Net-Zero 2050

U.S. Economy-Wide Deep Decarbonization Scenario Analysis

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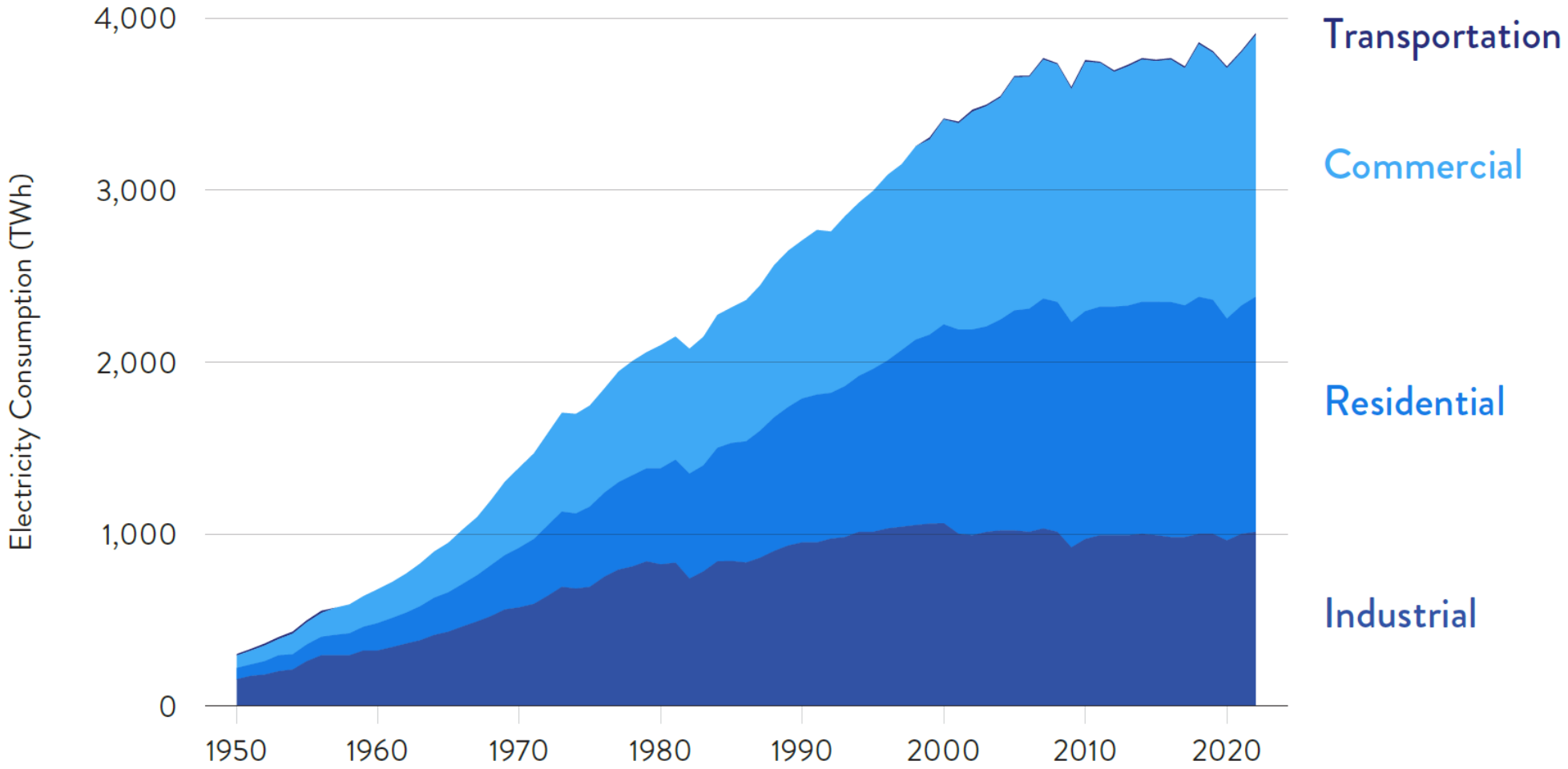
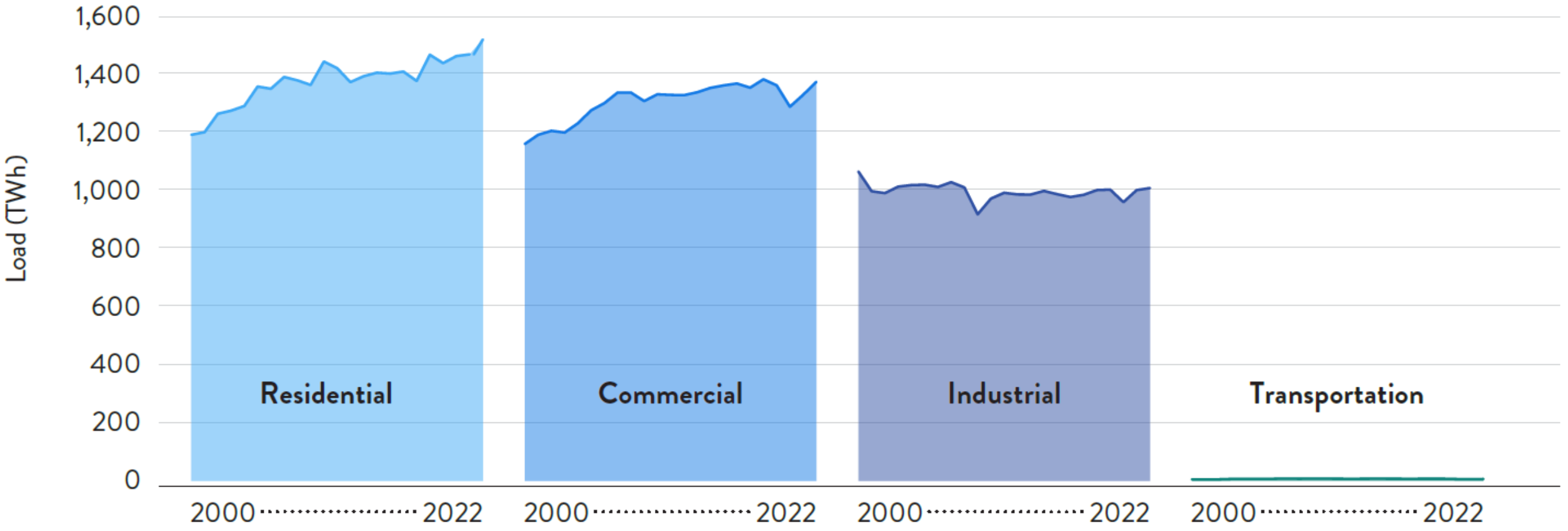
IEA Wind TEM# *113* on *NET ZERO ELECTRICITY SYSTEM STUDIES*
8-9th April 2024

ANNUAL ELECTRICITY CONSUMPTION



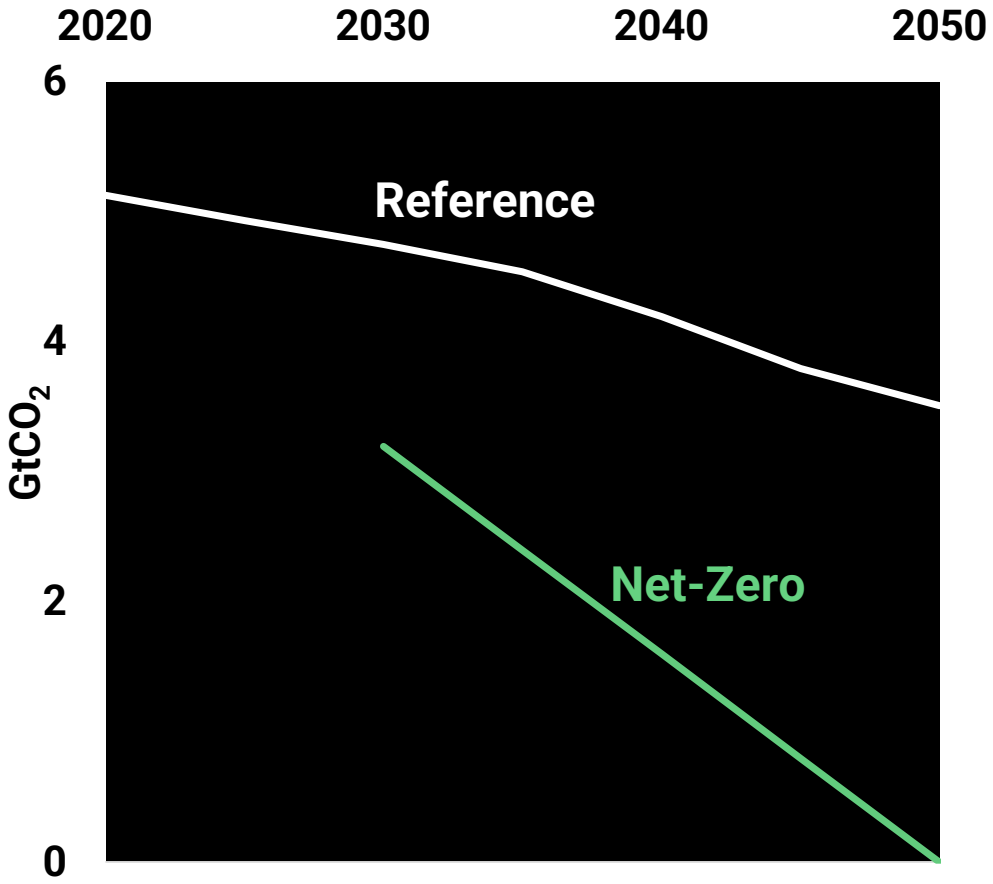
LOAD GROWTH



LCRI NET-ZERO 2050

Full report available at
lowcarbonlcri.com/netzero

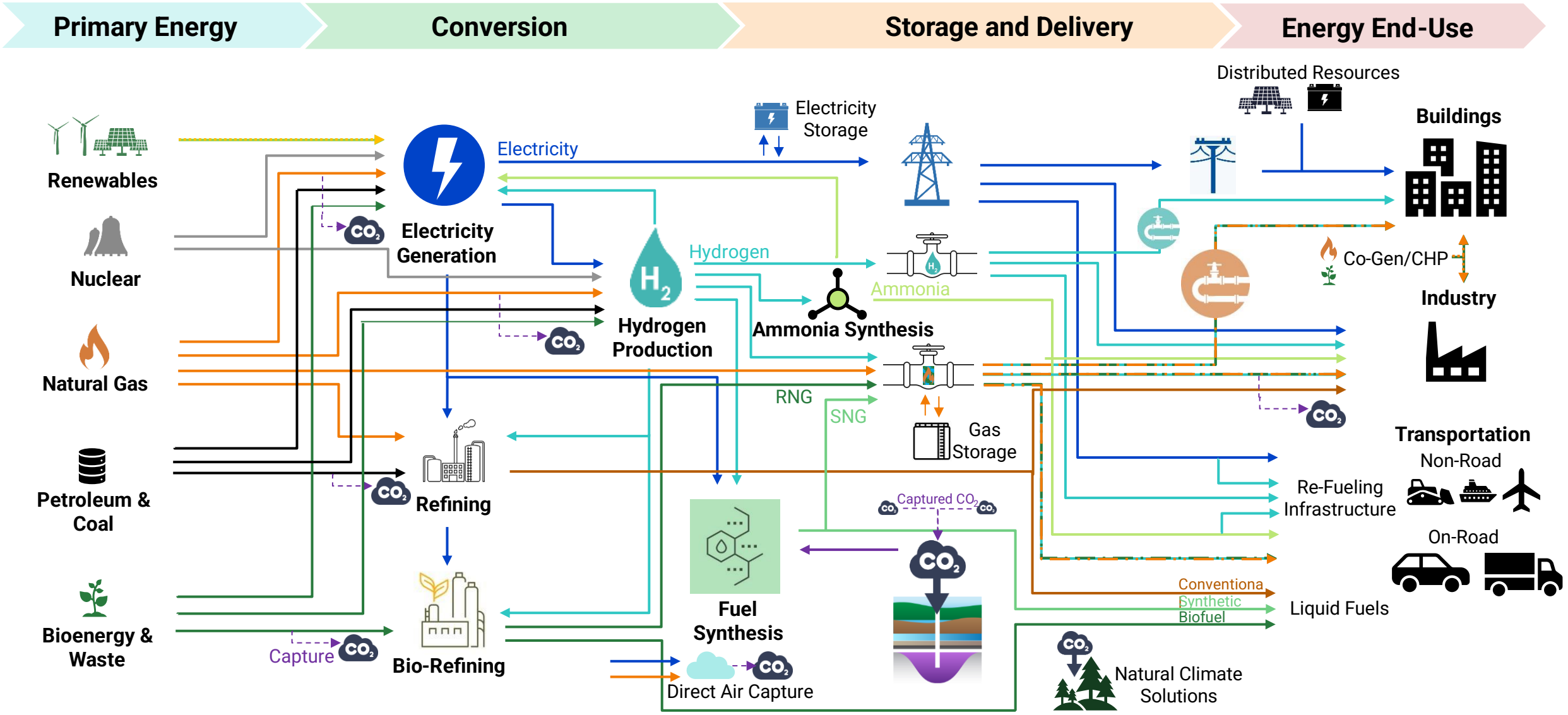
Reference with no new carbon policy, continued technology improvements



Net-Zero by 2050 with three core sensitivities around CCS, gas, bioenergy

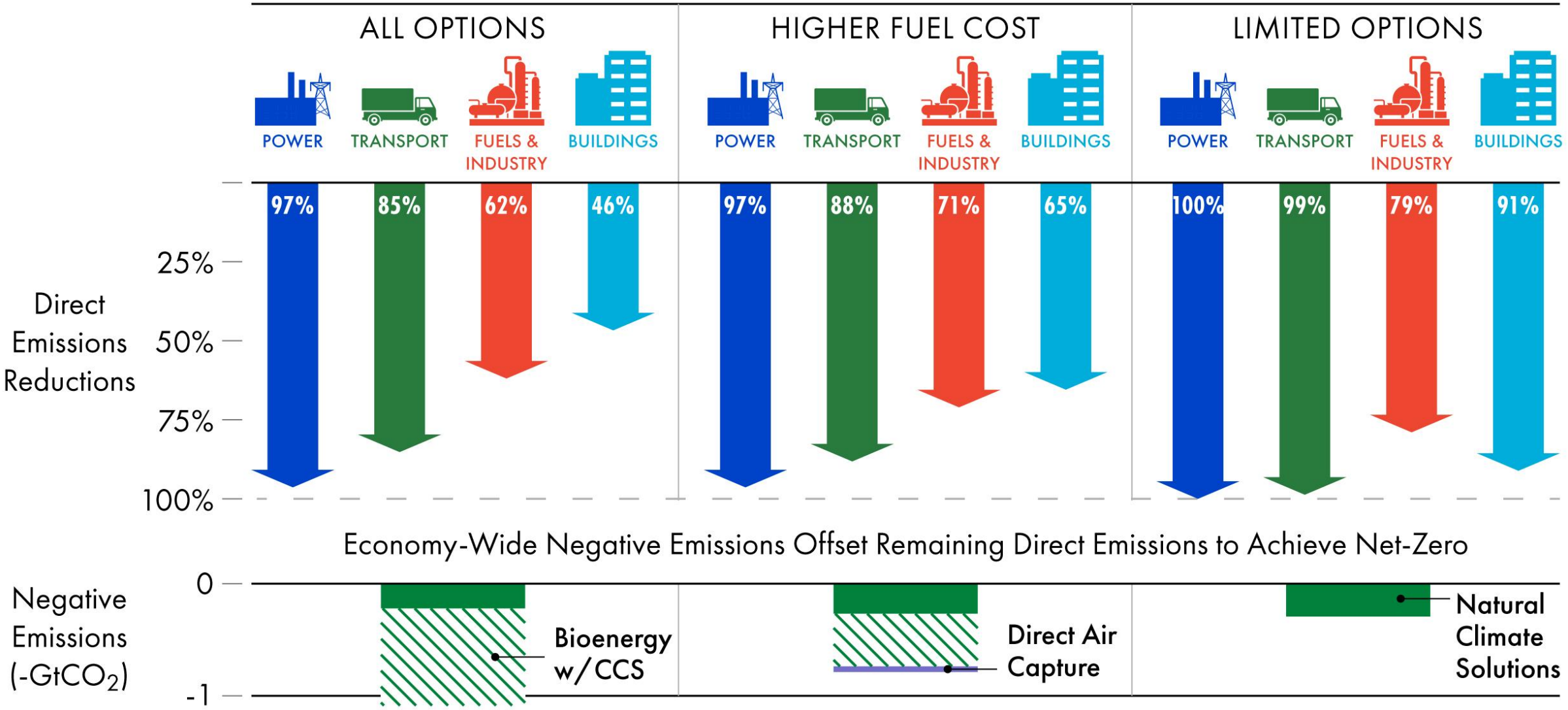
	All Options	Higher Fuel Cost	Limited Options
Geologic Storage of CO_2	Lower Costs	Higher Costs	Not Available
Natural Gas Supply Costs	Lower Costs	Higher Costs	Lower Costs
Bioenergy Feedstock Supply	Full	Supply Limited	Supply Limited

Economy-Wide Low-Carbon Energy Pathways

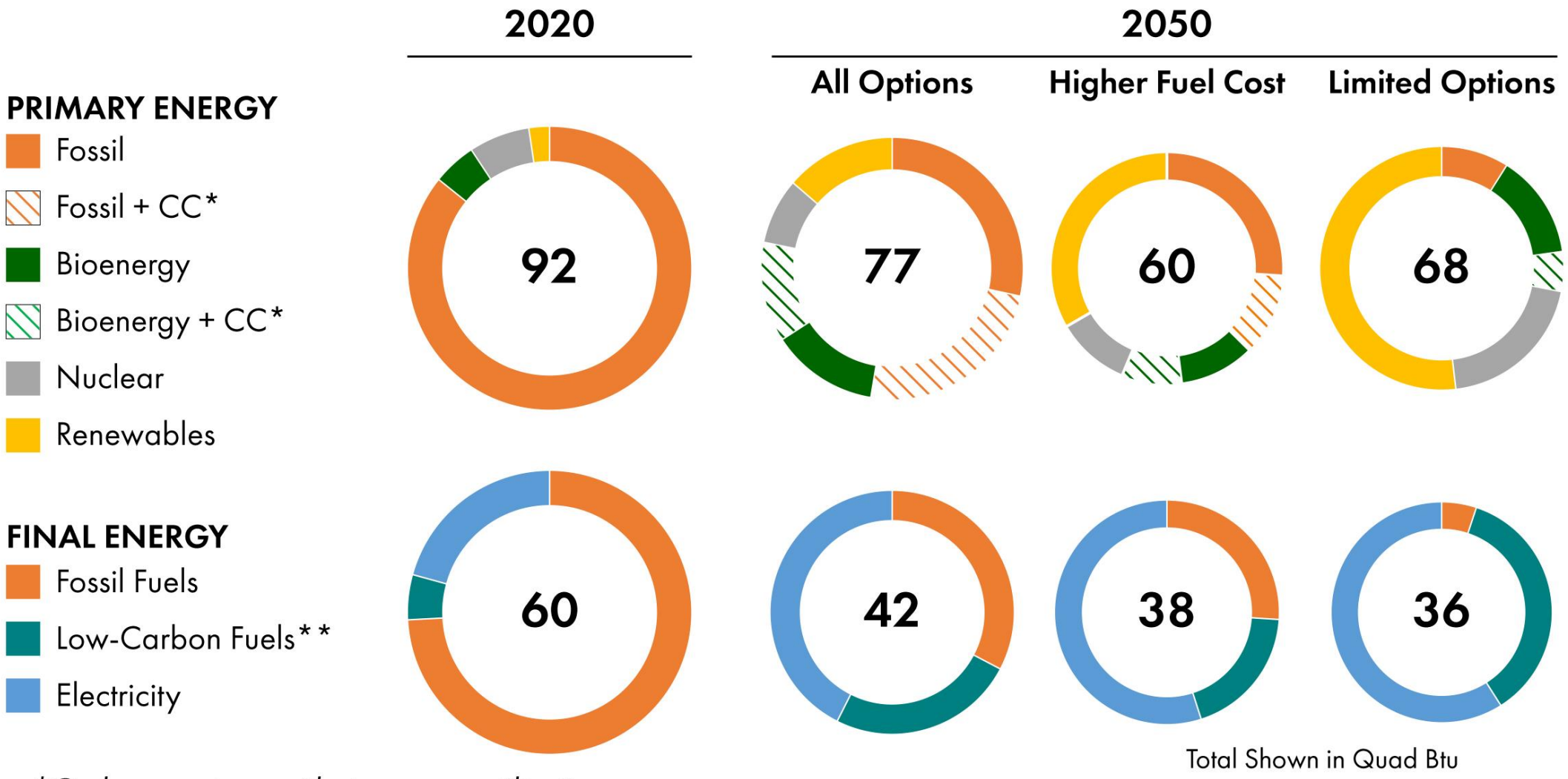


CO_2 Emission Reductions by Sector, 2005–2050

Net-Zero 2050 Scenarios



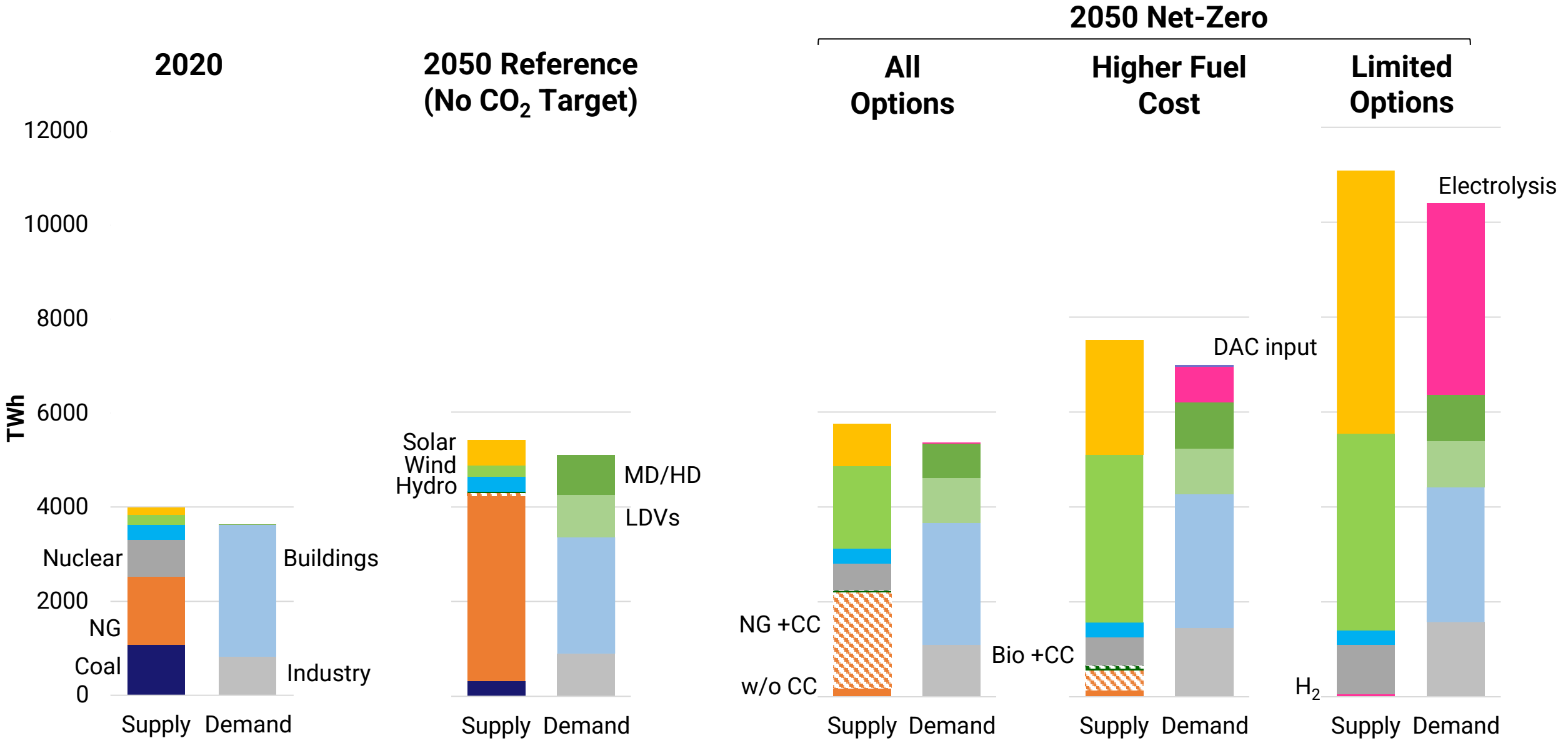
Primary and Final Energy in Net-Zero 2050 Scenarios



*Carbon capture, with storage or utilization

**Low-carbon fuels include hydrogen, hydrogen-derived fuels (e.g., synthetic fuels and ammonia) and bioenergy.

Decarbonization Drives Electric Load Growth



Key Messages and Takeaways

2020's 2030's 2040's

The Starting Point: Build on the 3 *Es*

Clean *electricity*, *efficiency*, and *electrification* are foundational to achieve substantial reductions

Technology Optionality High Value

Natural gas and biomass with CCS, along with direct air capture, are key to manage costs, while leveraging existing resources

Grid Modernization & Investment Underpins Progress

Support reliability, resilience, electrification, flexibility, asset utilization, and customer choice

Low-Carbon Fuels Fill Reduction Gaps

Scenarios show targeted use of a diverse portfolio of low-carbon fuels across power generation and end-use applications

Existing Low-Carbon Resources Amplify Their Value

Maintaining nuclear, renewables, and energy storage is critical to realizing a net-zero energy future

Gas Infrastructure Enables Reductions

Gas capacity and infrastructure are useful in all scenarios, with varying capacity factor and differences in the *type of gas* used

Net Zero Requires Technology Advances

RD&D to enable clean, firm electric supply (e.g., advanced nuclear, CCS, biofuels, hydrogen) and low-carbon fuels

Customer Adoption, Affordability & Equity

Reaching goals depends on 100M+ households and businesses participating and adopting low-carbon technologies

Regional Differences: Technology mix, electrification, and role of gas vary significantly by region, with climate as a key driver.

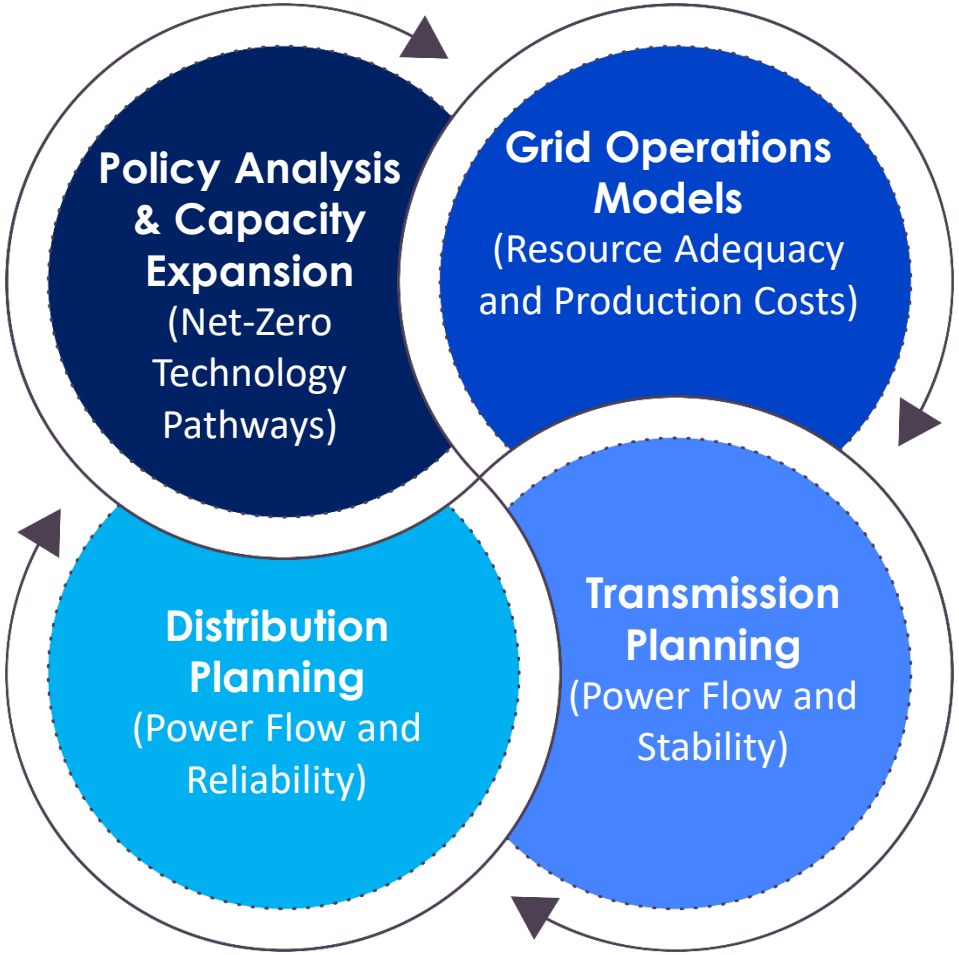
Integrated Strategic System Planning (ISSP)

Integrated Planning for Strategic Questions

Least-cost pathway to electric sector decarbonization?

Sufficient capacity, energy, and flexibility to reliably balance supply and demand?

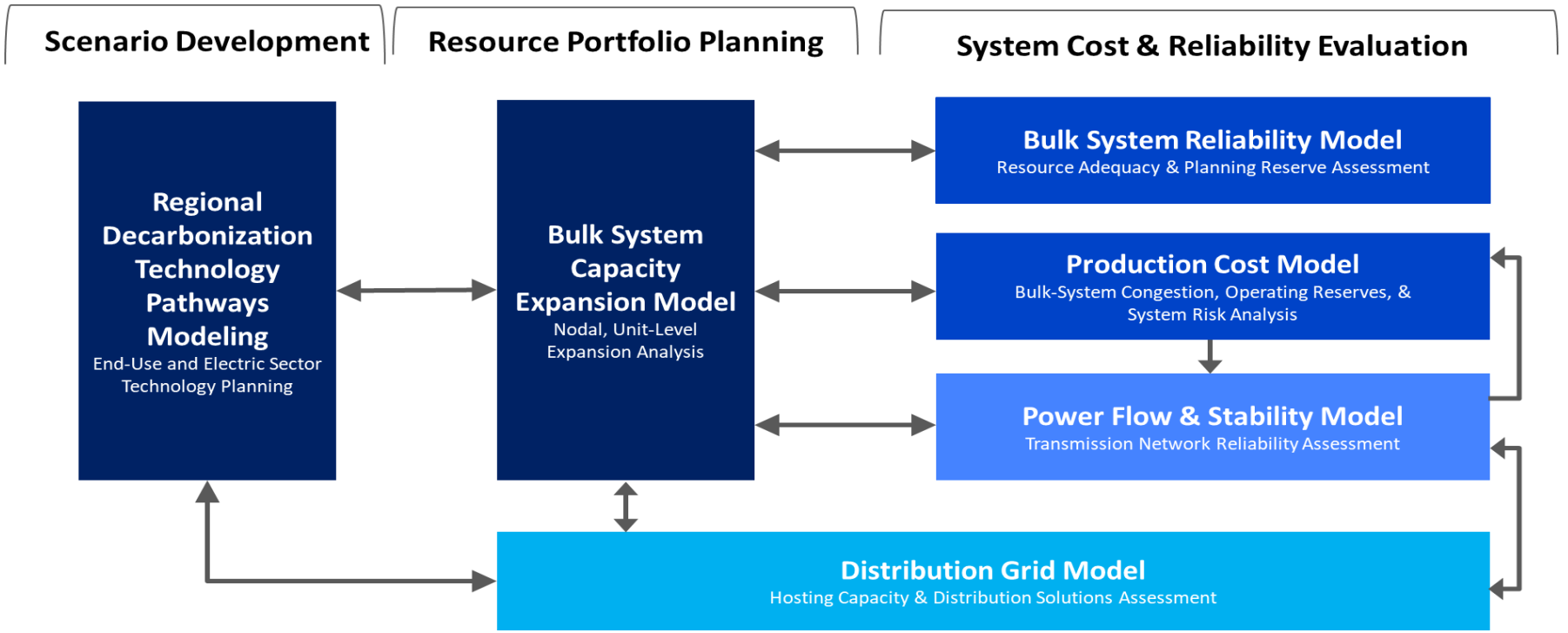
T&D investments for reliability/resiliency for a distributed, inverter-based supply mix?



Develops a generalizable analytical framework to assess future expansion plans across supply (G) and delivery (T&D) & ensures reliability

Integrated Strategic System Planning

Workflow from macro model to stability assessments



Integrated Strategic System Planning Initiative: Modeling Framework, Demonstration Study Results, and Key Insights (Product ID 3002028640)

Guidelines for Linking Power Flow Analysis with Production Cost Modeling Tools for Integrated Strategic System Planning: Needs, Screening Methods, and Best Practices (Product ID 3002028535)

Linking Capacity Expansion, Resource Adequacy, and Production Cost Modeling Tools for Integrated Strategic System Planning (Product ID 3002028534)

Wide-Area Distribution Assessments for Integrated Strategic System Planning (Product ID 3002028536)

Resource Adequacy for a Decarbonized Future

epri.com/resource-adequacy

Scope and Deliverables

RA Process

- Recommended Metrics and Criteria
- Future Scenario Database and Tool

Models and Data

- Emerging Resource & Demand Side Models
- Model Data Development Tools

Analysis Tools

- Existing RA Tool Capabilities
- New Algorithms and open-source code

Case Studies — Evaluation of existing and development of new capabilities based on 4-6 regional RA case studies covering differing RA issues and tools.

Tech Transfer — Reports and workshops to be conducted to disseminate results and to promote broad adoption in commercial tools.

25+ Participants

Southern California Edison, CPS Energy, Duke Energy, Associated Electric Cooperative Inc., Hawaiian Electric, American Electric Power, LCRA, ConEdison, Ameren, TVA, Austin Energy, New York State of Opportunity / NY Power Authority, LA DWP Los Angeles Department of Water & Power, Arkansas Electric Cooperative Corporation, Southern Company, SRP, NERC North American Electric Reliability Corporation, MISO, SPP Southwest Power Pool, aps, ISO new england, pjm, Entergy, evergy, New York ISO Independent System Operator, Manitoba Hydro, NPCC, Inc.

Partners

TELOS ENERGY

ASTRAPÉ CONSULTING innovation in electric system planning

GE

MOMENTUM ENERGY INSIGHTS

Blue Marble Analytics

ENELYTIX® powered by PSO

External Advisory — NARUC, NREL, ESIG, GridPath, RROs, DOE, ISOs/RTOs, G-PST, Consultants, Universities, etc.)

EPRI Resource Adequacy Decision Support Framework

The case studies, together with extensive review of other studies and consultation with industry stakeholders, provided the evidence base upon which a guideline and decision support framework was developed.

Strategic Guidance: Assessment Design Principles

Resource Adequacy Philosophy

Use this to:

→ Review the purpose and scope of resource adequacy assessments

→ Leverage foundational principles in process design

→ Compare existing assessment processes to verify completeness

Scenario Selection Guidance

Q1 '24

Use this to:

→ Identify the range of variables and factors that may influence the outcome of adequacy assessments

→ Prioritize approach to considering each of the variables within assessment processes

Metrics & Criteria Guidance

Use this to:

→ Review the metrics and criteria used to measure adequacy around the world

→ Understand how metrics are calculated and the differences in the risk conveyed by the metrics

Tactical Decision Support: Study Execution Decision Support

Technology & System Models

Use this to:

→ Review methods by which supply and demand technologies are represented in adequacy models

→ Determine appropriate level of detail that is recommended for each asset type

Data Requirements

Use this to:

→ Review recommended data sources, variables, extent and quality required to parameterize models

→ Determine appropriate level of detail that is recommended for each variable

Assessment Tool Capabilities

Q1 '24

Use this to:

→ Review the analysis capabilities of commonly applied resource adequacy assessment tools

→ Compare the approaches applied within each, in the context of the recommended model and data guidance

Research Gaps

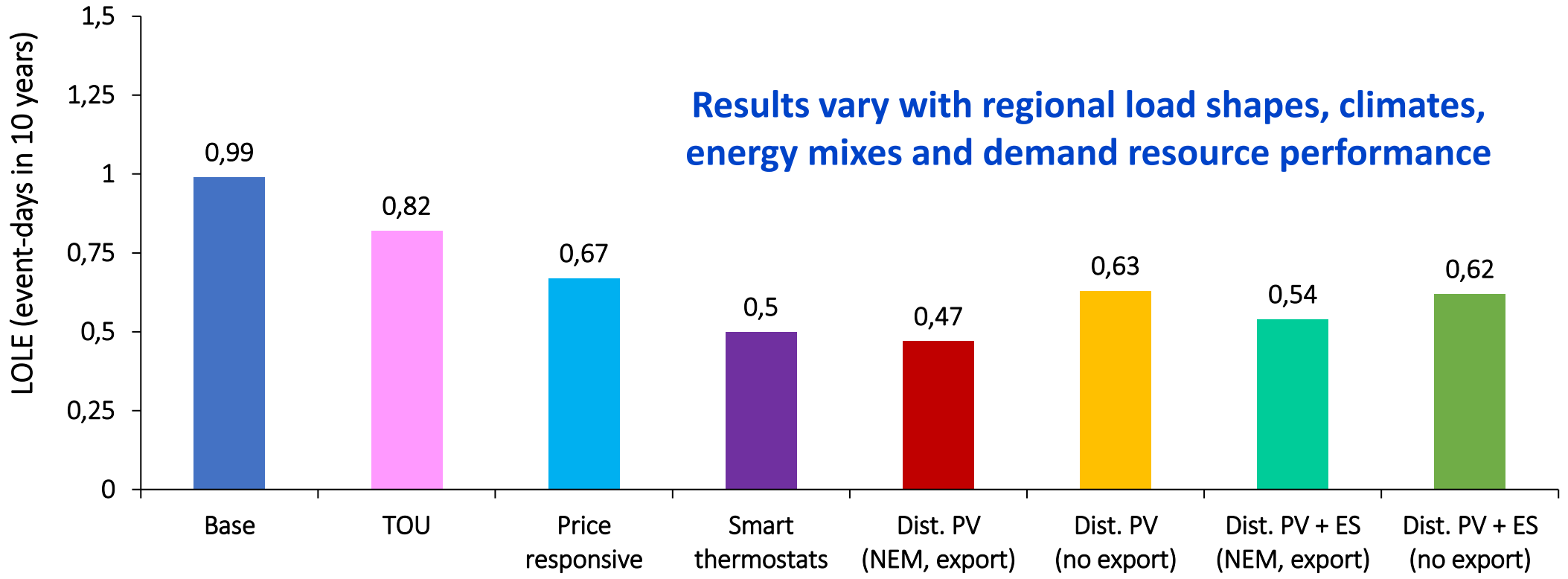
Resource Adequacy Gap Assessment

Use this to:

→ Understand the unmet challenges faced by resource adequacy stakeholders, with prioritization of next tasks.

Resource Models: Demand Flexibility Potential Value

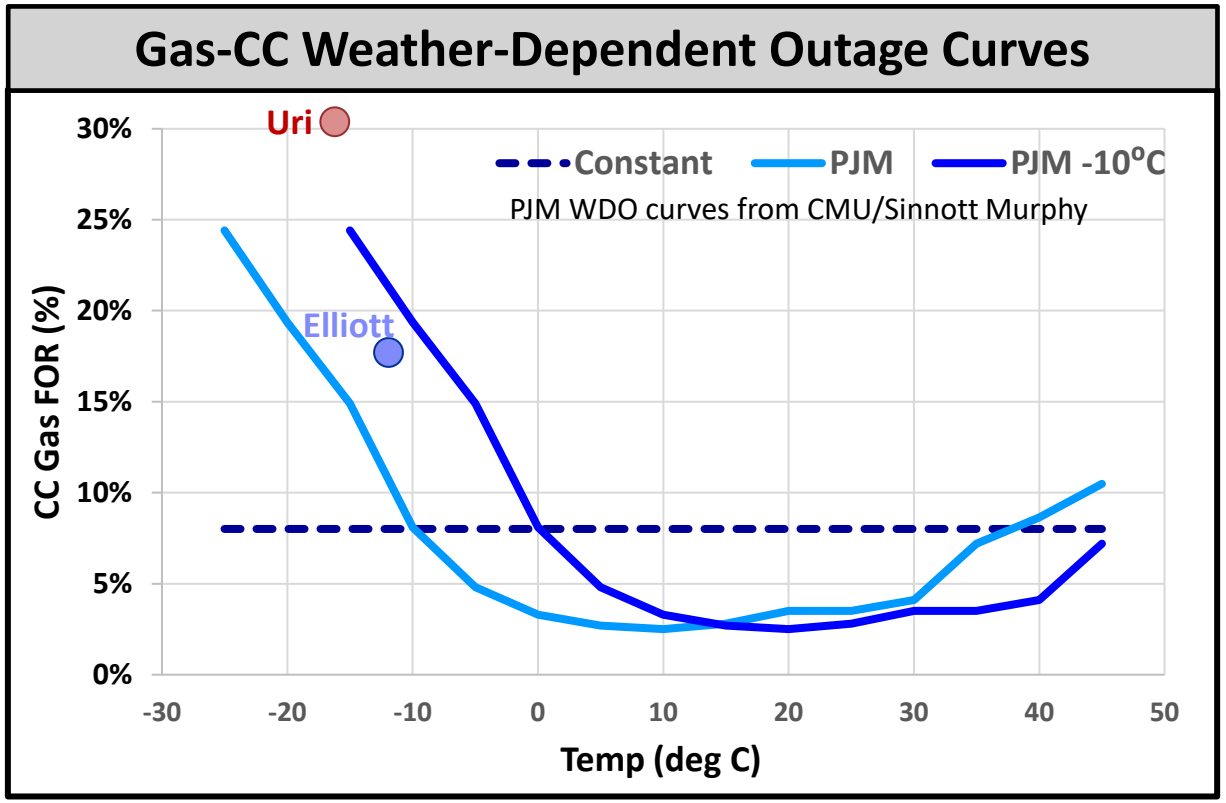
Potential reduction in LOLE from 900 MW (3% peak demand) of various distributed resource types (technology and tariff) for specific utility system



Methodology for modeling DER/VPP contributions to resource adequacy

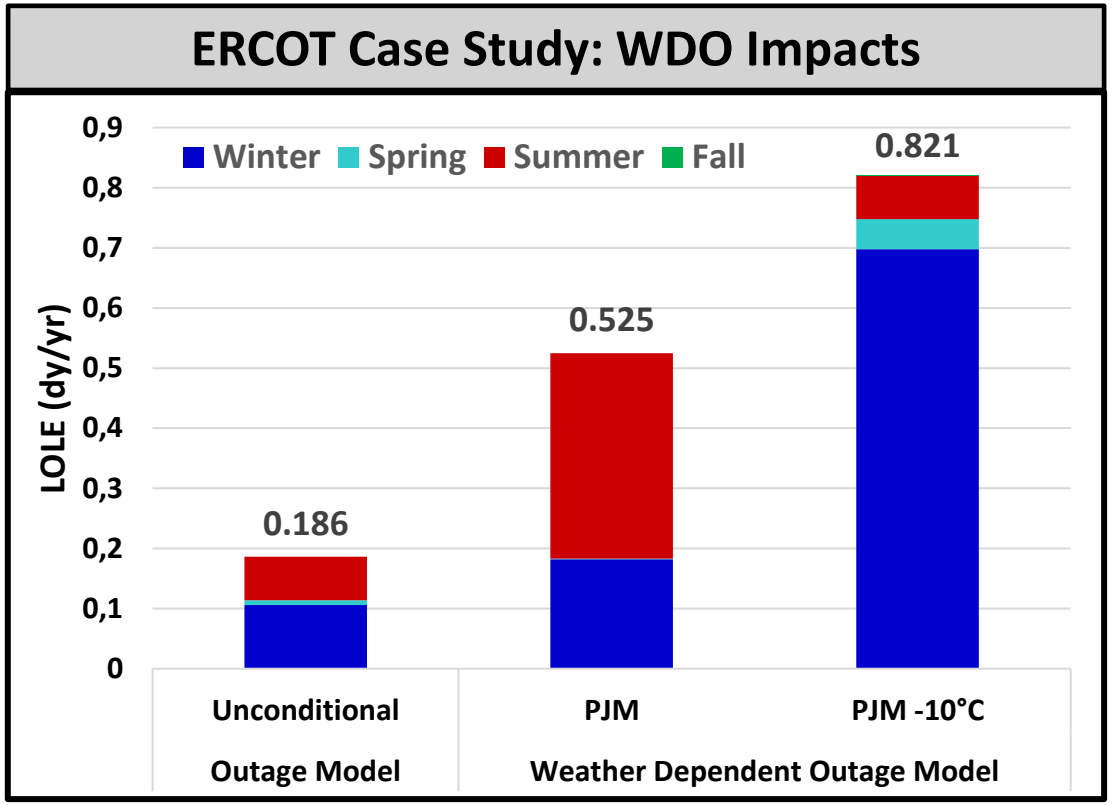
Resource Models: Weather Dependent Outages (WDO)

Gas-CC Weather-Dependent Outage Curves



Extreme temperature impacts generator forced outage rates

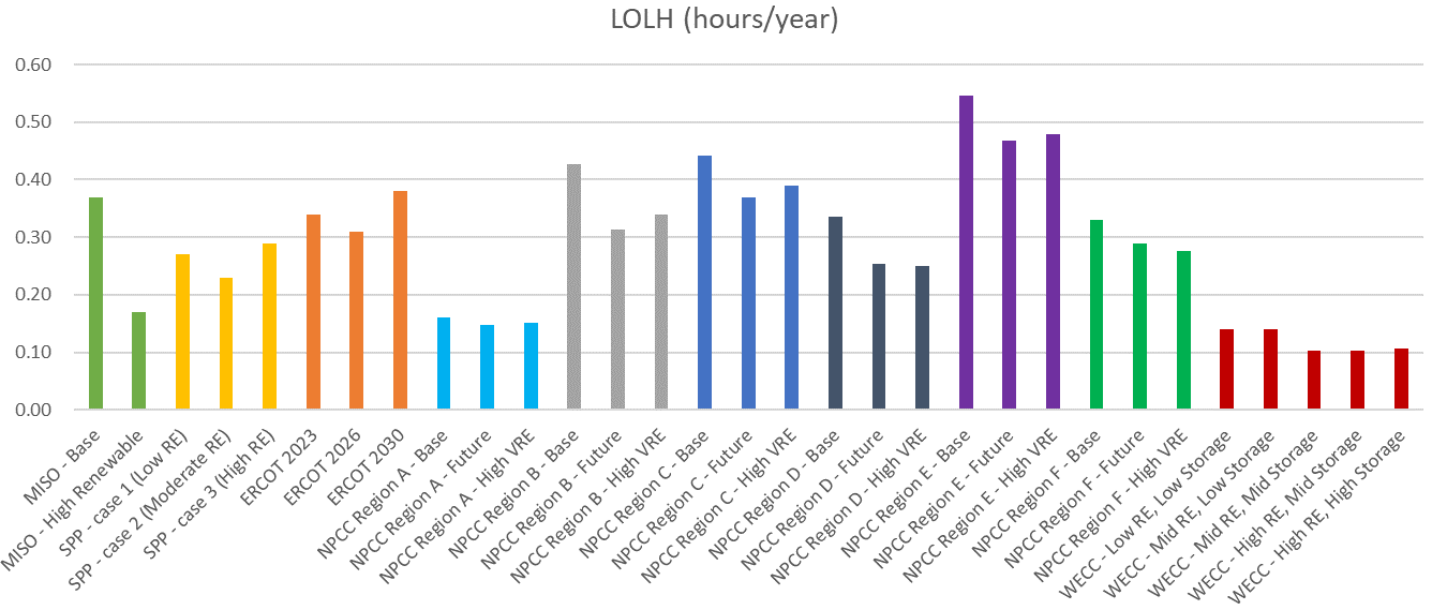
ERCOT Case Study: WDO Impacts



Including WDO in RA risk assessment exposes additional risk

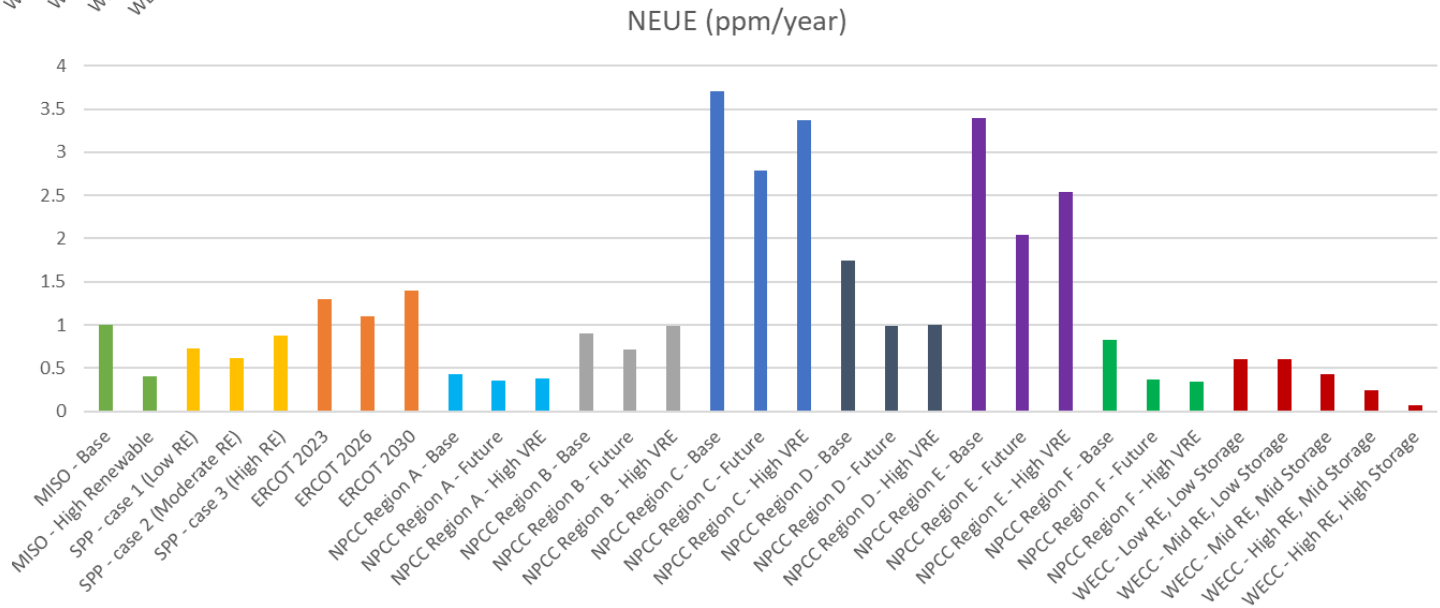
EPRI RAI provides methodology for creating generation WDO curves, modeling guidance (renewables, storage, and, transmission, et. al.), and guidance on data and application in tools

Adequacy Avoid relying on a single metric



LOLE gives information of the expected number of days when a loss of load occurs but doesn't give information on the magnitude of that load loss.

All case study portfolios shown here were brought to a LOLE of 0.1 days/year, and yet show different results for LOLH and EUE.



All case study results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Mailing List

EPRI Climate Resilience and Adaptation Initiative (READi)

CLIMATE READi
RESILIENCE AND ADAPTATION INITIATIVE

- **COMPREHENSIVE:** Develop a *Common Framework* addressing the entirety of the power system, planning through operations
- **CONSISTENT:** Provide an informed approach to climate risk assessment and strategic resilience planning that can be replicated
- **COLLABORATIVE:** Drive stakeholder alignment on adaptation strategies for efficient and effective investment

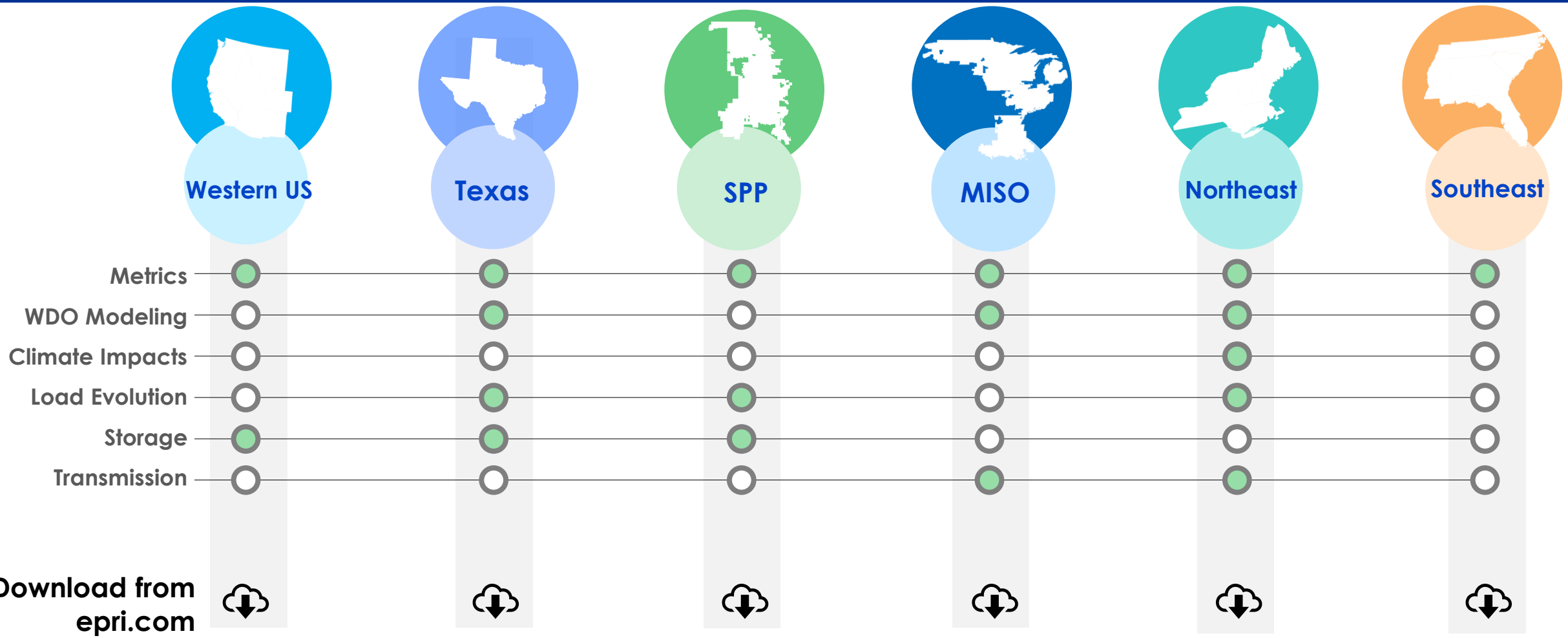
Workstream 1	Workstream 2	Workstream 3
Physical Climate Data & Guidance	**Energy System & Asset Vulnerability Assessment**	**Resilience / Adaptation Planning & Prioritization**
• Identify climate hazards and data required for different applications • Evaluate data availability, suitability, and methods for downscaling & localizing climate information • Address data gaps	• Evaluate vulnerability at the component, system, and market levels from planning to operations • Identify mitigation options from system to customer level • Enhance criteria for planning and operations to account for event probability and uncertainty	• Assess power system and societal impacts: resilience metrics and value measures • Create guidance for optimal investment priorities • Develop cost-benefit analysis, risk mitigation, and adaptation strategies

Deliverables: Common Framework

- Climate data assessment and application guidance
- Vulnerability assessment
- Risk mitigation investment
- Recovery planning
- Hardening technologies
- Adaptation strategies
- Research priorities

Adequacy: Foundational Case Studies

Six case studies of future systems were carried out for different levels of renewables and storage to assess a range of key questions and study tool capabilities that are relevant for each region. These do not replace standard planning studies, but are a look at how resource adequacy issues may evolve across the continent.



Resource Adequacy Forum

What is it?

Deep dive series on RA modelling from leading projects and assessments

Who is it for?

Resource Adequacy practitioners, stakeholders in adequacy assessment processes

Format

Practitioner deep dive on topical study followed by reactions and topical break-out

21

February

12:30 EST, 18:30 CET

Webcast 4: Extreme Events in Resource Adequacy

17

April

12:30 EST, 18:30 CET

Webcast 5: Energy Storage in Resource Adequacy

19

June

12:30 EST, 18:30 CET

Webcast 6: Wide-Area Assessments