Future of Electrification

Caitlin Murphy

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nrel.gov/EFS

Study sponsored by U.S. DOE-EERE Office of Strategic Analysis

The *Electrification Futures Study* explored 5 crucial questions:

Load

How might electrification impact electricity **demand** and **use patterns**?

Capacity

How would the electricity system need to **transform** to meet changes in demand?

Operation

How would the system operate, with high levels of electrification, to meet **reliability** needs in 2050?

Flexibility

What role might **demand-side flexibility** play to support reliable operations?

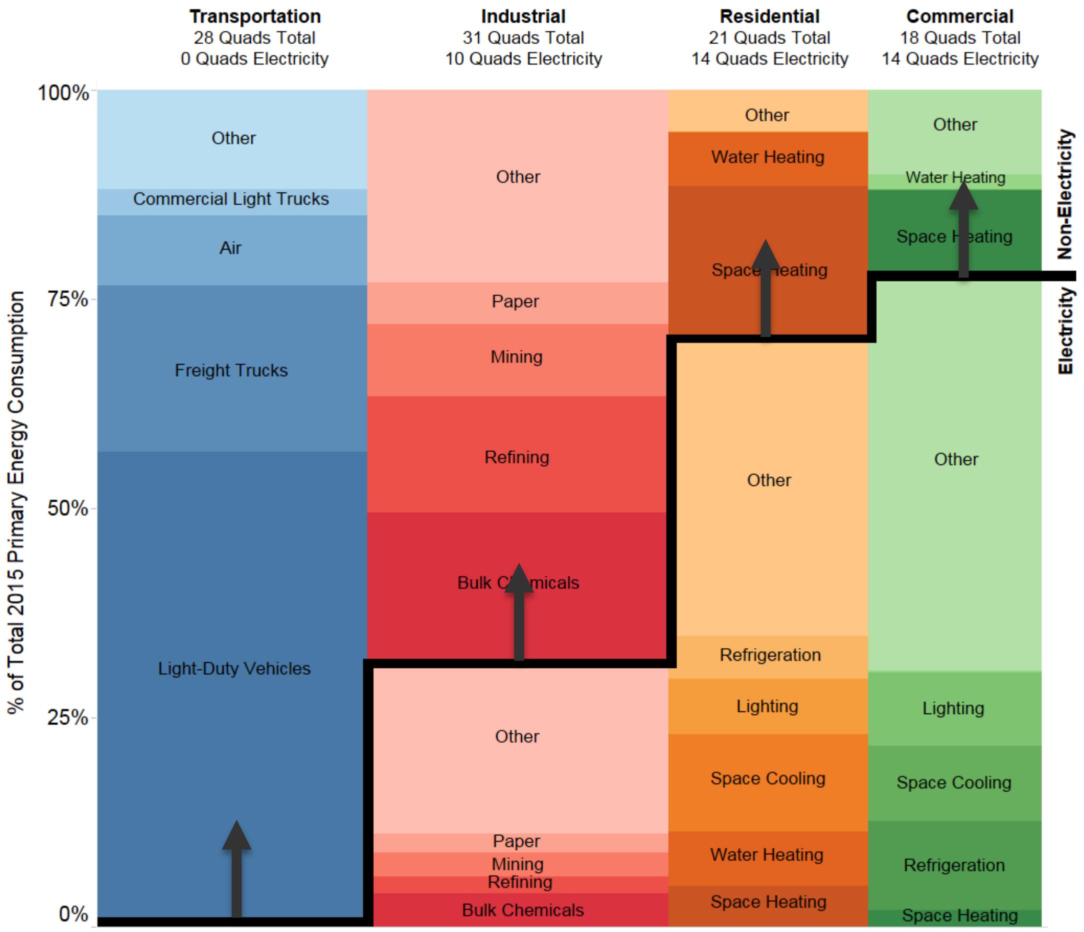
Impacts

What are the potential **costs, benefits, and impacts** of widespread electrification?

The Potential for Electrification

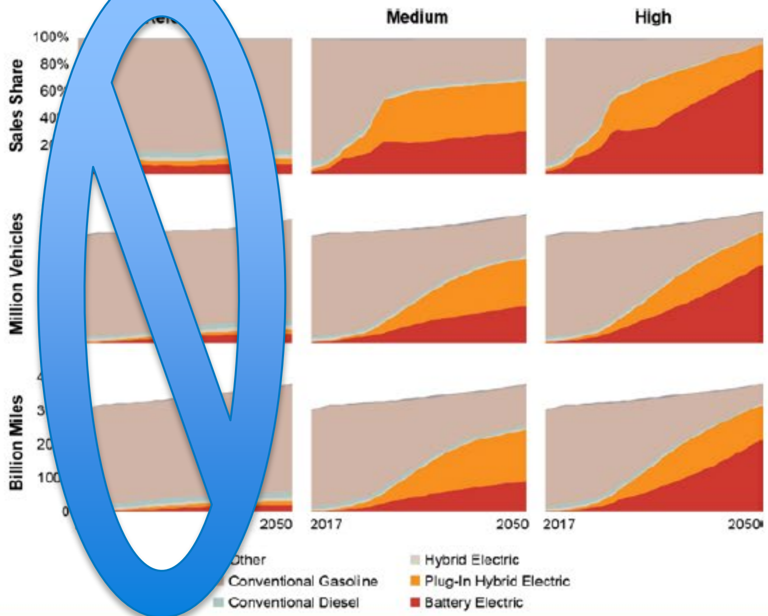
- **Electrification**: the shift from any non-electric source of energy to electricity at the point of final consumption
  - Direct electric technologies only
  - Not exploring new sources of demand

- **Contiguous U.S. energy system,** including transportation, residential and commercial buildings, industry
  - Sectors cover **74% of primary energy in 2015**
  - Did not consider electrification of air transport, petroleum refining and mining, CHP, outdoor cooking



How might electrification impact electricity demand and use patterns?

Example for light-duty vehicles



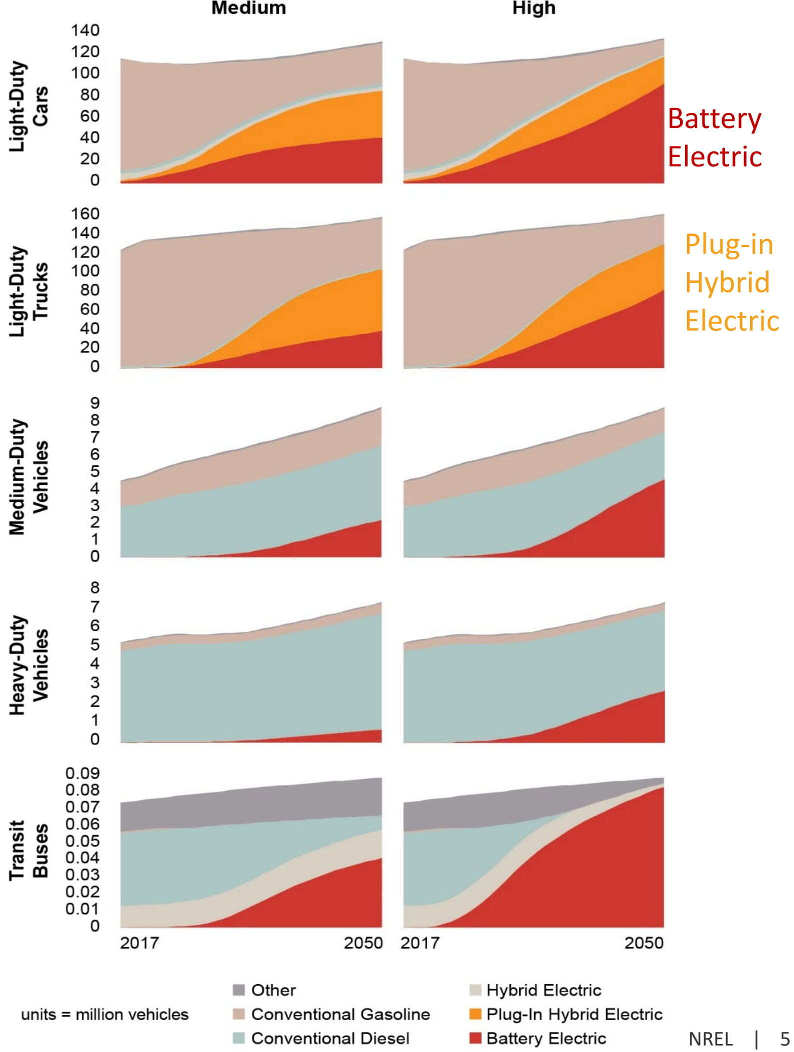
Sales shares determined from a combination of expert judgment based on current trends & consumer choice models (e.g., NREL ADOPT model for LDVs)

EnergyPATHWAYS model used for stock rollover and detailed energy accounting

Principles: technology-rich assessment, bottom-up accounting, cross-sectoral breadth, national scope with state-level detail

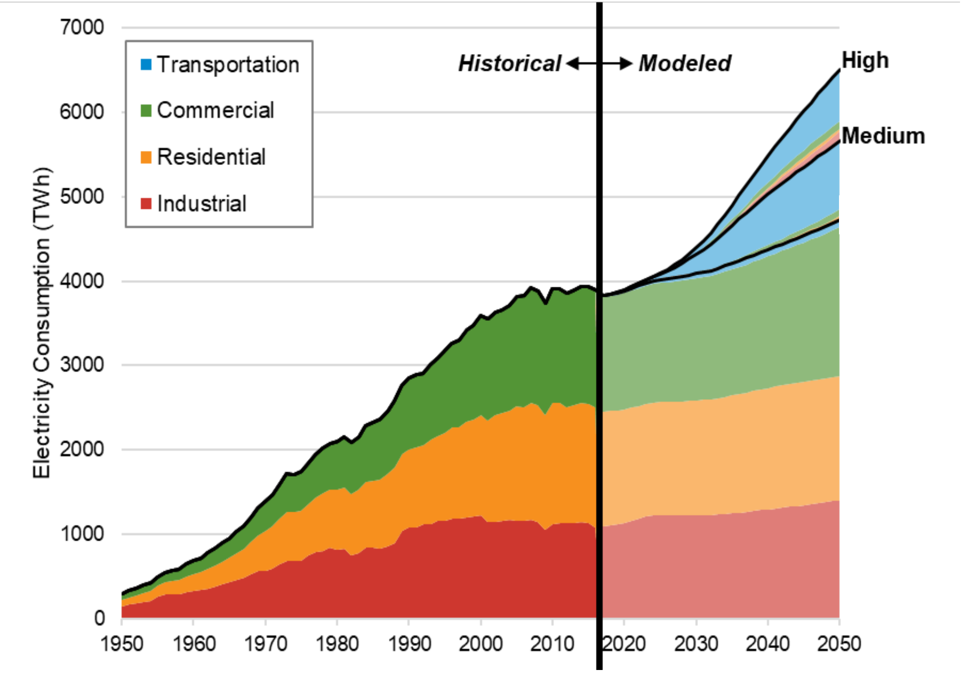
Transportation electrification insights

- The greatest opportunities lie in **light-duty plug-in electric cars and trucks,** in part because fully electric vehicles accounted for <1% of the on-road LDV fleet in 2021
- **Electric freight trucks** can play a major role, particularly for short-haul applications and in more transformational scenarios
- **Transit buses** are prime candidates for electrification
- The High electrification scenario requires significant infrastructure investment, with 138,000 DCFC stations (447,000 plugs) and 10 million non-residential L2 plugs



Source: Mai et al. 2018

Vehicle electrification dominates incremental growth in *annual* electricity demand



Greater electricity consumption

Possibly higher, sharper, and more frequent peaks in 2050
(in the absence of demand flexibility)

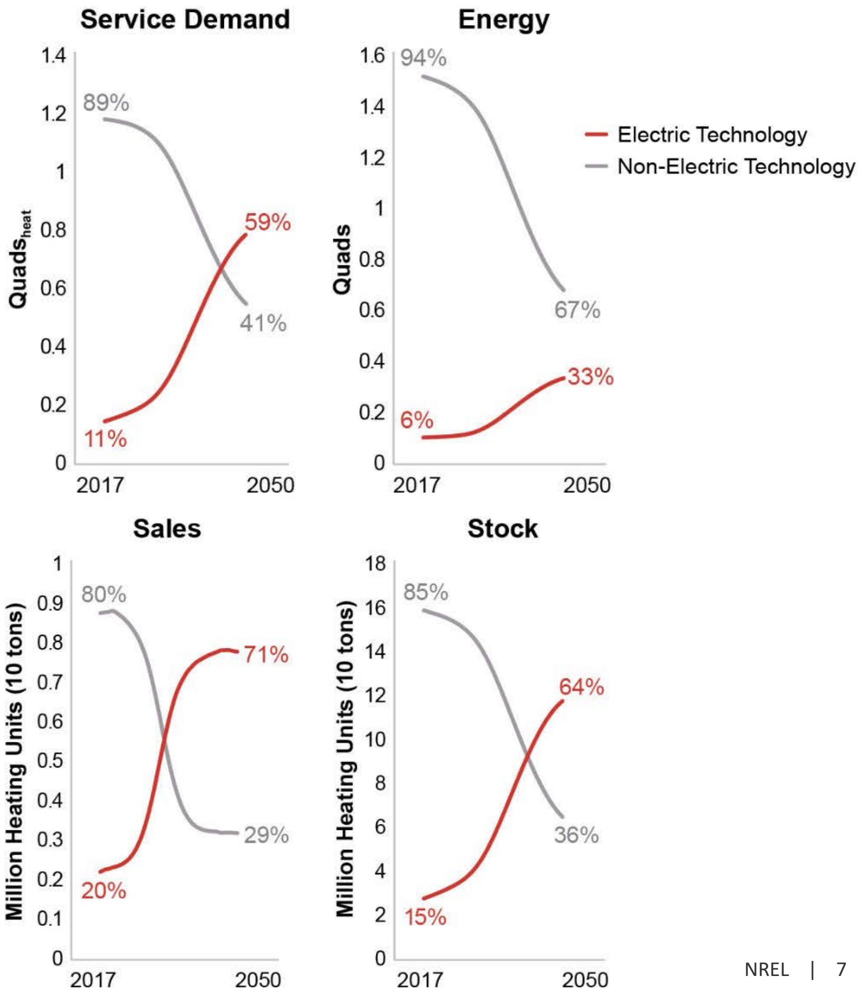
Source: Mai et al. 2018, Murphy et al. 2021, Sun et al. 2020, Zhou and Mai. 2021

Building electrification insights

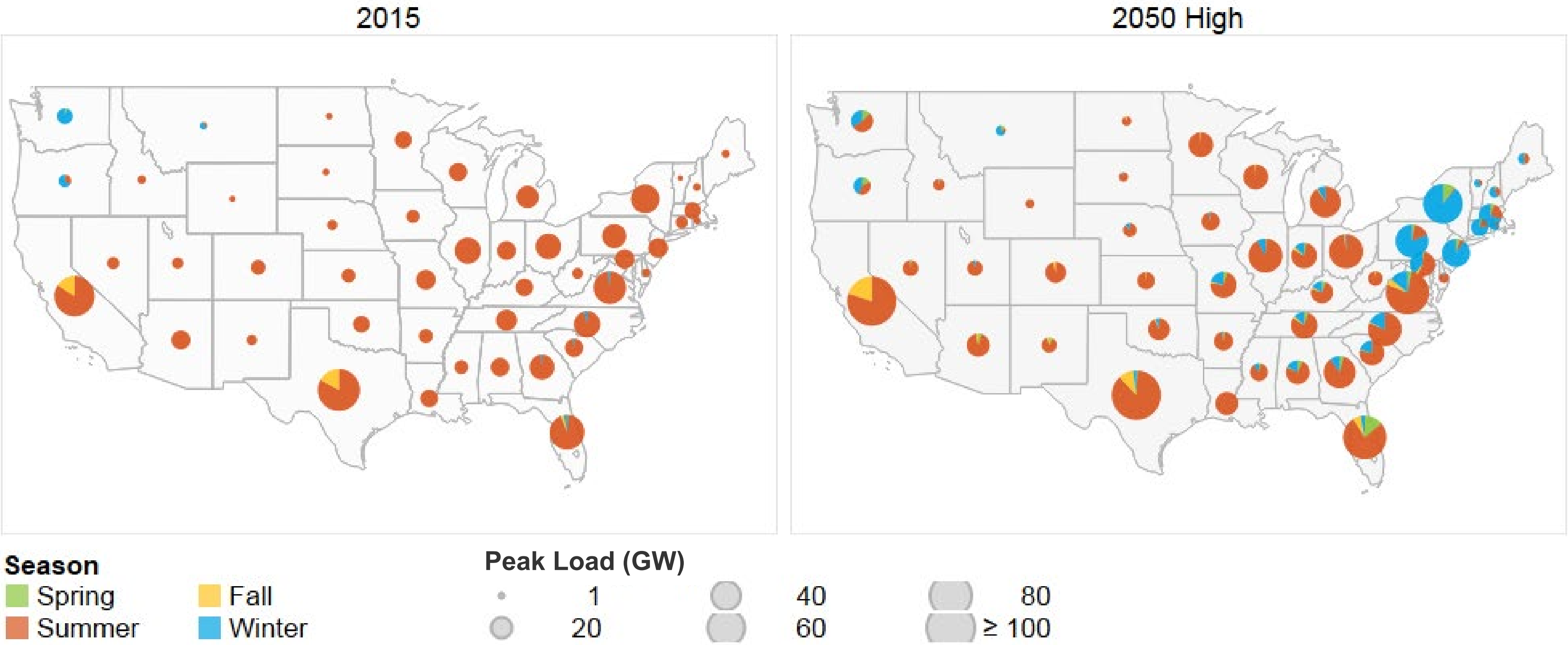
- Electricity already powers a significant share of buildings end-use services
- Electrification opportunities in buildings are most significant for **space and water heating**
- Air-source **heat pumps** are the key buildings electrification technologies: electric equipment provides up to 61% of space heating, 52% of water heating, and 94% of cooking services in the combined commercial and residential building sectors by 2050 (High scenario)

Source: Mai et al. 2018

Commercial Space Heating (High)

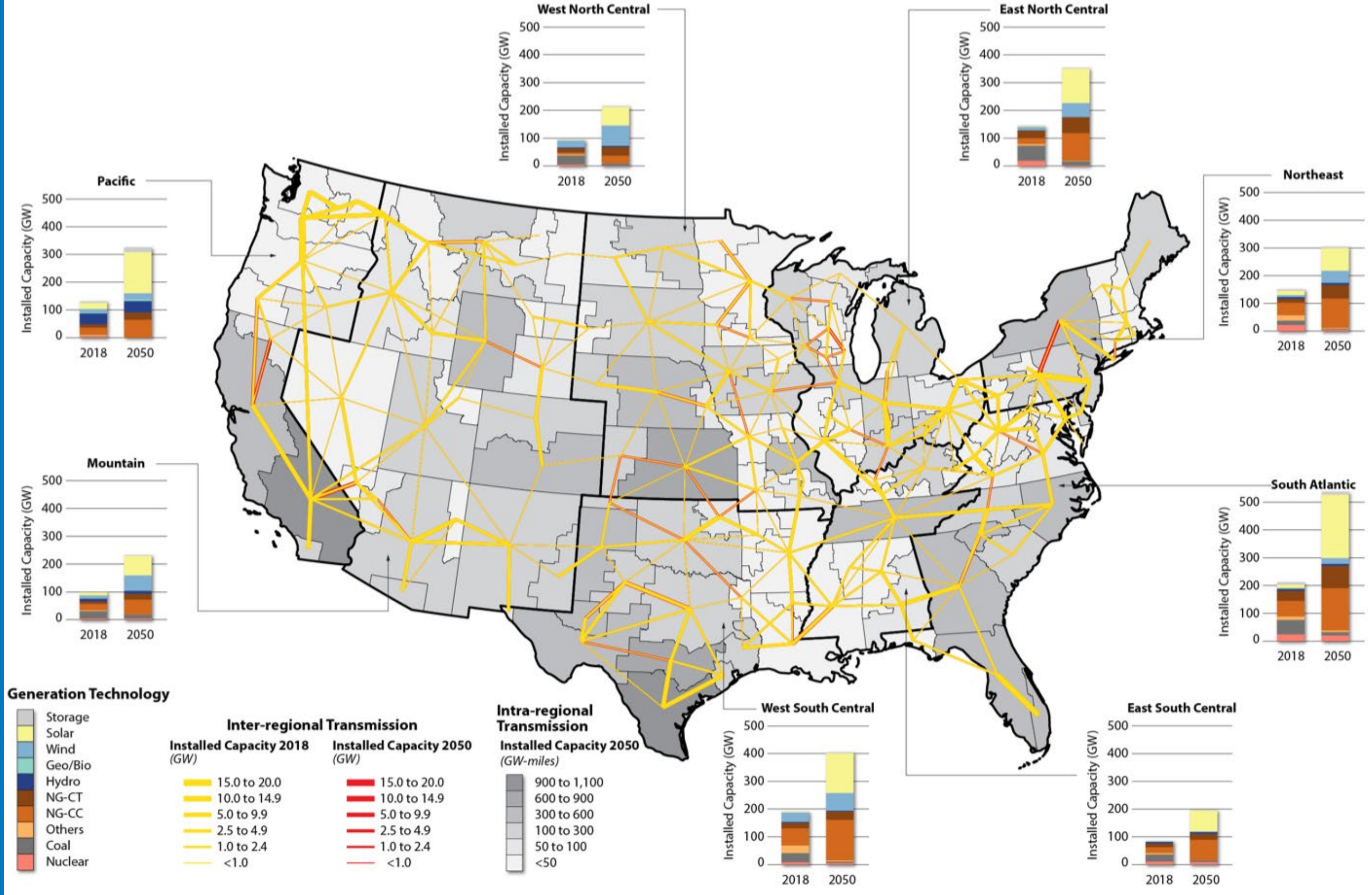


Electric space heating has the most pronounced impact on the timing and magnitude of peak demand



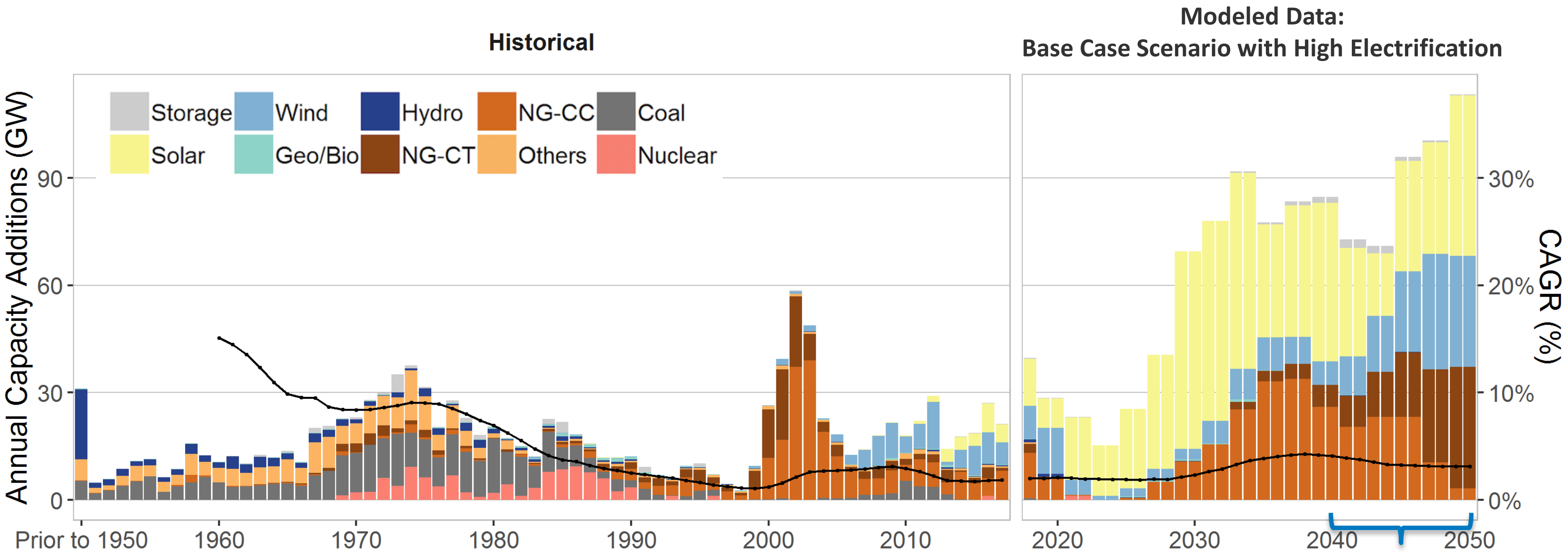
Note: Summer = June-August, Fall = September-November, Winter = December-February, Spring = March-May

Demand growth drives the expansion of renewable energy resources, energy storage, and long-distance transmission capacity



Murphy et al. (2021), https://www.nrel.gov/docs/fy21osti/72330.pdf

Demand growth drives the expansion of renewable energy and energy storage capacity



Solar: ~30-45 GW/yr
Natural Gas: ~35 GW/yr
Wind: ~20 GW/yr
even higher rates in some scenarios

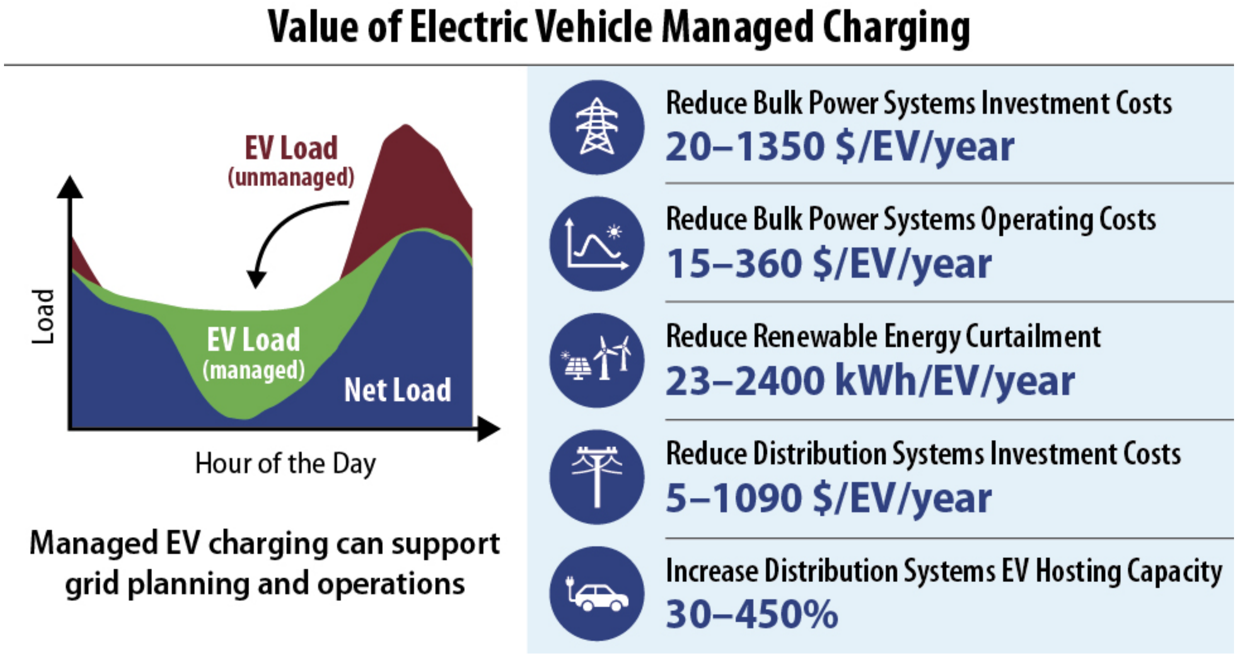
Murphy et al. (2021), https://www.nrel.gov/docs/fy21osti/72330.pdf

Flexible loads provide value by mitigating power sector **infrastructure** needs, systems costs, and price volatility

Electrification Futures Study analysis indicates that flexible loads:

- **Reduce bulk electric system costs** in all scenarios
- **Mitigate** some electrification-induced **investments**
- **Reduce operational costs by up to 10%**
- Enhance the ability of electrification to decarbonize the energy sector by **reducing VRE curtailment**
- **Reduce price volatility**

Caveat: no incremental cost to implement load shifting considered



Anwar et al., 2021. "Assessing the value of electric vehicle managed charging: a review of methodologies and results." *Energy & Environmental Science*

Available EFS Resources and Results

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

EPRI

EVOLVED ENERGY RESEARCH

NORTHERN ARIZONA UNIVERSITY

OAK RIDGE National Laboratory

U.S. DEPARTMENT OF ENERGY

- Technology cost and performance (December 2017)
- Demand-side adoption scenarios (June 2018)
- dsgrid model documentation (August 2018)
- Methodological approaches (July 2020)
- Supply-side evolution scenarios (January 2021)
- Power system operation with flexible loads (May 2021)

Study sponsored by U.S. DOE-EERE Office of Strategic Programs

Best-in-Class Tool: SLOPE Scenario Planner

Helping communities visualize energy futures through 2050

How can various energy strategies help my community achieve our energy goals?

- Build, view, and compare pre-defined future energy scenarios and their associated costs, emissions, and consumption levels
- Explore energy supply and demand scenarios at very high spatial resolution.

How do system cost and emission impacts of various energy strategies compare?

- See energy and carbon emissions implications of electricity decarbonization, building and transportation electrification, and (soon) energy efficiency scenarios down to the county level
- Model how combining strategies can result in emissions and cost reduction tradeoffs or synergies.

maps.nrel.gov/slope/scenarios

Scenario Planner Unique Features

INTEGRATION OF MODELS AND ANALYSES

Leverages and integrates state-of-the-art NREL tools and impactful analyses.

FLEXIBLE SCENARIO OPTIONS

Presents energy, emissions, and economic metrics for a wide range of options for energy transformation.

SECTORAL INTERACTIONS

Captures how energy demand and supply sectors interact and respond to key strategies such as widespread electrification.

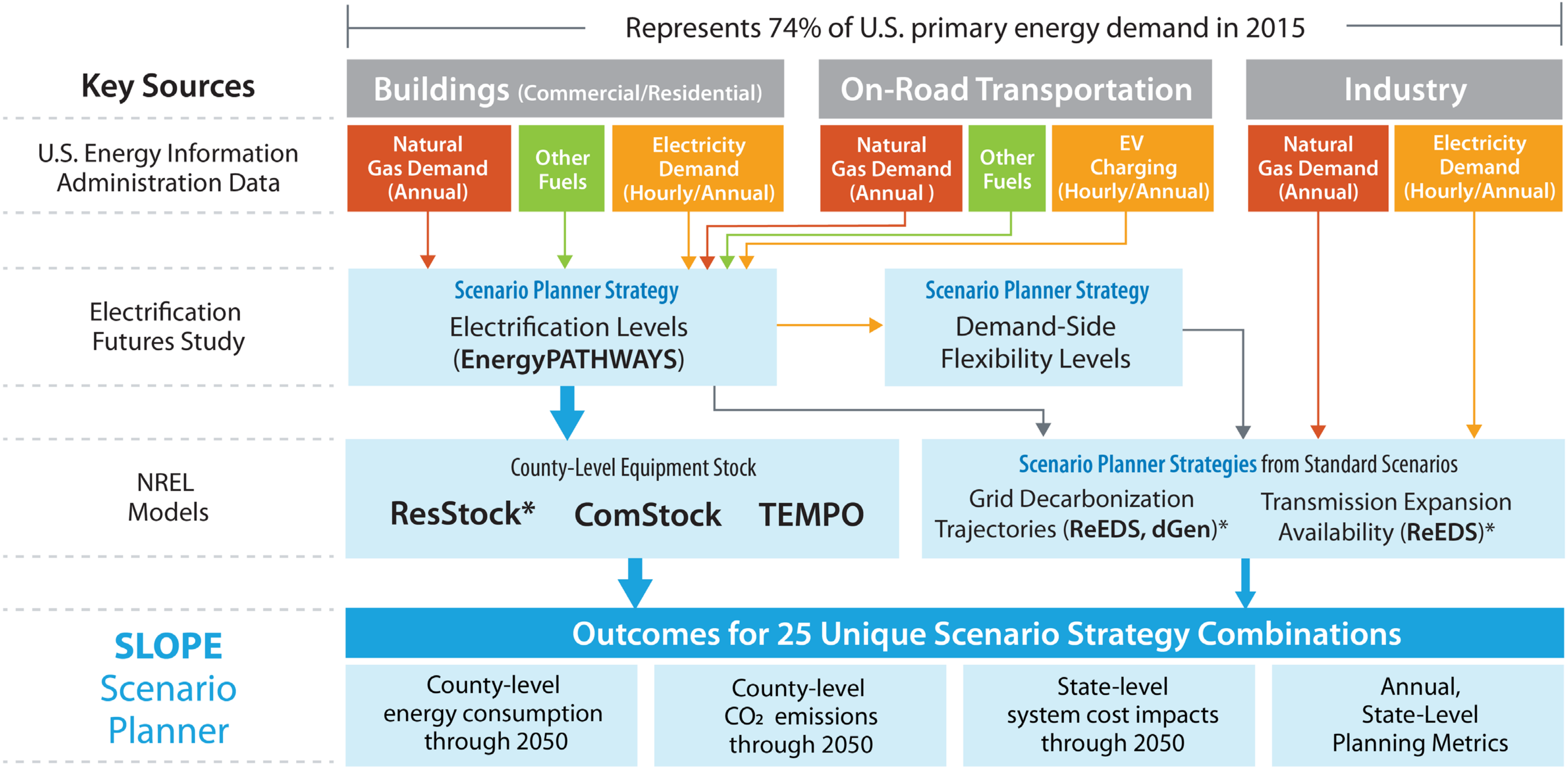
LOCALIZED RESULTS

Translates the results of impactful national studies to the local level for community decision makers.

ACCESSIBLE USER INTERFACE

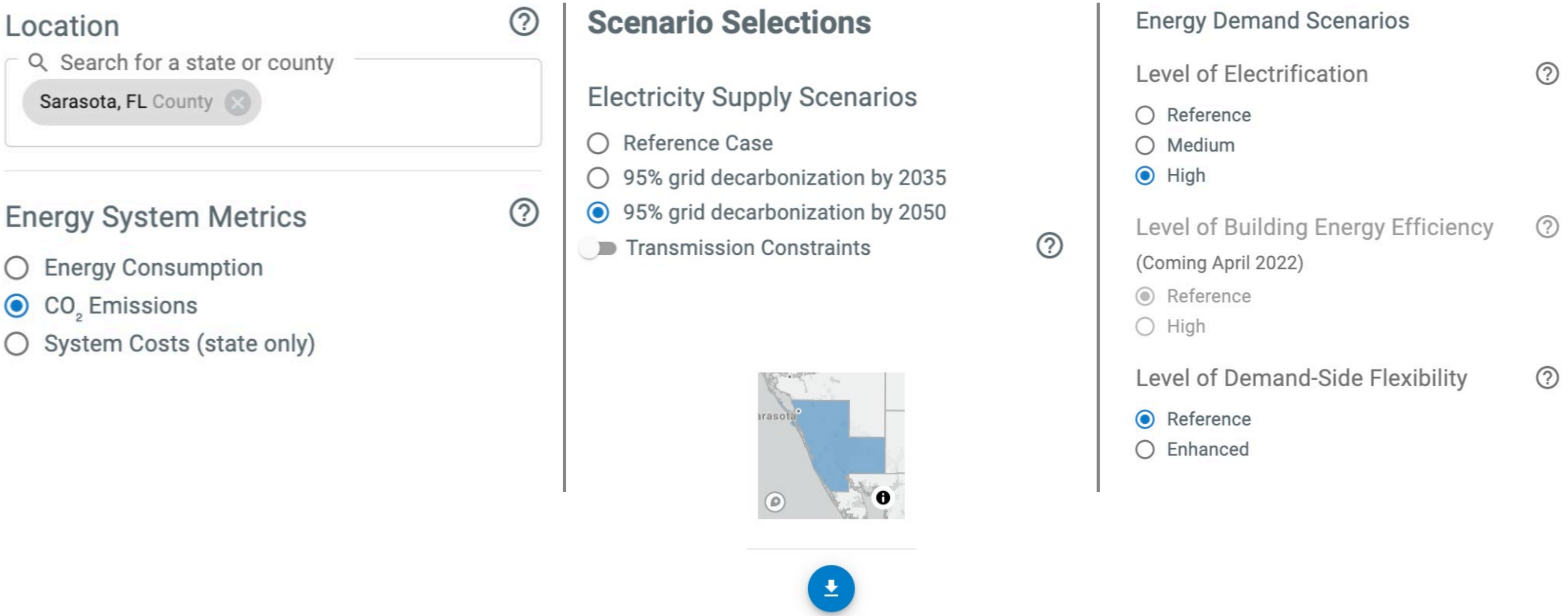
Presents complex scenario results in an accessible way for a wide range of decision makers to use and share.

Scenario Planner: Analysis Architecture



*Previous R&D 100 winners

Explore Supply and Demand Scenarios across Energy System Metrics



The Scenario Planner delivers planning metrics to inform next steps for clean energy transitions

Scenario 1: Reference Case

CO_2 Emissions - Sarasota, Florida

Details for Year 2045

	Residential	Commercial	Industrial	Transportation	Total
Electricity - CO_2 Million Metric Tons (MMT)	0.7101	0.6146	0.1628	0.04207	1.530
Non-Electricity - CO_2 Million Metric Tons (MMT)	0.1202	0.1537	0.1732	2.356	2.803
Total - CO_2 Million Metric Tons (MMT)	0.8303	0.7683	0.3360	2.398	4.332

Planning Metrics ?

State-level data only

Share of Space Heating Services Supplied by Electricity (%)	BEV and PHEV Share of Light-Duty Vehicles (%)	Share of Electricity Provided by Renewable Energy (%)	Reduction in Energy-Related CO2 Emissions from 2005 (%)	Net Change in System Cost from Reference Scenario (Billions 2020 $)
46.81%	10.97%	28.80%	22.55%	$0.000

Scenario 2: 95% Grid Decarbonization by 2050 & Widespread Electrification

CO_2 Emissions - Sarasota, Florida

Details for Year 2045

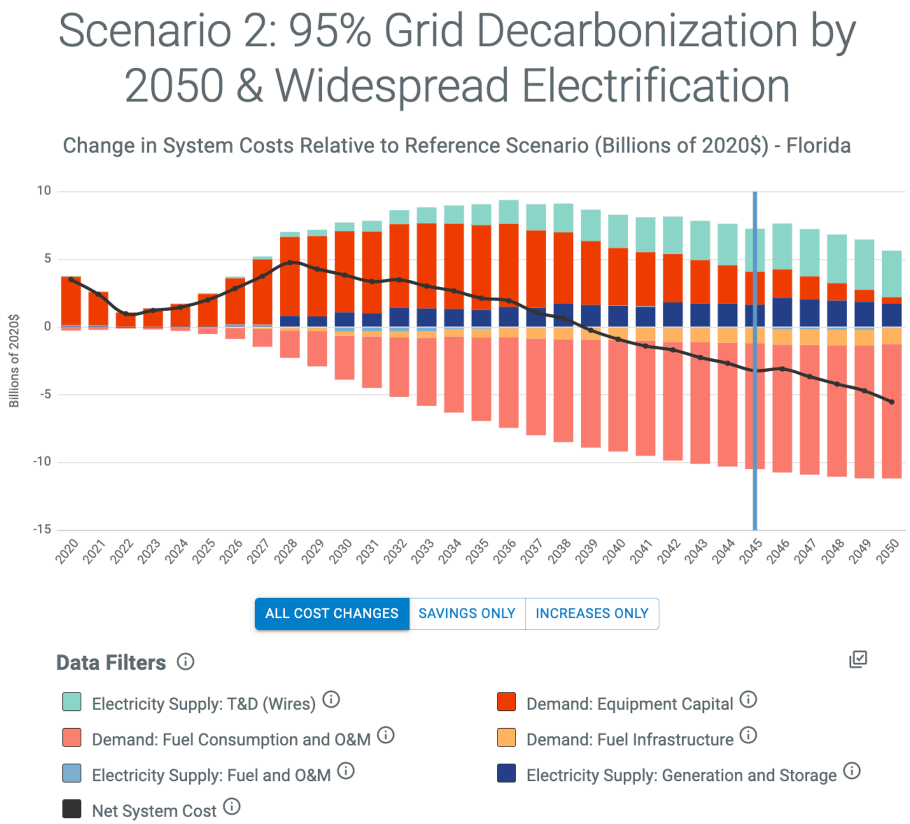
	Residential	Commercial	Industrial	Transportation	Total
Electricity - CO_2 Million Metric Tons (MMT)	0.2055	0.2016	0.05046	0.1621	0.6196
Non-Electricity - CO_2 Million Metric Tons (MMT)	0.07491	0.1059	0.1732	0.9175	1.272
Total - CO_2 Million Metric Tons (MMT)	0.2804	0.3075	0.2236	1.080	1.891

Planning Metrics ?

State-level data only

Share of Space Heating Services Supplied by Electricity (%)	BEV and PHEV Share of Light-Duty Vehicles (%)	Share of Electricity Provided by Renewable Energy (%)	Reduction in Energy-Related CO2 Emissions from 2005 (%)	Net Change in System Cost from Reference Scenario (Billions 2020 $)
80.25%	75.54%	72.05%	65.89%	$-3.217

Scenario Planner reveals for the first time changes in state-level system costs, including investment and savings tradeoffs



Thank you!

caitlin.murphy@nrel.gov

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