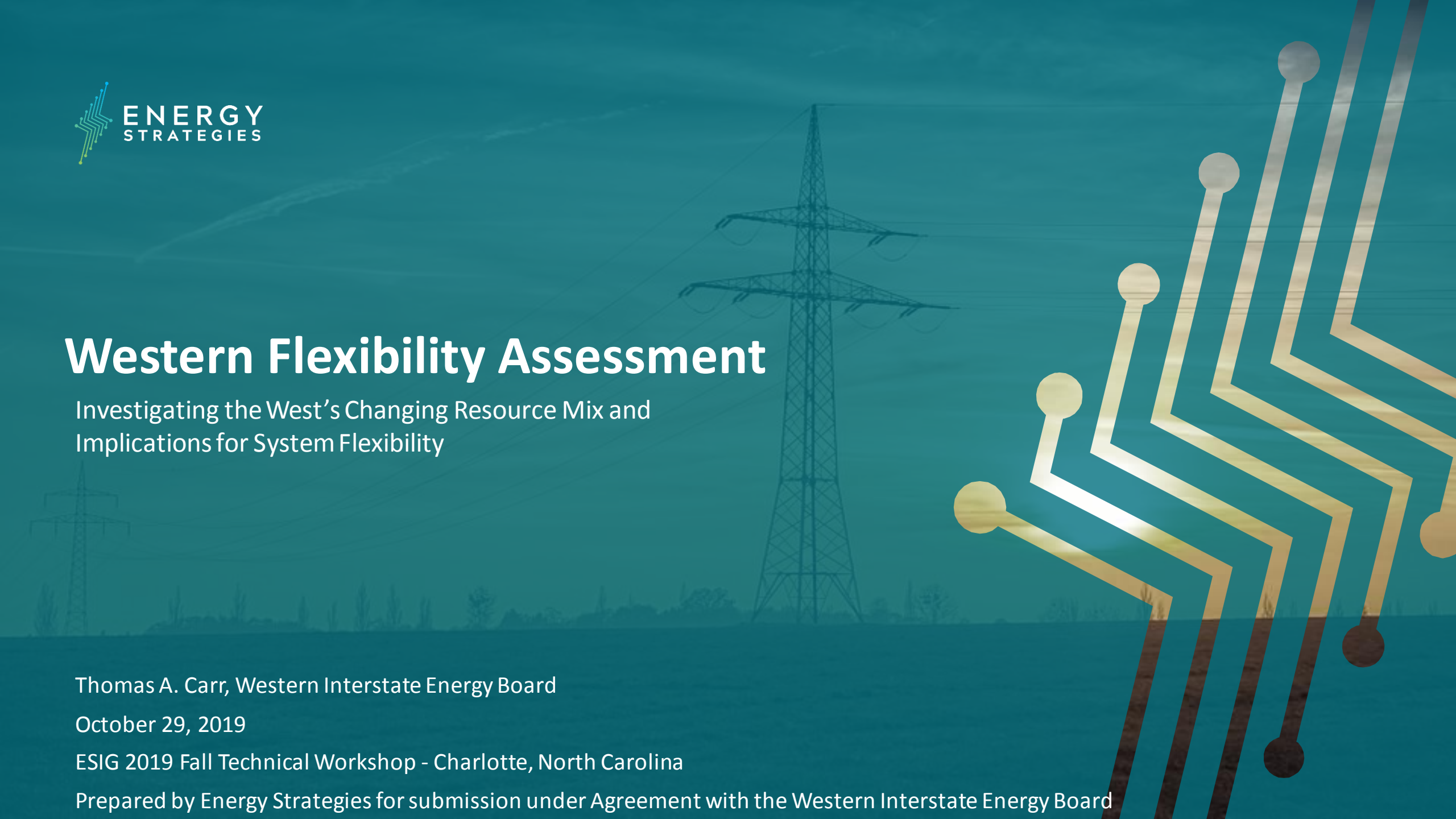


Western Flexibility Assessment

Investigating the West's Changing Resource Mix and Implications for System Flexibility

Thomas A. Carr, Western Interstate Energy Board

October 29, 2019

ESIG 2019 Fall Technical Workshop - Charlotte, North Carolina

Prepared by Energy Strategies for submission under Agreement with the Western Interstate Energy Board

Project Team and Structure

Project Steering Committee

Western Interstate Energy Board

Invenergy

AWEA American Wind Energy Association

EDF renewables

NEXTera ENERGY

nationalgrid ventures

ORION Renewable Energy Group LLC

AVANGRID

Technical Advisory Committee

- 16 industry experts from across the West, representing utilities, regional planning bodies, NGOs, states, and National Labs

WIEB Project Manager

Tom Carr, WIEB Staff

ENERGY STRATEGIES

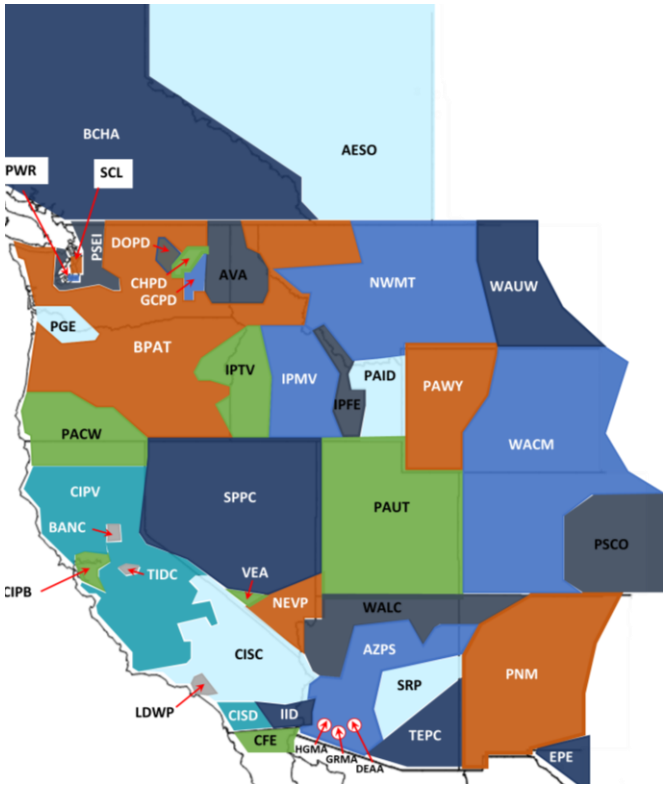
Ben Brownlee, Daniel Ramirez, Gary Simonson, Caitlin Liotiris, Kathleen Fraser, Keegan Moyer

- **Study benefited from technical support and data provided by WECC, BPA, and the Northwest Power and Conservation Council (NWPCC)**
- **Cameron Yourkowski (EDPR) and Tony Usibelli (WA) were instrumental in developing the original project proposal and organizing funders and committee structure**

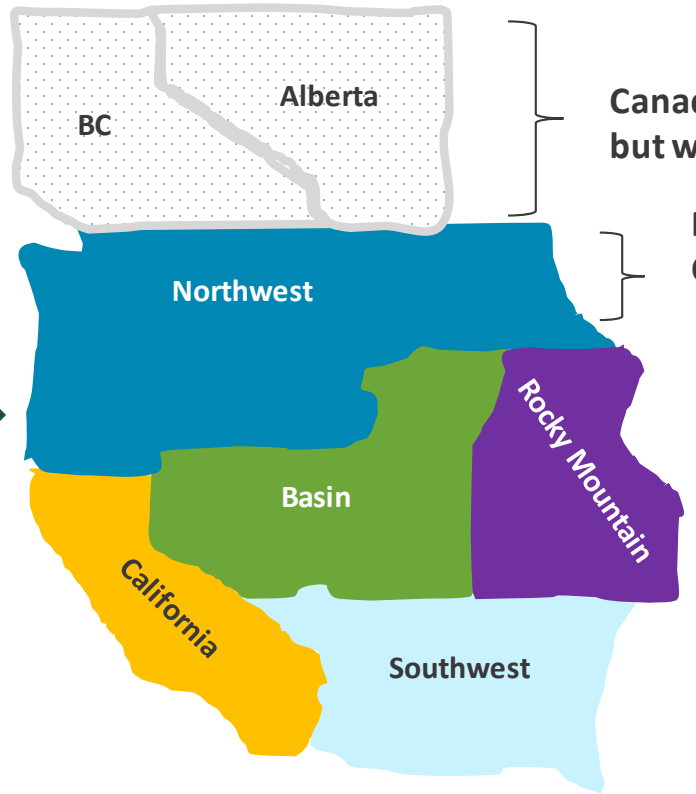
Study Footprint:

Results conveyed at regional-level, but modeling performed on full grid

WECC Balancing Areas



Study Regions



Canadian footprints are represented in modeling but were not focus of study – assumed BAU

Northwest region consistent with NW Power and Conservation Council footprint

Capacity expansion study captures transmission limitations between regions and limits inter-region resource selection based on inter-regional transmission limitations when appropriate

Full nodal analysis used in congestion and powerflow studies represent detailed system (no regional aggregation)

Projected RPS/Clean Energy Targets State

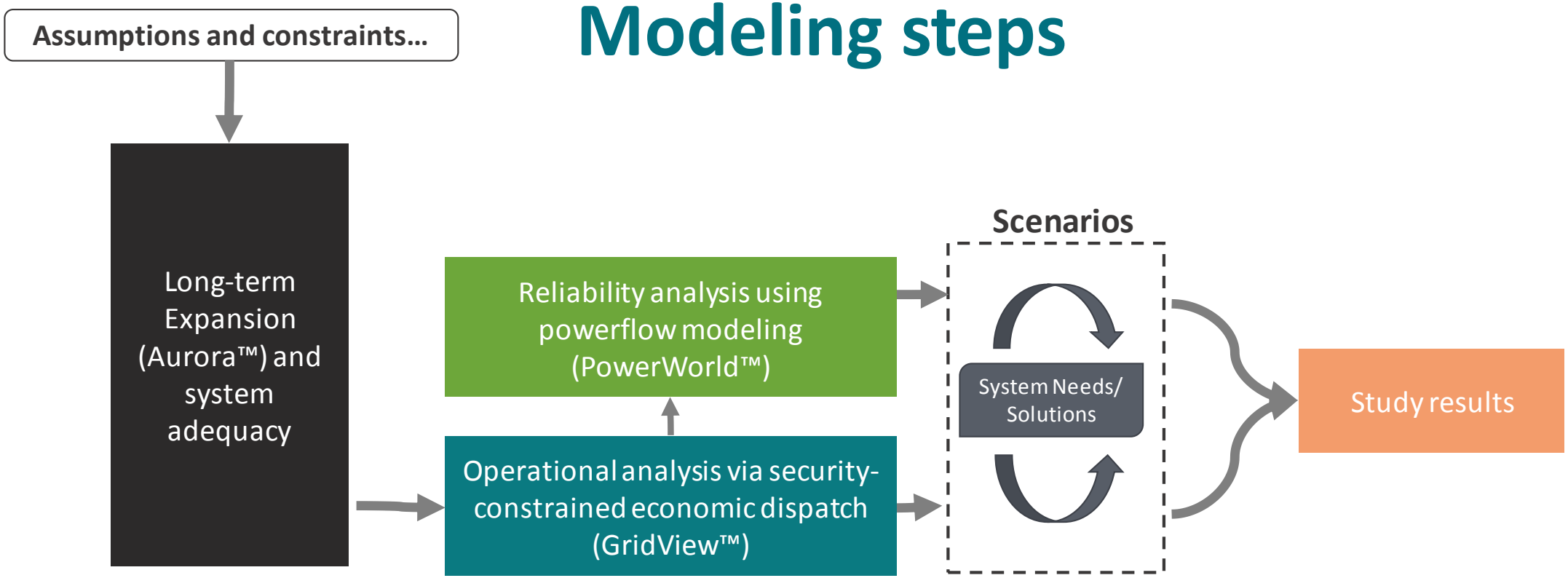
Year	California	Northwest				Intermountain		Rockies		Southwest	
	CA	OR	WA	ID	MT	NV	UT	CO	WY	AZ	NM
2020	33%	20%	15%	4%	15%	22%	0%	30%	0%	10%	20%
2021	33%	20%	15%	8%	15%	22%	0%	30%	0%	11%	20%
2022	33%	20%	15%	12%	15%	26%	0%	30%	0%	12%	20%
2023	33%	20%	20%	16%	15%	26%	0%	32%	0%	13%	20%
2024	44%	20%	25%	20%	15%	34%	0%	36%	0%	14%	20%
2025	44%	27%	30%	24%	15%	34%	0%	40%	0%	15%	25%
2026	44%	27%	35%	28%	15%	34%	0%	44%	0%	15%	30%
2027	52%	27%	40%	32%	15%	42%	0%	48%	0%	20%	35%
2028	52%	27%	45%	36%	15%	42%	0%	52%	0%	25%	40%
2029	52%	27%	50%	40%	15%	42%	0%	56%	0%	30%	45%
2030	60%	35%	55%	44%	15%	50%	0%	60%	0%	35%	50%
2031	63%	35%	60%	48%	15%	50%	0%	64%	0%	40%	53%
2032	66%	35%	65%	52%	15%	50%	0%	68%	0%	45%	56%
2033	69%	35%	70%	56%	15%	50%	0%	72%	0%	50%	59%
2034	72%	35%	75%	60%	15%	50%	0%	76%	0%	55%	62%
2035	75%	45%	80%	64%	15%	50%	0%	80%	0%	60%	65%

Study Period

Cap and Invest

Carbon Cap and 80% RPS by 2035

Modeling steps



1. An expansion plan was developed to meet state policies and adequacy, with extra adequacy studies for Northwest.

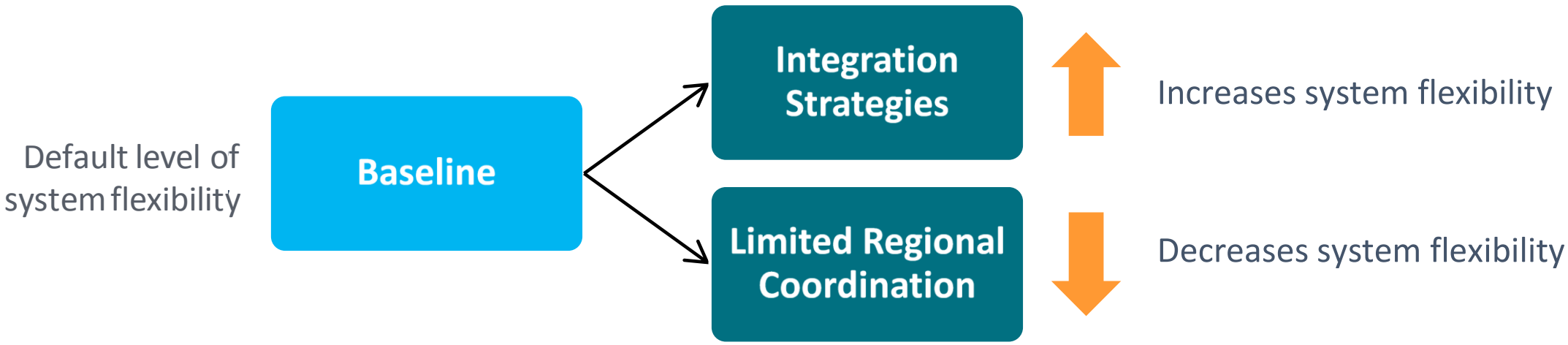
2. Production cost modeling was performed to evaluate system performance. Solutions were evaluated and system conditions during stressed hours are passed to powerflow model.

3. Powerflow modeling evaluates reliability for steady-state performance. Needs and solutions are considered.

4. Results from all studies synthesized to draw conclusions

Baseline Case

Baseline Case – "expected future"
Scenarios: (1) higher flexibility and (2) lower flexibility

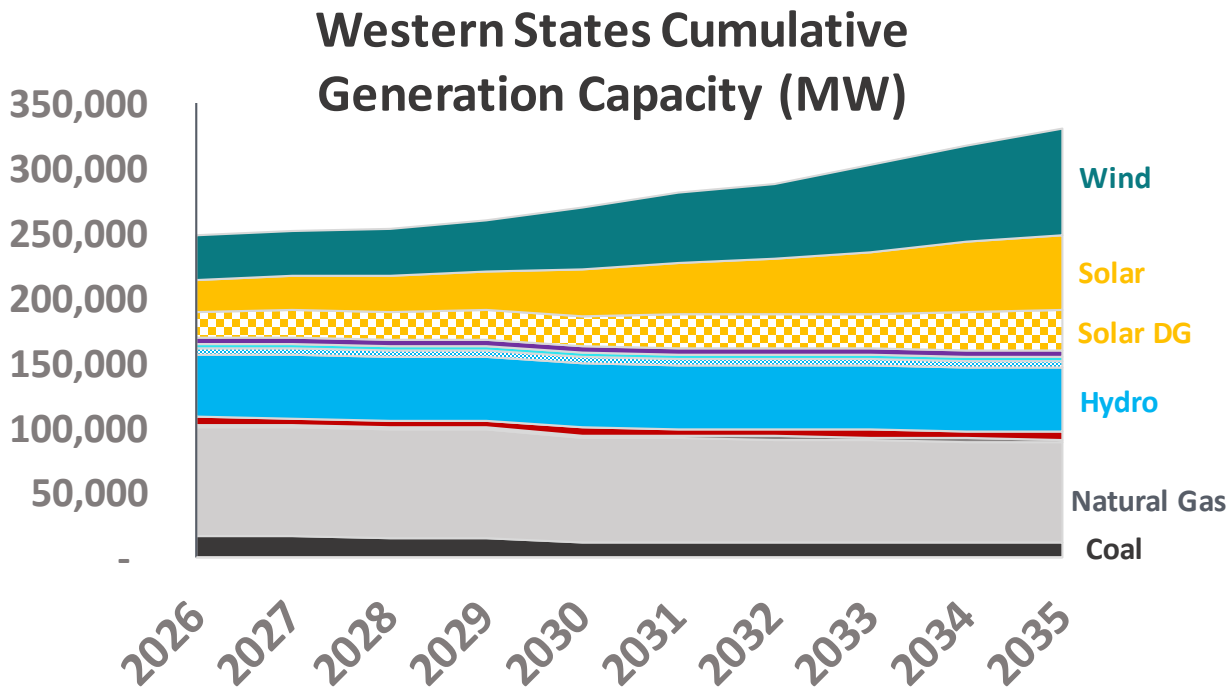


Baseline Case represents "default" amount of system flexibility

- **Renewable resources** are deployed to meet modeled state clean energy policy requirements
- **Regionalization** of energy markets occurs (i.e. no transmission service charges between BAAs)
- **Load growth** occurs consistent with recent regional and balancing area forecasts – 165 GW by 2035
- Assumed near-term integrated resource portfolios (IRPs) resources are constructed, then capacity expansion modeling (AURORA™) **added resources** for remainder of study period
- Announced and assumed **coal retirements** total 7 GW by 2026
- Assumes a small set of **"near-term" transmission projects** with a direct path to cost recovery are built

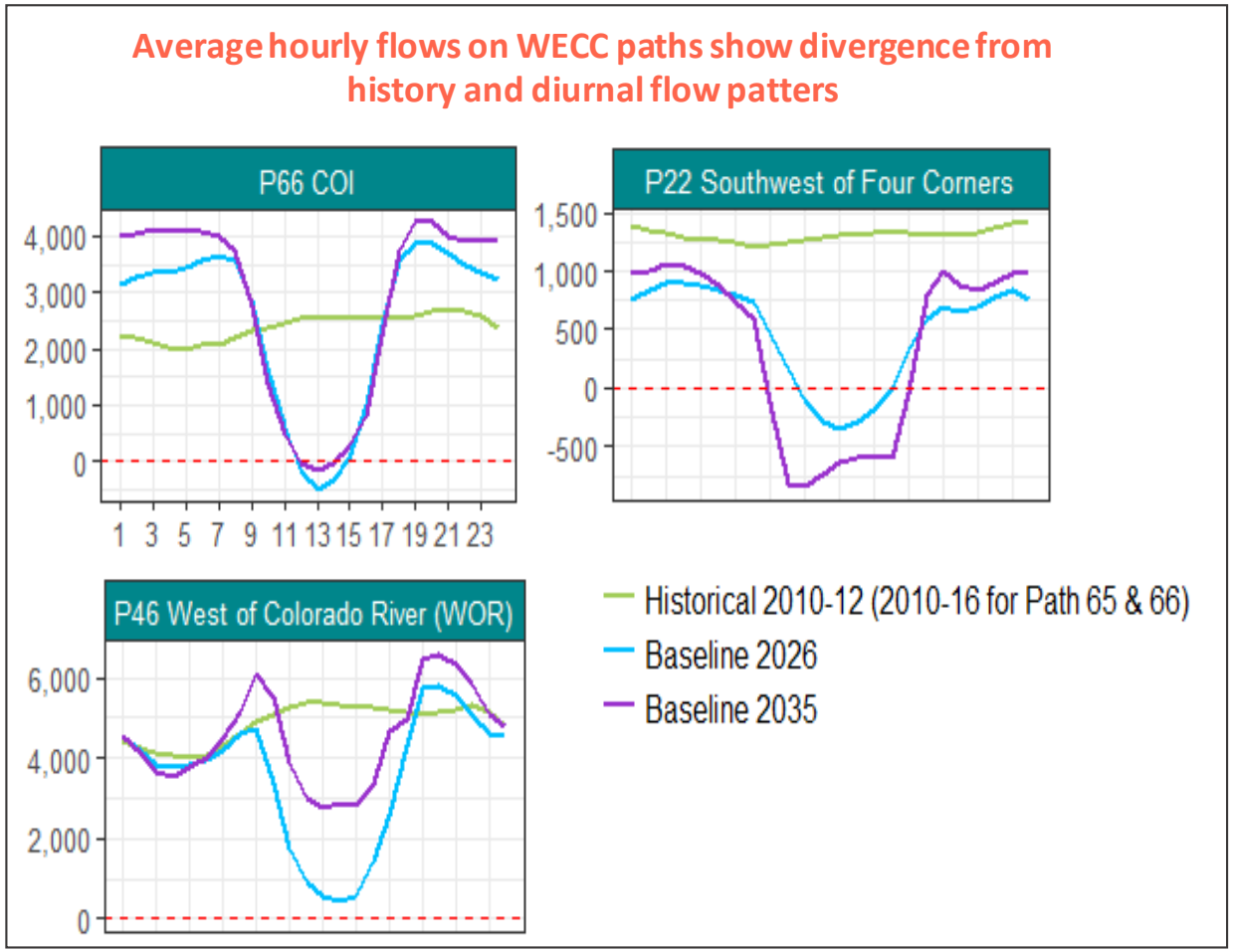
Clean Energy Target Based on Assumed Policies

33%	64%
2026	2035

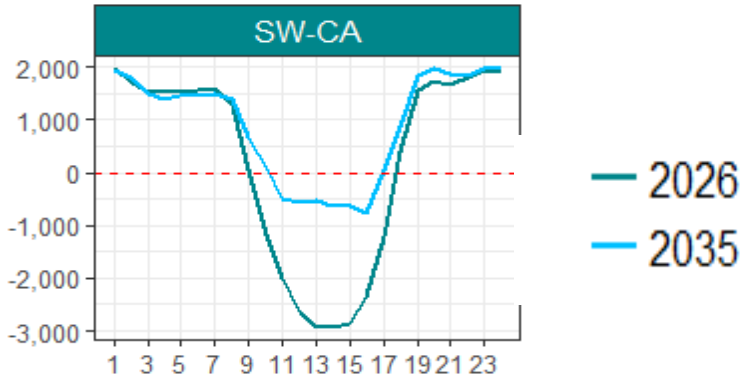


Baseline Case	Study Year 2026	2035
Curtailments (%)	3%	20%
Clean Energy Penetration (%)	✓ Hit target 33% 36%	✗ Missed target 64% 52%
Transmission Congestion	Isolated/Low	High
Production Costs ($B)	$11.1	$10.0
CO_2 Emissions (Million Metric Tons)	161	134

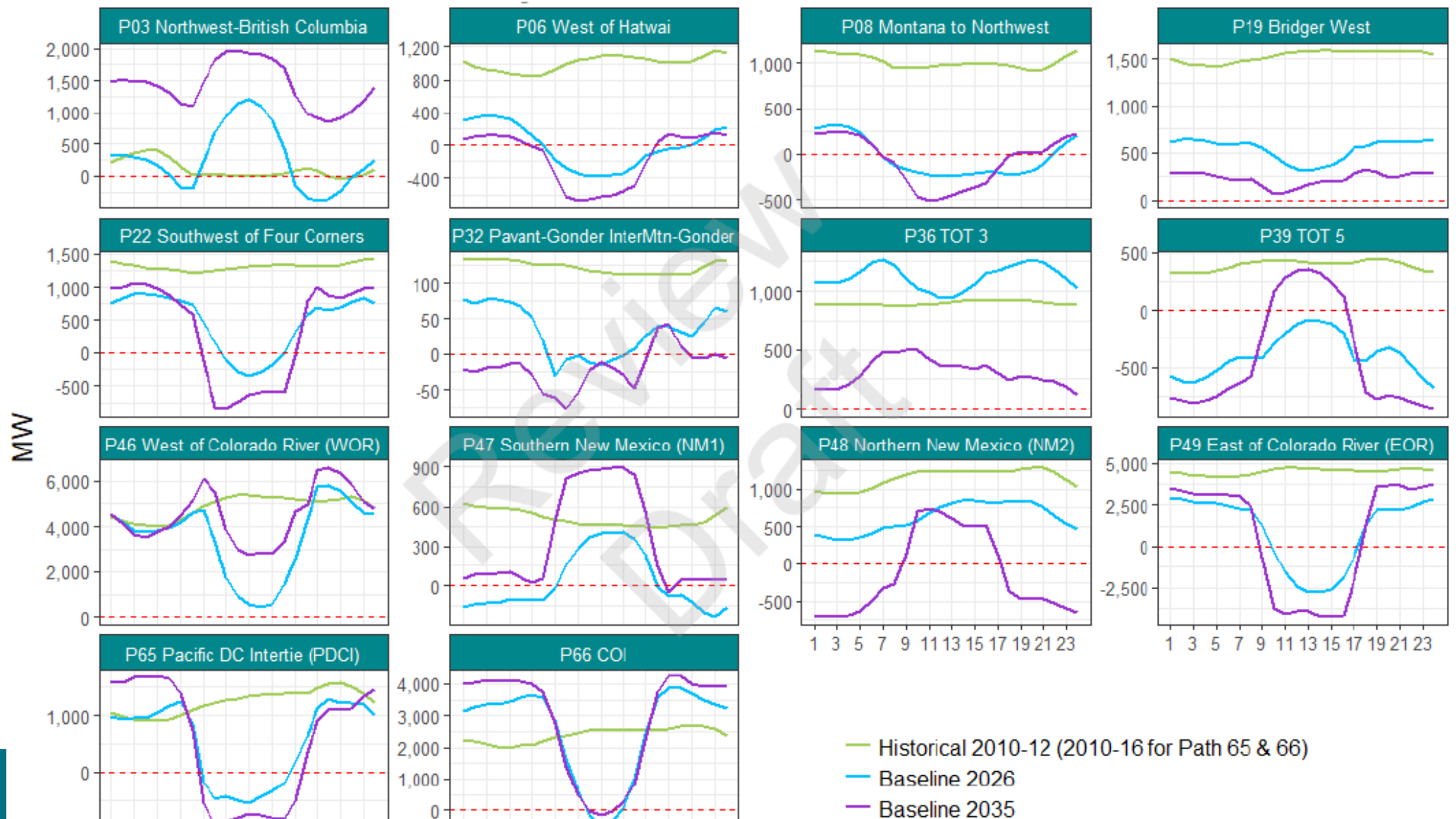
Interregional power flows increase and support system flexibility



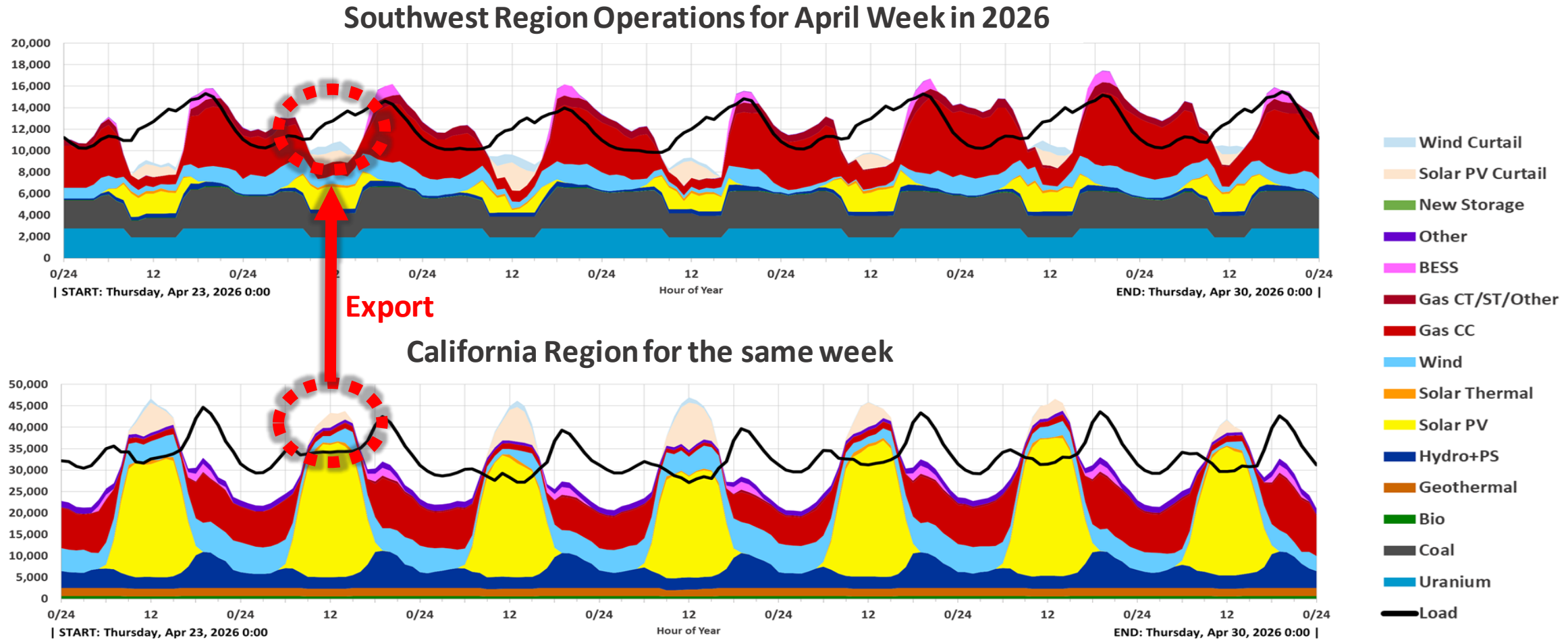
- Results indicate that interregional power flows may change significantly from historical levels – more dynamic use of system indicates "unplanned" value in system
- Diurnal changes in flow patterns become the new norm
- In certain instances, interregional power flows can decrease under high penetrations of renewables



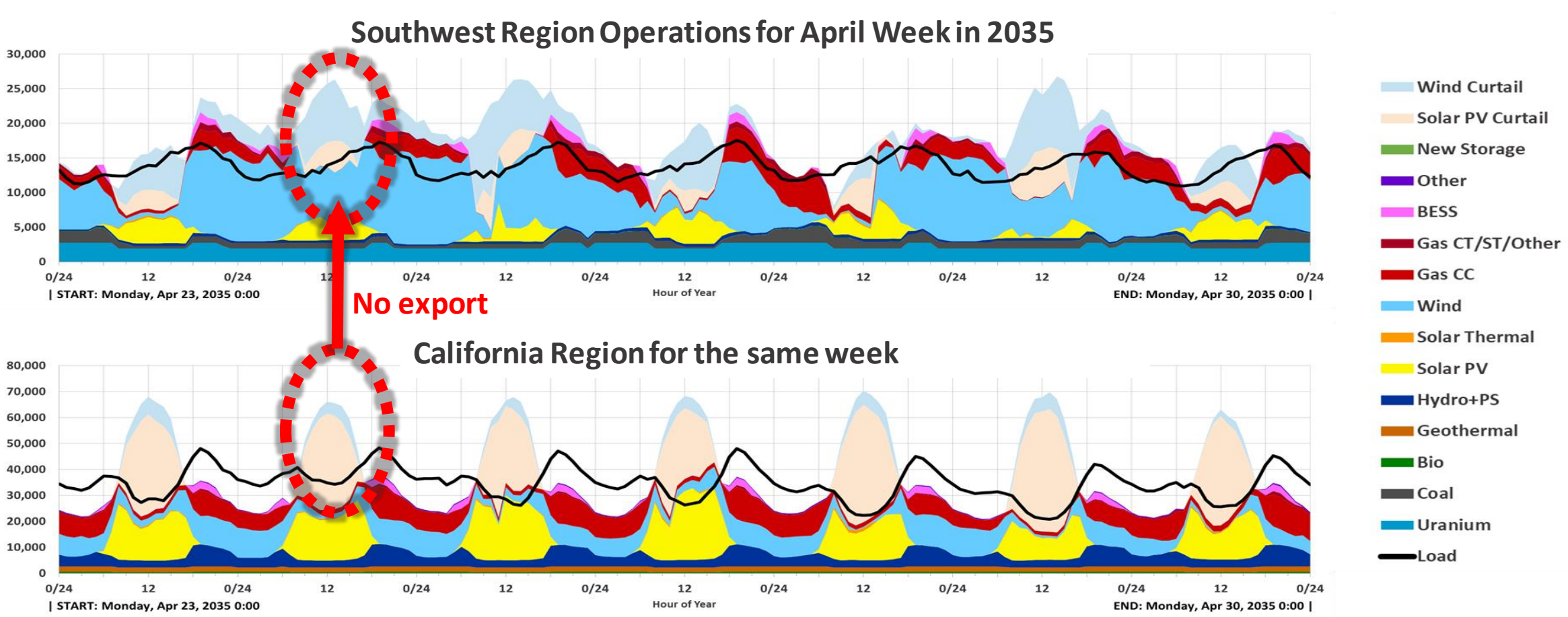
Changes in Daily Power Flows on Major WECC Paths



In the 2020's, interregional exchange is viable and common flexibility strategy



By the 2030s, a lack of buyers for excess renewable power is partially to blame for the flexibility challenges

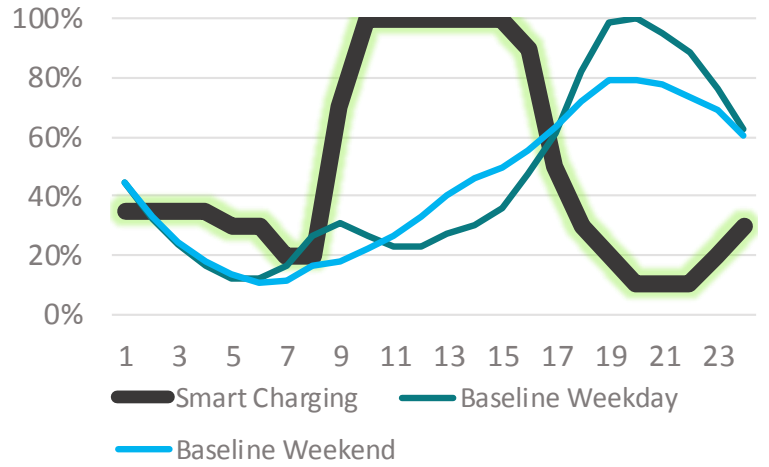


SCENARIOS

Integration Strategies Scenario

- ***Increases flexibility*** **not already built into Baseline Case**
  - ❖ "How effective are investments or decisions that increase system flexibility?"
- **Key assumptions:**
  - ❖ New **transmission upgrades** to help deliver renewable power to loads
  - ❖ Major build-out of long-duration **storage** (10 GW) and 4-hour battery storage co-located at new renewable energy facilities (32 GW)
  - ❖ **Managed charging** of EV-loads
  - ❖ Additional **resource diversity** and enhanced generator siting

Assumed EV Charging Shape (avg. day)



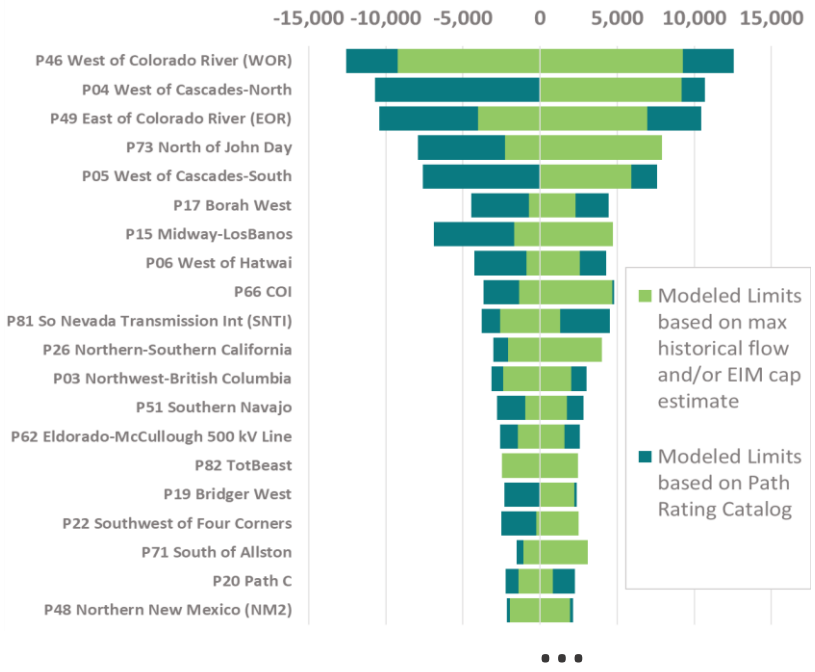
Assumed Incremental Storage (GW)

Technology	2026	2035
4-hr Battery	2.1	32.5
12-hr Pumped Storage	0.60	10.2

Limited Coordination Scenario

- ***Removes institutional flexibility*** **built into Baseline Case in the form of wholesale market coordination**
  - ❖ "What if increased coordination of Western wholesale power markets **does not occur**"?
- **Key assumptions:**
  - ❖ Western EIM continues, but a West-wide day-ahead wholesale market does not materialize
  - ❖ Flows on key paths are limited to historical maximums
  - ❖ Ramping of flows on key paths are limited to historical maximums

Path limits based on historical values



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On-Peak & off-peak non-firm wheeling charges assumed for all day-ahead transactions

Business-as-usual transmission operations and efficiency

Key Results from the 3 Scenarios

Study Year	System Flexibility:	Lower ↓	Benchmark	Higher ↑
	Study Case:	Limited Coordination	Baseline	Integration Strategies
2026	Curtailments (%)	11%	3%	0%
2035		46%	20%	9%
2026	2026 Target 33% Renewable Penetration (%) 2035 Target 66%	34% ✓	36% ✓	37% ✓
2035		49% ✗	52% ✗	69% ✓
2026	CO2 Emissions (Million Metric Tons)	165	161	159
2035		151	134	108
2026	Production Costs ($ Billions)	$12.1	$11.1	$10.7
2035		$11.3	$10.0	$7.8

Summary

- ✓ The West can achieve near-term (2026) policy targets with modest curtailments and without major changes to system flexibility. However, over time policy targets become more difficult to achieve.
- ✓ Regions will rely heavily on imports/exports to meet flexibility needs, and transfers between regions will increase significantly in the coming years. Interregional power flows will change from historic patterns.
- ✓ By the 2030s, the "flexibility cost" of not having coordinated wholesale markets becomes severe and policy goals may not be attained without more flexibility to the system.
- ✓ A balanced set of flexibility solutions are likely needed. The urgency in implementing these solutions increases over time. Market coordination, flexibility investments, customer programs and new operational practices are all going to help and are all likely to be required.
- ✓ The Western transmission system is robust and dynamic, providing value in unanticipated ways. However, more transmission will likely be needed to provide capacity/flexibility to meet long-term policy goals.

THANK YOU

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ENERGY STRATEGIES

Supplemental Slides

Baseline Case Details

- **What it is:** Assumes that planned or potential RPS or GHG reduction policy is implemented in certain states; intended to represent an expected future
- **What it is NOT:** An endorsement or prediction of any specific policy or a determination around specific infrastructure needs

Western Mix (MW): Forecast for Baseline Case in 2025

Resource Type	2019	2025	Change
Coal	28,112	20,670	(7,442)
DG	12,534	18,744	6,210
Gas	83,712	82,358	(1,354)
Geo	2,666	2,753	87
Hydro	49,161	48,912	(248)
Nuclear	7,443	6,321	(1,122)
Other	2,400	2,738	338
Other Thermal	756	586	(171)
Solar	16,062	20,769	4,707
Storage	5,260	8,082	2,822
Wind	21,627	26,186	4,559
TOTAL	**229,732**	**238,118**	**8,386**

Data sources: EIA, WECC Anchor Data Set, California PUC IRP (2017-18), utility IRPs

Assumed State Policy for Baseline Case

Year	California	Northwest				Intermountain		Rockies		Southwest	
	CA	OR	WA	ID	MT	NV	UT	CO	WY	AZ	NM
2020	33%	20%	15%	4%	15%	22%	0%	30%	0%	10%	20%
2021	33%	20%	15%	8%	15%	22%	0%	30%	0%	11%	20%
2022	33%	20%	15%	12%	15%	26%	0%	30%	0%	12%	20%
2023	33%	20%	20%	16%	15%	26%	0%	32%	0%	13%	20%
2024	44%	20%	25%	20%	15%	34%	0%	36%	0%	14%	20%
2025	44%	27%	30%	24%	15%	34%	0%	40%	0%	15%	25%
2026	44%	27%	35%	28%	15%	34%	0%	44%	0%	15%	30%
2027	52%	27%	40%	32%	15%	42%	0%	48%	0%	20%	35%
2028	52%	27%	45%	36%	15%	42%	0%	52%	0%	25%	40%
2029	52%	27%	50%	40%	15%	42%	0%	56%	0%	30%	45%
2030	60%	35%	55%	44%	15%	50%	0%	60%	0%	35%	50%
2031	63%	35%	60%	48%	15%	50%	0%	64%	0%	40%	53%
2032	66%	35%	65%	52%	15%	50%	0%	68%	0%	45%	56%
2033	69%	35%	70%	56%	15%	50%	0%	72%	0%	50%	59%
2034	72%	35%	75%	60%	15%	50%	0%	76%	0%	55%	62%
2035	75%	45%	80%	64%	15%	50%	0%	80%	0%	60%	65%

Cap and Trade (CA); Cap and Invest (OR, WA); Carbon Cap and 80% RPS by 2035 (ID, MT); Study Period

*Shaded cells indicate assumed policy incremental to BAU

Load

- WECC-wide gross load at **0.8% CAGR**
- **25 GW** of distributed PV by 2035
- **8.3 GW** of new demand from EVs by 2035

Transmission

- Only approved upgrades assumed in-service
- No Full Gateway, B2H, other regional projects
- Montana transmission available in 2025

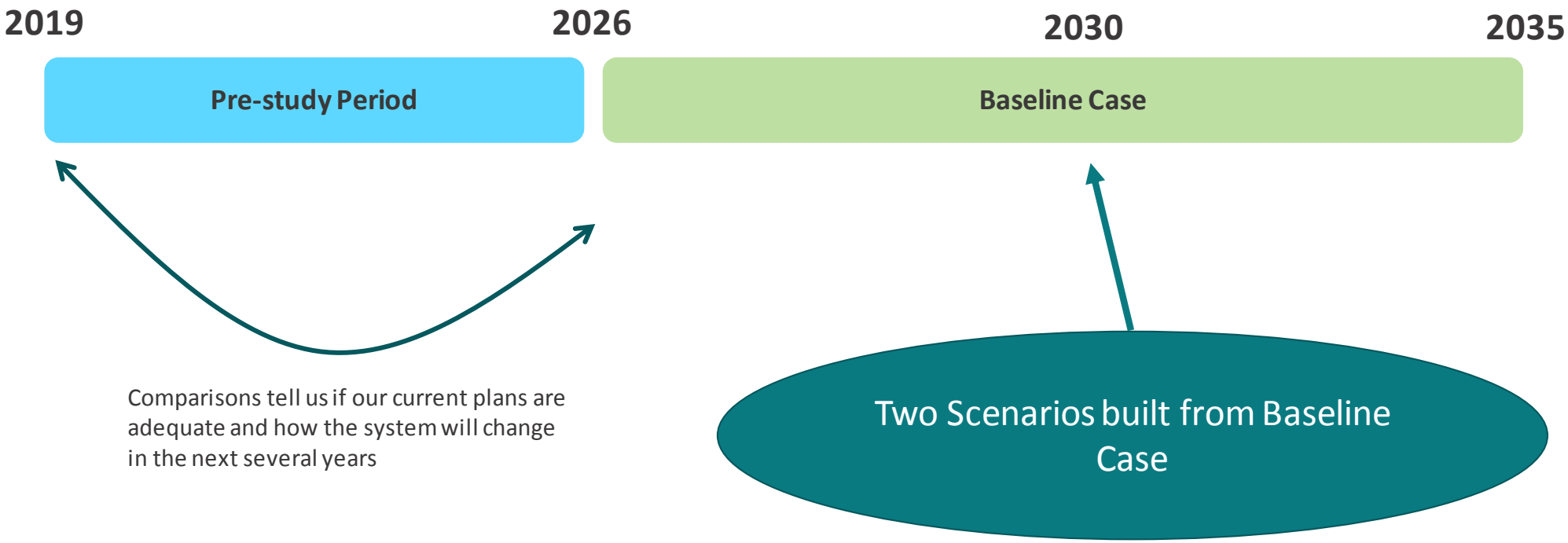
Generation

- Announced and anticipated coal retirements
- 2030 CA build consistent with 17-18 IRP
- Resource potential capped at state-level

Other

- DA market implemented by 2025
- 2035 carbon price based on CEC IEPR: $36.44 / ton (2019$)
- Henry Hub (2019$/mmBtu) 2026: $3.83 2035: $4.77

Study Period



Baseline Case Curtailment and Clean Energy Penetration by Regions

Regional load served by clean energy[28]	2026		2035	
	Curtailment (%)	Penetration (%)	Curtailment (%)	Penetration (%)
Basin	0%	14%	15%	32%
California	3%	49%	25%	56%
Northwest	1%	26%	12%	60%
Rocky Mountain	5%	35%	26%	65%
Southwest	2%	34%	18%	36%
Western U.S.	**3%**	**36%**	**20%**	**52%**
	Clean energy target: 33%		**Clean energy target: 64%**	

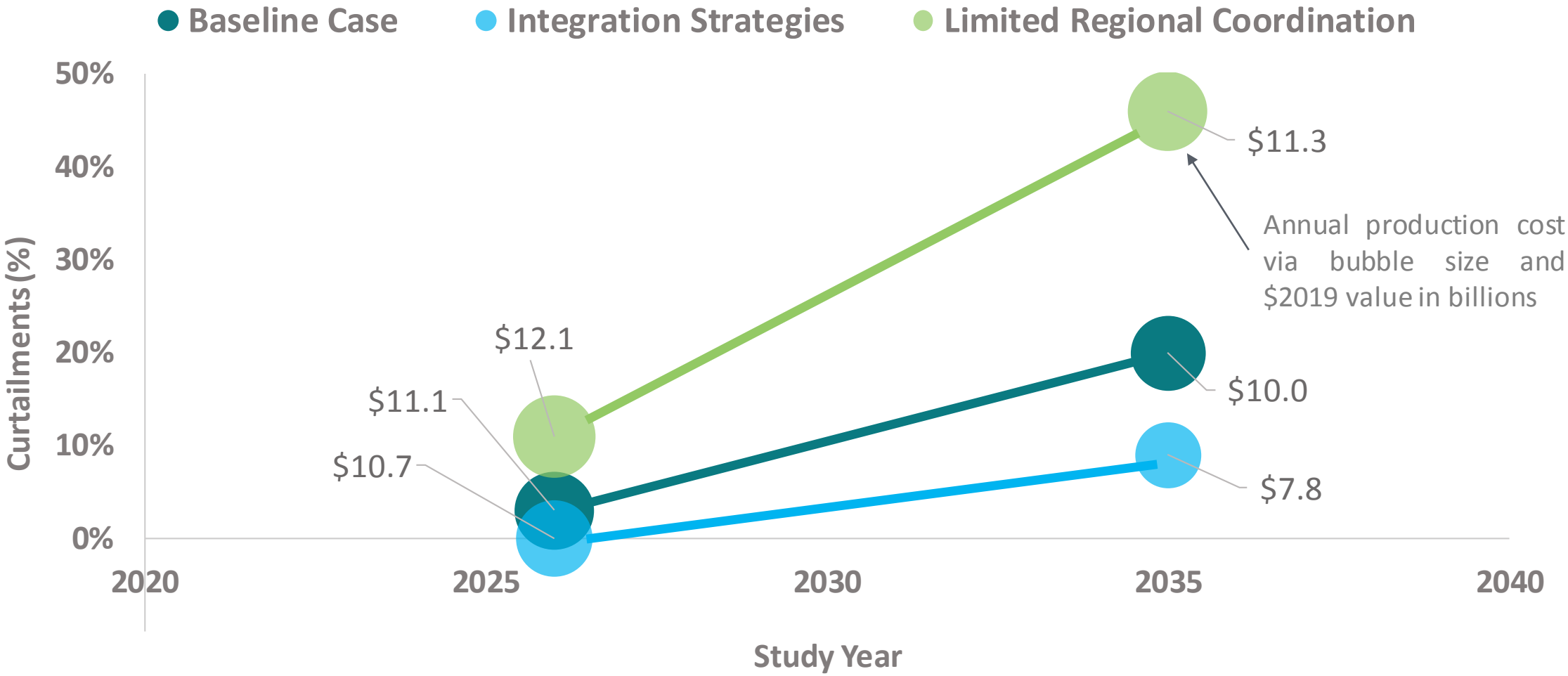
Integration Strategies Curtailment and Penetration by Regions

Regional load served by clean energy[36]	2026		2035	
	Curtailment (%)	Penetration (%)	Curtailment (%)	Penetration (%)
Basin	1%	13%	12%	34%
California	0%	51%	8%	81%
Northwest	1%	26%	7%	68%
Rocky Mountain	0%	37%	11%	76%
Southwest	0%	35%	8%	55%
Western U.S.	**0%**	**37%**	**9%**	**69%**
	Clean energy target: 33%		**Clean energy target: 64%**	

Limited Regional Coordination Curtailment and Penetration by Regions

Regional load served by clean energy[37]	2026		2035	
	Curtailment (%)	Penetration (%)	Curtailment (%)	Penetration (%)
Basin	23%	13%	51%	30%
California	12%	46%	33%	53%
Northwest	2%	26%	15%	56%
Rocky Mountain	3%	32%	26%	54%
Southwest	7%	34%	36%	34%
Western U.S.	**11%**	**34%**	**46%**	**49%**
	Clean energy target: 33%		**Clean energy target: 64%**	

Summary of Key Study Metrics



A balanced set of solutions are likely needed to increase system flexibility to levels necessary to assumed policy goals