Grid Planning for Vehicle Electrification

Evolving Grid Planning Practices for Electric Vehicles

Presentation to Indiana Utility Regulatory Commission
IRP Contemporary Issues Technical Conference

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INTEGRATION GROUP

ESIG DER Working Group Task Force

Facilitated by

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20 October 2023

Agenda

- About the Task Force
- Set the Stage
- 4 High-level Steps to Grid Planning
- Processes and Wrap Up
- Q&A

Forecast EV Futures

Characterize Locational and Temporal Impacts

Develop Roadmaps & Grid Plans

Mitigate the Largest Impacts

Grid Planning for Vehicle Electrification Task Force

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Grid Planning for Vehicle Electrification

an ESIG DER Working Group Task Force
Funding by U.S. Department of Energy, project management by Berkeley Lab

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Project Objective

Develop, evolve, and standardize best practices and next steps for power system planning with respect to vehicle electrification. Emphasis on distribution planning, while considering the bulk power system & operational impacts.

Outcomes & Key Questions

1. **Forecasting Electrified Future**
   - Adoption rates, fleets impact, pace of change in electrification and T&D investments
2. **Locational Aspects**
   - Where should EV charging take place?
   - "No Regrets" approaches to electrification that also ensure asset utilization
3. **Temporal Aspects**
   - Integrating charging timing and flexibility of EVs into planning
   - Planning on the influence of price signals, software, and hardware controls
4. **Prioritized Industry Needs within a Holistic Electrification Framework**
   - Reference framework for broad electrification planning considerations
   - What gaps do we need to fill today? Are there blind spots likely to cause problems?

Task Force Members

Consortium of regional grid planners, distribution utilities, researchers, manufacturers, charging operators, fleet owners, etc.

Project Timeline & Deliverables

Special task force sessions from November 2022 – September 2023 concluding with whitepaper and webinar on key insights

Find out More

https://www.esig.energy/distributed-energy-resources-der-working-group/

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Set the Stage

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EVs to Increase Demand in Coming Years

Transportation electrification is accelerating due to:

Customer Demand

- 38% of US adults are likely to consider purchasing an EV for their next car[1]

Commitments from Vehicle Manufacturers

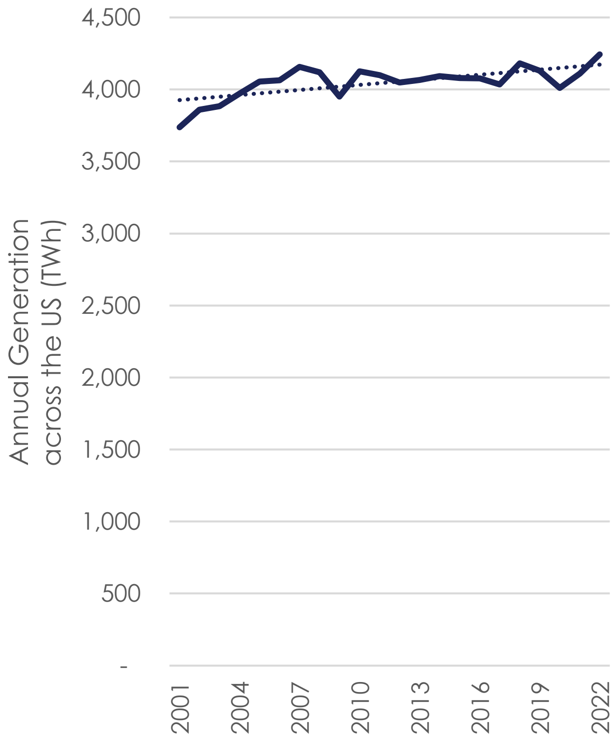
- Ford, General Motors, Toyota, and Volkswagen each invested at least $6 billion annually from 2019 through 2022 in EVs and digital technologies[2]

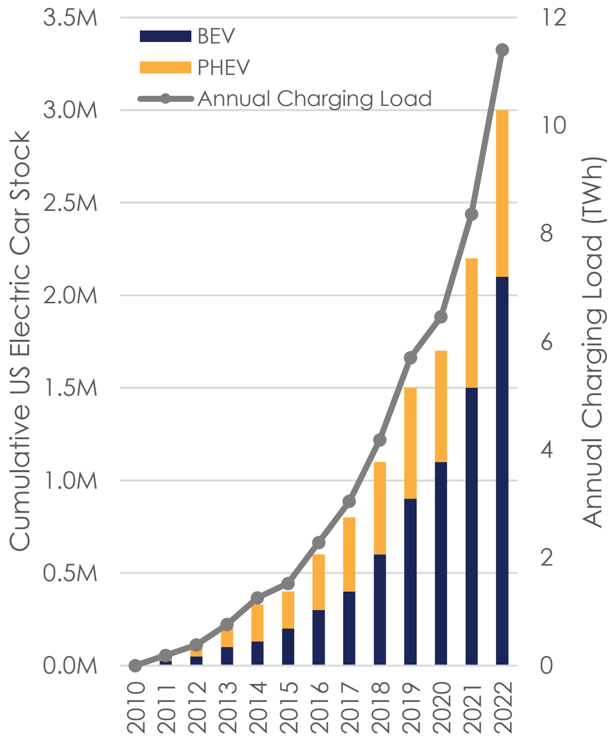
Public Policy

- Inflation Reduction Act provides tax credits of up to $7,500 per vehicle
- Nearly $24 billion has been committed to build out the public charging network

NREL projects 33M LD EVs in U.S. by 2030

Disrupting a trend of flat demand growth





Sources: 1. Pew Research Center, 2023; 2. IEA, 2023. Data for Image left: EIA ; Data for image right: IEA, 2023. NREL data via Wood, et. al., 2023.

EVs 10x near-term Stationary Battery Market

Huge opportunity for load flexibility

120 GWh

Utility-scale batteries planned through 2025

1,200 GWh

Storage in 33M EVs on road by 2030

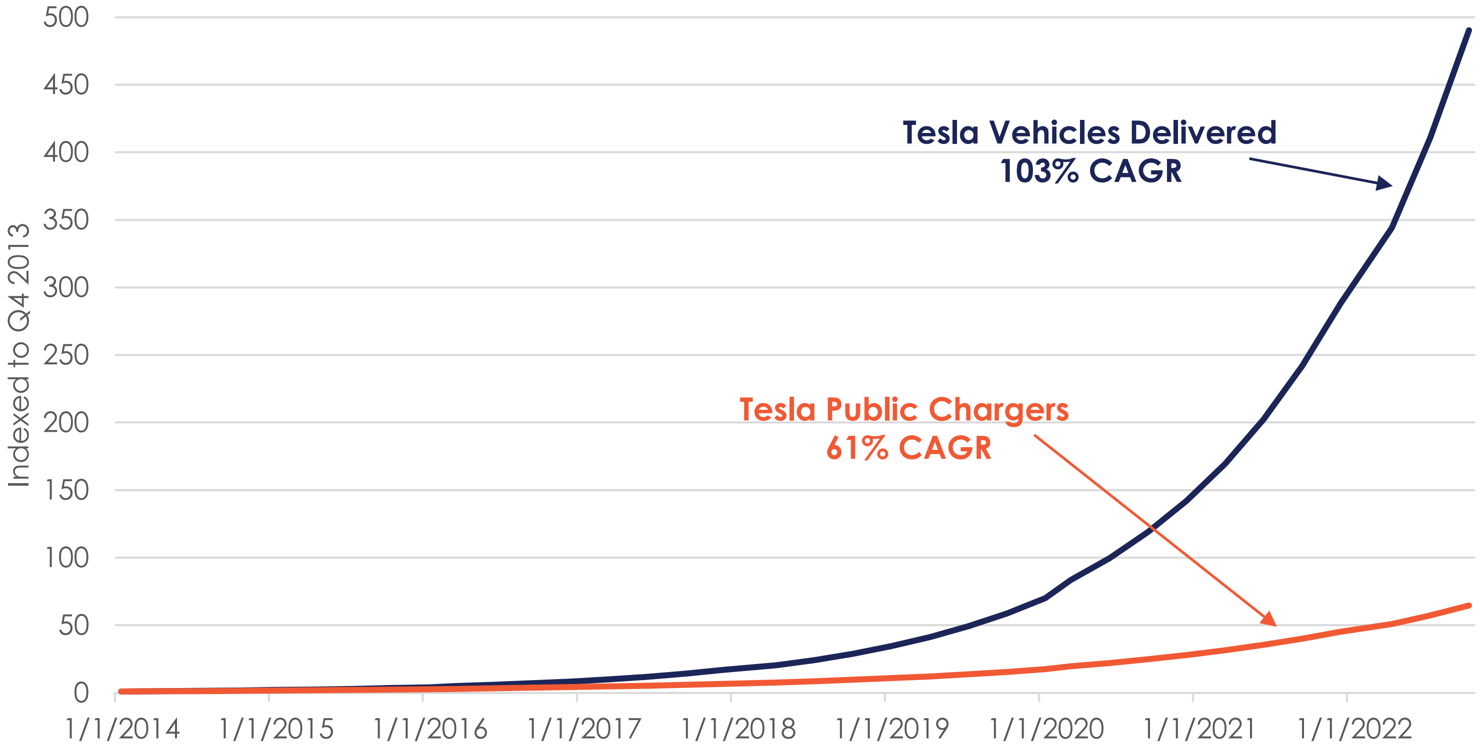
Nearly unprecedented change:

- EVs are first major load growth since air conditioning in the 1960s.
- Demand from 1 EV ≈ 1 house
  - Concentration of EVs can overwhelm local distribution system capacity.
- Adoption rates to vary significantly across communities
  - Cumulative distribution investment across the country could be $200B by 2050 to facilitate EVs.[1]
- ISO-New England forecasts that by 2032:
  - Transportation electrification will increase annual energy requirements for the region by 10% and contribute between 8% and 12% to system peaks.[2]

Sources: 1. Cutter, 2021. 2. Black, 2023

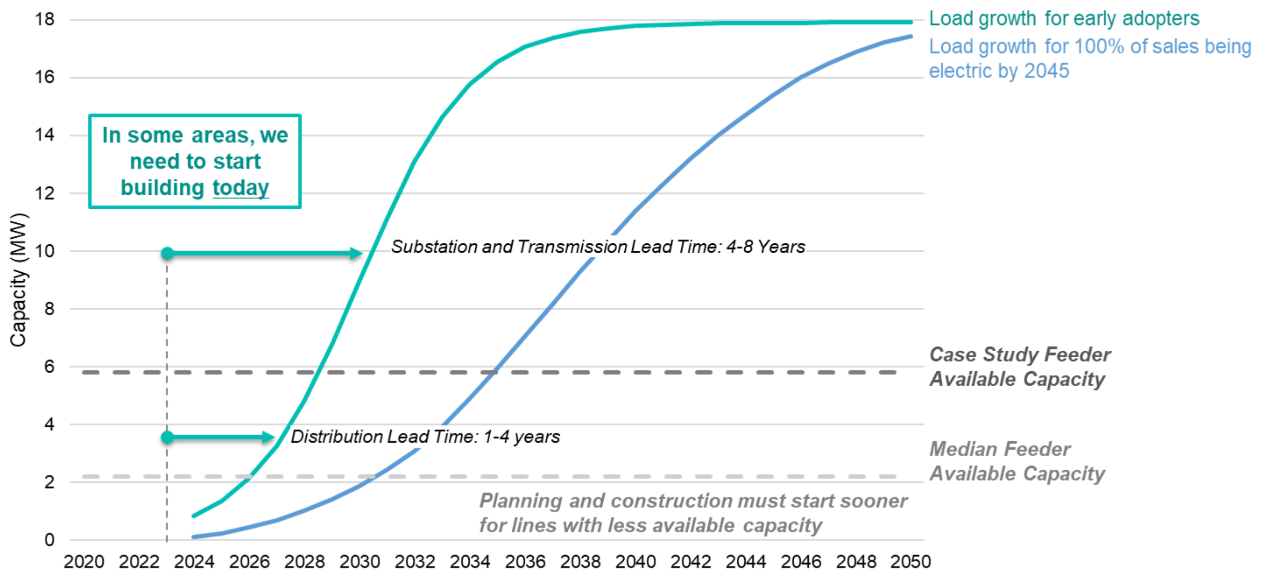
Widening Gap Between Vehicles and Chargers

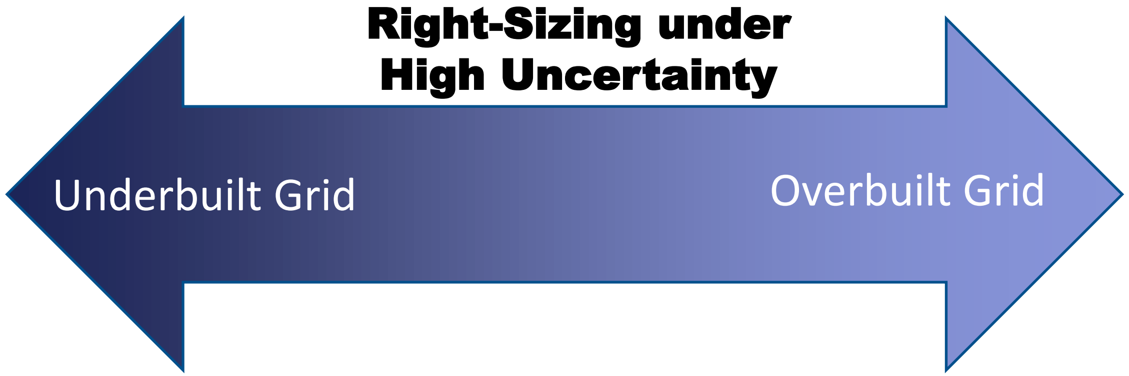
T&D infrastructure could become a limiting factor for future EV adoption



Impacts of Near-term Decisions on Long-term Load Growth

- Given lead times, decisions are needed today to support electrification targets in some areas.
- Long lifecycles mean that grid equipment is used for 45-50 years.





Risks:
- Unreliable grid
- Stunted public interest in EVs
- Long waits for charger installs

Risks:
- Expensive underutilization
- Inequitable burden of costs

Sources: Image left : National Grid. The Road to Transportation Decarbonization: Readying the Grid for Electric Fleets. 2023. Image Right: ESIG

4 Steps to Grid Planning

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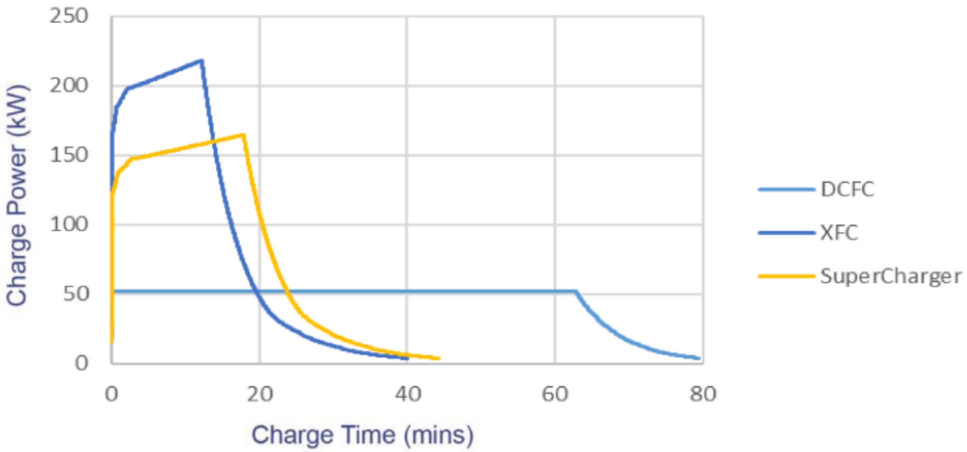
Focus: Best Planning Practices to Support EVs

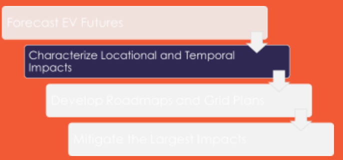
- Forecast EV Futures
- Characterize Locational and Temporal Impacts
- Develop Roadmaps and Grid Plans
- Mitigate the Largest Impacts

Forecast EV Futures: Understand EV Trends

- **Use Case**: Differentiate how a particular vehicle will be used across the year
  - School buses vs. city buses
  - Commuter vs. secondary vehicles
- **Technology**
  - Larger batteries with faster charging
  - Potential future technology development
  - Different rates across state of charge



Sources: Image top: Axios; Image Bottom: INL Caldera, 2023

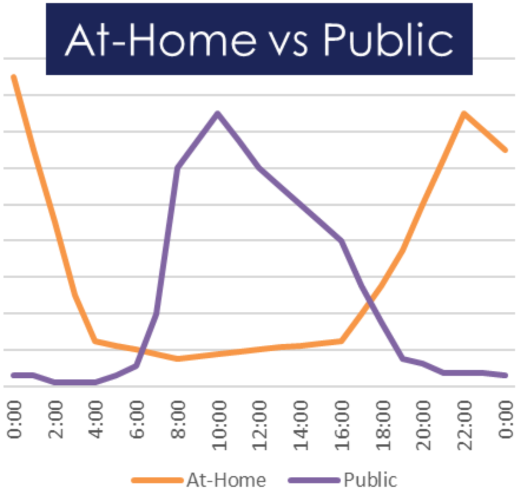


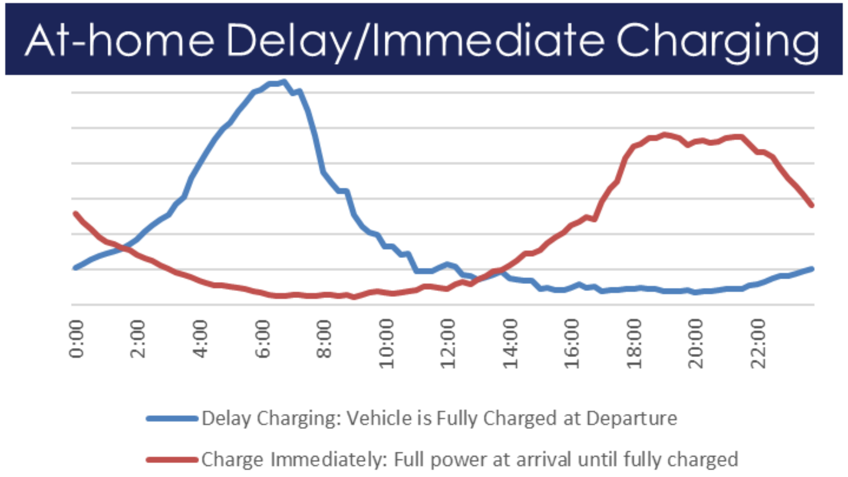
Characterize Impacts: Timing

Uncertainty Abounds in Charging Timing

Variables have dramatic impact on the naïve charge profile:

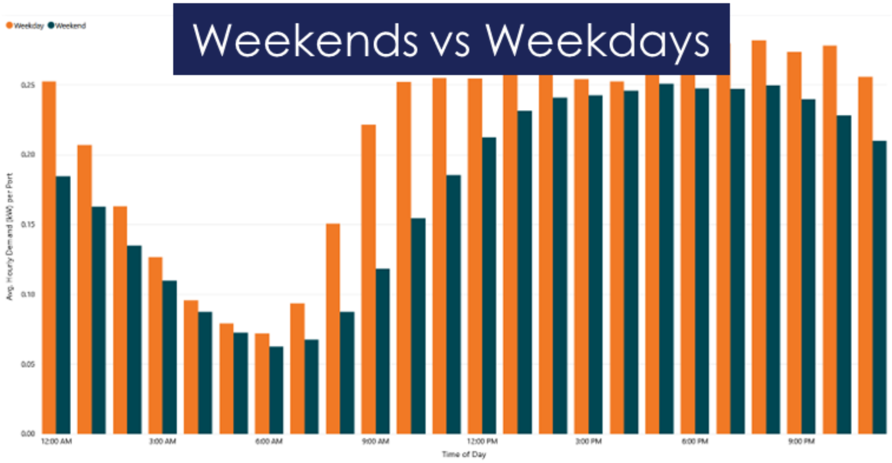
- At-home vs. public charging
- Customer settings for charge urgency
- Weekday, holidays and seasonal traffic patterns

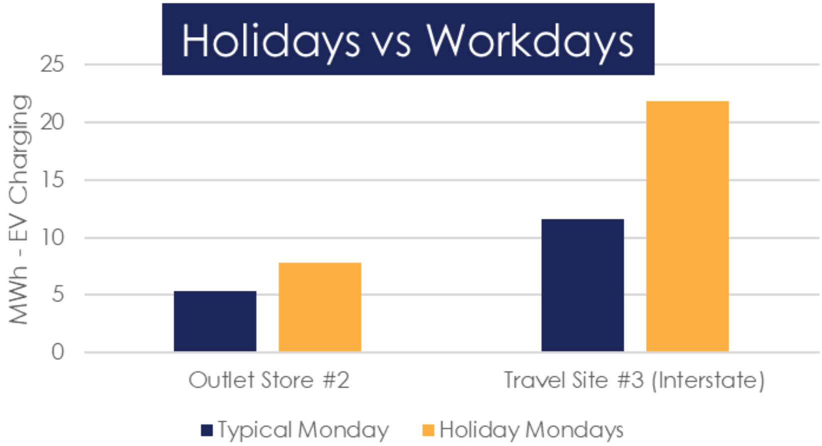




Weather can affect EV charging needs:

- Battery charge efficiency
- Occupant comfort
- Transportation needs



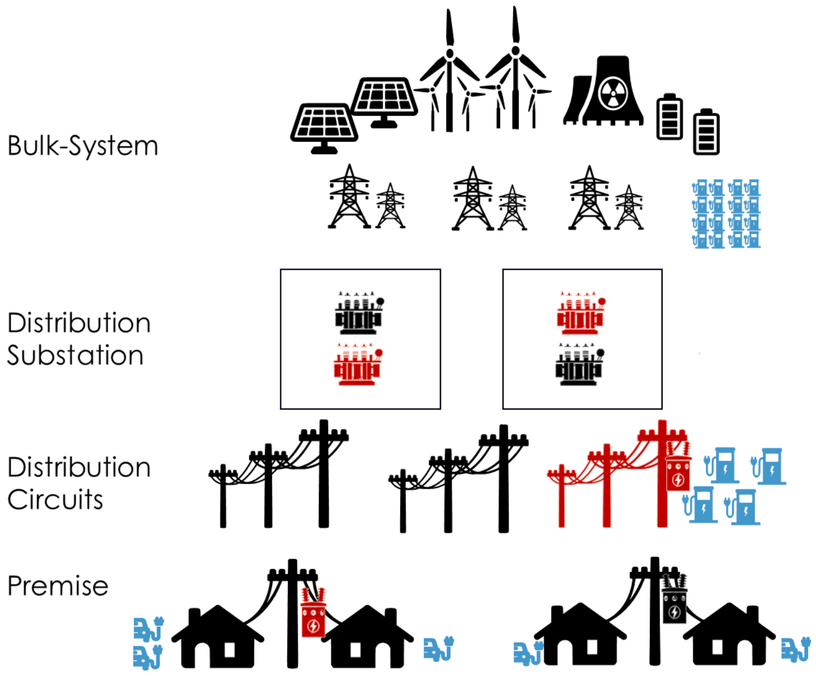


Data Sources: Top Left: EVI-lite-Pro, 2023; Top Right: Powell, Cezar, Rajagopal, 2023; Bottom Left: EV-Watts, 2023; Bottom Right: Tesla.

Characterize Impacts: Location

Topological Location

- Grid constraints can limit charging availability at each topological location
- Consider access to public charging in areas with multi-family housing and higher percentages of renters



Geographic Location

- Concentration of EVs in a specific city
- Eversource used GPS data to understand that winter traffic was roughly 10% higher than summer in Cambridge, Massachusetts, due to local universities

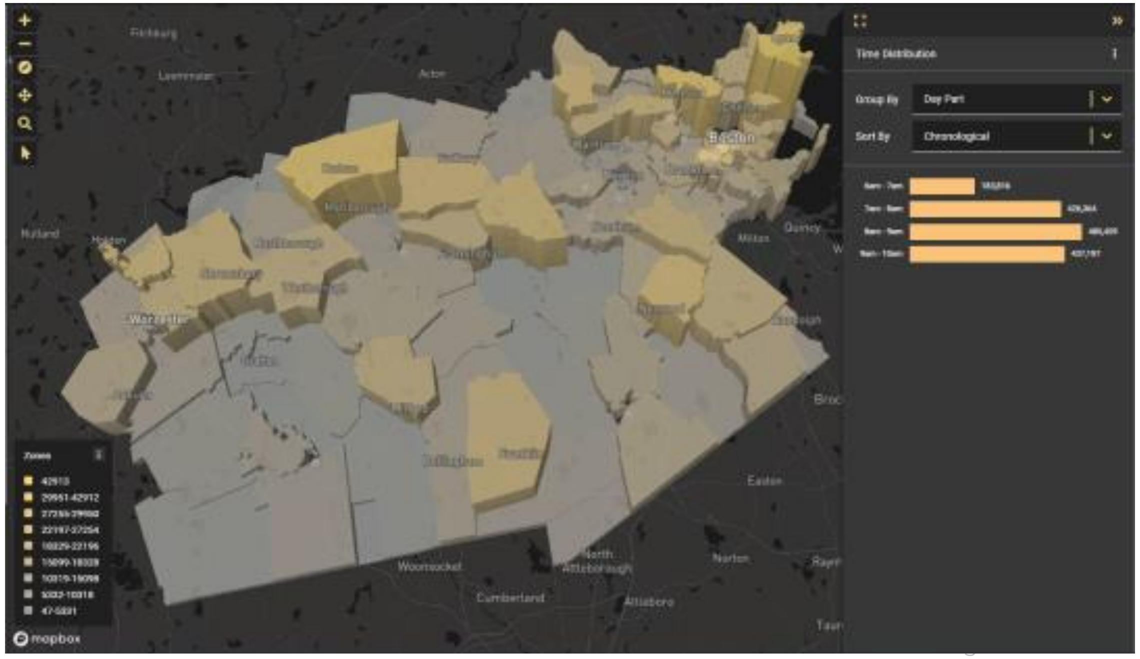
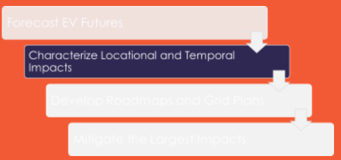


Image Sources: Left: ESIG. Right: Eversource, 2023.



Characterize Impacts: Scenarios

- Given all these variables and uncertainty, **using scenarios can bound the problem**
- Grid Planners can evaluate **bookends** to think through the processes and implications of key assumptions on local trends
- Scenarios that **target the medium-term** (10ish years) can be informative, rather than overly speculative
- Scenarios should **highlight different plausible ways** that the grid might be stressed:
  - Stressor on the charge-time expectations from consumers, such as customers prioritizing rapid 15-minute charging
  - Stressor on MHD growth
  - Stressor on strong customer preference for at-home charging

Data Sources: Top Left: EVI-lite-Pro, 2023; Top Right: Powell, Cezar, Rajagopal, 2023; Bottom Left: EV-Watts, 2023; Bottom Right: Tesla.

Developing Roadmaps and Grid Plans

Overarching Goal: Long-term study findings are integrated in the medium- and short-term plans to avoid widespread interconnection constraints. Too often, long-term study results are left in isolation.

FUTURE-READY PLANS

Start now; spread costs of labor and infrastructure upgrades over many years.

TARGETED SYSTEM UPGRADES

Occur where forecasting scenarios or historical data show grid needs at specific locations.

INTERCONNECTION PLANS

Deal with discrete near-term requests to interconnect new loads.

Developing Roadmaps and Grid Plans

Future Ready Plans

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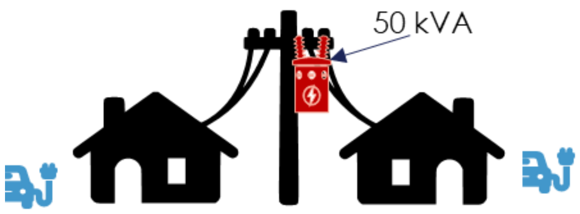
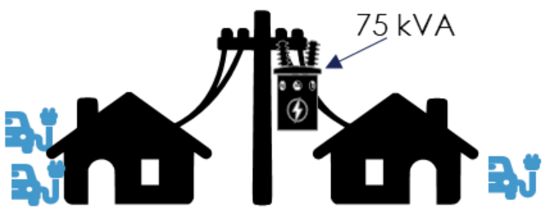
Equipment Standards



Exegol Utility District

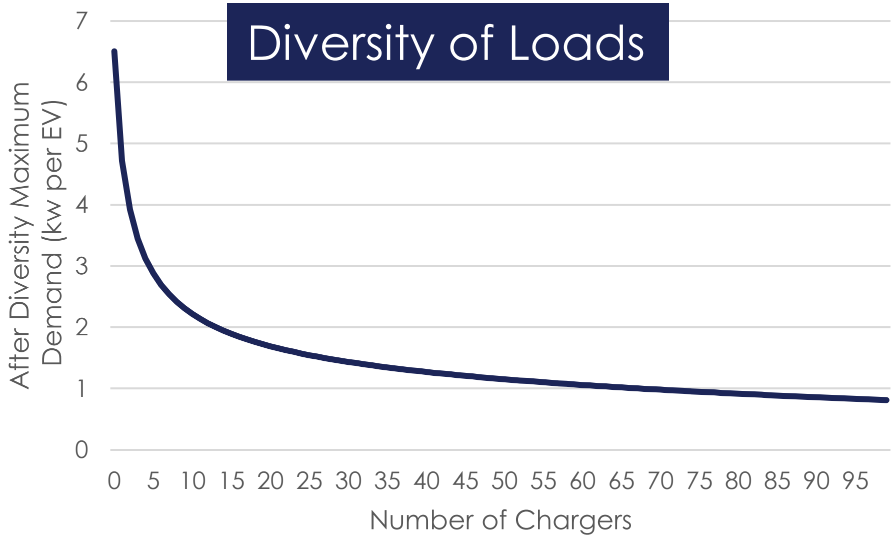
When equipment is a candidate for replacement, the utility replaces legacy designs with similar design standards that may become overloaded with incremental EVs.



Tatooine Cooperative

When equipment is a candidate for replacement, either at end of life or when doing things like pole replacement, the utility replaces legacy designs with future-ready solutions.

Diversity of Loads



Equipment Standards are used to streamline inventory, installations, engineering, etc.

- May direct decisions on:
  - Voltage class: 4kV->12kV->26kV
  - Equipment sizing: 50 kVA ->75kVA transformer for 10 customers
  - Land parcel procurements: square footage required for substations
- Evaluate increased system equipment capacity instead of building more undersized network

Diversity of Loads inform equipment sizing

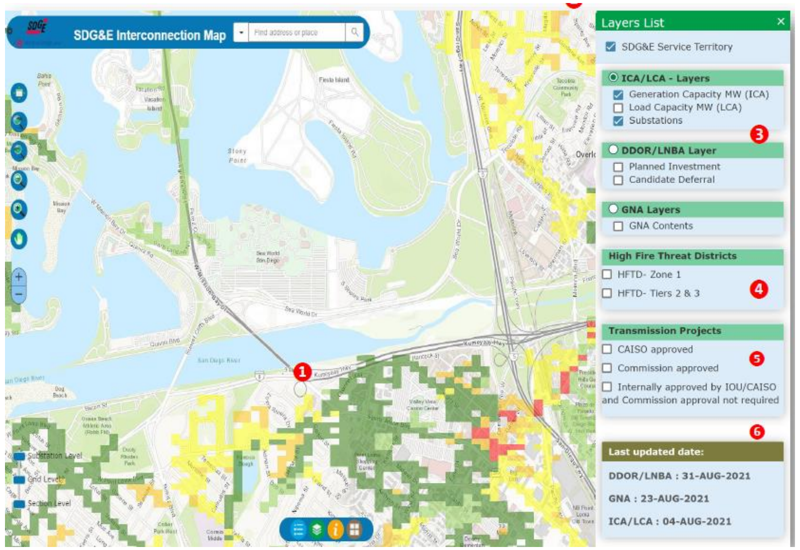
- Example: Pat charges on Tuesday, Sam on Wednesday, so grid equipment is sized for one EV
- EVs are new, so diversity needs to be calculated
  - Coordinate with smart charging designs

Image Sources: Top: ESIG; Bottom: Data from Vector

Developing Roadmaps and Grid Plans

Interconnection Plans

Learn from recent developments in rooftop PV

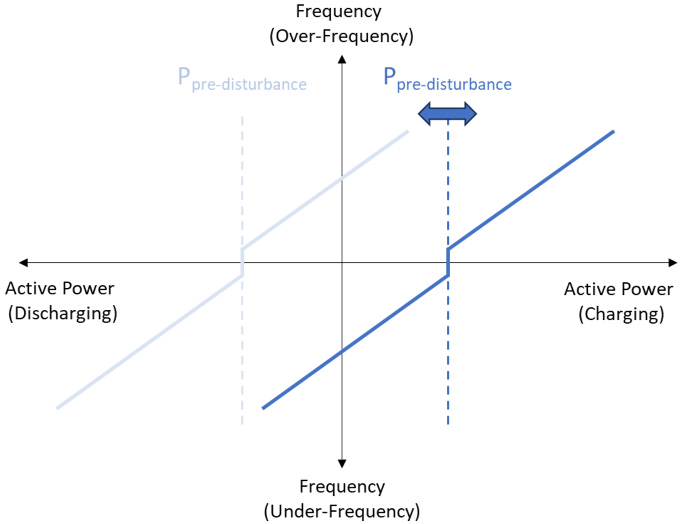


Interconnection Capacity Maps / Queues

Orange Button

Solar Data Standard*

Articulate Process and Data Requirements



Define Grid Friendly Behavior

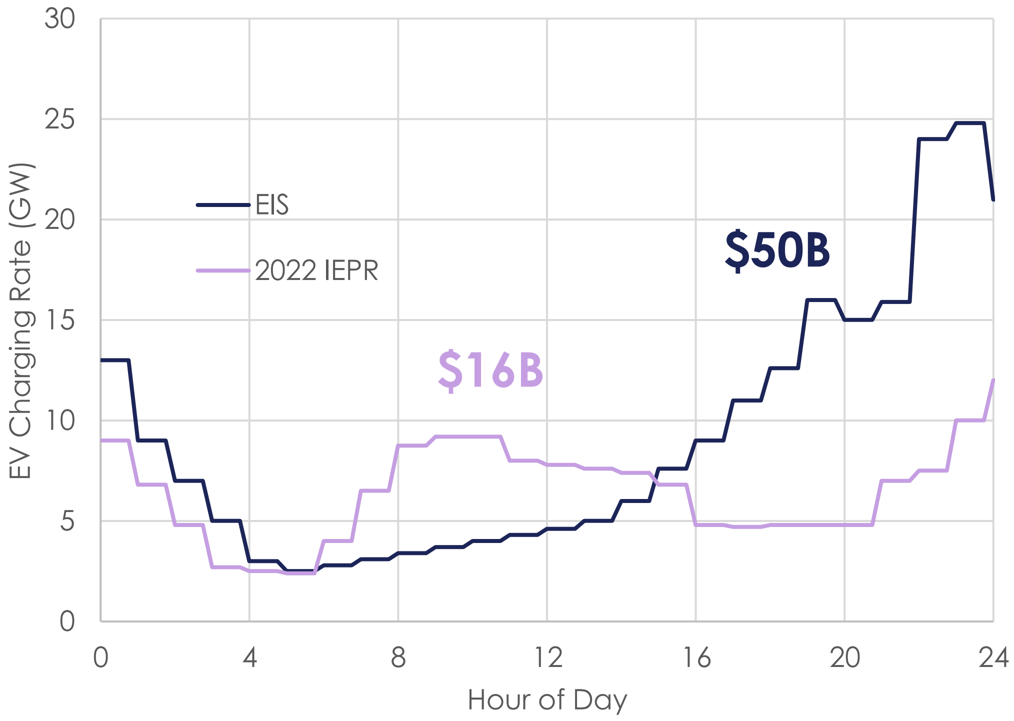
*used to facilitate the exchange of data among PV stakeholders

Data Sources: Left: SDG&E, Center: Orange Button logo, Right: ESIG

Mitigating the Largest Impacts

- **Historically, load profiles = static inputs**
  - Even impacts of TOU or DSM = static
- **EV loads ≠ static**
  - Smart EV charging can address various grid needs based on value
- EVs can **evolve** demand-side planning
  - Demand management to address multiple needs depending on situation
  - Not a static input that requires a specific grid solution
- Not a silver bullet: EV-related infrastructure will still be needed

Recent Work in California highlights the importance of smart charging for the cost of distribution upgrades



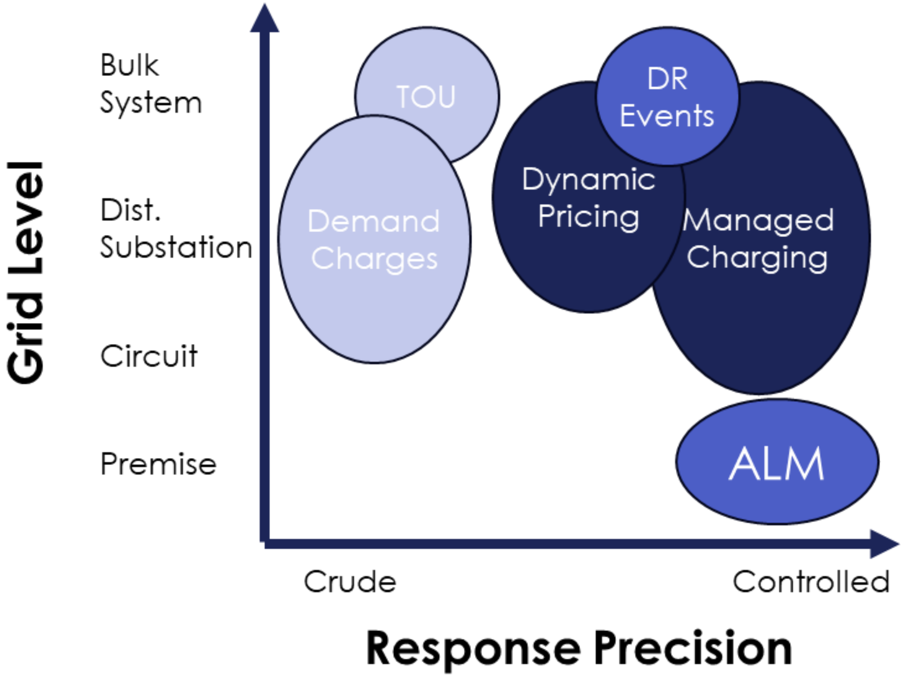
DSM = Demand-side management

Source .Energy Systems Integration Group; data courtesy of Kevala, 2023; Public Advocates Office, 2023.

Mitigating the Largest Impacts

Many Flavors of Smart Charging

- Smart charging can be accomplished through pricing or control programs, with preset or dynamic definitions, to address grid challenges at different levels.
- Cost and ease to implement smart charging measures are characterized **relative to each other** and should be evaluated against alternatives, such as infrastructure improvements.



	Classification		Suitability to Address Challenges at Multiple Levels				Ease to Implement	Cost
Mitigation Measure	Signal	Timing	Site	Dist.	Trans.	Gen.		
Demand Charge	Pricing	Preset						
Time of Use (TOU)	Pricing	Preset						
Dynamic Price Signal	Pricing	Dynamic						
Customer Response to Event-Based DR	Control	Dynamic						
Dynamic Managed Charging	Control	Dynamic						
Automated Load Management (ALM)	Control	Preset						

Source .Energy Systems Integration Group

Mitigating the Largest Impacts

Automated Load Management

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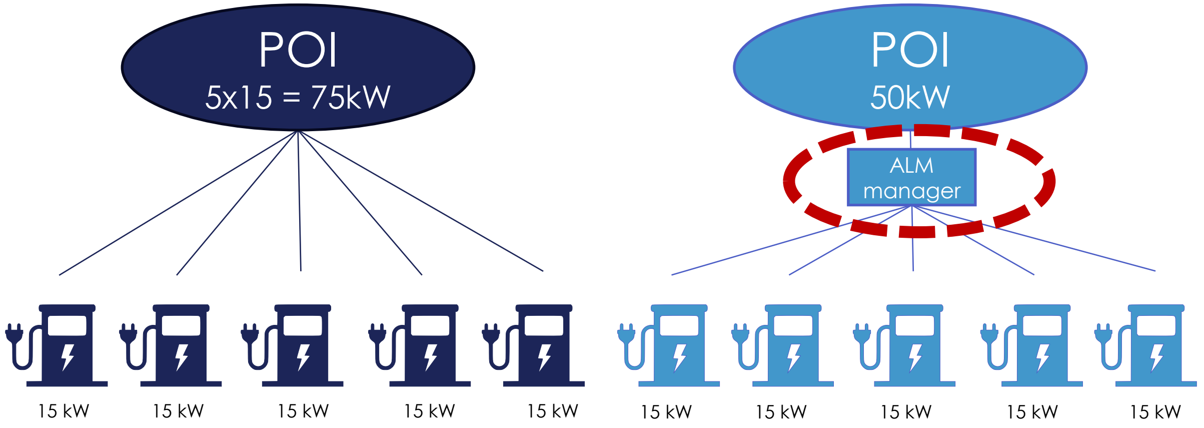
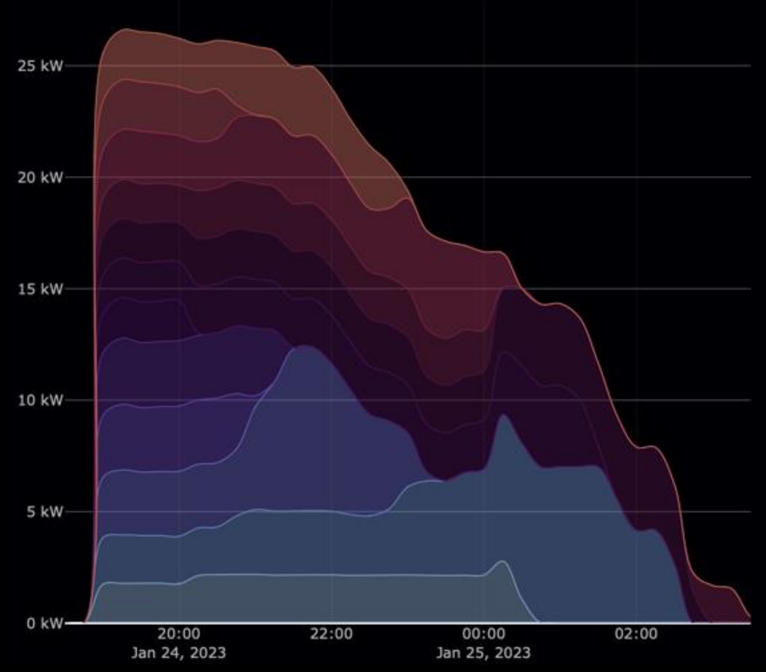
Automated Load Management (ALM) is software that schedules and prioritizes EV demand at a given point of interconnection (POI) to remain within a specified range over time.



- The CPUC found that "utilization of ALM will help lower program costs and promote efficient use of electric grid infrastructure."[1]
- When using ALM, PG&E observed cost savings ranging from $30,000 to $200,000 per project.[2]

ALM in Action

The Irish Post uses ALM to manage infrastructure constraints. In this example, the total nameplate rating of the supply equipment is 88 kW, while the site interconnection limit is 28.9 kW. By using ALM to charge the vehicles at different times of night, the aggregate vehicle profile remains under the interconnection limit.



Source . 1. Decision Authorizing Pacific Gas and Electric Company's Electric Vehicle Charge 2 Program, 2022; 2. Opening Brief of Pacific Gas and Electric Company, 2022; Image right courtesy The Mobility House AG

Mitigating the Largest Impacts

Challenges and Coordination

Challenges:

- **Customer Participation** - Convincing customers to participate, incentivized by the value stream that the utility or aggregator can monetize, can prove unsuccessful.
- **Preserving Benefits of Load Diversity** - Smart charging can disrupt diversity by concentrating charging during specific time periods.
- **Communication and Control -** The architecture to enable smart charging requires data exchanges across multiple software systems designed by different vendors with different risk tolerances.
- **Pricing Sensitivity and Reliability -** Pilots point toward the potential of smart charging, but work remains to understand customer sensitivity to locational price differentiation and around disaster events (hurricanes).
- **Modeling** - Even after data on smart charging is widely available, grid planning tools and processes will need to be updated to consider smart charging as an option.

Coordination:

- The effects of distributed solar+storage and EVs should be **analyzed together**.
- **Bi-directional charging** is important because of the potential scale of storage accessible in EVs.

Process Improvements and Wrap-Up

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Aligning the Grid Planning Process with the Need

Given the scale of grid planning for vehicle electrification, new processes could be helpful

Existing Processes

While today's grid planning processes vary across the country, they generally include:
- Annual system reviews
- Regularly updated grid plans with a medium-to-long-term planning horizon
- Isolated evaluation of interconnection requests

Customer-Collaborative Processes

The grid planning process is a collaborative effort between planners and customers which allows:
- Multiple options for interconnection
- Multiple locational alternatives
- Open communication

Proactive Multi-Stakeholder Processes

With the volume and multiple use cases of EVs, proactive processes are sometimes best-suited to address challenges with:
- Ensuring equity
- Facilitating regional networks
- Providing clear roadmaps for electrification planning progression

Summary and Key Points

- **Lots of uncertainty, but decisions are needed today**
  - Opportunities to improve forecasting
  - Opportunities to proactively shape customer perception

- **A lot of demand management will be needed, particularly in the short term**
  - Learn if we can rely on it throughout grid planning
  - Prioritize infrastructure where demand management cannot defer investment

- **Many grid planning improvements are outside of normal processes:**
  - Future-ready systems – reconsidering design standards
  - Using demand side management as a grid solution
  - Collaborative and multi-stakeholder processes

THANK YOU

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Backup Slides

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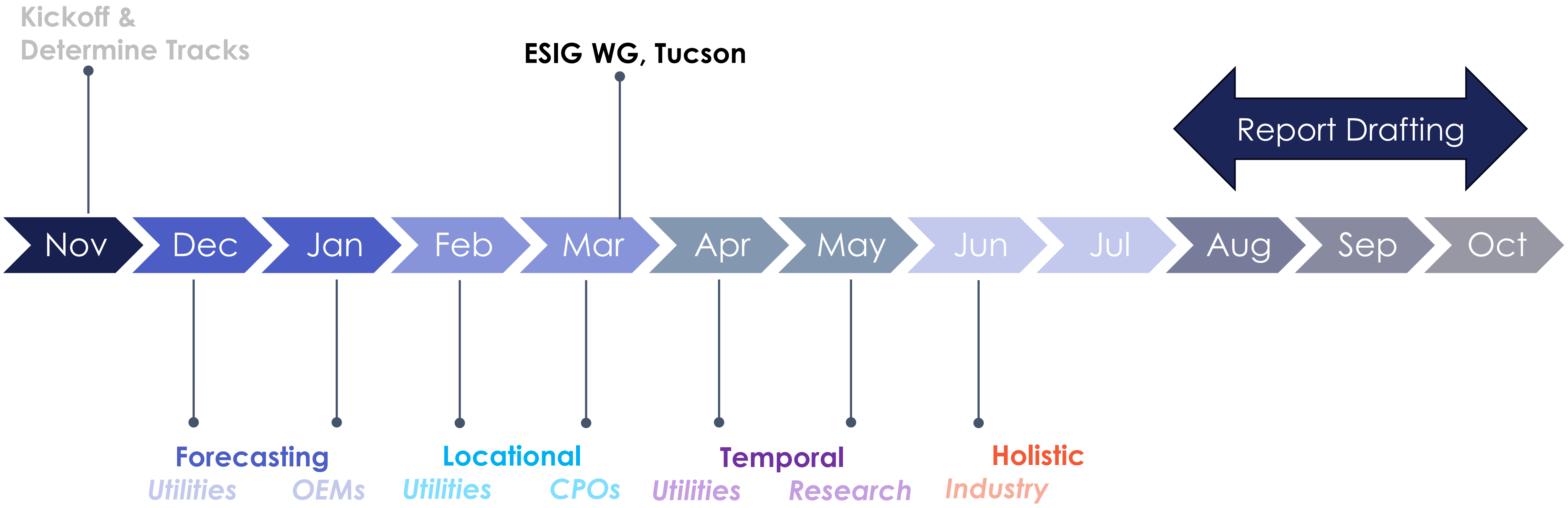
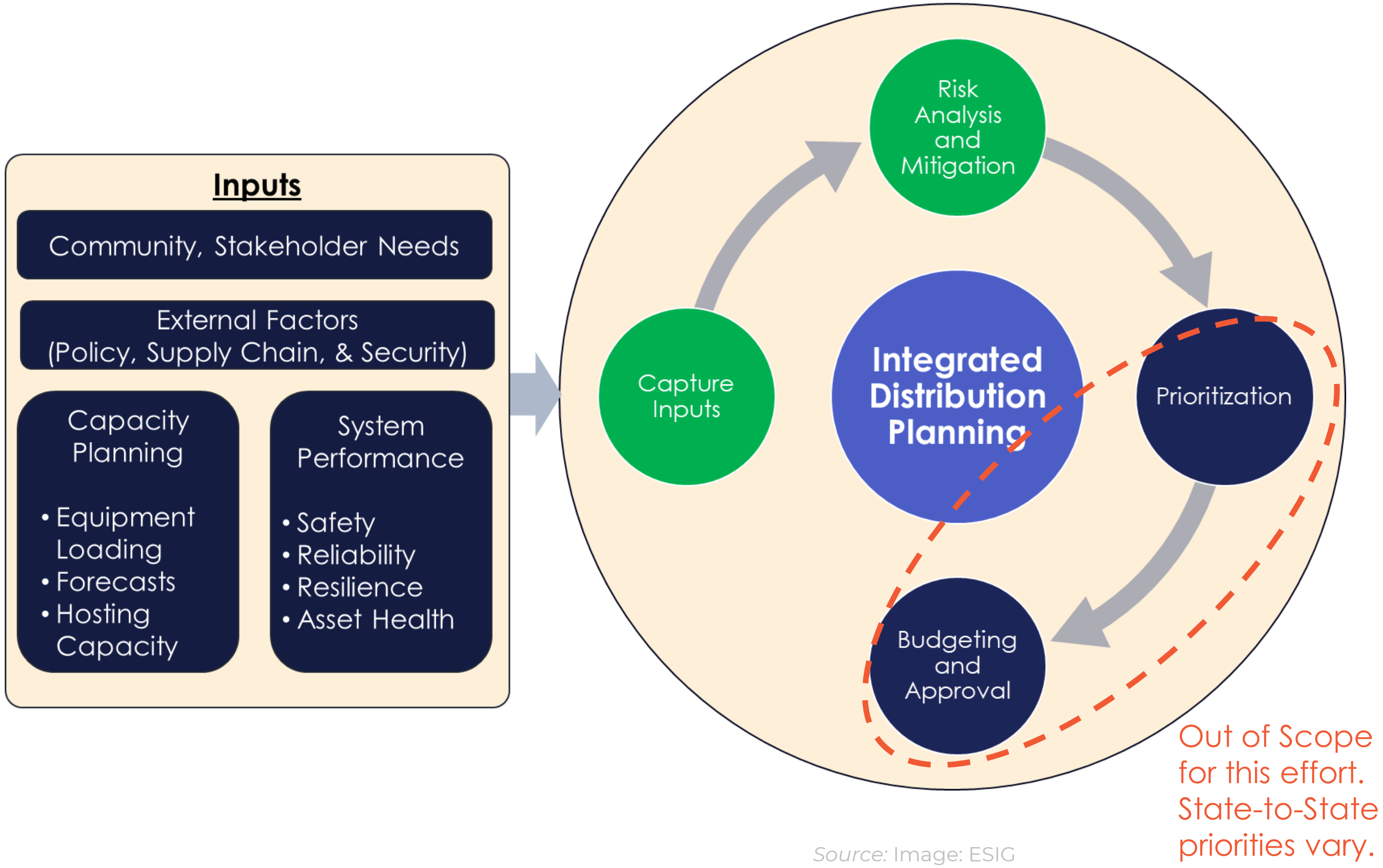
Timeline & Deliverables



Grid Planning in the Context of EVs

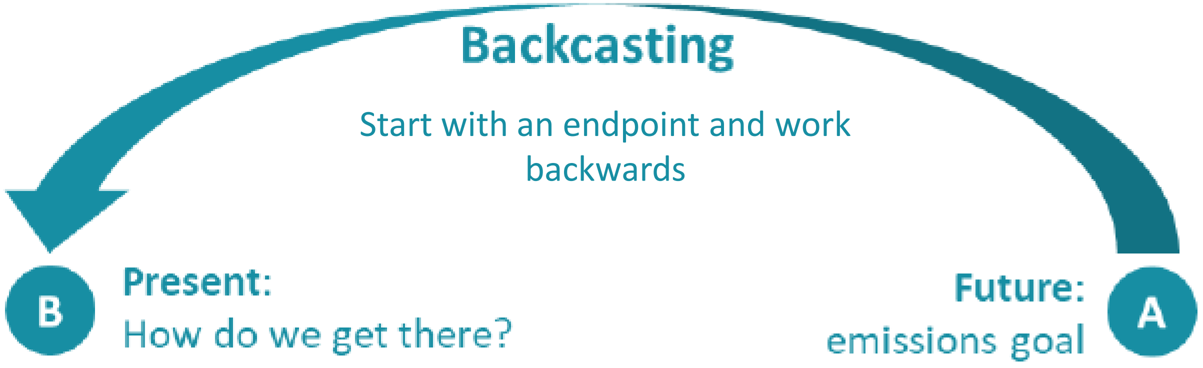
How should planners address EVs alongside other distribution planning considerations?

- EVs are among **multiple considerations** for customer-centric grid planning.
- Many states are adopting an integrated distribution system plan (IDSP) process.
    - Some require dedicated sections within the IDSP for electrification.
    - Some require separate plans addressing electrification.



Source: Image: ESIG

Forecast EV Adoption



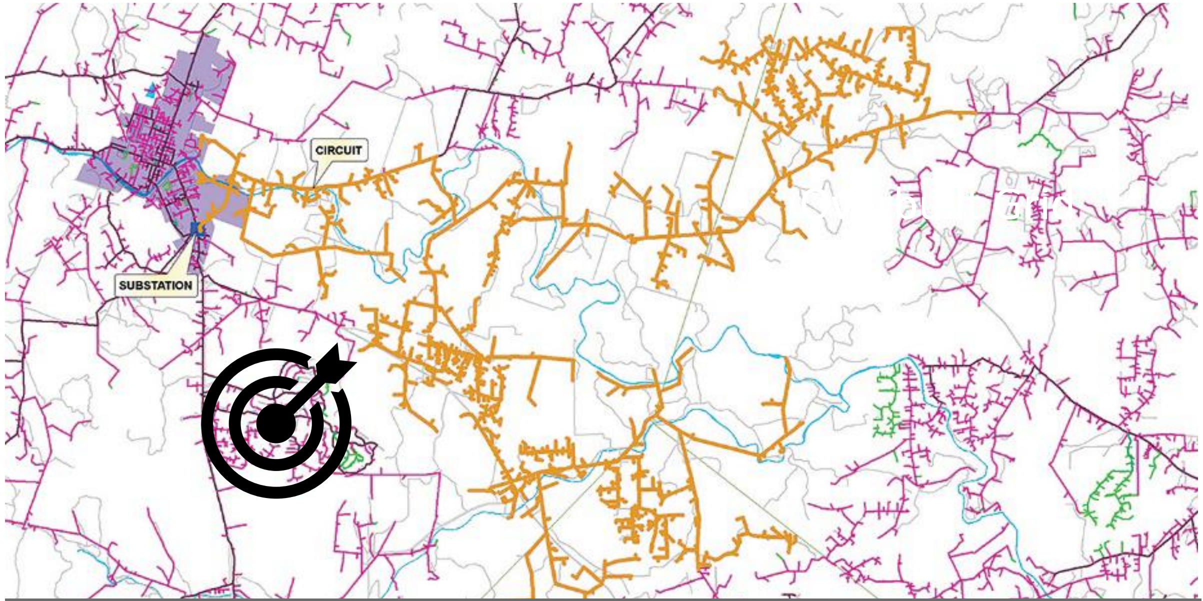
Adoption Trends

- Light-Duty Stock Turnover Models
  - Incorporate historical trends, policy and economics
  - Backcasting from stated policy objectives
- Medium- and Heavy-Duty (MHD) vehicles can introduce large loads with highly variable needs
- Location, Location, Location
  - Electrification likelihood models capture local trends and key indicators at levels granular enough to help prioritize grid upgrades
- Better Data Collection
  - Start with DMV, but it may not be enough
  - Systemic data collection on behalf of grid planning at the time of vehicle purchase
  - Surveys and Fleet Partnership Programs

Sources: Image top: Jones, 2023; Image Bottom: Oncor, 2023

Developing Roadmaps and Grid Plans

Targeted System Upgrades



Storage Deployed for EV Integration:

SCE is planning to use relocatable storage as a short-term solution to facilitate a timely customer interconnection while a permanent solution (wires or non-wires solution) is being constructed. Attempting to serve customers that are asking for large service upgrade in short lead times, SCE plans to procure thirty-seven 1MW/4MWh energy storage units over the next 5 years and anticipates a large need for these to facilitate MHD electrification.

Targeting Amid Uncertainty

Longer planning horizons

- Distribution planning typically looks out 5-10 years, but largest impacts of EVs are 10+ years out
- By proactively identifying areas, we can more evenly distribute rate impacts.
- By waiting, we risk infeasible timelines to address needs.

Adaptability

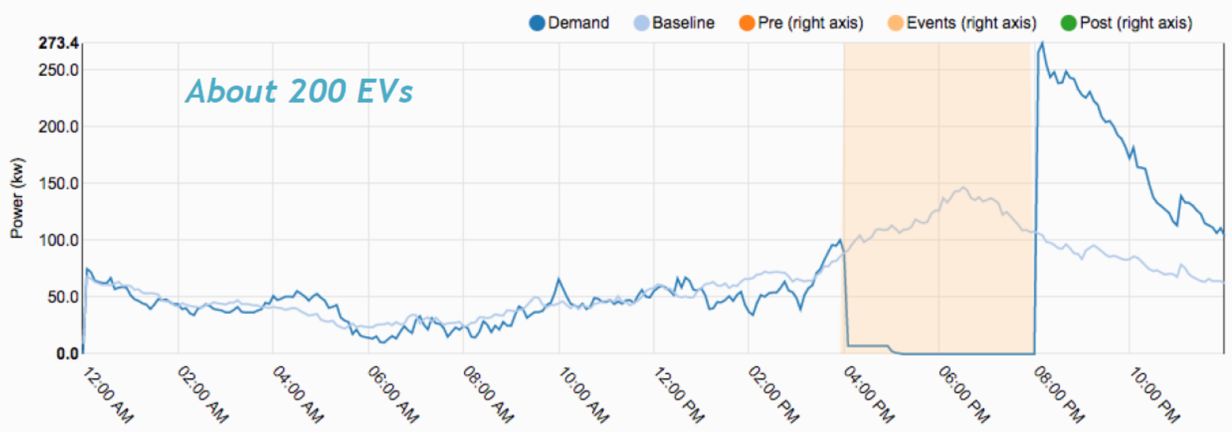
- Short-term solutions may look different than the long-term answers as we learn more about customer behavior and adoption rates.

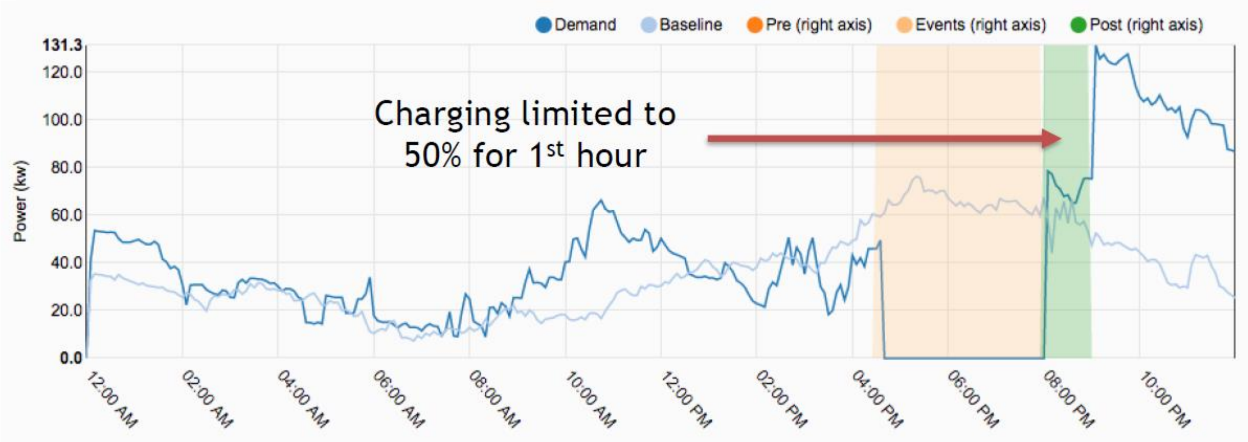
Data Sources: SCE

Mitigating the Largest Impacts

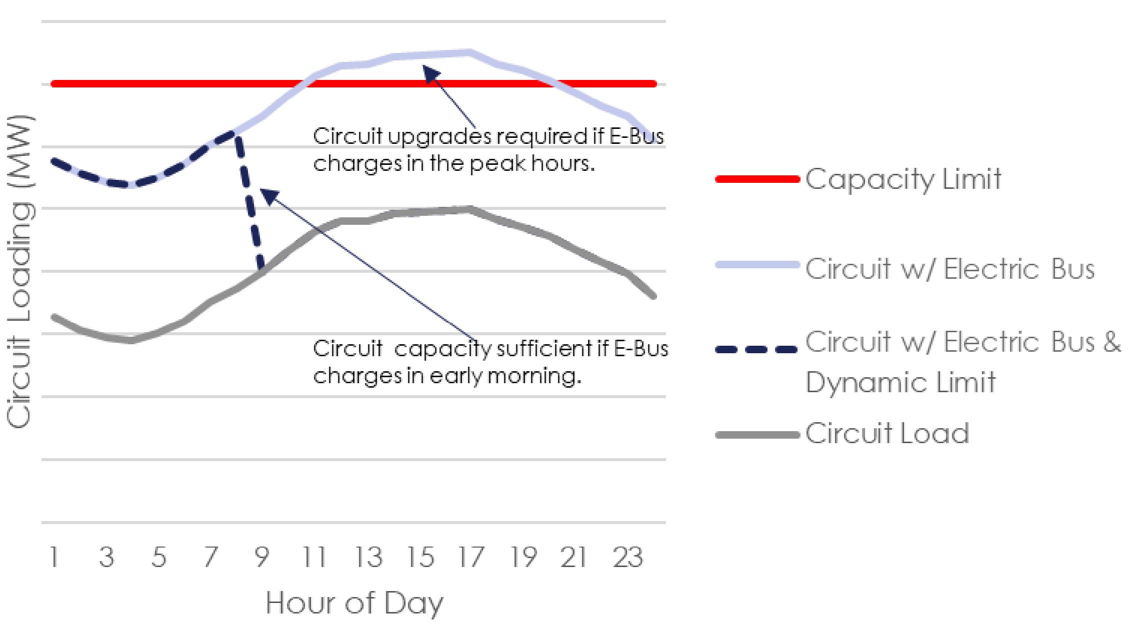
EVs Responding to Changing Grid Conditions

Care should be given to demand response events to avoid unintended consequences.





Managed charging allows dynamic interconnection limits with restrictions on when the EV can charge.



Source .Image left: Green Mountain Power. Right: ESIG

When to Use Which Process

Shading indicates suitability of process to address EV Need

Managed Light-Duty Vehicles

Existing Processes
- Daily/routine charging
- L2 demand charging
- Elastic demand

Customer-Collaborative Processes
- Perceived charging deserts
- Service provider request

Proactive Processes
- Heavy deployment
- Existing grid heavily loaded
- Inflexible demand

Highways & Corridors

Existing Processes
- Minimal highway throughput

Customer-Collaborative Processes
- Private highways

Proactive Processes
- Grid capacity limited along highways
- Regional EV growth
- MHD vehicles

Fleets

Existing Processes
- Small fleets
- Sufficient highway charging

Customer-Collaborative Processes
- EV timing & location inflexible
- Large fleets

Proactive Processes
- Multiple fleets competing for capacity
- Limited land availability

Underserved Communities

Existing Processes
- Planning processes include equity layer
- EV & smart charging incentives

Customer-Collaborative Processes
- Multi-family housing developers

Proactive Processes
- Avoid charging paradox
- Heavy industry adjacent

Coordinating Equitable Plans

- Who pays for grid upgrades?
  - Electrification may make electricity more affordable on a dollar per kilowatt-hour basis due to the increased consumption of electricity. At the same time, infrastructure investments will exert upward pressure on rates.
  - Uncertain costs for electricity will need to be balanced with uncertain costs for fossil fuels as policy makers aim for equitable energy burdens.
- What happens if the load doesn't show up?
  - Improper planning and cost allocation could inequitably burden low-income ratepayers with the costs from affluent early adopters.
- Multiple dimensions to equity:
  - Distributional equity will help protect vulnerable customers from undue energy burden.
  - Transitional equity will ensure that the shift to vehicle electrification happens at a pace that communities can handle.
  - Procedural equity promotes inclusive engagement of affected parties in the decision-making process.