Transmission Expansion Study for Colorado

Assessing the Need for Expanded Transmission Capacity

March 22nd , 2024

Prepared for the:

COLORADO ELECTRIC TRANSMISSION AUTHORITY

GRIDWORKS

ENERGY STRATEGIES

Study Background and Meeting Purpose

- **In 2023, the State of Colorado directed CETA (SB23-016) to study the need for expanded transmission capacity in the State.**
- **In response, CETA conducted an RFP process seeking an independent consultant to conduct a transmission planning study that analyzes the need for expanded capacity in Colorado to:**
  - Help meet forecasted demand for electricity
  - Achieve the State's emission reduction goals
  - Improve powerflows on the system
  - Improve grid reliability
- **Project tasks identified in RFP that will be undertaken as a part of the study include:**
  1. Facilitating a comprehensive **stakeholder engagement** process, with a focus on modeling input assumptions and scenario analyses
  2. Reviewing, compiling and summarizing **utility and independent developer transmission plans** within Colorado
  3. Performing a **holistic transmission capacity expansion study** for Colorado
  4. Conducting a **gap analysis** that compares transmission projects included in utilities and independent developer plans to the project needs identified in the study

- **Purpose of today's meeting:**
  - ✓ Review draft 10-year assessment
  - ✓ Review draft 20-year Reference Case capacity expansion plan
  - ✓ Review scenario proposals and collect feedback
  - ✓ Continue review of study methods

Study Goal and Key Attributes

- **Study Goal: Adopt a long-run, holistic approach to identifying Colorado's need for expanded transmission capacity**
  - Look at "new" planning issues and scenarios not yet explored in other forums, with unique focus on 20-year horizon
  - Consider broad drivers of transmission: demand, policy, congestion, & reliability
  - Provide CETA with insight into any transmission "gaps" that may exist, assessing the ability of new transmission solutions to fill such gaps
- **Approach rooted in independent analysis, with input and advice from stakeholders, Colorado utilities, and transmission developers alike**

Key Attributes of CETA Transmission Study

- 10- & 20-year horizons
- Reference Case
- Scenarios
- Statewide resource forecast
- Resource potential analysis
- Wide range of Tx solutions
- Tx benefit analyses
- Resource busbar mapping
- Tx gap analysis
- Land use factors
- Stake-holder engage ment

Clarifying the intent of this work

What it is…

- ✓ Focused on identifying Colorado transmission needs, featuring a gap analysis that will target identification of some (but not all) needs that are not already met by planned projects
- ✓ An effort to identify viable transmission solutions that could meet the identified needs
- ✓ An independent assessment that seeks to benefit from broad stakeholder and utility input on models, data, and approaches
- ✓ A consideration of transmission projects that are "in-flight" and are likely to be built
- ✓ Concerned with identifying potential grid challenges

What it is not…

- × An ERP for Colorado utilities, a state-sponsored resource plan, or an endorsement of the same
- × A "state-wide" transmission plan – the goal is not to complicate the planning landscape & roles in Colorado
- × Designed to result in the "approval" of any individual transmission line
- × A detailed permitting, siting, or cost allocation exercise
- × Focused on supporting specific utility or developer transmission projects
- × A "selection" or formal endorsement of any particular transmission solution for a given need or corridor
- × An effort to "re-do" or undermine utility transmission planning

Study will feature 10- and 20-year horizons, with a focus on identifying long-run transmission gaps that may impact Colorado's ability to service loads, integrate new resources, and benefit from inter-state power exchanges

Meeting Content

1. Schedule Review, Stakeholder Comments, and Q&A Document [15min]
2. Draft 10-year Transmission Study Results and Conclusions [25 min]
3. Draft 20-year Reference Case Capacity Expansion Plan [20 min]
4. Scenario Proposals & Stakeholder Feedback [30 minutes]
5. Methodology Updates [10 min]
6. Stakeholder Questions [15 min]
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Timeline and Stakeholder Engagement

- **Initial Report due to the PUC by Sept. 1, 2024**
  - Transmission Plan Review
  - Holistic Transmission Study – 10- and 20-year horizons
  - Transmission Gap Analysis
  - Associated presentation and executive summary
- **Stakeholder Comment Period – Q3 2024**
- **Final Report due to the Joint Energy Committees by Jan. 31, 2025**
  - Final report
  - Associated presentation and executive summary

- **Stakeholder Meeting #1 – Feb. 9, 2024**
  - Methodology, reference case, busbar mapping, questions
- **Stakeholder Meeting #2 – Today**
  - Proposed study scenarios and stakeholder feedback
- **Stakeholder Meeting #3 – Early May**
  - Review 20-yr Reference Case reliability results with stakeholders and seek input on potential solutions
  - Production cost model preliminary results
- **Stakeholder Meeting #4 – July 2024**
  - Review production cost modeling results, top transmission expansion opportunities and dialogue on study outcomes
- **On-Going Informal Exchange**

Meeting Participation

"Active stakeholder engagement is a very important principle for this project."

- Mute your mic when you are not talking
- Hold questions until after the presentations
- Raise your hand when you wish to speak or use the chat
- Turn on your camera while talking
- Be respectful in your comments
- Share your ideas; leave time for others
- We are recording

Comment Themes & Q&A Document

- **Several recommendations for scenarios**
- **Advanced Transmission Technologies, reconductoring, Grid Enhancing Technologies**
- **Storage, Distributed Energy Resources, Virtual Power Plants**
- **Seams issues, market integration, ties to Southwest Power Pool and/or Eastern interconnect**
- **Clarifications on study methodology, assumptions, and busbar mapping**
- **Suggestions for other transmission plans to include**

See Q&A document on CETA webpage for answers to specific questions

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10-Year (2035) Study Purpose and Approach

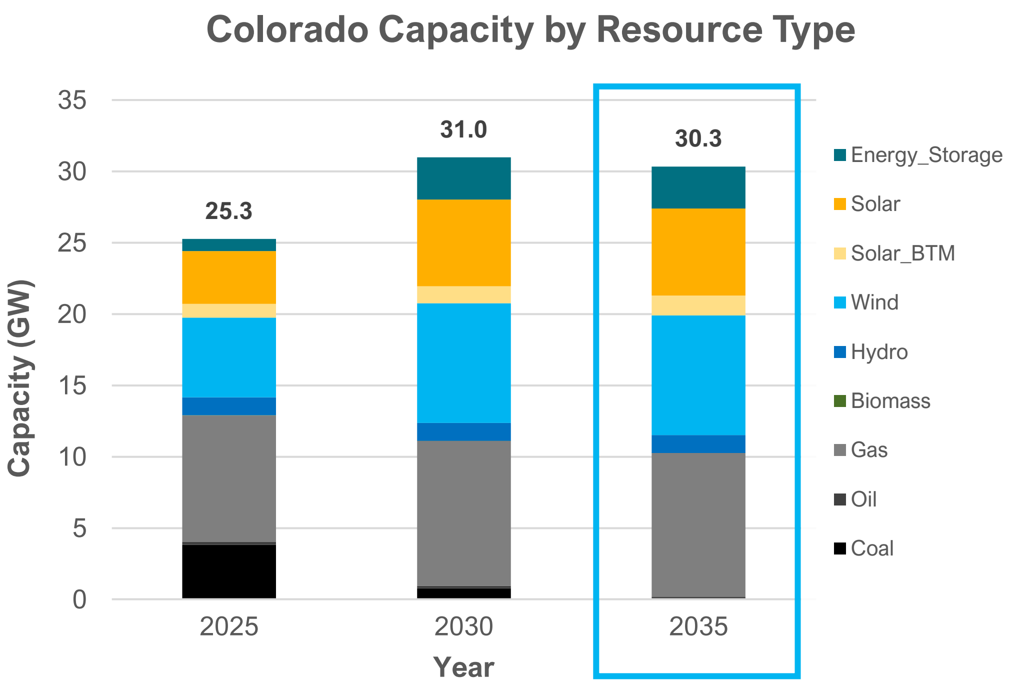
The study goal is to assess the ability of Colorado's planned transmission system to accommodate forecasted levels of load and generation consistent with Colorado utility ERP forecasts. Any potential transmission needs from this assessment will be considered alongside 20-year needs so that planning efficiencies can be considered.

- **Two grid conditions were considered to test for both (a) broad transmission reliability ("Reliability Case") as well as (b) the potential for deliverability constraints ("Deliverability Case")**
  - For the purposes of this study we refer to "deliverability" to describe the ability of a localized system to transmit power from resources to loads during times of system stress
- **Another purpose of the study is to build models that will serve as a starting point for the 20-year reliability and production cost model assessments**
- **The study team reviewed each generator in Colorado to ensure representation of retirements, planned generation additions, and planned transmission projects**

Key Assumptions	
Seed Case	WECC 2034 HS
Loads	Scaled 2034 loads in Colorado powerflow areas by ~2% based on growth forecasts in Colorado utility ERPs
Study Scope	Limited to steady-state contingency analysis and monitoring for thermal violations and voltage instability.
Monitoring	All busses, lines, and transformers >100-kV in Colorado were monitored for violations
Contingencies	Study focused on NERC Category P0 (system enact, N-0) and NERC Category P1 (single contingency, N-1) performance
Criteria	System performance was evaluated against NERC and WECC reliability standards, specifically: • NERC TPL-001-5.1 Transmission System Planning Performance Requirements • WECC TPL-001-WECC-CRT-4 Transmission System Planning Performance
System Adjustments	The study did not consider redispatch or congestion management as a means to mitigate transmission violations
Benchmarking	Pre-existing issues in the seed case were reviewed and excluded from the analysis when insignificant. The majority of such issues were low-voltage transformer and line overloads.

Key Assumptions for 10-year Study

- **Generation plans:** Resources in Colorado included existing, planned (contracted/firm), and conceptual additions all per utility ERPs
    - Total capacity operational in 2035 is based on a forecast of ~19 GW of existing generation, 9.7 GW of planned capacity (per ERPs), and 1.37 GW of generic conceptual capacity (per ERPs)



Colorado resource mix for study

- **The primary difference between the Reliability Case and the Deliverability Case was:**
    - Generation dispatch by case and resource vintage/type as follows:

	Reliability Case Dispatch		Deliverability Case Dispatch	
	Existing	Planned/ Conceptual	Existing	Planned/ Conceptual
Thermal	90-100%	90-100%	100%	100%
Wind	67%	30%	67% / 80%*	100%
Solar	86%	50%	85%	100%
Storage	TBD%	0%	0% / 100%*	100%

*Dispatch of resources in study pocket

    - Study zones – The Reliability Case was a **state-wide study** where all lines and zones in Colorado were evaluated simultaneously, whereas the Deliverability Case was a **zone-by-zone assessment** evaluating the ability of the system to accommodate maximum output for a given zone during peak conditions
        - Study zones informed by transmission constraints: NE Colorado; SE Colorado; SLV; Western Slope
    - The Deliverability Case assumptions were heavily informed by PSCo transmission planning dispatch assumptions used by PSCo to assess the ability to add Network Resources to the system
- **Load in Colorado planning areas was assumed to be 15,231 MW for both studies**

ENERGY STRATEGIES

Planned Transmission Projects

A comprehensive transmission plan and project review was conducted to identify projects that are likely to be in-service by the 10-year study horizon. Projects not included in the 10-year horizon ("conceptual projects") will be considered as alternatives to meeting any identified transmission needs.

- **Planned projects** collected by Colorado utilities and included in the 10-year study

Colorado Power Pathway (PSCO)	ISD
Seg. 1: Ft. St Vrain - Canal Crossing 345 kV	2026
Seg. 2: Canal Crossing - Goose Creek 345 kV	2025
Seg. 3: Goose Creek - May Valley 345 kV	2025
Seg. 4: May Valley – Tundra 345 kV	2027
Seg. 5: Tundra – Harvest Mile 345 kV	2027

Responsible Energy Plan (TSGT)	ISD
Burlington-Lamar 230 kV	2025
Boone-Huckleberry 230 kV	2026
Big Sandy-Badger Creek 230 kV	2028

- **Conceptual projects** not included in the 10-year study but collected from developers or utilities:

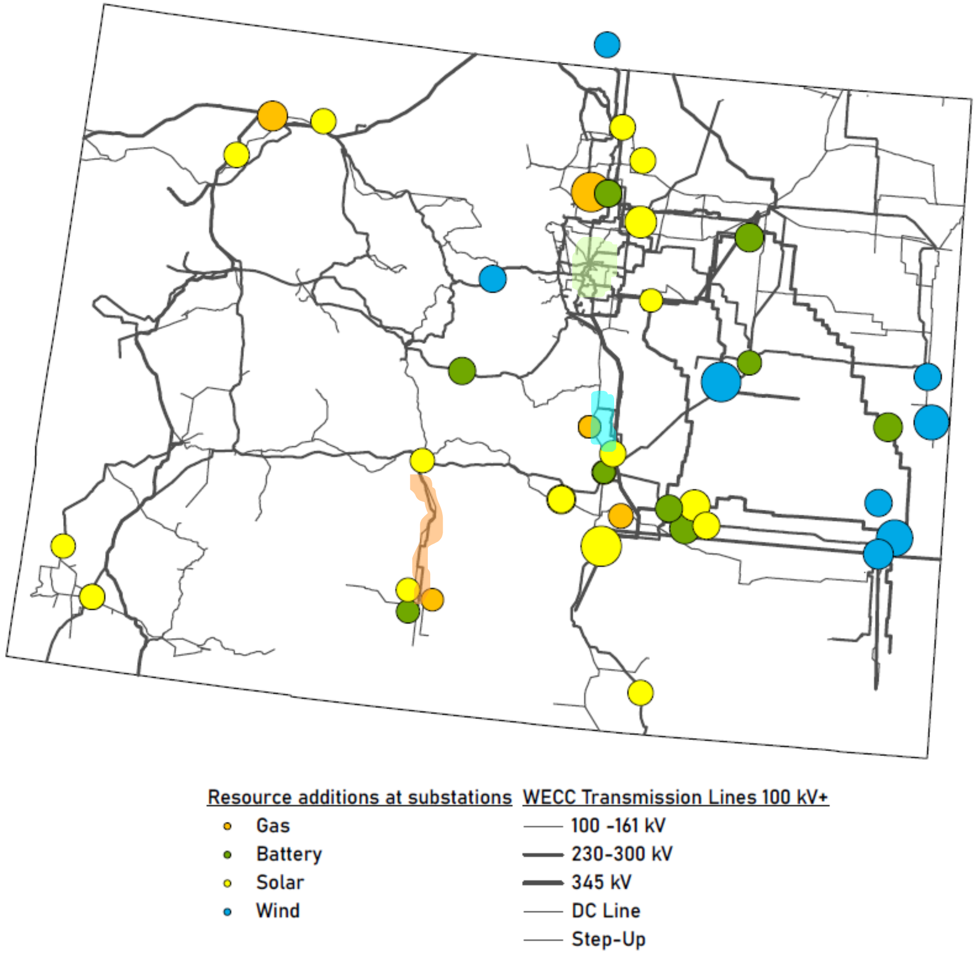
Conceptual	Sponsor
San Luis Valley – Poncha 230 kV	PSCO, TSGT
CPP Seg. May Valley - Longhorn	PSCO
Three Corners Connector	Grid United
Limon – Colby HVDC	Brookfield Renewable
…	…

The list of planned projects is not comprehensive and includes only major projects assumes in the 10-year study horizon. Other smaller upgrades were modeled and validated in the case.

Additionally, we are continuing to collect conceptual projects from Stakeholders through March 22nd.

10-Year Results and Findings: Reliability

Colorado Transmission System, Assumed Resource Additions through 2035, and Reliability Issues



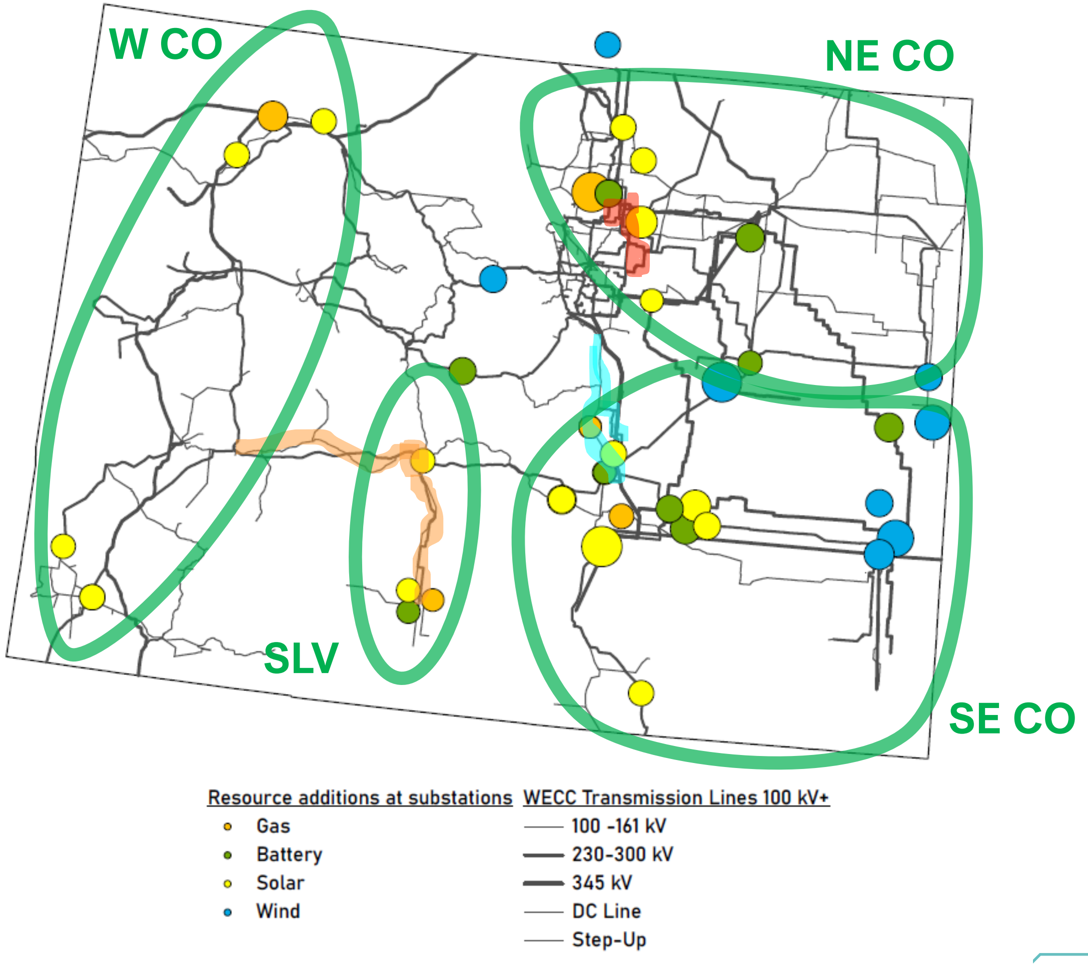
Study Results and Findings

- **Denver Metro Area**
  - Results: N-0 and N-1 contingencies caused overloads in and around the Denver-metro system, specifically on lines near Gray Street, Capital Hill, and Leetsdale.
  - Conclusion: Due to study's focus on identifying transmission gaps, current proposal is to assume such issues are mitigated in 20-year assessment as local transmission providers are aware of violations and are actively pursuing solutions.
- **Colorado Springs & Pueblo Areas**
  - Results: Contingency overloads were observed on some of the CSU and BHE 115 kV systems, specifically near Kelker, Fuller, and West Station.
  - Conclusion: Issues were localized and in some cases pre-existing. CSU issues may be due to inadvertent flows. West of Pueblo loading observed in other studies. **Will continue to monitor in 20-year assessment and propose solutions pending input from transmission owners and CETA stakeholders.**
- **San Luis Valley**
  - Results: Observed some typical contingency loading on the radial transmission into San Luis Valley.
  - Conclusion: This is a known issue. **Will explore long-term need and right size solutions based on 20-year assessment**

All other areas of the system had acceptable levels of N-0 and N-1 performance for 10-year study horizon

10-Year Results and Findings: Deliverability

Colorado Transmission System, Assumed Resource Additions through 2035, and Deliverability Issues



Study Results and Findings

- **West Colorado (W CO)**
  - Results: No significant issues were observed.
  - Conclusion: As additional resources are added to the Western Slope, we expect to observe loading on the local lower voltage systems and the transfer paths to the Front Range.
- **San Luis Valley (SLV)**
  - Results: In addition to the radial SLV system, some additional loading observed on the 115 kV system west of Poncha.
  - Conclusion: **Will explore long-term need and right size solutions based on 20-year assessment.**
- **Northeast Colorado (NE CO)**
  - Results: System overloads observed north of Denver, around Ft. St. Vrain, Green Valley, and Keenesburg.
  - Conclusion: **Will continue to monitor, as the lines in this area provide a path into the metro loads from the northeast that may need to be reinforced to accommodate 20-year resources.**
- **Southeast Colorado (SE CO)**
  - Results: Observed additional overloads on the CSU system due to flows through area.
  - Conclusion: As resources are added in the southeast (outside of CSU footprint), it is expected that the **parallel CSU system will be impacted,** and potential mitigations identified. Known issue is being exacerbated and will be addressed in 20-year pending future resource mix.

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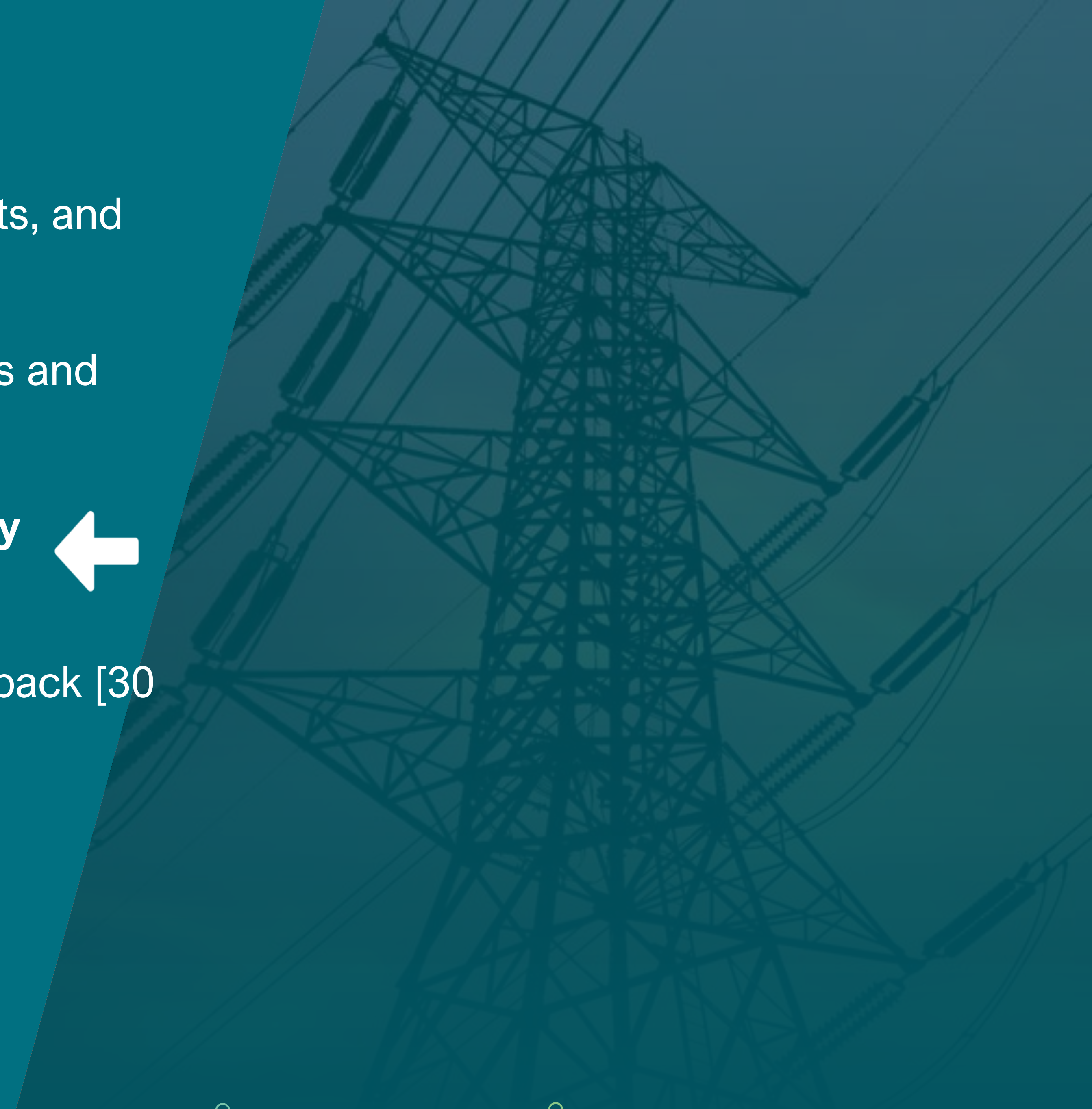
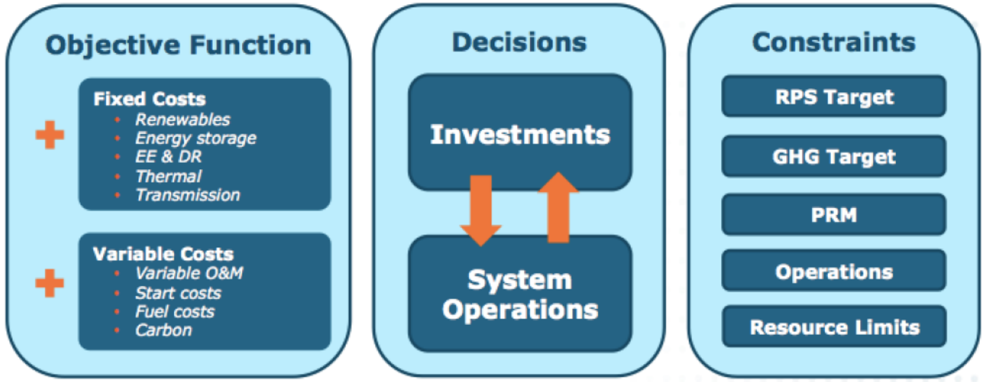


Developing the 20-Year Expansion Plan

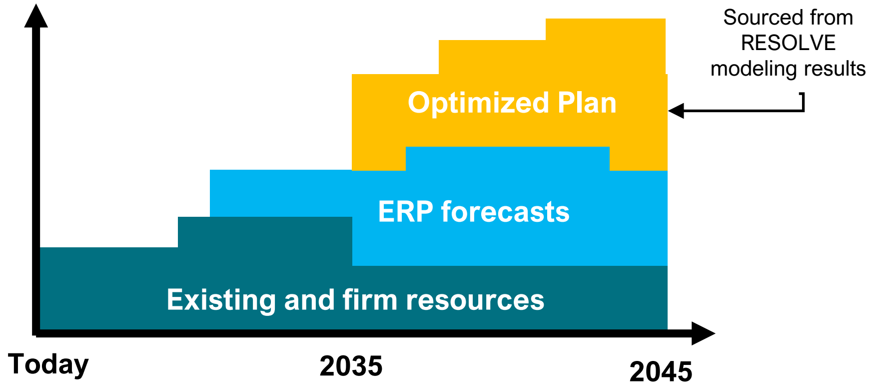
- **Energy Strategies obtained, validated, and updated the RESOLVE model used in the 2021 Colorado GHG Reduction Roadmap, developed by Energy & Environmental Economics Inc. (E3) for the Colorado Energy Office (CEO)**
  - "RESOLVE is a capacity expansion model that uses linear programming to identify optimal long-term generation […] investments in an electric system, subject to reliability, technical, and policy constraints."
- **The primary role of RESOLVE in this study was to establish a credible resource plan for the State of Colorado, above and beyond ERP Plans, in the 20-year timeframe <u>appropriate for transmission planning analyses</u>**
  - Model includes baseline resource forecast of existing, planned, and proposed (conceptual) generation additions outlined by Electric Resource Plans for utilities in the State of Colorado
  - RESOLVE identifies **additional expansion resource** in 2035 – 2045 sufficient to meet reliability, technical, and policy constraints

RESOLVE Model Overview



Credit: E3, Public RESOLVE Documentation

Hypothetical Colorado Resource Plan

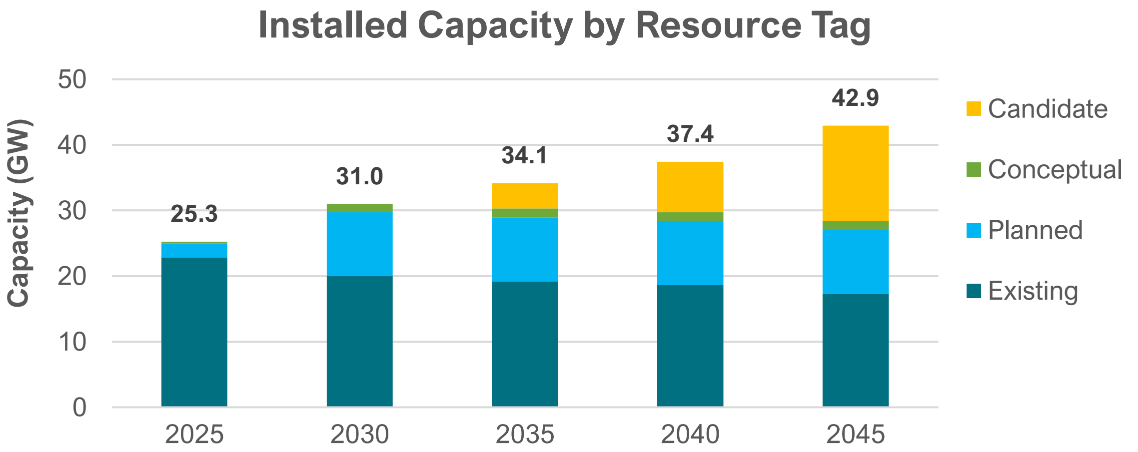


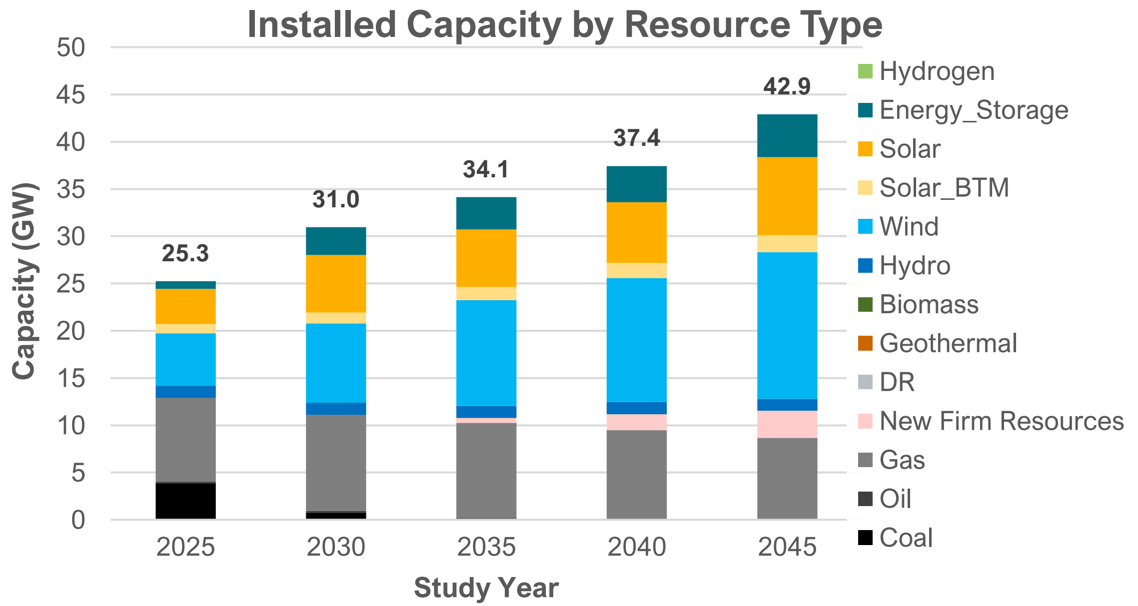
Key Assumptions: 20-year Expansion Plan

Study Horizon	Model captures 2025 to 2045 horizon in 5-year increments
	Candidate resources selected by model from 2035 onward to meet planning constraints (PRM, energy, policy)
Generators	Existing, planned, & conceptual additions through 2035 consistent with Colorado utility ERPs
	Resource capital expansion & FO&M costs source from 2023 NREL Annual Technology Baseline (ATB)
Load	Load accounting represents electrical loads served by Colorado in-state generators
	Peak load & energy demand growth consistent with NREL moderate electrification future scenario (EFS), which was benchmarked to Colorado utility ERP forecasts
Reliability	18% planning reserve margin (PRM) requirement, consistent with review of Colorado ERPs
	Diminishing capacity contribution from wind & solar captured via ELCC surface, with resulting ELCC for wind and solar benchmarked & validated against Colorado ERP ELCCs
Transmission	Model does not include transmission upgrade costs, which will be addressed through transmission analysis after busbar mapping occurs
	Modeled proxy import capability equal to 5% of Colorado peak load in 2035
Carbon Trajectory	Updated carbon trajectory consistent with Colorado's current goals of 80% reduction by 2030 and 0% by 2050
	Coal units assumed to remain in-service until retirement date – no “must-run” constraint

Reference Case 20-Year Capacity Expansion Plan

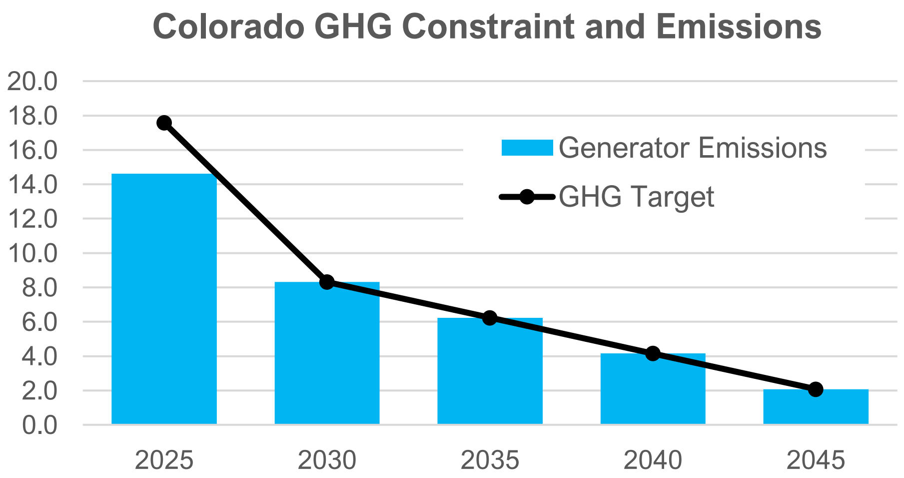
- **Study only considers generators located within the State of Colorado (no out-of-state), with load adjusted accordingly**
- **Generators are categorized into one of four "resource tags:**
  - **Existing:** Resources in-service as of EIA 2023 860
  - **Planned:** Resources planned but not yet in operation (unit-specific)
  - **Conceptual:** Resource plans identified in Colorado ERPs (not site-specific; i.e., 200 MW of Wind by 2034)
  - **Candidate:** Resources selected by RESOLVE capacity expansion algorithm to meet modeled reliability, technical, and policy constraints
- **Study begins adding candidate resources to the mix in 2035**
  - Coal resources decrease to near-zero levels by 2035, largely replaced by Gas and New Firm (e.g., hydrogen, carbon capture) resources
  - Significant increase in wind, solar, and storage resources (planned, conceptual, and candidate) throughout the 10 to 20-year horizon

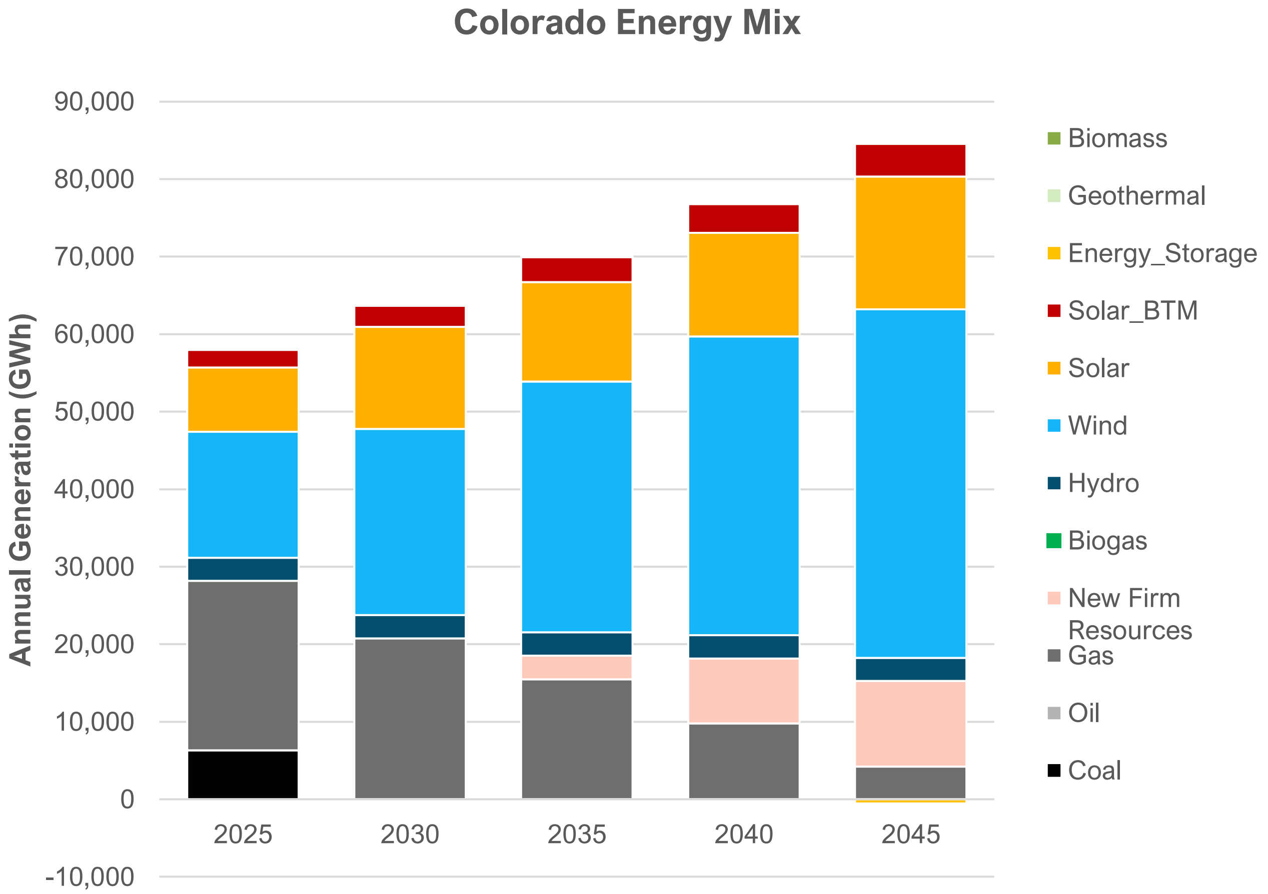




Reference Case 20-Year Expansion Plan Meets GHG Target for Colorado

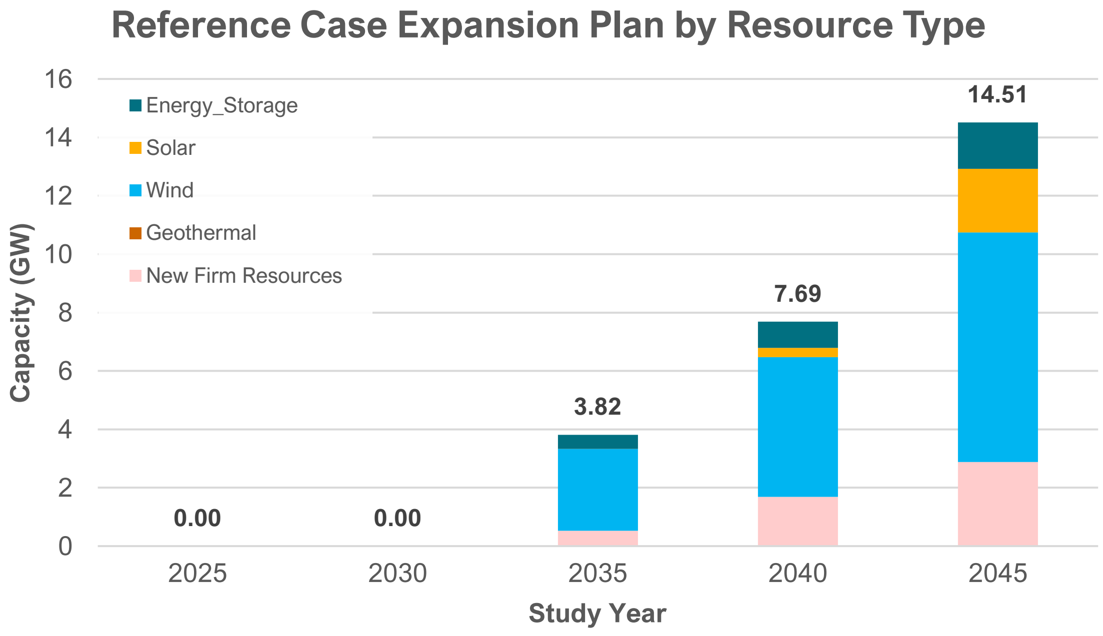
- **Study shifts to clean energy over study horizon to meet carbon cap**
  - Wind provides increasing share of energy
  - Solar increases share moderately
  - Renewable curtailment increases from 3 – 12% over study horizon
  - Firm resources phase out & adopt clean fuels or practices over time to meet carbon constraints
  - Imports made available to model for energy, but not utilized



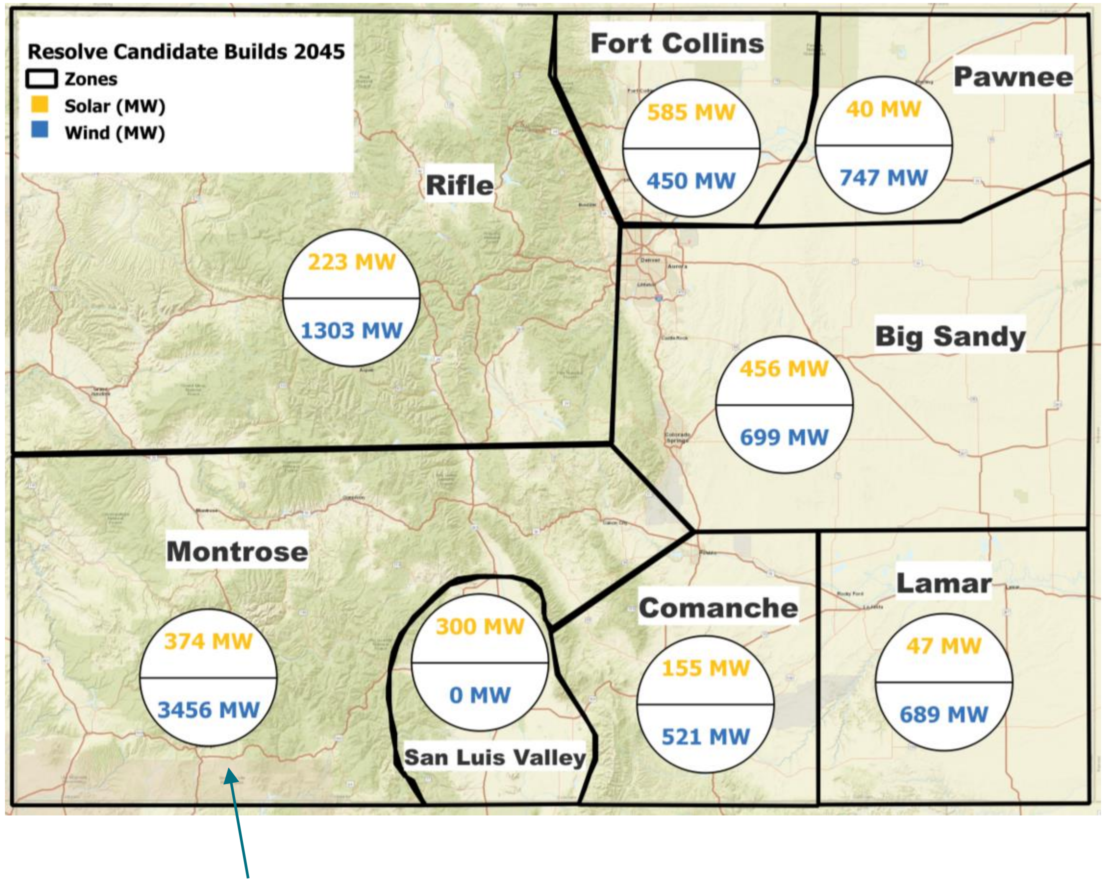


Reference Case 20-year Capacity Expansion Plan: Zonal Results

- **Expansion plan includes wind, new (clean) firm resources, solar, and battery**
  - Wind & solar resource candidates were location-specific and will be used for subsequent busbar mapping & inclusion into the 20-year power flow analysis



Reference Case 20-Year Expansion Plan by Zone



Note that **Rifle** and **Montrose** wind likely to be relocated based on transmission constraints and commercial interest factors – see future slides

Busbar Mapping of Reference Case 20-year Expansion Plan

- Busbar Mapping: The process of refining the geographically coarse portfolios, developed through capacity expansion modeling, to specific substations for analysis
- First conducted as “proof of concept” for the CPUC IRP 2018-2019 TPP portfolio
- Busbar Mapping Scope: Mapping focuses on generic future utility-scale generation and storage resources that are not already in baseline

Input: Developed from Commercial Interest And Capacity Expansion Modeling Results

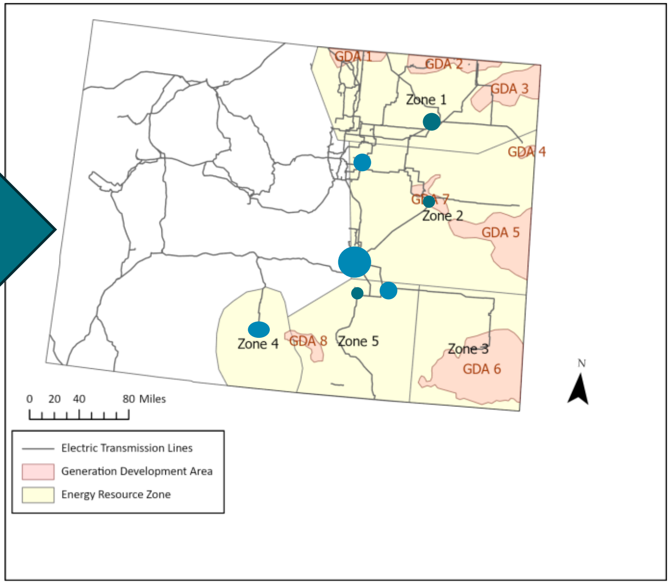
Resource Type	MW by 2045
Biomass	50
Wind	8,000
Utility-Scale Solar	20,000
Distributed Solar	8,000
Battery Storage	20,000
Long Duration Storage	500
Demand Response	500
Total	49,050

Model resource name	2045 Total (MW)
Zone 1 Solar	838
Zone 2 Solar	11,240
Zone 3 Solar	0
Zone 4 Solar	814
Zone 5 Solar	7,106

Note: Arbitrary values for illustrative purposes only

Mapping Process

Output: Substation-level location for resources

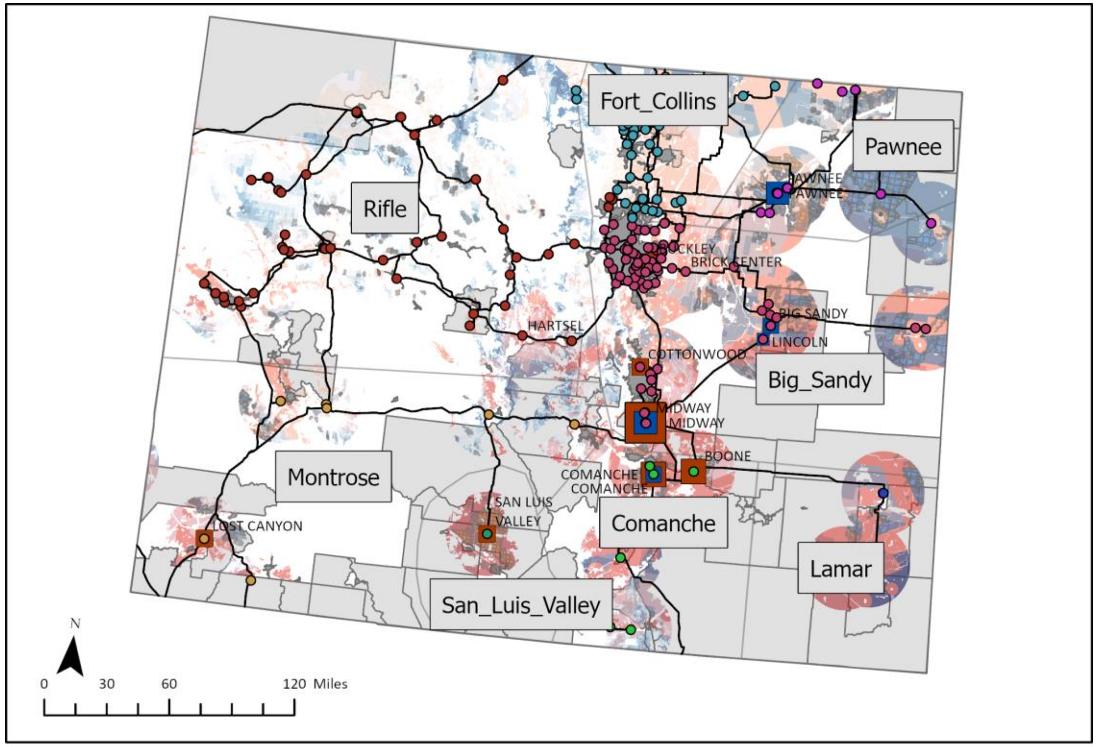


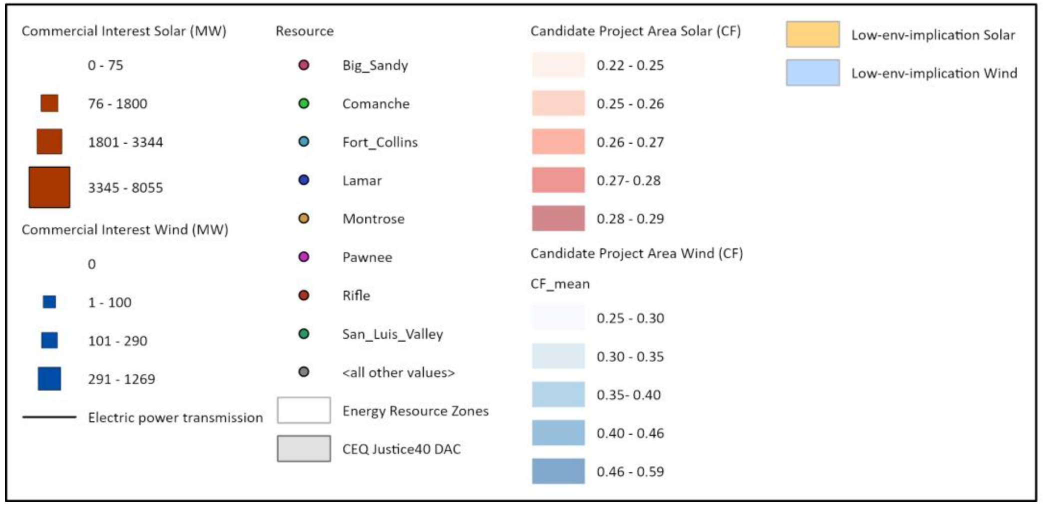
Screening Criteria

Selected Portfolio					Market facto	Techno-econo	Interconnection feasibility	Land Use and Environmental	Social		
Resource	**Resource Area**	**Type**	**Unit**	**2045**	**Commercial Interest**	**Total Resource Potential**	**Resource Potential within 20-mi of existing substation**	**Resource Potential within 20-mi of existing substation AND NOT**	**Resource Potential Located within a Disadvantaged Community**	**Minimum Across Criteria**	**Adjusted portfolio**
Fort_Collins_Solar_1a_Candidate	Fort_Collins	Solar	MW	585	-	301,198	246,134	916	14,307	-	146
Pawnee_Solar_1b_Candidate	Pawnee	Solar	MW	40	741	493,925	404,220	70,554	131,073	741	62
Big_Sandy_Solar_2_Candidate	Big_Sandy	Solar	MW	456	11,539	1,171,650	541,383	38,762	154,341	11,539	804
Lamar_Solar_3_Candidate	Lamar	Solar	MW	47	-	567,212	223,017	3,914	240,654	-	12
San_Luis_Valley_Solar_4_Candida	San_Luis_Valley	Solar	MW	300	720	175,347	61,352	24,829	67,575	720	314
Comanche_Solar_5_Candidate	Comanche	Solar	MW	155	6,278	410,520	214,573	12,204	98,380	6,278	347
Rifle_Solar_6a_Candidate	Rifle	Solar	MW	223	72	441,933	307,700	13,056	80,993	72	110
Montrose_Solar_6b_Candidate	Montrose	Solar	MW	374	765	290,424	148,754	13,636	69,839	765	387
Fort_Collins_Wind_1a_Candidate	Fort_Collins	Wind	MW	450	-	14,382	16,517	314	616	-	364
Pawnee_Wind_1b_Candidate	Pawnee	Wind	MW	747	1,269	37,650	31,221	8,667	12,308	1,269	1,269
Big_Sandy_Wind_2_Candidate	Big_Sandy	Wind	MW	699	1,355	49,187	22,742	5,183	6,305	1,355	1,355
Lamar_Wind_3_Candidate	Lamar	Wind	MW	689	-	16,178	6,937	862	7,932	-	556
Comanche_Wind_5_Candidate	Comanche	Wind	MW	521	290	17,091	8,879	415	6,767	290	476
Rifle_Wind_6a_Candidate	Rifle	Wind	MW	1,303	-	61,484	34,615	1,964	6,896	-	1,053
Montrose_Wind_6b_Candidate	Montrose	Wind	MW	3,456	-	27,868	12,739	1,563	7,189	-	2,792
Total				**10,045**	**23,029**					**23,029**	**10,045**

Portfolio Adjustments

- The portfolio includes 2,180 MW generic future solar. This is less than the solar commercial interest (20,115 MW).
  - It is about 1/10th of the solar commercial interest.
- The portfolio includes 7,865 MW generic future wind. This is greater than wind commercial interest by about 2x (2,914 MW).
- The portfolio is in alignment with land use, environmental, or social criteria for almost all zones, with few exceedances.
  - There are two zones with small land use/environmental criteria exceedances for wind (Comanche, Fort Collins - about 100 MW each)
- There are disadvantaged communities in all zones where federal Justice40 incentives may be available, but there are no designated energy communities in Colorado by IRA definition.
- Solar commercial interest is higher than RESOLVE solar selections overall.
- Adjustments are made to the zonal resource in locations where the solar resource exceeds commercial interest.
  - Excess solar removed from a few areas of low commercial interest (Fort Collins, Lamar, and Rifle) and added to areas of high commercial interest (primarily adding to Big Sandy and Comanche areas)
- The RESOLVE-selected wind portfolio amounts are higher than commercial interest overall.
- Adjustments are made to the zonal wind levels to better align with commercial interest where information is available.
  - Excess wind removed from areas of high exceedance of commercial interest (Rifle and Montrose areas) and added to areas with high commercial interest (primarily Pawnee and Big Sandy)

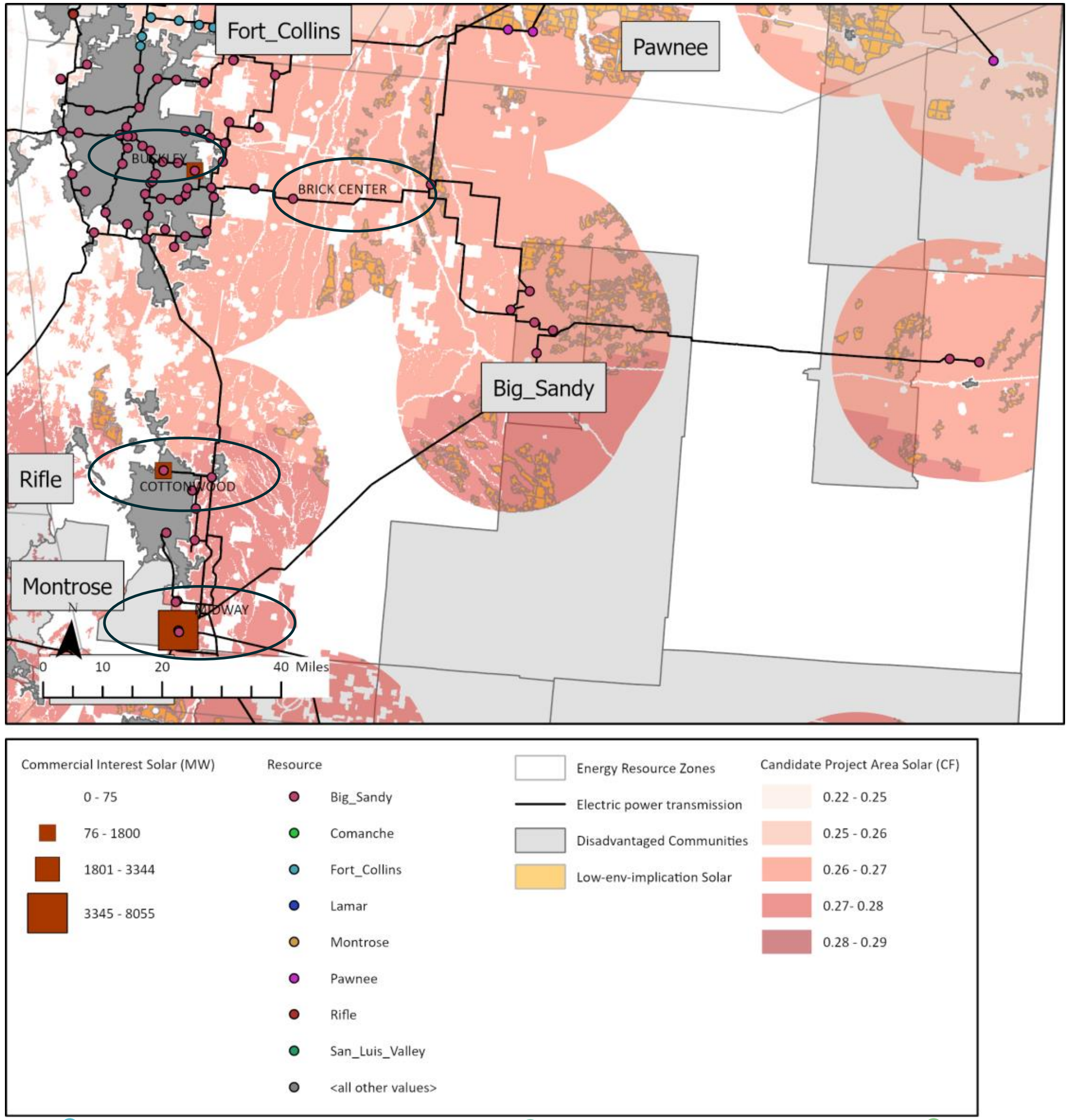




Montara

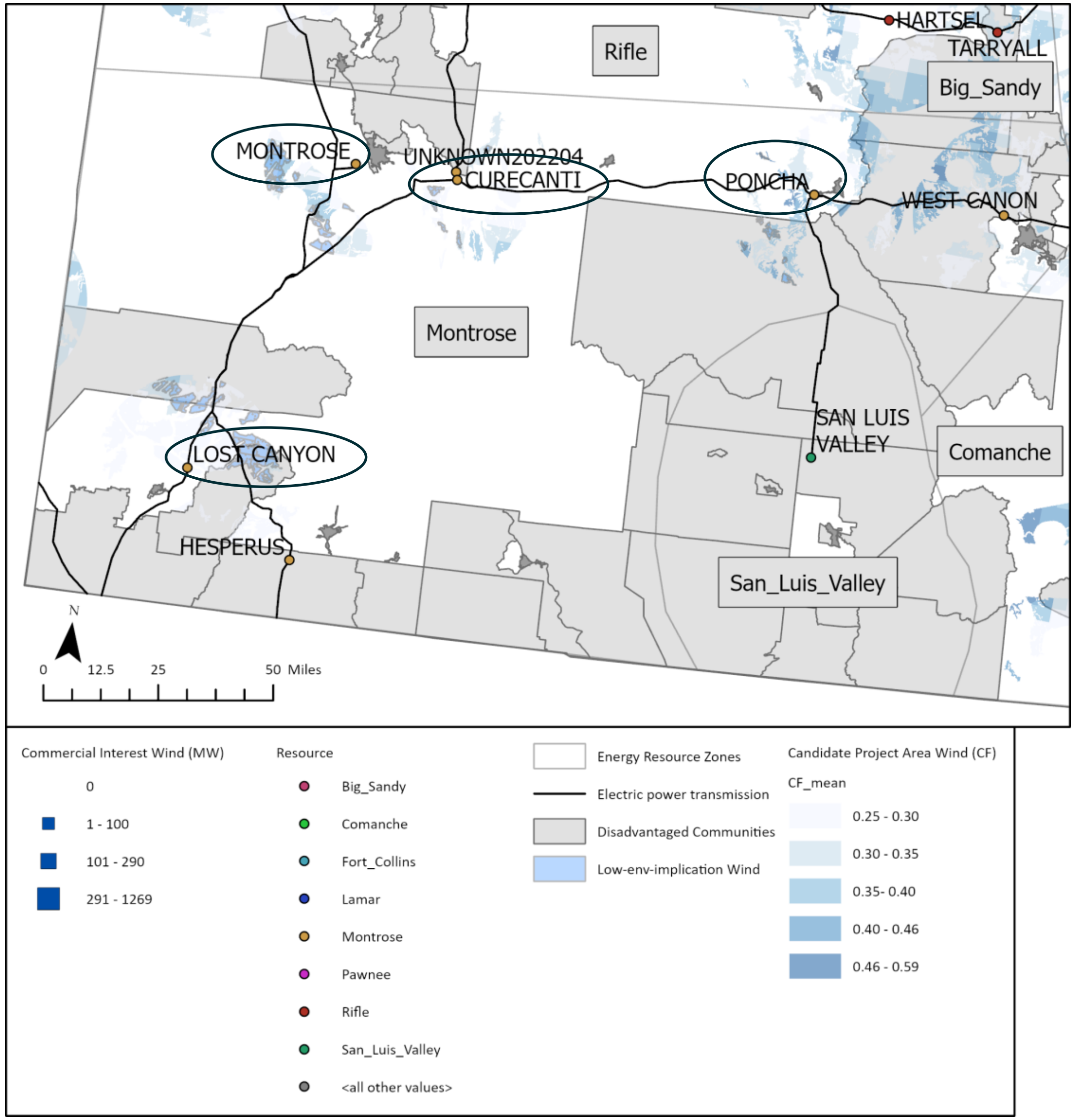
Example Implementation of Screening Criteria: Big Sandy Solar

Substation Name	Commercial Interest (MW)	Low-Env-Implication Resource (MW)	Disadvantaged Community Resource (MW)
MIDWAY	8055	2589	750
BUCKLEY	1800	0	0
COTTONWOOD	1609	2277	0
BRICK CENTER	75	4603	0



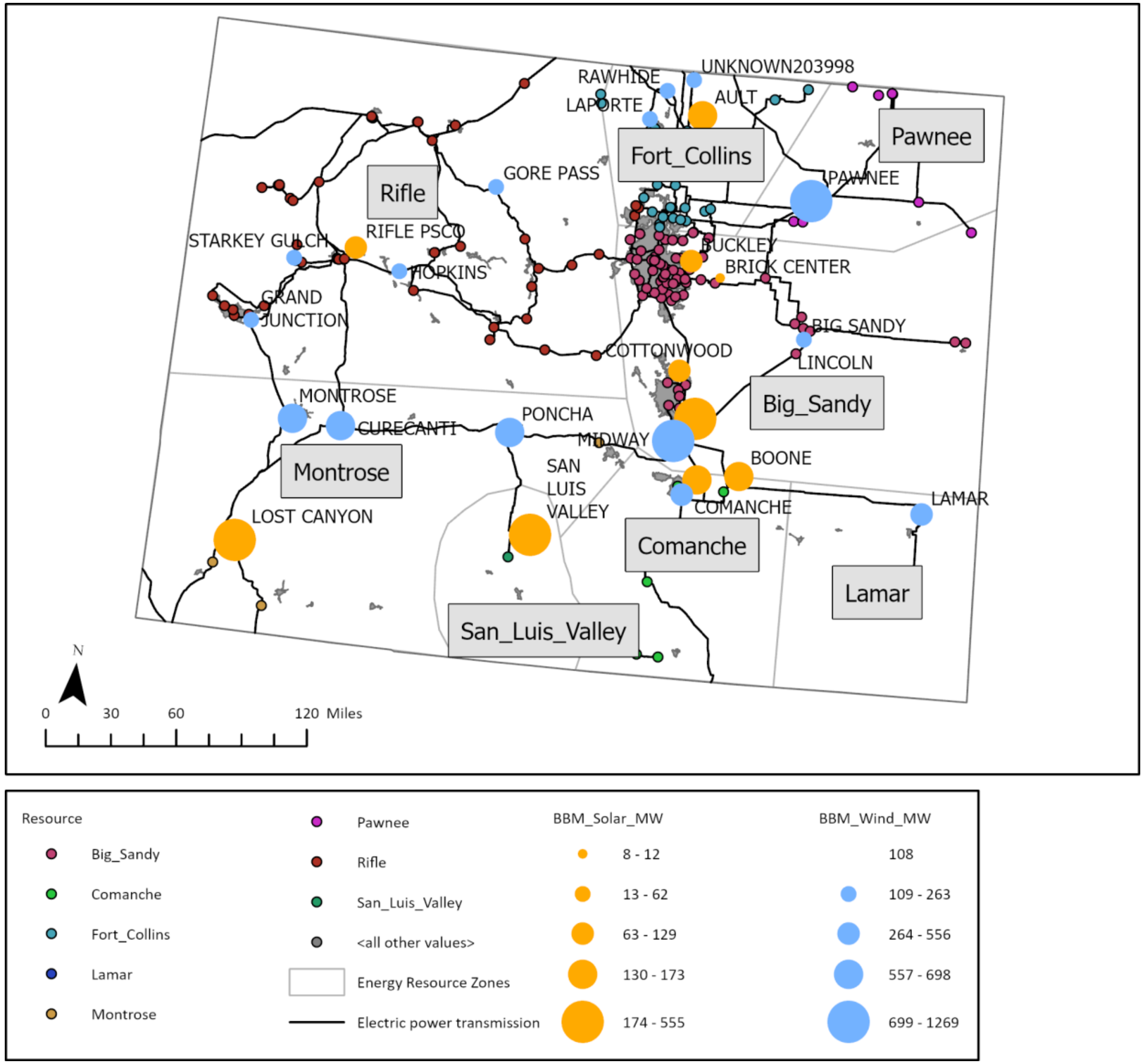
Example Implementation of Screening Criteria: Montrose Wind

Substation Name	Commercial Interest (MW)	Low-Env-Implication Resource (MW)	Disadvantaged Community Resource (MW)
CURECANTI	na	71	0
LOST CANYON	na	742	350
MONTROSE	na	592	0
PONCHA	na	107	70



Example Busbar Mapping Result

Substation_Name	Resource_Area	Solar MW	Wind MW
AULT	Fort_Collins	146	
RAWHIDE	Fort_Collins		121
UNKNOWN203998	Fort_Collins		121
LAPORTE	Fort_Collins		121
PAWNEE	Pawnee	62	1269
MIDWAY	Big_Sandy	555	1043
BUCKLEY	Big_Sandy	129	
COTTONWOOD	Big_Sandy	113	
BRICK CENTER	Big_Sandy	8	
BIG SANDY	Big_Sandy		203
LINCOLN	Big_Sandy		108
LAMAR	Lamar	12	556
SAN LUIS VALLEY	San_Luis_Valley	314	
COMANCHE	Comanche	173	476
BOONE	Comanche	173	
RIFLE	Rifle	110	
GORE PASS	Rifle		263
STARKEY GULCH	Rifle		263
HOPKINS	Rifle		263
GRAND JUNCTION	Rifle		263
LOST CANYON	Montrose	387	
CURECANTI	Montrose		698
LOST CANYON	Montrose		698
MONTROSE	Montrose		698
PONCHA	Montrose		698
Total		**2180**	**7865**



Montara

ENERGY STRATEGIES

Data Sources

- Commercial Interest: LBNL Queued Up study (2023)
- Substations: U.S. Federal Homeland Infrastructure Foundation Level Data (HIFLD) 2020
- Total Wind and Solar Resource Potential: Wu et al (2023)
- Wind and Solar Resource Potential NOT located in Environmentally sensitive areas: Wu et al (2023)
- Disadvantaged Communities: U.S. White House Council on Environmental Quality EJ Screen Tool
- IRA Energy Communities: U.S. Department of Energy Office of Scientific and Technical Information

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Scenario Purpose

- **The CETA transmission study is setup around a Reference Case, which is intended to reflect a “status quo” trajectory that will serve as a starting point for up to three additional scenario assessments**
- **Energy Strategies proposed several scenario drivers for consideration at the initial CETA stakeholder meeting**
  - A request was made for stakeholders to submit comments outlining their preferred scenarios and approaches
  - Scenarios should represent different but plausible futures or grid conditions that are likely to impact transmission needs and aggressively “stress” the transmission system
- **Responses from stakeholders emphasized a preference for scenarios to :**
  - Explore holistic “futures” in the state as well as “events” that would explore how Reference Case infrastructure responds to unique grid or weather conditions
    - Futures = Holistic long-run futures based on macro drivers, such as policy, prices, and load growth that could impact the need and for transmission
    - Events = Unique & primarily weather-driven grid events that could impact the need for transmission
  - Consider scenarios that capture alternatives to traditional planning and are materially difference than the Reference Case
  - Extreme weather events, market scenarios, energy autonomy, advanced transmission technologies, & unplanned load growth were all persistent themes
- **The proposals that follow are based heavily on the stakeholder feedback received**

Scenario Proposals Developed Based on Stakeholder Interest: Final scenarios presented at next meeting

Planning Scenarios

"Regional Integration"

- **Explore transmission need implications of:**
  - Resource co-optimization with SPP region (new resource candidates in SPP)
    - RESOLVE will establish a new resource plan in response, which will be compared to the Reference Case and evaluated for transmission need via powerflow analysis
  - Removal of inter-state transmission constraints in operational study to help explore the amount to of inter-state transmission Colorado may need
    - Results will be compared to Reference Case inter-state flows
  - Develop representation of RTO market for Colorado and TBD neighboring states (including SPP) to assess transmission congestion impacts
- **Purpose of study suite is to understand how & where transmission needs change under a future with alternative regional integration outcomes**

"High Demand"

- **Assessment of transmission impact of load growth & electrification**
- **Scenario to feature demand changes due to:**
  - Increased "point loads" caused by new data centers, hydrogen production, aviation fuels, etc.
  - Increased electrification of broader Colorado economy, including transportation, heating, and manufacturing / industry
- **RESOLVE will establish a new resource plan in response, which will be compared to the Reference Case and evaluated for transmission need via powerflow analysis**
- **Purpose of study is to understand how & where transmission needs change under a future with very high demand**
  - Will focus assessment on reliability and deliverability analysis and results compared to Reference Case

Extreme Event Scenario

"Transmission Resiliency"

- **Powerflow study designed to explore transmission needs under extreme weather event**
- **Summer (heat dome) or winter (polar vortex) scenario**
  - Stakeholders, please advise one which is likely to generate the most stress in Colorado
  - Helpful to emulate historic event in constructing model representation
- **Modeling can consider:**
  - High or low temperatures and impact on demand
  - Drought implication on hydro output
  - Low wind, low solar production
  - Limited imports/exports due to constrained neighboring regions
  - Transmission outages
  - Generation maintenance or forced outages of generation fleet
- **Statistically-driven inputs**
- **Conduct reliability analysis on Colorado system and compare results with Reference Case**

Note that each of the three issues core to the scenarios are not addressed in the study's Reference Case

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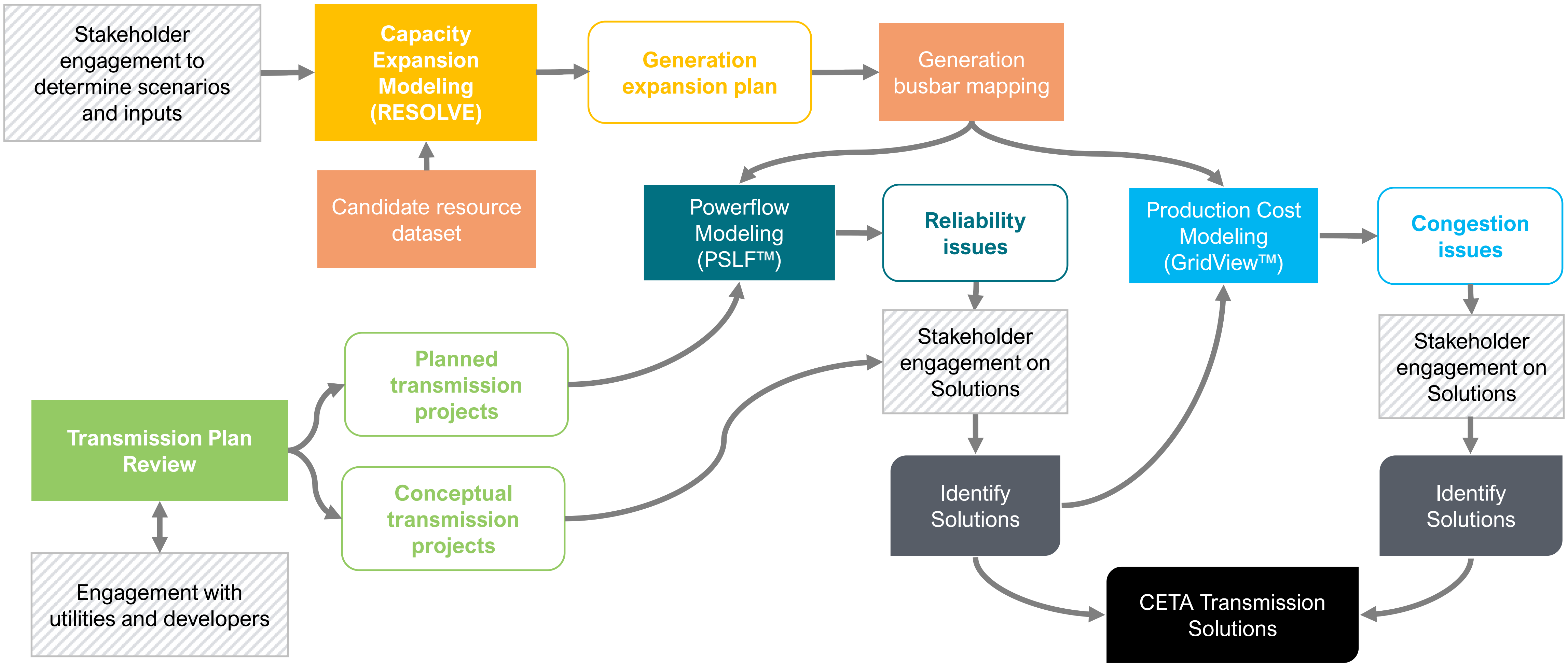
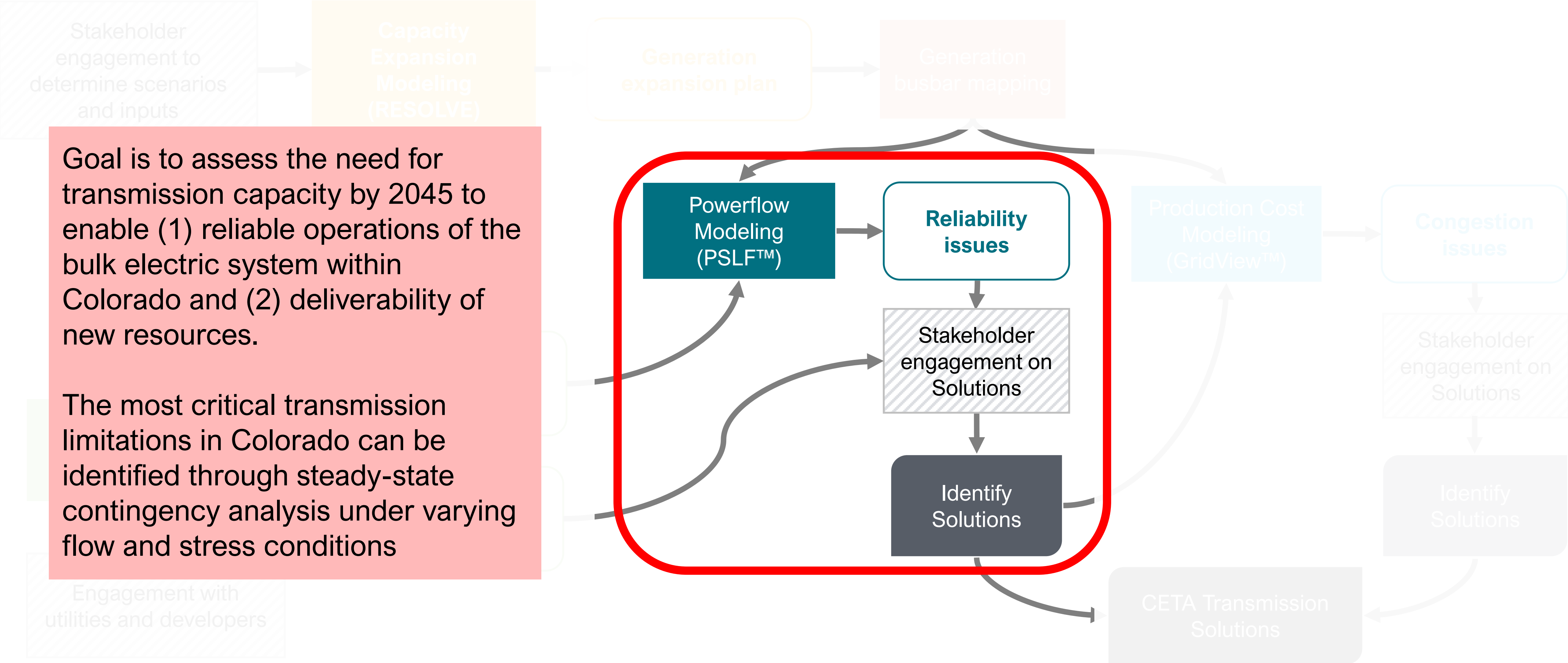
Study Methodology: Overview of Study Process



Study Methodology: Powerflow Assessment (20-year)

Goal is to assess the need for transmission capacity by 2045 to enable (1) reliable operations of the bulk electric system within Colorado and (2) deliverability of new resources.

The most critical transmission limitations in Colorado can be identified through steady-state contingency analysis under varying flow and stress conditions



ENERGY STRATEGIES

Study Methodology: 2045 Powerflow Assessment

- **The powerflow assessment will be performed once the resource portfolio – inclusive of planned, conceptual, and expansion resources identified via RESOLVE – has been identified for the 20-year horizon and has been mapped to busbars**
  - The goal of the busbar mapping exercise is to reasonably site resources in a way that is appropriate for identifying potential transmission needs/gaps in Colorado.
- **To develop the 20-year powerflow models, resources will be added to busbars and loads will be adjusted (using the 10-year case as a starting point) to align with peak demand forecasted in RESOLVE**
- **We do not anticipate adding additional transmission projects to the 20-year cases beyond those planned projects included in the 10-year Reference Case**
- **We plan to perform assessments exploring two grid conditions for the 2045 Reference Case – similar to the 2035 Reference Case assessment – to test for both (a) broad transmission reliability concerns ("Reliability Case") as well as (b) the potential for deliverability constraints ("Deliverability Case")**
  - However, we will be adjusting our methods for the evaluation so that the study can be best positioned to explore transmission challenges not otherwise addressed in other planning efforts

Study Methodology: 2045 Powerflow Assessment (cont.)

Methods for Performing Reliability and Deliverability Assessments

Reliability Case

- Case emulates peak load condition with operationally-appropriate generation dispatches required to balance supply and demand under stressed condition
  - Anticipate performing study using a single case, although multiple “zonal” cases may need to be developed (e.g., SLV, Lamar)
- The entire system is being challenged in this case – no one area of the system is designed to have extraordinary stress
  - Availability of imports limited by physical system constraints
- Steady-state contingency analysis performed on Colorado system will reveal bulk transmission areas lacking capacity required to maintain NERC reliability standards during stressed conditions
- Line monitoring, contingencies and reliability criteria will be identical to those used in the 10-year assessment
  - We will explore the use of redispatch as a means to mitigate select violations depending on the location and magnitude of the violation
    - This helps us focus our study on real transmission limitations versus those that are a product of specific assumptions, such as the dispatch of a single generator sited conceptually

Deliverability Case

- Case developed to study deliverability (e.g., reliable transfer) of resources located in “pockets” that have similar electrical characteristics and transmission constraints
  - Each of these pockets is studied **individually** to ensure the local system is sufficient to transmit generation from resource zones to load during stressed system conditions
    - Testing all zones at high output at once generally results in excess energy that isn’t realistic to model
  - Assumes basic interconnection requirements of resources are met
- Proposed method mirrors an “off-peak” deliverability analysis where we are primarily concerned with identifying & correcting transmission deficiencies that would cause excessive congestion or curtailment within a given resource pocket
  - Upgrades are also likely to support deliverability during on-peak conditions, which is the focus of the Reliability Case (see left)
- Generation within the study pocket is increased during the study to test the ability of resources to be dispatched when resources outside the pocket are unavailable

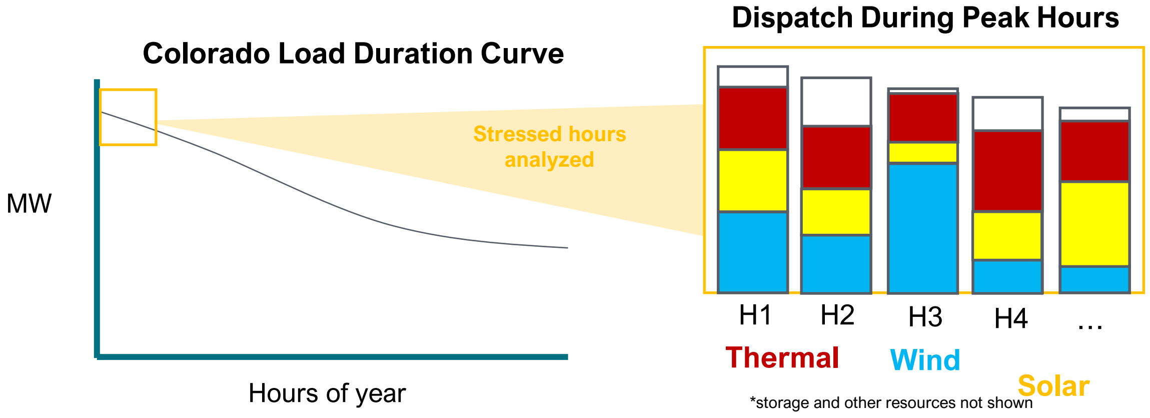
ENERGY STRATEGIES

Study Methodology: 2045 Powerflow Assessment (cont.)

Methods for Performing Reliability and Deliverability Assessments

Reliability Case

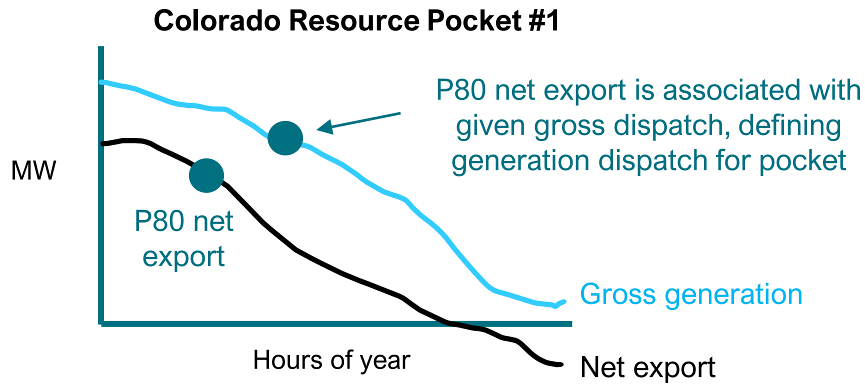
- Dispatch conditions will be informed by a review of hourly data from the 2045 nodal production cost model study
- The top 5-10 net load hours will be reviewed and a representative dispatch level for each individual resources in Colorado will be developed based on this data



By capturing weather-correlated operations during stressed conditions we can develop a condition appropriate for system-wide reliability analysis that is superior to “rule of thumb” study assumptions

Deliverability Case

- Dispatch conditions will be informed by a review of hourly data from the 2045 production cost model study, this time aggregated for each study “pocket”
  - Determination of dispatch values is critical study assumption subject to debate and variance at RTOs/ISOs (see next slide)
- We will process the data to identify resource dispatches that align with P80 net export conditions for a given study pocket
  - We are not trying to address all congestion and therefor adopt this exceedance methodology as remaining congestion will be identified and addressed as appropriate in economic studies



We then perform N-0 and N-1 contingency analysis on the case to identify the incremental export (import) needs (in MWs) and intra-zone transmission limitations. Contingencies are limited to those within the zone and along intra-zonal ties.

Transmission Solutions: Methodologies to Evaluate Technologies

Technology / Solution	What it does and how to model it?	When is it appropriate?
Reconductor / rebuild	Increases capacity of existing line by replacing existing line with a higher capacity ACSR or ACSS conductor. Conductor will be selected based on the degree of thermal overload. Modeled in power flow by replacing old line with upgraded facility with higher rating and impendence. Very good data availability for modeling purposes.	Considered for overloaded lines at 230 kV or below with flows less than ***1600 amps***, or 345 kV line with flows less than ***2400 amps.*** Use ACSR or ACSS conductors.
Co-located new build	Add a new line in parallel to an existing line, with minimal expansion of existing ROW. Modeled in power flow tool as a new line with same terminals as the existing line. Very good data availability for modeling purposes, although in some cases ability to evaluate development feasibility can be limited.	Considered when outages results in overloads on two or more lines along with voltage violations. Best suited for increasing power transfer capacity from high generation areas to load centers when reconductoring is not effective due to contingency limitations.
Greenfield new build	Add a new line with a new ROW. Modeled in power flow tool as a new lines with possibly new substations. Very good data availability for modeling purposes, although in some cases ability to evaluate development feasibility can be limited.	Considered in areas with significant increase in load or resource requiring large amounts of power transfer, typically in regions with weak connections but significant proposed load or resource growth. ***Will be considered only if adding voltage support, line reconductor or using grid enhancing technologies do not address issues***.
Advanced conductor rebuild	Reconductor or rebuild an existing line with advanced conductors which have ratings ~2X that of ACSR or ACSS. Modeled in power flow using appropriate impedance and rating of selected advanced conductor. It should be noted that loadability of advanced conductors decreases with line length. So, increased rating of advanced conductors is only useful for uncompensated lines less than 70 miles in length and compensated lines less than 170 miles in length.	***Considered when overload on a line exceeds thresholds identified for reconductor/rebuild with ACSR***. Only considered for line less than 70-80 miles in length.

Draft summary subject to change in implementation

Transmission Solutions: Methodologies to Evaluate Technologies (cont.)

Technology / Solution	What it does and how to model it?	When is it appropriate?
Advanced conductor greenfield	Add a new line using advanced conductors on a new ROW.	Considered in similar situations as greenfield new build. Advanced conductor considered when power transfer requirement cannot be met with ACSR conductors.
Energy storage as a transmission solution	Energy storage can operate in charging or discharge mode to mitigate overloads by shifting flows on physical system during certain configurations or system conditions, such as during an outage or during periods of low load. Modeled in powerflow tool as generator or load dispatched appropriately. Very good data for modeling purposes.	Evaluated in regions with significant load or resource growth, but limited ability to build new transmission. One scenario is to add ***local energy storage in load centers and relieve congestion on major ties into the area***. Storage located near large wind or solar facilities may be considered to manage line flows during low load periods.
Advanced powerflow controller	Device attached to a transmission line that dynamically decreases flow and redirects through other paths. Modeled as a FACTs device on a line in power flow tools.	Used to address 1 or 2 overloads in a meshed system. ***Best candidates are lines with overloads <125%***. Cannot be used in a radial system.
Dynamic line ratings (DLR)	DLR adjust the capacity of transmission lines based on real-time environmental conditions, primarily temperature, to optimize line usage and increase efficiency. Case studies have demonstrated improvements from DLR of 5% to 40%. Considering Colorado's average winter temperatures of 28°F to 45°F, applying DLR could bump the rating significantly. Higher summer average temperatures would limit the feasibility of DLR for heavy summer planning models.	Best suited to address congestion occurring in non-stressed hours (e.g., shoulder or off-season) and will not help support load service or deliverability. Use an ambient temperature rating increase ***Considered for overloads less than 110-115% of existing rating in shoulder or winter cases only.***

Draft summary subject to change in implementation

References to Inform Transmission Solutions Modeling and Methodologies

1. **MISO MTEP Cost Estimation Guide**
2. **US DOE Advance Transmission Technologies, December 2020**
3. **Enabling Principles for Dual Participation by Energy Storage as a Transmission and Market Asset, February 2022**
4. **Development of Line Loadability Characteristics for EHV and UHV Transmission Lines, IEEE 1979**
5. **Accelerating Transmission Expansion by Using Advanced Conductors in Existing Right-of-Way, Energy Institute at Haas, November 2023**
6. **GETting Interconnected in PJM, February 2024**
7. **Idaho National Laboratory, Advanced Conductor Scan Report, December 2023**
8. **PJM Dynamic Line Rating Methodology**
9. Unlocking the Queue with Grid Enhancing Technologies
10. The Benefits of Innovative Grid Technologies, currENT, 8 December 2021

ENERGY STRATEGIES

CETA Transmission Gap Analysis: *Proposed* framework to document transmission needs, drivers, gaps, and solutions

Transmission Need & Driver	**Planning Horizon & Scenario**	**Gap Analysis**	**Viable Solutions**	**CETA Study Solution(s)** (based on fit, cost, benefits, etc.)
[General description of transmission line/path issue and quasi-technical description of driver, which is likely to be reliability, deliverability of resources, or economics/congestion]	*[Dote if issue is present in 10- and/or 20-year horizon, and the scenario driving the issue]*	*[Describe any known projects that are planned or conceptual that could address the issue if modified and/or constructed.]*	*[Describe solutions that are technically viable at addressing the identified need. This could include any and all of the technologies on the prior slides. It will note electrical terminus when applicable and any new substations.]*	*[Consider performance, fit, cost, benefits (if applicable), development feasibility, among other factors in identifying solutions best positioned to address need]*

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15 minutes

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Next Steps (before May stakeholder meeting)

- **Develop Final 2045 Reference Case Expansion Plan & Busbar Mapping**
  - The 2045 portfolio will be mapped to busbars and will be used to inform 2045 Powerflow Reference Case and 2045 Production Cost Model Reference Case
  - **We will communicate a draft busbar mapping and methodology via email and will ask for specific areas of feedback in that email**
- **Finalize Scenario Scopes and Develop Draft Scenario Models**
  - Expansion plans and modeling assumptions will be developed as applicable to each scenario and presented at the May stakeholder meeting
  - **Stakeholder feedback welcome on proposed scenario scopes**
- **Develop Draft 2045 Powerflow Reference Case and Draft Reliability/Deliverability Assessment**
  - In May we will present assumptions and preliminary results for this analysis, including potential system needs and solutions
- **Develop Draft 2045 Production Cost Model (PCM) Reference Case & Draft Economic/Interchange Assessment**
  - In May we will present assumptions and preliminary results for this analysis

Send all comments and written input by April 5th to cboies@gridworks.org

Stakeholder Communications

- **Transmission study webpage on the CETA site**
- **Meeting summary, recording and slide deck – will circulate to the distro list and post on the CETA webpage**
  - To be added to the distro list: cboies@gridworks.org
- **Input on proposed scenarios due April 5**
  - Send to cboies@gridworks.org
- **Next meeting: Early May**