# Models for Planning the Future of Electric Power

## Insights and Perspectives from EPRI's REGEN Model

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Energy Systems and Climate Analysis

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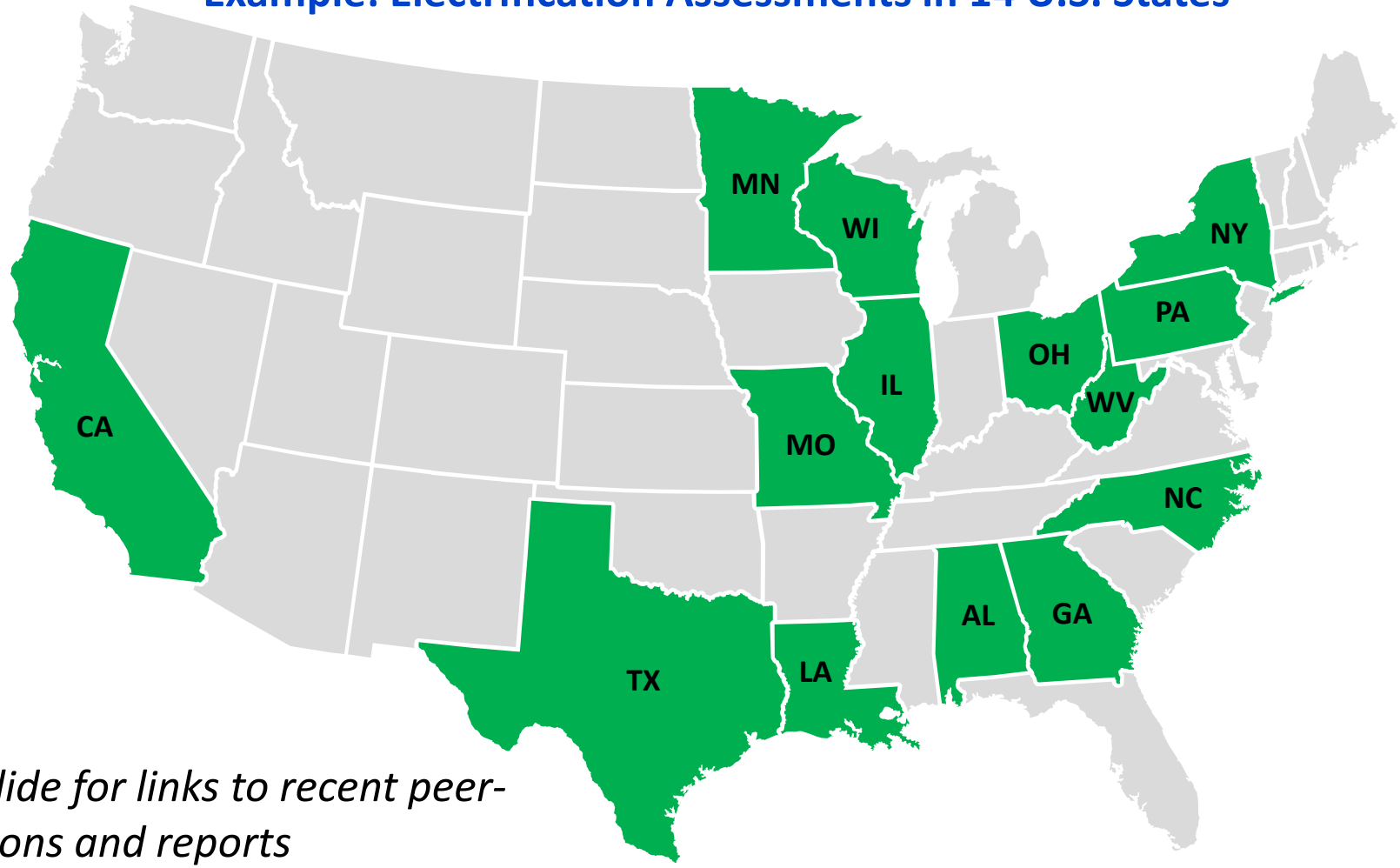
# Policy Analysis
# Technology Insights
# Energy Use Trends

- A framework for understanding drivers of change in the electric sector and energy system
- Industry-leading representation of end-use load changes, variable renewables, and energy storage
- Supported by EPRI engineering expertise and technology projections

# How Is REGEN Used? Policy and Technology Analyses

## Example: Electrification Assessments in 14 U.S. States

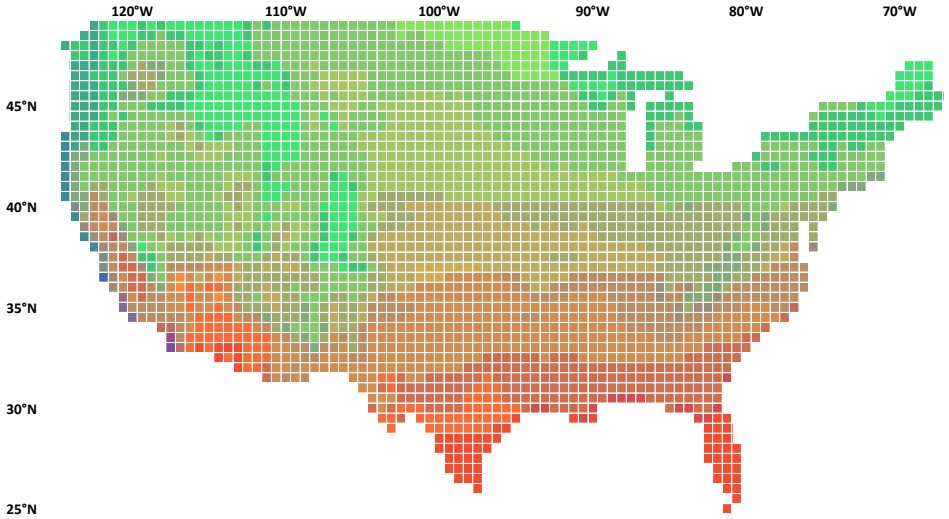



*See bibliography slide for links to recent peer-reviewed publications and reports*

**Other recent applications include high renewables, $CO_2$ targets, and proposed state/federal policies**

# REGEN Strength: Detailed End-Use Modeling

## Energy Use

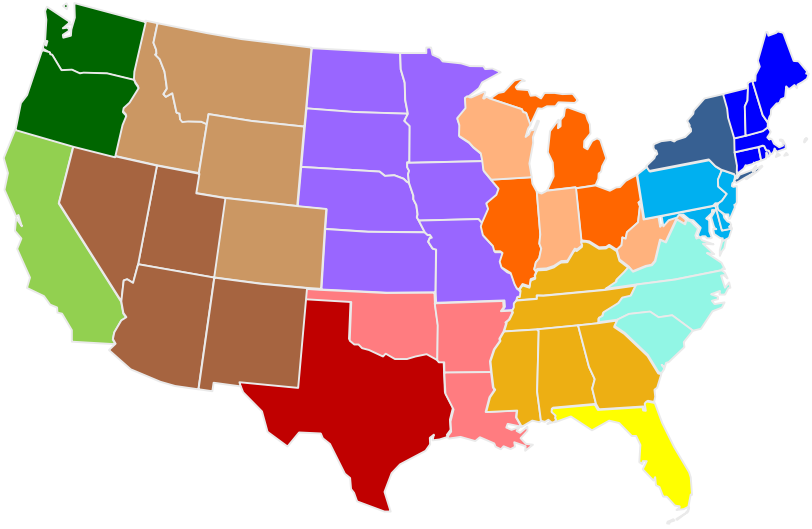



- Climate zones
- Building types
- Household characteristics
- Industrial mix
- End-use technology detail

**Synchronized Hourly Load, Renewables, & Prices**

**Model Outputs:**
- Generation Capacity
- Wholesale Prices
- End-Use Mix
- Emissions, Air Quality, and Water
- Demand Profiles

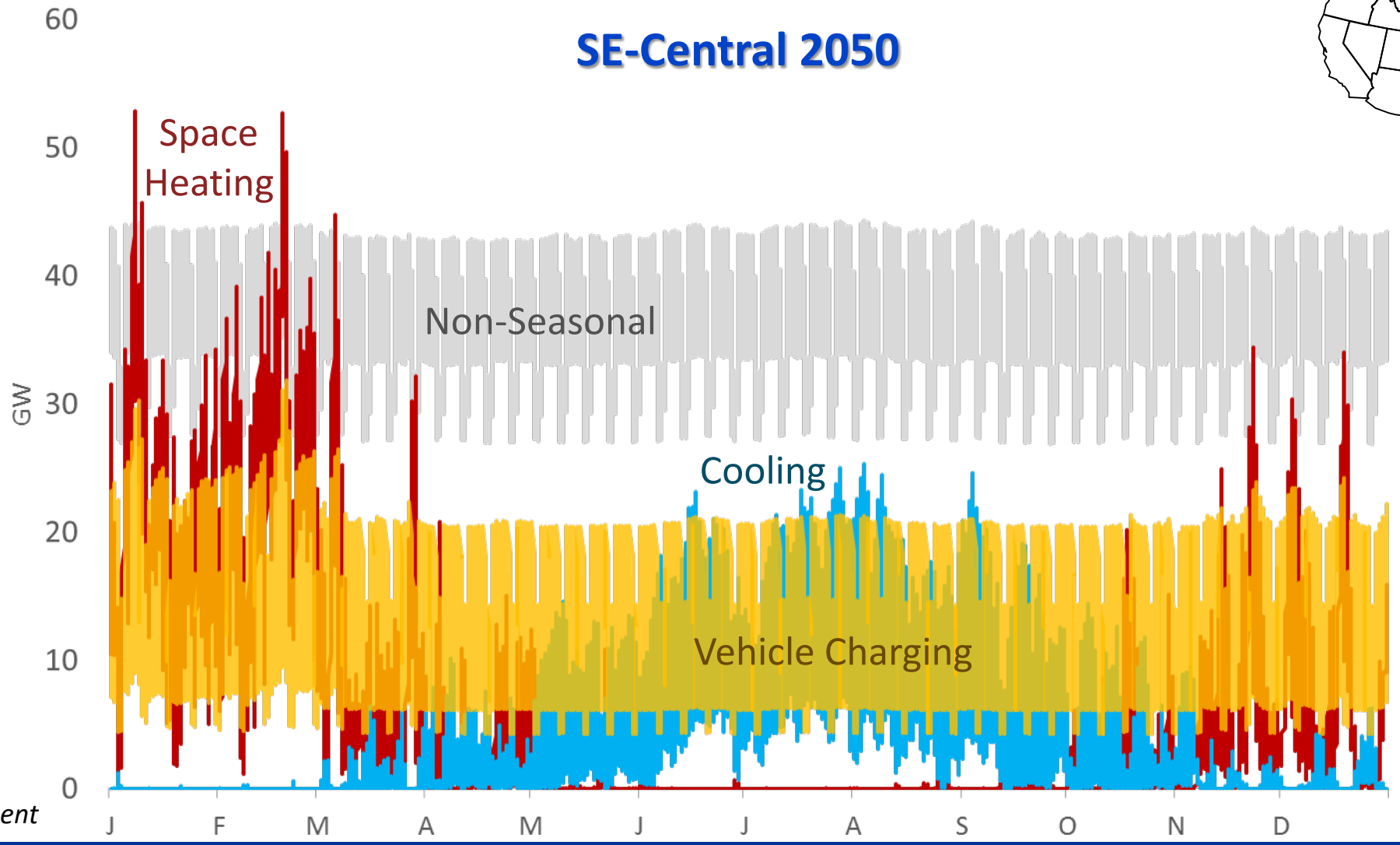
## Electric Sector



- Investment and dispatch
- Transmission
- Renewable integration
- Energy and capacity requirements
- State-level policies and constraints

**EPRI's state-of-the-art modeling system synchronizes energy end-use and electric sector scenarios**

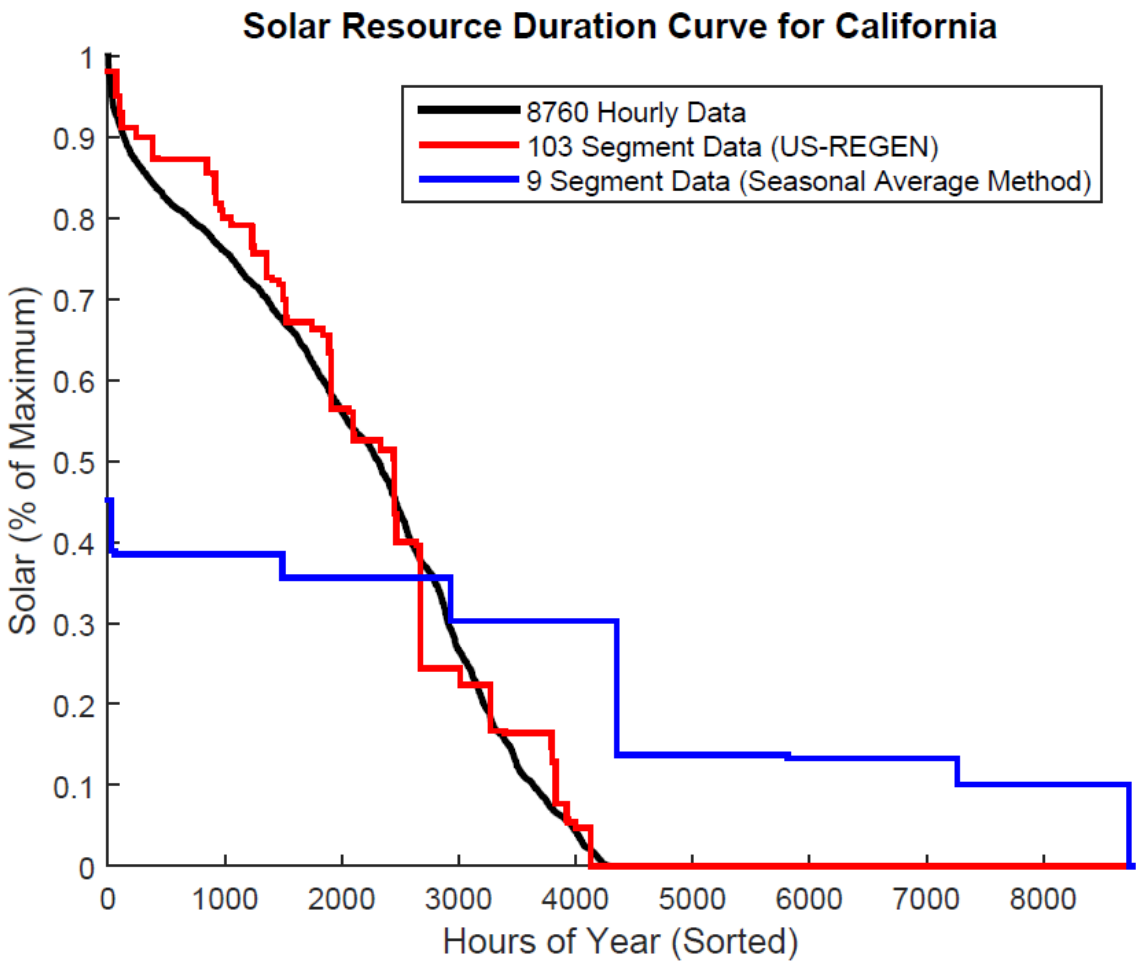
# REGEN Strength: Detailed End-Use Modeling




*Source: EPRI (2018), U.S. National Electrification Assessment*

**REGEN tracks how hourly sectoral load shapes change over time from electrification and efficiency**

# REGEN Strength: Representation of Variable Renewables

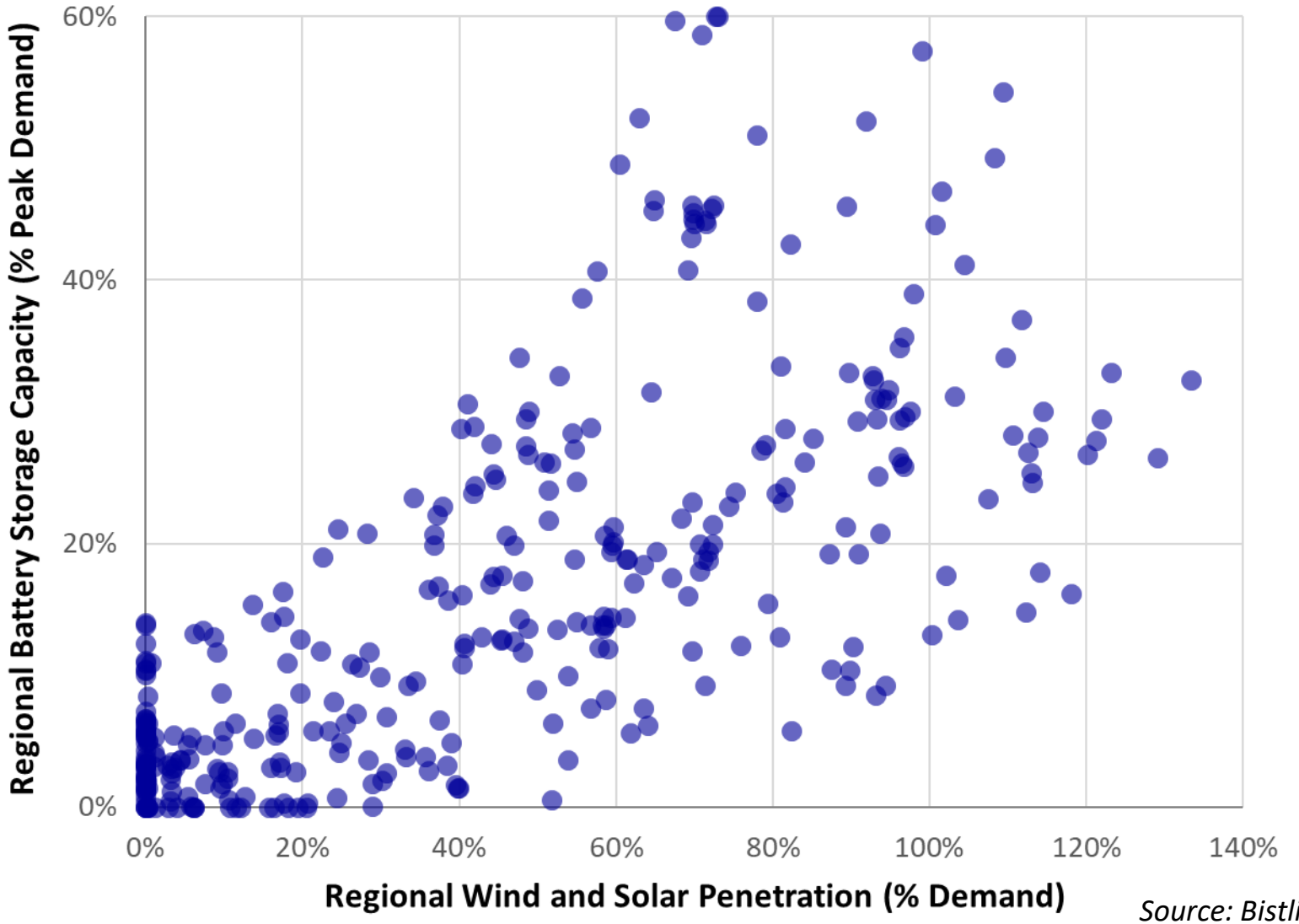



- US-REGEN employs an innovative "representative hour" selection algorithm to capture hourly wind, load, and solar shapes
- Captures correlations in a longer time horizon model better than other approaches (e.g., Seasonal Average Method)

*Source: Blanford, et al. (2018), "Simulating Annual Variation in Load, Wind, and Solar by Representative Hour Selection" (The Energy Journal)*

**Representing spatial and temporal variability are important for assessing system-dependent value**

# REGEN Strength: Representation of Energy Storage

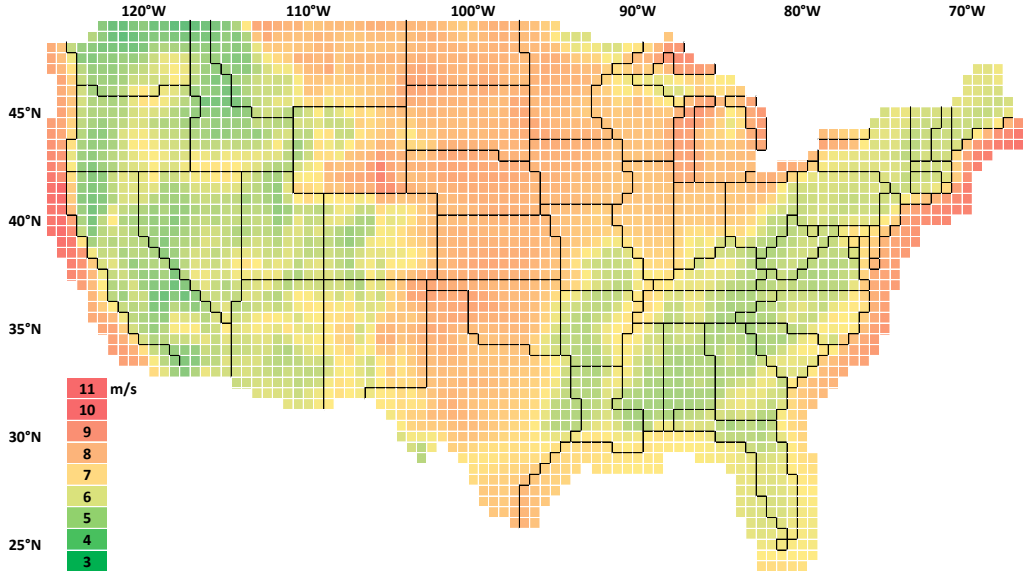



- Hourly resolution and chronology are important for capturing energy storage value
- Use 8,760 hours with single year investment and dispatch
- Storage valuation varies by region and assumptions about future technologies, markets, and policies (figure shows sensitivities on renewable costs, gas prices, $CO_2$ policy)

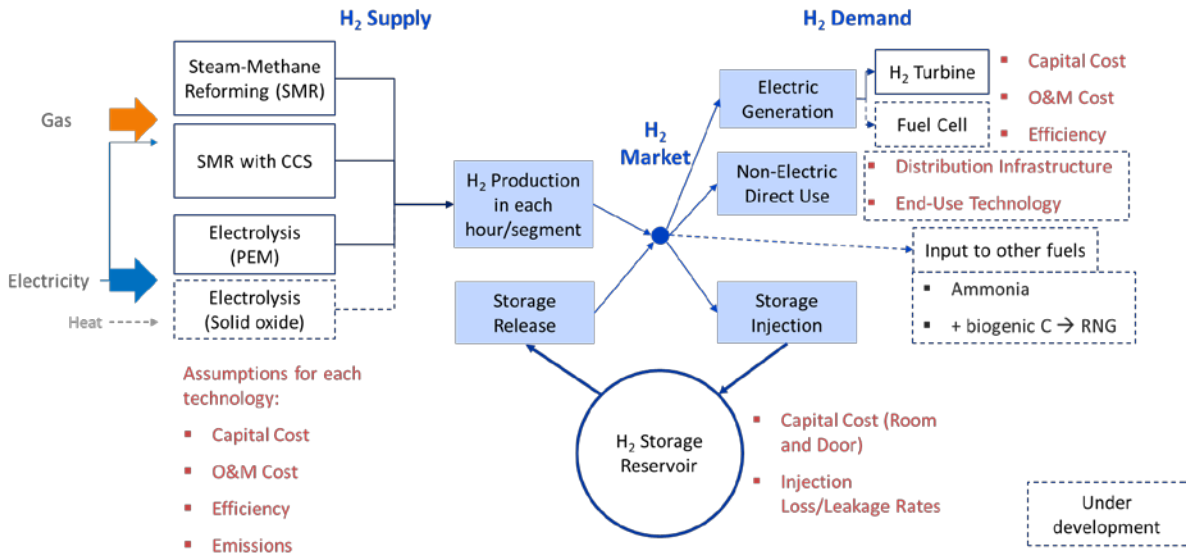
*Source: Bistline and Young (2019), "Economic Drivers of Wind and Solar Penetration in the U.S." (Environmental Research Letters)*

# REGEN Future Development Priorities

1. Increasing spatial and temporal granularity for utility-level analysis
2. Linking to reliability and production cost models
3. Adding low-carbon fuel pathways to the end-use model
4. Using decomposition approaches to solve more detailed models




*Average wind speed at 100m (1980–2015) based on NASA's MERRA2 dataset*




*Updated hydrogen module in REGEN*

**Improvements are aimed to help stakeholders understand evolving challenges facing the electric sector**

# Together…Shaping the Future of Electricity

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# Bibliography


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- Young and Bistline (2018), The Costs and Value of Renewable Portfolio Standards in Meeting Decarbonization Goals, *Energy Economics* (link)
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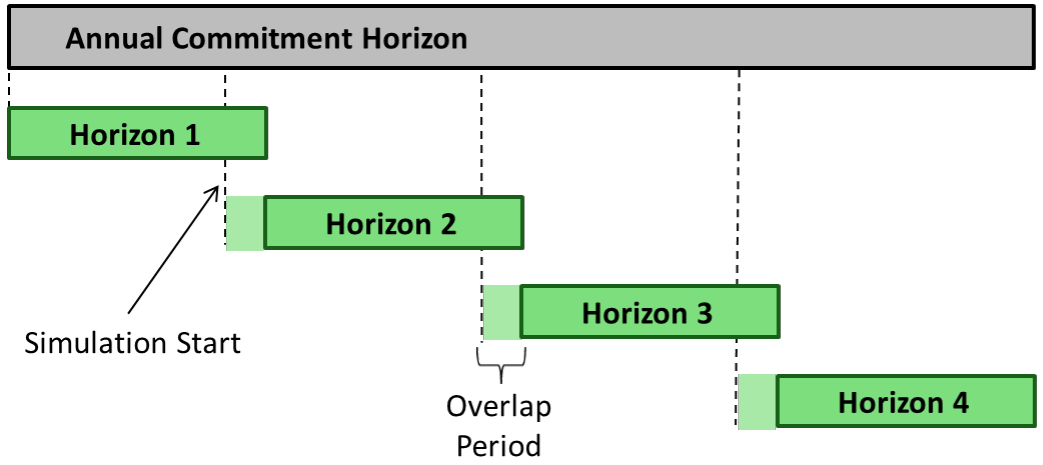
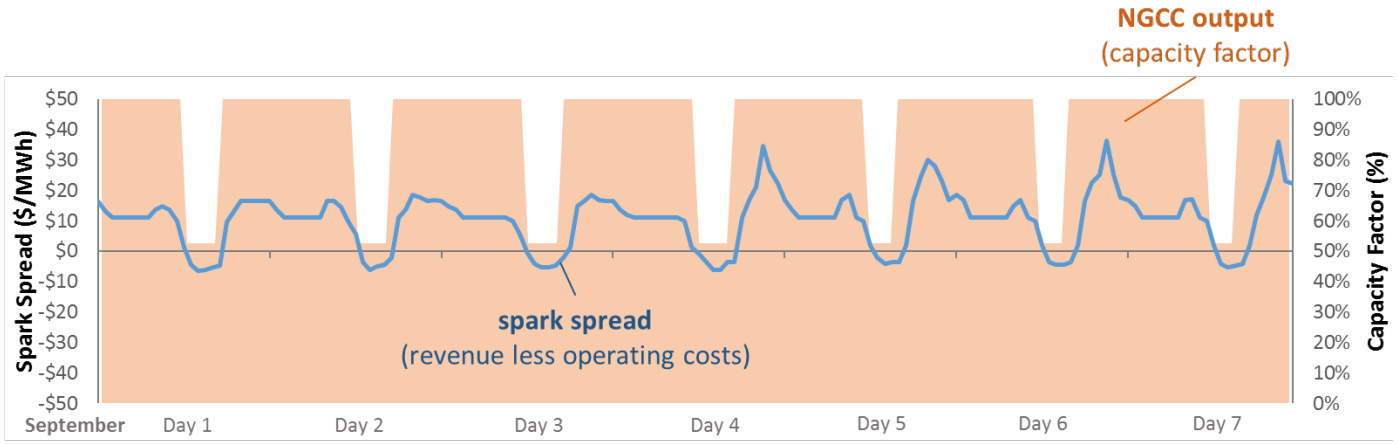
**For more information, see our website at https://eea.epri.com/**

# Multiple "Flavors" of REGEN to Address Specific Questions

| | Integrated | Electric Only | | |
|---|---|---|---|---|
| | **Dynamic** | **Dynamic** | **Static** | **Unit Commitment** |
| **Optimization Horizon** | Multi-decadal (35 years) | Multi-decadal (35 years) | Annual | Annual |
| **Temporal Granularity** | ~100 segments per year | ~100 segments per year | 8,760 hours | 8,760 hours |
| **Capacity Mix** | Endogenous | Endogenous | Endogenous | Exogenous (from dynamic model run) |
| **Unit Aggregation** | 100+ capacity blocks per region (dispatched together) | 100+ capacity blocks per region (dispatched together) | 100+ capacity blocks per region (dispatched together) | Individual units |
| **Storage** | N/A | N/A | Endogenous | Exogenous |
| **Geographical Detail** | User-specified regions, less than 20 | User-specified regions | All user-specified regions | All user-specified regions |
| **Dispatch Constraints** | Load balancing | Load balancing | Load balancing | Balancing, min. load limits, ramp rates, start costs, etc. |
| **Optimization Type** | Linear program | Linear program | Linear program | Mixed-integer program |
| **Sectors** | Entire economy | Electric Sector | Electric sector | Electric sector |
| **Energy Demand** | Endogenous; detailed end-use model | Fixed, may use supply curves for some inputs | Fixed | Fixed |
| **Fuel Prices** | Fixed | Fixed, may use supply curves for some inputs | Fixed | Fixed |

# REGEN Features:
# Soft-Linked to an In-House Unit Commitment Model




- Provides detailed annual snapshots of system operations with unit-level costs and constraints using capacity mixes from the dynamic model
- ***Advantages:*** Hourly temporal resolution and chronology more accurately represent the covariance of resources, trade, storage, and operational constraints
- ***Disadvantages:*** No subhourly impacts, intra-region transmission constraints, or uncertainty