Many Thanks To:

- U.S. Department of Energy
- Lawrence Berkeley National Laboratory
- ESIG DER WG
- Task Force Members
  - Utilities
  - Vehicle Manufacturers
  - Aggregators
  - Charging Operators
  - Regulators
  - State Energy Offices

The work described in this presentation was funded by the U.S. Department of Energy’s Office of Energy Efficiency and Renewable Energy under Lawrence Berkeley National Laboratory Contract No. DE-AC02-05CH11231.

https://www.esig.energy/grid-planning-for-vehicle-electrification/
How big of a change is this?

**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

**Values constantly growing**

Manufacturers in the United States could supply around 10M new light duty plug-in electric vehicles each year by 2030, assuming an average pack size of 80-100 kWh.³

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Transportation electrification continues to accelerate

Drivers: customer demand, commitments from vehicle manufacturers, public policy targets and incentives

The pace of EVs on the road has far exceeded public charging network roll-out for a variety of reasons, including a lack of sufficient grid infrastructure. This trend is also seen in non-Tesla charger deployments and highlights the accelerating demands of grid planning to support vehicle electrification.

1Tesla Comments to the California Energy Commission, 9/1/2023. 2NREL. 2023. The 2030 National Charging Network

U.S. EV Adoption Scenarios (light-duty)

33 million EVs = 1200+ GWh
Uncertainty Abounds

Adoption Rates?

How many vehicles are expected by when?
- Type of vehicles (SUV, trucks)
- Technology Change (efficiency & battery technology)
- Use Cases (LDV, MDV, fleets)

Location of Charging?

Where will charging take place?
- Home vs. workplace charging?
- Which communities will see adoption first?
- Where do people drive?

Timing of Charging?

When will vehicle owners charge?
- Hourly charging profiles
- Event-based planning (holidays, storms, etc.)
- Rate design and incentives

The answer to each of these questions has significant implications for power system planning and cost, particularly for distribution networks.
Rightsizing upgrades
Need to balance cost and pace of distribution upgrades under uncertainty

Two studies looking at California, show vastly different costs...

Electrification Impact Study¹

$50B

Distribution Grid Electrification Model²

$16B

Right-Size under High Uncertainty

Underbuilt Grid

Overbuilt Grid

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

Risks:
• Expensive underutilization
• Inequitable burden of costs

¹ Kevala, 2023. ² Public Advocate’s Office, 2023
Prioritizing Grid Planning Actions to Take Today
Priorities for effectively integrating vehicle electrification into grid planning

1. **Improve forecasting** by considering multiple vehicle end uses, new vehicle technologies, and more data sources. Use of scenarios to capture the uncertainty of locational and temporal grid impacts.

2. **Embrace smart charging** options at every level of the grid from the premise to the bulk system. Targeted smart charging, operating limits, and strategically located storage can help bridge immediate load growth while long-term solutions are implemented.

3. **Incorporate future-ready equipment** to allow for upsizing of infrastructure or enable future upsizing whenever equipment is being replaced.

4. **Promote proactive upgrades** identified by a multi-stakeholder group because EV adoption and charging needs can grow much faster than utility upgrades can be implemented.
Forecast at a granular level by capturing the key variables

- **Adoption**: how many and when will people switch to EVs?
- **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 charging rates across state of charge

Sources:
Improving Forecasting: 
Getting to location through Use Cases

2030 EV National Adoption

Use Cases – Current LDVs

a) Car
b) SUV
c) Pickup
d) Van

MISO Changes By State

Number of Chargers by State

Proportion of Charger Type by State

Within a service territory (Portland, Oregon)

1NREL. 2023. The 2030 National Charging Network
2MISO. 2023. Based on EIA data with participation rates applied.
3PGE. 2023.
Improving Forecasting: Getting to Timing

At Home Vs Public Charging

At Home Charging: Immediate vs Delayed

Public Charging: Holidays vs Workdays

Charging Profiles Vary by Location and time of year

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1 Data: 2022. Powell, Cezar, & Rajagopal
2 Data: EVI-lite-Pro
3 Data: Provided to ESIG
Embrace Smart Charging:
Many Flavors of Smart Charging – pricing, control, preset, and dynamic

Traditional assumptions for what can be accomplished with demand flexibility should be re-evaluated in the context of EVs.

- San Diego Gas & Electric observed that 77% to 87% of charging happened off-peak.¹
- TOU pilots from 2008-2012 targeting the whole home resulted in a 2% to 21% peak reduction.²
- UK study showed participants with EVs reduced peak by 47% compared to 28% for non-EV drivers.³

A 2024 DOE study found: **Managed charging techniques can decrease incremental grid investment needs by 30%**.⁴

- While the analysis uses modeled load shapes and distribution circuits and charging profiles that are agnostic to other loads, it indicates the magnitude of reduced grid investments that are possible with smart charging.
Embrace Smart Charging:
Can address multiple grid needs simultaneously

Care should be given to avoid unintended consequences in the design of programs, with costs evaluated against traditional upgrades.

Managed charging allows dynamic operating and interconnection limits with restrictions on when the EV can charge.
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.”
- When using ALM, PG&E observed cost savings ranging from $30,000 to $200,000 per project.

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.
Incorporate Future-Ready Equipment: Use Infrastructure that can support the future

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

- Can direct decisions about:
  - Voltage class: 4kV -> 12kV -> 26kV
  - Equipment sizing: 50 kVA -> 75kVA transformer for 10 customers
  - Land parcel procurements: square footage required for substations

**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
  - Coordinate with loss of equipment life strategy

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 the utility is doing things like pole replacement, the utility replaces legacy designs with future-ready solutions.
Incorporate Future-Ready Equipment: Lessons Learned from BTM PV

Learn from recent developments in rooftop PV

At the charger level

Define Grid Friendly Behavior

In the digital infrastructure

Capacity Maps and Queues
Promote Proactive Upgrades:
Getting Proactive, but intelligently

Future-ready grid upgrades that take place over decades will not be sufficient to meet all projected EV charging needs. Some locations may need upgrades today. Widespread just-in-time upgrades of distribution equipment to support the level of electrification projected would be both costly and infeasible for utility construction crews.

Right-Sizing under High Uncertainty

**Underbuilt Grid**
- Unreliable grid
- Stunted public interest in EVs
- Long waits for charger installs

**Overbuilt Grid**
- 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
Adaptability

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

Multi-Stakeholder Input

- These upgrades can be strategically implemented, based on improved forecasting techniques, and identified by a multi-stakeholder group, to help ensure a targeted and efficient response to changing needs.

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.
Practice and Process Adaptations
Align the Grid Planning Process with the Need

**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**

A customer-collaborative process between planners and customers allows for open communication about:

- Multiple options for interconnection
- Multiple locational alternatives

**Proactive, Multi-Stakeholder Processes**

Given the volume and multiple use cases of EVs, proactive processes can be well suited to:

- Ensure equity
- Facilitate regional networks
- Provide clear roadmaps for electrification planning progression

*Given the scale of grid planning for vehicle electrification, new processes can help*

- Even with the best planning practices (what the grid engineer can do), process changes can enable more effective and holistic grid planning for EVs.
- Regulatory and policy support will be needed for proactive upgrades.
## When to Use Which Process

Shading indicates suitability of process to address EV Need

<table>
<thead>
<tr>
<th>Managed Charging of Light-Duty Vehicles</th>
<th>Charging Along Highways and Corridors</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Existing processes</strong></td>
<td><strong>Existing processes</strong></td>
</tr>
<tr>
<td>Daily-routine charging</td>
<td>Minimal highway usage</td>
</tr>
<tr>
<td>Demand for L1 charging</td>
<td>Along private highways</td>
</tr>
<tr>
<td>Elastic demand</td>
<td>Grid limitations along highways</td>
</tr>
<tr>
<td><strong>Customer-collaborative processes</strong></td>
<td>Regional EV growth</td>
</tr>
<tr>
<td>Perceived charging deserts</td>
<td>Interregional trucking</td>
</tr>
<tr>
<td>Service provider requests</td>
<td></td>
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<tr>
<td><strong>Proactive processes</strong></td>
<td></td>
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<tr>
<td>High vehicle deployment</td>
<td></td>
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<tr>
<td>Heavily loaded distribution</td>
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<tr>
<td>Inflexible demand</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Charging of Vehicle Fleets</th>
<th>Charging in Underserved Communities</th>
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</thead>
<tbody>
<tr>
<td><strong>Existing processes</strong></td>
<td><strong>Existing processes</strong></td>
</tr>
<tr>
<td>Small fleets</td>
<td>Equity considerations included</td>
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<tr>
<td>Sufficient highway charging</td>
<td>Incentives for EV purchase and smart charging</td>
</tr>
<tr>
<td><strong>Customer-collaborative processes</strong></td>
<td>New multi-family housing</td>
</tr>
<tr>
<td>Inflexibility in timing and location</td>
<td></td>
</tr>
<tr>
<td>Large fleets</td>
<td><strong>Proactive processes</strong></td>
</tr>
<tr>
<td><strong>Proactive processes</strong></td>
<td>Insufficient opportunity for charging</td>
</tr>
<tr>
<td>Multiple fleets competing for capacity</td>
<td>MHD vehicles near communities</td>
</tr>
</tbody>
</table>
Summary and Key Points

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

• **Smart Charging will be helpful**
  - Learn how to rely on it in grid planning
  - Prioritize infrastructure where demand management cannot defer investment

• **Many grid planning improvements are outside of normal activities:**
  - Future-ready systems – reconsidering design standards
  - Proactive upgrades with uncertainties
  - Collaborative and multi-stakeholder processes
THANK YOU

Sean Morash

Sean.morash@telos.energy
The ideas expressed are the views of the presenter, and not the Minnesota Public Utilities Commission.
EV Registrations in Minnesota

<table>
<thead>
<tr>
<th>Year</th>
<th>Registrations</th>
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</thead>
<tbody>
<tr>
<td>2018</td>
<td>10,064</td>
</tr>
<tr>
<td>2019</td>
<td>13,013</td>
</tr>
<tr>
<td>2020</td>
<td>18,749</td>
</tr>
<tr>
<td>2021</td>
<td>23,897</td>
</tr>
<tr>
<td>2022</td>
<td>34,473</td>
</tr>
<tr>
<td>2023</td>
<td>50,356</td>
</tr>
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</table>
Distribution Planning Objectives

The Commission is facilitating comprehensive, coordinated, transparent, integrated distribution plans to:

- Maintain and enhance the safety, security, reliability, and resilience of the electricity grid, at fair and reasonable costs, consistent with the state’s energy policies;
- Enable greater customer engagement, empowerment, and options for energy services;
- Move toward the creation of efficient, cost-effective, accessible grid platforms for new products, new services, and opportunities for adoption of new distributed technologies; and,
- Ensure optimized utilization of electricity grid assets and resources to minimize total system costs.
- Provide the Commission with the information necessary to understand Xcel’s short-term and long-term distribution system plans, the costs and benefits of specific investments, and a comprehensive analysis of ratepayer cost and value.

Commission review of distribution system plans are not meant to preclude flexibility for utilities to respond to dynamic changes and on-going necessary system improvements to the distribution system; nor is it a prudence determination of any proposed system modifications or investments.

(Source: IDP Filing Requirements as adopted in 2018)
IDP Requirements

1. Timing

2. Stakeholder Process

Utilities must hold at least 1 stakeholder meeting prior to filing, covering DER Forecasts, 5-Year Investment Plan and System Capabilities

3. Filing Requirements

A. Baseline Data
   • System
   • Financial
   • DER

B. Hosting Capacity and Interconnection

C. DER Futures Analysis (Scenario Planning)

D. Long-Term Distribution System Investment Plan (5 & 10 year)

E. Non-Wires Alternatives Analysis

F. Transportation Electrification Plan (IOUs only)
Transportation Electrification Plans
February 1, 2019 Order in Docket 17-879 (Commission’s EV Inquiry)

• Series of findings defining transportation electrification as in the public interest and defining the utility’s role in encouraging electrification

• Required utilities to file EV program and pilots

• Required utilities to file Transportation Electrification Plans that ID’d EV initiatives over the next two years and the extent to which they would:
  • Facilitate availability and awareness of public charging infrastructure and residential charging options for both single family and multiple unit dwellings, including programs or tariffs in development to address flexible load or reduce metering and data costs;
  • Educate customers on the benefits of EVs;
  • Assist in the electrification of vehicle fleets with a focus on medium and heavy-duty trucks and buses;
  • Offer DCFC specific tariffs and which tariffs are currently in use;
  • Optimize EV benefits by, for example, aligning charging with periods of lower customer demand and higher renewable energy production and by improving grid management and overall system utilization/efficiency; and
  • A discussion of current and planned charging practices/tariffs for public charging stations along with a discussion of any concerns related to those charging practices.
2020-2022 TEPs: Evolution of Filing Requirements

- Number of EVs in service territory, by type where possible
- Number of customers and vehicles on each off-peak or managed charging rate, energy consumed, and average hourly load profiles by month.
- Level of demand resulting from EVs during each hour of the day, or during each time period in a utility’s time-differentiated tariff
- Hourly EV consumption or if not yet available, during each time period in a utility’s time-differentiated tariff, for each EV tariff offered by the utility.
- Number and capacity of known Level 2, DCFC Stations
- System upgrades to accommodate EV charging; total costs paid by utility & by customer; average cost per upgrade by customer group
- EV adoption and load forecast (energy and capacity) forecast scenarios by sector.
- Summary of ongoing transportation electrification efforts, including existing programs and projects in development over at least the next 2 years.
- How the utility plans to facilitate public charging infrastructure; residential charging options for both single family and multiple unit dwellings; flexible load; and fleet electrification.
- A summary of customer EV education initiatives
- How the utility plans to optimize EV benefits, including alignment of charging with periods of lower customer demand and higher renewable energy production and by improving grid management and overall system utilization/efficiency.
- Summaries of any proposals or pilots submitted to other regulatory agencies or jurisdictions
- Attachments or links to the most recent reports for any ongoing EV pilots or programs.
- 5-year budget for future and historical expenditures by budget category
- An estimate for each system upgrade needed to accommodate EV charging, and an estimate of the expenditures on other investments that improve a utility’s ability to serve EV load
- Non-pilot EV program evaluations that examine the cost-effectiveness of the programs as currently designed and potential changes that could improve their cost-effectiveness.
• Combined Transportation Electrification Plans with Integrated Distribution Plans

• “Combining utility TEPs with IDPs is likely to improve the administrative efficiency of each regulatory proceeding, as transportation electrification and related utility distribution system planning functions are substantially linked to one another, and over time, they are likely to become inextricably linked.”
• Quantitative information incorporated into existing IDP sections:
  • Baseline Data
  • Financial Data
  • DER Scenario Analysis

• New TEP section for qualitative data:
  • Summary of new and ongoing programs
  • Facilitation of specific EV initiatives
  • Optimization of EV benefits
  • Education and awareness initiatives
• May 2023 – Minn. Stat. 216B.1615: ELECTRIC VEHICLE DEPLOYMENT PROGRAM
  • Requires investor-owned utilities to file Transportation Electrification Plans which Commission must approve, modify, or reject
  • Change from acceptance of TEPs to approval of TEPs

• Shift how TEP/IDPs are evaluated together
  • TEPs include programmatic approvals for EVs, different review process than IDP or original TEPs
  • Still examine grid impacts, budget, and forecasts as part of broader IDP
• First combined IDP/TEPs

• Only Xcel Energy filed for program approvals
  • Considered on faster timeline than overall IDP
  • Approved with modifications - May 9, 2024, Order

• Minnesota Power and Otter Tail Power did not have programs ready – plans looked at current programs, upcoming filings
  • Approved with overall IDPs verbally last week

• Next IDP/TEPs due November 1, 2025
Benefits of Merged TEP/IDPs
Xcel Energy Distribution Budget 2018-2028

- $250
- $500
- $750
- $1,000

2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028

- Actual
- Forecast

- Metering
- EV Programs
- Local Gov’t
- Grid Mod
- New Customer
- Other
- Reliability/Power Quality
- Capacity
- Age Related
Comparison to related programs

Xcel Energy - Selected Budget Areas

Xcel Energy - Transportation Electrification Spending by Budget Category
2019-2024 (SM)
Forecasting – view in context of overall load changes

- First IDP for Xcel Energy to use LoadSEER - allows for spatial forecasting of DERs, EVs, electrification on the distribution grid
Load Forecasting – large overall load growth

Xcel Energy IDP Scenarios: 30-Year Distribution Peak Demand Forecast (MW)

<table>
<thead>
<tr>
<th>Year</th>
<th>Net IDP Low</th>
<th>Net IDP Med</th>
<th>Net IDP High</th>
<th>Native IDP Low</th>
<th>Native IDP Med</th>
<th>Native IDP High</th>
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<tbody>
<tr>
<td>2023</td>
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<td>2051</td>
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</tbody>
</table>
View EV contribution to load forecast

Xcel Energy IDP Scenarios: Residential LDV growth

# of Annual Vehicle Additions

2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033

IDP Low  IDP Med  IDP High
## Cost Allocation and Upgrades

<table>
<thead>
<tr>
<th>Shared Cost Allocation</th>
<th>Proactive Upgrades</th>
<th>Reactive Upgrades</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Build distribution budgets around DER and electrification forecasts.</td>
<td>• Grid upgrades are made in response to individual customer requests.</td>
<td></td>
</tr>
<tr>
<td>• Assign incremental infrastructure costs via typical class cost allocation methods, e.g., in next rate case.</td>
<td>• Costs assigned via typical class cost allocation methods, e.g., in the next rate case.</td>
<td></td>
</tr>
<tr>
<td>• Benefits customers adopting DER and electrification by reducing or eliminating wait time and cost of interconnection.</td>
<td>• Benefits customers adopting DER and electrification by eliminating the cost of interconnection; benefits ratepayers by ensuring upgrades are used and useful.</td>
<td></td>
</tr>
<tr>
<td>• Risks include deploying assets that are not used and useful if forecasts are not accurate, the potential for shifting costs of upgrades onto non-benefitting customers, and risk of inequitable investments.</td>
<td>• Risks include continued wait-times in the interconnection process, the potential for shifting costs of upgrades onto non-benefitting customers, and risk of inequitable investments.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Individually Allocated Costs</th>
<th>Proactive Upgrades</th>
<th>Reactive Upgrades</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Build distribution budgets around DER and electrification forecasts.</td>
<td>• Grid upgrades are made in response to individual customer requests.</td>
<td></td>
</tr>
<tr>
<td>• Individual customers, where appropriate, pay a fee to cover their share of the upgrade at time of interconnection.</td>
<td>• Individual customers, where appropriate, pay a fee to cover their share of the upgrade at time of interconnection.</td>
<td></td>
</tr>
<tr>
<td>• Benefits customers adopting DER and electrification by reducing or eliminating wait times for interconnection; benefits ratepayers by reducing the costs of upgrades via reimbursement over time.</td>
<td>• For the most part the model in place today</td>
<td></td>
</tr>
<tr>
<td>• Risks include deploying assets that are not used and useful if forecasts are not accurate, and the potential for shifting costs of upgrades onto non-benefitting customers if forecasts or reimbursement fees are not accurate.</td>
<td>• Benefit is ensuring upgrades are used and useful.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Risks include wait time and interconnection costs for DER and electrification customers.</td>
<td></td>
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</tbody>
</table>
Cost Allocation and Upgrades

July 2, 2024 Verbal Decision – Commission led workgroup on establishing a framework for cost allocation and proactive upgrades for electrification and DERs, goal completion date July 1, 2025

Topics to address include:
• How to allocate the costs of proactive upgrades
• How to ensure any proactive upgrades are distributed in an equitable manner throughout a utility’s service territory
• If costs are socialized among ratepayers, whether portions of the upgraded capacity should be reserved for certain customer classes
• How a proactive upgrade program would integrate with a utility’s planned distribution investment programs
• How a utility’s other capacity programs and changes to distribution standards impact available hosting capacity
• How to determine where and when there is a need for proactive upgrades using forecasted DER and load adoption
• Whether there should be changes to any of a utility’s service policy provisions such as Contributions In Aid of Construction (CIAC).
Thank You!

Hanna Terwilliger

Hanna.Terwilliger@state.mn.us

mn.gov/puc