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 3, 2020

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ACRONYMS AND ABBREVIATIONS

Acronym or Abbreviation	**Term**
2020 Scenario Report	2020 20-Year Scenario Analysis Report
BHCE	Black Hills Colorado Electric Utility Company, L.P.
Black Hills or BHE	Black Hills Colorado Electric, LLC, d/b/a/ Black Hills Energy
CCPG	Colorado Coordinated Planning Group
Commission or CPUC	Colorado Public Utilities Commission
Companies	Black Hills, Tri-State and Public Service
Company	Black Hills, Tri-State or Public Service
CPWG	Conceptual Planning Work Group
CSU	Colorado Springs Utility
DER	Distributed Energy Resources
DG	Distributed Generation
EIM	Energy Imbalance Market
ERP	Electric Resource Planning
EV	Electric Vehicle
FERC	Federal Energy Regulatory Commission
HVDC	High Voltage Direct Current
IOU	Investor Owned Utility
ISO	Independent System Operator
JDA	Joint Dispatch Agreement
LDC	Local Distribution Company
MW	Megawatts
MWTG	Mountain West Transmission Group
NECO	Northeast Colorado
Public Service or PSCo	Public Service Company of Colorado
PV	Photovoltaic
RES	Renewable Energy Standard
RTO	Regional Transmission Operator
SPP	Southwest Power Pool
SB07-100	Colorado Senate Bill 07-100
SCADA	Supervisory Control and Data Acquisition

Acronym or Abbreviation	Term
TP	Transmission Provider
Tri-State or TSGT	Tri-State Generation and Transmission Association, Inc.
WECC	Western Electricity Coordinating Council
WEIM	Western Energy Imbalance Market

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 2020 20-Year Conceptual Scenario Report ("2020 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 five 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.

In addition to the Companies' scenarios, the Colorado Coordinated Planning Group ("CCPG") evaluated a scenario through the Conceptual Planning Work Group ("CPWG"). As with all CCPG activities, the CPWG was open to all interested stakeholders.

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

The 2020 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.

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.

Black Hills Scenarios

Included below is a brief summary of each of the scenarios explored by Black Hills. Full descriptions, including rationale, drivers and assumptions behind each scenario, can be found in Appendix A.

BHCE Scenario #1: Significant penetration of Distributed Energy Resources

This scenario recognizes potential increased penetration of Distributed Energy Resources ("DER"). This scenario focuses on development and growth of DER technologies. As public interest in DER increases, the increased output can have an impact on system voltage and line flows that are much different than present day system conditions. Increased efficiency and public interest in DER should be considered in transmission planning assessments and incorporated into transmission plans as appropriate.

BHCE Scenario #2: Significant Increased in End-Use Electrification

The scenario explores the impacts of substantial demand growth across the system as well as a more pronounced demand peak due to widespread electrification of end-use processes such as manufacturing and transportation. This load growth would be pervasive across the state but particularly disruptive in urban areas, creating challenges in reliably delivering energy to meet the demand, but also managing potentially problematic power quality or stability issues. Peak demand growth as well as consumption pattern changes in areas of probable load development should be considered in transmission planning assessments and incorporated into transmission expansion plans as appropriate.

BHCE Scenario #3: Significant Increase in Renewable Energy Resources & Battery Storage

This scenario considers the impact of an increased capacity of reduced carbon Renewable Energy Resources and the changes of potential voltage profiles and the possible system changes in power flow. The various power output profiles of Solar and Wind Generation, in conjunction with battery storage, can have unique impacts on the system voltages and flows when compared to current-day nonrenewable energy resources. The performance of increased renewable energy capacity and battery storage should be considered in transmission planning as appropriate.

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 43 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 2020 conceptual scenarios are summarized below. Full descriptions, including rationale, drivers and assumptions behind each scenario, can be found in Appendix B.

Tri-State Scenarios

In developing its scenarios for inclusion in the 2020 Rule 3627 filing, Tri-State considered key public policy, industry, and technology drivers that are likely to influence

– possibly to a significant degree – the operation and evolution of Colorado's transmission system over the course of the next 20 years.

Drivers identified in 2020 have many similarities to those discussed in Tri-State's 2018 20-Year Conceptual Scenarios. The increasing role of distributed generation resources discussed in 2020 Scenario 1 is consistent with a similar discussion in the 2018 Scenario 3. Likewise, increased East-West interconnection discussed in 2020 Scenario 2 is consistent with a similar discussion in the 2018 Scenario 4. 2020 Scenario 3, Increased Energy Storage, was not expressly discussed in the 2018 20-Year Plan, and is being included this year to reflect new possibilities related to new legislation in Colorado.

TSGT Scenario #1: Increased Role of Distributed Energy Resources

Distributed Energy Resources ("DER") continue to play an increasing role in Colorado's energy mix. This scenario focuses on the growth of distributed energy technologies such as solar Photovoltaic ("PV") generation, advancements in energy storage, and increased interest in and deployment of other distributed resources such as community wind, geothermal, biomass, small and micro hydropower, coal mine methane, synthetic gas produced by pyrolysis of municipal solid waste, and recycled energy, as well as associated public policy developments. This scenario assumes continued and significant advancement and growth of such resources coupled with low load growth and higher efficiency, and considers the potential impact of such resources on the transmission system.

TSGT Scenario #2: Increased East-West Interconnection

This scenario focuses on increased coordination and transfer capabilities between the Eastern and Western Interconnections. This scenario focuses specifically on the potential for new DC-Tie facilities, improvements to existing DC-Tie facilities, and the construction of new DC transmission lines. Tri-State's recent announcement regarding its intent to join the Western Energy Imbalance Service further increases the relevance of this scenario.

TSGT Scenario #3: Increased Energy Storage

Energy storage will likely play an increasing role in Colorado's energy mix. This scenario assumes significant advancement and growth of energy storage technology and considers the potential impact of such resources on the transmission system. In addition to serving as a resource to meet peak demand, energy storage also has important implications for transmission. In particular, energy storage, in appropriate cases, has the potential to defer or replace more traditional transmission projects. While energy storage costs have been falling quickly, and energy storage is currently a relatively expensive way to meet these needs, the energy storage capacities necessary to address transmission issues are generally very large. Nevertheless, should the price of energy storage continue to fall, storage may become a more significant component of Tri-State's transmission system planning. If this were to become the case, some new traditional transmission projects, such as those related to congestion relief, could be deferred or modified to the extent that a more cost-effective energy storage solution exists. While storage is unlikely to replace transmission projects primarily related to serving new load, it may have a substantial effect on other types of projects to the extent that storage can serve as an alternative.

C. Public Service

Public Service, one of four utility-operating company subsidiaries of Xcel Energy Inc., is an investor-owned utility ("IOU") serving approximately 1.5 million electric customers in the State of Colorado. Public Service serves approximately 75% of the State's population. Its electric system peaks in the summer with a 2019 peak customer demand of 6,881 Megawatts ("MW"). The entire Public Service transmission network is located within the State of Colorado and consists of over 4,700 circuit miles of transmission lines. Colorado is on the eastern edge of the Western Electricity Coordinating Council ("WECC") region, also referred to as the Western Interconnection, which operates asynchronously from the Eastern Interconnection. The Public Service transmission system has been interconnected with the transmission system of another Xcel Energy operating company, Southwestern Public Service Company, since December 31, 2004 via a jointly owned tie line with a 210 MW High Voltage Direct Current ("HVDC") back-to-back converter station. The Public Service retail service territory includes the Denver-Boulder metro area, as well as the I-70 corridor to Grand Junction, the San Luis Valley, Greeley, Sterling, and Brush. The Company's largest retail electric customer is EVRAZ North America, an industrial steel mill located in Pueblo.

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 pending environmental legislation, 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 7-10 years. Longer-term scenario analyses can help provide indicators and drivers that could prompt changes in the transmission solutions. This allows decision makers to make better-informed decisions for long-term based assets.

Public Service believes that conceptual scenario analysis also has the ability to help transmission planning and generation planning to become better integrated. These plans, even though conceptual, may inform the Electric Resource Planning ("ERP") process to some extent by identifying what may become the more cost-effective areas of the state to build generation due to transmission availability. By advancing these conceptual plans ahead of the ERP process, Public Service is also able to give developers and communities a heads-up on where the next lower cost resources could be located. This will also support the generation resource planning process by including possible resource costs and locations, and available transmission capacity for a period of 15 to 20 years into the future. In addition, resource plans that utilize the results of a competitive bidding process may help identify the general differences in cost between generation plans and their associated transmission expansion plans and cost. Likewise, transmission planners would be informed by the projected generation in the resource plans as a means to develop transmission expansion alternatives that could provide transmission access for various generation options.

Public Service continues to be involved in regional energy market development in the Western Interconnection as a means to improve management of conventional and variable energy resources as well as realize potential cost savings for our customers. Some studies have been conducted to identify the benefits of regional markets through stakeholder proceedings by WECC, evaluations of an Energy Imbalance Market ("EIM") by the Western Interstate Energy Board, as well as sub-regional studies including the analysis performed by the utilities from the Mountain West Transmission Group initiative and the most recent study performed by Public Service and the utilities in Public Service's Balancing Authority Area in the Joint Dispatch Agreement ("JDA Parties"). In December 2019, Public Service along with the JDA Parties announced their intent to join the Western Energy Imbalance Market ("WEIM") operated by the California Independent System Operator. Public Service's stance on regional markets is based on the following factors: 1.) pooled balancing obligations create a diversity benefit and reduced ramping requirements; 2.) improved transmission asset utilization can be attained through security-constrained economic dispatch; and 3.) reduction in required planning reserve capacity margin for resource adequacy needs, including consistency in application to all utilities. The issues around consolidated tariff administration for transmission access associated with potential regional market enhancements remain unresolved at this time.

Public Service Long-Term View

Public Service continues to be interested in the future scenarios that were described in the 2018 Scenario Report. Because potential future scenarios are numerous, and due to the uncertainties mentioned above, the long-term view of the build-out of the state's transmission system is uncertain. However, when looking at the results of the CCPG and past WECC scenario analyses, some common themes emerge. One is the potential for a transmission network that connects eastern Colorado to the Front Range load centers. Both the CCPG and past WECC scenarios indicate such a system may be necessary, if drivers emerge such as an increased requirement for renewable resources, or if a compelling reason arises to export power to other regions. The Lamar-Front Range Transmission Plan is another project that could play a role in facilitating these previously explored needs for cost-effective resource development in northeast Colorado as well as the southeast parts of the State.

Public Service Scenarios

In the planning cycle leading to the 2016 and 2018 20-Year Conceptual Scenario Reports, Public Service contemplated three possible scenarios. Those included:

1. Regional Market Dispatch
2. Significant Load Growth
3. High Penetration of Distributed Generation

These are scenarios that remain of interest to Public Service; and as a result, Public Service is providing updates on how each of these have actually started to impact the Company. Additionally, Public Service has added a fourth scenario of interest based on the Governor's roadmap: 100% Renewable Energy by 2040, and a fifth scenario based on new political proposals in Colorado where the gas Local Distribution Company ("LDC") system is eliminated.

Public Service Scenario #1: Regional Market Dispatch

This scenario contemplates the development of a large-scale regional market within the Western Interconnection that assumes a least-cost interconnection-wide dispatch with transmission solutions. This scenario assumes the development of an energy market across the interconnection that dispatches the least-cost generation across the least-cost transmission expansion needed to serve load. The Mountain West Transmission Group ("MWTG") was a coalition of 10 electricity service providers, including Public Service, representing approximately 6.4 million customers and 16,000 miles of transmission line primarily in the U.S. Rocky Mountain Region. MWTG began discussions in 2013 to evaluate a suite of options ranging from a common transmission tariff to membership in an existing Regional Transmission Operator ("RTO"). Extensive analyses indicated that RTO membership and market participation may provide greater benefits to customers than a common tariff alone. In April 2018, Public Service announced its withdrawal from MWTG.

In December 2019, Public Service announced that it intends to pursue participation in the Western EIM currently administered by the California Independent System Operator ("ISO"). The EIM is a real-time, imbalance energy market designed only to impact short term operations. The trans-mission impacts of participation in the EIM are minimal, as the market is only able to utilize the unused transmission capacity owned by participants. The project is in the early stages. In the first quarter of 2020, Public Service and the other JDA entities plan to hold discussions with the WEIM staff to determine a viable project schedule, leading to execution of a formal Implementation Agreement, which will be filed with FERC. Implementation into the EIM is expected in either April 2021 or April 2022.

Public Service Scenario #2: Significant Load Growth

This scenario is similar to the Significant Load Growth Associated with Oil and Gas Development scenario that has been considered in previous filings; however, this scenario broadens the scope beyond oil and gas development to include additional demand drivers such as population growth, electric vehicles, and natural gas to electric conversions in the Denver Metro Area, Northeast Colorado and the Western Slope.

The Weld County Expansion planning effort is contemplated to add high-voltage transmission plan in the northeast Colorado region to facilitate load growth, improve reliability, provide access to potential resources in the region, and complement longer-term transmission projects in northeast Colorado. Public Service is working through the CCPG to further develop these coordinated transmission plans.

Public Service Scenario #3: High Penetration of Distributed Generation

This scenario contemplated a future where distributed generation ("DG") would serve a significant portion of utility load, which could result in a reduced need for transmission expansion. Although this scenario could potentially slow the investment of new transmission development, transmission may be necessary to address other drivers and changes in energy delivery. This scenario continues to be of interest to Public Service. It is important to note Public Service has implemented over 550 MW of DG on its system through community solar programs such as Solar*Rewards and Solar*Rewards Community, which facilitates Community Solar Gardens and Public Service expects to continue to add DG in the coming years.

Public Service Scenario #4: 100% Renewable Energy by 2040

As discussed in the Public Policy section of the 10-year Report, Governor Jared Polis unveiled a "Roadmap to 100% Renewable Energy by 2040 and Bold Climate Action" on May 30, 2019. The roadmap seeks to transition the state of Colorado to 100% renewable energy by 2040.

A transition to 100% renewable energy would have a significant impact on transmission planning in the 20-year period. Load growth may occur from the electrification of transportation will and electrification of buildings will represent load growth as space heating and manufacturing needs shift from direct fossil fuels to electricity. Additionally, the Governor's roadmap contemplates the addition of new renewable energy generation resources. It will present a transformative future for Colorado's energy economy, of which electric transmission planning will be vital for delivery and reliability.

Public Service Scenario #5: LDC Gas Phaseout

This scenario addresses the potential elimination of the gas LDC system in response to new political proposals in Colorado. Public Service's 20-Year Transmission Plans would be impacted by the gas LDC phase out, which could significantly increase the current peak demand for electricity and call for commensurate additional transmission to add significant renewable generation.

IV. Colorado Coordinated Planning Group Scenario

The CCPG is a sub-regional group of WestConnect that includes transmission providers ("TPs") within the Rocky Mountain region and is open to stakeholder participation. Formed in 1991, the CCPG cooperates with state and regional agencies to assure a high degree of reliability in joint planning, development, and operation of the high voltage transmission system. The CCPG established the Conceptual Planning Work Group ("CPWG") in summer 2010 to develop 20-year planning models that could be used to evaluate longer-term transmission issues.

For this 3627 planning cycle, the CPWG created transmission models to reflect a 2040 planning horizon. Both peak and off-peak models were developed. The off-peak model reflected approximately 55% of the load that was in the peak model with high wind penetration and no solar. Wind generation was modeled at 20% of capacity for the peak case and 80% for the off-peak case. Additional details can be found in the CPWG 2040 Scenario Report. These models may be used by interested stakeholders to perform conceptual analyses.

The CPWG year 2040 Scenario Report is included as Appendix D.

The 2040 and previous year reports can also be found at:

http://regplanning.westconnect.com/ccpg_conceptual_planning_wg.htm

2020 Scenario Analysis Appendices

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 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	
(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 Distributed Energy Resources

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 to 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 install residential and commercial charging stations due to the increasing ownership of EV.

4. Indicators

- Increased sales and public interest of electric vehicles 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 intense resources and increase the use of lower carbon intense 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*

Black Hills has an ongoing RFP for renewable resources in our Colorado transmission system. Current Colorado policy shows 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 reliably 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 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 resource 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 may require additional transmission lines to provide a reliable serve to 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 intense generation facilities can cause large power flows through systems when the normal paths to load are unavailable. Added 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 Distributed Energy Resources

1. *Description*

DER continue to play an increasing role in Colorado's energy mix. This scenario focuses on the growth of distributed energy technologies such as solar PV generation, advancements in energy storage, and increased interest in and deployment of other distributed resources such as community wind, geothermal, biomass, small and micro hydropower, coal mine methane, synthetic gas produced by pyrolysis of municipal solid waste, and recycled energy, as well as associated public policy developments. This scenario assumes continued and significant advancement and growth of such resources coupled with low load growth and higher efficiency, 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 2018 biennial review process	

3. *Assumptions and Drivers*

- The price of solar PV continues to fall.
- There is continued interest and increased penetration of community-based and behind-the-meter business models that make solar PV available to more consumers.
- Energy storage technologies, particularly batteries, continue to improve and prices continue to fall, leading to wider deployment both in front of and behind the meter.
- Technological advances and regulatory policies are prompting utilities to explore the various applications of energy storage such as demand response, peak shaving, integration of renewables, and ancillary services.
- Existing and potentially increased state renewable energy standards and carbon reduction policies continue to drive the need for renewable resources at both the

utility and consumer levels. These policy drivers are complemented by changing market forces that result in competitive prices for renewable resource generation.

- Siting and permitting of central station power plants will become increasingly difficult.

- State regulatory policies involving interconnection, distribution system planning, and energy storage continue to evolve to drive increased levels of DER penetration.

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

An increase in DERs has the potential to delay or eliminate the need for new utility generation resources and significant transmission expansion, particularly if the DERs produce power during periods of peak demand. Distributed generation also has the potential to provide back-up power and reduce utility costs to the end user.

A potential consequence of high penetrations of distributed generation is that it can pose challenges to entities responsible for grid reliability. DERs are not always constructed at the location that is most beneficial to grid operations, and are not necessarily sized to meet system requirements. Furthermore, the wide range of DER types and sizes create uncertainties as to their operations and reliability. At high concentrations, DERs can impact the frequency and voltage performance of the local grid, especially following disturbances. The magnitude of their impact can be analyzed and incorporated into grid modeling, but only if the responsible entities participate in the analysis process.

TSGT Scenario #2: Increased East-West Interconnection

1. *Description*

This scenario focuses on increased coordination and transfer capabilities between the Eastern and Western Interconnections. This scenario focuses specifically on the potential for new DC-Tie facilities, improvements to existing DC-Tie facilities, and the construction of new DC transmission lines. This scenario is particularly relevant in light of Tri-State's recent announcement of its intent to join the Western Energy Imbalance Service.

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 2018 biennial review process	

3. *Assumptions and Drivers*

- Several Colorado utilities have joined the Western Energy Imbalance Service through Southwest Power Pool ("SPP").

- One anticipated advantage of membership in SPP is the possibility of operating the transmission system and associated generating assets in the Eastern and Western Interconnections as a single, optimized market.

- Full realization of these benefits may require the construction of improved or new facilities linking the two interconnections. If the initial market operations are successful, this could create an incentive to increase the transfer capacity between the two interconnections.

- The cost of future DC-ties or DC-lines could be subject to the SPP planning and cost-allocation process.

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

Increased east-west interconnection would result in many of the same benefits and impacts discussed above with respect to participation in an organized market, although they are separate concepts. Better east-west interconnection could complement market participation, but is not necessary for such market participation to occur. Instead, east-west interconnection would allow resources on Colorado's system to be used more readily on the SPP system, and vice versa. Under this scenario, resources could be dispatched across the entire SPP footprint.

In general, this scenario could result in potential production savings costs from increased interconnection and the ability to schedule greater power flows between the eastern and western systems. Because the increased interconnection could provide more system flexibility, generation reserve requirements may be reduced and some new transmission projects may be avoided through regional solutions that also provide local transmission benefits.

It is possible that the costs of improvements to existing DC-Ties as well as the costs of constructing new DC-Ties or DC lines between the Eastern and Western Interconnections would be allocated among the SPP membership, thereby potentially sparing Colorado utilities costs that would have been required if they sought to undertake such system improvements on their own.

TSGT Scenario #3: Increased Energy Storage

1. *Description*

Energy storage will likely play an increasing role in Colorado's energy mix. This scenario assumes significant advancement and growth of energy storage technology and considers the potential impact of such resources on the transmission system. In addition to serving as a resource to meet peak demand, energy storage also has important implications for transmission. In particular, energy storage, in appropriate cases, has the potential to defer or replace more traditional transmission projects. While energy storage costs have been falling quickly, energy storage is currently a relatively expensive way to meet these needs, and the energy storage capacities necessary to address transmission issues are generally very large. Nevertheless, should the price of energy storage continue to fall, storage may become a more significant component of Tri-State's transmission system planning. If this were the case, some new traditional transmission projects, such as those related to congestion relief, could be deferred or modified if a more cost-effective energy storage solution exists. While storage is unlikely to replace transmission projects primarily related to serving new load, it may have a substantial effect on other types of projects to the extent that storage can serve as an alternative.

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	
(V)	Scenarios Requested by Commission in 2018 biennial review process	

3. *Assumptions and Drivers*

- 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.

- Further storage-related legislation in addition to HB18-1270 continues to drive the use of storage.

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

In this scenario, storage is used as an alternative to traditional transmission projects, allowing those projects to either be deferred, modified, or avoided altogether. Further, in this scenario, storage would be used to address and ameliorate transmission congestion and allow existing transmission assets to be utilized more effectively. These developments potentially would reduce the number and/or size of new transmission projects and also could potentially reduce associated transmission costs. 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. Finally, increased storage capacity on the system is likely to increase the ability to integrate additional renewables and improve reliability due to the dispatching challenges associated with variable resources. While traditional transmission projects likely would continue to be necessary for serving new loads, as well as for certain other functions for which storage is not a practical alternative, increased energy storage has the potential to create significant transmission benefits in Colorado.

Appendix C

Public Service Scenarios

Public Service Scenario #1 Regional Market Dispatch

1. Description

This scenario contemplates the development of a large-scale regional market that assumes a least-cost interconnection-wide dispatch with transmission solutions. This scenario has assumptions similar to the scenarios developed by WECC, which implicitly include an energy market across the interconnection that dispatches the least cost generation across the least cost transmission expansion needed to serve load but on a more regional basis. Public Service acknowledges that in Colorado, announcements have been made by Public Service and Balancing Authority participants to join WEIM, while Tri-State and WAPA announced intentions to join EIS (with SPP). These could create complexities with this 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	
(V)	Requested by Commission	

3. Potential Benefits and Transmission Impacts to Colorado

Regional market operations, including the production-optimized cases used by WECC as a proxy, provide congestion price signals that indicate areas where transmission expansion could reduce societal costs for energy supply. The difficulty that still remains are the movement to a market based dispatch, regional tariff, and a means to address transmission investment and cost allocation.

Public Service Scenario #2: Significant Load Growth

1. *Description*

This scenario assumes that there are additional areas of load growth within the state such as oil and gas development and also additional demand drivers such as population growth, electric vehicles, and natural gas to electric conversions in buildings in the Denver Metro Area, Northeast Colorado and the Western Slope.

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*

Significant load growth in the state could lead to additional transmission requirements, but possibly more local than regional. Public Service continues to engage with CCPG groups such as the Northeast Colorado ("NECO") Subcommittee, which has been developing transmission plans for northeast Colorado, particularly in Weld County. In addition, Public Service has several planned and conceptual transmission projects for the Western Slope of Colorado that could be implemented depending on actual and forecasted load growth in the area.

Public Service Scenario #3: High Penetration of Distributed Generation

1. *Description*

This scenario addresses a situation that results in DG serving a significant portion of utility load, which could result in a reduced need for transmission expansion. Although this scenario could potentially slow the investment of new transmission development, transmission may be necessary to address other drivers and changes in energy delivery.

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*

Although this scenario could potentially slow the investment of new transmission development, transmission may be necessary to address other drivers and changes in energy delivery. A high penetration of DG could require changes in generation cost allocation; evaluations of new distribution reliability issues; increased flexible generation resources which could be different than the current resource mix that could result in the overbuild of capacity to ensure the appropriate resource flexibility; significant impact to reliability protection schemes on the distribution system; and the development of 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 #4: 100% Renewable energy by 2040

1. *Description*

This scenario addresses the Public Policy section of the 10-year Report. Governor Jared Polis unveiled a “Roadmap to 100% Renewable Energy by 2040 and Bold Climate Action” on May 30, 2019. The roadmap seeks to transition the state of Colorado to 100% renewable energy by 2040. However, this 100 percent renewable energy goal has not been placed into state statute by the Colorado Legislature.

A transition to 100% renewable energy would have a significant impact on transmission planning in the 20-year period. Large amounts of electric load growth would occur from the electrification of transportation and other forms of electrification under this scenario. Additionally, the Governor’s roadmap contemplates the addition of vast amount of new renewable energy generation and storage resources. Should this scenario be realized one day, it would present a transformative future for Colorado’s energy economy, of which electric transmission planning will be vital for delivery and 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	X
(IV)	Various load growth projections	X
(V)	Requested by Commission	?

3. *Potential Benefits and Transmission Impacts to Colorado*

Although this scenario takes into account load growth as referenced in Scenario #3, Public Service will need to also consider required transmission system changes to continue to provide reliable service and increase renewable generation injection capability along with the challenges it presents.

Public Service Scenario #5: Gas LDC Phaseout

1. *Description*

This scenario is new to the 2020 3627 report and responds to new public policy proposals in Colorado and elsewhere in the United States, whereby gas LDC (Local Distribution Company) systems eventually would be eliminated. Certain cities such as Berkeley, California, and Bellingham, Washington, have begun to implement policies where new gas installations in housing or buildings are prohibited, and these policy developments point to future efforts to retrofit all existing buildings to electrify space and water heating tasks otherwise performed by natural gas. Similar discussions and proposals have even begun in Colorado. The objective of such policies is to reduce or eliminate carbon dioxide emissions from the combustion of natural gas in buildings, and also to reduce or eliminate methane leakage in the supply chain of natural gas that no longer would be extracted, processed, and transported to buildings. Under this scenario, the Public Service gas LDC would be phased out over 20 years.

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 benefit of the gas LDC phaseout scenario is elimination of emissions from the combustion of natural gas. However, based on similar scenarios considered in Xcel Energy's Northern States Power System, the power generation and delivery system of Public Service, including the transmission, would need to massively increase. This would be required to replace the space and water heating tasks now performed by natural gas as delivered by the Public Service LDC (Public Service's service territories for electric and gas do not perfectly overlap, but we are ignoring that here in this high level discussion). Such a scenario likely would be accompanied by a very strong policy focus on renewable energy and other non-emitting generation in the power sector. The combination of dramatically increasing the generating capacity of the power system, and sourcing much of that growth from renewables, would call for significant amounts of additional transmission.

Another impact would be changing the traditional peaking of the power system. Public Service's system is summer peaking, but under this scenario the new electrical heating load would drive it to become a winter peaking electric system. This would create new planning implications for operational issues such as outage schedules, as the system would have two peaks per year. This scenario also likely would be accompanied by policies that create a high degree of electric vehicle (EV) implementation in Colorado, which would create still more increased load.

Appendix D

CCPG Scenario

CCPG Scenario: 20-Year Impact of State Statute RES Levels

1. ***Description***

This scenario contemplates that the requirements for utilities to serve demand with renewable energy will be modeled at 30% for Public Service and Black Hills, 20% for Tri-State, and 10% for all other utilities. Several sensitivities of this scenario were evaluated by the CCPG including a normal 2040 summer peak load and an off peak load scenario.

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

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	
(IV)	Various load growth projections	
(V)	Requested by Commission	X

3. ***Assumptions and Drivers***

- 30% Renewable Energy Standards ("RES") for Public Service and Black Hills, 20% for Tri-State, and 10% for other utilities
- 1.04% load growth
- Off-peak case with light loads and high wind outputs
- Renewable and conventional generation amounts and locations were contributed by the TPs and stakeholders.
- Transmission plans were added to a power flow analysis
- Detailed one-line diagrams were created from the power flow analysis for the summer peak case and the off-peak case

4. ***Indicators***

- Transmission plans include the Public Service Colorado Senate Bill 07-100 ("SB07-100") facilities and additional transmission lines to accommodate the RES assumptions

- Transmission lines added from the resources to load center based on engineering judgment and empirical knowledge

5. Potential Impacts to Colorado

If load continues to increase as modeled, significant transmission may need to be developed in the state to deliver renewable energy to load centers.

COLORADO COORDINATED PLANNING GROUP

CONCEPTUAL WORK GROUP

<u>Year 2040 Conceptual Power Flow Models</u>

January 6, 2020

Table of Contents

I. EXECUTIVE SUMMARY

The Colorado Coordinated Planning Group ("CCPG") created a Conceptual Planning Work Group ("CPWG") to create transmission planning models that could be used to consider longer-term issues beyond the typical 10-year planning horizon normally evaluated by transmission planners.

In 2019, the CPWG agreed to create 2040 transmission models for both peak and off-peak loading conditions. Public Service Company of Colorado, Black Hills Energy, Tri-State Generation and Transmission, and Colorado Springs Utility submitted their forecasted loads and generation dispatch to build the two models. The models provide a starting point for planners to evaluate "what-if" scenarios using a 20-year planning horizon. The models are available upon request, but subject to applicable non-disclosure agreements.

II. YEAR 2040 MODELING

A. Process

The participating utilities provided their forecasted 2040 peak summer load demand numbers and year 2017 historical load demand and energy consumption numbers as the starting point. The set of load demand numbers were used to calculate the incremental increase in demand from 2017 to 2040 for each utility. The percentage of increase in the demand numbers was used to calculate the energy output needed to meet the RES requirement for each utility. Each of the utilities also provided their mix and type of renewable resources that existed in 2017 and the renewable resources they plan to add to their system by 2040 to fulfill their energy requirements, assuming 30% for Public Service and Black Hills, 20% for Tri-State[1] and 10% for all other utilities. In addition, each utility agreed to identify the Energy Resource Zone ("ERZ") locations for their proposed renewable resources generation and their plant locations for their conventional generation to meet their load requirements. Tables 1-

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[1] Under HB10-1001 and SB13-252, investor-owned utilities are required to generate 30% of their electricity from renewable energy, of which 3% must come from distributed energy resources, cooperative utilities to generate 20% of their electricity from renewables by 2020, and 10% for others.

5 calculate each utility's generation needs based on the loads plus 16% reserves; Tables 7-8 allocate the required generation to their proposed generation plant locations and ERZs.

B. Assumptions

The following assumptions were used to develop the 20-year conceptual models for the State of Colorado, as agreed to by participants of the CPWG.

Load Demand Forecasts and Energy Consumptions

Black Hills Energy ("BHE"), Public Service Company of Colorado ("PSCo"), Colorado Springs Utilities ("CSU"), Platte River Power Authority ("PRPA"), and Tri-State Generation and Transmission ("Tri-State"), each provided a demand and energy "Base Case Forecast" for the year 2040, and an actual 2017 demand and energy load, *see* Table 1-5. The composite of the individual utility 2040 year information is shown in Table 6. Tables 1-5 show calculations for the generation output plus 16% generation reserve margin for the year 2040. The tables also show calculations for the renewable generation demand for the off-peak conditions. Where no numbers were submitted by a utility, 20% of wind generation capacity was assumed during the peak and 80% wind generation capacity available for the off-peak.

C. Heavy Summer Model

Base case forecast-summer peak

Using the existing actual 2017 demand and energy load and the 2040 demand and energy load forecasts from each individual utility, a generation dispatch was developed for each utility. The load forecast information from Table 1-6 shows that the composite load for these utilities was 10,649 MW for actual 2017 and 13,305 MW for 2040, the Base Case forecast. The load increase from 2017 to 2040 is 2656 MW. The incremental generation needed to cover this load increase is 3081 MW. Table 6 shows the allocation of generation required to meet the Base Case 2040 summer peak.

D. Off-peak Model

The off-peak model assumed an early spring or fall morning when load is about 55% of the summer peak.

<u>Base case forecast off-peak</u>

Each utility provided information as to how much of their renewable generation would be on during the off-peak load period. Tables 1-5 show the renewable and conventional generation that is modeled in the off-peak case. The off-peak model assumed wind generation at 80% of capacity and solar generation to be at 0% of capacity. Attached Table 6 shows the generation allocation. The total incremental wind level of off-peak generation for 2040 was calculated to be 3842 MW.

The off-peak case modeled a significant amount of the system load being served by renewable generation, with wind generation serving about half of the state load.

E. Allocation of Generation

a) For conventional generation, Table 7 shows the location and allocation of the assumed conventional generation in Colorado to make up for the load growth and 16% reserve margin.
b) For renewable generation, attached Table 8 shows the location and the allocation of the various renewable resources in the various ERZs as reported by the utilities.

F. Conceptual and Planned Transmission Projects in the Models

a) San Luis Valley Projects (conceptual)
b) Northern Greeley Area Plan (planned)
c) Southern of Greeley Area Plan (conceptual)
d) Southwest Weld Expansion Plan (planned)

G. Possible Coal Retirements by 2040

Some of the noteworthy coal plant retirements modeled are:

a) Comanche Unit 1 and Unit 2, 360 MW each (retired)
b) Hayden Unit 1 and Unit 2, 212 MW and 286 MW (modeled offline)
c) Craig Station Unit 1 (retired, replaced by fictitious renewable generator per Tri-State's request, 518 MW)
d) Pawnee, 535 MW (retired, replaced by gas generator per Public Service's request)
e) Nucla Station, 100 MW (retired)

III. HIGH-LEVEL COMPARISONS

In comparing the Colorado loads of the proposed 2040 study year with the 2038 study year, the 2038 load is comparable in magnitude to the 2040 study year – 13,093 MW for year 2038 versus 13,305 MW for year 2040. Since it was assumed that each utility's percentage renewable energy requirement used in preparing the 2040 case was the same as the 2038 case, this implies that any studies done in the 2018 filing still apply and do not need to be repeated.

In comparing the incremental generation of the proposed 2040 study year with 2038 study year, the total amount of generation needed to meet the future 20-year demand also is comparable in magnitude – 3635 MW for year 2036 versus 3265 for year 2040. The total generation values for both the peak and off-peak cases have the 16% WECC reserve margin requirement built in.

In comparing the transmission network of the proposed 2040 study year with 2038 study year, there are no significant changes between the 2038 study year and 2040 study year.

IV. DESCRIPTION OF THE TABLES, FIGURES, AND APPENDICES

Tables 1-6: Generation types (renewable and conventional) needed to meet the state energy renewable assumptions by 2040.

Table 7: Allocation and location of the conventional generation

Table 8: Information provided by utilities of generation based on ERZ location.

Figure 1: Diagram of the modeled power flow of the 2040 heavy summer base case.

Figure 2: Diagram of the modeled power flow of the 2040 off-peak base case.

Black Hills Colorado 2040

FILL IN SHADED CELLS WITH DATA

I. HISTORICAL TEST YEAR - 2017: DEMAND, ENERGY, PERCENT RPS, AND RENEWABLE RESOURCES

	Demand MW	Energy MWh	RES	RES Energy MWh	Renewable Resource Capacity Factor	Renewable Resource Nameplate Capacity MW	Renewable Resource Energy Output - MWh
Present Year Demand, Energy, and RPS	398	1,950,000	30%	585000			
Wind					0.38	90	299592
Solar					0.00	0	0
Photo voltaic					0.00	0	0
With Storage					0.00	0	0
Hydro					0.00	0	0
Bio-mass					0.00	0	0
Total present year renewable capacity						90	
Total present year renewable energy							299,592

II. GENERATION TO BE ADDED BETWEEN THE PRESENT YEAR AND YEAR TWENTY

	Capacity Factor	Nameplate Capacity MW	Energy Output - MWh
Wind	0.38	119	396127
Solar	0.18	24	37843
Photo voltaic	0.00	0	0
With Storage	0.00	0	0
Hydro	0.00	0	0
Bio-mass	0.00	0	0
Other	0.00	0	0
Total Added Renewable Capacity		143	
Total Added Renewable Energy			433970
Total Renewable Energy up to Year Twenty			733,562

III. YEAR TWENTY - 2040: FORECASTED DEMAND, ENERGY, AND PERCENT RES

	Demand MW	Energy MWh	RES	RES Energy MWh	Total Existing RES Energy up-to Year Twenty - MWh	Additional RES Energy Needed at Year Twenty	Additional Capacity Needed at Year Twenty
Growth 0.43% per year	439	2,477,000	30%	743100	733,562	9538	41

IV. RENEWABLE (ENERGY) GENERATION RATIO'D TO MEET THE RES REQUIREMENT AT YEAR TWENTY

	Renewable Resource Energy Output - MWh	Renewable Resource Capacity Factor	Resultant Nameplate Capacity MW
Wind	9046	0.38	3
Solar	492	0.18	0
Photo voltaic	0	0.00	0.0
With Storage	0	0.00	0.0
Hydro	0	0.00	0.0
Bio-mass	0	0.00	0.0
Other	0	0.00	0.0
Total Renewable Energy from Generation added in Year Twenty:	9538		

V. ON-PEAK CALCULATIONS AT YEAR TWENTY

	Total Nameplate Capacity MW	On-Peak Capacity Credit	Resultant Capacity MW	Planning Reserve Requirement
Wind	209	0.20	41.8	0.16
Solar	24	0.65	15.6	
Photo voltaic	0	0.00	0	
With Storage	0	0.00	0	
Hydro	0	0.00	0	
Bio-mass	0	0.00	0	
Other	0	0.00	0	
Incremental Conventional/Other Generation	-10	1.00	-9.8	
Net On-Peak Generation added at Year Twenty			47.6	

VI. OFF-PEAK CALCULATIONS AT YEAR TWENTY

Off-Peak Multiplier of Peak Demand: 0.55 Off-Peak MW: 241

	Total Nameplate Capacity MW	Off-Peak Capacity Credit	Resultant Capacity MW
Wind	209	0.80	167
Solar	24	0.00	0
Photo voltaic	0	0.00	0
With Storage	0	0.00	0
Hydro	0	0.00	0
Bio-mass	0	0.00	0
Other	0	0.00	0
Incremental Conventional/Other Generation	-141	1.00	-141
Net Off-Peak Generation Available at Year Twenty			26

TABLE 1

Public Service Company of Colorado 2040

FILL IN SHADED CELLS WITH DATA

I. HISTORICAL TEST YEAR - 2017: DEMAND, ENERGY, PERCENT RPS, AND RENEWABLE RESOURCES

	Demand MW	Energy MWh	RES	RES Energy MWh	Renewable Resource Capacity Factor	Renewable Resource Nameplate Capacity MW	Renewable Resource Energy Output - MWh
Present Year Demand, Energy, and RPS	6750	31,165,286	30%	9,349,586			
Wind					0.38	3157	10551568
Solar					0.29	286	718203
Photo voltaic					0.00	0	0
With Storage					0.00	0	0
Hydro					0.00	0	0
Bio-mass					0.00	0	0
Total present year renewable capacity						3443	
Total present year renewable energy							11,269,771

II. GENERATION TO BE ADDED BETWEEN THE PRESENT YEAR AND YEAR TWENTY

	Capacity Factor	Nameplate Capacity MW	Energy Output - MWh
Wind	0.38	969	3225607
Solar	0.29	722	1834169
Photo voltaic	0.00	0	0
With Storage	0.00	0	0
Hydro	0.00	0	0
Bio-mass	0.00	0	0
Other	0.00	0	0
Total Added Renewable Capacity		1691	
Total Added Renewable Energy			5,059,776
Total Renewable Energy up to Year Twenty			16,329,547

III. YEAR TWENTY - 2040: FORECASTED DEMAND, ENERGY, AND PERCENT RES

	Demand MW	Energy MWh	RES	RES Energy MWh	Total Existing RES Energy up-to Year Twenty - MWh	Additional RES Energy Needed at Year Twenty	Additional Capacity Needed at Year Twenty (MW)
Growth 0.992% per year	8471	44,753,088	30%	13,425,926.40	16,329,547	(2,903,621)	1721

IV. RENEWABLE (ENERGY) GENERATION RATIO'D TO MEET THE RES REQUIREMENT AT YEAR TWENTY

	Renewable Resource Energy Output - MWh	Renewable Resource Capacity Factor	Resultant Nameplate Capacity MW
Wind	-2449774	0.38	-734
Solar	-453847	0.29	-180
Photo voltaic	0	0.00	0.0
With Storage	0	0.00	0.0
Hydro	0	0.00	0.0
Bio-mass	0	0.00	0.0
Other	0	0.00	0.0
Total Renewable Energy from Generation added in Year Twenty:	-2903621		

V. ON-PEAK CALCULATIONS AT YEAR TWENTY

	Total Nameplate Capacity MW	On-Peak Capacity Credit	Resultant Capacity MW	Planning Reserve Requirement
Wind	4126	0.20	825.2	0.16
Solar	1008	0.65	655.2	
Photo voltaic	0	0.00	0	
With Storage	0	0.00	0	
Hydro	0	0.00	0	
Bio-mass	0	0.00	0	
Other	0	0.00	0	
Incremental Conventional/Other Generation	516	1.00	516.0	
Net On-Peak Generation added at Year Twenty			1996.4	

VI. OFF-PEAK CALCULATIONS AT YEAR TWENTY

Off-Peak Multiplier of Peak Demand: 0.55 Off-Peak MW: 4659

	Total Nameplate Capacity MW	Off-Peak Capacity Credit	Resultant Capacity MW
Wind	4126	0.80	3301
Solar	1008	0.00	0
Photo voltaic	0	0.00	0
With Storage	0	0.00	0
Hydro	0	0.00	0
Bio-mass	0	0.00	0
Other	0	0.00	0
Incremental Conventional/Other Generation	-2203	1.00	-2203
Net Off-Peak Generation Available at Year Twenty			1098

TABLE 2

Colorado Springs Utility 2040

FILL IN SHADED CELLS WITH DATA

I. HISTORICAL TEST YEAR - 2017: DEMAND, ENERGY, PERCENT RPS, AND RENEWABLE RESOURCES

	Demand MW	Energy MWh	RES	RES Energy MWh	Renewable Resource Capacity Factor	Renewable Resource Nameplate Capacity MW	Renewable Resource Energy Output - MWh
Present Year Demand, Energy, and RPS	890	4,746,000	10%	474600			
Wind					0.00	0	0
Solar					0.00	0	0
Photo voltaic					0.00	0	0
With Storage					0.00	0	0
Hydro					0.29	28	71131
Bio-mass					0.00	0	0
Total present year renewable capacity						28	
Total present year renewable energy							71,131

II. GENERATION TO BE ADDED BETWEEN THE PRESENT YEAR AND YEAR TWENTY

	Capacity Factor	Nameplate Capacity MW	Energy Output - MWh
Wind	0.00	0	0
Solar	0.25	264	573535
Photo voltaic	0.00	0	0
With Storage	0.00	0	0
Hydro	0.29	7	17783
Bio-mass	0.00	0	0
Other	0.00	0	0
Total Added Renewable Capacity		271	
Total Added Renewable Energy			591318
Total Renewable Energy up to Year Twenty			662,449

III. YEAR TWENTY - 2040: FORECASTED DEMAND, ENERGY, AND PERCENT RES

	Demand MW	Energy MWh	RES	RES Energy MWh	Total Existing RES Energy up-to Year Twenty - MWh	Additional RES Energy Needed at Year Twenty	Additional Capacity Needed at Year Twenty
Growth 1.0% per year	1119	5,494,000	10%	549400	662,449	-113049	229

IV. RENEWABLE (ENERGY) GENERATION RATIO'D TO MEET THE RES REQUIREMENT AT YEAR TWENTY

	Renewable Resource Energy Output - MWh	Renewable Resource Capacity Factor	Resultant Nameplate Capacity MW
Wind	0	0.00	0
Solar	-97875	0.25	-44.7
Photo voltaic	0	0.00	0.0
With Storage	0	0.00	0.0
Hydro	-15173	0.29	-6.0
Bio-mass	0	0.00	0.0
Other	0	0.00	0.0
Total Renewable Energy from Generation added in Year Twenty:	-113049		

V. ON-PEAK CALCULATIONS AT YEAR TWENTY

	Total Nameplate Capacity MW	On-Peak Capacity Credit	Resultant Capacity MW	Planning Reserve Requirement
Wind	0	0.20	0.0	0.16
Solar	264	0.65	171.6	
Photo voltaic	0	0.00	0	
With Storage	0	0.00	0	
Hydro	35	1.00	35	
Bio-mass	0	0.00	0	
Other	0	0.00	0	
Incremental Conventional/Other Generation	59	1.00	59.0	
Net On-Peak Generation added at Year Twenty			265.6	

VI. OFF-PEAK CALCULATIONS AT YEAR TWENTY

Off-Peak Multiplier of Peak Demand: 0.55 Off-Peak MW: 615

	Total Nameplate Capacity MW	Off-Peak Capacity Credit	Resultant Capacity MW
Wind	0	0.80	0
Solar	264	0.00	0
Photo voltaic	0	0.00	0
With Storage	0	0.00	0
Hydro	1	0.00	0
Bio-mass	0	0.00	0
Other	0	0.00	0
Incremental Conventional/Other Generation	146	1.00	146
Net Off-Peak Generation Available at Year Twenty			146

TABLE 3

Platte River Power Authority 2040

FILL IN SHADED CELLS WITH DATA

I. HISTORICAL TEST YEAR - 2017: DEMAND, ENERGY, PERCENT RPS, AND RENEWABLE RESOURCES

	Demand MW	Energy MWh	RES	RES Energy MWh	Renewable Resource Capacity Factor	Renewable Resource Nameplate Capacity MW	Renewable Resource Energy Output - MWh
Present Year Demand, Energy, and RPS	662	3,270,147	10%	327015			
Wind					0.00	0	0
Solar					0.25	30	65700
Photo voltaic					0.00	0	0
With Storage					0.00	0	0
Hydro					0.00	0	0
Bio-mass					0.00	0	0
Total present year renewable capacity						30	
Total present year renewable energy							65,700

II. GENERATION TO BE ADDED BETWEEN THE PRESENT YEAR AND YEAR TWENTY

	Capacity Factor	Nameplate Capacity MW	Energy Output - MWh
Wind	0.00	0	0
Solar	0.00	0	0
Photo voltaic	0.00	0	0
With Storage	0.00	0	0
Hydro	0.00	0	0
Bio-mass	0.00	0	0
Other	0.00	0	0
Total Added Renewable Capacity		0	
Total Added Renewable Energy			0
Total Renewable Energy up to Year Twenty			65,700

III. YEAR TWENTY - 2040: FORECASTED DEMAND, ENERGY, AND PERCENT RES

	Demand MW	Energy MWh	RES	RES Energy MWh	Total Existing RES Energy up-to Year Twenty - MWh	Additional RES Energy Needed at Year Twenty	Additional Capacity Needed at Year Twenty
Growth 1.0% per year	834	4,263,450	10%	426345	65,700	360645	172

IV. RENEWABLE (ENERGY) GENERATION RATIO'D TO MEET THE RES REQUIREMENT AT YEAR TWENTY

	Renewable Resource Energy Output - MWh	Renewable Resource Capacity Factor	Resultant Nameplate Capacity MW
Wind	0	0.00	0
Solar	360645	0.25	164.7
Photo voltaic	0	0.00	0.0
With Storage	0	0.00	0.0
Hydro	0	0.00	0.0
Bio-mass	0	0.00	0.0
Other	0	0.00	0.0
Total Renewable Energy from Generation added in Year Twenty:	360645		

V. ON-PEAK CALCULATIONS AT YEAR TWENTY

	Total Nameplate Capacity MW	On-Peak Capacity Credit	Resultant Capacity MW	Planning Reserve Requirement
Wind	0	0.20	0.0	0.16
Solar	30	0.65	19.5	
Photo voltaic	0	0.00	0	
With Storage	0	0.00	0	
Hydro	0	1.00	0	
Bio-mass	0	0.00	0	
Other	0	0.00	0	
Incremental Conventional/Other Generation	180	1.00	180.0	
Net On-Peak Generation added at Year Twenty			199.5	

VI. OFF-PEAK CALCULATIONS AT YEAR TWENTY

Off-Peak Multiplier of Peak Demand: 0.55 Off-Peak MW: 459

	Total Nameplate Capacity MW	Off-Peak Capacity Credit	Resultant Capacity MW
Wind	0	0.80	0
Solar	30	0.00	0
Photo voltaic	0	0.00	0
With Storage	0	0.00	0
Hydro	0	0.00	0
Bio-mass	0	0.00	0
Other	0	0.00	0
Incremental Conventional/Other Generation	110	1.00	110
Net Off-Peak Generation Available at Year Twenty			110

TABLE 4

Tri-State 2040

FILL IN SHADED CELLS WITH DATA

I. HISTORICAL TEST YEAR - 2017: DEMAND, ENERGY, PERCENT RPS, AND RENEWABLE RESOURCES

	Demand MW	Energy MWh	RES	RES Energy MWh	Resource Capacity Factor	Resource Nameplate Capacity MW	Renewable Resource Energy Output - MWh
Present Year Demand, Energy, and RPS	1949	10,834,712	20%	2,166,942.40			
Wind					0.45	368	1440985
Solar					0.25	30	66751
Photo voltaic					0.00	0	0
With Storage					0.00	0	0
Hydro					0.77	352	2374310
Bio-mass					0.00	0	0
Total present year renewable capacity						750	
Total present year renewable energy							3,882,047

II. GENERATION TO BE ADDED BETWEEN THE PRESENT YEAR AND YEAR TWENTY

	Capacity Factor	Nameplate Capacity MW	Energy Output - MWh
Wind	0.48	104	439121
Solar	0.31	100	268056
Photo voltaic	0.00	0	0
With Storage	0.00	0	0
Hydro	0.00	0	0
Bio-mass	0.00	0	0
Other	0.00	0	0
Total Added Renewable Capacity		204	
Total Added Renewable Energy			707177
Total Renewable Energy up to Year Twenty			4,589,224

III. YEAR TWENTY - 2040: FORECASTED DEMAND, ENERGY, AND PERCENT RES

	Demand MW	Energy MWh	RES	RES Energy MWh	Total Existing RES Energy up-to Year Twenty - MWh	Additional RES Energy Needed at Year Twenty	Additional Capacity Needed at Year Twenty
Growth 1.79% per year	2928	14,641,995	20%	2,928,399.00	4,589,224	-1660825	979

IV. RENEWABLE (ENERGY) GENERATION RATIO'D TO MEET THE RES REQUIREMENT AT YEAR TWENTY

	Renewable Resource Energy Output - MWh	Renewable Resource Capacity Factor	Resultant Nameplate Capacity MW
Wind	-680404	0.46	-167
Solar	-121166	0.28	-49
Photo voltaic	0	0.00	0.0
With Storage	0	0.00	0.0
Hydro	-859255	0.77	-127.4
Bio-mass	0	0.00	0.0
Other	0	0.00	0.0
Total Renewable Energy from Generation added in Year Twenty:	-1660825		

V. ON-PEAK CALCULATIONS AT YEAR TWENTY

	Total Nameplate Capacity MW	On-Peak Capacity Credit	Resultant Capacity MW	Planning Reserve Requirement
Wind	472	0.20	94.4	0.16
Solar	130	0.65	84.5	
Photo voltaic	0	0.00	0	
With Storage	0	0.00	0	
Hydro	0	0.00	0	
Bio-mass	0	0.00	0	
Other	30	0.00	0	
Conventional and Contract Purchases	399	1.00	399	
Incremental Conventional/Other Generation	558	1.00	557.7	
Net On-Peak Generation added at Year Twenty			1135.6	

VI. OFF-PEAK CALCULATIONS AT YEAR TWENTY

Off-Peak Multiplier of Peak Demand: 0.55 Off-Peak MW: 1610

	Total Nameplate Capacity MW	Off-Peak Capacity Credit	Resultant Capacity MW
Wind	472	0.80	378
Solar	130	0.00	0
Photo voltaic	0	0.00	0
With Storage	0	0.00	0
Hydro	0	0.00	0
Bio-mass	0	0.00	0
Other	0	0.00	0
Conventional and Contract Purchases	399	1.00	399
Incremental Conventional/Other Generation	-152	1.00	-152
Net Off-Peak Generation Available at Year Twenty			625

TABLE 5

2040 Base Forecast
for Colorado

Heavy Summer Peak
Incremental Generation -MW
from 2017 to 2040

Utility	2040 Load- MW	Incremental 2017-2040 Load-MW	Gen Wind Gw	Gen Solar Gs	Gen Hydro Gh	Gen Bio-mass Gb	Gen Other Go	Gen Conventional or Purchases	Gen Total
Black Hills Colorado	439	41	42	16	0	0	0	0	57
Public Service	7985	1235	825	655	0	0	0	516	1996
Colorado Springs Utilities	1119	229	0	172	35	0	0	59	266
PRPA	834	172	0	0	0	0	0	200	200
Tri-State G&T	2928	979	94	85	0	0	0	957	1136
Totals	13305	2656	961	927	35	0	0	1732	3655

55% Off-Peak	2040 Load- MW	Incremental 2017-2040 Load-MW	Gen Wind Gw	Gen Solar Gs	Gen Hydro Gh	Gen Bio-mass Gb	Gen Other Go	Gen Conventional or Purchases	Gen Total
Black Hills Colorado	241	23	167	0	0	0	0	0	167
Public Service	4392	679	3301	0	0	0	0	284	3585
Colorado Springs Utilities	615	126	0	0	35	0	0	32	67
PRPA	459	95	0	0	0	0	0	110	110
Tri-State G&T	1610	538	378	0	0	0	0	526	904
Totals	7318	1461	3846	0	35	0	0	953	4833

TABLE 6

Allocation of Conventional Generation - Year 2040

		Base MW
PSCo		
	Pawnee-100%	516
Black Hills		
	N/A	0
Colo Spgs Utilities		
	Nixon-100%	59
Platte River		
	Rawhide-100%	200
Tri-State		
	Craig and Contract Purchases	957
	Total	957
	Total	1732

TABLE 7

Year 2040 - Name plate Demand
Provided by utilities

Wind Generation

		ERZ1	ERZ2	ERZ3	ERZ4	ERZ5
Black Hills						209
PSCo		665	3219	237		
CSU						
PRPA		70				
Tri-State			472			
	Total	735	3691	237	0	209

Solar Generation

		ERZ1	ERZ2	ERZ3	ERZ4	ERZ5
Black Hills						24
PSCo			812		129	120
CSU						264
PRPA						
Tri-State			130			
	Total	0	942	0	129	408

TABLE 8

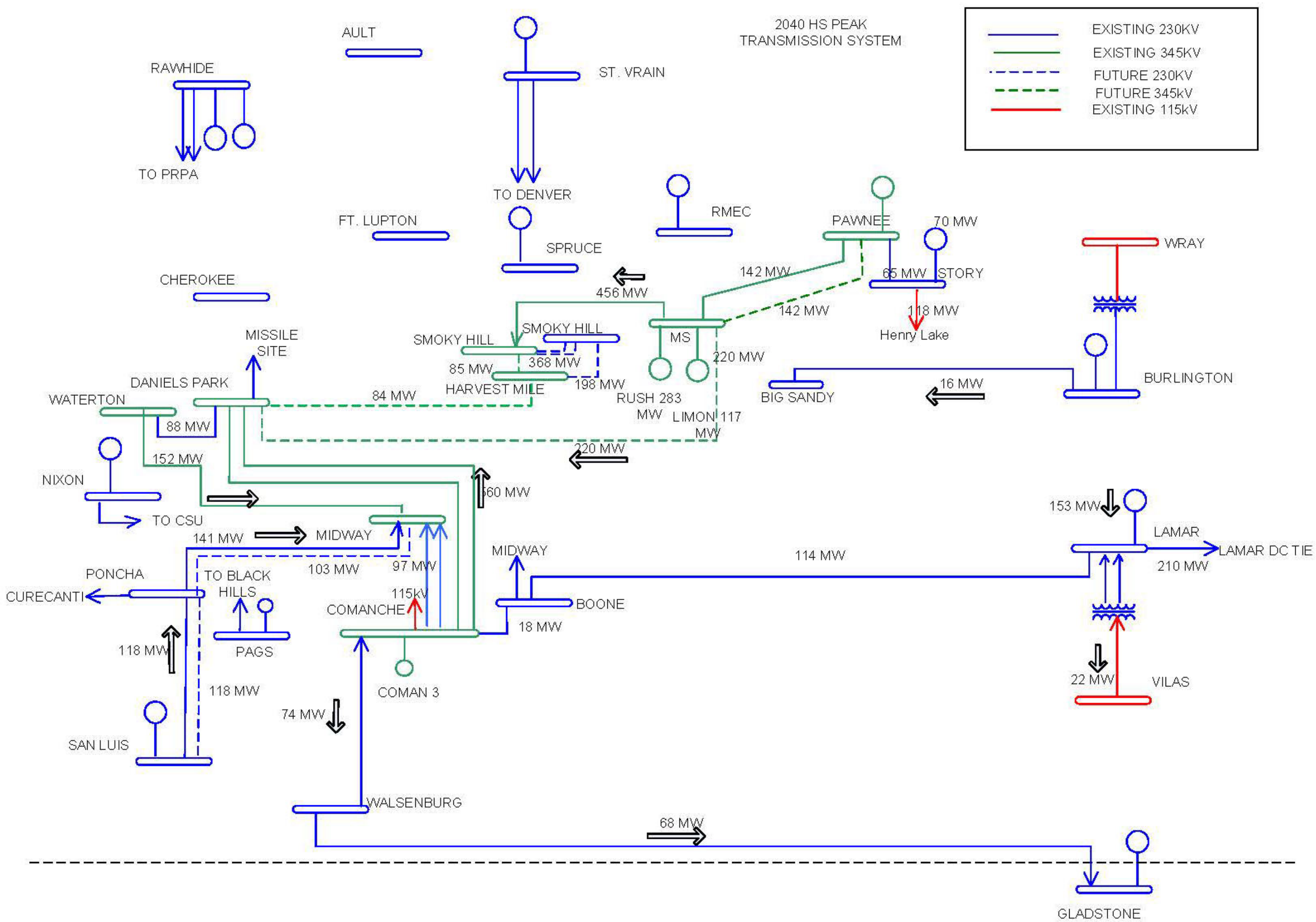
2040 HS PEAK
TRANSMISSION SYSTEM
EXISTING 230KV
EXISTING 345KV
FUTURE 230KV
FUTURE 345kV
EXISTING 115kV
AULT
RAWHIDE
TO PRPA
ST. VRAIN
TO DENVER
RMEC
FT. LUPTON
SPRUCE
PAWNEE
70 MW
WRAY
CHEROKEE
142 MW
65 MW
STORY
456 MW
142 MW
118 MW
Henry Lake
SMOKY HILL
SMOKY HILL
MS
MISSILE
SITE
85 MW
368 MW
220 MW
DANIELS PARK
HARVEST MILE
198 MW
BURLINGTON
WATERTON
84 MW
RUSH 283
MW
BIG SANDY
16 MW
88 MW
LIMON 117
MW
152 MW
220 MW
NIXON
560 MW
TO CSU
153 MW
LAMAR
141 MW
MIDWAY
LAMAR DC TIE
MIDWAY
114 MW
210 MW
PONCHA
TO BLACK
HILLS
103 MW
97 MW
CURECANTI
115kV
COMANCHE
BOONE
18 MW
118 MW
PAGS
22 MW
VILAS
118 MW
COMAN 3
74 MW
SAN LUIS
WALSENBURG
68 MW
GLADSTONE

FIGURE 1

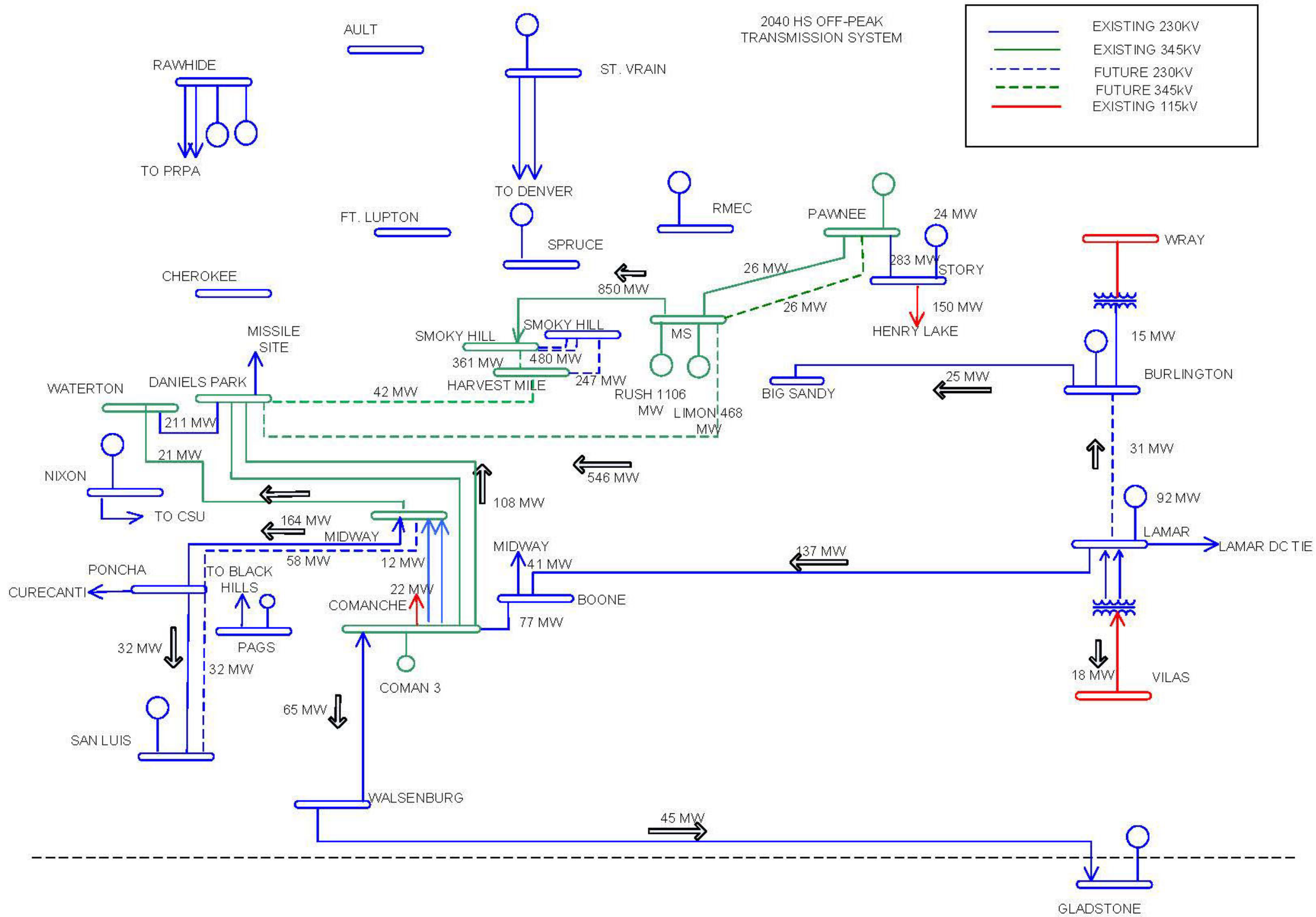
2040 HS OFF-PEAK
TRANSMISSION SYSTEM
EXISTING 230KV
EXISTING 345KV
FUTURE 230KV
FUTURE 345kV
EXISTING 115kV
AULT
RAWHIDE
TO PRPA
ST. VRAIN
TO DENVER
FT. LUPTON
SPRUCE
RMEC
PAWNEE
24 MW
283 MW
STORY
150 MW
HENRY LAKE
WRAY
CHEROKEE
26 MW
26 MW
850 MW
MS
SMOKY HILL
SMOKY HILL
361 MW
480 MW
247 MW
HARVEST MILE
RUSH 1106
MW
LIMON 468
MW
MISSILE
SITE
WATERTON
DANIELS PARK
42 MW
211 MW
21 MW
NIXON
TO CSU
546 MW
108 MW
164 MW
MIDWAY
58 MW
12 MW
MIDWAY
41 MW
BOONE
77 MW
PONCHA
CURECANTI
TO BLACK
HILLS
PAGS
22 MW
COMANCHE
COMAN 3
32 MW
32 MW
SAN LUIS
65 MW
WALSENBURG
45 MW
GLADSTONE
15 MW
BURLINGTON
BIG SANDY
25 MW
31 MW
92 MW
LAMAR
LAMAR DC TIE
137 MW
18 MW
VILAS

FIGURE 2