California Grid Readiness

White Paper: Stakeholder and Public Awareness

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Overview

Chapter 1: California Future Electrification Landscape

Chapter 2: Impact on California's Electric Grid

Chapter 3: Electric Grid Investment Needs

Chapter 4: Societal and Policy Implications

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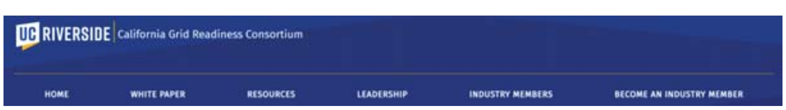

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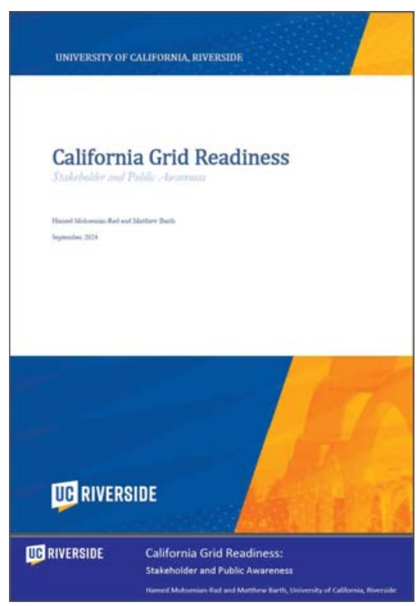

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Future Electrification Landscape

Transportation Electrification

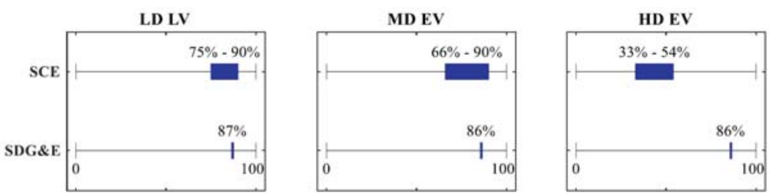
Current (2023) Statistics Across California

Light Duty:	1,502,119
Medium/Heavy Duty:	3,782

Truck Type	Annual kWh / Vehicle	Reference
Car	3,508	[8]
SUV	4,932	
Van	5,163	
Pickup	5,769	
Light-Medium-Duty	8,079	[11]
Medium-Duty	17,667	
Heavy-Duty	20,703	

Note: Median Monthly Home Electricity Usage: 750 kWh

Example Utility Projections (2045)



[15][16][17]

Other Third-Party Projections:

25% to 90% [7][8][13]
Different Assumptions

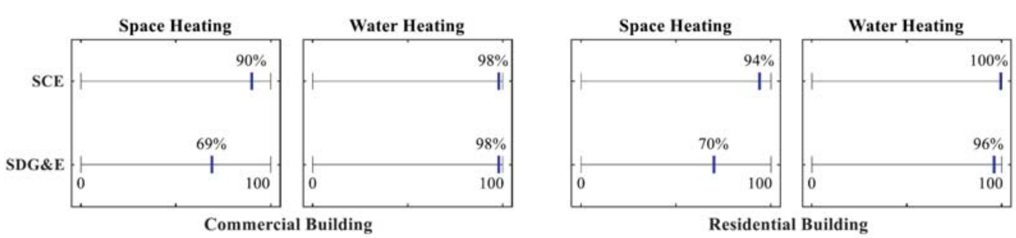
Future Electrification Landscape

Building Electrification

Residential Buildings	New Construction	Water Heating
Commercial Buildings	Retrofitting Existing Building	Space Heating
		Home Appliances
		(cooking, dryers, etc.)

Hotwater.com

Example Utility Projections (2045)



[15][17]

A household with building electrification and one EV → Double Electricity Usage [18].

Impact of Policy Requirements

Example: If CARB passes a rule phasing out NOx emitting appliances, then it may increase the share of space/water heating to 100% [36].

Future Electrification Landscape

Load Growth in Other Sectors

Other Forms of Transportation

Locomotives and Cargo Handling Equipment

Railjournal.com

Pacmar.com

Hydrogen Fuel Production

Hydrogen Electrolysis (for Hydrogen Vehicles and Energy Storage)

freightwaves.com

Manufacturing

Boiling and Heating (Food Processing, Steel Production, etc.)
Water Supply and Wastewater Management ← Impact of Climate Change

Computational Load

Data Centers ← Impact of Artificial Intelligence (AI)

techradar.com

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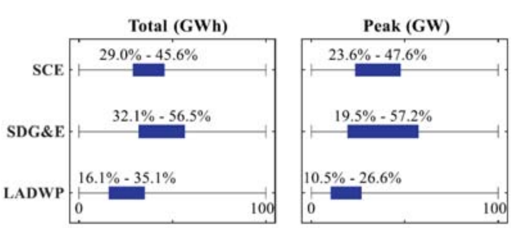
Impact on California's Electric Grid

Increased Loading (Total and Peak)

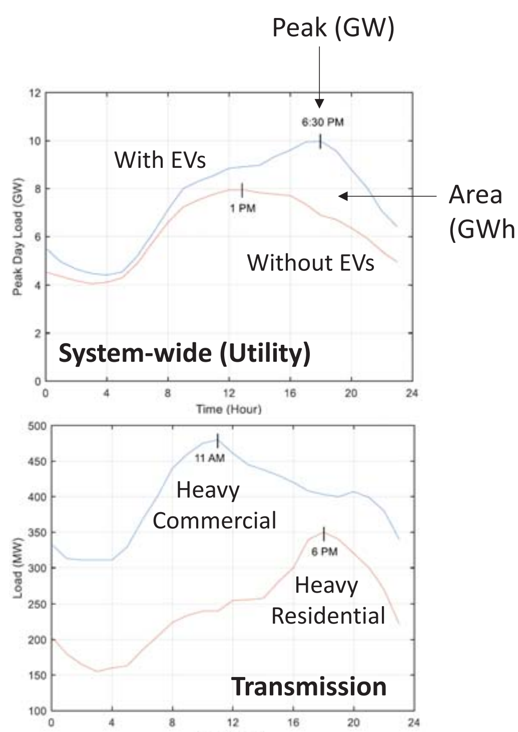
Total Energy Usage: Gigawatt-Hour (**GWh**)
Peak Power Usage: Gigawatt (**GW**)

System-wide: State's or Utility's Overall Service Territory
Transmission: Transmission Lines and Substations
Distribution: Distribution Lines and Substations

Example Utility Projections (2035)



[13][15]
[16][17]



Example: Projected LAWDP Daily Load Profiles [13].

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Impact on California's Electric Grid

Impact on Transmission and Distribution Capacity

Increased Load ➞ Need to Increase Capacity (Will Take a Long Time)

In the Short Term: Use Current Capacity more Efficiently

Transmission

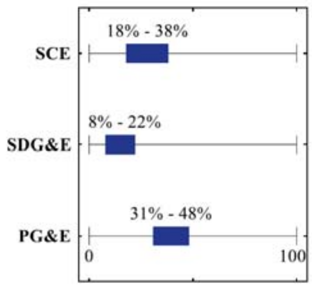
Distribution

RiversideCA.gov

Example Third-Party Projections (2035)

Transmission lines in California will have to **triple** by 2050 (due to electrification and diversified generation) [44].

Percentage of overloaded **distribution** Circuits [7].



Substation Transformer Banks: 40% Overloaded
Feeders: 35% Overloaded
Service Transformers: 32% Overloaded

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Impact on California's Electric Grid

Impact on Transmission and Distribution Operation

Power Quality, Protection, and Stability

Voltage Fluctuations ➞ 120 V
Voltage Violations ➞ ±5%
Harmonic Distortions ➞ Power Electronics Equipment
Protection Equipment Malfunction ➞ Power Electronics Equipment
Stability Issues ➞ Oscillations, New Dynamic Modes

(Such as EV Chargers, PV Inverters, etc.)

Related Issue: Permitting Process

Customer-side — Individuals/businesses to install EV charging stations, DERs, and certain building electrification technologies
Utility-side — Utilities need to implement the upgrades that they need in their networks.

➞ Current bottleneck. Customer permitting takes a long time and sometimes only partially granted [71].
(Utility needs upgrades before it can approve more customer-side permitting requests.)

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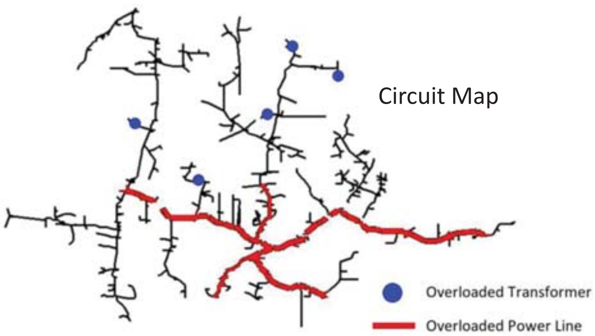
Electric Grid Investment Needs

Investment in Grid Equipment

Many circuits need upgrades

But only few pieces in each circuit need upgrades



An example, based on the analysis in [73].

Cost: See the White Paper → Unit Costs, Overall Costs

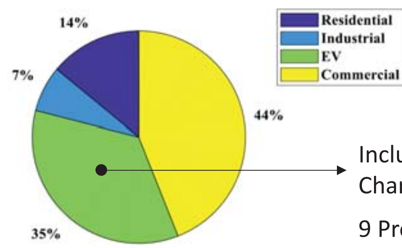
Case Study: City of Jurupa Valley (Riverside County)

Ten-year outlook for net load growth [74]:

In 2023: 127 MVA

In 2024: 172 MVA

35% Increase



Includes 30 New EV Charging Station Projects

9 Projects > 1 MVA Load (Each)

Largest Project: 15 MVA

Upgrades:

- 6 New Distribution Circuits
- 3 Substation Capacity Upgrades
- 1 New Transmission Line

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Electric Grid Investment Needs

Investment in Grid Edge (Customer-Side) Coordination Technologies

Demand Response

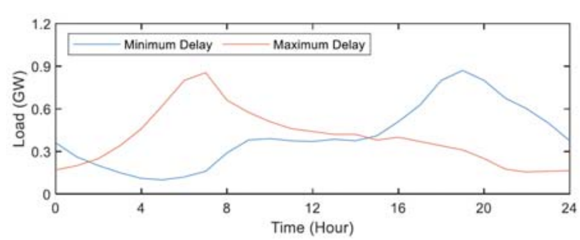
To influence the amount or the timing of electricity usage.

Example: Delay in charging EVs *without* affecting mobility needs.

Do not shift to night time → Transformer cooling at night.

Flexible and Agile → Respond to varying grid conditions.

Other flexible loads: water heaters, pumping water, air-conditioning, process control, certain computational load, and home appliances (washer, dryer, dish-washer, etc.).



Projected load profiles of EV charging [13].

Morning: *Solar* Evening: *No* Solar

Distributed Energy Resources (DER) Management

DERs are complementary to the bulk power resources (large power plants).

Examples: Vehicle-to-Grid (V2G) discharge and storage-as-a-service.

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Electric Grid Investment Needs

Investment in Advanced Operation, Control, and Protection Technologies

Operation and Management Software

- Advanced Distribution Management System (ADMS);
- Outage Management System (OMS);
- Meter Data Management System (MDMS)
- Demand Response Management Systems (DRMS);
- Distributed Energy Resource Management Systems (DERMS);
- Energy Management Systems (EMS);
- Advanced Metering Infrastructure (AMI);
- Fault Location, Isolation, and Service Restoration (FLISR).

Updating Operation and Protection Set-Points and Strategies

Updating Forecast and Probabilistic Operation Models

DERMS

OMS

Protection Hardware/Software

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Electric Grid Investment Needs

Investment in Grid Resilience Technologies

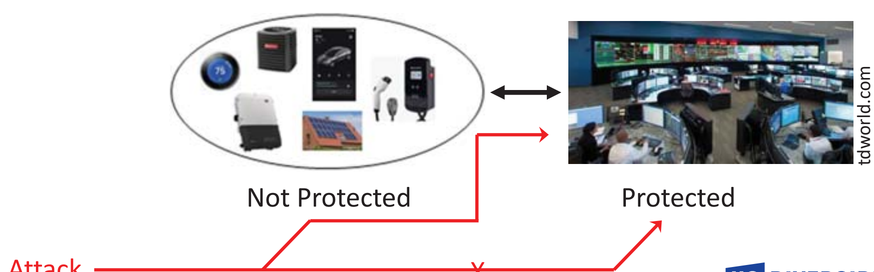
Investment in Advanced Monitoring and Data Intensive Technologies

Investment in Cyber-Security Technologies →

Turning controllable loads and DERs into "**physical botnets**" against the electric grid – similar to distributed denial-of-service (DDoS) attacks on the Internet.

Investment in Workforce Training

(See the White Paper for more details)



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Societal and Policy Implications

Broader Social Impact

Decarbonization ⟶ Reducing GHG emissions (climate change), Improved air quality, healthier communities, etc.

Grid Resilience ⟶ Reliable service in the face of more severe and more frequent weather events

Impact on Equity

Example: Affluent neighborhoods are adopting to electrification technologies more quickly [27].

⟶ Prioritizing grid upgrades in areas with higher electrification adoption rates can naturally lead to more focus on these affluent neighborhoods, exacerbating inequality in grid upgrades.

Example: Passing the cost of upgrades to customers will increase *electricity burden* on lower-income customers [102].

In contrast, reduced fossil fuel expenses will reduce the customers *overall* energy cost [15].

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Societal and Policy Implications

Example Policy Challenges

Supply Chain

For supply of grid equipment (transformers, cables, etc.) ⟶ Can result in delays, increased costs, and bottlenecks.

Regulations

Policy considerations should [1]:
1) Maintain the safety and reliability of the electric system
2) Prevent unreasonable impacts on customers' utility bills

Permitting Delays

Grid upgrades must be planned and completed in advance of customers installing EV-charging equipment to avoid bottlenecks.

Cost and Planning

It may be preferable to invest in more expensive solutions that support long-term growth rather than cheaper, incremental options [8].

Simultaneously upgrading for new loads, new solar generation, and energy storage reduces the overall upgrade costs [73].

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Societal and Policy Implications

Stakeholder Communication and Coordination

Example Stakeholders
State Agencies (CPUC, CEC, CARB, etc.)
Federal Agencies (DOE, FERC, EPA, EIA, etc.)
Investor-Owned Utilities
Publicly-Owned Utilities
Independent System Operator
City Governments
County Governments
Tribal Governments
Housing Authorities
Neighborhood Councils
Community Organizations
Environmental Justice Organizations
Community Choice Aggregators (CCAs)
Academic and Research Institutions
Workforce Training Groups
Customer Advocate Groups
Local Business Groups
Developers
Unions
Technology Providers

Key Recommendation: Data Coordination and Oversight

To ensure comprehensive and reliable data gathering, **a single state agency** could be designated to oversee various policy (and technical) issues concerning electrification and grid readiness.

Data from different agencies can be streamlined into one shared system. This will help identify gaps in data inaccuracy to improve models and better plan future upgrades and investments.

Other Recommendations:
- Early and Holistic Planning
  (Regulations, Supply Chain, Workforce Training, Cyber-Security, etc.)
- Transparent and Equitable Investment
- Robust Stakeholder Engagement
- Public Awareness

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Thank You!

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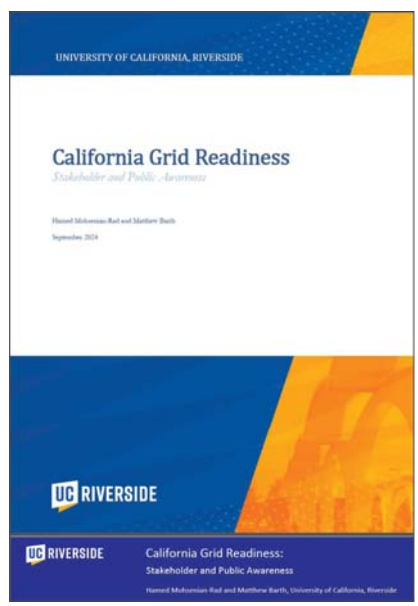

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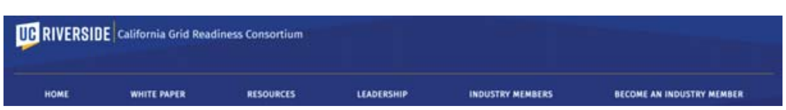

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