low-carbon technologies, from energy efficient buildings to sustainable transportation. The social impacts have included stronger community relations, including with key businesses, and additional private finance attracted through grant funds as well as strengthened local-, regional-, and state-level cooperation on just transitions and green economy. The community recently applied for a government grant to develop the Tono Solar Farm, which would cover nine acres of reclaimed mining property and has the potential to become the largest solar energy project in Washington State. Although many positive trends have emerged, some challenges remain, and these have brought about further deliberations such as on education grant expansion.

While many lessons can be drawn from the Centralia case, the overarching one is the importance of creating circumstances that aim to maximize benefit for all major stakeholders. The initial deal endeavored to create a 'win-win' by meeting the state's decarbonization goals, addressing community development, and enabling the plant operator to benefit. Incorporating community concerns and revising legislation to reflect a longer closure timeline obviated the loss of workers' livelihoods and began to pave the path to community acceptance.

A second overarching lesson is the importance of having a vision for benefiting the community in the near- and the long-term. First, the capacity for community investments was multiplied by leveraging government funds and cost share from the private sector so that more dollars could directly benefit the community and region. A portion of these funds was applied toward producing immediate benefits through 'shovel-ready' jobs and lowered monthly energy bills. This, in turn, added to residents' disposable income and a created a source of additional spending within the local economy. At the same time, a strategy for long-term nurturing of the community's human and natural resources targeted quality of life improvements, investments in clean energy and labor-intensive industries, and expansion of education benefits to workers' families and future generations. The process was difficult but the deal ultimately enabled easier transitions for both the community and for TransAlta, which has maintained a presence in the local economy and recovered some investments it had made over the years.

3. St. Johns, Arizona

The Coronado Generating Station (CGS) in St. Johns, Arizona is operated by the Salt River Project (SRP) utility company. The CGS facility began operating in the late 1970s with two 410.9 megawatt (MW) coal-fired units (Global Energy Monitor 2023), and net summer generation for both units is 762 MW. SRP's 2035 Sustainability Goals Five-Year Action Plan outlines a schedule to reduce emissions through retirement of coal generating resources over the next 15 years (SRP, n.d.) Currently, coal for the CGS plant is transported by rail from Antelope Mine in Wyoming and Spring Creek Mine in Montana. Since the power plant does not rely on local coal for fuel, the plant closure's overall economic impact on the community is reduced. The 159 jobs provided by the plant are important to the small community.

The utility company's two-phase approach ensures plans are in place before the closure. Phase 1 is a near-term plan that will be implemented closely following plant closure. Initial findings presented to SRP suggested the most feasible technology options are battery storage, biomass, long duration energy storage (LDES), photovoltaic (PV) solar, and wind. Longer-term solutions considered in Phase 2 include hydrogen-fired generation, LDES, advanced nuclear, and natural gas as a bridge to low- or no-carbon generation.

3.1. Community Characteristics and Perspectives

Roughly half of the operating coal power plants in the United States are located in rural areas. The selection of CGS and Apache County for this study provides perspective regarding the coal-to-nuclear transition in one of these rural communities. Apache County is in the northeastern corner of Arizona, in the four corners region of Arizona, New Mexico, Utah, and Colorado. Nearly three-quarters of the population resides in rural areas. Most of the county encompasses the Navajo Nation and the Fort Apache Indian Reservation. St. Johns, the Apache County seat, is located in rural eastern Arizona and has a 2021 population estimate of 3,388 residents. Due to the prevalence of trade work in the region, education attainment levels differ when compared to national averages, showing higher concentrations of individuals without high school degrees and lower concentrations of individuals with bachelor's degrees or higher (Headwaters Economics, n.d.). St. Johns also has a high concentration of lower income households and over 20% of the population lives below the national poverty level (Headwaters Economics, n.d.).

CGS is a major employer in St. Johns and contributes significantly to local government tax revenues. Local residents are actively involved in SRP's efforts to include them in the decision-making process about replacing CGS with other electricity-generating technologies. Although Apache County relies less on mining, as the plant sources its coal from outside the state, utilities still represent a sizable portion of employment.

The community's economic vitality relies on CGS for stable, well-paying jobs. The president of Northland Pioneer College, an area educational institution, also explained that loss of CGS without a new generation technology would substantially reduce property tax income and significantly impact programs and schools that depend on those tax dollars (Gateway for Accelerated Innovation in Nuclear 2023). Given that historically marginalized communities with reduced access to education and educational funding may be impacted disproportionately, this is a greater concern for St. Johns where there is a higher Native American population.

3.2. Planning Process and Considerations for Pathway Development

The local government is involved as a stakeholder but most of the driving force for planning has come from interactions between SRP and the local workforce and community members. The area is not heavily populated so it is common for power plant employees to hold elected positions within local government, which can help bring workers' perspectives to government decisions. Stakeholders engaged in the process include North Pioneer College, SRP, local labor unions, local government, Arizona state leaders, the U.S. Department of Energy (DOE), the Hopi Indian Reservation, Navajo Nation, and Fort Apache Indian Reservation.

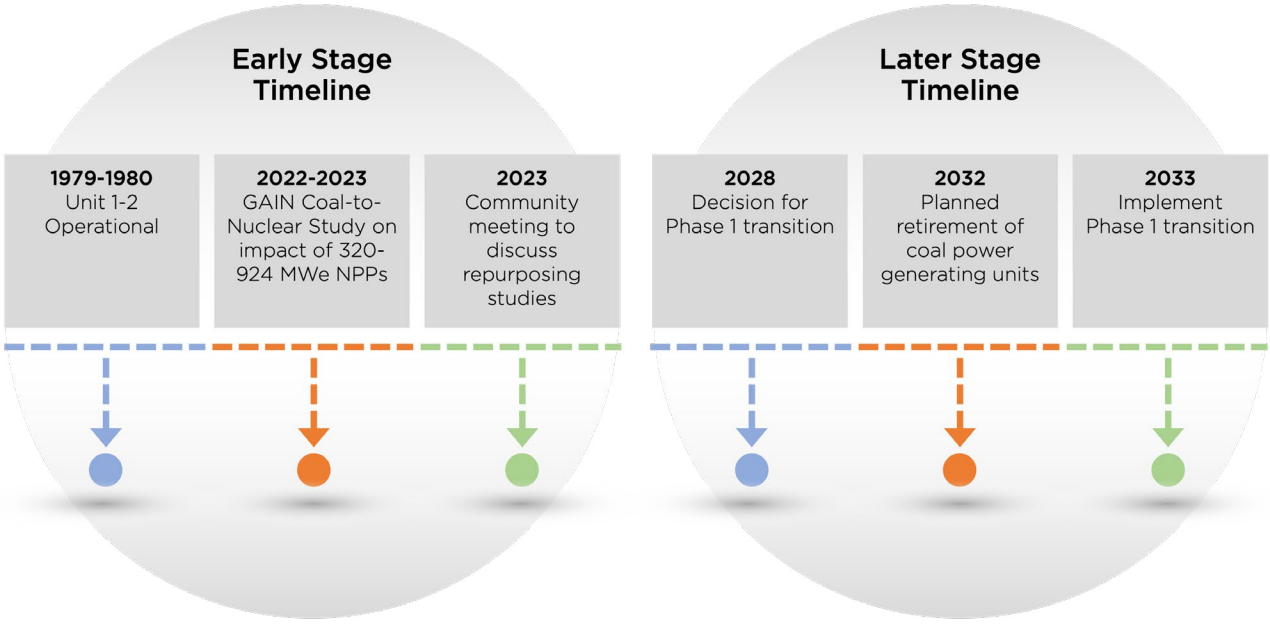

Figure 3: Timeline of Coronado Generating Station closure. The timeline for Phase 2 is undecided. (Timeline is depicted as points but may represent actions taken over broader time ranges.)

SRP is looking for a Phase 1 transition to replace the coal power plant starting in early 2033. The utility company is considering biomass, battery storage, LDES, PV solar, and wind, with a decision expected by 2028. Phase 2 timing has not been decided but will likely overlap with the later part of Phase 1. Technologies under consideration for this longer-term transition include advanced nuclear (small modular reactors, or SMRs), a hydrogen-fired power plant, LDES, and a natural gas-fired power plant. The delay in selecting a Phase 2 solution is based on various uncertainties regarding the technology readiness of long-term options being considered.

A Kiewit study focused on technical evaluation and feasibility screening and ultimately provided a comprehensive list of possible replacement technologies (Kiewit Engineering Group 2023). An SRP coal- to-nuclear transition study was conducted and funded through the Gateway for Accelerated Innovation in Nuclear (GAIN) (Gateway for Accelerated Innovation in Nuclear 2023). During the presentation of these studies, nuclear energy received some community support.

The coal transition pathway selection process has included detailed analysis of location-specific variables. These variables include site characterization, technology cost estimates, community input, long-term energy demand forecasts, economic and environmental impact, workforce availability, and cost support from federal tax relief. While SRP is not ready to select the technologies that will replace fossil generation at the plant, the utility has committed to the employees that the site will be repurposed and is commencing the work necessary to develop such a plan.

3.3. Outcomes and Key Lessons Learned

In the St. Johns case, the process of selecting a replacement for the CGS facility is ongoing as many factors must be weighed carefully. To aid in the selection process, socio-economic and environmental impacts were extensively analyzed for the coal-to-nuclear transition scenario in the CGS-GAIN study. Similar studies for other pathways were not completed or are not publicly available. According to the CGS-GAIN report, a nuclear plant is expected to directly employ between 100 and 270 workers, depending on vendor choice and plant configuration. The total employment impact is expected to create or sustain between 320 and 924 jobs when including jobs created through increased economic activity from the local supply chain and plant employees' household spending. The total economic output impact is expected to range between $233 and $672 million annually. The fiscal impact on local government is also worth considering; current tax receipts for CGS are $69 million annually. Nuclear plant tax payments are not known but will be established with assistance from the State of Arizona. The St. John's case was chosen to illustrate an approach to selecting electricity-generating technology that involves extensive evaluation of other options.

The expected job growth following a coal-to-nuclear transition will also lead to additional population growth as new workers add households to the region. In addition, education attainment for plant workers is expected to shift toward an increased need for university degrees; however, many jobs can be retained with little or no additional training, as shown in Figure 4.

The utility company has been transparent about its plant closure plans. As a result, the process to find a replacement also has been transparent. The nuclear power opportunity is being evaluated along with other renewable electricity sources, and research study results are presented to the public in ways that allow open discussion and common consent.

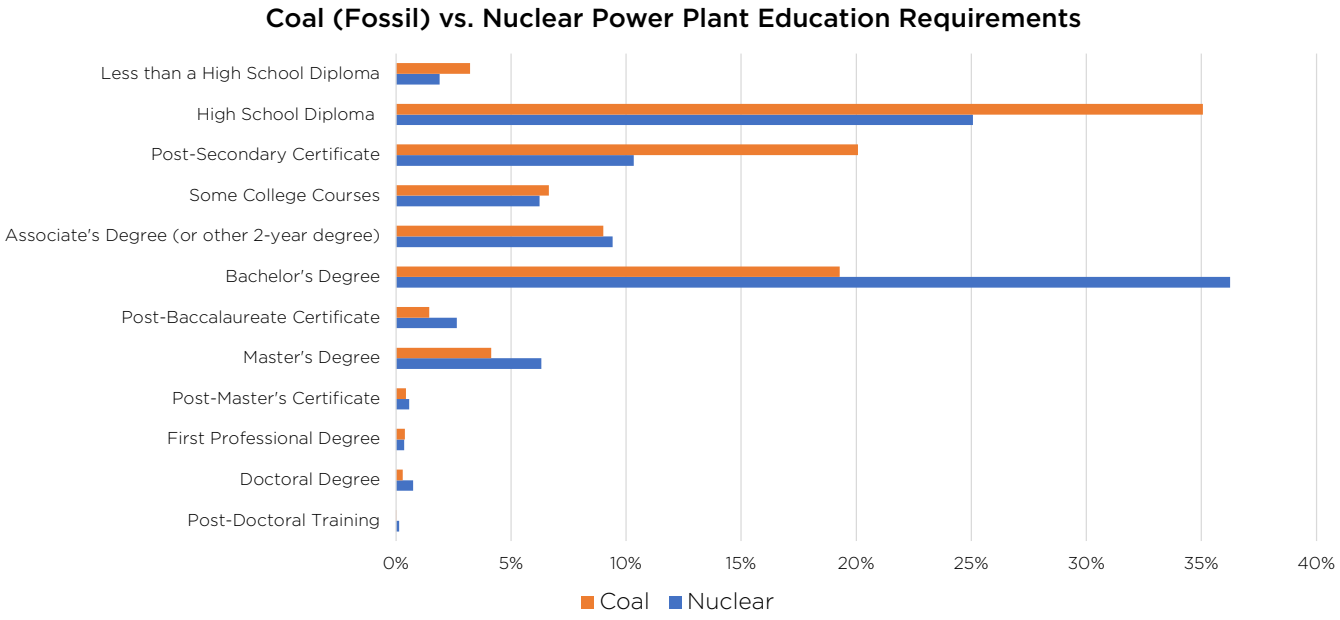

Figure 4: Education requirements for coal versus nuclear power plants. Source: Bureau of Labor Statistics.

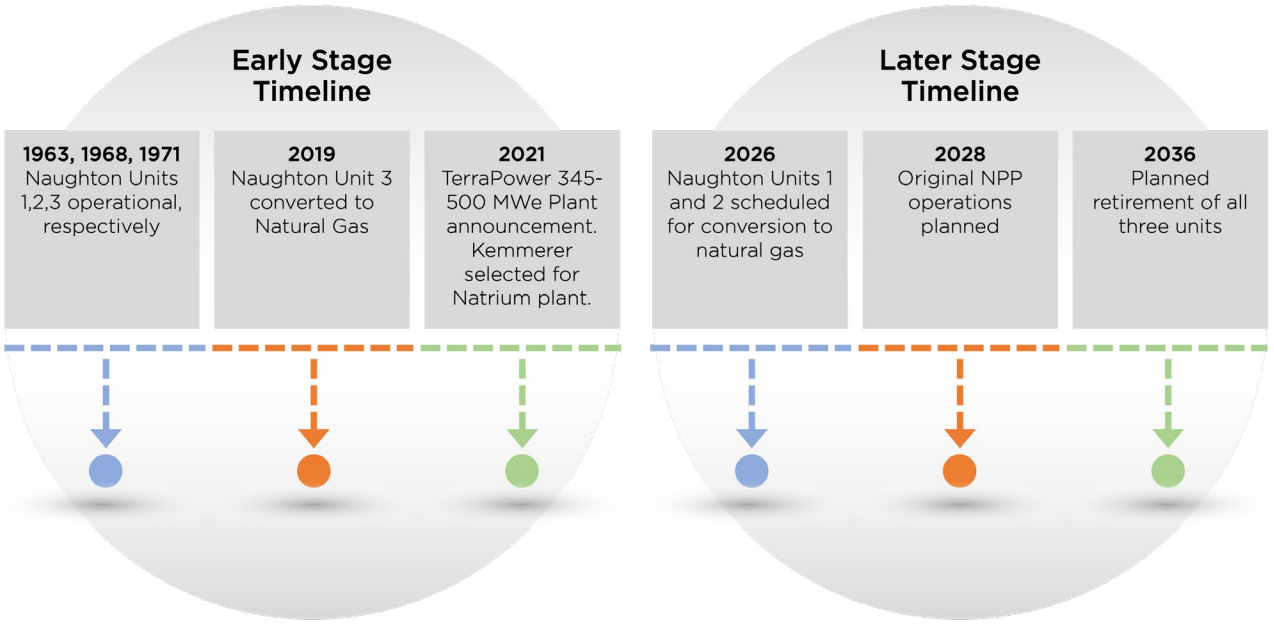

Figure 5: Timeline of Kemmerer plant closure. (Timeline is depicted as points but may represent actions taken over broader time ranges.)

4. Kemmerer, Wyoming

Kemmerer is a long-established energy and mining community formed in 1897 when the Union Pacific Coal Company discovered the region's coal reserves. In 1950 it became home to the world's largest open pit coal mine. In 1963, the Naughton coal power plant was commissioned. Now, both mining and power generation are some of the most significant area employment opportunities. Kemmerer specifically relies heavily on coal and coal power generation for jobs and tax dollars.

While the first generating unit in Naughton was built in 1963, two others were built in 1968 and 1971. In 2019, one of the three units was converted to natural gas and the combined nameplate capacity was rated at 832 MWe. The final two units were scheduled for closure in 2025 with the new gas plant planned for retirement in 2029. Due to the upcoming retirements, PacifiCorp has begun evaluating replacement options.

Upon investigating alternative generating technology, PacifiCorp stated that renewables or natural gas are cheaper generation options than more than half of its existing coal plants. Subsequently, the planned plant closures created an opportunity for more profitable electricity-generating technology (McKim 2019). PacifiCorp selected the Natrium nuclear reactor developed by TerraPower under the DOE Advanced Reactor Demonstration Program with $2 billion planned investment from the DOE ("Next-Gen Nuclear Plant and Jobs Are Coming to Wyoming" 2021) and similar private investment[3].

3. The Natrium project is planned to move forward; the utility is also planning to convert two remaining coal power plant units with natural gas in 2026, with lifetime expected until 2036 (Pacificorp 2023).

4.1. Community Characteristics and Perspectives

Mining and utilities continue to be significant employers in this small town of 2,422 residents (as of 2021). All the coal used in the Naughton Power Plant in Kemmerer comes from the local coal mine, which means that a plant shutdown could lead to a coal mine shutdown. This is true of multiple Wyoming coal plants. It made sense to build plants where large coal reserves existed but it has put communities with local economies overly dependent on specific industries at risk of downturns. This is illustrated for Lincoln County, where Kemmerer is located, in the employment snapshot shown in Figure 6. Mining, which includes both coal mining and oil drilling operations, and utilities represent some of the largest area employers. Well-paid energy and mining jobs have helped the region maintain higher-than-average wages.

As of 2021, more than 800 of the county's nearly 12,000 jobs were based in mining and utilities. High wage trends have been observed in multiple other energy communities, where additional community benefits are reaped from high wages and property taxes paid by the local utility and mining businesses.

As one resident explained, "If both the mine and plant went under, it would mean the loss of hundreds of jobs [in Kemmerer] and the two largest taxpayers in the county" (McKim 2019).

4.2. Planning Process and Considerations for Pathway Development

Coal power plant shutdowns were planned in Kemmerer before many current small modular reactor designs were even an option. The process to create interest in nuclear replacement options was somewhat unique. With multiple future coal power plant closures in Wyoming, the scenario created an opportunity for potential sites to compete for a nuclear reactor. Reactor developer TerraPower announced the decision to locate an advanced nuclear reactor in Wyoming through a press release in collaboration with the Governor's office. The developer engaged with all stakeholders (all levels of government, community residents, workforce, education institutions, and the utility company) during the specific site selection process. After narrowing the potential sites down to four, the Kemmerer site was announced.

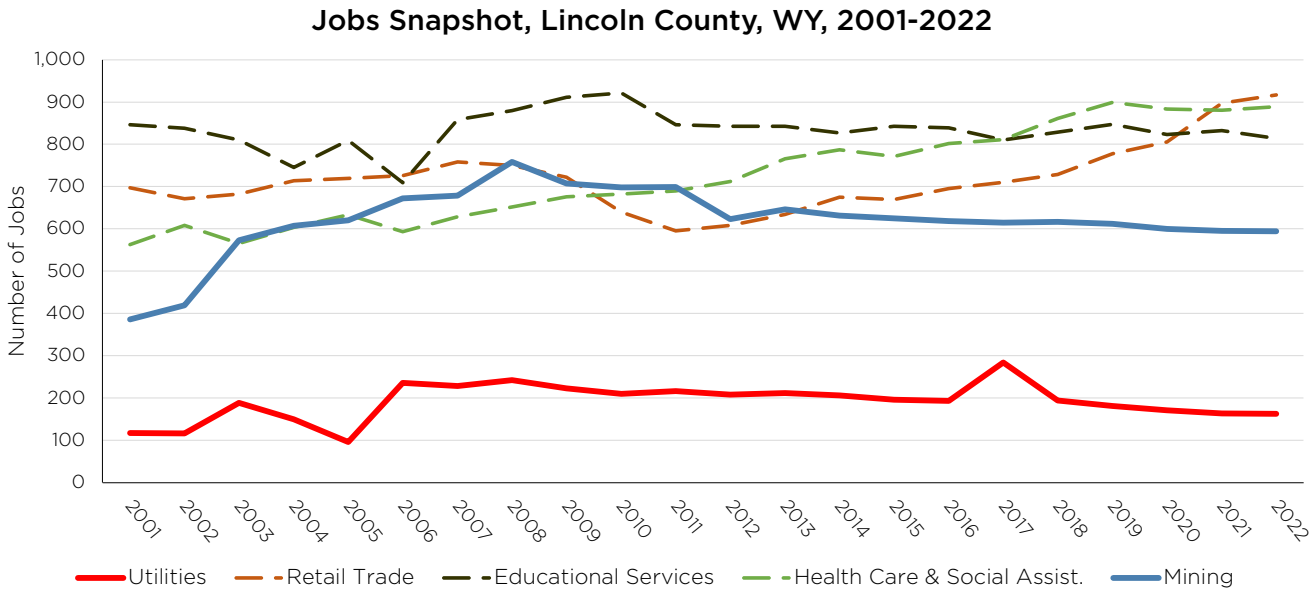

Figure 6: Employment by trade in Lincoln County, Wyoming. Source: Headwaters Economics.

After selection of the site, PacifiCorp indicated that training programs would be available to existing Naughton staff, should additional skills be required for work at Kemmerer Unit 1. In the process, another key stakeholder sprang into action: Western Wyoming Community College. With an established coal power plant training and hiring pipeline, the college has begun the process of altering courses to meet nuclear power plant requirements and preemptively transition a workforce pipeline to the new plant. The college has met with DOE national laboratories and educational institutions with nuclear programs to support this transition.

Pathway development was established by TerraPower, Rocky Mountain Power, and the community, recognizing the mutual benefit from leveraging reuse of transmission resources available at the Naughton location. Reasons for Kemmerer's selection included the experience of the Naughton employees on specific equipment types, the site's physical characteristics, the ability of the site to obtain a license from the Nuclear Regulatory Commission, access to existing infrastructure, and the needs of the grid (Gruver and McCombs 2022, TerraPower 2021).

In addition, the community needed to find a new way to support their economy with the looming coal power plant closure. Ultimately, the decision to add a TerraPower-designed nuclear reactor with molten salt storage was deliberate and driven by the need to compensate for the variability of wind and solar generators in the area (Fitzpatrick, Maffly, and Schott 2023). This, combined with the added support for federal dollars, made being a nuclear first mover a viable option.

4.3. Outcomes and Key Lessons Learned

The Kemmerer case provides a look at a much different coal-to-nuclear pathway than what is occurring in St. Johns. The community characteristics are similar in that they are both rural communities that will face major economic repercussions if the coal power plants close without being replaced. In this case, the decision has been made and plans are moving forward for the Natrium reactor.

TerraPower's Natrium reactor is expected to employ 250 workers directly with a total employment impact, once supply chain jobs and community are included, as high as 1,000 based on similar sized reactors. Additionally, the total output impact could surpass $600 million based on similar sized reactors. Educational attainment for plant workers is expected to retain about the same mix of university type degrees to non-university degrees. Training will be available where needed; however, many jobs can be retained with little or no additional training. The Natrium reactor will reuse the coal power plant water supply, water storage pond, switchyard, transmission corridor, and meteorological tower data. This will leverage local subcontractors which will help keep jobs in the area and gain further community support.

In contrast to the "bottoms up" approach that St. Johns is taking, site selection for Kemmerer followed more of a "top down" approach not initiated by the community. In the end, the result created a somewhat competitive environment for communities to be selected and one news source remarked that town officials were 'ecstatic' about landing the project.

5. Muskegon, Michigan

B.C. Cobb was a 500 MW power plant owned by Consumers Power Company that consisted of five units: two 313 MW coal-fired units and three 187 MW natural gas units that had been converted from coal to natural gas. The units were built between 1948 and 1957 in Muskegon, Michigan on 300 acres of land. The units were retired in 2015 and 2016 and the plant was demolished in 2020. When the plant was active, it provided 100 full-time jobs, $70 million in local tax revenue, and $4 million in property tax revenue. In 2011, the plant was the single largest taxpayer in the county area and represented approximately 17% of the county seat's tax base (Tarekegne, Kazimierczuk, and O'Neil 2021).

The Cobb power plant was retired mainly because the plant owner decided to remove coal from the generation mix, as it was more economic to use natural gas and renewable energy sources to generate electricity at the time. Furthermore, the reduction in coal use would also help to align with the company's commitment to reduce its fleet's greenhouse gas emissions. The Cobb plant had outlasted its 50-year lifespan and the area had a generation surplus. All these factors made retiring the Cobb plant a logical decision.

5.1. Community Characteristics and Perspectives

In 2020, Muskegon had a population of 175,824 with 74% classified as living in an urban area. Muskegon has been characterized by high poverty rates, with nearly 28% of its population living below the poverty line as of 2019 (Tarekegne, Kazimierczuk, and O'Neil 2021). Recognizing that the plant's old age, declining performance, and ever-growing environmental footprint would impose larger economic consequences than its closure (Tarekegne, Kazimierczuk, and O'Neil 2021), the community did not fight to save the facility.

Although the community was not involved in the direction and timeline of the plant's retirement process, Consumers Power Company made a significant effort to be transparent about their proposed plans. Throughout the process, the city worked on behalf of the community to ensure that residents' needs were being met; for example, city officials were able to move up the plant demolition timeline in exchange for approving permits for oversized backfill rocks on the site.

5.2. Planning Process and Considerations for Pathway Development

The owner prepared the community for plant retirement as early as 2012. However, there was not much community involvement or input with the transition of the property. The property was sold to Forsite in 2017; afterwards, it was purchased by Verplank Family Holding Company in 2020. Verplank had been considering the site for many years as a potential location for repurposing. The company developed a new deep water port facility at the former B.C. Cobb site in August 2022 (Grand Haven Tribune 2022) without using any public funding, tax incentives or grants (Coseo Properties, Inc., 2022). The new industry was developed because of the site's proximity to Lake Michigan and the availability of land to load, unload, store construction aggregate such as limestone, slag, trap rock, and ice control salt (Coseo Properties, Inc., 2022). The new facility can handle more than 1 million tons of material annually.

5.3. Outcomes and Key Lessons Learned

In addition to the job creation and tax revenue benefits the port brings to the area, the Verplank port facility supports Muskegon's downtown and lakeshore redevelopment plan. The port facility's benefits include both environmental remediation of the retired power plant and a reduction in large truck traffic in the city. The new port facility reduces congestion and noise by shifting commercial freight activity away from other docks on Lake Michigan closer to residential and downtown areas (Coseo Properties, Inc., 2022).

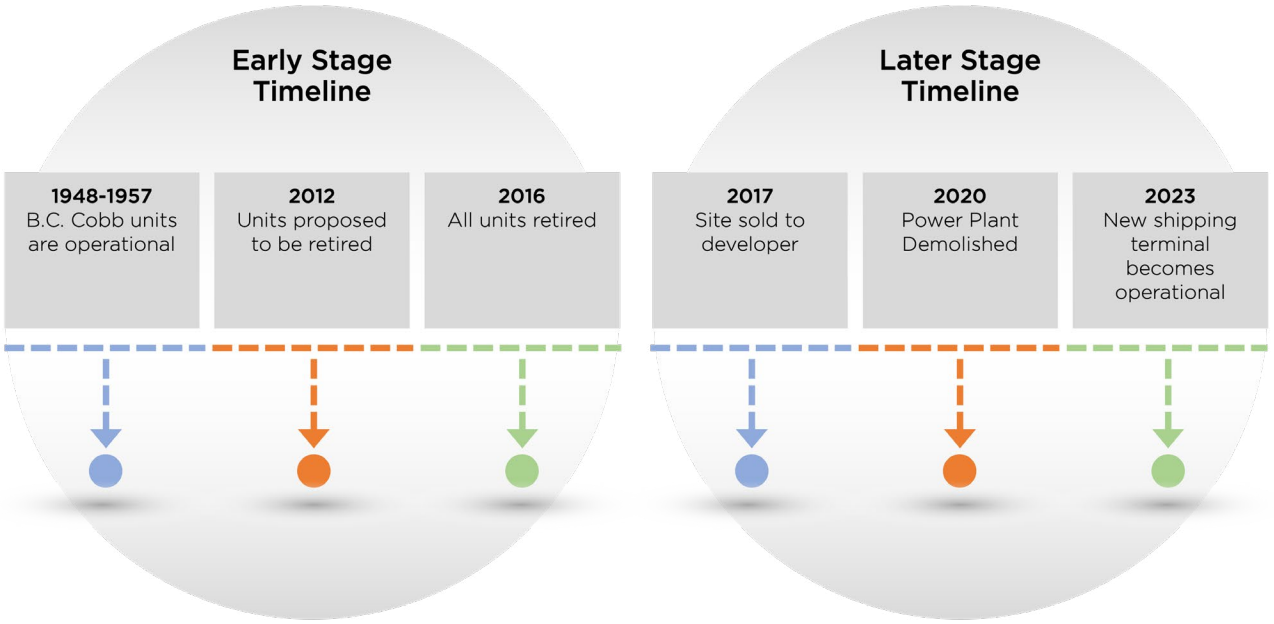

Figure 7: Timeline of B.C Cobb plant closure. (Timeline is depicted as points but may represent actions taken over broader time ranges.)

This case study was selected to show how long a retired power plant can remain abandoned or as unused land after demolishing. This plant represents the abandonment statutes and little community involvement in the repurposing effort of many U.S. retired coal-fired power plants. For example, the Mitchell (300 MW) and Elrama (500 MW) coal-fired power plants located in southwestern Pennsylvania have been abandoned since their retirements in 2013 and 2014. These plants still have structures standing and could benefit from recent resources and funding available to communities for economic development. Advertising and making these resources available to these community entities is key.

The B. C. Cobb power plant was retired in 2016 before federal support of Just Energy Transitions had accelerated in 2021. Public knowledge of available state and federal support and resources for existing site closures is important for helping communities like these that are similarly struggling with abandoned sites.

6. Saint Paul, Virginia

The Virginia City Hybrid Energy Center (VCHEC) was commissioned by Dominion Energy in 2012 and is located in St. Paul, Wise County, Virginia. The plant was designed to process and convert waste coal (gob) and biomass into as much as 610 MW of electricity (Dominion Energy, n.d.). When commissioned, the plant featured state-of-the-art circulating fluidized bed boilers and air quality control systems to achieve significantly lower emissions than traditional coal-fired power plants. The plant operates at a lower-than-designed capacity, thus generating less revenue and operating less efficiently. In 2014, the plant was fined $47,651 by the Virginia Department of Environmental Quality for emitting carbon monoxide and other gases at levels exceeding state regulations. While the company is not in favor of plant closure, consumer and environmental advocate groups are pushing for retirement, citing the plant is costing ratepayers money. In 2021, Dominion developed a study, "Virginia City Hybrid Energy Center Pathways for Economic Viability," to examine alternative options.

The VCHEC employed over 2,000 people to construct the facility (Virginia Electric and Power Company 2022). The plant employs approximately 153 full-time employees, supports 300 to 400 indirect jobs in the area, and provides $8.5 million in annual property tax revenues for Wise County, or 15% of the county's budget. An additional $40 million per year for the county is supported by local economic activities indirectly stimulated by plant operation, including more than $3.5 million in charitable donations. Local mines that supply coal to the plant are at risk of closure when the power plant retires, worsening job impacts in surrounding counties (Tarekegne, Kazimierczuk, and O'Neil 2021).

6.1. Community Characteristics and Perspectives

Wise County's population in 2020 was 32,586 which is a 13% decrease from its 2010 population census (St. Paul is a small town in Wise County with 1,000 residents). In the 1880's, coal mining became the major resource produced in the area (Wikipedia contributors 2023), but mining has decreased over the years. In July 2012, Dominion Energy built the VCHEC in Wise County as a hybrid power plant that co-fires 80% coal and up to 20% biomass. This was a good fit for a community that was facing a decrease in coal mining jobs. The plant, originally designed to operate at around 80%, has

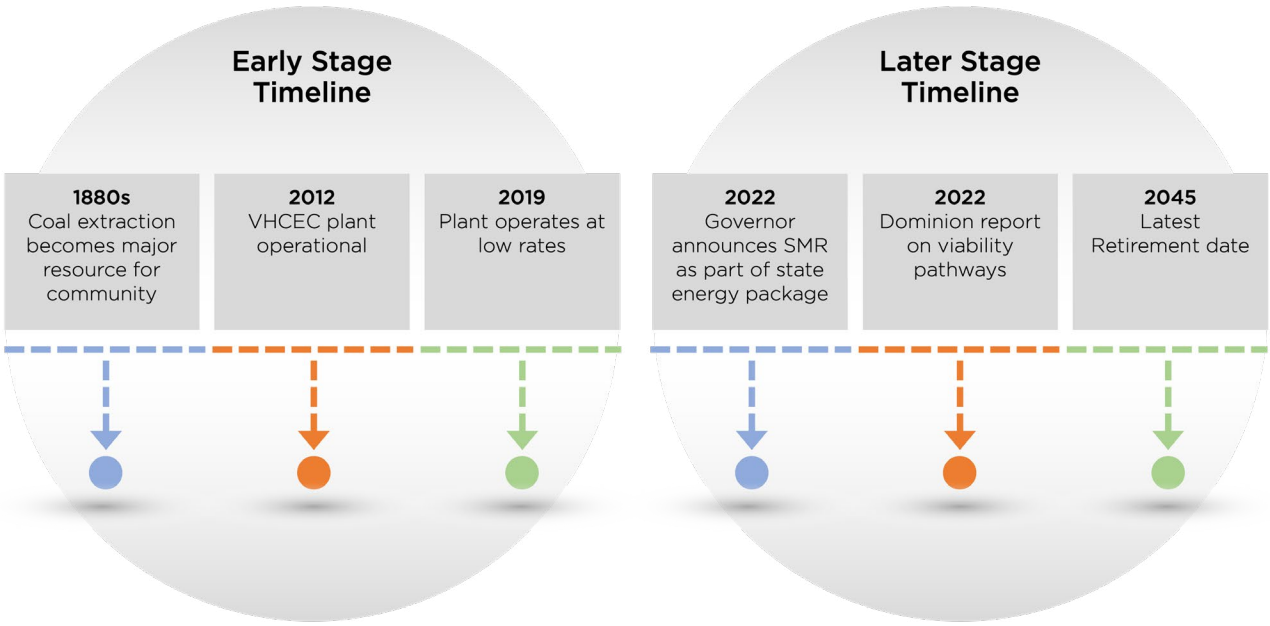

Figure 8: Timeline for the Virginia City Hybrid Energy Center closure. (Timeline is depicted as points but may represent actions taken over broader time ranges.)

decreased its capacity factor sharply over the last 5 years and is slated to retire (Cates, Israelsen, and Feaster 2020).

The community has mixed views on the facility retirement. The plant's economic benefits are important to the community and the plant provides an environmental benefit by using over 4 million tons of local waste coal (gob) which facilitates local gob site remediation efforts. The power plant also has had opponents since its conception, with environmental groups rejecting the idea of constructing a new fossil fueled power plant and others claiming the plant would be an uneconomic investment. After only eight years of operation, plant opponents were relieved to hear discussions of shutting down the facility (Tarekegne, Kazimierczuk, and O'Neil 2021). Both plant opponents and supporters fear the potential impacts of retirement on the local economy, school budgets, businesses, and livelihoods (Tarekegne, Kazimierczuk, and O'Neil 2021).

While there are no firm pathways for development after the plant retires, the Wise County residents and surrounding communities developed the following list of best practices (Tarekegne, Kazimierczuk, and O'Neil 2021):

1. Start community engagement early and continue throughout the plant decommissioning process.
    - **a.** Offer in-person, virtual, and written comment opportunities.
    - **b.** Conduct listening sessions to hear concerns and desires from affected communities.
    - **c.** Use a transparent process providing trusted information throughout.
2. Integrate the power plant decommissioning timeline into the state's climate and clean energy transition targets.
3. Conduct plant decommissioning impact assessments, communicate results to affected communities, and coordinate the appropriate remediation plans.
4. Identify funding to support decommissioning and the affected communities upfront.
5. Plan early for post-decommissioning projects to replace lost jobs, revenues, and economic activity.
    - **a.** Gather community input for the post-decommissioning plans realizing economic development is not a one-size-fits-all proposition.
    - **b.** Recognize the cultural, social, environmental, and long-term health impacts faced by communities.

6.2. Planning Process and Considerations for Pathway Development

The Virginia Clean Economy Act of 2020 requires the VCHEC plant to close by 2045 but closure could occur sooner due to low utilization. While an earlier draft of the landmark Clean Economy Act would have required VCHEC to close by 2030, pressure from Southwest Virginia lawmakers secured an amendment allowing it to stay 15 years longer (Vogelsong 2022).

In a recent independent study, the VCHEC was considered one of seven potential sites to develop nuclear SMRs in Virginia (Cameron 2023). Dominion also had performed a study on the power plant, analyzing the repurposing of approximately 65 acres of land for solar, wind, energy storage, and SMRs (Paullin 2022). The Dominion study ruled out solar, wind, and energy storage for multiple reasons. With regard to solar, the 65 acres would support only 6 MW of a ground mounted PV solar generation facility. Due to the distance from an interconnect and small facility capacity, financial and technical challenges made this option infeasible. Wind was not a viable option due to the unavailability of ridgetops; the site does not support the economic development of an onshore wind facility and there have been no utility-scale onshore wind-generating facilities constructed within Virginia. The company investigated a 600 MW lithium-ion energy storage facility at the coal plant site and determined it infeasible, as other locations were considered a better customer value (Virginia Electric and Power Company 2022). While the study asserted that the site could support various SMR technologies including a 300 MW design, Dominion noted that SMR technology is still under development, none have been built in the United States so far, and further investigation would be required before selecting the technology (Cameron 2023).

6.3. Outcomes and Key Lessons Learned

The Virginia City Hybrid Energy Center is still in operation as of fall 2023. Transparency with the power plant closing, future actions, and replacement of jobs and tax revenue is key to the community. Consumer and environmental advocate groups pressed the plant owner to produce the 2021 "Virginia City Hybrid Energy Center Pathways for Economic Viability" report. A lesson learned is that transition effects are eased when community leaders and state and local officials increase planning and communication early in the process.

7. Tocopilla, Chile

Chile, a country in South America of 19 million people with renewable electricity generation of over 50%, has set an ambitious commitment to achieve GHG neutrality by 2050 in its Climate Change Law (21455, 2022), including accelerated coal phase out by 2040. Chile's 2020 update to its Nationally Determined Contribution includes key goals for reaching an emissions peak in 2025, a maximum of 95 metric tonnes of CO2 equivalent (Mt CO2e) in 2030, a maximum GHG emissions budget of 1,100 MtCO2e from 2020 to 2030, and a reduction in black carbon emissions by 25% by 2030, relative to 2006 levels. Chile is a founding member of the Net Zero World initiative and Chile's Ministry of Energy and the DOE multi-laboratory Net Zero World team established a Just Transition Working Group with a focus in the short-term on providing technical assistance and capacity building for the coal-dependent community of Tocopilla, a city of 25,000 in the north of Chile with the country's highest poverty rate. The Net Zero World Chile Just Transition Working Group is also receiving updates on the AES coal-to-molten salt conversion project in the neighboring community of Mejillones, Chile.

In Tocopilla, there are two power stations: the Tocopilla station owned by Engie—comprising four coal units, one natural gas combined cycle unit, and three gas turbines units—and the Nueva Tocopilla owned by AES Andes, comprising two coal units. Engie shut down its Tocopilla coal power station (440 MW) completely in 2022; one 350 MW combined cycle gas turbine power plant is still operational and remains in use for the regional mining industry.

The agreement to close the coal power plants was reached between the Ministry of Energy and private sector plant owners. The main drivers for closing the power plant came from national level decarbonization goals and international commitments established by the Paris Agreement. The Chilean government felt the time had arrived to transition toward other opportunities such as renewable energy generation by leveraging the solar, wind, and offshore water resources in the region.

Recently Chile committed to achieve carbon neutrality by 2050. The commitment was made in the National Energy Policy and the Long-Term Climate Change Strategy as part of the Climate Change Law which passed in 2022. The Long-Term Climate Change Strategy was defined as part of the Climate Change Law and defines the initiatives that Chile has committed to in order to address climate change challenges and transition to a carbon neutral economy. Within the Climate Change Law, emissions goals and budgets are defined for each sector. Specifically in the energy sector, the following four goals are defined:

- By 2025, 65% of the coal units will be retired or reconverted.
- By 2030, 80% of the electricity produced in the country must be renewable. The electricity system must be ready to achieve this goal.
- Work and initiatives will be conducted to ensure that coal facilities can be retired or reconverted during the first couple of years of the next decade.
- By 2050, 100% of the electricity produced must come from zero emissions sources.

Chile's Plan for Retirement or Conversion of Coal Units (Ministry of Energy 2020b) is the announcement of a voluntary but binding retirement plan for coal power plants and represents an unprecedented process in Chile to move towards a cleaner energy sector (Government of Chile 2021). The plan was guided by the Ministry of Energy and developed with representatives of non-governmental organizations, public sector, civil society, companies, universities, labor unions, municipalities, and international organizations. The Working Group for Retirement and/or Reconversion of Coal Units was then created to establish conditions for gradual and safe cessation of coal power plant operation based upon technical, environmental, and socioeconomic criteria. Further analysis was conducted[4] on the impacts of coal phaseout on energy security, power grid efficiency, local economic activity, and environmental aspects to inform the phaseout strategy.

Once the Tocopilla Power Station closure plan was announced in 2018, Engie led the decommissioning process. In 2019, Engie decommissioned two of the four coal-fired units and tried to help the displaced employees by moving them to other jobs within the company. Engie provided new work opportunities for current employees and moved some to a nearby power plant community in Mejillones, providing temporary employment until the Mejillones power station closure, which is planned to begin in 2024 and finish in 2025.

7.1. Community Characteristics and Perspectives

Tocopilla has been described by public officials as a close-knit community, with a population of

4. Cross-sector actors engaged in the analysis included the companies that owned the coal power plants (AES Gener, Colbun Enel and Engie), the public sector (Ministry of Energy, Ministry of Environment, National Energy Commission, National Electric Coordinator), consumer associations (ACENOR, ODECU and Mining Council), trade associations (Generadoras de Chile), non-governmental organizations (WWF Chile, Casa de la Paz and Chile Sustentable), worker unions and civil society organizations (COSOC of the Ministry of Energy and Carbon Central Workers Union, the Illustrious Municipality of Tocopilla), academia (Pontifical Catholic University of Chile, Adolfo Ibanez University), and international organizations such as GIZ.

25,186 people from the 2017 census. Geographically, this community is somewhat isolated due to the fact that no large cities are nearby and available roads from the closest major city of Antofagasta, some 200 km away, are limited. Typical jobs for community members include mining, port activities, and power generation. There are significant challenges in accessing technical and professional education and many young residents leave the area in pursuit of better opportunities. The average education level for residents 15 years or older in Tocopilla is 10.03 years, which is lower than the regional and national average (Andrade 2019). Tocopilla has the highest incidence of poverty at the regional level (10.9% of the population as of 2017), so transition plans must ensure that the plant's closure does not exacerbate economic disparities.

When the closure plan for the coal plant was announced in 2018, although both workers and citizens positively valued the closure of coal plants as a way to achieve emission reductions and improve health outcomes for the community, workers were worried about their jobs; the plant had been a source of stable employment for the community. Workers were not prepared to shift to other economic sectors and there were many questions regarding the need for closure, next steps, and how the transition would affect jobs and environmental quality.

To address these concerns, the Chilean Ministry of Energy published Part I of the Just Energy Transition Strategy in 2021 to guide development of local Just Transition plans tailored to each community. The strategy was developed with a broad set of stakeholders and identifies immediate state commitments and defines a work plan focused on eight initiatives built around four pillars:

1. People-centric energy transition
    - **a.** Promote employment and the development of the population which will be negatively affected by the shutdown of coal facilities. Support the development of new sources of employment or new business activities within or outside the energy sector.
    - **b.** Support the social wellbeing of the affected people, workforce and community, including the most vulnerable and those impacted by the shutdown or reconversion of coal facilities.
2. Economic development and productivity support
    - **a.** Promote new investments into the areas affected by the shutdown or reconversion of coal facilities.
    - **b.** Promote research, development and innovation focused on the creation of new services or productive endeavors in the areas affected by the shutdown or reconversion of coal facilities.
3. Environmental development and territorial focus
    - **a.** Strengthen the regulatory framework, aiming to increase the feasibility of projects for new uses of the spaces or infrastructure associated with the coal facilities.
    - **b.** Develop new uses for the spaces or infrastructure associated with the coal facilities and plans which are aligned with the desires of the affected areas.
4. Participation and public/private involvement-focused governance

a. Design a governance framework that enables execution and management of the initiatives defined for each area. Encourage broad social diffusion initiatives are implemented.

b. Facilitate and articulate financial support for sector policies and private initiatives that allow for a coordinated and coherent set of actions, which in turn lead to a just and sustainable transition from the shutdown and/or reconversion of coal facilities.

7.2. Planning Process and Considerations for Pathway Development

The Just Energy Transition Strategy is the general framework which should be implemented in the affected areas through the local action plans in the communities where the coal generation facilities are located. That is the case in Tocopilla, where a cross-ministry process was developed for the preparation of a Just Socio-Ecological Transition Plan for Tocopilla, owing to its cross-sectoral nature.

In 2022, the Chilean Ministry of Energy led a participatory process to develop a just socio-ecological transition action plan to mitigate the impacts of coal plant closures in the community of Tocopilla, with a focus on generating new job opportunities, environmental recovery and care, and other citizen priorities including education, health, and sustainable development. Furthermore, as a partner in the Net Zero World Initiative, Chile has worked closely with the initiative to identify a Tocopilla Sister City Stakeholder Local Committee and develop and provide eight different Just Transition webinar topics. In 2023, Lawrence, Kansas was selected as a potential U.S. Sister City to provide mutual support and share key learnings with Tocopilla.

In addition, the Ministry of the Environment expanded the concept of just ecological transition to just socioecological transition, which includes developing decent jobs. The Ministry of Energy incorporated the new definition adopted by the Ministry of Environment into the Just Energy Transition concept. The Just Socioecological Transition is defined as the process to empower Chilean society through participation and transformation. The transformation is focused on evolving the economic model from reliance on extraction-centered industries, which are impacted by the climate crisis and are related to ecological vulnerability, to a model of innovative and sustainable economic sectors. Additionally, the Ministry of Environment hopes that such an economic model will lead to greater income equality, environmental and social justice, decent labor and maximization of the population wellbeing by re-establishing the ecological balance.

An Interministerial Committee for the Just Socioecological Transition (ICJST) was created with the primary objective of advising the President of Chile in the areas where policy could be developed, or where institutions could be transformed to help advance the just socioecological transition. The coordination process included the ministries of Economy, Education, Energy, Environment, Health, and Labor and other entities to build synergies and help identify actions, programs, and projects to mitigate the negative impacts of coal power plant closures. The Ministry of Energy led development of the plan and process; the Ministry of the Environment is responsible for implementation and leads the ICJST.

With support from various ministries and public departments, worker training is being conducted in areas specific to each sector. To date, courses and training have been held in energy matters (PV panel installation and the installation of electric vehicle charging infrastructure, for example).

While the government of Chile has developed some plans and training programs to support workers, the plant repurposing is a private sector decision. In Chile, the energy market is 100% private; company decisions and investments do not receive state financial support in the form of funding, subsidies, or tax credits. The city of Tocopilla is not involved in the repurposing plans for the Engie plant. Engie is analyzing options for repurposing this site and considering various pathways such as water desalination, hydrogen, and energy storage. Geographically, Tocopilla is located alongside the ocean and is characterized as a desert climate. During the year, there is virtually no rainfall and on average, Tocopilla gets over 2700 hours of sunshine per year, roughly 89 hours per month ("Tocopilla Climate: Average Temperature by Month, Tocopilla Water Temperature," n.d.).

7.3. Outcomes and Key Lessons Learned

Since Tocopilla is in the early stages of its transition, pathways and their outcomes and impacts are unknown. Some key lessons learned are that: (1) A key aspect for mitigating the coal plant closure effects is the state commitment to promote actions responding to the demands and needs of the population involved; (2) From this state commitment is born cross-sector coordination, such as through the ICJST, necessary to jointly build processes for the implementation of actions, projects, and programs; and (3) Plans must be developed by considering the relevant local knowledge of the affected citizens in each geographic location. An important example are the novel processes such as youth participation and reviews for gender and human rights expert institutions to address the energy transition and the Just Socioecological Transition.

8. Synthesis and Key Insights

Each community is unique and transitions must be tailored to local and national contexts, with recognition that access to financing is a key differentiator between wealthy and low-to-middle income countries. This analysis examines six community fossil fuel transitions in two different country contexts to provide insights on lessons learned and best practices for inclusive processes and decision-making criteria that bring forth positive community outcomes. In both the United States and Chile, a coordination mechanism is established across government agencies and the importance of stakeholder engagement is recognized. In many cases, the government, local community groups, and electric utility or industry players have critical roles in transition planning and support.

In the cases examined, decisions are highly dependent on transition drivers, whether voluntary, market, or regulatory in nature. Table 1 shows the key drivers and planned or implemented solutions across the case studies. U.S. community transitions are driven by a combination of environmental concerns and market processes, which in turn are determined by plant economics and development opportunities for the private sector. In the Chile case, the drivers are environmental and economic, as well as regulatory, in support of the nation's sustainability goals. While the private sector develops repurposing plans in Chile, the national government plays a critical role in broader transition support by developing regulatory frameworks to stimulate economic development, providing tailored stakeholder engagement and workforce training, and supporting sustainable development goals.

Table 1: A snapshot across communities of the key drivers and the solutions they are pursuing.

Case Study Community	Key Drivers	Solutions
Centralia, Washington, USA	Governor executive order; state government legislation	$55M Transition Fund for energy, economic, and community development
St. Johns, Arizona, USA	Greenhouse gas (GHG) goals and interactions of utility, the local workforce and community members (an inclusive, bottom-up process)	On-going decision process: includes consideration of biomass, battery storage, long-duration storage, PV, wind, nuclear
Kemmerer, Wyoming, USA	End-of-life retirement and desire for cheaper, cleaner generation options. Nuclear path driven by grid reliability needs, existing infrastructure and workforce, and physical site characteristics	Coal-to-nuclear; educational attainment; pathway development between nuclear industry and the community recognizing mutual benefits from job retention and reuse of transmission resources
Muskegon, Michigan, USA	Plant owner's decision to remove coal from generation; attractive site - new industry developed due to proximity of the site to Lake Michigan	Land repurposed for deep water port facility to load, unload, store construction aggregate such as limestone, slag, trap rock, and ice control salt
Saint Paul, Virginia, USA	Concerns from consumer and environmental advocacy groups regarding pollution and cost burden to ratepayers	Nuclear SMRs under consideration; community- developed best practices
Tocopilla, Chile	National government-led voluntary yet binding retirement plan	Cross-ministry just transition process and worker training; private company analyzing pathways such as water desalination, hydrogen, solar manufacturing, and energy storage

Of the six communities analyzed in this report, three have formalized their transition plans or have completed their transitions: Centralia, Muskegon, and Kemmerer. Key decisions towards finalizing pathway selections were determined by the transition drivers and community characteristics, which can be broadly classified into five types:

1. Natural assets, geographic features, and existing infrastructure
2. Existing businesses and community resources
3. Existing skill sets of the local workforce
4. Improved energy quality
5. Improved community health and environmental outcomes

In the case of Centralia, a major driver was improved health and environmental outcomes, which led to investments being focused around innovative clean energy technologies. The particular solutions selected, however, were built around specific community characteristics. For example, energy efficiency and weatherization were chosen not only to enable decarbonization and energy cost savings, but also due to the characteristics of the local workforce, which included an abundance of suppliers and contractors who could readily perform the necessary upgrades.

This meant that not only would jobs be created immediately by labor-intensive industries, but also those jobs would be filled by the local community without the need to import skills from outside: the energy efficiency and distributed generation effort was serviced primarily by local contractors. In fact, when Ohio State performed quantitative analysis on this case study, the metric for which Centralia most distinguished itself was in its creation of new small businesses, many of them in the specialty construction sector, which includes most energy efficiency functions (Messenger and Partridge 2023).

Another Centralia characteristic is its location, lying off of a major interstate highway and located within driving distance of two major American cities: Seattle, Washington and Portland, Oregon. As a result, it was quickly recognized that community development investments would potentially attract new businesses, employers, and significant revenue sources such as sports tourism. General investments in the quality of life led to business-attracting conditions such as population retention and improved public spaces and educational programs.

Furthermore, the coal transitions board leveraged existing programs and community assets to disseminate the funds and stimulate additional private investments efficiently and quickly. For example, the residential energy efficiency funds were channeled through the existing Lewis County Public Utility District's energy efficiency program. At the same time, local community action agencies (CAAs), which had existing programs targeting low-income populations, were tasked with disseminating the grants to low-income residents. The board also leveraged the local college to provide expanded job training and vocational training programs and opportunities. In fact, the Centralia College Training Center, which the Coal Transition Grant Board helped to fund, was cited by DOE as a critical component in the recently announced Pacific Northwest Hydrogen Hub that will leverage the region's abundant renewable resources to produce clean hydrogen exclusively via electrolysis ("Regional Clean Hydrogen Hubs Selections for Award Negotiations," 2023).

By leveraging local labor and existing community assets, with an eye towards long-term sustainable growth and economic revitalization, Centralia's coal transition has opened up new innovation possibilities. These include the clean hydrogen hub and Tono solar farm that address multiple criteria for decarbonization and health, social, and economic benefits. Many communities and counties struggling economically amid energy transitions have ecosystems similar to Centralia's. The criteria for Centralia's investment decisions—creating high jobs-intensity, leveraging the local workforce and resources, engaging existing institutions, increasing disposable income, and enhancing quality of life—could be replicable in other small and rural communities with economies in need of sustainable and effective development strategies.

In the other two communities with completed or formalized transition plans—Muskegon and Kemmerer—the plan was led by the private sector where pathways are determined based on technical and economic feasibility, as well as specific community characteristics. In Muskegon, after many years of sitting idle, the Cobb plant site was repurposed into a water port facility. This decision was based on leveraging existing infrastructure and geographic features, including proximity to water and major roadways for transporting equipment, an existing port infrastructure, and land to store and process stone. Although community engagement processes had not been developed at the time, criteria for pathway selection included community benefits, such as environmental remediation of the site and shifting of commercial freight activity away from the residential and downtown areas of Muskegon (Coseo Properties, Inc. 2022). This decision supported the community's downtown redevelopment plan and improved residents' overall quality of life.

In Kemmerer, the transition driver was also market-based, and the community was competitively selected by TerraPower as a site for a nuclear reactor with molten salt storage. The community characteristics driving this decision were the need to compensate for the variability of wind and solar generators in the area and to bring in new sources of revenue and employment for the small town of Kemmerer, which was highly dependent on coal mining and generation. The existing infrastructure and local workforce characteristics also formed the basis of this decision. Converting the Naughton power plant into a nuclear facility would allow reuse of transmission assets and leverage the expertise of existing workers familiar with operating the equipment.

In the remaining three case studies—St. Johns, St. Paul, and Tocopilla—the transition processes are in various stages of being evaluated and formalized. While there is less information on pathway selections and outcomes due to the early transition stages, characteristics guiding consideration of various pathways in these communities can be generalized into three types:

1. Economic opportunity and technical feasibility

2. Implementation timelines

3. Natural and geographic features

St. Johns presents an interesting case where one criterion for pathway selection is the implementation timeline. While the long-term solution under consideration is SMRs, the utility has also developed a Phase 1 plan that would allow St. Johns to remain an energy-producing community while awaiting further evaluation and potential buildout of nuclear power. Coal will be replaced with technologies that can be implemented on a faster timeline, including biomass, wind, PV solar, and energy storage, which will also generate local employment for this small community. The utility has engaged in a transparent and thoughtful transition process with input from the community, labor unions, local college, and all levels of government, thereby increasing the chances of positive outcomes aligned with the common vision of stakeholders.

In the St. Paul case, the Virginia City hybrid plant will be closed primarily due to environmental pressures. The asset owner Dominion is driving the transition and leading analysis of technical and economic criteria. Due to the community's considerable distance from an interconnect and the facility's small capacity, solar generation has been deemed unfeasible. Wind was not selected because the community lacked relevant geographical features such as ridge tops that would support economic development of an onshore wind facility. Similarly, a lithium-ion energy storage facility at the coal plant site was considered undesirable as other locations in Virginia could provide better customer value. Dominion has determined that the site could support SMR technologies, but the option is under evaluation and a definitive path has not been selected. The community itself has developed good practices that include early and sustained community engagement; integration of transition timelines into broader state climate goals; transparency on pathway impact assessments and remediation plans; and financial support for affected communities. These guidelines are widely applicable and essential when the goal is supporting better decisions.

Lastly, Tocopilla's transition is occurring in a different country context where the energy market is entirely private, and companies' decisions are neither handled by the government nor eligible for state financial support. However, all company initiatives must be framed within state-defined policies and international commitments to achieve carbon neutrality by 2050. Repurposing options under consideration are based, in part, on natural characteristics such as its ocean location and desert climate; the asset owner is evaluating various transition pathways including water desalination, hydrogen, solar manufacturing, and energy storage. The government's role in supporting the transition is based on characteristics of the community's value system, which prioritizes environmental recovery, job creation, education, health, and sustainable development. Furthermore, the Chilean government coordinates across ministries and with local governments to nurture the regulatory and investment climate needed for economic revitalization and sustainable development. The government also has created a novel participatory process to develop a fair socio-ecological transition plan for Tocopilla and yield outcomes that align with local development and sustainability goals. This long-term vision for social and environmental well-being, complemented by near-term worker training and economic development, makes Tocopilla a case worth studying.

Across the various community types and transition drivers, a recurring lesson emerges: through early and sustained engagement and a concerted effort to benefit all parties, a smoother transition can be achieved. There is much to be learned from the processes developed for stakeholder engagement and joint decision making in Chile and across the communities examined in the United States. Rich insights are derived regarding how local assets can be leveraged for just and efficient resource distribution and how immediate needs and a long-term vision can be wedded to focus strategic investments.

Overall takeaways from these studies indicate that criteria must be adapted to the local context and significant effort should be invested early in the process to ensure a just and equitable transition. For some communities, the primary success factor was creating local, labor-intensive jobs, bolstered by substantial government support and clean energy investments. Others focused on optimizing local infrastructure or ensuring energy quality and resilience after phasing out coal power plants. Central to this process is identifying trade-offs among potential pathway options and considering justice metrics. For communities embarking on transition planning, a decision framework for navigating these trade-offs and evaluating justice outcomes would be invaluable. This is examined further in the next chapter.

9. Next Steps for a Decision Framework

In this section, a decision framework is proposed to support decision-making by fossil energy-dependent communities and the regional and national governments supporting them. The concept is sketched out in the general terms that follow and is intended to be evaluated with further input and response from communities, decision makers, and experts. The goal of the proposed tool is to inform fossil fuel transitions by putting people and community at the heart of decision making. The concept builds on the existing body of work described as follows.

To date, substantial effort has been invested in creating community development guidebooks and sharing lessons; however, these resources do not provide the necessary planning insights for policymakers and communities to evaluate options and tradeoffs. Several initiatives have aimed to simplify this process by introducing checklists or decision tools. For example, a Decommissioning Checklist developed by the Pacific Northwest National Laboratory can help stakeholders in power plant decommissioning to ensure an equitable process. Online tools like the Jobs and Economic Development Impacts (JEDI) from the National Renewable Energy Laboratory estimate economic impacts of constructing and operating power plants and other facilities. The World Bank supports two tools: (1) the Land Utilization Rating Application (LURA), a web-based application for better coal transition approaches; and (2) Repurposing for Advanced Coal Transition (ReACT), which identifies suitable coal power plants for early retirement and evaluates potential repurposing options. Of these, JEDI is best suited for project-level evaluation but is not applicable to broad regional economic assessments. While LURA emphasizes technical land-use assessments, it does not prioritize socio-economic implications arising from such changes. ReACT, though multi-faceted, is best suited to conceptual planning for infrastructure repurposing. Notably, existing tools do not incorporate justice metrics in informing fossil fuel transitions.

A new decision-making tool that encompasses essential metrics on economic implications and equitable outcomes of fossil fuel transitions is necessary to fill this gap; combining insights from case studies and iterative forecasting make it possible to develop such a tool. The proposed tool is to serve as a guide for the planning process, offering strategic insights and identifying gaps and tradeoffs for stakeholders. The primary audience served would be fossil fuel communities in the planning phase, particularly those navigating complex considerations related to economic and community effects, and the local and national governments supporting them.

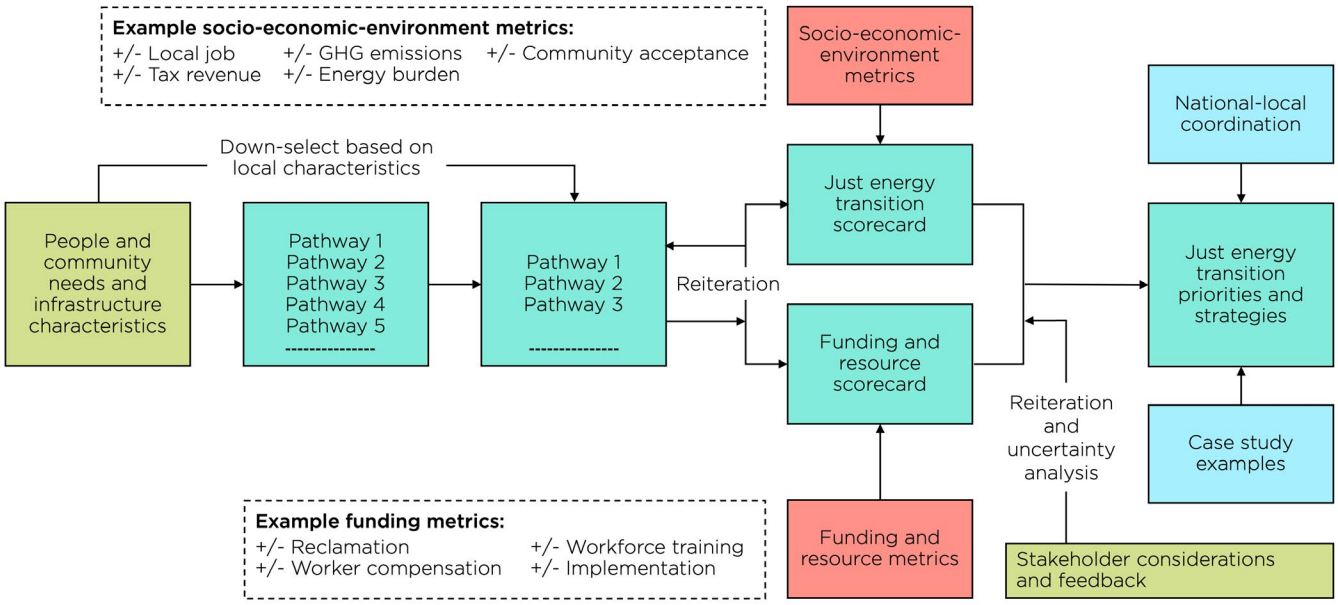

Figure 9: Example of proposed architecture for the fossil fuel transition decision tool.

Figure 9 illustrates a proposed architecture for the decision framework, which draws inspiration from several earlier efforts (Tarekegne, Kazimierczuk, and O'Neil 2022, Barlow, Tapio, and Tarekegne 2022, "Energy Justice Scorecard" 2022, "A Framework for Just Transitions – Just Transition Initiative," n.d.). Initially, the tool would prompt users to input essential data concerning people, community, and infrastructure characteristics. The tool would then refine transition pathway alternatives—for example, pursuing nuclear power plant development might be less favorable for a community facing water resource constraints—and generate timelines and rankings of energy and non-energy pathways based on the Delphi method described as follows, while also accommodating user modifications and iteration. This enables users to weigh their options and effectively formulate near- and long-term plans.

The Just Energy Transition Scorecard is intended to assess multiple dimensions encompassing social, environmental, and economic factors shown in Figure 10. Building upon existing research (Barlow, Tapio, and Tarekegne 2022) potential outcome-based or performance metrics could include indicators such as:

- Number of local jobs created
- Changes in local tax revenue
- Changes in GHG emissions
- Changes in energy burden and energy access
- Changes in energy reliability
- Changes in local environmental quality

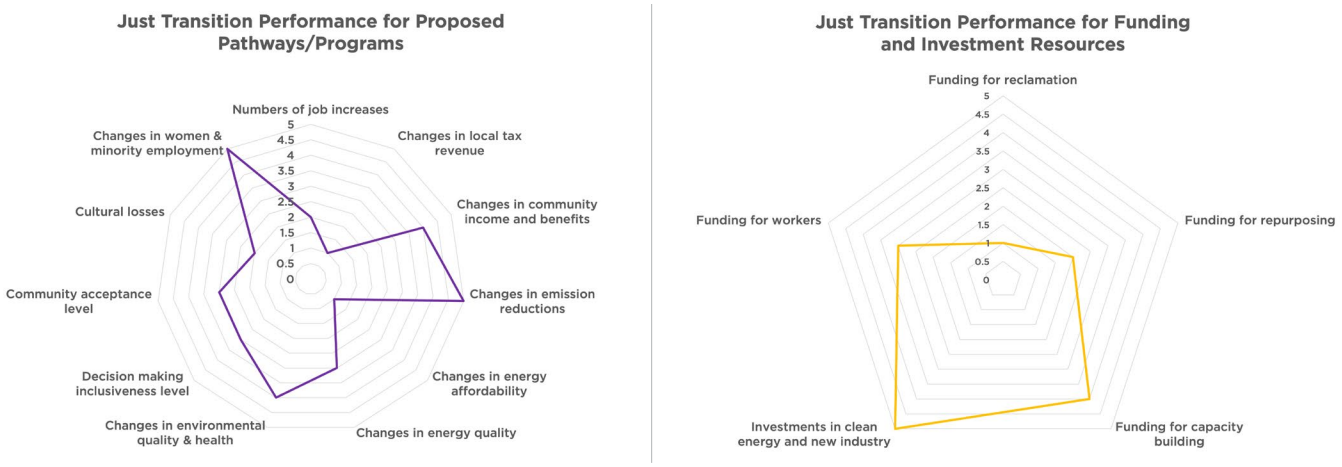

Figure 10: Example of proposed scorecards for Just Energy Transition performance and funding and investment needs.

Additionally, procedural justice is considered by incorporating process-based metrics like community acceptance levels, information sharing, and transparency. These metrics are aligned with principles of justice and consideration for how fossil fuel transitions may impact disadvantaged communities. The scoring methodology can hinge on varied techniques including the Delphi method, a renowned decision-making strategy that uses expert panels for group decision-making and iterative forecasting, making it especially apt for highly complex and unpredictable matters. JEDI, for example, can be employed to determine the default economic impact of a specific pathway anchored in community and project traits.

Scoring results must be subjected to rigorous iteration and uncertainty analysis and selection of specific metrics and their respective weightings need further refinement through stakeholder consultation. The scorecard's utility is further enhanced by permitting users to modify the default values and by assimilating learnings from broader case studies conducted in the future. Finally, the scorecard criteria and outcomes can serve as valuable inputs into and a framework for stakeholder dialogues, even if a user decides not to follow the tool step by step.

The proposed tool would also provide a snapshot of funding and investment resources to help users identify gaps. The required funding for each pathway is somewhat predetermined in the tool, based on the scale and nature of projects and number of affected communities. To estimate financial resources needed for worker compensation or pensions, the tool would rely on user input on the number of affected workers. Additionally, the scale of workforce training programs and education subsidies needed would be contingent on the impacted population and the pathway options chosen by the user.

Specific site conditions and selected pathways could also prompt a need for additional reclamation funding. While site reclamation does not typically generate a significant number of jobs, it is vital to the well-being of local communities and paves the way for future developmental opportunities. As seen in previous case studies, improving the community's quality of life leads not only to better health outcomes but to additional benefits such as population retention and cost savings, and paves the way for new revenue sources. This tool can also offer insights into the scale of investments and time needed for certain pathways, such as those required to launch a new advanced nuclear power plant project or energy storage manufacturing facility.

Exploring local clean energy or energy efficiency investment possibilities is equally important. Previous studies (Pollin and Callaci 2018, Pollin 2015) indicate that the U.S. economy sees a more significant job influx from clean energy investments compared to job losses from the phasing out of the fossil fuel industry. Specifically, a $1 million clean energy investment results in approximately 17 jobs across various U.S. sectors, whereas the same amount invested in existing fossil fuel infrastructure yields five jobs. Given these socioeconomic advantages, an ideal transition strategy would offset job losses from coal power phase-outs with local investments in energy efficiency and clean energy. This strategy was part of the reason for successful outcomes enjoyed by the community of Centralia, examined earlier; however, tailoring opportunities to suit the local context is crucial.

In summary, through the combination of case studies and the methodologies described herein, a more comprehensive decision-making framework can be developed to help guide policymakers, communities, and private sector players in evaluating tradeoffs, timelines, investment needs, and just transition metrics for energy and non-energy pathways. Further discussion and input are required to evaluate the utility of this tool.

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