Renewables Integration for 85% carbon emissions reduction by 2030… and beyond

Grid Performance Evaluation of IBRs

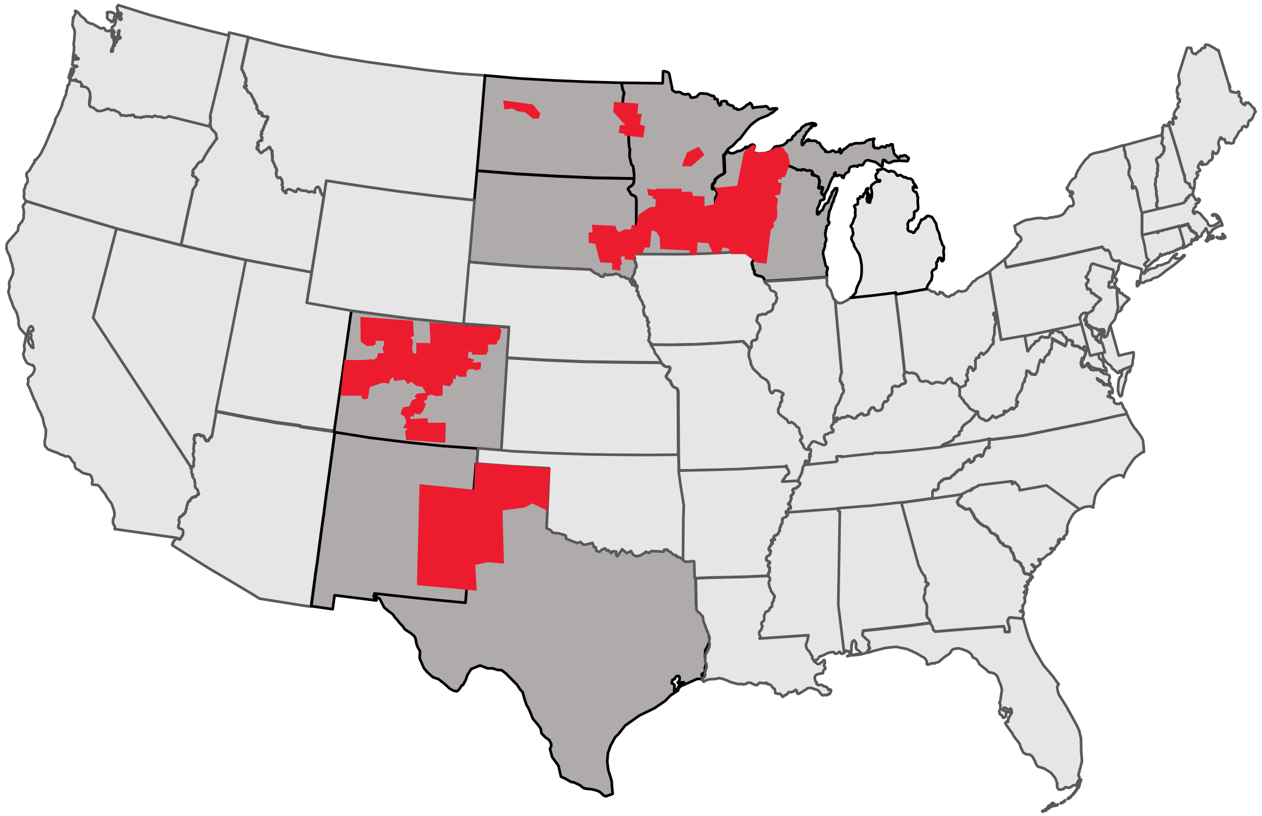
Hari Singh, PhD, PE

Integrated System Planning

NREL Power Electronics Grid Interface (PEGI) Workshop

May 24-25, 2023

Xcel Energy



Serving eight states

3.7 million electricity customers

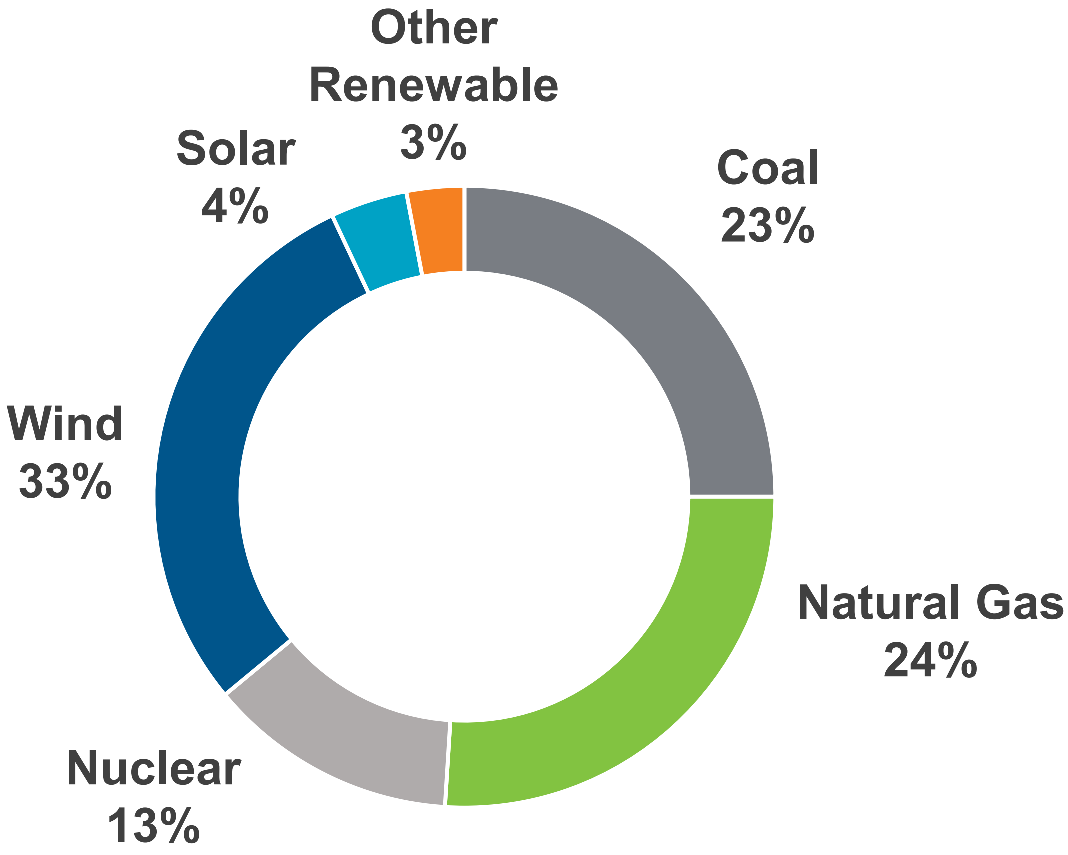
2.1 million natural gas customers

Nationally recognized leader:

- Wind energy
- Energy efficiency
- Carbon emissions reductions
- Innovative technology
- Storm restoration

Data based on 2021 Sustainability Report. To view full report: xcelenergy.com/sustainability.

2022 Energy Mix – Xcel Energy



Clean Energy Transition

2005

21% Carbon-free

Nuclear, Wind, Solar and Other Renewables | Coal and Natural Gas

2022

53% Carbon-free

Nuclear, Wind, Solar and Other Renewables | Coal and Natural Gas

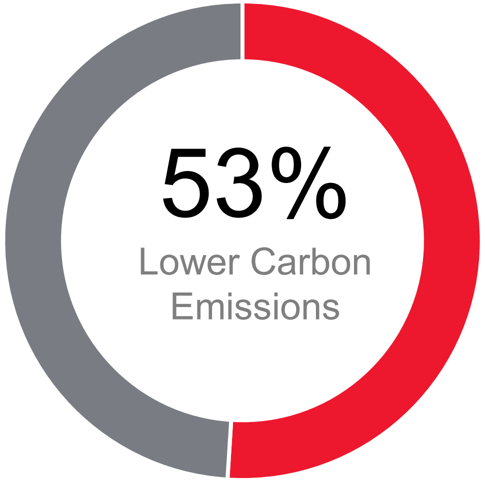
2030 Estimate

79% Carbon-free

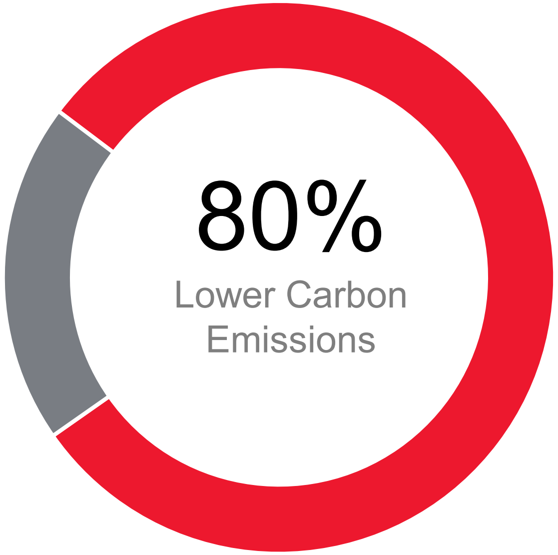
Nuclear, Wind, Solar and Other Renewables | Coal and Natural Gas

A Bold Vision for a Carbon-free Future

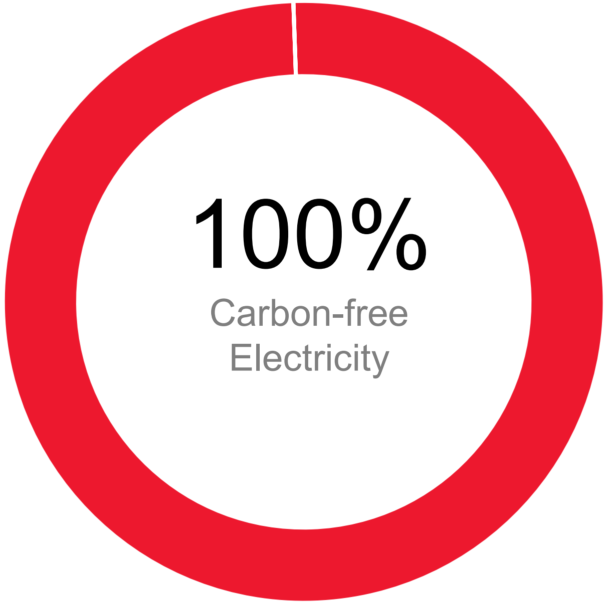
2022
Results



2030
Goal

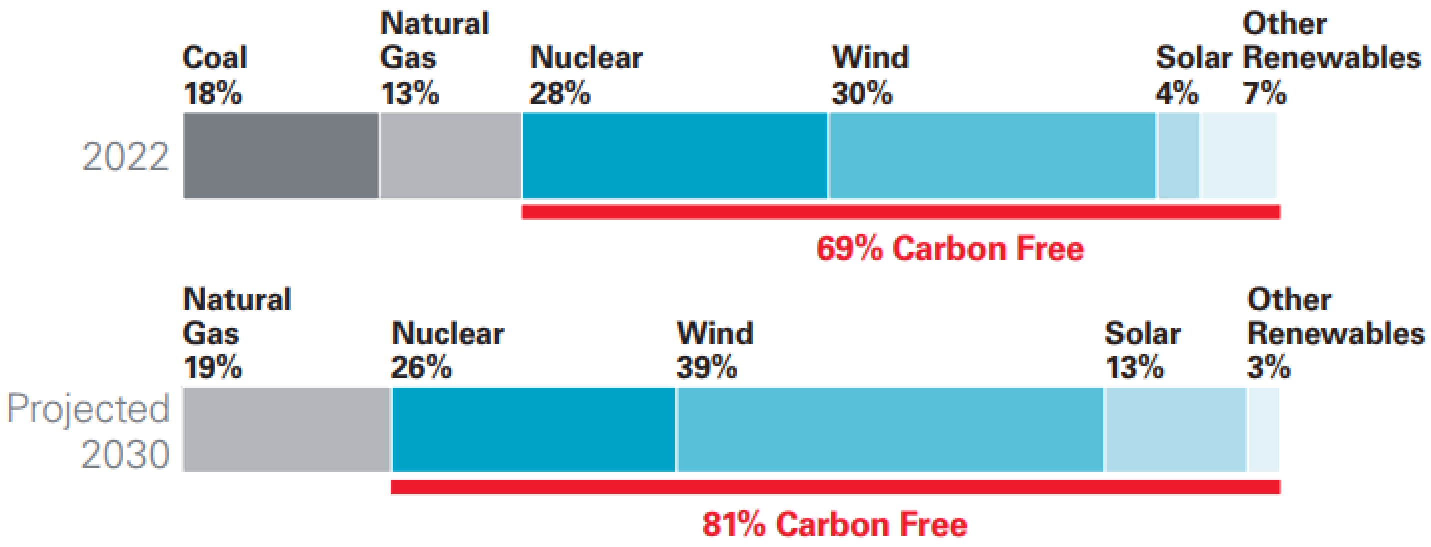


2050
Vision

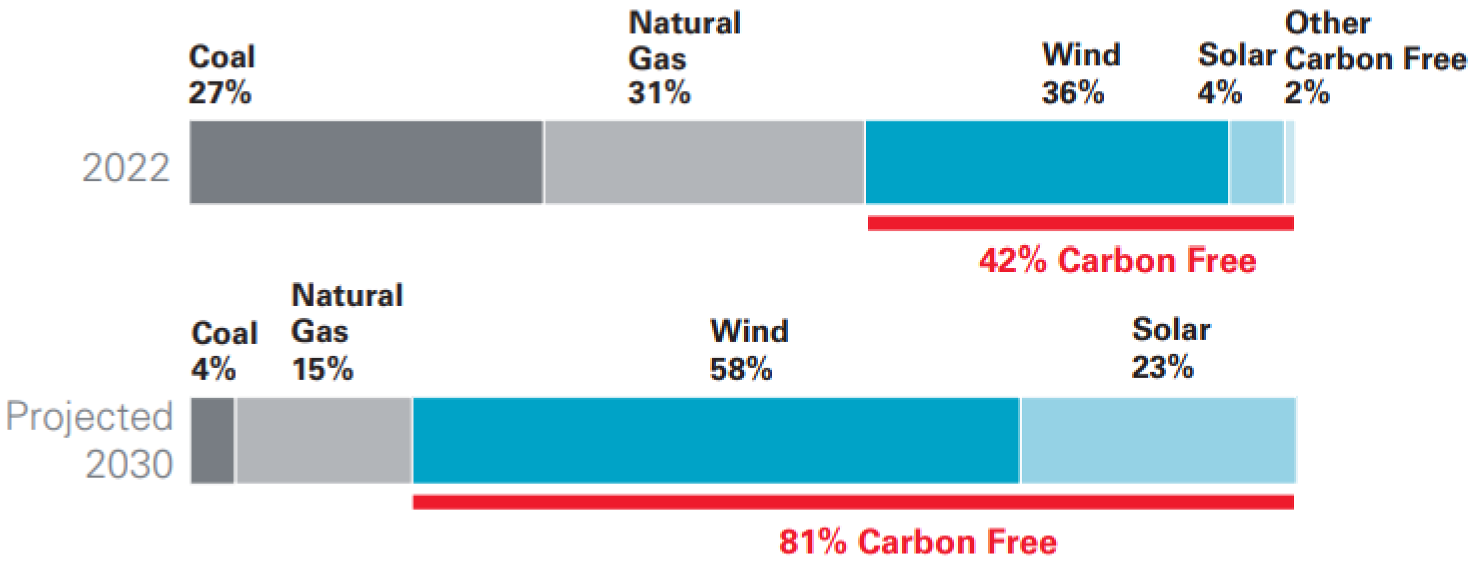


Company-wide carbon emissions reductions from serving our customers, compared to 2005

Upper Midwest energy mix



Colorado energy mix



Colorado's Clean Energy Plan (CEP) for 80x2030 Goal

Coal Action Plan
End our use of coal by the end of 2030 to reduce emissions

New Clean Energy
Addition of clean energy resources including wind, solar and storage

Colorado's Power Pathway
560 miles of new 345 kv transmission infrastructure

Maintain Reliability
Firm dispatchable resources to support the transition

Resource Additions between 2025 and 2030: 5700 MW on Tx, 1200 MW on Dx

Wind = 2400 MW

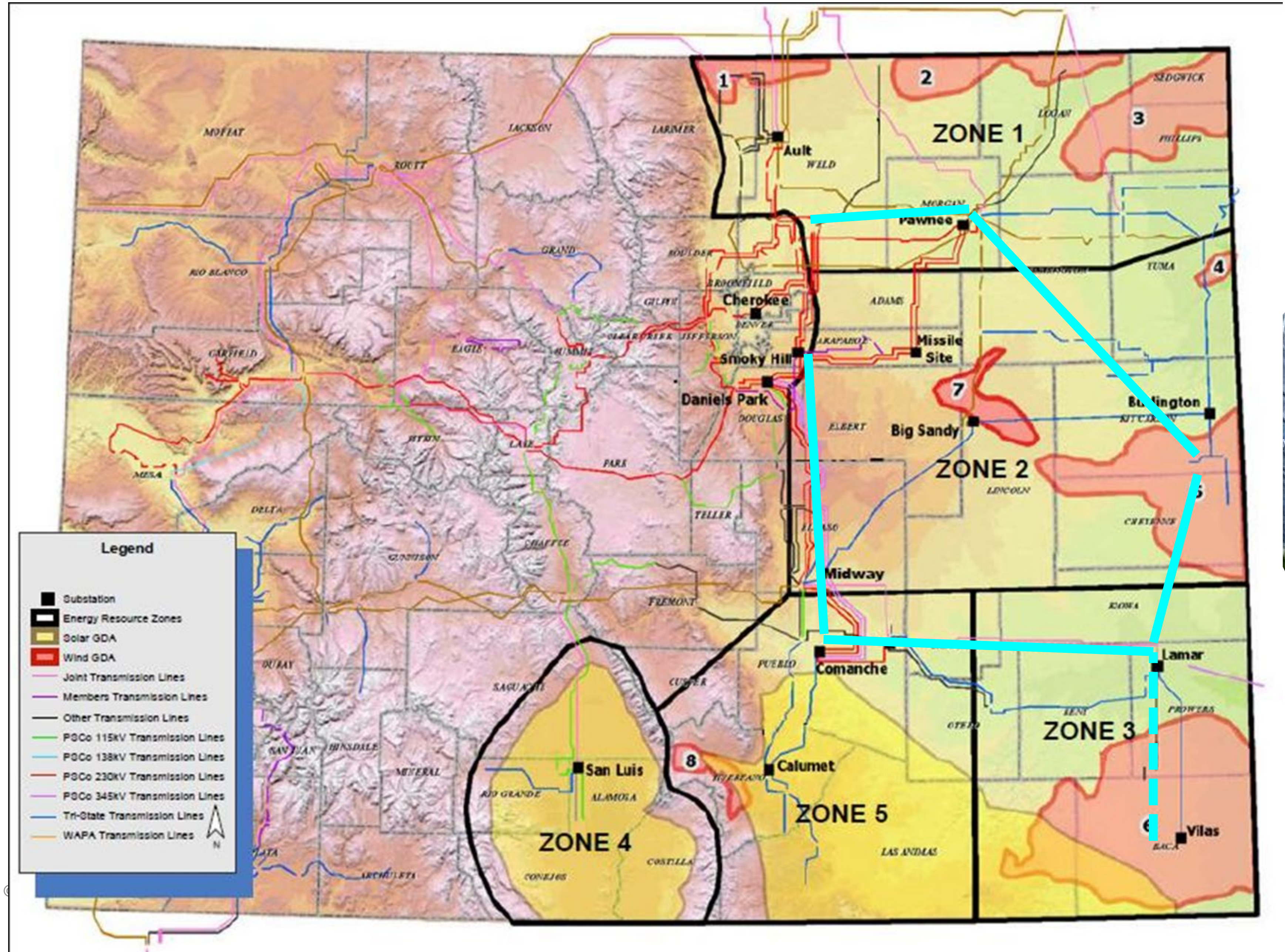
Solar = 1600 MW

Storage = 400 MW

Firm Dispatchable = 1300 MW

Distributed Solar = 1200 MW

Colorado's Power Pathway for Access to ERZs



Comanche Area Resource Transformation 2022-2025

Aggregate Comanche Coal Generating Plant Retirements = 1410 MW

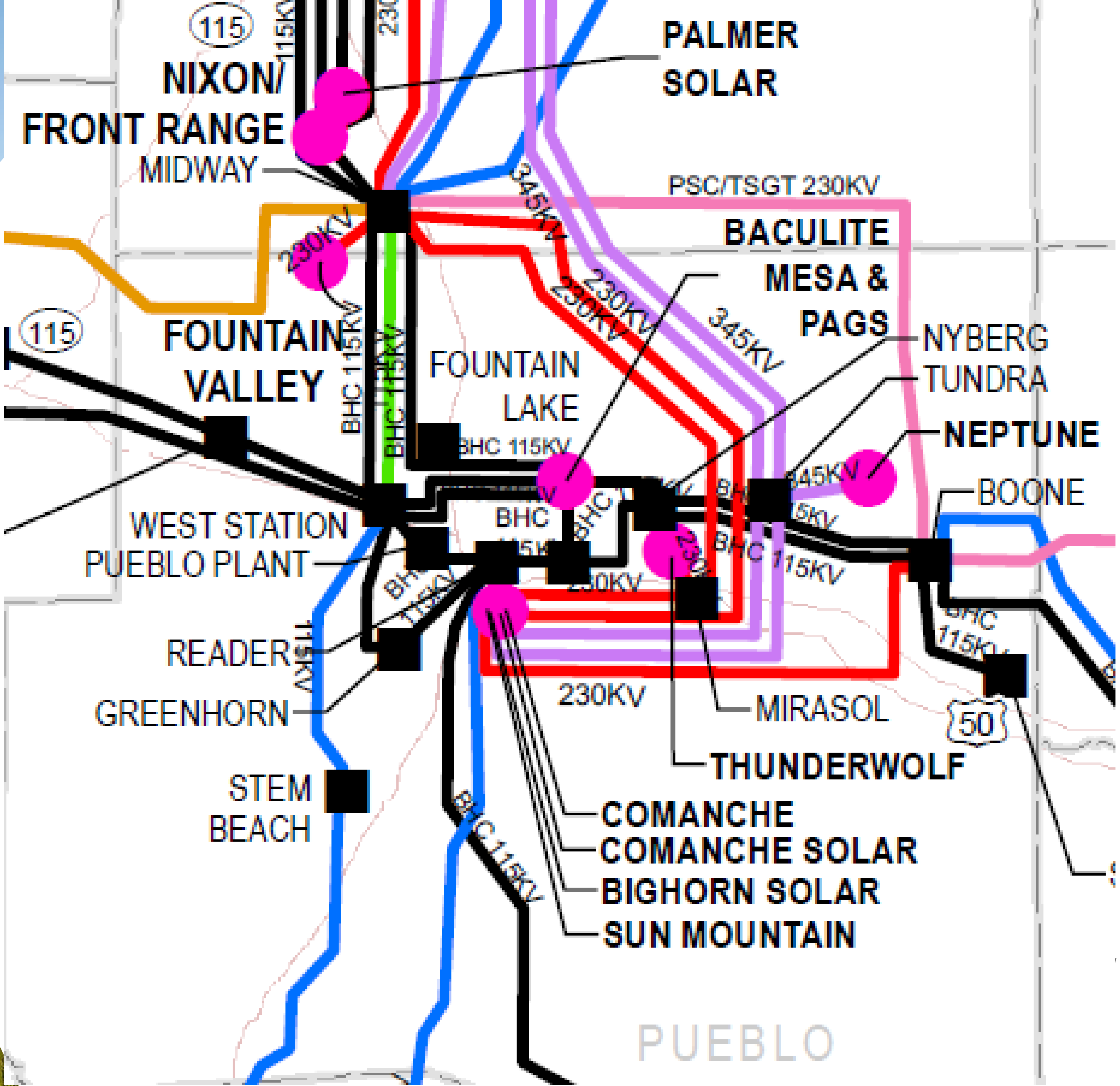
- Com-1 = 325 MW (EOY 2022) Com-2 = 335 MW (EOY 2025) Com-3 = 750 MW (EOY 2030)

Aggregate VRE Resource (i.e. IBR) Additions in Comanche Area = 1135 MW

- Three PV Solar Gen plants at Comanche 230kV (Y2022) = 120+240+200 = 560 MW
- Two Hybrid Gen plants (PV Solar + Battery Storage) in electrical proximity to Comanche (Y2023)
- Thunder Wolf @230kV POI = 250 MW Neptune @345kV POI = 325 MW

Acceptable System Performance Study performed using EMT models for VRE IBRs to evaluate:

- Voltage Ride-Through (VRT) capability
- PLL (Phase Locked Loop) Instability
- IBR Unit / Plant Controller Interactions or Instability


115
NIXON/
FRONT RANGE
MIDWAY
PALMER
SOLAR
PSC/TSGT 230KV
345KV
230KV
BACULITE
MESA &
PAGS
FOUNTAIN
VALLEY
FOUNTAIN
LAKE
BHC 115KV
NYBERG
TUNDRA
NEPTUNE
BOONE
WEST STATION
PUEBLO PLANT
BHC
READER
GREENHORN
STEM
BEACH
MIRASOL
THUNDERWOLF
50
COMANCHE
COMANCHE SOLAR
BIGHORN SOLAR
SUN MOUNTAIN
PUEBLO

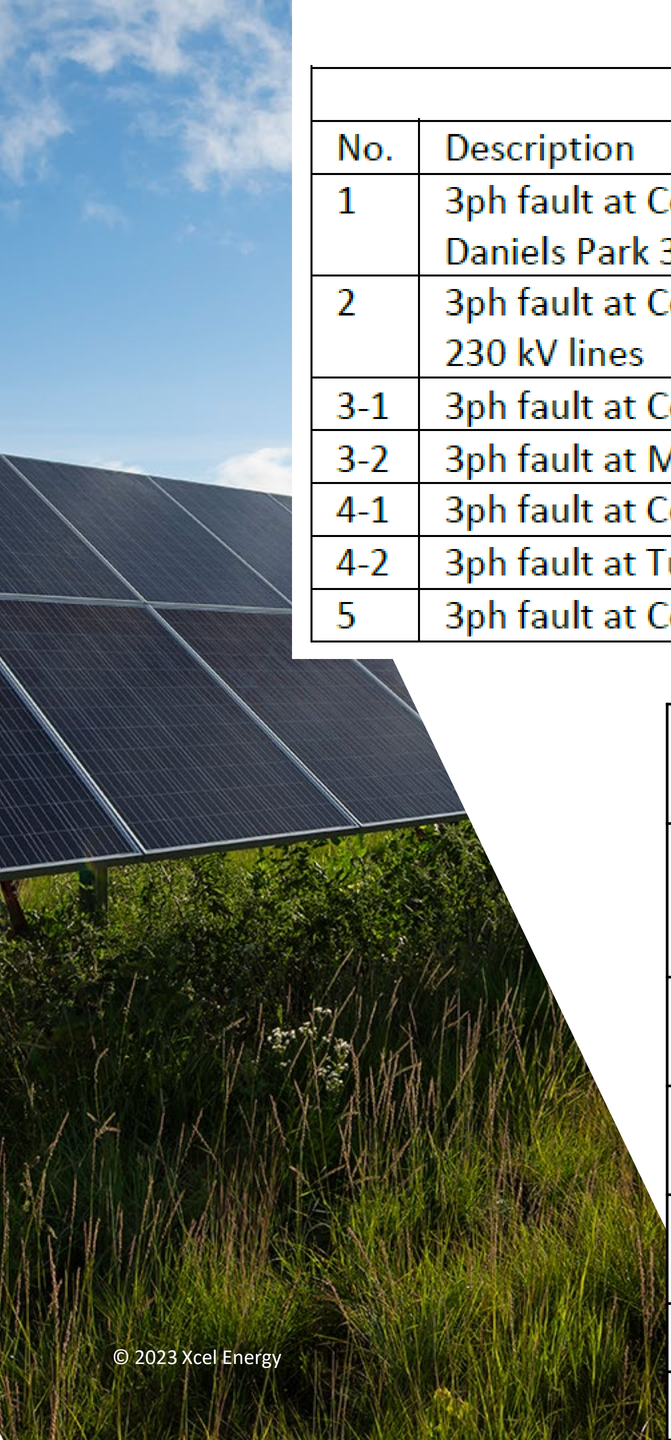


Table 2-1: Selected Disturbances

Disturbance		TPL Category
No.	Description	
1	3ph fault at Comanche 345 kV followed by loss of Comanche - Daniels Park 345 kV and Tundra - Daniels Park 345 kV lines	P7.1
2	3ph fault at Comanche 230 kV followed by loss of Comanche - Midway 230 kV and Mirasol - Midway 230 kV lines	P7.1
3-1	3ph fault at Comanche 230 kV followed by loss of Comanche - Mirasol 230 kV line	P1.2
3-2	3ph fault at Mirasol 230 kV followed by loss of Mirasol - Midway 230 kV line	P1.2
4-1	3ph fault at Comanche 345 kV followed by loss of Comanche - Tundra 345 kV line	P1.2
4-2	3ph fault at Tundra 345 kV followed by loss of Tundra - Daniels Park 345 kV line	P1.2
5	3ph fault at Comanche 230 kV followed by loss of Comanche - Boone 230 kV line	P1.2

Scenarios	Comanche Area Aggregate IBRs	3ph Fault Clearing Time	Notes
Base	1135 MW	345kV = 4.5 cy 230kV = 5.5 cy	At Coman = 560 MW Proximate = 575 MW Normal Clearing Time (NCT)
1	1135 MW	345kV = 18 cy 230kV = 22 cy	4 x NCT
2	2360 MW (~2 x Base)	same as above	At Coman = 1210 MW Proximate = 1150 MW
3	3020 MW (~2.7 x Base)	same as above	At Coman = 1860 MW Proximate = 1150 MW
4	3020 MW	NCT	
5	3020 MW	NCT	SynCond @ Coman

Disturbance No.	Base Scenario	Sensitivity Scenario 1	Sensitivity Scenario 2	Sensitivity Scenario 3	Sensitivity Scenario 4	Sensitivity Scenario 5
1				(1)	(2)	(3)
2					Not Tested	
3-1		Not Tested				
3-2						
4-1						
4-2						
5			Not Tested			

(1) System unable to maintain stability

(2) System is stable with undamped oscillations

(3) System is stable with undamped oscillations. Oscillation magnitude smaller compared to (2)

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5	3020 MW	NCT	SynCond @ Coman

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EMT (PSCAD) Model Verification (Validation?) Tests

Model Usability Verification

Model Electrical Configuration Verification

Plant Controller Verification

Basic Performance Verification

- Initialization Test
- Balanced / Unbalanced Fault Ride-through Test
- Overvoltage Ride-through Test
- Voltage & Active Power Reference Step Change Tests
- Grid Frequency Response and Ride-through Test
- Grid Voltage Phase-Angle Change Ride-through Test
- POI SCR Change Test

Basic Protection Verification

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High Fidelity Validated IBR Models – the Value

- Essential for gaining confidence in grid performance study results
  - ✓ identify grid performance improvement need and evaluate solutions in planning horizon
  - ✓ establish operating limits (SOLs/IROLs) in operating horizon
- Are simulation-based IBR model verification/validation tests sufficient?
  probably better than nothing
- Is system disturbance event-recording based IBR model validation ideal?
  perhaps, but does not help with predictive grid performance studies
- Is laboratory-based IBR model testing & validation the pragmatic middle ground?
  if capable of validating plant-level models
- Could a grid-interface platform help enhance confidence in IBR model fidelity and/or help evaluate grid reliability solutions?
  absolutely!

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