20-YEAR CONCEPTUAL SCENARIO REPORT

For the State of Colorado

To comply with

Rule 3627
of the
Colorado Public Utilities Commission
Rules Regulating Electric Utilities

February 1, 2024

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ACRONYMS AND ABBREVIATIONS

Acronym or Abbreviation	Term
2024 Scenario Report	2024 20-Year Conceptual Scenario Report
Black Hills	Black Hills/Colorado Electric Utility Company, L.P., d/b/a Black Hills Energy
Commission or CPUC	Colorado Public Utilities Commission
CPWG	Conceptual Planning Working Group
FERC	Federal Energy Regulatory Commission
HVDC	High Voltage Direct Current
Public Service or PSCo	Public Service Company of Colorado
RES	Renewable Energy Standard
Roadmap	Colorado Greenhouse Gas Pollution Reduction Roadmap
SCADA	Supervisory Control and Data Acquisition
SPS	Southwestern Public Service Company
Tri-State or TSGT	Tri-State Generation and Transmission Association, Inc.
VPPs	Virtual Power Plants

I. Executive Summary

Rule 3627, which was adopted by the Colorado Public Utilities Commission ("CPUC" or "Commission") in 2011, requires the preparation and biennial submission of 10-year transmission plans and conceptual long-range scenarios that consider a 20-year transmission planning horizon. The first 10-year transmission plan was submitted jointly by Black Hills/Colorado Electric Utility Company, L.P., d/b/a Black Hills Energy ("Black Hills"), Public Service Company of Colorado ("Public Service" or "PSCo"), and Tri-State Generation and Transmission Association, Inc. ("Tri-State" or "TSGT") (each referred to individually as a "Company" and collectively as the "Companies") on February 1, 2012. In 2012, the Companies were not required to submit 20-year conceptual scenarios. The first 20-Year Conceptual Scenario Report was filed in 2014 with subsequent reports filed in 2016 and 2018. This 2024 20-Year Conceptual Scenario Report ("2024 Scenario Report") has been jointly prepared and is being submitted by the Companies.

Scenario-based analysis is a technique for considering uncertainties that may impact decision-making in today's world based on potential future conditions. It may be useful when evaluating long-term investments despite the inability to accurately predict future conditions. While it is impossible to predict the future with complete accuracy, scenario development can assist with the identification of strategic choices that utility planners, project developers, regulators, and advocates may reasonably need to consider over a 20-year time period.

The scenarios offered in this filing include three provided by Black Hills, three from Tri-State, and four from Public Service. The Companies' scenarios generally address what the future state of the transmission system might look like in Colorado based on the occurrence of different factors or events, including changes in generation mix, load growth, load demand, social, economic, generation technology, transmission assumptions, and changing public policy requirements.

II. Overview of the Colorado 20-Year Conceptual Scenarios Analysis

The 2024 Scenario Report identifies and assesses various credible future alternatives and provides information that can be used individually or in conjunction with utilities, coordinated planning organizations, lawmakers, and other industry stakeholders to further evaluate the ongoing transmission needs in the State of Colorado. These scenarios describe a set of economic, technological, and societal circumstances that the Companies believe could conceivably come to pass. Transmission planning study models are not developed to represent the 20-year conceptual scenarios.

Consistent with the requirements of Rule 3627(e), the Companies' conceptual scenarios discussed herein include, at a minimum:

- Reasonably foreseeable future public policy initiatives;
- Possible retirement of existing generation due to age, environmental regulations, legislation or economic considerations;
- Emerging generation, transmission, and demand limiting technologies;
- Various load growth projections;
- Studies of any scenarios requested by the Commission in the previous biennial review process; and
- Changes in market conditions.

III. Company Perspectives on Conceptual Scenarios Analysis

A. Black Hills

Black Hills recognizes the potential for 20-year conceptual planning to contribute to the development of 10-year transmission plans. While not all utilities and planning organizations will always agree about whether a particular future scenario is probable or realistic, simple consideration of the impacts of any and all given scenarios can only add

value to each Company's planning process. One distinction that sets Black Hills apart from some other entities in Colorado is that, as an electric utility under the jurisdiction of both the Federal Energy Regulatory Commission ("FERC") and the Colorado Commission, we must consider potential future federal and/or public policy initiatives that may not directly impact other entities. When considering the large number of potential future scenarios for this report, Black Hills also had the opportunity to explore and draw on the implications of various driving factors experienced by its sister electric utilities in Wyoming and South Dakota.

It is Black Hills' view that much of the planning work that previously has been performed within the various utilities and regional planning groups and reported in the preceding Rule 3627 20-Year Scenario Reports generally suggested transmission development to enhance reliability and connect planned and potential resources located along the southern and eastern part of Colorado to the Denver area load center. The increase of PV and DG interconnections will have a growing impact on future transmission scale renewables. The magnitude and timing of future transmission expansion, as well as the degree of participation from utilities and other entities, could be driven by any combination of drivers mentioned in Rule 3627(e).

For the purposes of this filing, Black Hills considered scenarios that are variations of those included in the previous filings, as well as new scenarios unique to this filing. The scenarios described below were selected by contemplating scenarios that provided dissimilar yet significant impacts to the transmission system while remaining plausible. There are no specific transmission plans associated with the scenarios described herein, but rather a general discussion of potential impacts and considerations.

B. Tri-State

Tri-State brings a unique perspective to the 20-year conceptual scenario planning process under Commission Rule 3627(e). While Black Hills and Public Service are investor-owned, vertically integrated electric utilities providing retail electric service in Colorado, Tri-State is a not-for-profit, generation and transmission cooperative providing

wholesale electric power to its 42 Member Systems located in four states: Colorado, Nebraska, New Mexico, and Wyoming.

Unlike Black Hills and Public Service, Tri-State is a regional power provider and its transmission system is designed and operated without specific regard to individual state boundaries. Rather, Tri-State operates an integrated, interconnected, interstate transmission system to deliver reliable, affordable, and economic power to its Member Systems. There also are generation resource differences that influence Tri-State's long-range conceptual transmission scenario perspectives, as compared to other utilities. Tri-State's generation resources are located in Colorado, New Mexico, Wyoming, and Arizona and require an interstate transmission system that efficiently moves that power to its Member Systems in Colorado and elsewhere.

In addition to these fundamental differences in transmission system and generation resource considerations, Tri-State faces other considerations that are the same or similar to those that apply to Black Hills and Public Service, including compliance with Colorado's Renewable Energy Standard, dynamic market forces, a changing resource mix driven by federal and state public policy developments, and expanding deployment of distributed generation and other technologies.

Tri-State's view of the long-range conceptual future is not limited to possible developments in Colorado and must consider the load-serving, reliability, economic, social, and technological needs of all of its Member Systems and the states in which they are located. All of these considerations influence Tri-State's conclusions with respect to what may constitute "credible alternatives" for purposes of 20-year conceptual scenarios.

Tri-State's 2024 Conceptual Scenarios, including rationale, drivers and assumptions behind each scenario, can be found in Appendix B.

C. Public Service

Public Service is one of four electric utility operating companies of Xcel Energy Inc., which is an investor-owned utility serving approximately 1.6 million electric customers in

the State of Colorado. Its electric system is summer peaking, with a 2023 peak customer demand of 7,364 MW. The entire Public Service transmission network is located within the State of Colorado and consists of approximately 5,000 circuit miles of transmission lines. Colorado is on the eastern edge of the WECC transmission system, which constitutes the Western Interconnection. The Western Interconnection operates asynchronously from the Eastern Interconnection. The Public Service transmission system is interconnected with the transmission system of its affiliate, Southwestern Public Service Company ("SPS"), via a jointly owned tie line with a 210 MW High Voltage Direct Current ("HVDC") back-to-back converter station. Most of the Public Service retail service customers are located in the Denver-Boulder metro area. However, the Public Service retail service territory also includes portions of the I-70 corridor to Grand Junction, the San Luis Valley region, and the cities and towns of Greeley, Sterling, and Brush.

One of Public Service's strategic priorities is to be a leader in transitioning its resource mix to clean energy sources. Xcel Energy, Public Service's parent company, aspires to deliver 100 percent carbon-free electricity to customers by 2050, with an interim goal of reducing carbon emissions from electric generation 80 percent below 2005 levels by 2030. In Colorado, Public Service's implementation of its 2030 clean energy goals comes through the Clean Energy Plan process created in SB19-236. Public Service filed its Clean Energy Plan with the Commission in 2021 in Proceeding No. 21A-0141E. The resulting resource and grid transformation needs are and will remain a significant factor in Public Service's transmission planning efforts for many years to come.

Public Service participates in CCPG, WestConnect, and WECC planning forums, including the subcommittees and working groups that perform transmission scenario analyses. Scenario outlooks differ from 10-year transmission analyses because the number of unknown factors to consider increases significantly with each year into the future. While 10-year plans tend to identify specific or conceptual transmission projects, the longer-term scenario analysis generally results in narrative descriptions of what major drivers to the power supply market might look like from a transmission perspective in the future. These drivers include generation mix, load growth, load

demand, transmission assumptions, and pending public policy requirements. Potential impacts to the transmission system are not described in terms of specific projects, but by conceptual descriptions of different drivers and scenarios that may impact transmission.

Scenario investigation can be informative to decision makers, especially during times of high uncertainty and risk as a result of factors such as uncertain economic conditions, changing environmental policy priorities, changes in penetration of renewable energy mix, and changes in efficiency standards. In the utilities industry, 10-year transmission planning analysis is sometimes referred to as "just-in-time planning" because the average time to analyze, site, permit, and construct transmission facilities to meet a known need is approximately seven to 10 years. Public Service's near-term planning and investment cycles are primarily driven by Colorado's public policy requirements and Public Service's goals for emissions reductions both in the electric sector as well as in other sectors of the economy. The 20-year scenarios will help inform the Company's efforts as it monitors developments that will come after the major compliance milestone of 2030 and toward a carbon-free electric system by 2050, consistent with Public Service's goals and Colorado policy.

Consistent with the Commission's directives in Decision No. C22-0319-I, Public Service provides the following supporting information concerning its 2044 load and generation forecasts. Public Service provides this data for informational purposes only and notes that this data was not used in any analysis supporting the qualitative scenarios identified in this Report. Public Service's generation data is based on Phase I of its 2021 ERP & CEP and load forecast data is based on Public Service's Fall 2022 load forecast, as filed with the Commission on March 31, 2023 in the ERP Annual Progress Report in Proceeding No. 21A-0141E. Expected summer and winter peak coincident generation mix information is provided at a system level consistent with the values developed in Portfolio SCC10-USA in Phase I of Public Service's 2021 ERP & CEP. The expected cost of electricity is sourced from Portfolio SCC10-USA and represents wholesale energy costs only with all delivery costs excluded. Public Service expects that the values identified in this table will change based on the selection of a Phase II resource

portfolio in the 2021 ERP & CEP but provides Phase I data in this report based on the timing of a final Phase II decision.

Table 3. 2044 Public Service Forecasted Electric Resource Planning Load and Generation Data

Summer Peak – Native Load	Winter Peak – Native Load	Reduced summer peak load when BTM generation is maximized	Reduced winter peak load when BTM generation is maximized	Expected summer peak coincident generation mix	Expected winter peak coincident generation mix	Expected Cost of Electricity (2024$/MWh)
7,918 MW	6,519 MW	7,590 MW	6,519 MW[1]	65% natural gas 11% storage 13% solar[2] 11% wind	76% natural gas 12% wind 11% storage	$157.50

Public Service Long-Term View

Based on the Company's goals, interest from customers and policymakers, and driven by technology change, there is one fundamental priority that Public Service anticipates will drive the next 20 years of change in the electric sector in Colorado: decarbonization. Public Service's generation and transmission systems sit at the precipice of transformational change driven by the Company's 2021 ERP & CEP, as well as by future resource acquisitions anticipated in 2024's Just Transition Plan resource solicitation and further upcoming resource plans. Nevertheless, while the approval and implementation of these near-term plans will be the primary drivers of change through the next decade, Public Service still sees longer-term uncertainty driven by policy, technology, and consumer interest. Public Service remains interested in considering the future scenarios that were originally described in the 2022 20-Year Scenario Report, which themselves built upon scenarios that have been identified and refined through

[1] Public Service's forecasted 2044 winter peak hour occurs during a time in which there is no forecasted BTM generation.

[2] Solar includes both behind-the-meter distributed and utility-scale resources.

previous reporting cycles. The scenarios identified by Public Service in this report help provide alternative viewpoints of a future that has the common destination of a carbon-free electric system.

The Commission has raised increasing concerns about the ability of near-term planning processes to sufficiently align the development of needed transmission with the speed of clean energy deployments. Public Service is working to ensure that its transmission planning processes are oriented towards the identification and development of "no-regrets" transmission solutions and believes that the 20-Year Scenarios identified here can play an informative role in the near-term planning processes to better align system expansion plans with reasonably expected longer-term system needs.

Because potential future scenarios are numerous, and due to the uncertainties discussed within this Report, the long-term view of the build-out of the state's transmission system retains significant elements of uncertainty. However, despite this uncertainty, Public Service sees common themes across this range of scenarios that reinforces the value of transmission expansion in supporting customers' energy needs and meeting emissions reduction objectives. Transmission expansion is a major component of the transformation of Colorado's electric sector across Public Service's four scenarios. Based on these scenarios, Public Service sees four common elements of transmission development that are likely to be needed in Colorado over the next 20 years. These elements include:

1.) increased transmission to deliver energy within the growing Front Range load center;
2.) increased transmission capacity to interconnect and deliver wind and solar resources developed on Colorado's Eastern Plains;
3.) increased transmission capacity to interconnect and deliver solar resources developed in the San Luis Valley; and
4.) increased transmission links to neighboring regions to maximize the value of resource portfolios that are predominantly wind and solar.

While the scale and complexity of these common transmission elements are expected to vary by scenario, the common elements will continue to guide Public Service's ongoing long-term planning efforts.

Public Service Scenarios

To develop and refine the four scenarios in this Report, Public Service looked to some of the analyses conducted as part of the 2021 ERP & CEP, as well as key public policy drivers that are likely to affect energy consumption by our customers and across the economy more broadly. However, these scenarios are speculative and qualitative in nature and as such the necessary detail to model the complete impact of each scenario is unavailable and the quantitative results of such analyses are not likely to provide significantly more value than a qualitative analysis because the assumptions are inherently highly uncertain. The 20-Year Report is meant to provide a directional indication of the impacts of possible futures on the transmission planning process and the general need for transmission expansion in Public Service's footprint – as such they are not meant to identify specific projects or outcomes. By evaluating multiple future scenarios – none of which are meant to be projections or predictions – Public Service, the Commission, and stakeholders are able to identify common takeaways and/or insights from a wide variety of potential futures that will qualitatively inform ongoing transmission planning efforts. Longer-term scenario analyses can help provide indicators and drivers that could prompt changes in the transmission solutions, allowing decision makers to make better-informed choices concerning investments in long-lived infrastructure.

Public Service Scenario #1: Accelerated Climate Action

This scenario is consistent with the Governor's Roadmap to 100% Renewable Energy by 2040 and the Colorado Greenhouse Gas Pollution Reduction Roadmap ("Roadmap") to demonstrate the impacts of both accelerated decarbonization of Colorado's electric sector as well as the increased drivers of electric demand represented in the Roadmap. This broad scenario considers additional demand drivers such as population growth,

EVs, and beneficial electrification growth partially due to natural gas to electric conversions in the Denver Metro Area, northeast Colorado and the Western Slope.

Public Service considered upon the outputs of its Roadmap Scenario from Phase I of the 2021 ERP & CEP that considered how aggressive electrification policy would impact the resource need and system emissions. This data was not used to quantify the future adequacy of transmission capacity to accommodate the load and generation identified in this scenario; however, it provides a directional indication that loads would likely be higher under a more aggressive decarbonization and electrification scenario. This would likely require an increase in transmission as thermal based resources are less likely to be operating and more renewables would be required. Under this scenario, electrification also significantly increases the winter load and the likelihood that Public Service becomes a winter peaking system.

The Roadmap provides illustrative examples of the impacts that this scenario has on generation resources and demand. The Roadmap's "HB19-1261 Scenario" demonstrates a pathway for generation and load that is consistent with Colorado's statutory carbon reduction goals. While this scenario does not include 2044 data to allow for complete alignment with the time period in this 20-Year Report, the rate of change demonstrated between 2020 and 2040 is nevertheless useful for understanding the evolution in Colorado's electric sector. The HB19-1261 Scenario shows a doubling of electric load between 2020 and 2040. Because of the compounding effects of meeting more load while transforming the sources of electric generation, changes to the state's generation fleet are more substantial. This scenario sees the phaseout of coal generation by 2040, gas-fired generation holding relatively steady, wind capacity increasing by approximately six times current amounts and utility-scale solar capacity increasing nearly 30 times. New technologies not currently used at large scale in Colorado also are major contributors, with clean dispatchable technologies growing to over 7 GW and utility-scale storage growing by over 4 GW of capacity between 2020 and 2040.

Public Service Scenario #2: High Penetration of Distributed Energy Resources

This scenario is designed to consider the impact of additional DER on transmission system expansion needs, and contemplates a future in which DER adoption rates accelerate substantially and a comparatively smaller proportion of customers' energy demand are served by remotely-located renewable resources. Customer interest and improving economics could drive greater adoption of distributed solar, energy storage, and flexible loads. Advanced technological solutions such as Virtual Power Plants ("VPPs") could also result in a comparatively. Energy storage in particular would serve as a major driver in this scenario, as the pairing of distributed storage with solar has the potential to improve the economics and operational benefits of both technologies.

An increase in DERs can have a mixed impact on the transmission system. Depending on the aggregate size of DERs and the resulting net injection at a transmission location, some transmission facilities may see increased flow levels (loading) while others could have reduced loading. Although this scenario could potentially slow investment in new transmission development, transmission may be necessary to address other drivers and changes in energy delivery and to maximize the benefits and value of distributed resources. This scenario continues to be of interest to Public Service. It is important to note Public Service has implemented over 600 MW of DER on its system through solar programs such as Solar*Rewards and Solar*Rewards Community, and Public Service expects to continue to enable customer adoption of DERs in the coming years. In its RES Plan filed in December 2021, Public Service has proposed plans that would lead to the adoption of over 700 MW of additional distributed solar resources through 2025.

Based on analysis provided in Public Service's 2021 ERP and CEP, increased DER generation capacity is anticipated to serve as a replacement for utility-scale solar on the Public Service system. In this scenario, Public Service expects that additional generating capacity located in the Denver Metro Area would increase relative transmission needs in that part of the state, while the reduced need for utility-scale solar generation could reduce transmission needs in southern Colorado and the San Luis Valley.

Public Service Scenario #3: Nationwide Infrastructure Initiatives

This scenario focuses on substantially increased coordination and transfer capabilities between the Eastern, Western, and ERCOT Interconnections and the construction of a national-scale energy grid to enable higher penetrations of renewable energy and reflects ongoing Commission and federal interest in promoting greater regional and interregional ties within the electric grids of the United States. Under this scenario, Public Service anticipates the development of new DC-Tie facilities, improvements to existing DC-Tie facilities, and the construction of a new HVDC transmission network to enable wind and solar generation in remote parts of the central and southwestern United States to be delivered to major coastal population centers. Public Service has not developed any quantitative analysis in support of this scenario, but relied on its experience working with state, regional, and federal groups on transmission planning and transmission policy to understand how a more interconnected national grid could affect Colorado electric utility customers, and the need for additional investment in transmission in Colorado. Public Service also considered studies of interregional transmission expansion such as the National Transmission Needs Study published by the United States Department of Energy in October 2023 in the development of this scenario.

Public Service Scenario #4: Technological Advancements

This scenario addresses the potential for the rapid acceleration in the development and deployment of new technologies that help enable a carbon-free power system: zero-carbon dispatchable generation resources, long-duration energy storage, flexible loads, and advanced transmission technologies. In this scenario, Public Service's 20-Year transmission plans would be impacted by the advent of larger-scale zero-carbon generation technologies such as advanced nuclear reactors, hydrogen, or carbon capture on new or existing fossil-fueled generators. Energy storage also could play a major role under this scenario as new low-cost, long-duration storage technologies could economically solve seasonal variability in renewable energy output. Furthermore, advanced transmission technologies could further enhance the reliability, resiliency, and

efficiency of the transmission grid. There is a range of outcomes for transmission needs in this scenario, as technologies would have competing pressures on transmission development.

The impact on transmission needs in this scenario is likely dependent on both policy choices and the nature of technological advancements, as the need for transmission system expansion could be reduced relative to renewables-heavy scenarios given that some zero-emitting firm dispatchable technologies are expected function similarly to existing large-scale central-station generators. However, energy storage creates uncertainty for transmission development. If policy preferences or market developments contribute to the availability of zero-emissions dispatchable generators, transmission needs could be potentially smaller than if policy preferences or market developments result in the develop of a grid that uses significant amounts of energy storage resources to balance the intermittent output of wind and solar generation. While energy storage has the ability to offset or delay the need for transmission in some circumstances, it also can be used to enable higher renewable energy adoption, which would increase the need for transmission infrastructure to interconnect and deliver remotely located generation resources.

IV. 20-Year Base Case Scenario

In Decision No. R14-0845, the Commission directed the Companies to include "at least one scenario that utilizes an updated 20-year base case power flow model" as part of the 20-Year Conceptual Scenario Report. Through CCPG's Conceptual Planning Working Group ("CPWG"), the Companies have worked collaboratively with stakeholders to develop a 20-year base case power flow model to serve as the basis of this scenario in previous 20-Year Conceptual Scenario Reports. While detailed analysis is not performed on the 20-year planning models due to the increasing levels of uncertainly looking beyond the five and 10-year horizons, the Companies presented a 20-year base case power flow model reflecting peak and off-peak conditions developed from a 10-year WECC planning model reflect projected renewable energy development

based on current Renewable Energy Standard ("RES") requirements for investor-owned utilities and cooperatives, as well as conceptual transmission projects.

Due to personnel turnover on the CPWG in 2023, CCPG's efforts to develop the 20-year base case power flow model for the 20-Year Conceptual Scenario Report have been delayed and the Companies are not able to present the 20-Year Base Case Scenario at this time. The Companies are working diligently to complete the CPWG's development of the 20-year planning model and will make a supplemental filing to present the 20-Year Base Case Scenario following the completion of the CPWG's model development. The Companies will endeavor to make this supplemental filing by March 1, 2024, to ensure that stakeholders are afforded adequate time to review and comment on this scenario as part of the 2024 Rule 3627 proceeding.

2024 Scenario Analysis Appendices

Appendix A:	Black Hills Scenarios
Appendix B:	Tri-State Scenarios
Appendix C:	Public Service Scenarios

Appendix A

Black Hills Scenarios

Black Hills Scenario #1: Significant Penetration of Distributed Energy Resources

1. *Description*

This scenario considers potential impacts of an increase of both distributed resources capacity and efficiency. Present and future public opinion may continue the push for an increase of distributed resources on the power system. Significant levels of distributed generation under off-peak conditions may result in power flows not typically found in the current system and not typically considered.

2. *Rule 3627 (e) Application*

Rule	Credible alternatives	Apply
(I)	Reasonable foreseeable future policy initiatives	**X**
(II)	Possible retirement of existing generation due to age, environmental regulations or economic considerations	**X**
(III)	Emerging generation, transmission and demand limiting	**X**
(IV)	Various load growth projections	**X**
(V)	Requested by Commission	

3. *Assumptions and Drivers*

- Public policy initiatives coupled with continued public interest toward rooftop/-community solar may increase the current distributed capacity.
- Typical power output curves for renewable resources may interact with typical load curves to cause flows and voltages not seen in the current system.
- Decreased cost and increased efficiency of DER
- Increased large-scale DER additions

4. *Indicators*

- One of the primary indicators of increased DER penetration would be a decrease of rooftop/community solar costs and/or development that may increase the efficiency of any DER generation.

5. Potential Benefits and Transmission Impacts to Colorado

The impact of distributed generation may result in the power system experiencing power flow not typically observed in the current system. This could be a positive and a negative impact depending on location of energy resources. It could allow for more available transmission capacity due to reduced power flows, as distributed generation can serve load without consuming space on transmission lines. A possible negative impact may include the need for increased reactive power capacity to maintain voltage during lighter load conditions.

Black Hills Scenario #2: Significant Increase in End-Use Electrification

1. *Description*

This scenario considers a significant increase in the development of customer loads distributed across the system due to widespread conversion of end-use processes to be electric-driven. As emission reduction targets from the power sector are achieved, a shift in focus to other areas such as transportation and industrial processes is likely to occur. While this could place an immediate burden on the distribution system infrastructure as well as system operators, there also are risks that should be considered for the transmission system.

A driver for this scenario is a proliferation of renewable energy resources coupled with the retirement of carbon-based generation, which has the potential to present its own set of issues related to voltage deviations, etc. that could be particularly problematic on weaker parts of the transmission and sub-transmission system.

This scenario could be evaluated at a high level through the evaluation of an increased load forecast scenario in planning assessments, assuming minimal dispatchable thermal generation online.

2. *Rule 3627 (e) Application*

Rule	Credible alternatives	Apply
(I)	Reasonable foreseeable future policy initiatives	**X**
(II)	Possible retirement of existing generation due to age, environmental regulations or economic considerations	**X**
(III)	Emerging generation, transmission and demand limiting	**X**
(IV)	Various load growth projections	**X**
(V)	Requested by Commission	

3. *Assumptions and Drivers*

- Emerging technologies in the EV industry and increasing effective ranges of EVs make EV ownership more broadly desired.

- Technological advances in heat pump technology can provide an alternative to carbon-based heat sources for residential and commercial applications.
- The increase of installed residential and commercial charging stations due to the increasing ownership of EV.

4. Indicators

- Increased sales and public interest of EVs and installation of residential and commercial charging stations across the electric system.
- Potential increases in sales of heat pump technology could indicate a continuing increase of potential energy need previously served with a non-electric solution.

5. Potential Benefits and Transmission Impacts to Colorado

Significant distributed demand growth can have an impact on the local and regional transmission system. If load assumptions used in planning assessments under-estimate the demand, it can materially alter transmission plans of any size. Not only are capacity and voltage issues of concern, but another consideration is the loss of life impacts to transformers. Extensive EV charging under peak conditions impacts the capacity of the electric grid. Alternatively, off-peak charging may result in prolonged periods of increased transformer temperatures rather than the typical cool-down period. If not designed properly to operate in these conditions, transformer loss of life could result.

As transmission plans are developed, there should be close coordination with utility and industry stakeholders to ensure appropriate load assumptions are considered.

Black Hills Scenario #3: Increase in Renewable Energy Resources and Battery Storage

1. *Description*

This scenario considers the impacts of carbon regulations that may reduce the use of higher carbon-intensive resources and increase the use of lower carbon-intensive resources. A change in Colorado's generation portfolio may require improvements to the transmission system to ensure reliability and power delivery capabilities from typically more isolated generation centers to load centers in more centralized locations.

2. *Rule 3627 (e) Application*

Rule	Credible alternatives	Apply
(I)	Reasonable foreseeable future policy initiatives	X
(II)	Possible retirement of existing generation due to age, environmental regulations or economic considerations	X
(III)	Emerging generation, transmission and demand limiting	X
(IV)	Various load growth projections	X
(V)	Requested by Commission	

3. *Assumptions and Drivers*

Current Colorado policy continues to show an increased interested in carbon emission reduction and places a greater focus on renewable energy generation. With utilities adopting clean energy plans, the amount of thermal carbon-based generation on the system is being reduced.

4. *Indicators*

- Increased public and political interests in a reduction of carbon emissions.
- Development of more efficient and reliable battery storage to help dampen out potential issues during peak time power consumption.

5. *Potential Benefits and Transmission Impacts to Colorado*

The increased implementation of generation with reduced carbon output can have both negative and positive effects on the transmission system. The existing power

system typically delivers power from centralized generation facilities to customers. With changes to how power is generated, there may be upgrades and additions to the system to ensure continued reliability. The different power output capabilities of lower carbon emission generation may present issues when they are unable to output maximum power. This could indicate the need for either battery storage or generation that is able to operate should load increase above the available renewable output capabilities.

Another challenge that comes from an increase of renewable resources lies in finding a suitable location for large wind or solar farms. Such land may be scarce in locations that act as load centers. This land also may be at long distances from local load. This may require additional transmission lines to reliably serve load.

Benefits to increasing the renewable profile of Colorado exist despite the challenges in this scenario. An increase in renewable generation may require additional transmission infrastructure. Increased infrastructure may help to reduce loading on existing transmission and could negate the need for upgrades or rebuilds. Additionally, power flow from existing carbon-intensive generation facilities can cause large power flows through systems when the normal paths to load are unavailable. Adding renewables may provide an opportunity to reduce potential through flow issues that can occur during outages on existing transmission.

Appendix B

Tri-State Scenarios

TSGT Scenario #1: Increased Role of Hydrogen

1. *Description*

There has been considerable interest in and federal funding for hydrogen projects in recent years. While current use of hydrogen is limited, it is possible that this technology will become more widely used during the timeframe addressed by this conceptual scenario. Specifically, hydrogen may be used: (1) as a scalable, long-duration-energy-storage technology, (2) as an alternative fuel for transportation, and (3) in certain industries such as steel manufacturing.

This scenario assumes continued and significant advancement and growth of hydrogen production and use, and considers the potential impact of such resources on the transmission system.

2. *Rule 3627(e) Application*

Rule	Credible alternatives	Apply
(I)	Reasonably foreseeable future policy initiatives	X
(II)	Possible retirement of existing generation due to age, environmental regulations or economic considerations	
(III)	Emerging generation, transmission and demand limiting technologies	X
(IV)	Various load growth projections	X
(V)	Scenarios Requested by Commission in 2022 biennial review process	

3. *Assumptions and Drivers*

- Continued interest, research and development, and funding is available for hydrogen technology.
- Technological advancements in electrolysis and other technologies increase the efficiency, cost-effectiveness, and scalability of large-scale hydrogen production.
- The growth and integration of renewable energy sources continues at a rate and scale that can support the electricity needed for hydrogen production.

- There will continue to be a growing need for large-scale, long-duration energy storage solutions to manage the intermittency of renewable energy sources. Hydrogen may be one potential solution to this challenge.
- Governments and regulatory bodies will create favorable policies and regulations to support the hydrogen economy, including investments in infrastructure and research and development.
- Public perception and market forces favor adoption of hydrogen technology over other possible alternatives. This includes consumer acceptance, the development of hydrogen markets, and the establishment of supply chains.

4. Potential Transmission Impacts to Colorado

An increase in hydrogen production and utilization, particularly if produced through electrolysis, may have significant effects on the transmission system. A primary benefit is that hydrogen production can function as a controllable load, potentially providing flexibility to the transmission system. This adaptability can help to balance periods of high renewable energy output and reduce overall transmission requirements. Hydrogen production could be a key driver in integrating more renewable energy sources, like wind and solar, into the grid. Since these sources are intermittent, hydrogen production can act as a form of energy storage, utilizing excess electricity to produce hydrogen, which can be stored and used as needed.

The location and scale of hydrogen production facilities might not always be ideal from a transmission system perspective, however. These facilities could require new transmission lines or upgrades to existing ones, especially if they are located far from current infrastructure or renewable energy sources. The variable nature of hydrogen production, potentially influenced by fluctuating electricity prices and renewable availability, adds a layer of complexity to transmission system planning and operation.

Hydrogen production may also have the potential to offset other competing technologies, such as batteries, both for energy storage and transportation applications. If this occurs, the transmission requirements associated with increased hydrogen

production may be offset in part by decreased requirements associated with competing technologies such as batteries and electric vehicles.

TSGT Scenario #2: Grid Resilience and Extreme Weather

1. *Description*

This scenario centers on the increasing focus and attention to grid resilience and hardening, especially as related to extreme weather events. Increasing risks and impacts from wildfires, severe winter storms, and other extreme weather events have led to increased interest in transmission hardening and other resilience measures to ensure reliability.

2. *Rule 3627(e) Application*

Rule	Credible alternatives	Apply
(I)	Reasonably foreseeable future policy initiatives	X
(II)	Possible retirement of existing generation due to age, environmental regulations or economic considerations	X
(III)	Emerging generation, transmission and demand limiting technologies	X
(IV)	Various load growth projections	
(V)	Scenarios Requested by Commission in 2022 biennial review process	

3. *Assumptions and Drivers*

- Increasing Frequency of Extreme Weather Events: The scenario assumes a rise in the frequency and severity of extreme weather events such as wildfires and severe winter storms, driven by climate change and environmental factors.
- Vulnerability of Existing Infrastructure: current electrical grids are vulnerable to these extreme conditions, leading to power outages, disruptions, and other failures.
- Policy and Regulatory Support: The scenario assumes a regulatory environment that recognizes the need for grid hardening and is supportive of investments and innovations in this area.

- Public Awareness and Demand: The scenario suggests an increased public awareness and demand for reliable power supply, especially in the face of extreme weather conditions.

4. Potential Benefits and Transmission Impacts to Colorado

In Colorado, where weather conditions can range from heavy snowfalls in the Rockies to dry, fire-prone summers, upgrading electric transmission infrastructure for resilience and hardening could significantly enhance power reliability and efficiency. Such improvements would ensure a more consistent and stable power supply across diverse geographical areas, especially in rural areas. This could be crucial not only for residential consumers but also for businesses and essential services that depend on uninterrupted power.

Specific impacts could include:

- Projects to physically reinforce power lines, poles, and other infrastructure components to withstand extreme weather conditions like high winds, heavy snow, floods, and wildfires. For example, replacing wooden poles with steel or concrete ones, burying power lines underground in vulnerable areas, and using more durable materials where possible.
- Technological Upgrades: Implementing advanced technologies to improve the grid's resilience. This includes smart grid technologies that allow for better monitoring and control, quick identification of faults, and faster response times. It also involves the integration of advanced communication systems for real-time data exchange and decision-making.
- Increased Redundancy and System Design: Designing the grid in a way that minimizes the impact of failures. This could involve creating additional redundant pathways for electricity flow, so if one part of the grid fails, the power can be rerouted from another source.
- Disaster Preparedness and Response Planning: Developing and updating disaster response and recovery plans to deal with potential large-scale disruptions, ensuring a quick and efficient restoration of services.

TSGT Scenario #3: 100% Renewable Energy by 2050

1. *Description*

Renewable energy will play an increasing role in Colorado's energy resource mix. This scenario assumes significant advancement and growth of renewable energy and energy storage technology and considers the potential impact of such resources on the transmission system. This scenario focuses on the growth of renewable energy resources such as solar PV, geothermal, wind, biomass (from plants), and hydro power.

2. *Rule 3627(e) Application*

Rule	Credible alternatives	Apply
(I)	Reasonably foreseeable future policy initiatives	X
(II)	Possible retirement of existing generation due to age, environmental regulations or economic considerations	X
(III)	Emerging generation, transmission and demand limiting technologies	X
(IV)	Various load growth projections	
(V)	Scenarios Requested by Commission in 2022 biennial review process	

3. *Assumptions and Drivers*

- The price and efficiency of renewable energy resources continues to fall over time.
- The price of energy storage technologies, particularly batteries, continues to fall over time, making batteries a more cost-effective transmission alternative.
- New storage technologies emerge that allow for greater storage capacities to serve transmission needs.
- Higher penetrations of renewables require additional storage on the system.
- Energy management technologies continued to develop to ensure appropriate balance of generation and load with solely variable energy resources.

- Inverter (grid-forming) technology develops to ensure reliable resource performance under system disturbances.
- While Tri-State is not required to file a Clean Energy Plan with the Colorado Public Utilities Commission, this scenario is consistent with the public policy evidenced by the clean energy targets set forth in Colorado Revised Statute § 40-2-125.5(3)(a)(II).

4. Potential Benefits and Transmission Impacts to Colorado

To achieve 100% renewable energy, geographically diverse resources and significant development of energy storage will be required to ensure transmission system reliability.

In this scenario, storage is used as an alternative to some traditional transmission projects, while additional transmission investment is required to ensure adequate transfer capability under extreme import/export conditions due to weather. These developments potentially would reduce the number and/or size of new, local transmission projects and also could potentially reduce associated transmission costs. However, regional transmission projects likely would continue to be necessary to solve import/export congestion issues. Similarly, the increased addition of energy storage also could result in a more robust transmission system that may be better able to accommodate maintenance of transmission lines and ensure continued reliable power delivery during unscheduled transmission line outages. That said, it is also possible that, due to the location of new renewable generation in particular resource-rich locations, there may be significant cost increases associated with land acquisition for transmission and generation development. Due to the remote nature of most areas where renewable generation is sited, additional transmission would likely be needed to move these resources to load centers.

Appendix C

Public Service Scenarios

Public Service Scenario #1: Accelerated Climate Action

1. Description

The assumptions in this scenario are consistent with the "HB19-1261" scenario identified in the Roadmap paired with Governor Polis' stated goal of moving Colorado to 100% clean energy by 2040. Electric demand approximately doubles in the state by 2040, driven by population growth, EV adoption, and beneficial electrification of fossil fuel end uses such as heating. This scenario also assumes growth of renewable energy, clean firm generation, and energy storage consistent with the Roadmap scenario.

2. Rule 3627 (e) Application

Rule	Credible alternatives	Apply
(I)	Reasonably foreseeable future policy initiatives	X
(II)	Possible retirement of existing generation due to age, environmental regulations or economic considerations	X
(III)	Emerging generation, transmission and demand limiting	X
(IV)	Various load growth projections	X
(V)	Requested by Commission	

3. Potential Benefits and Transmission Impacts to Colorado

The transformation of the use and generation of electricity in the state would lead to major additional transmission requirements. The doubling of electric demand in the state would be expected to require similar expansion of transmission to serve that load, and changes to the types of resources that meet this load would require further expansion of the transmission system. It is possible that these transmission expansions would be more local than regional in nature. The Pathway Project is a local transmission project expected to serve as a new backbone transmission loop to collect renewable power from the Eastern Plains and deliver that energy to the Front Range load center. In order to meet new electric demand while remaining compliant with state emissions reductions policies, this scenario dramatically

increases the need to generate and deliver additional renewable energy from diverse, resource-rich regions of the state such as southeastern Colorado and the San Luis Valley. Another impact could be changing the traditional peaking of the power system. Public Service's system is summer peaking, but under this scenario increased electrification – especially of heating end uses – would be expected to change the load shape of the Public Service system. While a more even load curve could allow for the more efficient use of existing and new transmission, changes to peak demand could drive further transmission expansion.

Public Service Scenario #2: High Penetration of Distributed Energy Resources

1. *Description*

This scenario addresses a situation that results in customers' energy needs being met in significant part by DERs such as distributed solar, energy storage, and flexible loads. Additional DER deployment would comparatively reduce the need for utility-scale solar and, to a lesser extent, firm resources. Although this scenario potentially could slow the investment of new transmission development, transmission may be necessary to address other drivers and changes in energy delivery and to maximize the value of DERs.

2. *Rule 3627 (e) Application*

Rule	Credible alternatives	Apply
(I)	Reasonably foreseeable future policy initiatives	X
(II)	Possible retirement of existing generation due to age, environmental regulations or economic considerations	X
(III)	Emerging generation, transmission and demand limiting	X
(IV)	Various load growth projections	
(V)	Requested by Commission	

3. *Potential Benefits and Transmission Impacts to Colorado*

Although this scenario potentially could slow the investment of new transmission development by offsetting the need to develop additional solar resources in southern Colorado and the San Luis Valley, transmission expansion within load centers would be necessary to address other drivers and changes in energy delivery, as well as to maximize the value of DERs by enabling them to serve more distant loads with generation in excess of local demand. A high penetration of DER could require changes in generation cost allocation; new distribution reliability issues; increased flexible generation resources that could be different than the

current resource mix, potentially resulting in the overbuild of capacity to ensure the appropriate resource flexibility; significant impact to reliability protection schemes on the distribution system; and the need for additional distribution reliability management systems that to date are not widely deployed. These management systems would be analogous to Supervisory Control and Data Acquisition ("SCADA") systems for the real-time operation and management of the transmission system. Extensive communication networks would be required, as well as data handling.

Public Service Scenario #3: Nationwide Infrastructure Initiatives

1. ***Description***

This scenario addresses the creation of a national-scale "super grid" to enable renewable energy to be exported from areas of the country with the most advantageous resource quality (wind energy from the Great Plains and solar power from the Southwest) to population centers primarily along the East and West coasts. This would rely on the integration of the Eastern, Western, and ERCOT Interconnections through enhanced DC ties, as well as a large-scale build-out of multiregional HVDC lines.

2. ***Rule 3627 (e) Application***

Rule	Credible alternatives	Apply
(I)	Reasonably foreseeable future policy initiatives	**X**
(II)	Possible retirement of existing generation due to age, environmental regulations or economic considerations	**X**
(III)	Emerging generation, transmission and demand limiting	**X**
(IV)	Various load growth projections	
(V)	Requested by Commission	

3. ***Potential Benefits and Transmission Impacts to Colorado***

Colorado is well-situated to serve as an exporter of renewable electricity due to its high-quality wind and solar resources. In addition to the development of additional DC ties between the Eastern and Western Interconnects that potentially could be located in eastern Colorado as well as HVDC transmission lines that would link Colorado to more distant load centers, the increased ability to integrate renewable energy created by higher export capacity would drive substantial renewable energy generation in Colorado. This increase in renewable generation would require additional development of local traditional transmission facilities to serve as a collector system for these new wind and solar resources.

Public Service Scenario #4: Technological Advancements

1. ***Description***

Under this scenario, Public Service anticipates that rapid advancement of various technologies could create additional tools that advance the decarbonization of the power sector. These tools could include resources such as new dispatchable zero-carbon generating technologies, like advanced nuclear reactors, hydrogen, or fossil fuels with carbon capture, energy storage solutions with the ability to meet demand over longer periods or to bridge seasonal variability in renewable output, new flexible load resources, or new transmission technologies that enhance the reliability and efficiency of the power grid.

2. ***Rule 3627 (e) Application***

Rule	Credible alternatives	Apply
(I)	Reasonably foreseeable future policy initiatives	
(II)	Possible retirement of existing generation due to age, environmental regulations or economic considerations	**X**
(III)	Emerging generation, transmission and demand limiting	**X**
(IV)	Various load growth projections	**X**
(V)	Requested by Commission	

3. ***Potential Benefits and Transmission Impacts to Colorado***

Rapid advancement of carbon-free technologies such as those identified in this scenario would enable meeting state policy goals while prioritizing affordability and reliability for customers. While renewable energy will meet substantial proportions of energy demand in Colorado, centralized power stations or energy storage resources located closer to loads could reduce the need for additional transmission development. Advanced transmission technologies that enhance the reliability and efficiency of the transmission system also could allow for greater utilization of existing transmission facilities and delay or offset the need for the development of new transmission capacity needed to reduce or eliminate congestion.