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dsgrid

dsgrid
Demand-Side Grid Toolkit

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July 9, 2024

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Agenda

1. Problem statement
2. Tool overview
3. dsgrid is a load modeling approach
4. dsgrid is published datasets
5. dsgrid is open-source software
6. How to access
7. Q&A

Problem statement

Load forecasts have always been ***the key input*** *for power system planning*

NREL deeply understands **energy efficiency** and **renewable energy**

Electricity sector trends

Efficiency

ASHRAE Design Guides for Commercial Buildings

50% Energy Guide

Five 50% Guides are available for download or purchase. Learn More

LEARN MORE

30% Energy Guide

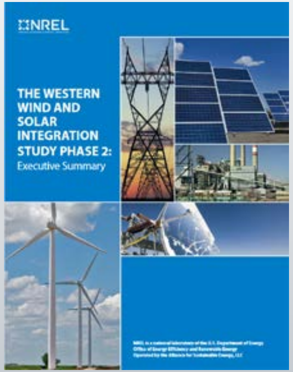
Six 30% Guides are available for download or purchase.

Building America Solutions for Residential Buildings

Supported by NREL tools and analyses 2007–2015

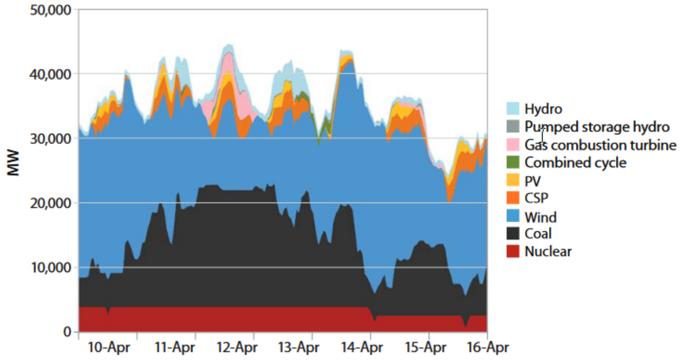
and beyond (ASHRAE 2024; U.S. DOE EERE 2024)

Variable renewable energy integration



NREL

THE WESTERN WIND AND SOLAR INTEGRATION STUDY PHASE 2:
Executive Summary

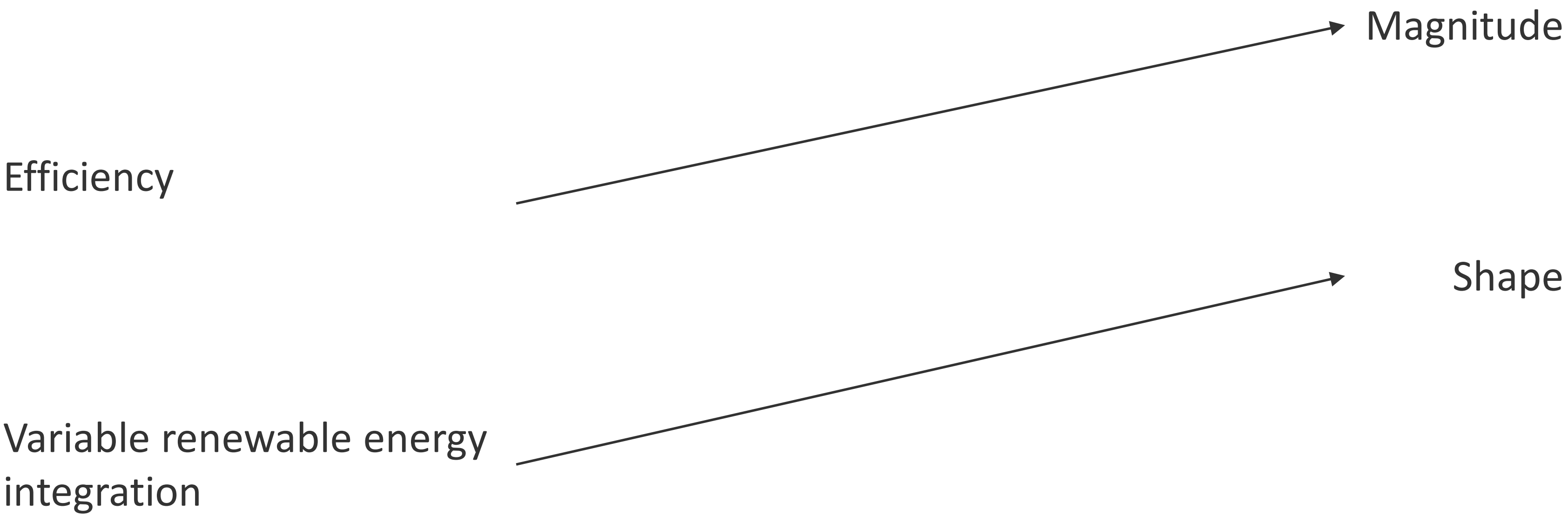


(Lew et al. 2013)

Energy efficiency impacts load magnitude; renewable energy makes load shape more salient

Electricity sector trends

Load characteristics



Magnitude

Efficiency

Shape

Variable renewable energy integration

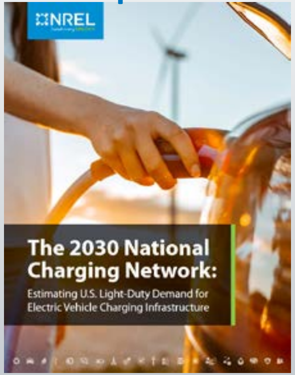
Electrification has followed efficiency; flexibility, including demand-side, complements renewables

Electricity sector trends

Efficiency, electrification, and efficient electrification

Variable renewable energy integration

Transportation

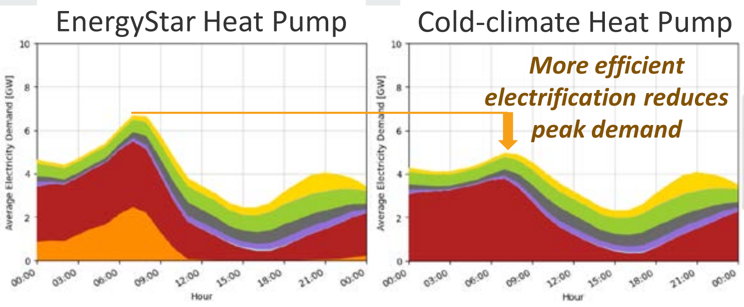


The 2030 National Charging Network:

Estimating U.S. Light-Duty Demand for Electric Vehicle Charging Infrastructure

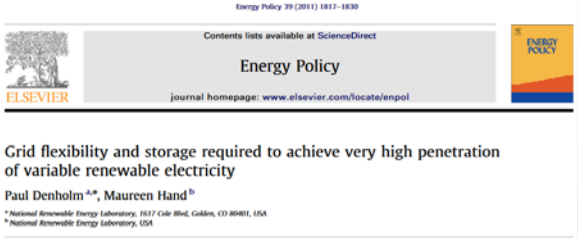
(Wood et al. 2023)

Buildings



More efficient electrification reduces peak demand

(White et al. 2024)



Energy Policy 39 (2011) 1817–1830

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Grid flexibility and storage required to achieve very high penetration of variable renewable electricity

Paul Denholm [a,*], Maureen Hand [b]

[a] National Renewable Energy Laboratory, 1617 Cole Blvd, Golden, CO 80401, USA

[b] National Renewable Energy Laboratory, USA

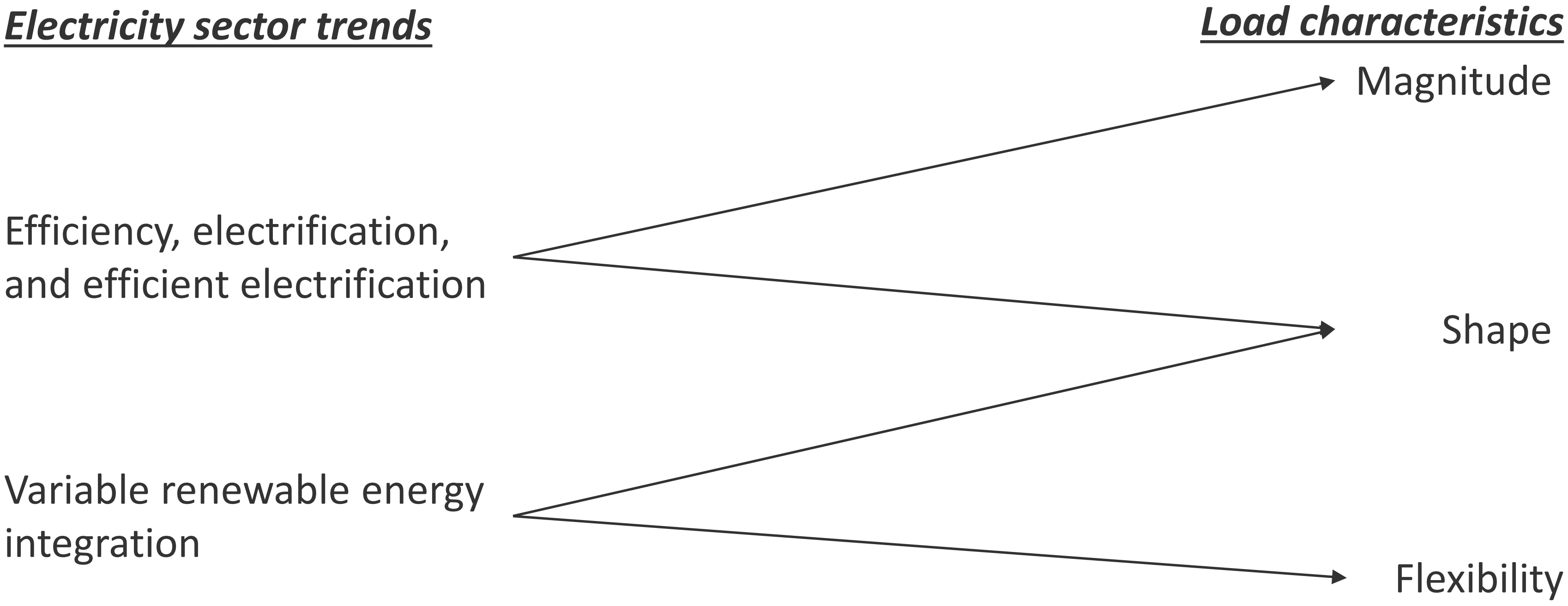
(Denholm and Hand 2011)

Demand Response and Energy Storage Integration Study

March 2016

(Ma et al. 2016)

NREL anticipated the long-term load forecasting challenges so many face today



Electricity sector trends

Efficiency, electrification, and efficient electrification

Variable renewable energy integration

Load characteristics

Magnitude

Shape

Flexibility

Looking forward, indirect electrification for industrial or energy storage end uses further complicates this picture by placing even more emphasis on flexibility and introducing close coupling with other fuels, feedstocks, and energy carriers.

NREL anticipated the long-term load forecasting challenges so many face today

- Time-synchronized load, wind, and solar data
- Cross-sectoral and cross-disciplinary
  - Buildings, transportation, and industry
  - Power sector
  - Physical resource and economics of load flexibility
- Deep uncertainty
  - Policy and technology adoption
  - Climate and weather
  - Population and macroeconomics

Magnitude

Shape

Flexibility

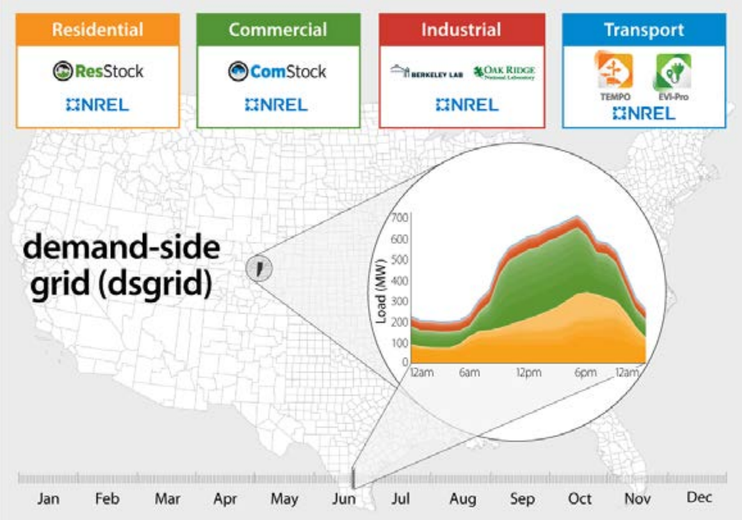
Tool overview

The demand-side grid (dsgrid) toolkit leverages bottom-up modeling of demand sectors to produce data for power system planning

dsgrid is …

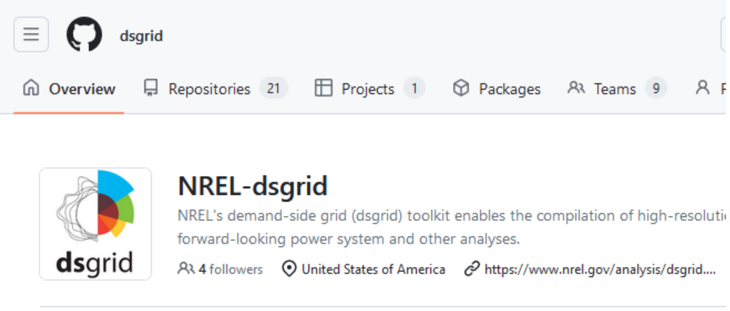
① **A load modeling approach** that leverages bottom-up modeling of buildings, transportation, and industry to enable:

- Future projections and what-if scenarios **for electricity load shapes** in addition to magnitude of annual energy use
- Understanding of **interactions** between demand-side and supply-side resources.



② **Published datasets** accessible through the Open Energy Data Initiative (OEDI)

③ **Open-source software** that flexibly and extensibly supports long-term load projection workflows, which require alignment across different geographic, temporal, and sectoral resolutions; timeseries manipulation; data query; and QA/QC



NREL-dsgrid

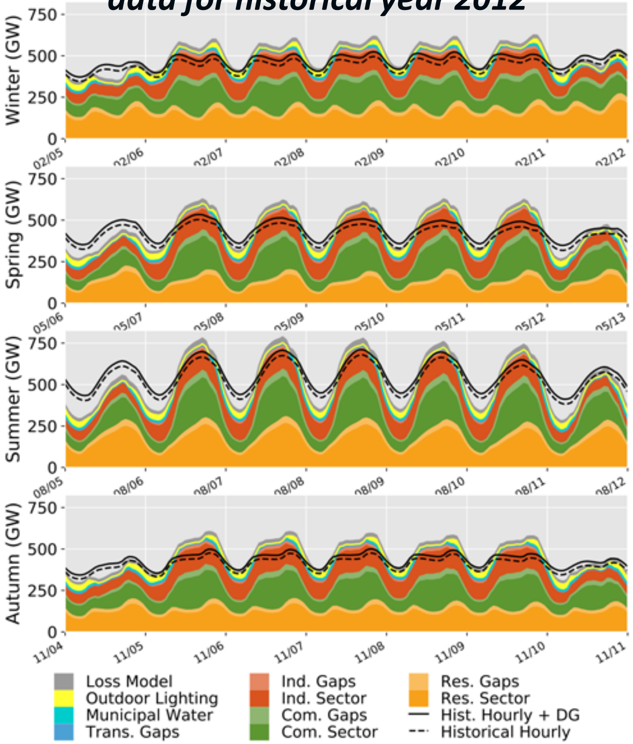
NREL's demand-side grid (dsgrid) toolkit enables the compilation of high-resoluti
forward-looking power system and other analyses.

4 followers United States of America https://www.nrel.gov/analysis/dsgrid....

1. dsgrid is a load modeling approach

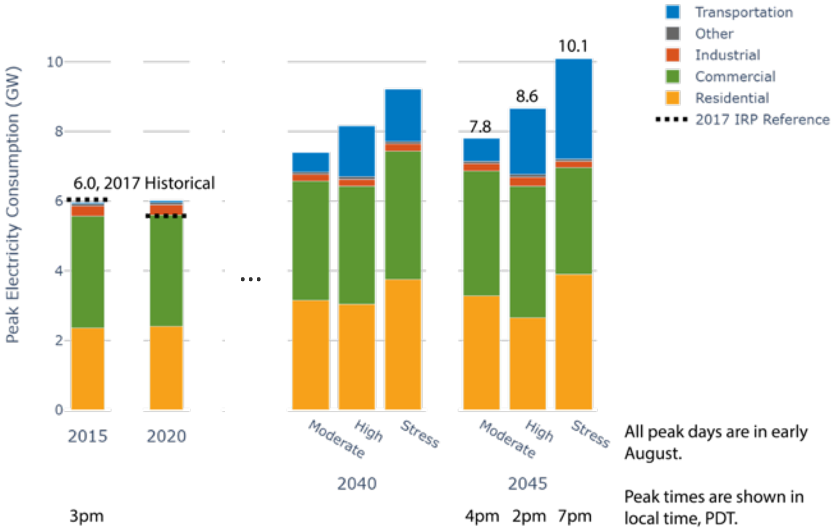
The dsgrid team assembles bottom-up, highly resolved load datasets

Proof-of-concept bottom-up load modeling data for historical year 2012



Hale et al. 2018: https://www.nrel.gov/docs/fy18osti/71492.pdf

Three load projections for the Los Angeles 100% Renewable Energy Study (LA100)



All peak days are in early August.

Peak times are shown in local time, PDT.

Hale et al. 2021: https://www.nrel.gov/docs/fy21osti/79444-3.pdf

LA100 Example

What electricity demands will LADWP need to meet starting now and continuing through 2045?

Demand Modeling Team

Buildings Models

- Residential
- Commercial

Industrial and Other Models

- Industrial
- Other commercial
- Water system
- Miscellaneous loads

Transportation Models

- Light-duty electric vehicles (EVs)
- Buses

Three Possible Futures for **Customer Electricity Demand**

Moderate

- Moderate electricity growth and efficiency
- 30% of passenger cars will be electric by 2045

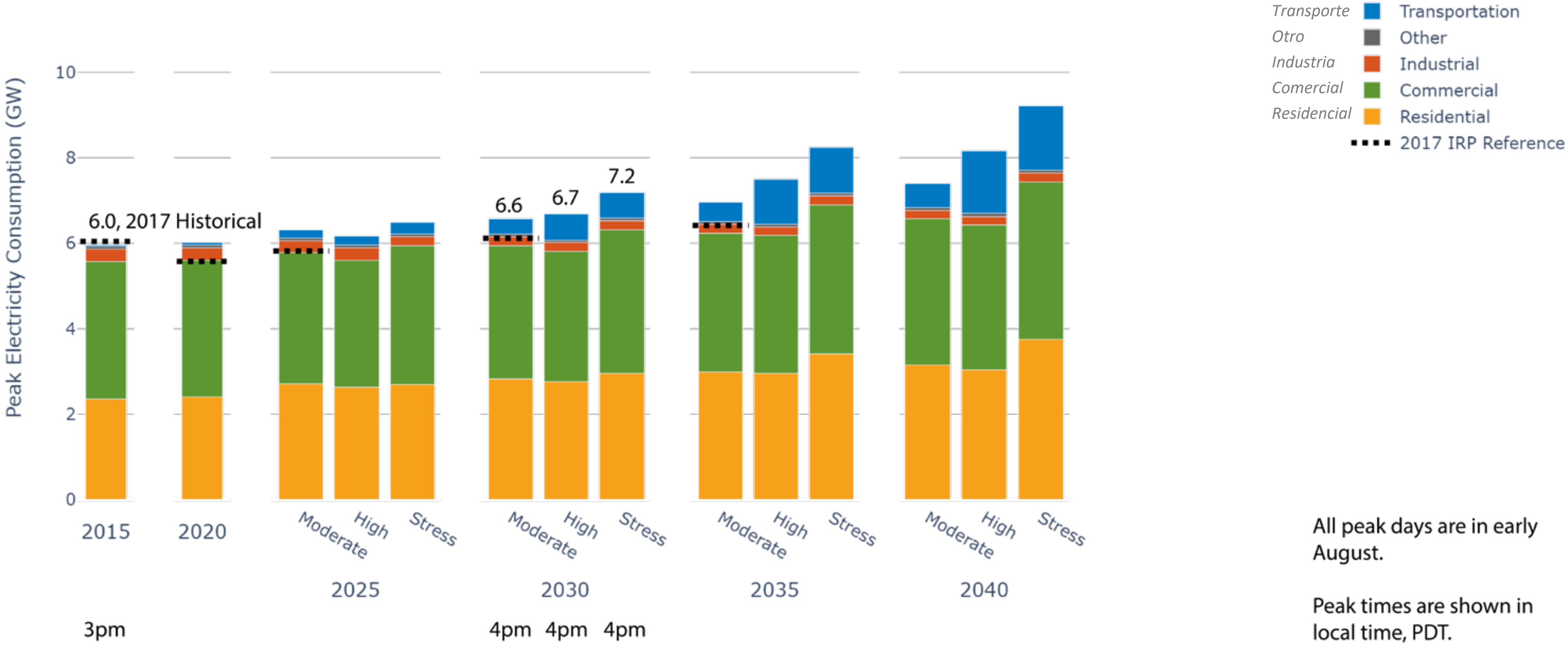
High

- Appliances and space and water heating switch from natural gas to electricity
- Buildings are weatherized; most efficient appliances are adopted
- 80% of passenger cars are electric
- Demand is more flexible in its timing

Stress

- All the electrification of **High**
- Significantly less energy efficiency
- Timing of demand is less aligned with renewable generation

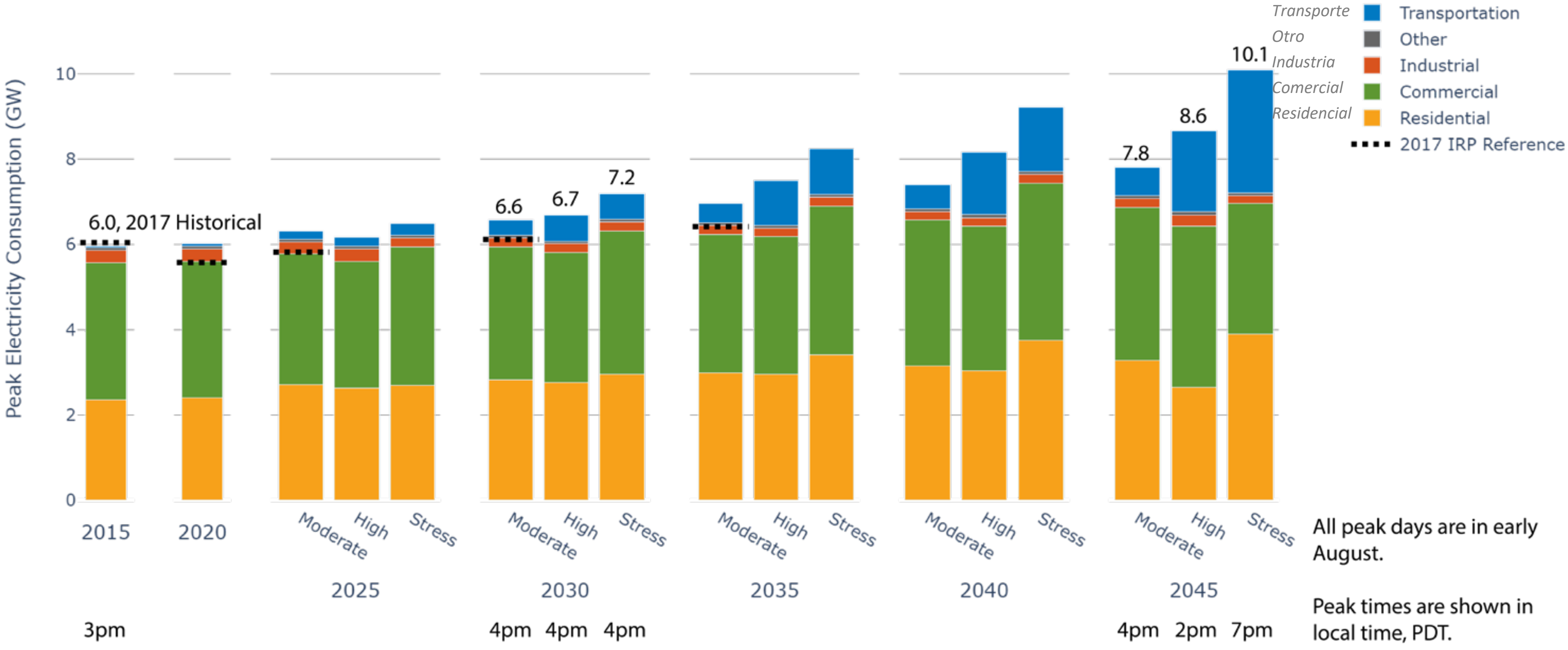
Energy efficiency drives the difference between the High and Stress projections 2025–2040



All peak days are in early August.

Peak times are shown in local time, PDT.

In 2045 with high electrification, where and when EVs are charged could help determine the time of system peak

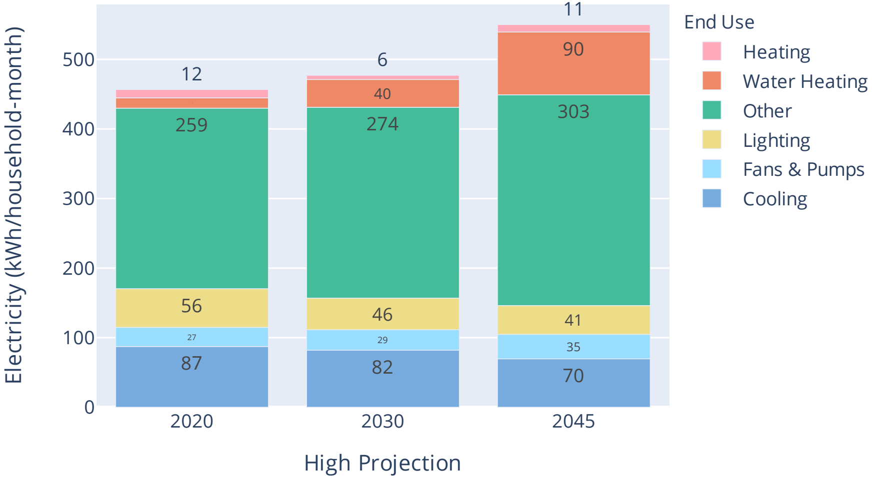


All peak days are in early August.

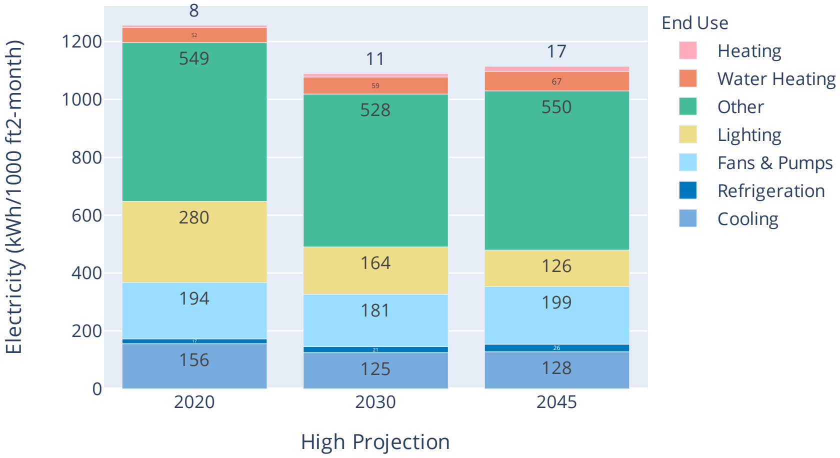
Peak times are shown in local time, PDT.

Different customer types see different impacts under the High projection

Residential Sector: Monthly electricity use increases because of electrification

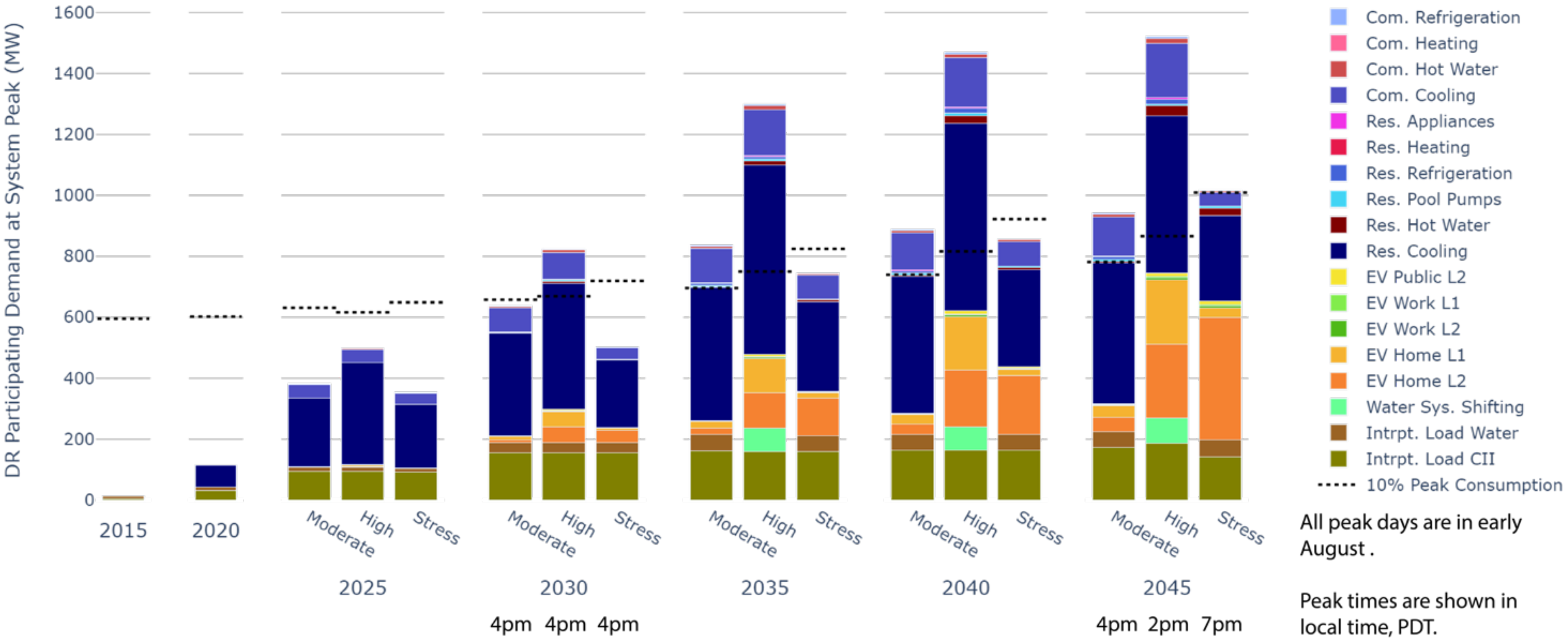


Commercial Sector: Efficiency is more impactful than electrification



Municipal water sector electricity use increases more than fourfold to reduce dependence on imported water.

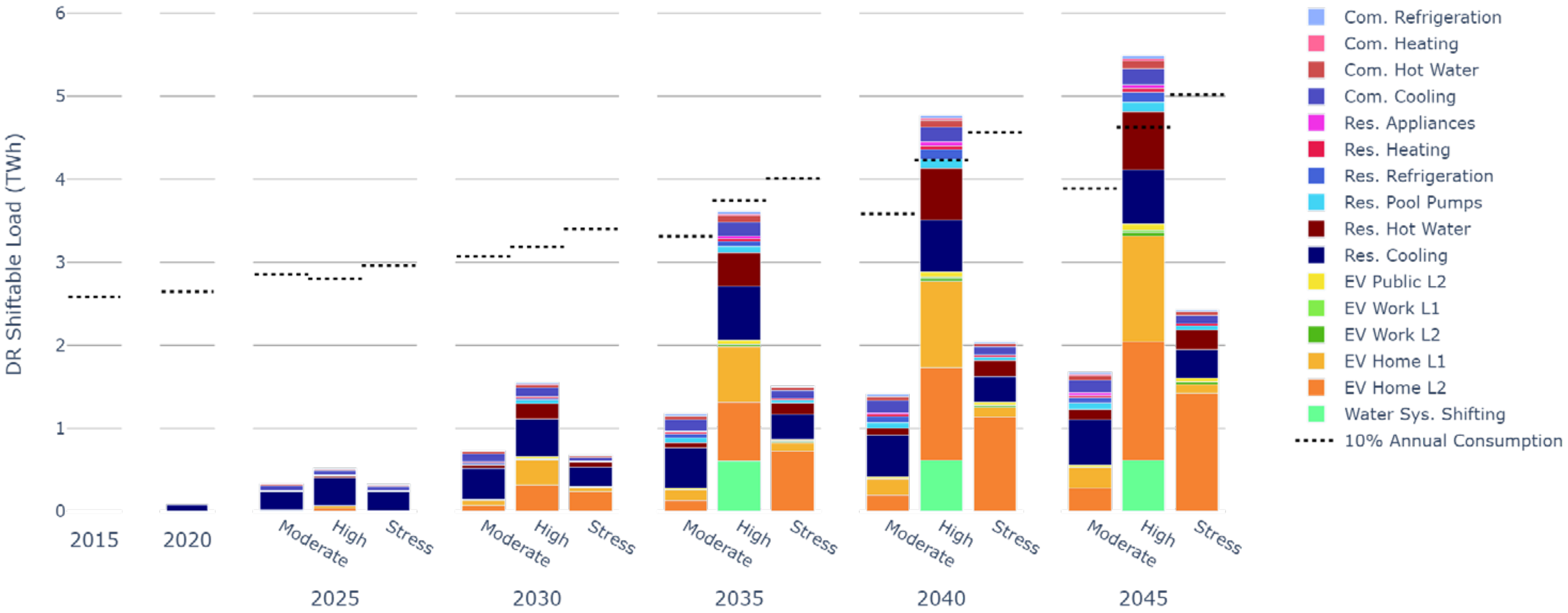
Total Demand Response Capacity: End-use demand at time of system peak



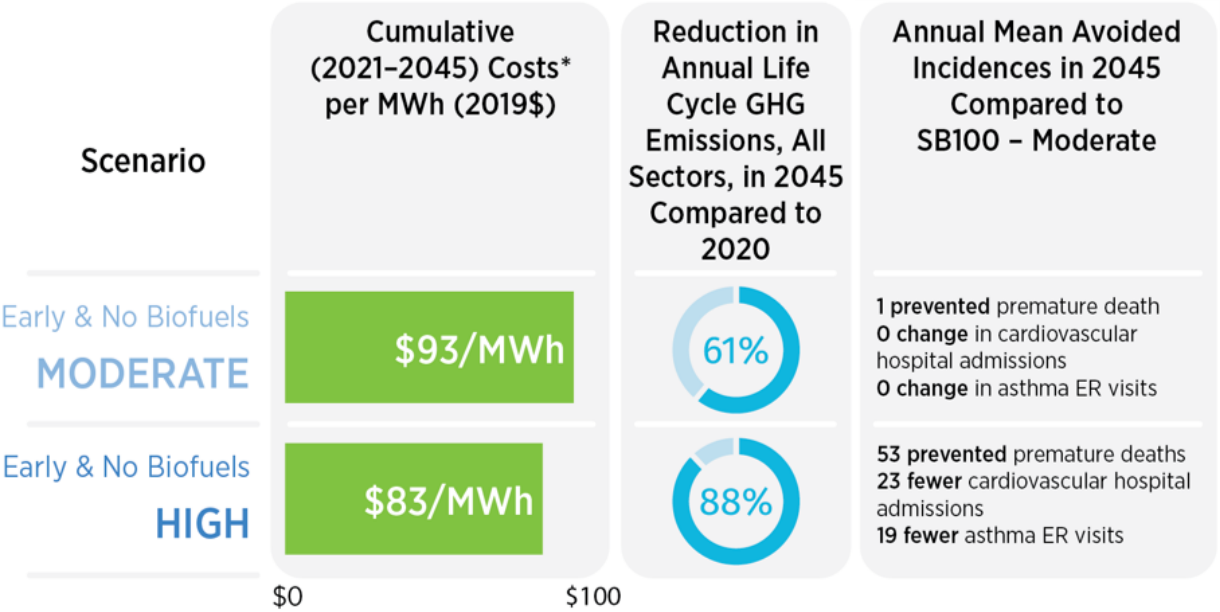
All peak days are in early August .

Peak times are shown in local time, PDT.

Total Demand Response Capacity: Shiftable end-use demand



High vs. Moderate: Lower per-unit costs, more greenhouse gas (GHG) reduction, and greater health benefits



Scenario	Cumulative (2021–2045) Costs* per MWh (2019$)	Reduction in Annual Life Cycle GHG Emissions, All Sectors, in 2045 Compared to 2020	Annual Mean Avoided Incidences in 2045 Compared to SB100 – Moderate
Early & No Biofuels **MODERATE**	$93/MWh	61%	**1 prevented** premature death **0 change** in cardiovascular hospital admissions **0 change** in asthma ER visits
Early & No Biofuels **HIGH**	$83/MWh	88%	**53 prevented** premature deaths **23 fewer** cardiovascular hospital admissions **19 fewer** asthma ER visits

*Revenue requirements per unit of generation to cover the annualized costs associated with expenditures measured in LA100--Not equivalent to rates.

2. dsgrid is published datasets

Original proof-of-concept data from the Electrification Futures Study (EFS)

Demand-Side Grid Model (dsgrid) Data from the Electrification Futures Project (EFS)

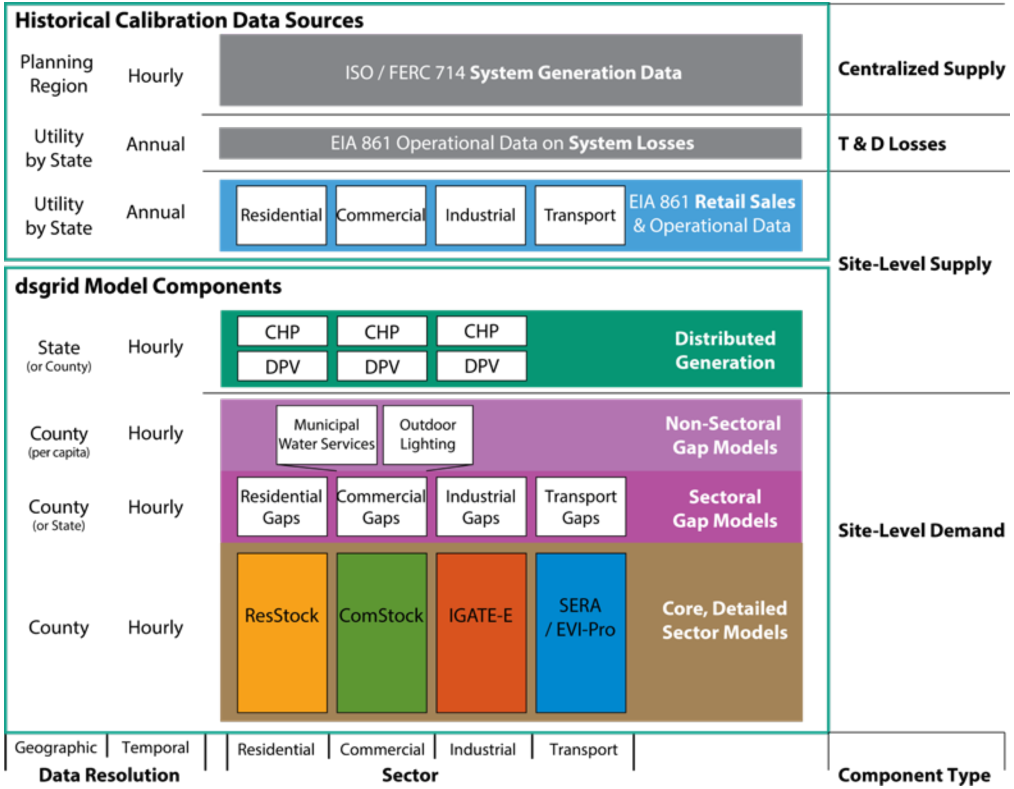
DOI 10.25984/1823248 Publicly accessible License

This data set contains the full-resolution and state-level data described in the linked technical report (https://www.nrel.gov/docs/fy18osti/71492.pdf). It can be accessed with the NREL-dsgrid-legacy-efs-api, available on GitHub at https://github.com/dsgrid/dsgrid-legacy-efs-api and through PyPI (pip install NREL-dsgrid-legacy-efs-api). The data format is HDF5. The API is written in Python

This initial dsgrid data set, whose description was originally published in 2018, covers electricity demand in the contiguous United States (CONUS) for the historical year of 2012. It is a proof-of-concept demonstrating the feasibility of reconciling bottom-up demand modeling results with top-down information about electricity demand to create a more detailed description than is possible with either type of data source on its own. The result is demand data that is more highly resolved along geographic, temporal, sectoral, and end-use dimensions as may be helpful for conducting electricity sector-wide "what-if" analysis of, e.g., energy efficiency, electrification, and/or demand flexibility

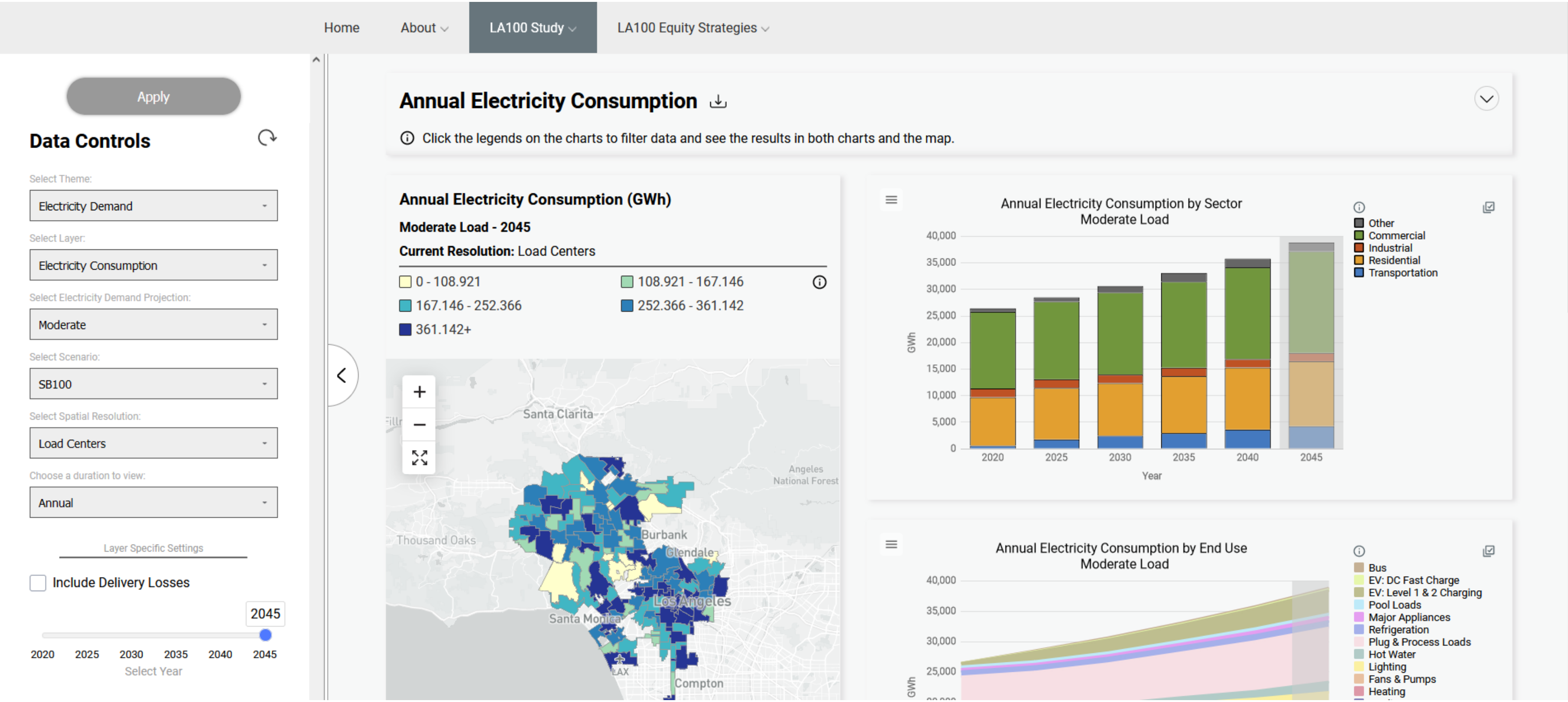
Although we conducted bottom-up versus top-down validation, the final residuals were significant, especially at higher geographic and temporal resolution. Please see the Executive Summary and/or Section 3 of the report to obtain an understanding of the data set limitations before deciding whether these data are suitable for any particular use case

New dsgrid datasets are under development. Please visit https://www.nrel.gov/analysis/dsgrid.html for the latest information which is also linked in the data resources.



Data: https://data.openei.org/submissions/4130
API: https://github.com/dsgrid/dsgrid-legacy-efs-api
Report: https://www.nrel.gov/docs/fy18osti/71492.pdf

LA100: Select data available from the LA100 Data Viewer



Data Controls

Select Theme: Electricity Demand

Select Layer: Electricity Consumption

Select Electricity Demand Projection: Moderate

Select Scenario: SB100

Select Spatial Resolution: Load Centers

Choose a duration to view: Annual

☐ Include Delivery Losses

2045

Annual Electricity Consumption

Click the legends on the charts to filter data and see the results in both charts and the map.

Annual Electricity Consumption (GWh)

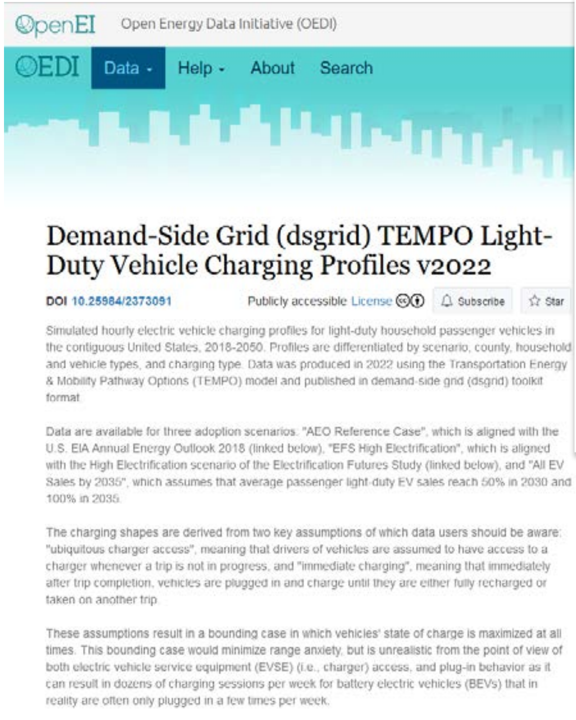
Moderate Load - 2045

Current Resolution: Load Centers

- 0 - 108.921
- 108.921 - 167.146
- 167.146 - 252.366
- 252.366 - 361.142
- 361.142+

Data viewer: https://maps.nrel.gov/la100/la100-study/data-viewer
Report: https://www.nrel.gov/docs/fy21osti/79444-3.pdf

Just released: High-resolution, simulated EV charging profiles for passenger light-duty vehicles



Demand-Side Grid (dsgrid) TEMPO Light-Duty Vehicle Charging Profiles v2022

DOI 10.25984/2373091 Publicly accessible License

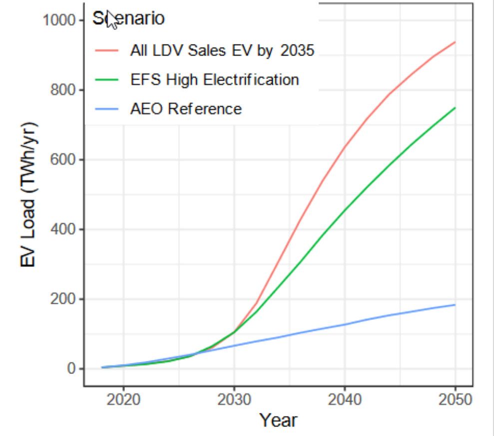
Simulated hourly electric vehicle charging profiles for light-duty household passenger vehicles in the contiguous United States, 2018-2050. Profiles are differentiated by scenario, county, household and vehicle types, and charging type. Data was produced in 2022 using the Transportation Energy & Mobility Pathway Options (TEMPO) model and published in demand-side grid (dsgrid) toolkit format.

Data are available for three adoption scenarios: "AEO Reference Case", which is aligned with the U.S. EIA Annual Energy Outlook 2018 (linked below), "EFS High Electrification", which is aligned with the High Electrification scenario of the Electrification Futures Study (linked below), and "All EV Sales by 2035", which assumes that average passenger light-duty EV sales reach 50% in 2030 and 100% in 2035.

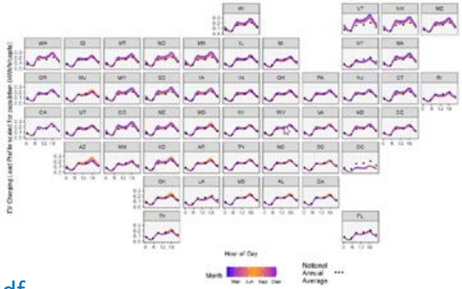
The charging shapes are derived from two key assumptions of which data users should be aware: "ubiquitous charger access", meaning that drivers of vehicles are assumed to have access to a charger whenever a trip is not in progress, and "immediate charging", meaning that immediately after trip completion, vehicles are plugged in and charge until they are either fully recharged or taken on another trip.

These assumptions result in a bounding case in which vehicles' state of charge is maximized at all times. This bounding case would minimize range anxiety, but is unrealistic from the point of view of both electric vehicle service equipment (EVSE) (i.e., charger) access, and plug-in behavior as it can result in dozens of charging sessions per week for battery electric vehicles (BEVs) that in reality are often only plugged in a few times per week.

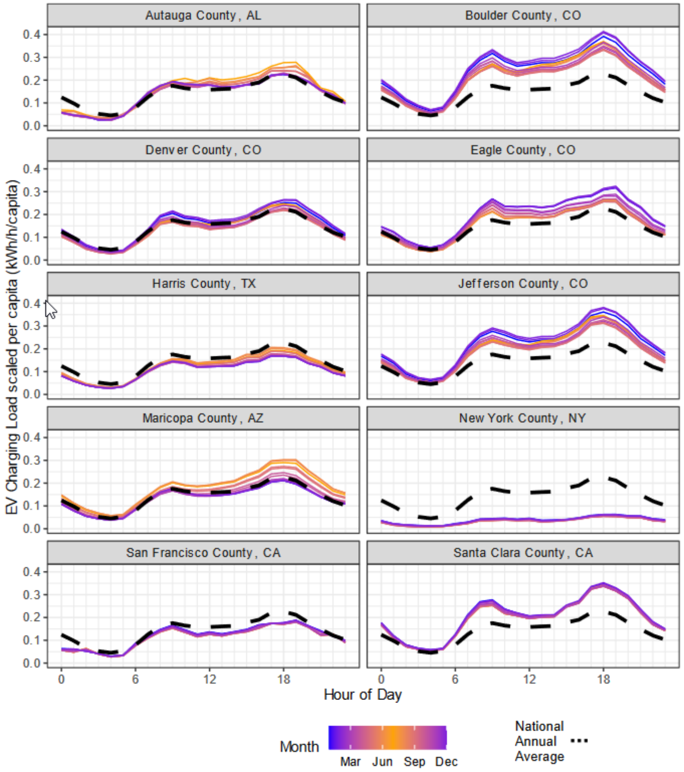
Projections of annual electricity use



State-level aggregate load shapes



Example county-level load shapes



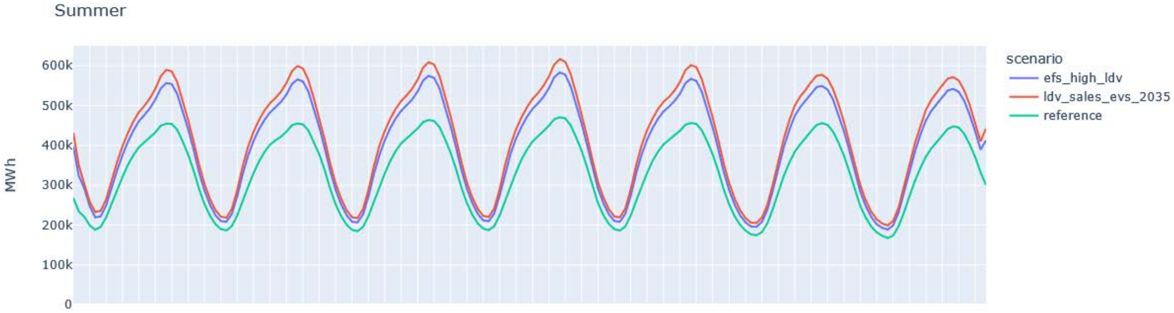
Data: https://data.openei.org/submissions/5958
Report: https://www.nrel.gov/docs/fy23osti/83916.pdf

3. dsgrid is open-source software

Highlights

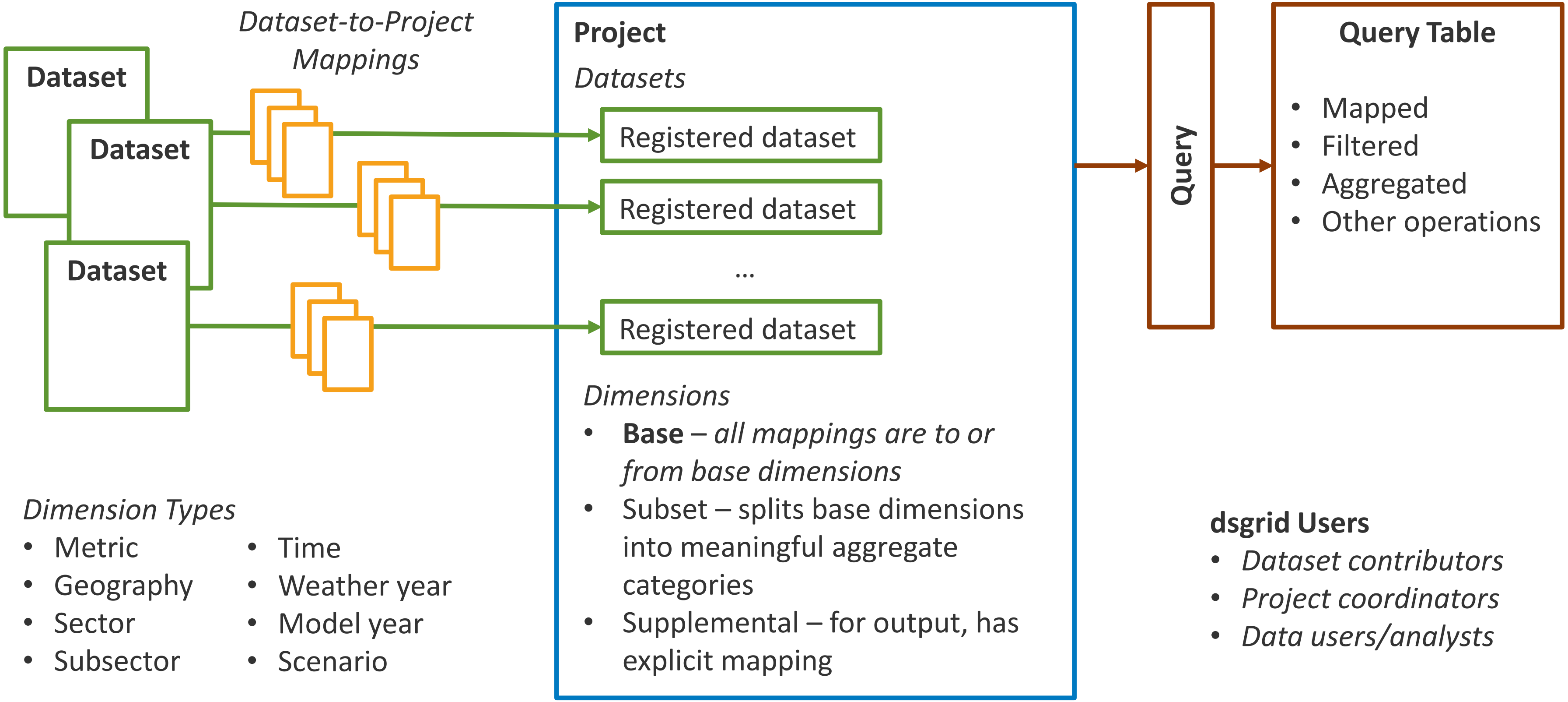
We designed the new dsgrid software based on lessons learned from EFS and LA100

- **Software can be used for any geographic scope**, including international (no hard-coded assumptions about geography, time, units, data sources)
- **Generic query interface** supports use by others, development of web application interfaces
- **Aligns dimensions, including timeseries data**, across disparate data sources and performs basic checking to ensure expected data are present and interpretable



- **Data alignment explodes data to TB scale**, e.g., 59 GB on disk, 164 GB in memory, to 3.7 TB in memory with 28 subsectors, 61 end uses, 3,000 counties, and aligned 8760 timestamps
- dsgrid software handles this explosion with Apache Spark, and the team is continually looking for ways to work with the data more efficiently.

dsgrid terminology



Dataset

Dataset

Dataset

Dataset-to-Project Mappings

Project

Datasets

Registered dataset

Registered dataset

…

Registered dataset

Dimensions

- **Base** – *all mappings are to or from base dimensions*
- Subset – splits base dimensions into meaningful aggregate categories
- Supplemental – for output, has explicit mapping

Query

Query Table

- Mapped
- Filtered
- Aggregated
- Other operations

Dimension Types

- Metric
- Geography
- Sector
- Subsector
- Time
- Weather year
- Model year
- Scenario

dsgrid Users

- *Dataset contributors*
- *Project coordinators*
- *Data users/analysts*

How are the loads mapped to the grid?

	Dataset Geography	**Project Base Geography**		**Supplemental Geography**
DECARB Example	• EMM regions • County • State • Census tract	• County	*Aggregation* → *Map*	• Regional Energy Deployment System (ReEDS) balancing authority
LA100 Example	• Sample buildings • Sample EVs • Agents (e.g., parcels)	• Agents (e.g., parcels)	*Electrical* → *Geography*	• Secondary transformers • Substations
Other Options	• Census tract • Feeder • Advanced metering infrastructure (AMI) meter	• Substation/bus • Feeder • Transformer		

dsgrid applications complete, in-progress, and under consideration

Application	Complete	In-Progress	Under Consideration
National-scale, high-resolution for bulk power system modeling	✓ ✓	✓ ✓ ✓	
City-scale, high-resolution for bulk power system modeling	✓		
City-scale, high-resolution for distribution system modeling	✓		
Distribution system operational & capacity expansion modeling			✓ ✓
International, country-level for bulk power system modeling			✓ ✓

What is your use case? *Reach out to dsgrid.info@nrel.gov if you might be interested in collaborating.*

How to access

How To Access

① **Reports**

- dsgrid model documentation (EFS proof-of-concept): https://www.nrel.gov/docs/fy18osti/71492.pdf
- LA100: https://www.nrel.gov/docs/fy21osti/79444-3.pdf

② **Data**

- LA100: https://maps.nrel.gov/la100/la100-study/data-viewer
- Electric vehicle charging profiles from TEMPO: https://data.openei.org/submissions/5958

③ **Code**

- dsgrid: https://github.com/dsgrid/dsgrid
- *Under-development:* national-scale dataset configurations: https://github.com/dsgrid/dsgrid-project-DECARB

Sign up for our newsletter by scrolling to the bottom of the dsgrid **website:** https://www.nrel.gov/analysis/dsgrid.html

The newsletter is the best way to receive timely information about:

- New publications
- New datasets
- Any major software announcements.

Follow us on GitHub: https://github.com/dsgrid

If you have specific inquiries, please email dsgrid.info@nrel.gov.

Q&A

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Thank you

www.nrel.gov

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