GRID SMART APPLICATIONS: ALIGNING ELECTRIC VEHICLE CUSTOMER CHARGING WITH GRID NEEDS

NARUC CENTER FOR PARTNERSHIPS & INNOVATION WEBINAR SERIES

MARCH 17, 2022

ABOUT NARUC

- The National Association of Regulatory Utility Commissioners (NARUC) is a non-profit organization founded in 1889.
- Our Members are the state utility regulatory Commissioners in all 50 states & the territories. FERC & FCC Commissioners are also members. NARUC has Associate Members in over 20 other countries.
- NARUC member agencies regulate electricity, natural gas, telecommunications, and water utilities.

NATIONAL ASSOCIATION OF REGULATORY UTILITY COMMISSIONERS
DEDICATED TO PUBLIC SERVICE
1889

ABOUT NARUC'S CENTER FOR PARTNERSHIPS & INNOVATION

- Grant-funded team dedicated to providing technical assistance to members.
- CPI identifies emerging challenges and connects state commissions with expertise and strategies to inform their decision making.
- CPI builds relationships, develops resources, and delivers trainings.

Regularly updated CPI fact sheet with recent publications & upcoming events under Quick Links at:

https://www.naruc.org/cpi-1/

NARUC Center for Partnerships & Innovation

Current Activities

Recently Released Publications

- Public Utility Commission Stakeholder Engagement: A Decision-Making Framework (Jan. 2021)
- Private, State, and Federal Funding and Financing Options to Enable Resilient, Affordable, and Clean Microgrids (Jan. 2021)
- User Objectives and Design Options for Microgrids to Deliver Reliability and Resilience, Clean Energy, Energy Savings, and Other Priorities (Jan. 2021)
- Understanding Cybersecurity for the Smart Grid: Questions for Utilities (Dec. 2020)
- Artificial Intelligence for Natural Gas Utilities: A Primer (Oct. 2020)
- Cybersecurity Tabletop Exercise Guide (Oct. 2020)

Forthcoming Resources

- NARUC-NASEO Task Force on Comprehensive Electricity Planning Blueprint for State Action and related resources
- A Guide for Public Utility Commissions: Recruiting and Retaining a Cybersecurity Workforce
- Cybersecurity Partnerships and Information Sharing
- Approaches to Economic Development in Decision-Making for Public Utility Commissions
- Regulators' Financial Toolbox on Advanced Metering Infrastructure

Recent Events

- Integrated Distribution Systems Planning: NARUC partnered with DOE national laboratories to deliver a virtual training in Oct. 2020 on forecasting, control and automation, metrics, resilience, PUC practices, and more. The next session will be held for Western state officials beginning Feb. 26, 2021. *Contact Dominic*
- NARUC-NASEO Task Force on Comprehensive Electricity Planning. Resources developed by the Task Force will be shared in a virtual workshop on Feb. 11, 2021. Read the Task Force fact sheet. *Contact Danielle*
- National Council on Electricity Policy (NCEP). Presentations from NCEP's December 2020 Annual Meeting are available as well as an updated Transmission and Distribution Resource Catalog. *Contact Kerry*
- Carbon Capture, Utilization and Storage Workshop Webinar Series. Recordings are available from a Western Interstate Energy Board- and NARUC-hosted six-part webinar series in Sept. and Oct. 2020. *Contact Kiera*

Available Virtual Learning Opportunities

- Cybersecurity Training for State Regulatory Commissions: NARUC is hosting a virtual cybersecurity training on Feb. 23-25, 2021. *Contact Ashton*
- National Council on Electricity Policy (NCEP). Register for a special session on Exploring Optimization through Benefit-Cost Analysis on Feb. 25, 2021. Learn More about NCEP. *Contact Kerry*
- Emergency Preparedness, Recovery and Resilience Task Force: The EPRR Task Force will meet Feb. 5, 2021 to discuss BRIC funding with FEMA. *Contact Will*
- Commission Staff Surge Calls. NARUC hosts quarterly calls on which commission staff discuss how different states approach emerging issues in electricity policy. The next call will be held in early **Mar., 2021**. Summaries from past calls are available. *Contact Kiera*
- Innovation Webinar Series. NARUC hosts monthly webinars for members and the public. ***Mar. 11:*** Data for the Public Interest: Empowering Energy Equity. ***Apr. 15:*** Initiative on Cybersecurity in Solar Projects. ***May. 13:*** Staffing the Evolving PUC Workforce. Register and find recordings of past events. *Contact Dominic*

Join us! NARUC hosts four working groups for members:

- Performance-Based Regulation. *Contact Kerry*
- Electric Vehicles. *Contact Jasmine*
- Microgrids. *Contact Kiera*
- Grid-Interactive Efficient Buildings. *Contact Danielle*

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JOSEPH VELLONE, EV.ENERGY

NREL
Transforming ENERGY

Aligning Electric Vehicle Customer Charging with Grid Needs

Matteo Muratori, PhD

M.B. Anwar, P. Jadun, E. Hale, B. Bush, P. Denholm, O. Ma, and K. Podkaminer

NARUC Innovation Webinar

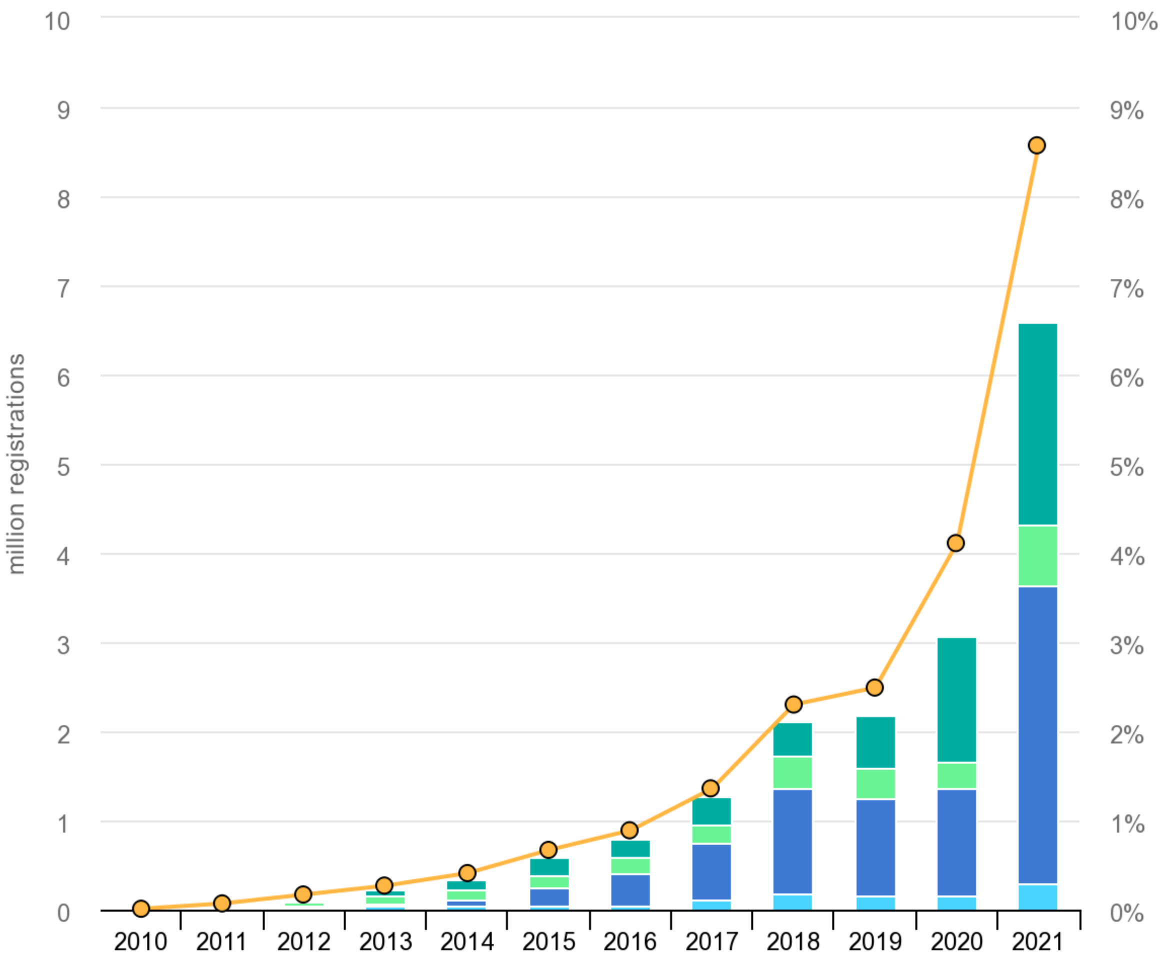
March 17th, 2022

U.S. DOE National Lab System

Battery Electric Vehicles: a Success Story

- **Electric vehicles (EVs)** are experiencing a rapid rise in popularity and adoption:
  - Technology has matured and **costs have declined**
  - **Support for clean transportation** has incentivized adoption and promoted awareness
  - Increased **charging opportunities** enabled adoption
- Expected **rapid growth in EV** adoption for passenger vehicles as well as medium- and heavy-duty trucks and other applications (off-road, planes, ships, etc.)
- EVs offer a pathway to decarbonize on-road transportation when coupled to **clean electricity**

Global EV Sales



- In 2019, 2.2 million electric cars were sold, representing just 2.5% of global car sales.
- In 2020, the overall car market contracted but electric car sales bucked the trend, rising to 3 million and representing 4.1% of total car sales.
- **In 2021, electric car sales more than doubled to 6.6 million, representing close to 9% of the global market and more than tripling their market share from two years earlier.**

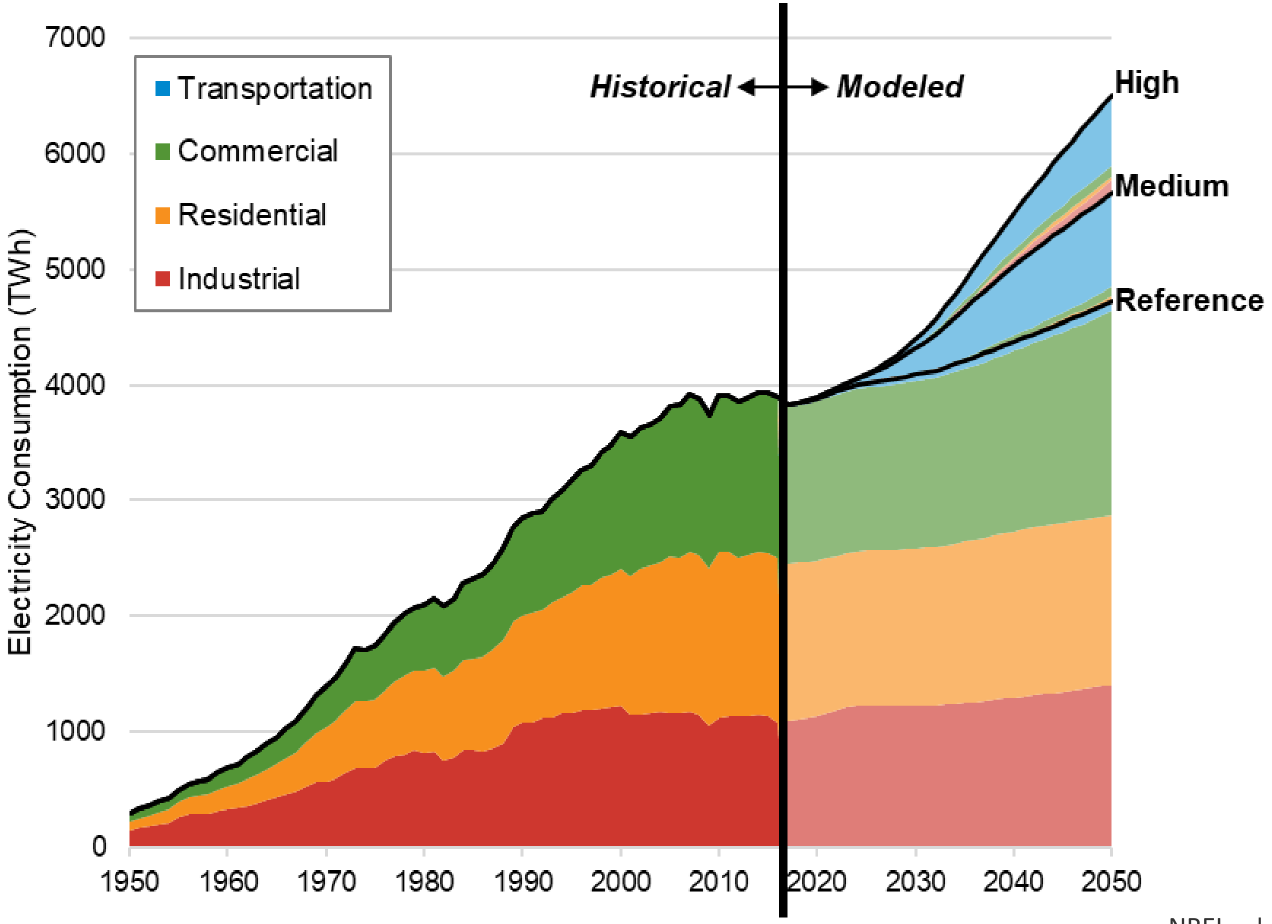
Source: https://www.iea.org/commentaries/electric-cars-fend-off-supply-challenges-to-more-than-double-global-sales

Impact of widespread electrification

Growing EV adoption offers an **opportunity to increase electricity demand**, and will require investments in generation, transmission, and distribution systems.

EFS High scenario, 2050:

- Transportation share of electricity use increases **from 0.2% in 2018 to 23% in 2050** (1,424 TWh electricity consumption increase), and more recent net-zero studies show even more aggressive growth



Source: https://www.nrel.gov/analysis/electrification-futures.html

How Valuable is Electric Vehicle (EV) Managed Charging?

- **Uncoordinated** charging of EVs will lead to increased system peak load, possibly exceeding the maximum power that can be supported by distribution systems and generally **increasing power system stress**
- Vehicles are underutilized assets parked ~96% of the time: **managed EV charging can satisfy mobility needs while also supporting the grid**:
  - We identify critical gaps and remaining challenges that need to be addressed to fully realize effective EV-grid integration

Energy & Environmental Science

ROYAL SOCIETY OF CHEMISTRY

REVIEW

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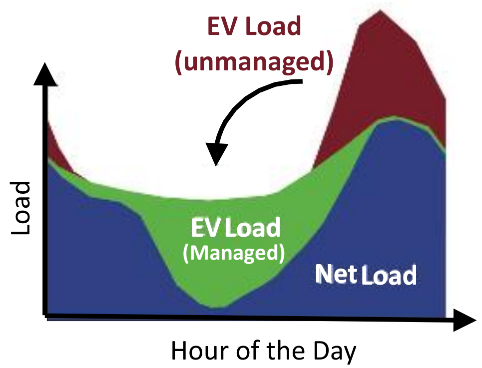
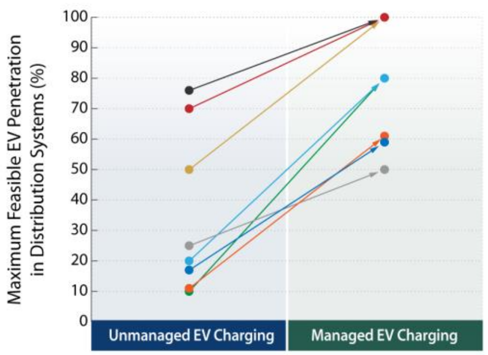
Cite this: *Energy Environ. Sci.*, 2022, **15**, 466

Assessing the value of electric vehicle managed charging: a review of methodologies and results

Muhammad Bashar Anwar,[a] Matteo Muratori,*[a] Paige Jadun,[a] Elaine Hale,[a] Brian Bush,[a] Paul Denholm,[a] Ookie Ma[b] and Kara Podkaminer[b]





The grid is also transforming

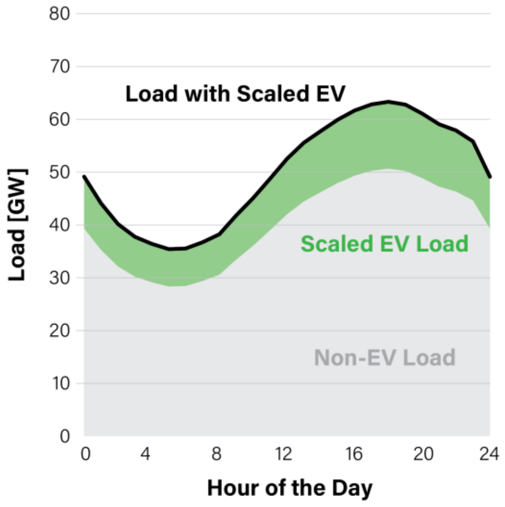
The **electric power system is undergoing profound changes**.

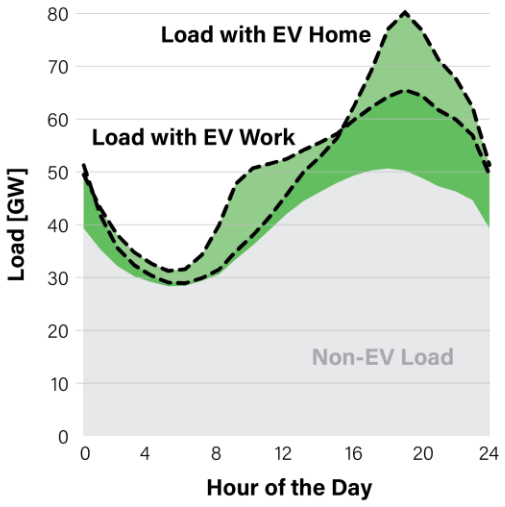
The traditional system paradigm of dispatching central generation to match demand is evolving into a **more integrated supply-demand system** in which demand-side distributed resources (generation, energy storage, and demand response) respond to supply-side requirements, mainly driven by variable renewable generation.

EVs are expected to be one of the largest sources (and often the single largest) of **demand-side flexibility**

When and *where* EV charging occurs will be as critical as *how much* electricity is needed

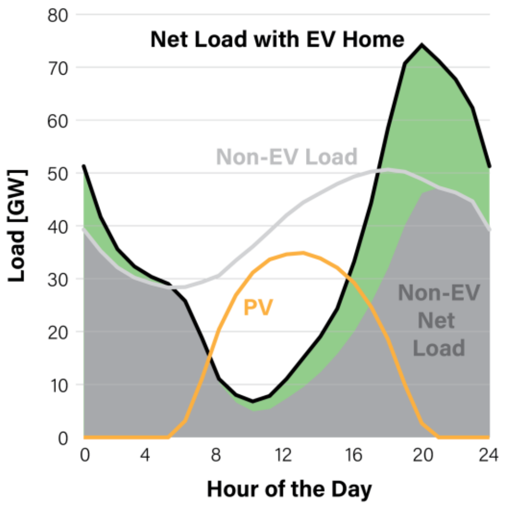
a) ASSUMPTION:
EV charging is often assumed to simply scale up electricity demand.

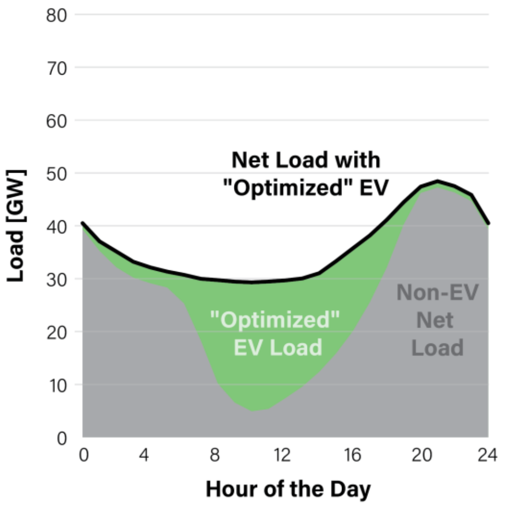




b) COMPLEXITY:
Future EV charging could change the shape of demand, depending on when and where charging occurs.

c) INTEGRATION:
EV charging can impact power system planning and operations, particularly with high shares of variable renewable energy.





d) FLEXIBILITY:
Optimizing EV charging timing and location could add flexibility to help balance generation and demand.

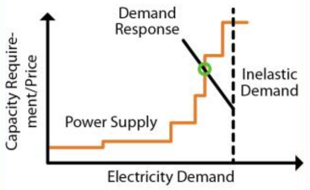
New class of models needed to assess the integration opportunities of EVs on the power system

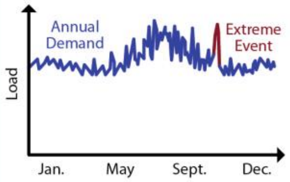
Source: *Muratori and Mai, 2020*

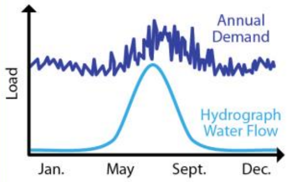
EVs can support the grid in multiple ways providing values for different stakeholders, including non-EV owners

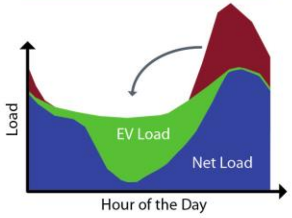
Smart electric vehicle-grid integration can provide flexibility – the ability of a power system to respond to change in demand and supply – by charging and discharging vehicle batteries to support grid planning and operations over multiple time-scales

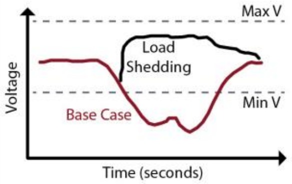
Power System Application	**Generation Capacity and Transmission/ Distribution Planning**	**Resilience To Extreme Events**	**Seasonal Planning (Hydro/Long-Term Storage Dispatch)**	**Commitment and Dispatch Decisions**	**Balancing and Power Quality**	**Support End Consumers**
Time scale	*Multi-year*	*Years (planning), hours (real-time response)*	*Months*	*Days to Hours and Sub-Hours*	*Seconds to sub-seconds*	*Years (planning), hours (real-time response)*
Vehicle-Grid Integration value	Ability to reduce peak load and capacity requirements and defer distribution systems upgrades if reliable EV charging flexibility is available	Load response to natural events (heat waves, tornados) or human-driven disasters, load postponement over days, and support microgrid management and grid restoration (V2G)	No role for EVs	Leverage EV charging flexibility to support supply dispatch and load-supply alignment (tariff management), variable renewables integration, operating reserves, energy arbitrage (V2G)	Provide voltage/frequency regulation and support distribution system operations	Tariff management (e.g., mitigate retail demand charges), complement other distributed energy resources (smart load, generation and storage), and minimize equipment aging/upgrades

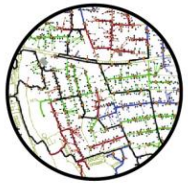










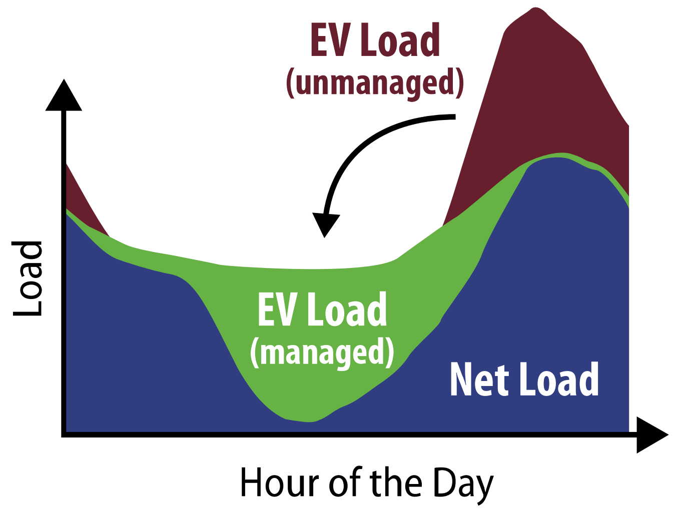


Source: Muratori *et al.* 2021. The rise of electric vehicles—2020 status and future expectations. Progress in Energy.

An Opportunity for Grid Integration

As electric vehicle (EV) adoption continues to grow, effective management of these flexible loads offers a unique opportunity to **support power systems during normal and extreme conditions**, with the potential to benefit EV users and other electricity consumers alike.

Value of Electric Vehicle Managed Charging



Managed EV charging can support grid planning and operations

Reduce Bulk Power Systems Investment Costs
20–1350 $/EV/year

Reduce Bulk Power Systems Operating Costs
15–360 $/EV/year

Reduce Renewable Energy Curtailment
23–2400 kWh/EV/year

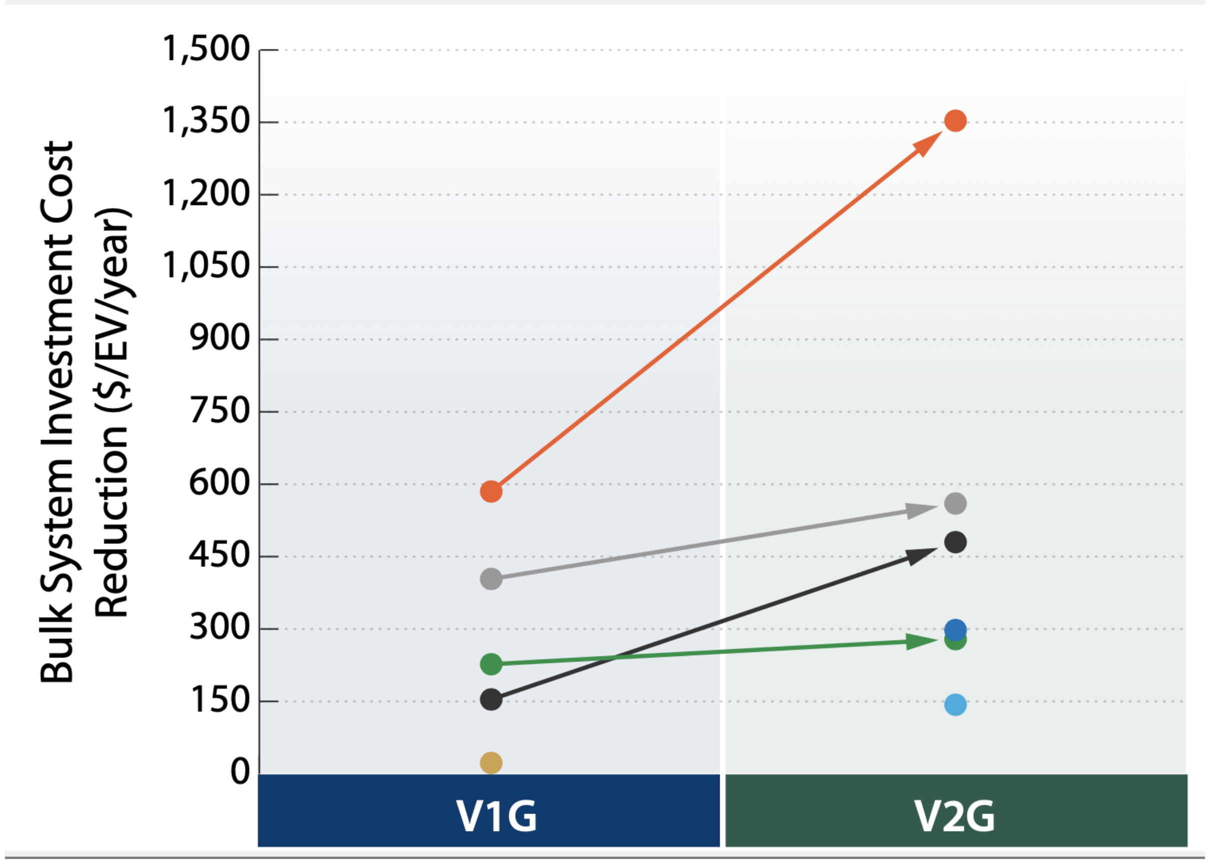
Reduce Distribution Systems Investment Costs
5–1090 $/EV/year

Increase Distribution Systems EV Hosting Capacity
30–450%

Source: Anwar et al. 2022. Assessing the value of electric vehicle managed charging: a review of methodologies and results. Energy & Env. Science.

Reducing bulk system investment costs

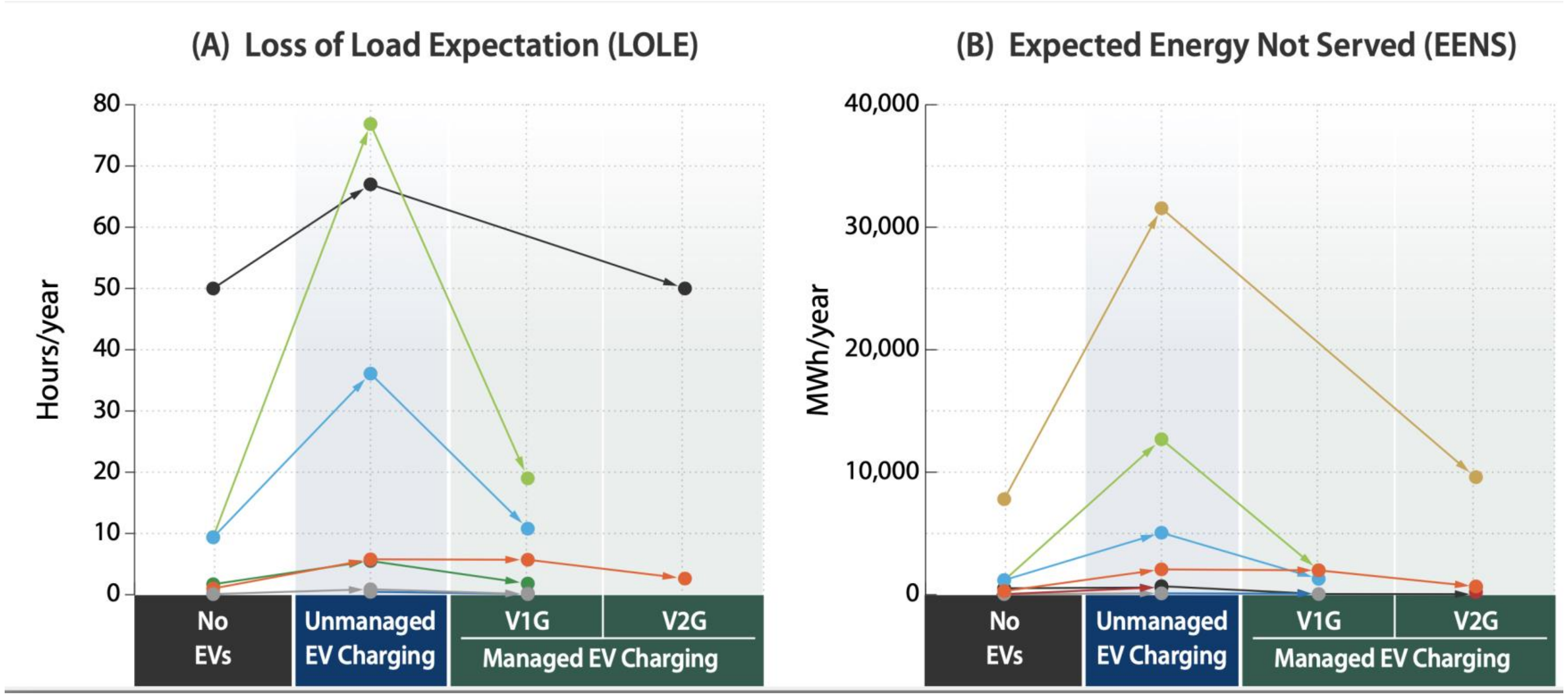
- Managed charging is shown to consistently provide **hundreds of dollars in investment cost savings per EV each year**.
- **V2G capability tends to enable greater investment cost reductions** compared to V1G; however, the extent of these benefits depends on system characteristics, EV adoption assumptions and EV flexibility modeling, and **enablement costs** (usually not explicitly considered in these studies).



Source: Anwar et al. 2022. Assessing the value of electric vehicle managed charging: a review of methodologies and results. Energy & Env. Science.

Impact on Reliability

Unmanaged EV charging invariably worsens **bulk power system reliability** (frozen system, no expansion assumed), while managed charging can offer reliability close to the case without EVs (again, without any system expansion)



Source: Anwar et al. 2022. Assessing the value of electric vehicle managed charging: a review of methodologies and results. Energy & Env. Science.

Concluding Remarks

EVs are not a burden for the grid, but a resource: managed charging can provide major benefits across multiple timescales, especially for high-renewable systems

- **Benefits change** for different power systems, charging strategies, and over time
- **Benefit-cost analyses** largely missing, especially for complex solutions (e.g., V2G)

Needs:

- More nuanced **demand-side modeling** to assess EV charging needs and flexibility
- Comprehensive **analyses across the entire power system** to explore tradeoffs across multiple aspects and cost/benefit to **inform evolving regulations and the design of future power markets**
- **Technologies, business models, and multi-sector collaborations required to untap this potential and engage/compensate EV users**
- Assessing **role/value of charging infrastructure** in enabling and supporting managed charging

References

1. International Energy Agency (IEA), 2020. Global EV Outlook 2020.
2. Muratori *et al.*, 2021. The rise of electric vehicles—2020 status and future expectations. Progress in Energy, 3(2).
3. Mai, *et al.*, 2018. Electrification futures study: Scenarios of electric technology adoption and power consumption for the United States (No. NREL/TP-6A20-71500).
4. Muratori, 2018. Impact of uncoordinated plug-in electric vehicle charging on residential power demand. Nature Energy, 3(3).
5. Muratori and Mai, 2020. The Shape of Electrified Transportation. Environmental Research Letters, 16(1).
6. Anwar *et al.*, 2022. Assessing the value of electric vehicle managed charging: a review of methodologies and results. Energy and Environmental Science, 15(1).

Questions?

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www.nrel.gov

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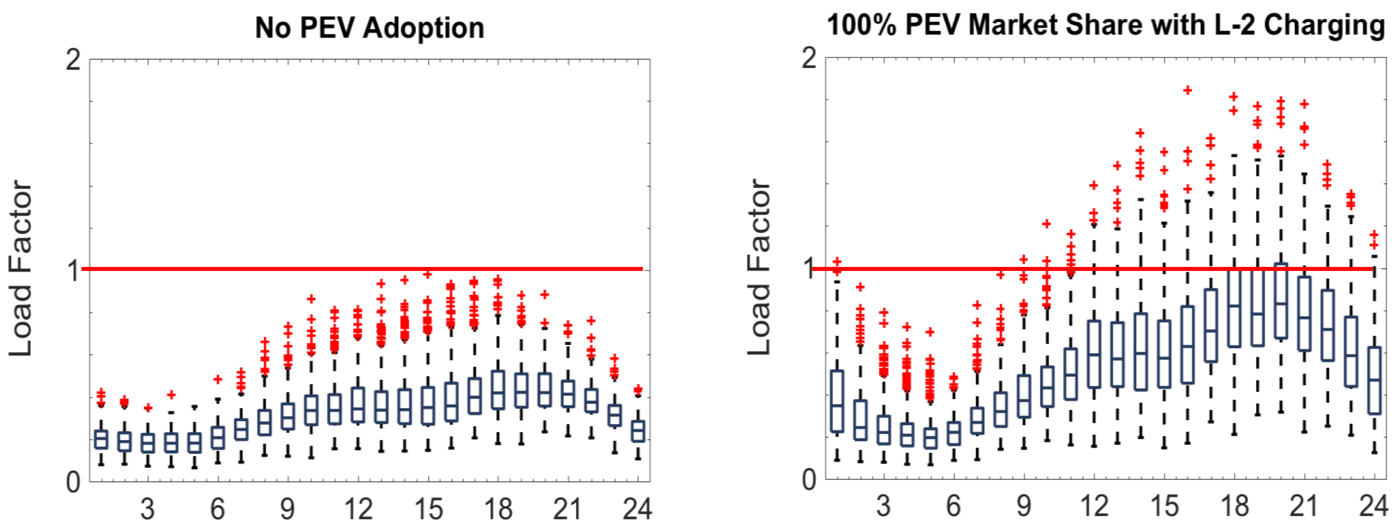
NREL Transforming ENERGY

Supplemental

Impact of Uncoordinated EV Charging

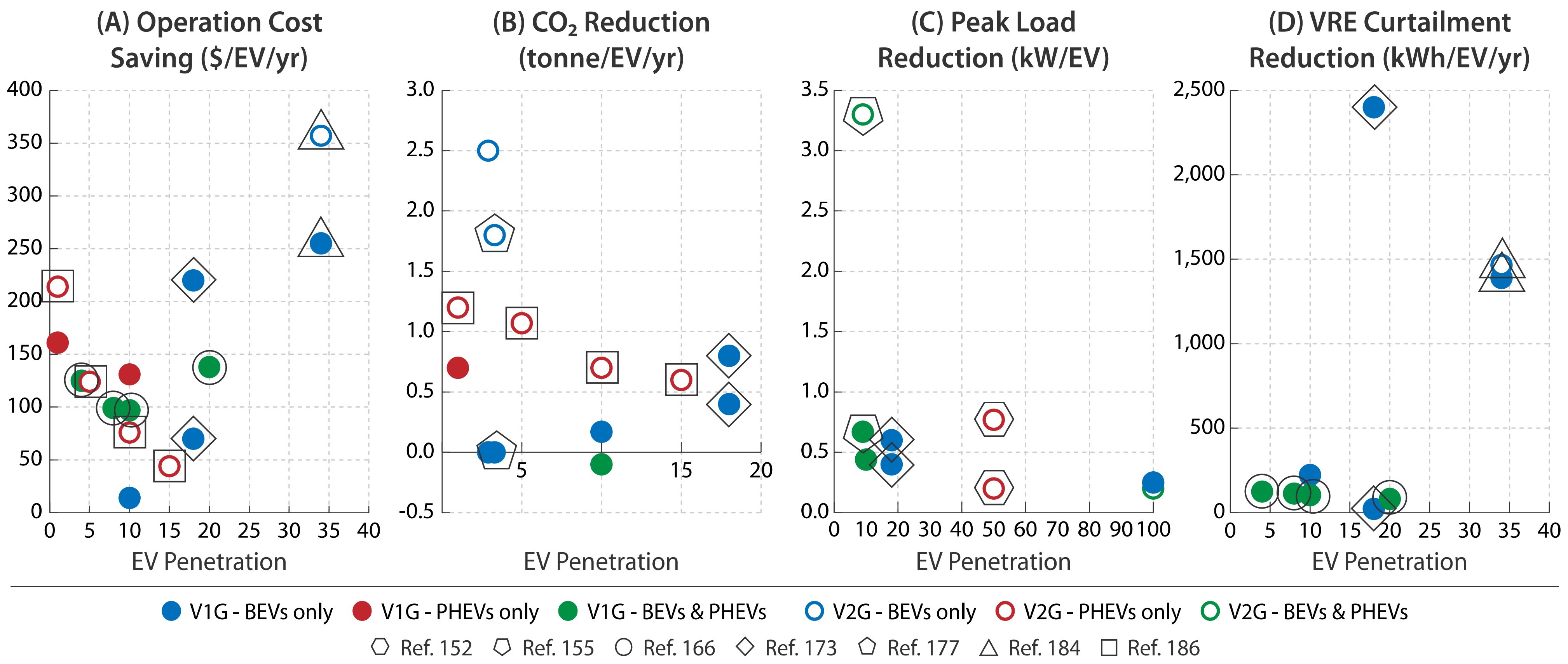
Residential EV charging represents a significant increase in household electricity consumption that can require upgrades of the household electrical system and unless properly managed it may lead to exceeding the maximum power that can be supported by distribution systems, especially for legacy infrastructure and during high demand times.

- **Clustering effects** in EV adoption and **higher power** charging exacerbates these issues
- Effective planning, smart EV charging, and distributed energy storage systems can help to cope with these potential issues.
- Key to **consider EVs in system upgrades**



Source: Muratori, M., 2018. [Impact of uncoordinated plug-in electric vehicle charging on residential power demand](). Nature Energy, 3(3), pp.193-201.

An Opportunity for Grid Integration



Source: Anwar et al. 2022. Assessing the value of electric vehicle managed charging: a review of methodologies and results. Energy & Env. Science.

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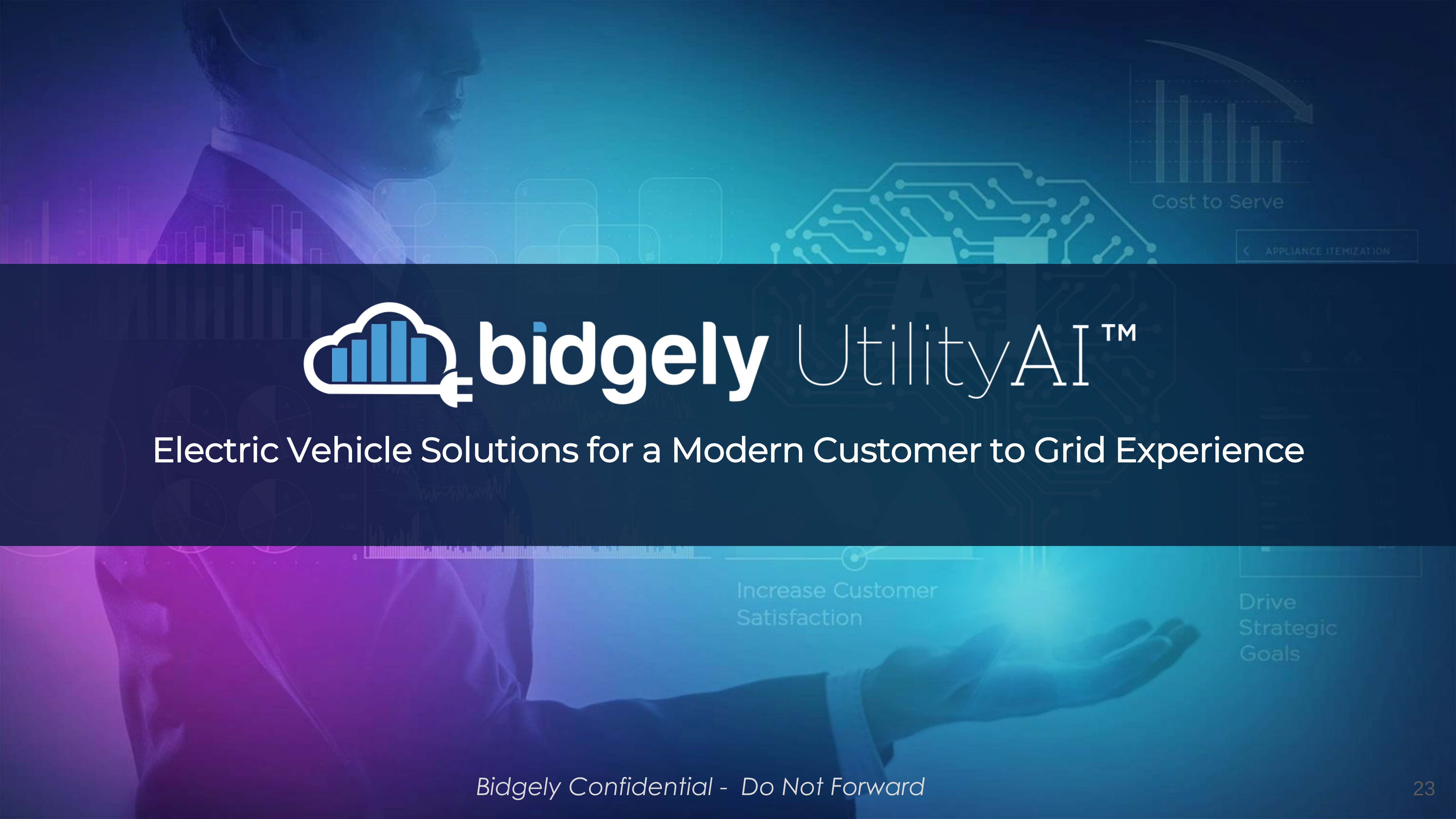
Electric Vehicle Solutions for a Modern Customer to Grid Experience



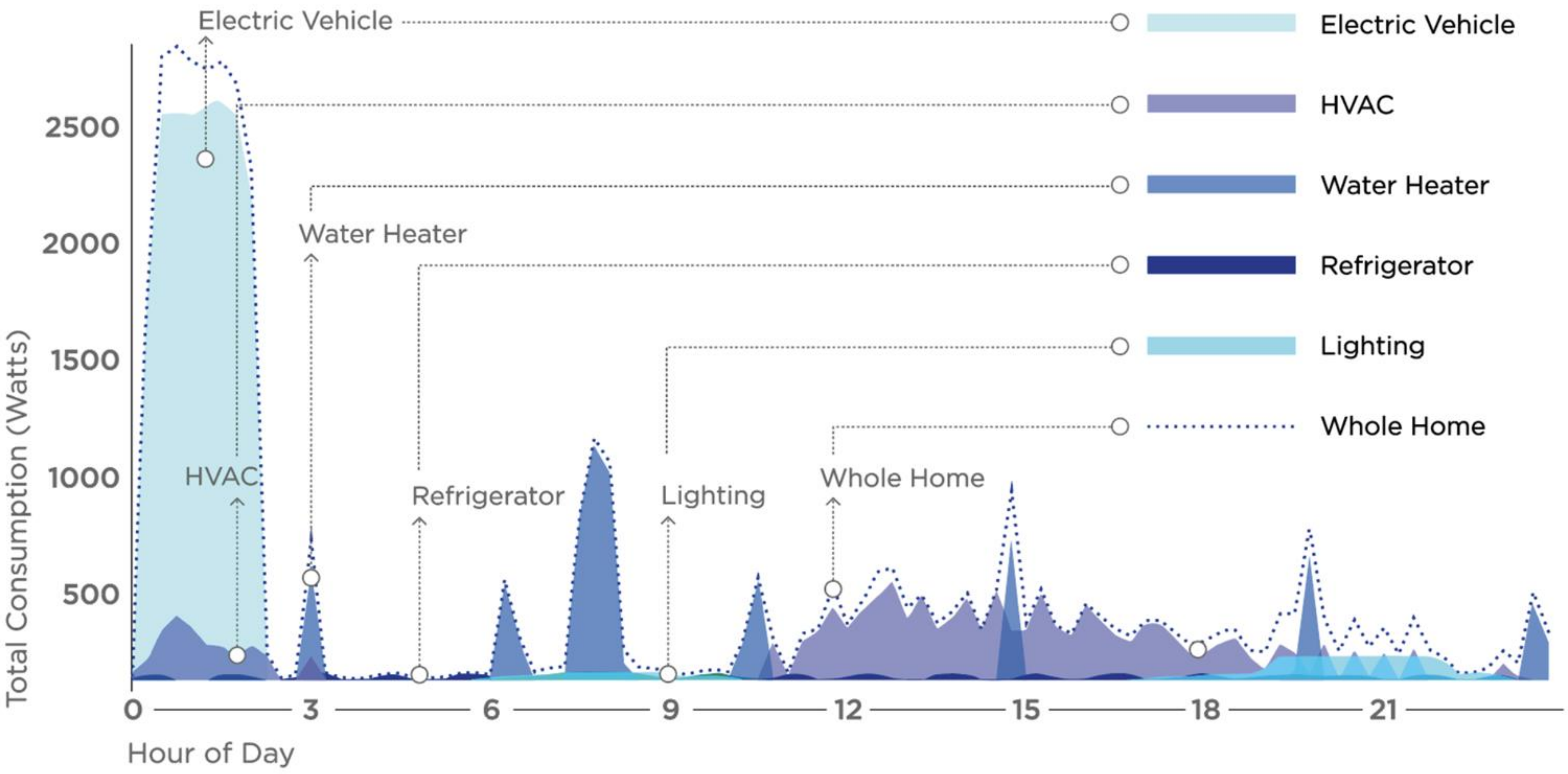
BIDGELY : WHO WE ARE

bidgely

is an AI-powered SaaS company
based in the Silicon Valley.

We unlock the power of data and AI for the modern energy provider, enabling them to achieve their strategic goals while delighting their customers.

OUR CORE TECHNOLOGY: AMI LOAD DISAGGREGATION



17 Patents	No Hardware Required	Applicable for all Meter Types	Zero Customer inputs required

PRINCIPLES FOR ELECTRIC VEHICLE PROGRAMS

Bidgely's Principles for Electric Vehicle Programs

Leverage AMI & Existing Technologies

AMI is incredibly powerful for EV programs and allows for detection and consumption analytics.

Engage Maximum Amount of Customers

Use opt-out behavioral as a baseline option to engage all EV owners.

Value Customer Choice

Give customers various options so they can select the choice that best fits their needs and lifestyle. Forcing a specific technology often excludes customers or introduces inequity.

Provide the Most Value

Provide the most value to the full customer population by properly valuing EV participation based on total system benefit. Leverage variable incentives to connect total system value with each participant.

Value Scalability

Consider EV adoption trends and projections when selecting technologies and ensure they are scalable to meet future needs.

Principles in Practice

Leverage AMI & Existing Technologies

- Consider where AMI is already deployed in design
- Leverage AMI based disaggregation

Engage Maximum Amount of Customers

- Use Opt-Out Methods
- Create a seamless and pleasant experience from baseline to advanced

Value Customer Choice

- Have diversity of technologies
- Have levels of participation
- Advanced programs offered after a baseline period

Provide the Most Value

- Vary incentives based upon grid value & existing usage patterns
- Shift from evaluating an incentive per car to incentive per kWh

Value Scalability

- Consider technical scalability
- Consider cost implications

AMI ANALYTICS FOR ELECTRIC VEHICLES

ADVANCED AMI ANALYTICS FOR EV

Customer Charging Attributes Identified by Bidgely:

* Opt out using AMI for all customers
**Opt-in for customers who also connect to car API

Charger Type	L2
Amplitude	11,900 W
# runs peak hours (winter)	3
Consumption Peak Hours (winter)	64.437 kWh
# runs peak hours (summer)	10
Consumption Peak Hours (summer)	425.814 kWh
Interval start-end time (avg)	8pm - 4am
Charging frequency (avg)	4 times / week
Location of Charge**	Home*
Load profile and flexibility analysis	

Grid Charging Attributes Identified by Bidgely:

*Dependent on the availability of the submeter data from public charging stations or feeder level data
**Utility provided mapping

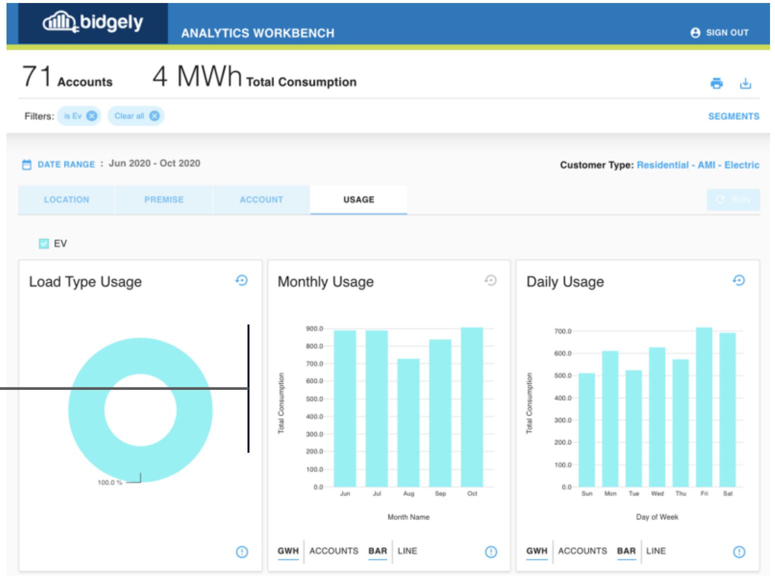
Percentage of Chargers Types	80% Lvl 2
Total Charging Consumption (by region, zip, substation, feeder)*	1,1700,000 W
Substation EV Load	48,000 W
Feeder EV Load	10,000 W
Transformer** EV Load	5,000 W
EV Load Forecast (on-demand, monthly)	50,000,000 W
Percentage of Customers Charging On Peak (by season)	78%
Geographies with High Charging	79237, 44383, 00001

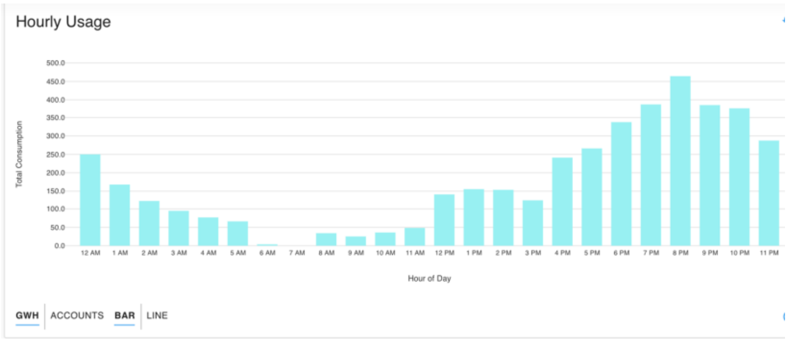
INTELLIGENT EV PROGRAM DESIGN

Summary
Total Number of EV Customers & EV Consumption Over Time

Monthly & Daily Usage
Breakdown of EV usage by month or day

Hourly Breakdown
Breakdown of EV usage by month or day





Before you design any program you'll need to know the who/what/when/where customers stand. Broadcast marketing risks spending dollars on the wrong participates (for example, 50% of EV users already charge off-peak, you don't need to incentivize them)

Bidgely provides data to help design programs based on:

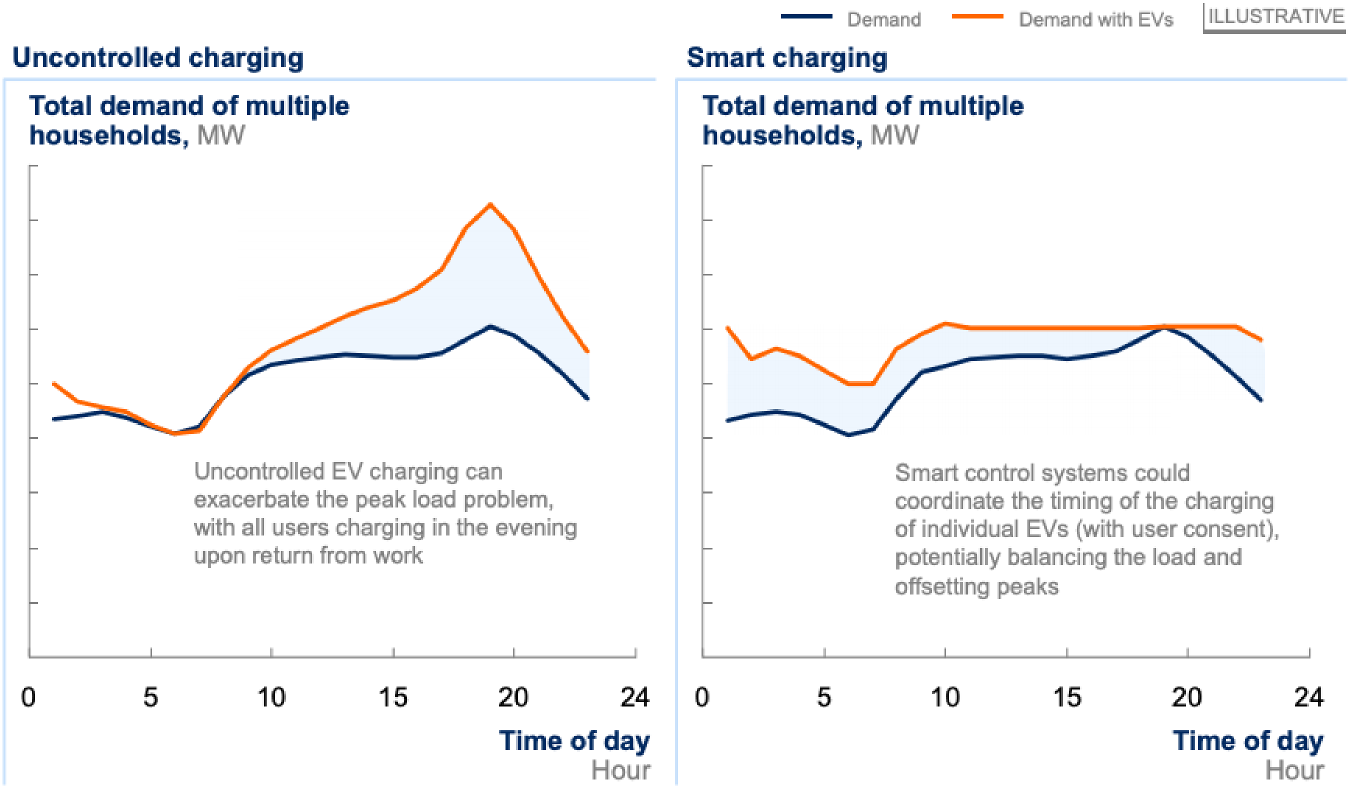
- Number of EV owners within a geography
- Number of EV owners charging that are on peak charging that season
- KWh of on-peak Charging
- Average charging duration
- Average trip mileage
- Average miles per week

MANAGED CHARGING PROGRAMS

EVs CAN MAKE OR BREAK THE GRID IN A FEW YEARS

Exhibit 4.3

Smart charging of EVs can avoid the peak load problem and become a key balancing component in demand side management



SOURCE: McKinsey

EVs Charging in High Demand Times

- Drive the peak even further creating more imbalance
- Increased capital investment
- Decreased reliability and resilience
- Pricing and rate complexity

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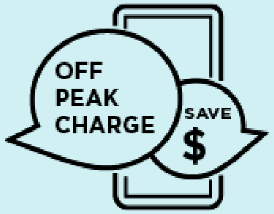
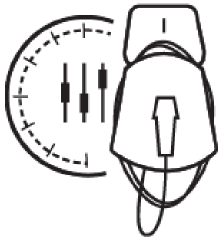
MANAGE EV CHARGING TO FLATTEN THE CURVE

Maximize customer choice while effectively managing EV loads with an Opt-Out to Opt-In Managed Charging Program.



Behavioral Load Shifting (Opt-Out)

- Peak Use detection
- Behavioral nudges to motivate change for peak chargers
- Incentive or non-incentive based results available



Managed Charging (Opt-In)

- Peak Use detection
- Direct control of the charger or car itself
- May be assisted with incentives

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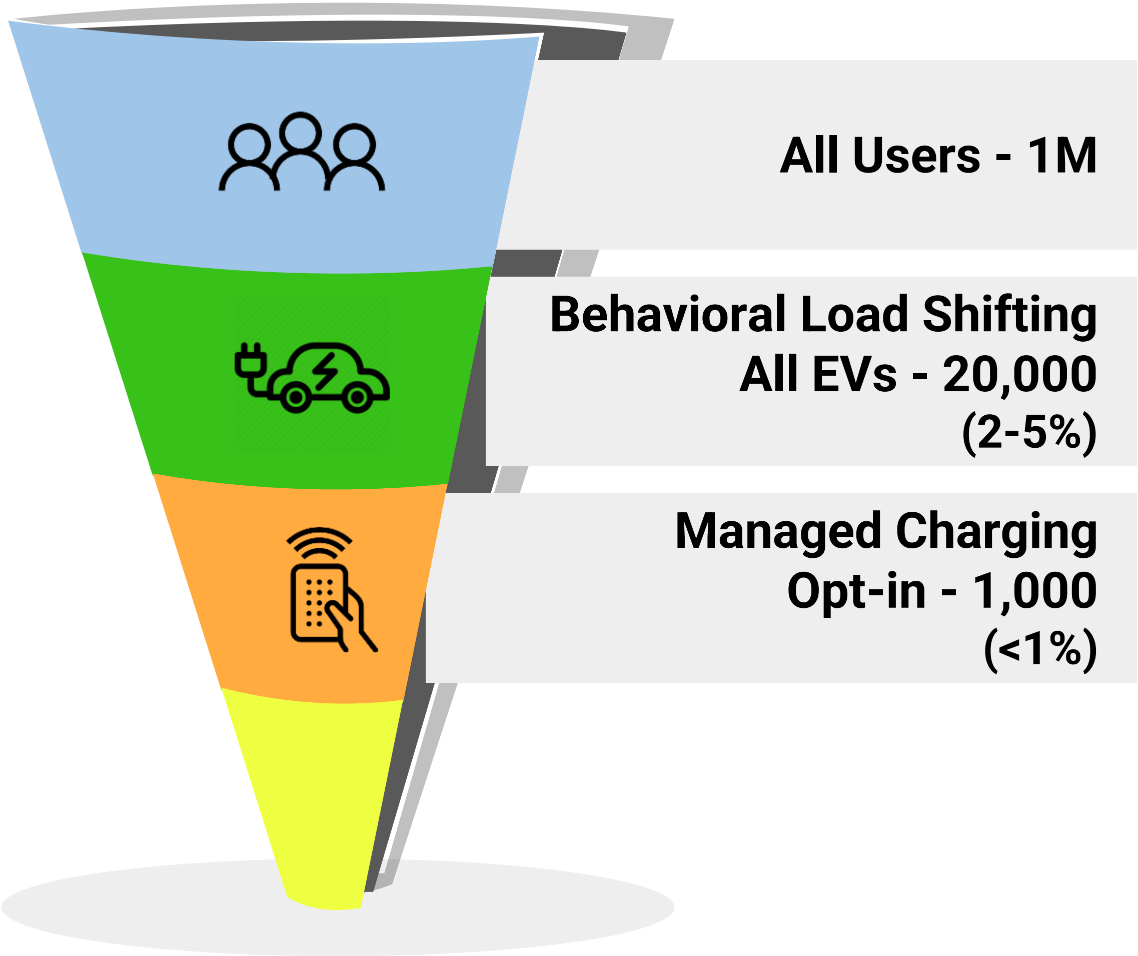
EV LOAD SHIFTING FOR ALL TO MAXIMIZE ENGAGEMENT



Engaging EV owners is more beneficial than just for shifting load. Utilities should engage all EV owners to grow the relationship as a "fuel provider"

Engage Maximum Amount of Customers

Customers should have options in how they'd like to participate in managed charging. Not all customers will feel comfortable giving control to their utility.

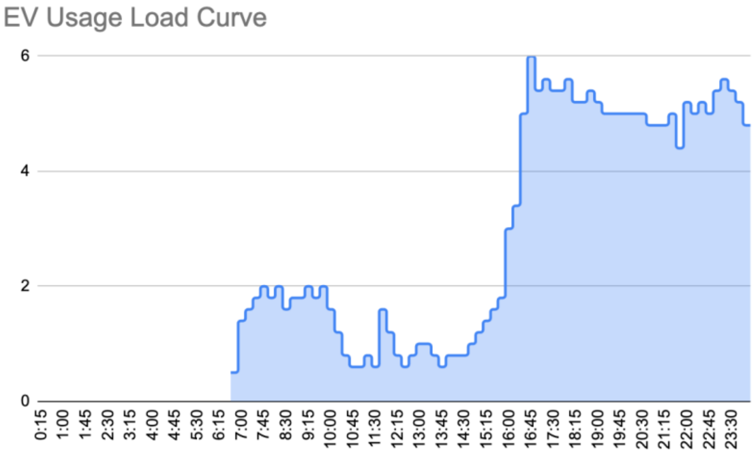
Value Customer Choice

COST EFFECTIVE ENGAGEMENT

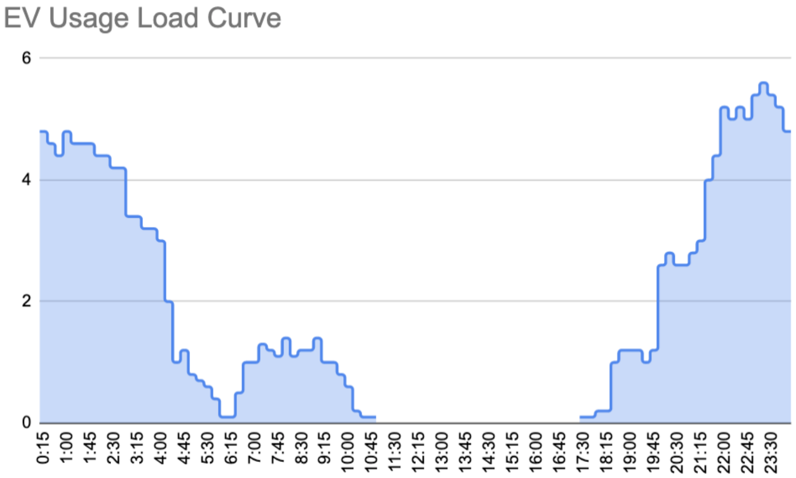
Provide the Most Value

Use intelligent program design with AMI analytics to value the potential of each shift to the grid. Why pay for a kWh that doesn't need shifting?

80% On-Peak Charging
4000 kWh annual EV charging
Charges 3+ times per week



15% On-Peak Charging
3000 kWh annual EV charging
Charges 1-2 times per week



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AMI BASED MANAGED CHARGING

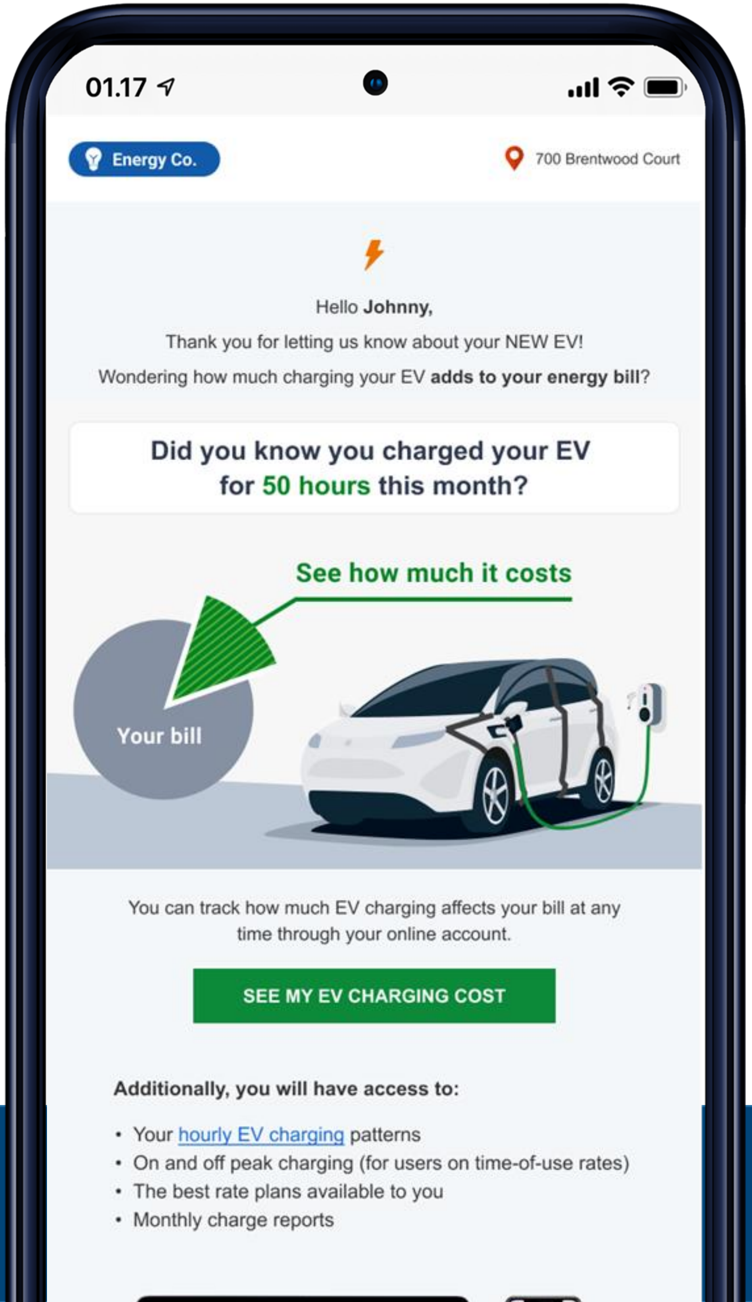
Shift EV charging times from on-peak hours to off-peak hours with passive managed charging

Leverage AMI & Existing Technologies

Data Ingestion → EV Analytics → EV Welcome & Recruitment → Behavioral & Incentive-Based Digital Nudges → Customer Shifts Charging Off Peak

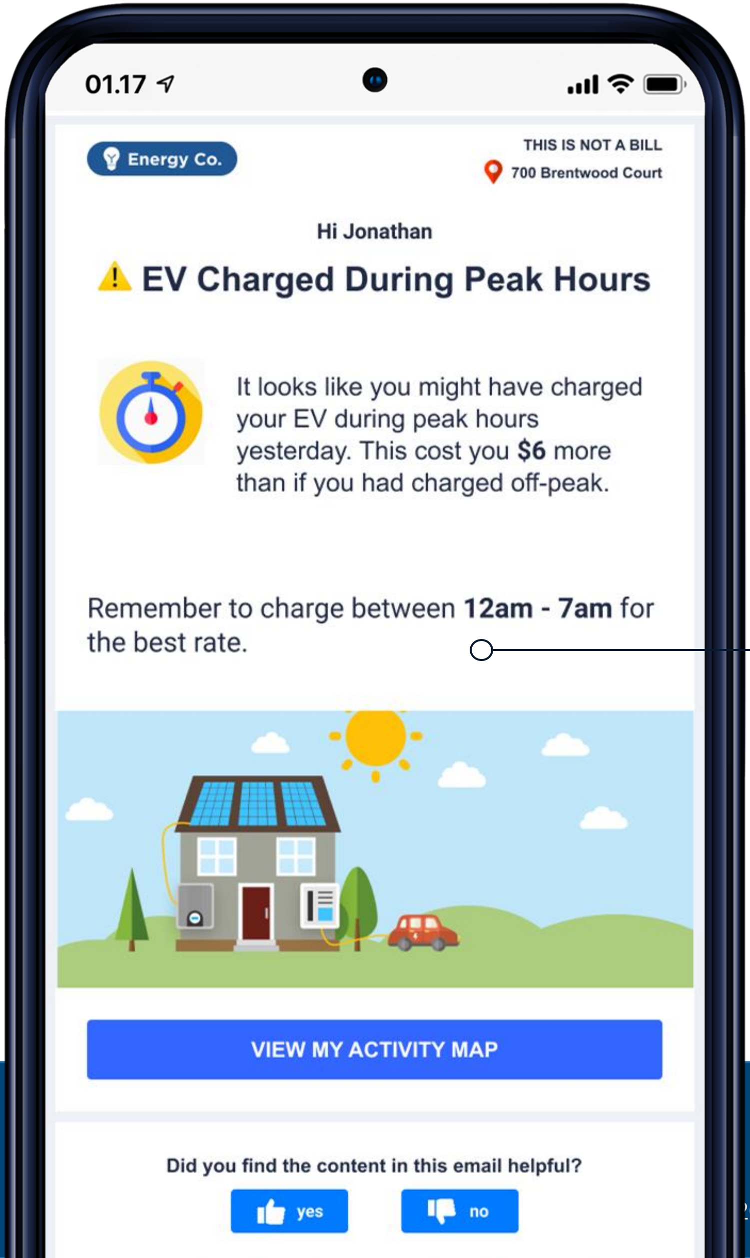
EV WELCOME EMAIL

Act as a trusted advisor to new EV owners by setting them up for ways to manage their EV charging



Alerts for Off-Peak Charging

Target customers with L2 charging to enroll in personalized alerts that educate them about opportunities to shift their charging times.



EV CHARGING TIME SUGGESTION

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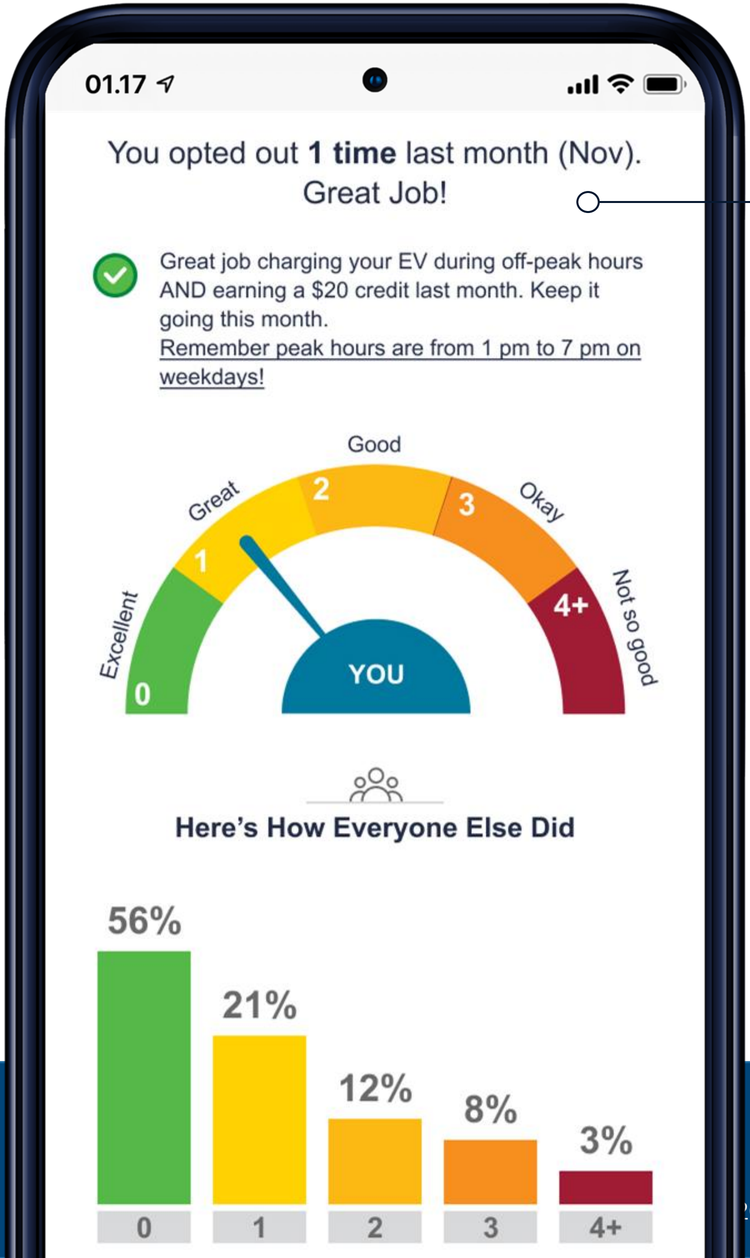
STRIKE SYSTEM PEAK CHARGING ALERTS

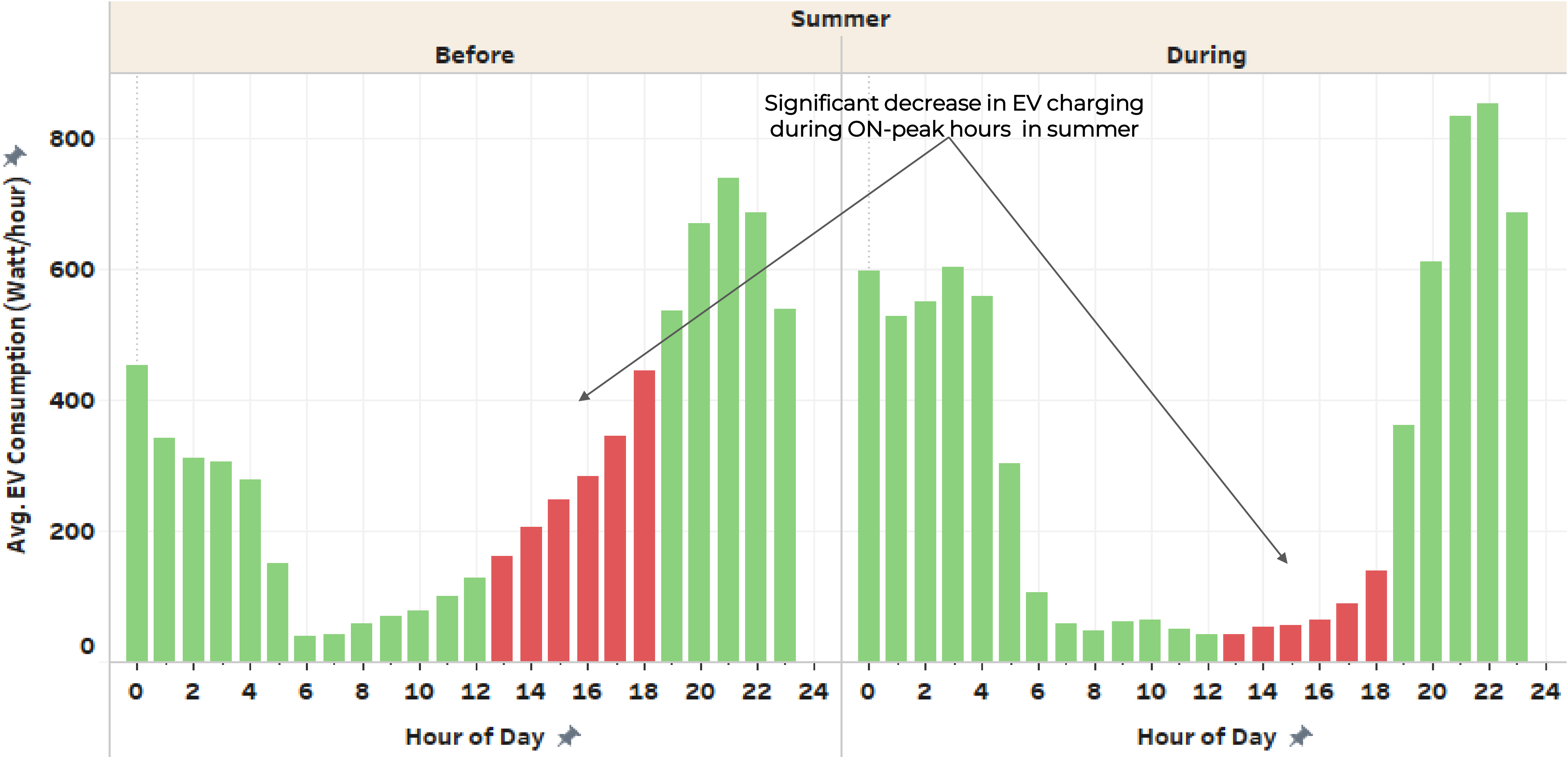
Strike system to motivate change

Motivate EV Charging at non-peak hours by monitoring and alerting customers when they charge at peak times followed by a monthly performance summary



1. REINFORCE REWARD AND POSITIVE BEHAVIOUR
1. EXPLICIT CALL OUT TO ACTION

Case Study

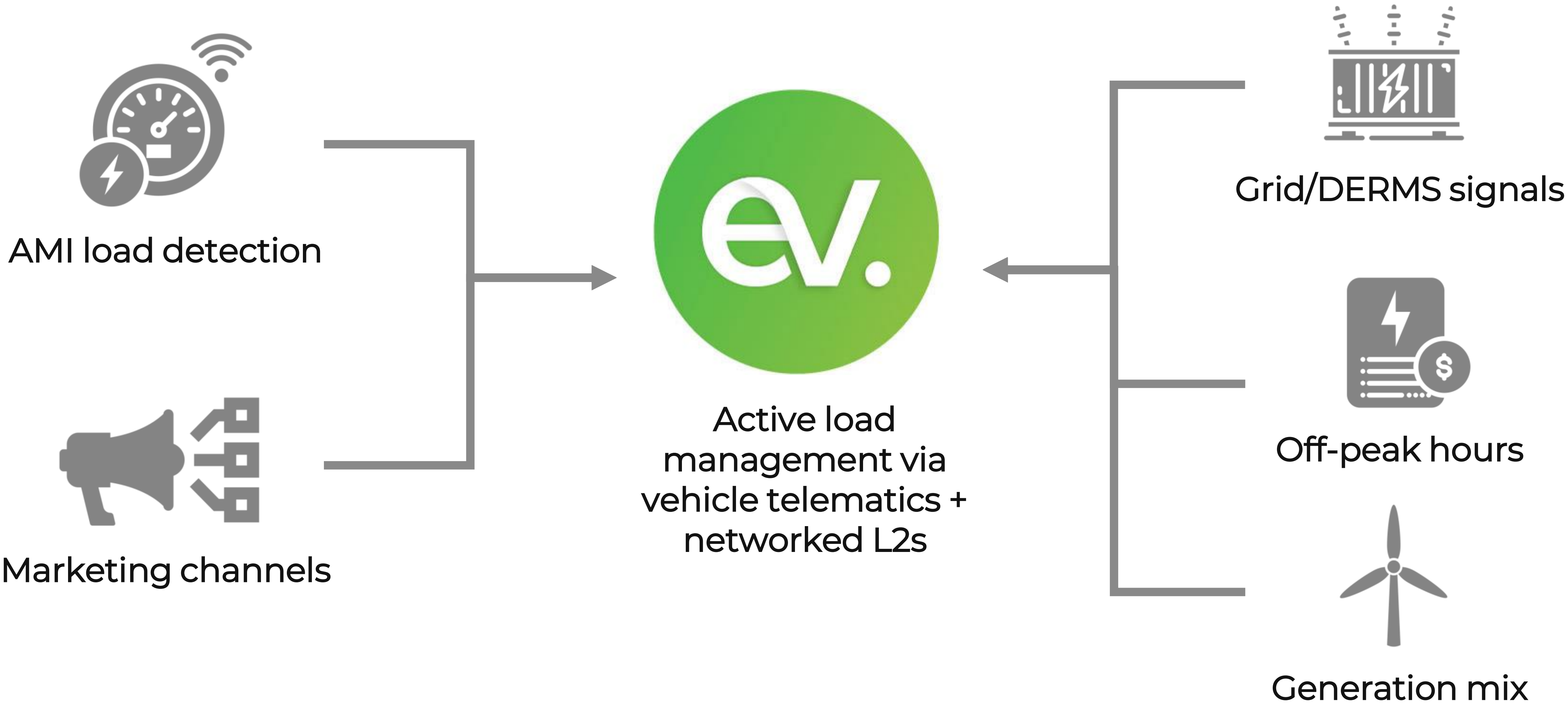

Summer
Before
During
Significant decrease in EV charging
during ON-peak hours in summer
Avg. EV Consumption (Watt/hour)
800
600
400
200
0
0 2 4 6 8 10 12 14 16 18 20 22 24
0 2 4 6 8 10 12 14 16 18 20 22 24
Hour of Day
Hour of Day


ONBOARDING
Confirmation
Welcome
PROMOTING
Education
Motivation
ENGAGING
Cost Tracking
Best Rate
BEHAVIORAL LOAD SHIFTING
Demand Shifting
Flex Charging
Managed Charging Promotion
MANAGED CHARGING
ELECTRIC VEHICLE JOURNEY
App Onboarding
Charge Tracking
Flex Charging Auto-handle
Value of Managed EV
MANAGED CHARGING

ev.energy's software focuses on direct EV load control & active managed charging for 3 key reasons

1. Avoid the rebound timer peak
2. Deliver 2x the load curtailment of passive programs
3. Provide utilities continuous, real-time optimization against grid conditions

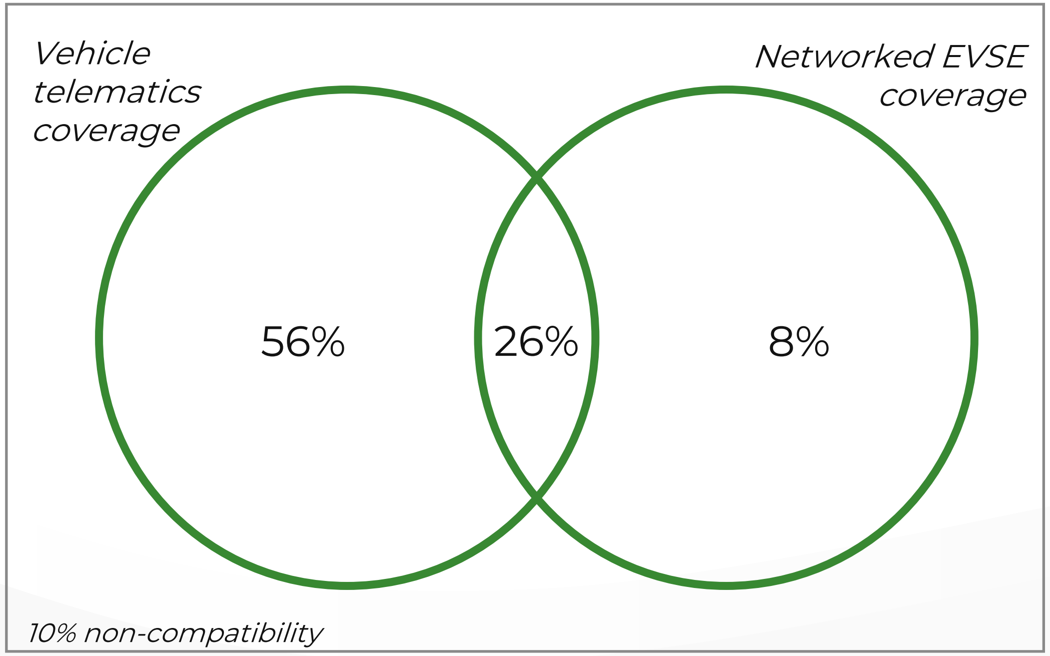
ev.energy enrolls customers, connects to their vehicle or charger, and manages EV charging according to utility/grid signals and customer needs



API COVERAGE

We maximize load control for utilities by connecting to both vehicles + EVSEs

APIs can control charging via the vehicle or EVSE– 90% customer coverage across the US



Source: Atlas EV Hub

Vehicle telematics

Tesla, Volkswagen, Jaguar, Land Rover, Ford, BMW, MINI, Audi, Chevrolet, Chrysler, Nissan, Hyundai, Volvo, Cadillac

Plus networked EVSEs

enel x, chargepoint, SemaConnect, Siemens, Smartenit, OCPP

5 utility use cases for ev.energy's software

Passive managed charging

Virtual time-of-use with off-peak rebates

nationalgrid

Active load-shifting

Actively shifting EV load to off-peak hours

MGE Madison Gas and Electric

Demand response

Actively curtailing load in response to dispatches

Southern Company

Local network optimization

Throttling charging on a local cluster of EVs

Ameren

Renewables alignment

Dynamically aligning EV load to green generation

SOUTHERN CALIFORNIA EDISON

NARUC Innovation Webinar series

One Thursday each month, 3-4pm ET

All NARUC members and stakeholders are invited

Leveraging Distributed Energy Resource Capabilities through Transactive Energy

- April 21, 2022 | 3:00 - 4:00 PM Eastern

Spring / Summer webinar dates: May 19, June 16, July 14

Topics and more webinar information will be added soon!

https://www.naruc.org/cpi-1/innovation-webinars/

NARUC thanks the U.S. Department of Energy for its support of this series.