

CIDER Software Final Report

July 2026

CIDER Project Team: NRECA Research, Camus Energy, Emulate Energy



CAMUS
Zero Carbon Grid Orchestration

Camus Energy Final Deliverable Task 2 – Resilience Interface Development

CIDER – Community Integrated Distributed Energy Resilience
DE-FOA-2597 Topic 2: Automation Strategies for Rapid Energy Restoration

Camus Energy

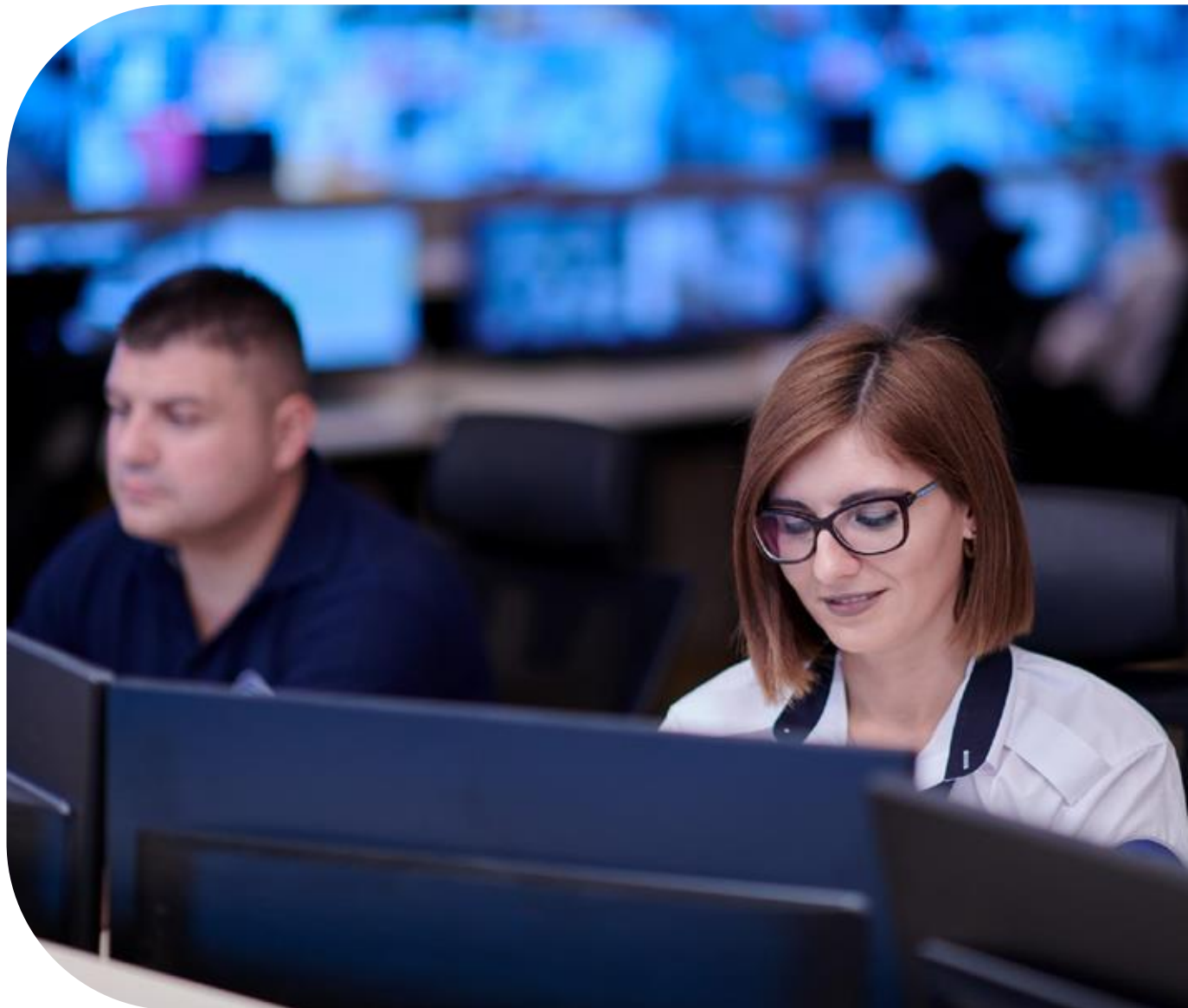
May 28, 2026

Utilities want to use DERs to save \$, boost resilience

Utilities are battling rising cost pressures and threats to resilience.

When actively managed, DERs can lower system-wide costs, reduce outages, and support faster, safer restoration, but **existing DER management systems (DERMS)** are **costly to implement** and **lack the grid awareness** needed to coordinate operation of DERs with traditional grid management.

To unlock cost savings and resilience benefits, **utilities, especially rural co-ops, need an affordable, scalable, and grid-aware approach to orchestrating DERs.**



The CIDER Team



Project lead, resilience analytics, and community outreach to understand how member resources can be harnessed to accelerate outage restoration



“Grid-aware” DERMS to enable monitoring and control of DERs with consideration for impacts on nearby grid equipment

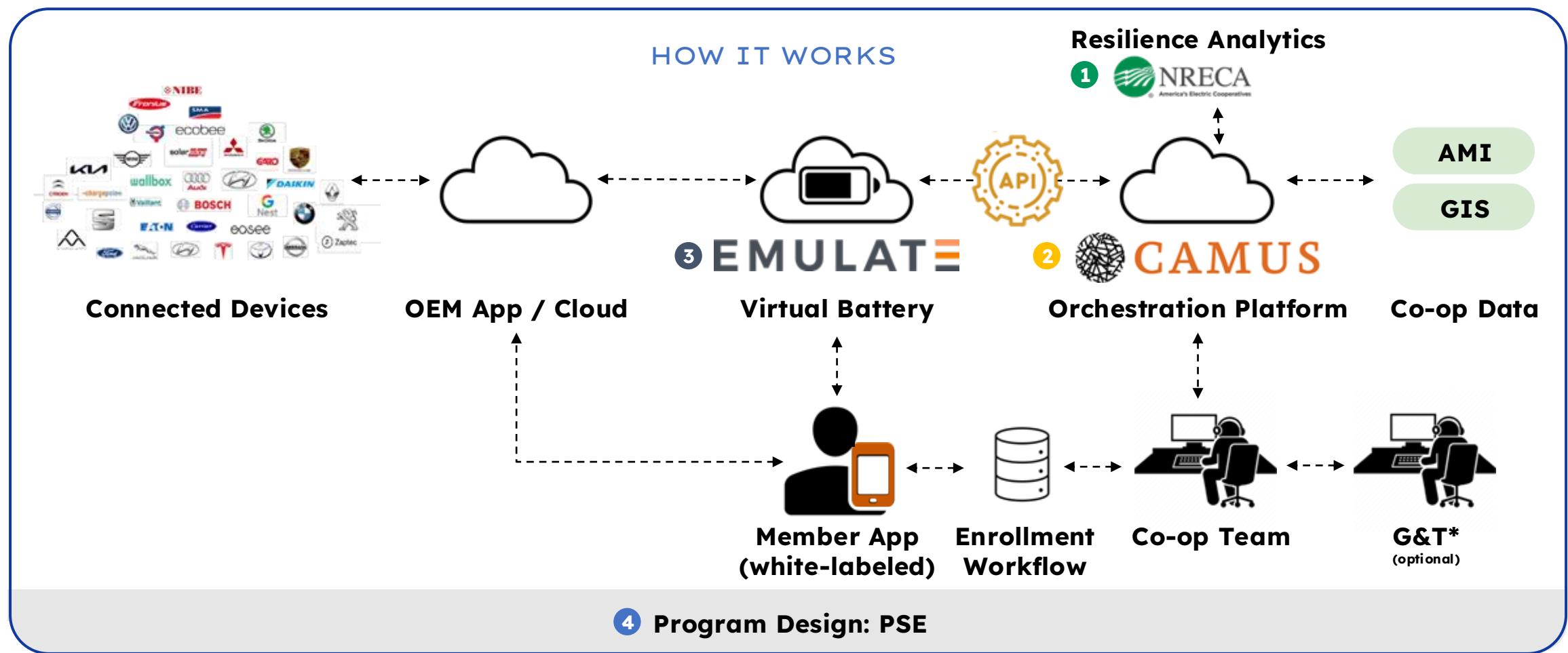


Home Energy Optimization software that quickly integrates member devices from multiple vendors into a DERMS as “virtual batteries” and enables members to optimize their home energy consumption



Program Design, working with the co-ops to identify, quantify and develop programs to increase DER adoption

Affordable, scalable, and grid-aware DER orchestration

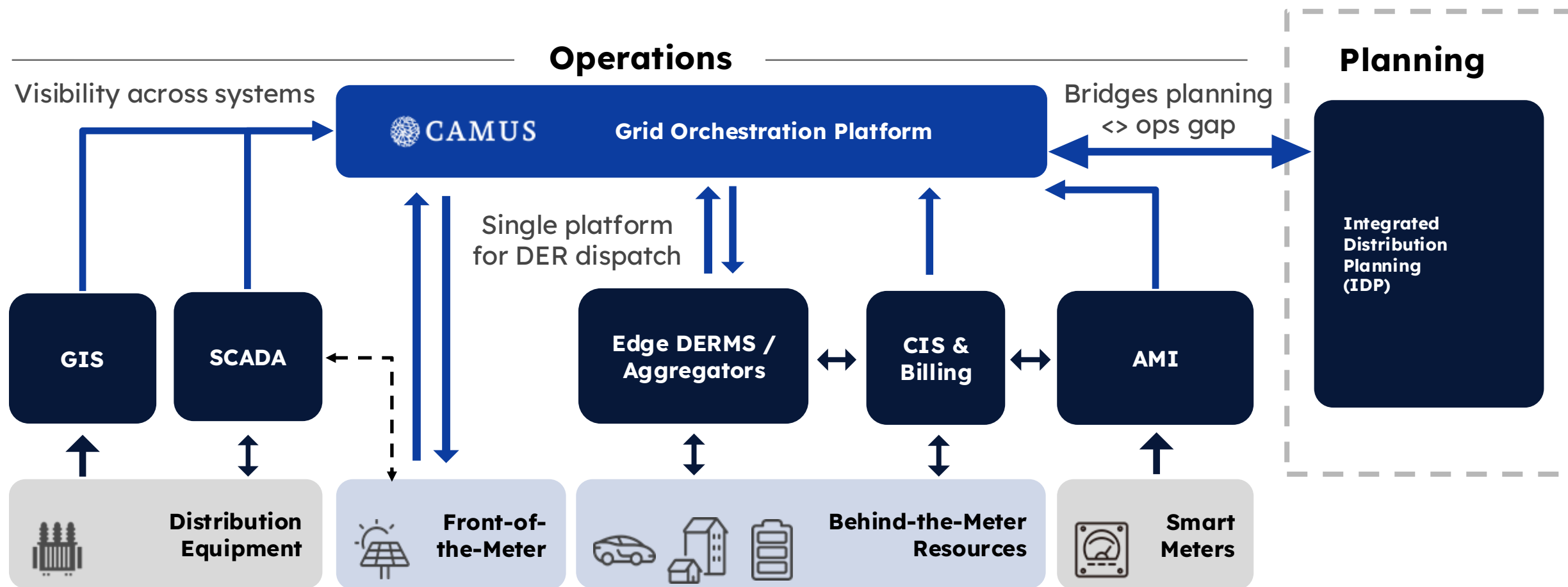


*Requires additional investment beyond grant funding

CIDER Project Task Overview

Task	Description	Lead
Task 1 – Restoration Toolchain Development	Under Task 1, tools will be developed to support the rapid development and deployment of new control schemes on the utility’s actual system in the midst of an emergent outage event.	NRECA
Task 2 – Resilience Interface Development	In this task, Camus Energy will lead the development of a Resilience Dashboard through a combination of real-time telemetry, modeled and forecasted demand and local generation with sub-feeder level of granularity.	Camus
Task 3 – VBAT and IoT Integration	Under this task, Emulate will lead the deployment of the aggregation platform by integrating it’s module into the existing app of the utility or when needed launch a standalone mobile application on Apple App Store and Google Play.	Emulate
Task 4 – Deployment, Measurement, and Verification	During this task, Camus Energy will deploy the Resilience Dashboard at up 5 geographically diverse utilities.	Camus
Task 5 – Outreach and User Growth	The outreach and user growth task will bring together cooperatives and community organizations to understand, improve upon, and disseminate best practices related to the technology developed in the project.	NRECA

A unified platform for grid insights, dispatch, & planning



Tackling key challenges for cooperative utilities via CIDER

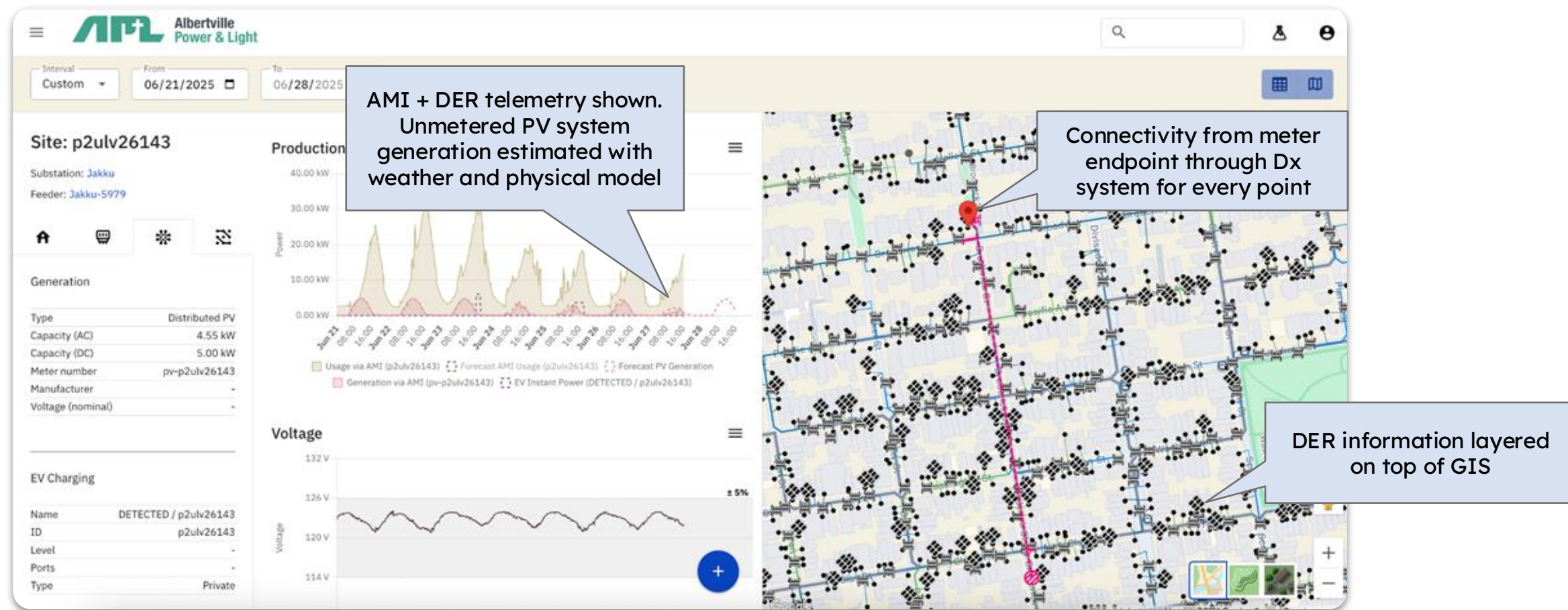
Grid Infrastructure Monitoring	Member & DER Management	Infrastructure Planning	Data Access & Intelligence
Monitor component loading (subs, feeders, xfmrs)	Detect under performing PV sites (to alert customers)	Model PV & EV adoption to assess long-term impacts	Provide unified GIS, AMI & DER data
Identify overloaded service transformers via AMI data	Disaggregate and simulate EV charging impacts	Benchmark feeders using DER and load indexes	Enable ad-hoc analysis in PowerBI, Tableau, etc.
Quickly identify data errors and collection gaps	Dispatch aggregate DERs to reduce demand charges	Run “what if” analyses for large loads and DERs*	Enable non-engineers to work with grid data

Co-ops must better understand how new loads and member resources are impacting their grids; the CIDER program provides a foundational platform for monitoring, analyzing, and managing these impacts.

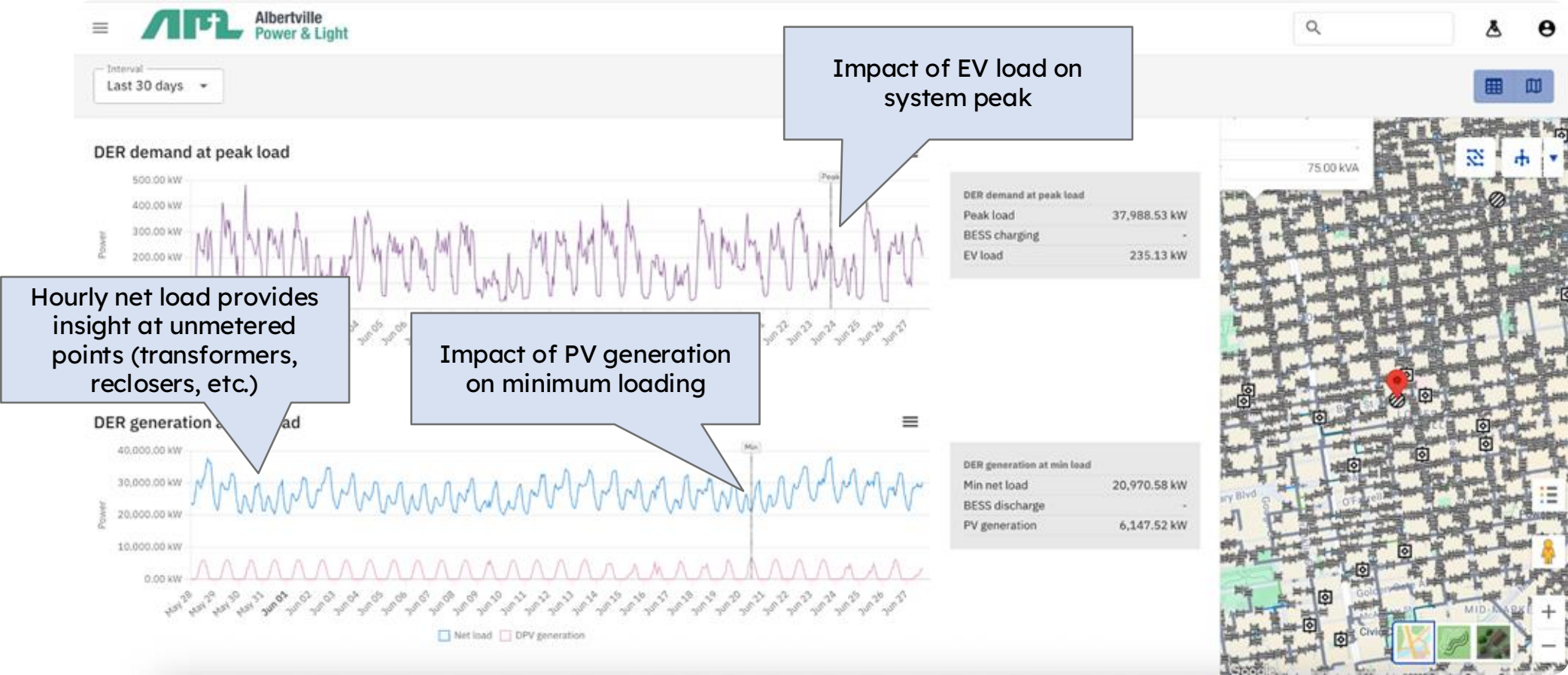
Task 2: Resilience Interface Deployment

Milestone	Description	Due Date	Status
M2.1 Requirements & Specifications	Requirements and Specifications - In this task, Camus Energy will scope devices and tools necessary for data integration and successful outcomes for the utility partner. This will include significant engagement across the utility partners' organization including the IT team, member engagement, operations, and engineering. This milestone will result in documentation of data integration plan, initial dashboard design and deployment, and engineering work plan.	Q1 (Sep. 2023)	Completed
M2.2 Alpha Version	Deploy initial configuration of Camus's real-time intelligence platform including integration of initial set of utility AMI/SCADA/GIS and customer facing data. We will select test feeders from two initial utilities for resilience pilot planning based on availability of smart meter, customer-facing DERs, and potential outage risk.	Q3 (Mar. 2024)	Completed
M2.3 Beta Version	The beta version of the software will provide a resilience dashboard quantifying flexible and critical load selected pilot feeders and release to key stakeholders for testing.	Q4 (Jun. 2024)	Completed
M2.4 Final Version	The final Resilience Dashboard will integrate into Camus's situational awareness platform and include visualization of flexible and critical loads across the systems for two pilot utilities.	Q8 (Jun. 2025)	Completed
M2.5 Adjustment to Customer Feedback	Fine tune based on quality assurance and engagement with utility customers and community partners.	Q12 (Jun. 2026)	Completed

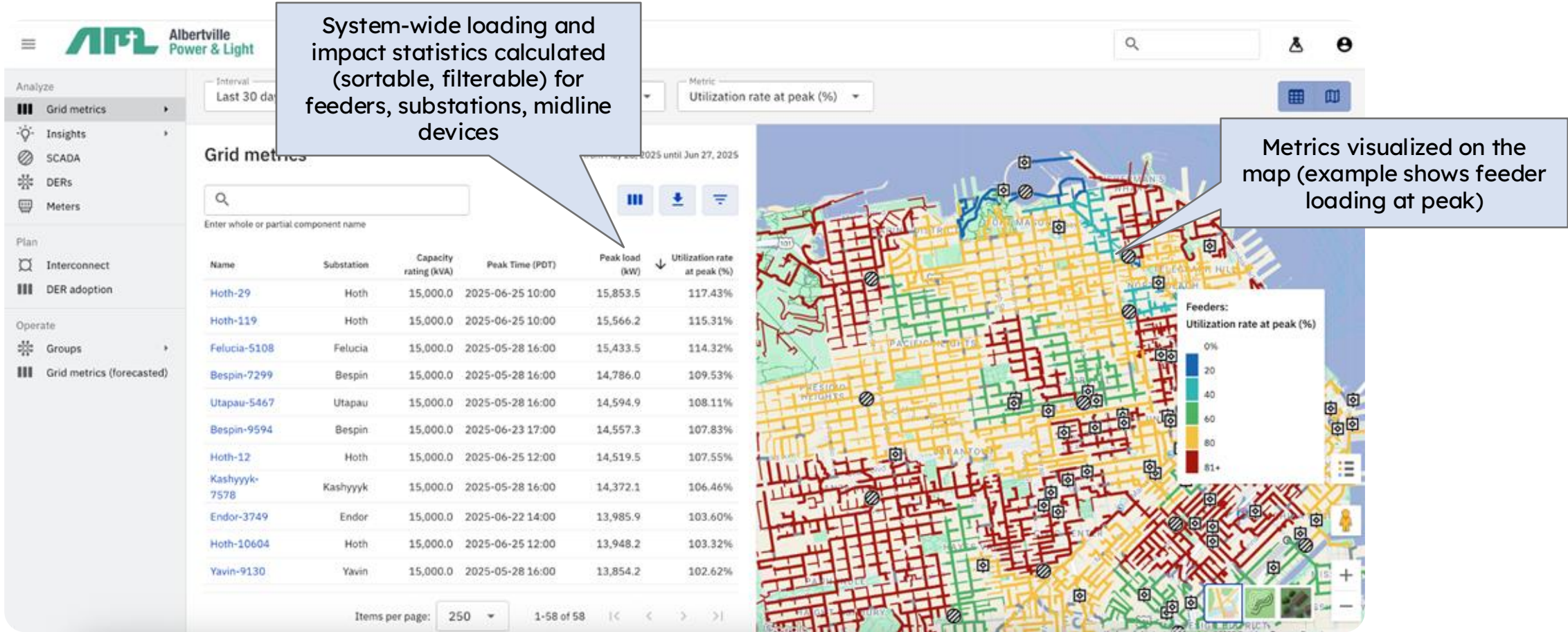
Camus combines time series, geospatial, and connectivity data



Time series (AMI) data is aggregated to every point in the system



System-wide metrics are rapidly visualized on a network map



Simple scheduling interface for consumer DERs (via Emulate)

Albertville
Power & Light

Search

Profile

Settings

Analyze

- Grid metrics
- Insights
- SCADA
- DERs
- Meters

Plan

- Interconnect
- DER adoption

Operate

- Groups
- Grid metrics (forecasted)

Groups /

Emulate Thermostat Integration

Control mode

Controls off

Controls

Performance

Users enter event day, and start and end time

DERs are modeled as virtual batteries that can be discharged

Change control mode

Temporary Schedule

	Date	Start time (PDT)	End time (PDT)	Energy (kWh)		
0	6/30/2025	2:00 PM	4:00 PM	-20.00		
1	7/1/2025	3:00 PM	5:00 PM	-20.00		

+ Add Waypoint

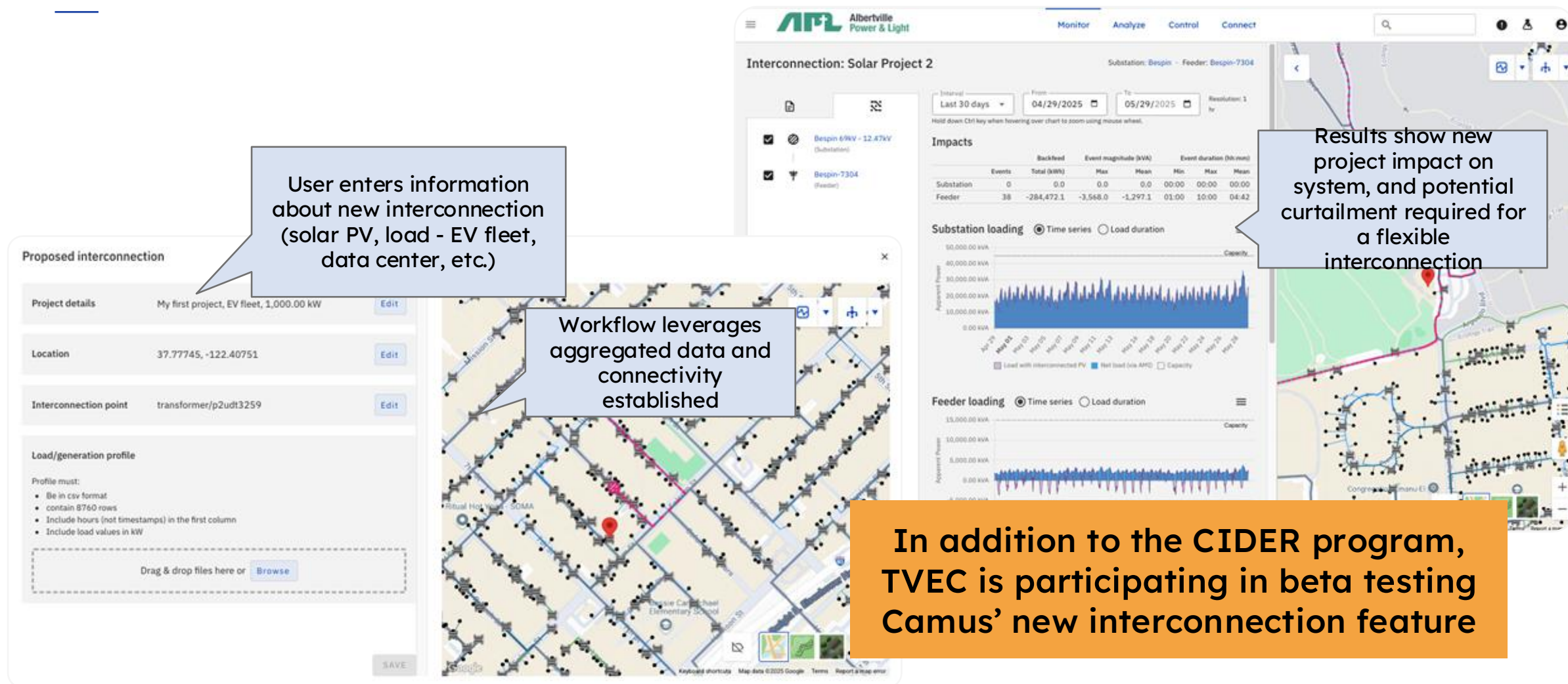
Upon schedule expiration, group will revert to:

☒ Controls off: All group members will enter "local" control mode and will not receive commands from Camus.

CANCEL AND SET NO SCHEDULE

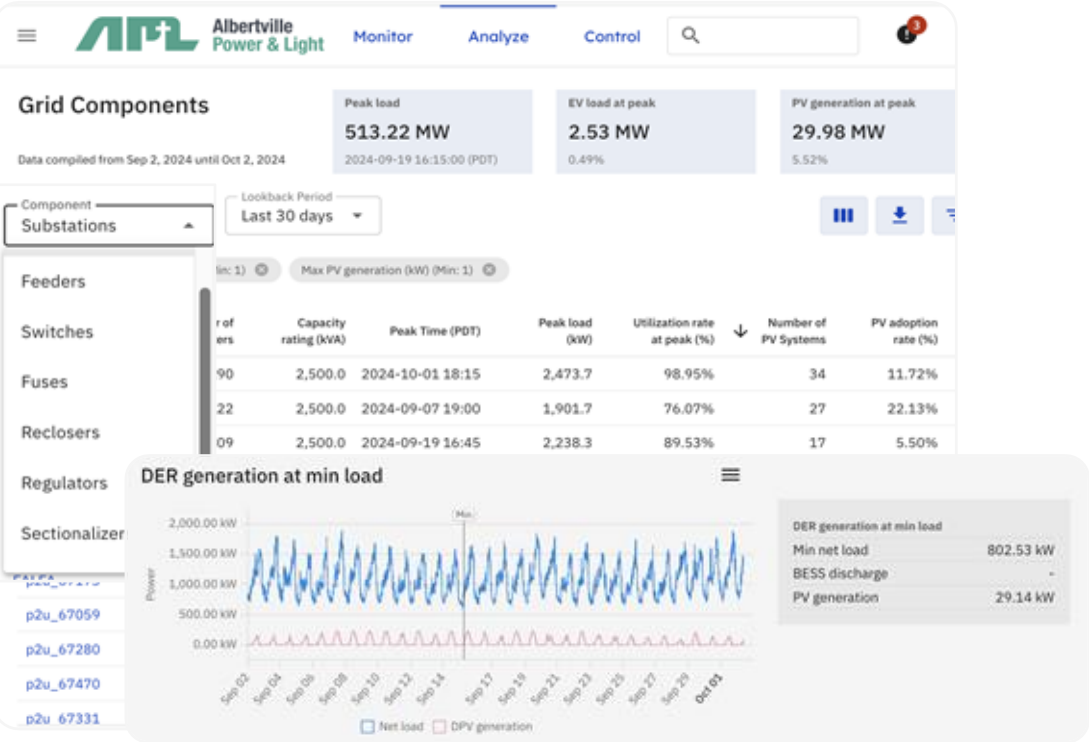
SET CONTROLS

Rapid assessment of flexible grid connections (solar, large loads)

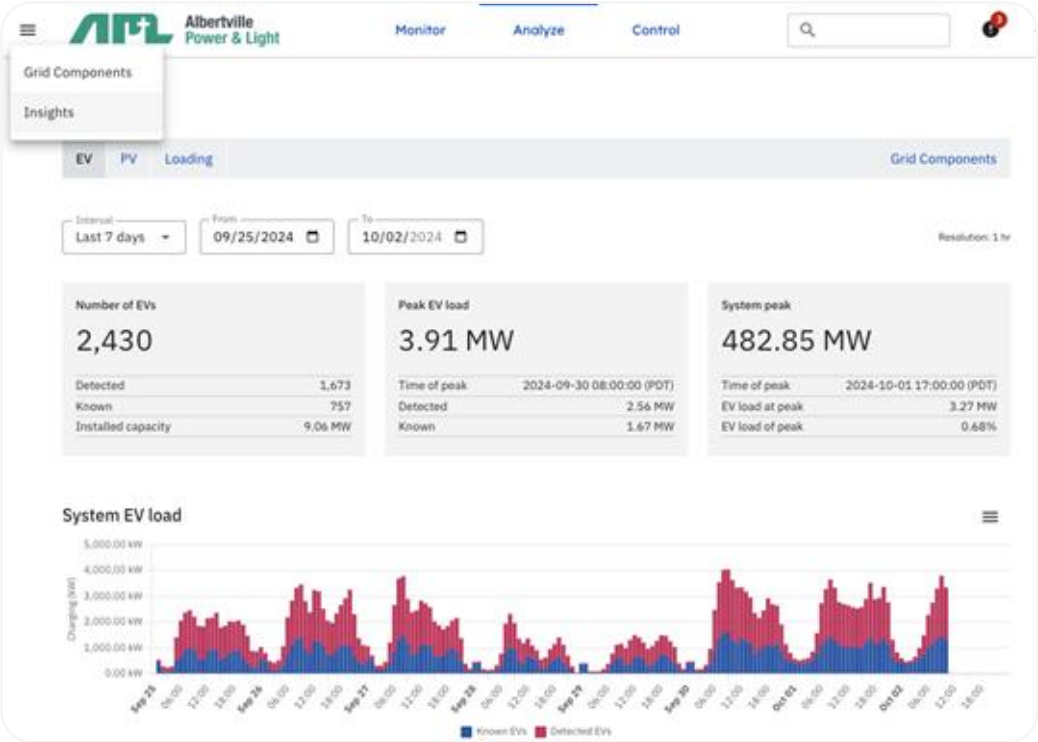


Full feeder connectivity and DER impact dashboards

- #1) Developed & deployed algorithm to establish full feeder connectivity based on GIS.**
- Enables loading & DER impact features for midline devices.
 - Deployed to CIDER phase 1 customers.
 - Now live for CIDER customers.



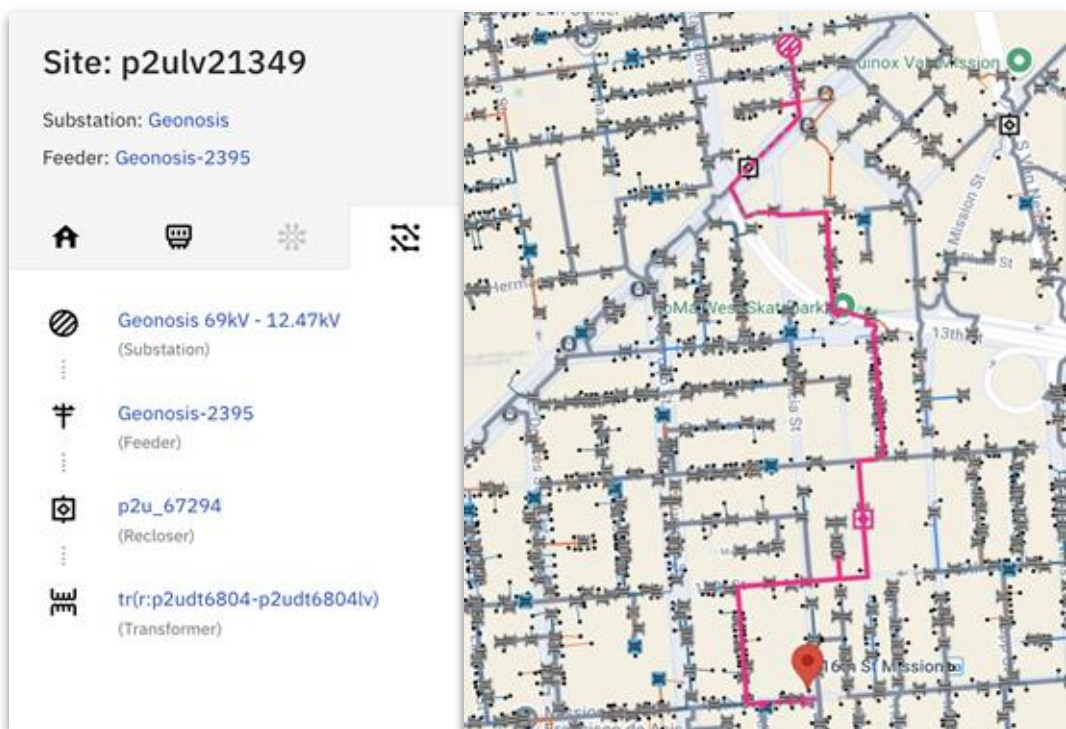
- #2) Developed insights dashboards for EV, PV, and loading to summarize grid impacts in digestible format.**
- Enables summary view of DERs and loading.
 - Validated in the Camus demo environment.
 - Now live for CIDER customers.



Feeder connectivity and voltage-violation visibility

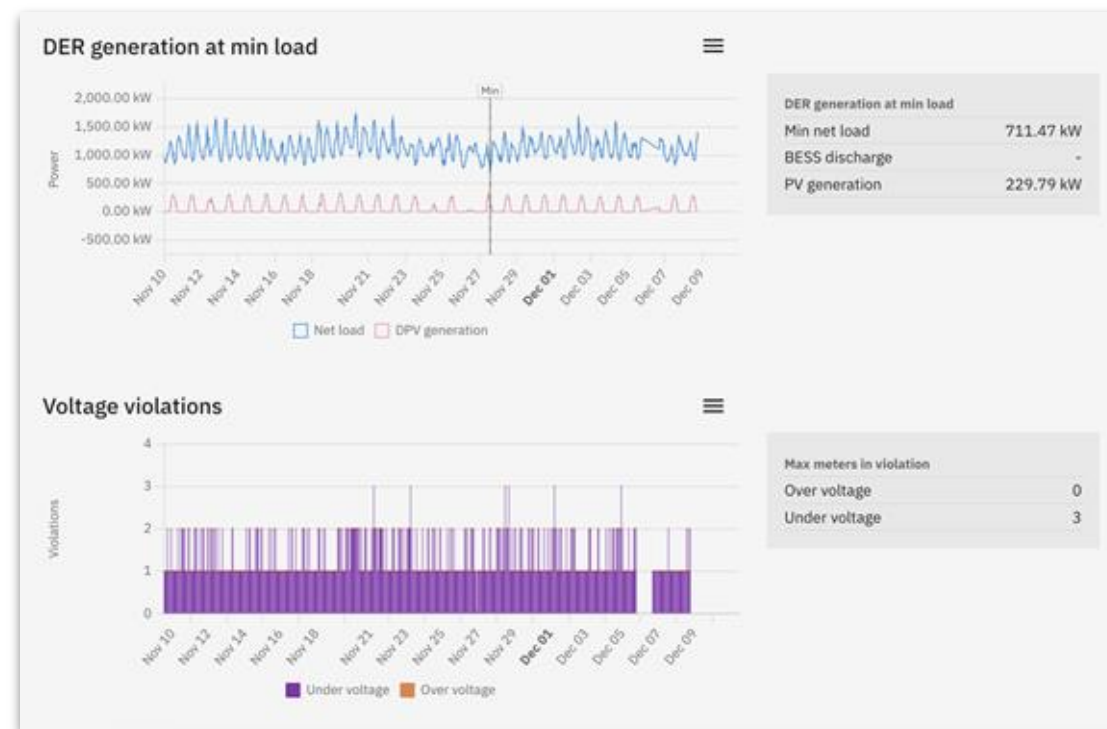
#1) Feeder connectivity visualization

- Map shows path from meter end point to substation, through feeder and midline devices; site left panel tab shows tabular view of upline devices
- Deployed for customers with connectivity established through GIS (Tipmont, Flathead)



#2) Voltage violation visualization

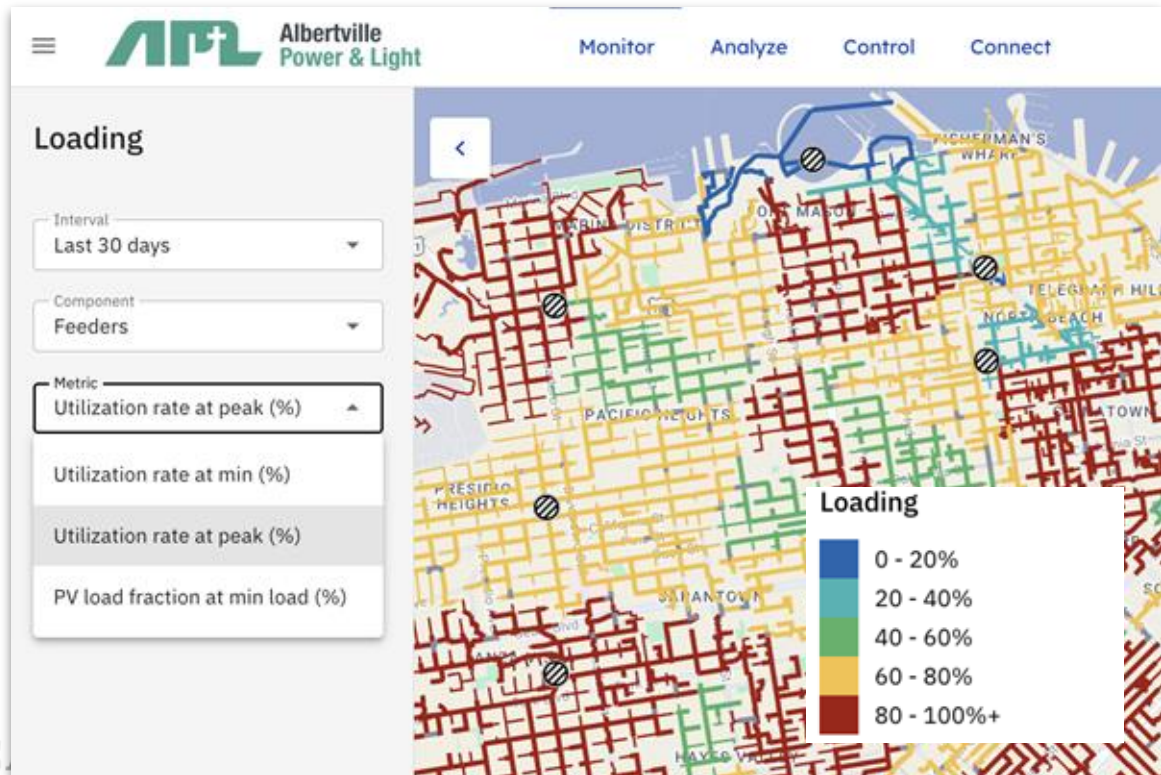
- New chart shows number of meters with over and/or under voltage violations (± 0.05 p.u) for each component (substation, feeder, transformer, etc.)
- Deployed for CIDER customers with voltage data ingested



System-wide feeder loading and voltage analytics

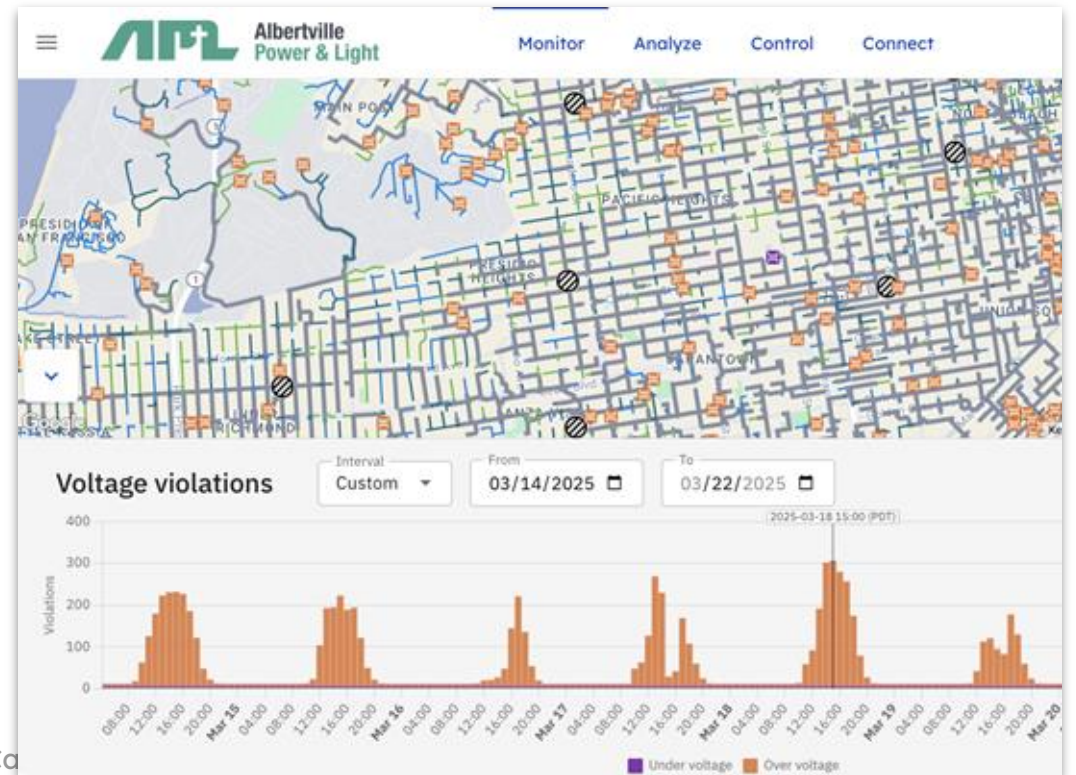
#1) Feeder loading visualization

- Map layer showing loading of feeders over last 30 days or 12 months; metrics include utilization rate at peak and min, and PV load fraction at min load.
- Allows users to visualize system loading ahead of interconnection workflows for EV and PV



#2) System wide voltage violations

- Meter level voltage violations aggregated in each hour across system and shown on time series chart. Transformers with meters over 1.05 p.u. and under 0.95 p.u highlighted on map.
- Allows users to find areas with voltage issues, and understand voltage violations over time.



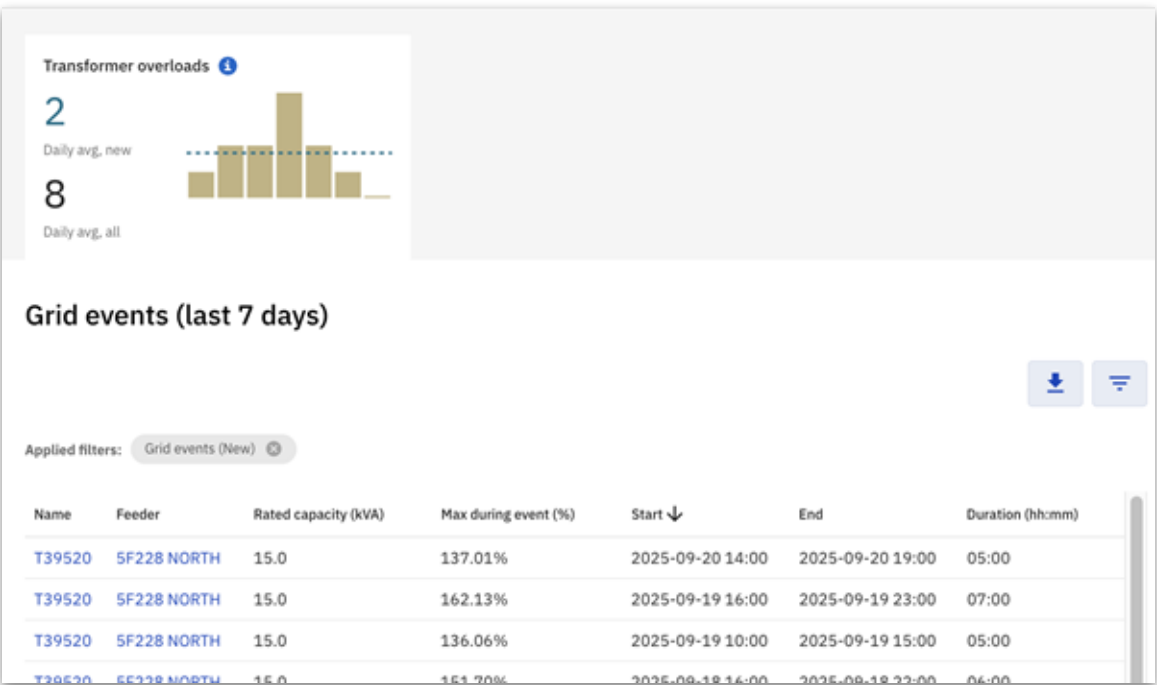
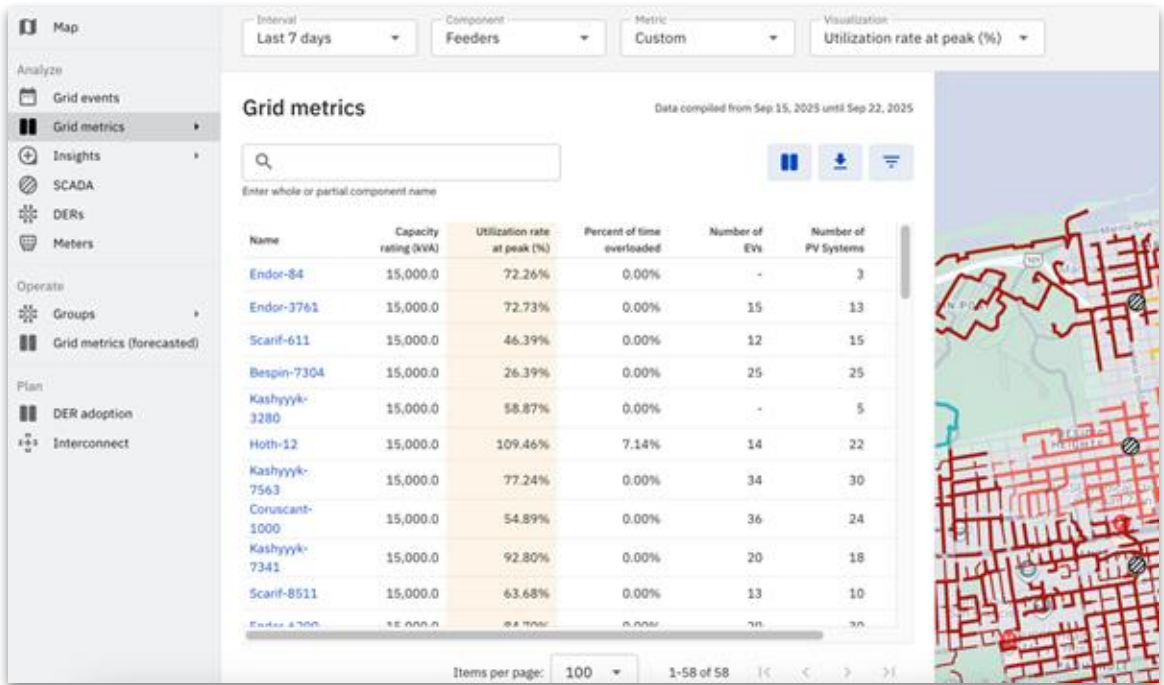
Job-oriented UI and grid events for transformer issues

#1) Deployed new UI, with more intuitive navigation

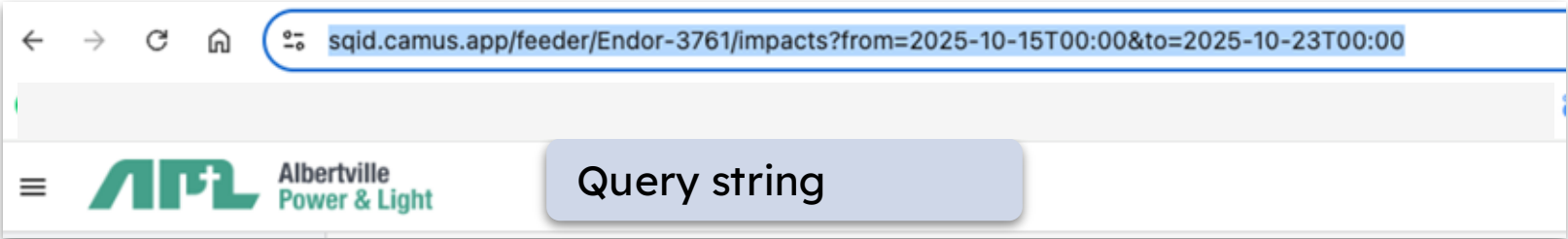
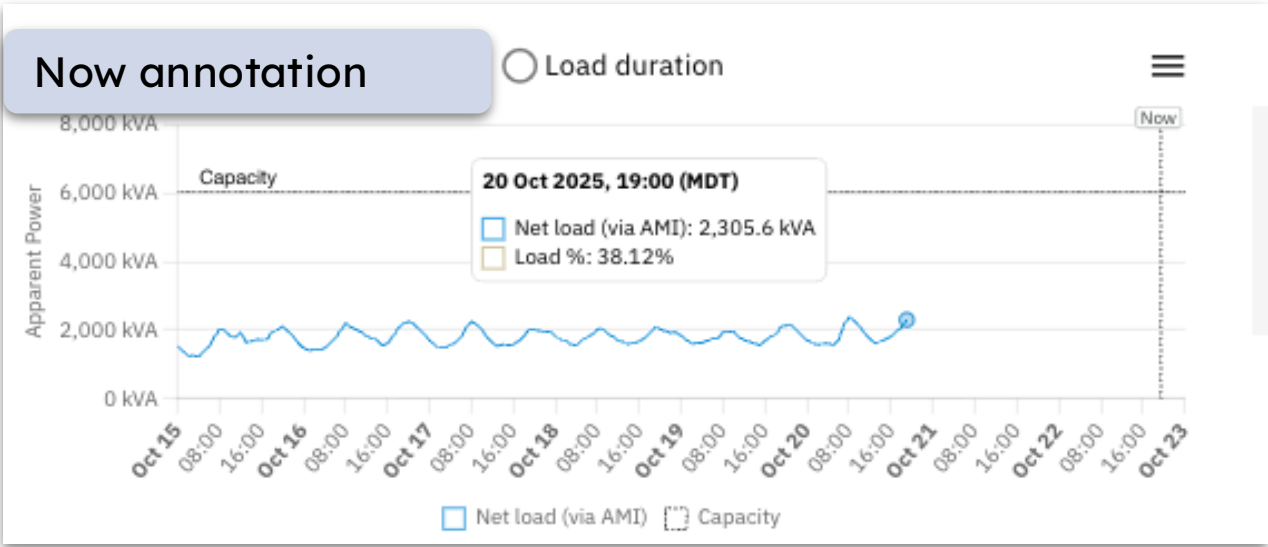
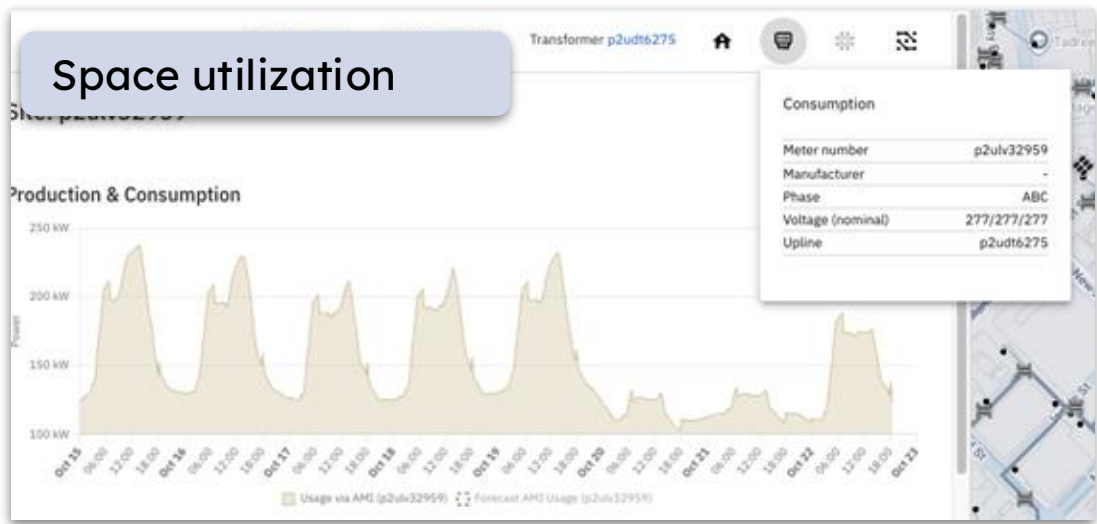
- Job oriented UI organized into by time horizon; analyze (historic), operate (current/forecasted), plan (future)
- Combined tabular and map visualization of grid-impact data

#2) Grid events for enhanced transformer loading analytics

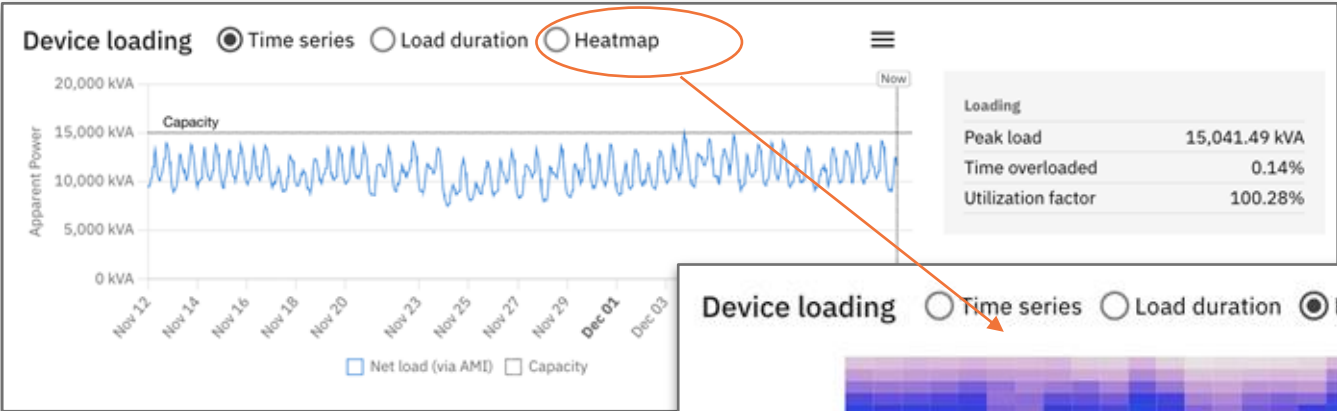
- Combines overloading severity and duration into trackable events that are flagged
- Includes filter for new events, de-emphasizing recurring events due to data issues.



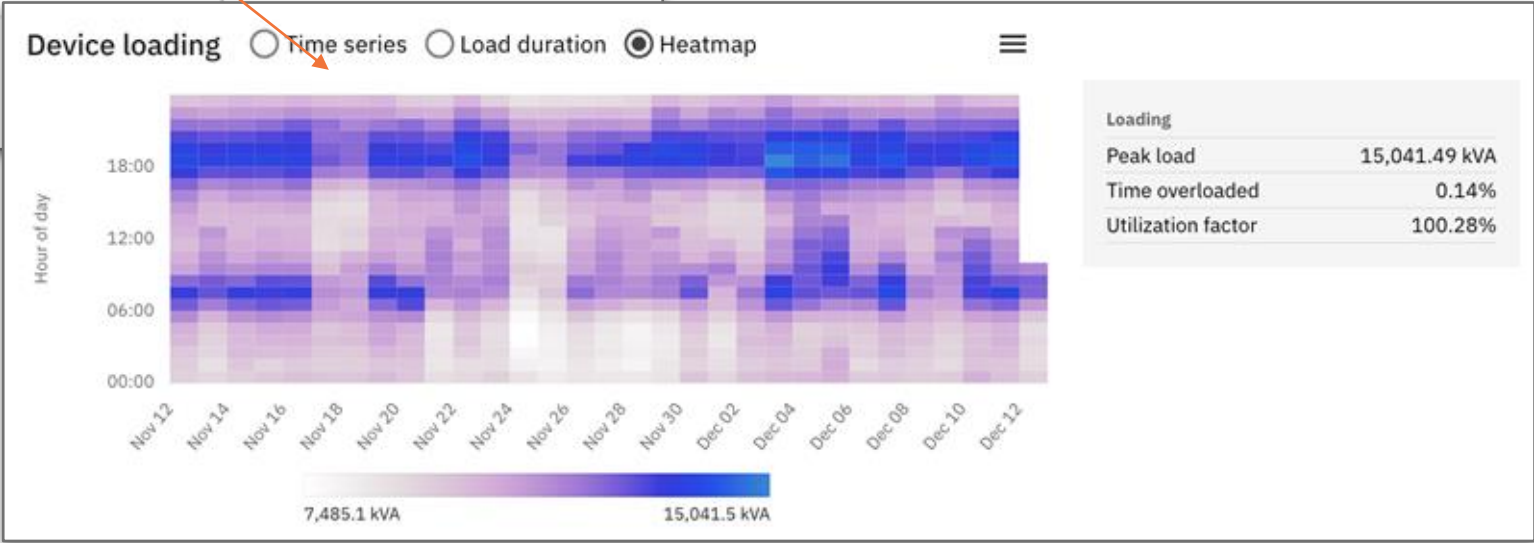
Usability enhancements



Loading heatmaps for hourly and seasonal patterns

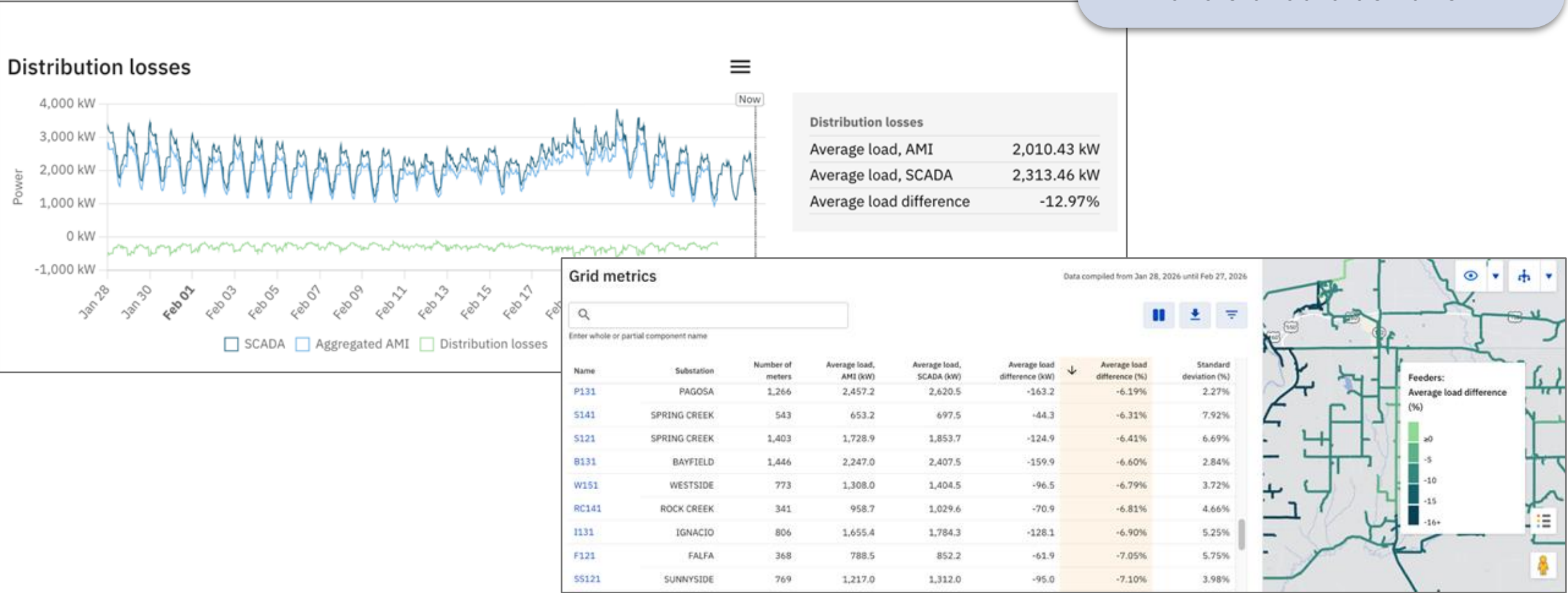


New toggle for device loading charts allow users to view data in hour by day grid to more easily identify hourly and seasonal trends in data.



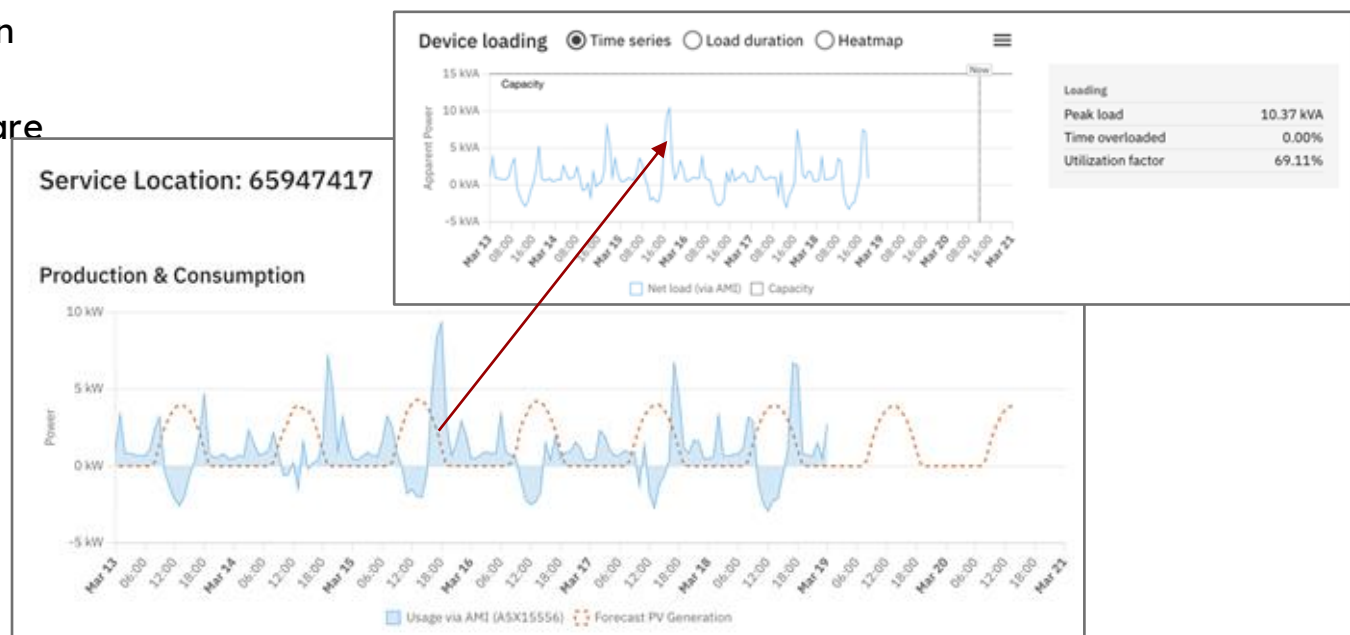
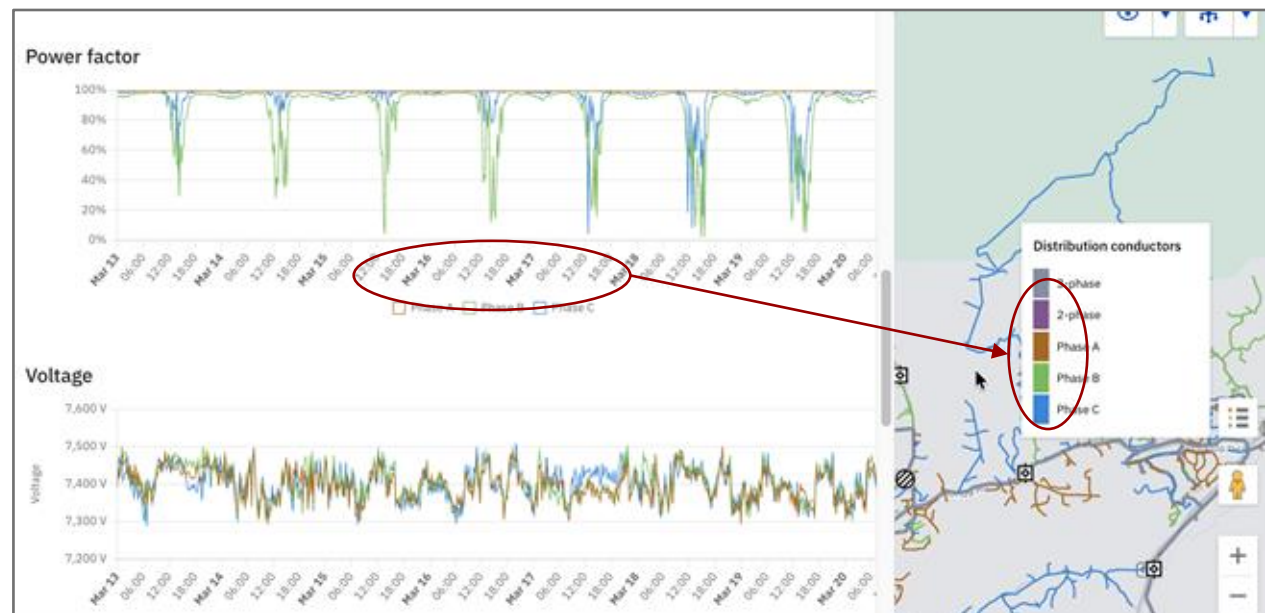
Distribution losses (SCADA vs AMI)

Allows users to view difference between SCADA and AMI at feeders & substations and filter based on average difference and standard deviation



Usability Enhancements

- **Impacts tab**
 - Decimation for faster chart performance
 - AMI aggregation time series only shown for hours with 80% or more of meters reporting data (aligning with grid metrics table)
- **Grid metrics table**
 - The csv download now only the columns visible in the table.
 - The filters for those columns visible in the table are shown at the top of the filter menu.
 - The number of meters column is now shown by default as this is a frequently used value.
 - The sorting now always sorts blank values last (whether ascending or descending).
- **Color updates**
 - Various updates to chart colors for consistency throughout the platform

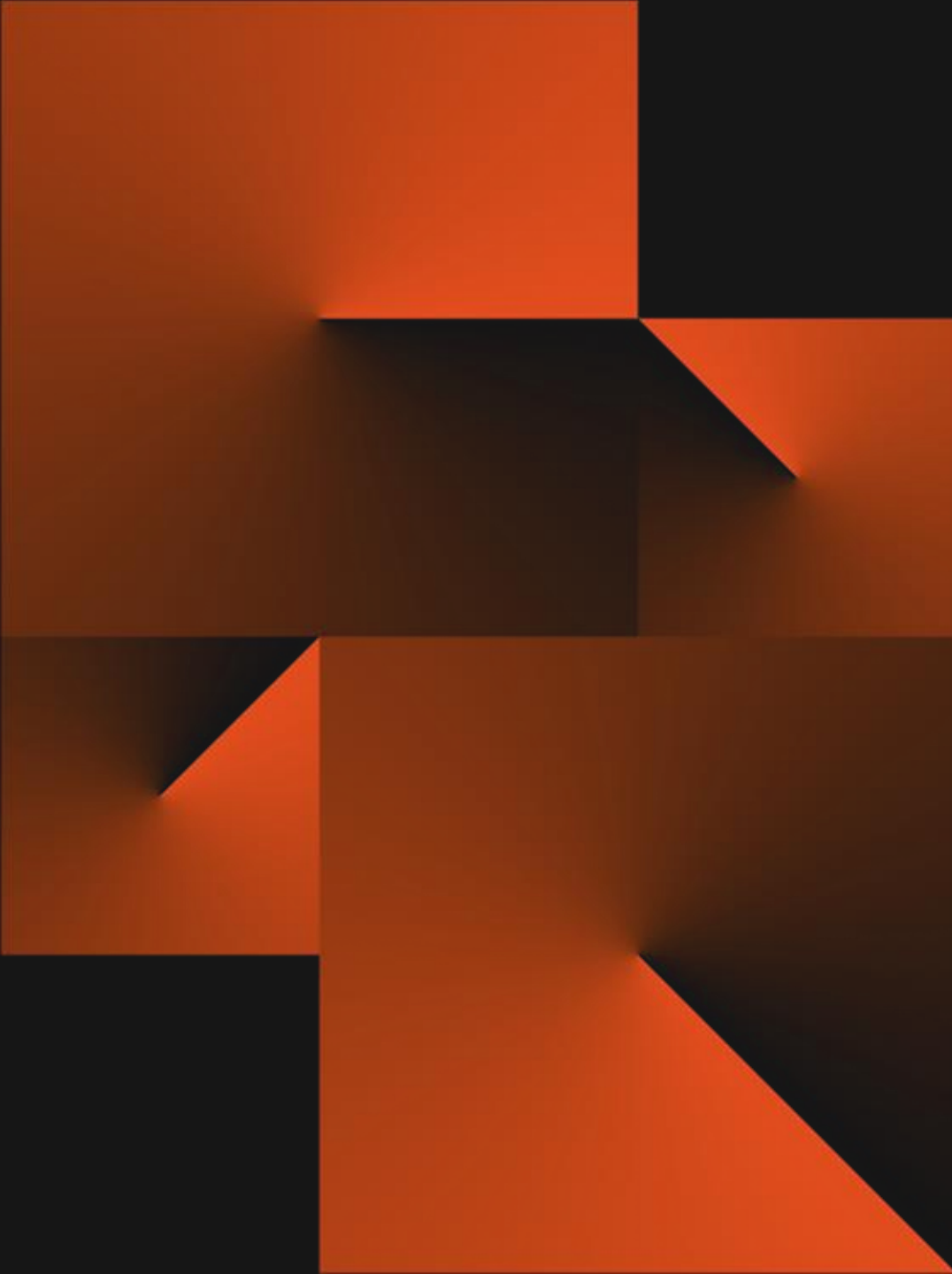


Usability enhancements pt. 2

- New date picker with commonly used date ranges available in drop down
- Persistence for time series selected/visible in charts
- Year added to timestamp of time series data charts
- Consolidated search field
- Date persistence for site left panel
- BESS manufacturer surfaced in site left panel
- Meter voltage by phase shown in site left panel
- Temporary schedule fallback for controls
- Downline meters and stats added to component details for all components except feeders and substations
- Control key to zoom on charts
- Communication status surfaced for controllable devices (ChargePoint only)

What the CIDER program and DOE funding built

- CIDER and DOE funding paid for grid-aware capabilities that did not exist in the platform before this project
- Full feeder connectivity algorithm and hierarchical AMI aggregation to unmetered points (transformers, reclosers, midline devices)
- Grid awareness suite: feeder loading, voltage-violation visualization, grid events, loading heatmaps, and distribution losses
- DER controls and scheduling through the Emulate virtual battery integration
- Secure data warehouse for sharing standardized DER data with NRECA researchers
- Job-oriented UI organized by analyze, operate, and plan



Emulate

CIDER Software Final Report

Deliverables: Task 3 – VBat and IoT Integration

Prepared for the U.S. Department of Energy

DERMS Has Been Too Costly and Complex for Co-ops to Adopt

- Historically, enterprise DERMS has been almost impossible for smaller co-ops to procure, integrate, and sustain.
- The CIDER Project is designed to overcome a variety of technical and financial barriers.

Limited Scale

Fewer meters over which to spread fixed implementation costs

Staff Constraints

Small teams with limited bandwidth for multi-vendor coordination

OEM Fragmentation

Different devices, APIs, app experiences and service models

Unclear Economics

Difficult to quantify avoided demand costs before launch

IT Integration Burden

Enrollment, messaging, billing and incentive workflows must fit existing CIS systems

CIDER

Run DERMS with minimal OEM overhead, leveraging the NISC infrastructure for customer acquisition and enrollment

Why this matters: Leveraging NISC's IT infrastructure provides an avenue for marketing and customer recruitment. An automated Home Energy Management optimizer lets co-ops roll out cost-reflective tariffs that cut consumer bills automatically, always within comfort. Together this democratizes DERMS for small US co-ops and reduces member bills

Yet DER Flexibility Is a Real, Untapped Source of Co-op Value

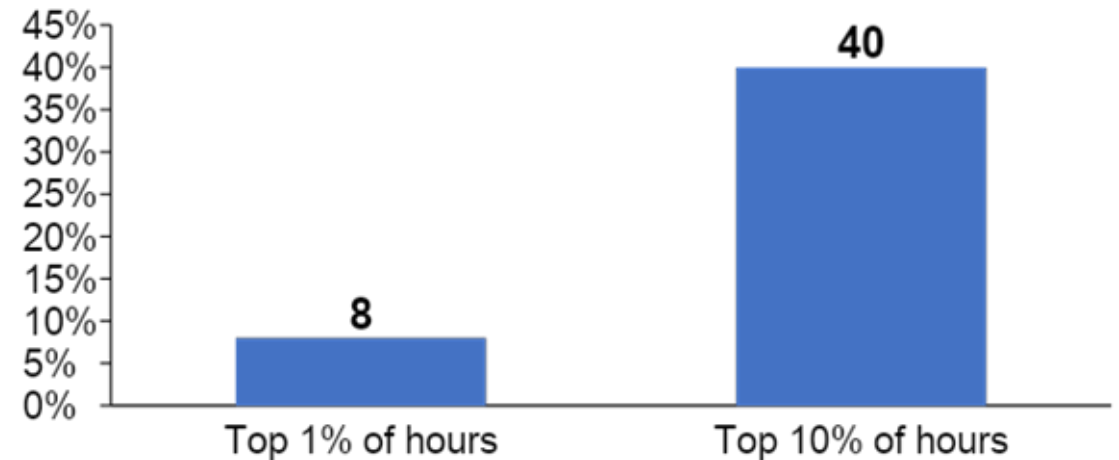
THE MECHANISM — DEMAND CHARGES

US distribution co-ops buy wholesale power in two parts: an energy charge (\$/kWh) and a demand charge (\$/kW) set by their peak demand.

Demand charges are the co-op's single largest controllable cost — commonly 30–50% of the wholesale power bill.

Cut the few hours that set the peak, and you cut the bill.

A few peak hours drive most of the cost



Sources: Holyoke G&E; Fayetteville PWC — demand $\approx$ 57% of a \$140M power bill. ERCOT 4CP $\approx$ \$80/kW-yr is one example; all co-ops face a coincident-peak charge.

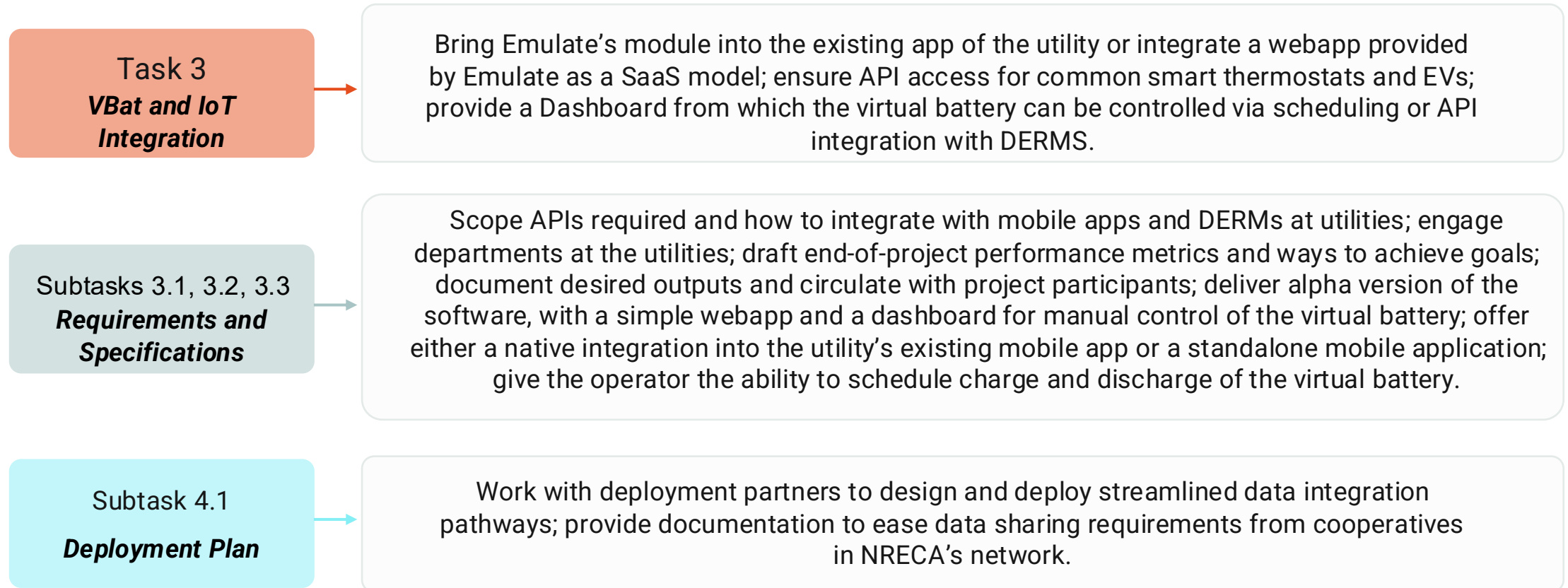
THE TAKEAWAY: There is clear value-creation potential for co-ops — but the blocker to widespread adoption is cost. For a small co-op, the cost of a DERMS is totally cost-prohibitive.

The CIDER Business Case: Operational Break-Even in Year One

The CIDER cost structure changes everything. DERMS providers typically contract OEMs to market, recruit members, and dispatch loads. CIDER instead lets the co-ops run marketing and customer acquisition on the NISC platform — a European-style acquisition model — with Emulate managing dispatch. Stripping out OEM overhead and fees drops the operational break-even to just a few hundred thermostats or ~30 BESS. That makes DERMS viable for the first time at co-op scale — CIDER democratizes DERMS for small US co-ops.

Per device / year	HVAC — Thermostat	BESS — Battery
Gross peak-shaving value	\$224	\$1,584
Co-op net (after all fees)	\$113	\$984
Member benefit (bill credit)	\$26 + \$50 one-time (Yr 1)	\$247 + \$1,000 one-time (Yr 1)
Breakeven (covers \$30k/yr fee)	~210 thermostats	~30 batteries

Our Approach in CIDER: Workstreams That Made DERMS Co-op-Ready



Co-ops Now Run the Entire DR Program Lifecycle In-House

The UDR portal gives a co-op everything it needs to design, dispatch, monitor and prove demand-response events in-house — no vendor in the loop.

1 Design any DR program in minutes

Define program type, eligible DER classes and target zones in the UI — five program types across 35 enrolled devices, no vendor build required.

2 Dispatch with feeder-level precision

Target events by program × DER type × grid zone — hundreds of combinations — so load relief lands exactly where the grid needs it.

3 Watch results live, mid-event

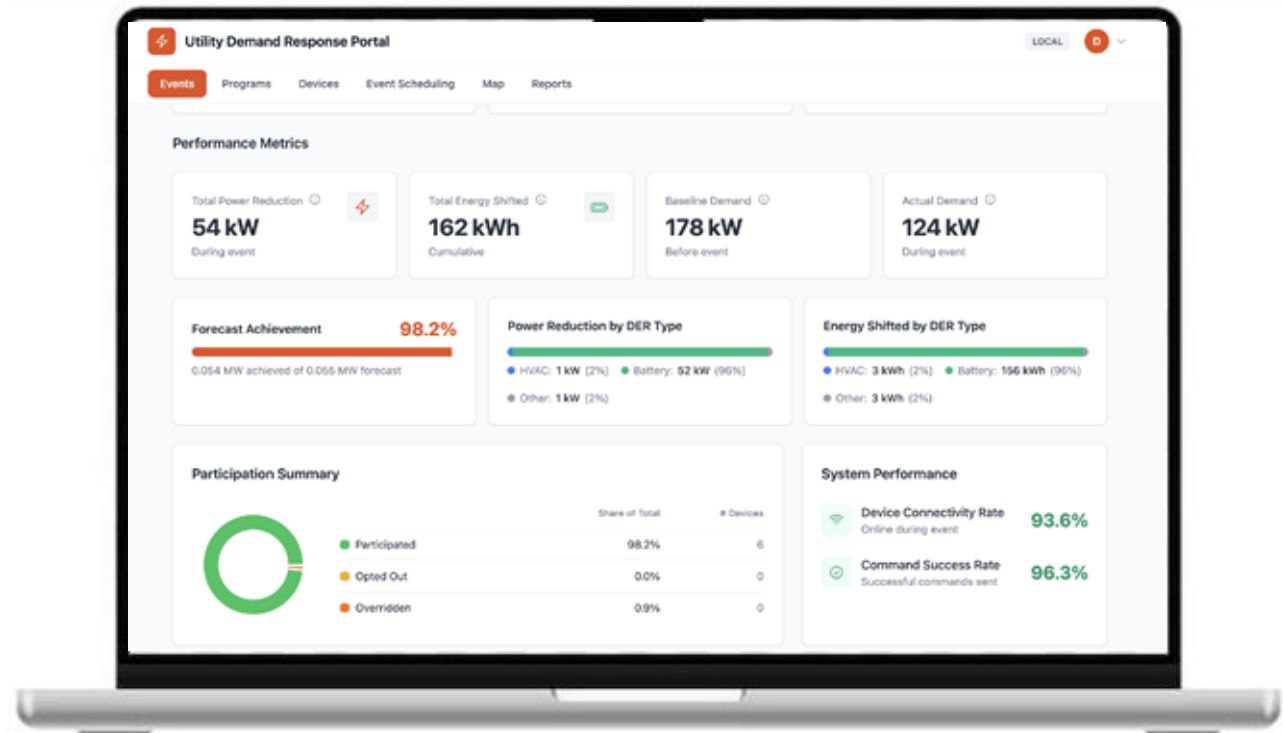
Real-time participation, power reduction and energy shifted, with metered baseline-vs-actual for every event as it runs.

4 Keep the whole fleet accounted for

Live online / offline status, setpoints and per-event participation across all 35 devices — issues surface before they cost performance.

5 Produce settlement-grade proof in one click

One-click CSV exports plus onboarding, error and M&V reports — audit-ready evidence for regulators and capacity-market settlement.



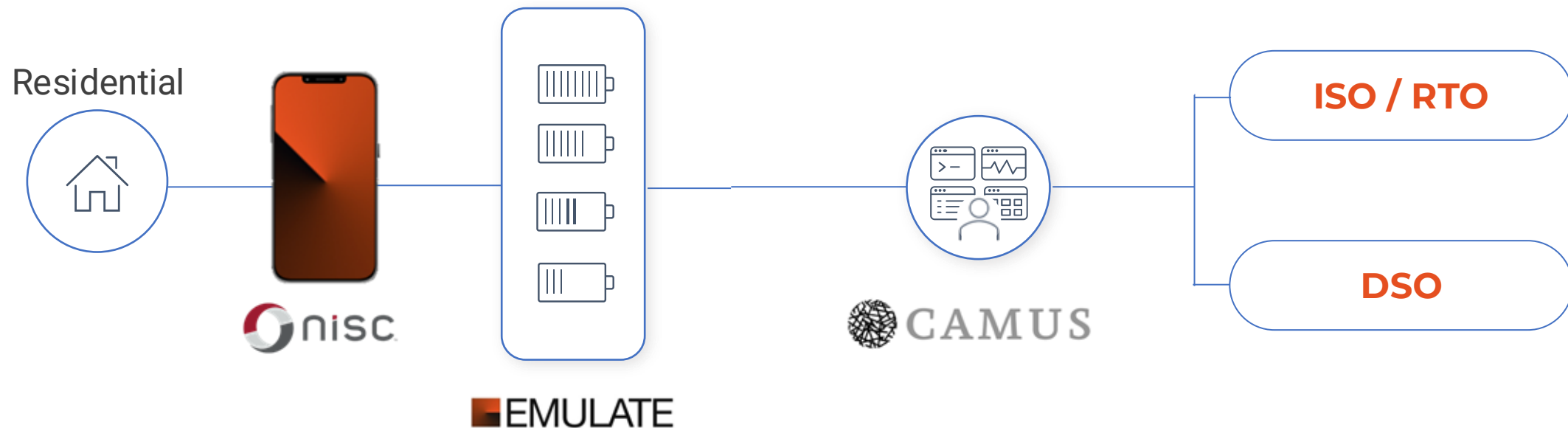
Emulate's Platform and Integration Points into NISC and Camus, proven in Europe, localized for Coop conditions

01 Residential devices connected and optimized

02 Creation of Emulate virtual batteries

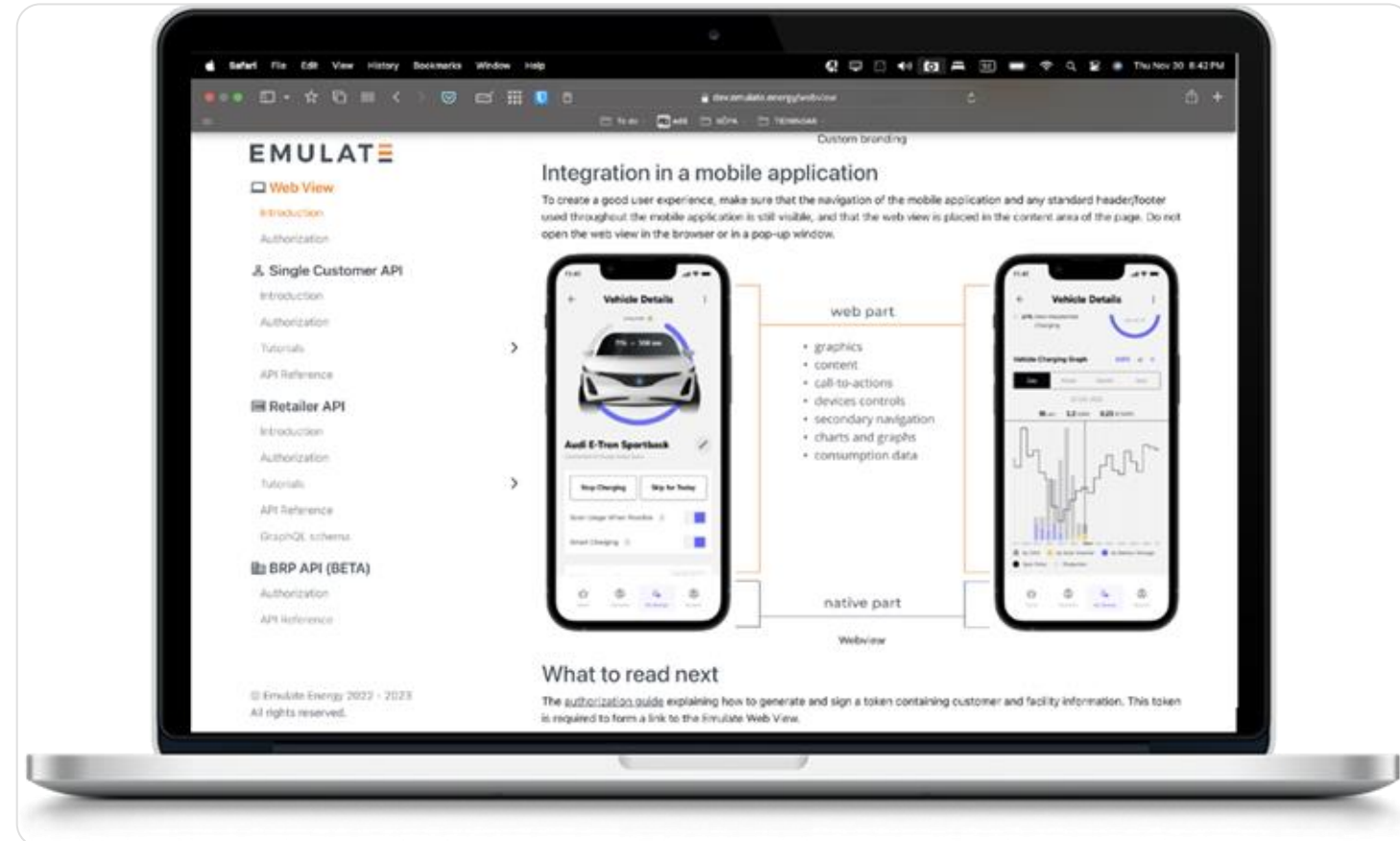
03 Virtual batteries plugged into DERMS / VPP

04 DERMS/VPP to maximize flexibility value across multiple markets



The Developer Portal Cuts Customer Support Costs That Slow Adoption

- Emulate upgraded its Developer Portal to provide improved user and device level diagnostics and insights.
- The Portal is a key factor in the ability to bring support costs for co-ops - a primary obstacle to DERMS adoption by co-ops: cost.



Enrollment Via NISC Smart Hub, Existing Infrastructure at 700 Coops

Today: Web-Based Enrollment

- End-users enroll via web form
- Member receives "Application received" notice
- Acceptance sent after NISC authentication

The form is titled "Smart Thermostat" and is divided into several sections: "Application Information" with fields for First Name, Last Name, Email Address, Account Number, Phone Number, and Customer Number; "Address Information" with fields for Street, City, State (a dropdown menu), Zip Code, Meter Number, and Service Location Number; "Thermostat Equipment Information" with a Manufacturer dropdown (options: Honeywell, Ecobee); and a "Documents" section with a "Choose File" button and a note about sample documents. A "Submit" button is at the bottom.

The page has a "Coop" header in an orange box. The title is "Application Received". The text says "Thank you for your application submission." and "Requested Date: 3/3/2025, 3:08 PM". The program is "AC Smart Thermostat". It lists the user's details: First Name: Blake, Last Name: Testerson IV, Street: 123 Easy Street, City: adsd, State: dasda, Zip Code: 1234124214, and Email Address: blake@emulate.energy.

The page has a "Coop" header in an orange box. The title is "Official Enrollment Notice". The text says "Enrollment in the Resource Program has been completed." and "Enrollment Date: 6/25/2025". The program is "AC Smart Thermostat". It lists the user's details: First Name: Ashley, Last Name: [redacted], Phone Number: [redacted], and Email Address: [redacted].

Future: Native Mobile Integration

- Smartphone-based enrollment via NISC app
- WebView integration for seamless UX
- Cloud-to-cloud vendor authorization

The screen shows a "Family Home" header with a lightning bolt icon. The title is "Add Your First Devices". The text says "Add your charging station, electric vehicle, heating & cooling system or other device to start saving money on your energy consumption." There are two buttons: "Add My EV" and "Add Other Device +1".

The screen shows a "Select a Device" header. The text says "Charge Your Vehicle Based on Optimal Energy Prices" and "Learn More". There is a search bar and a list of "Charging Station Brands" with options: Charge Amps, Charge Amps Down, Charge Amps Halo, Charge Amps Aura, DEXA, Easen, and Eaton.

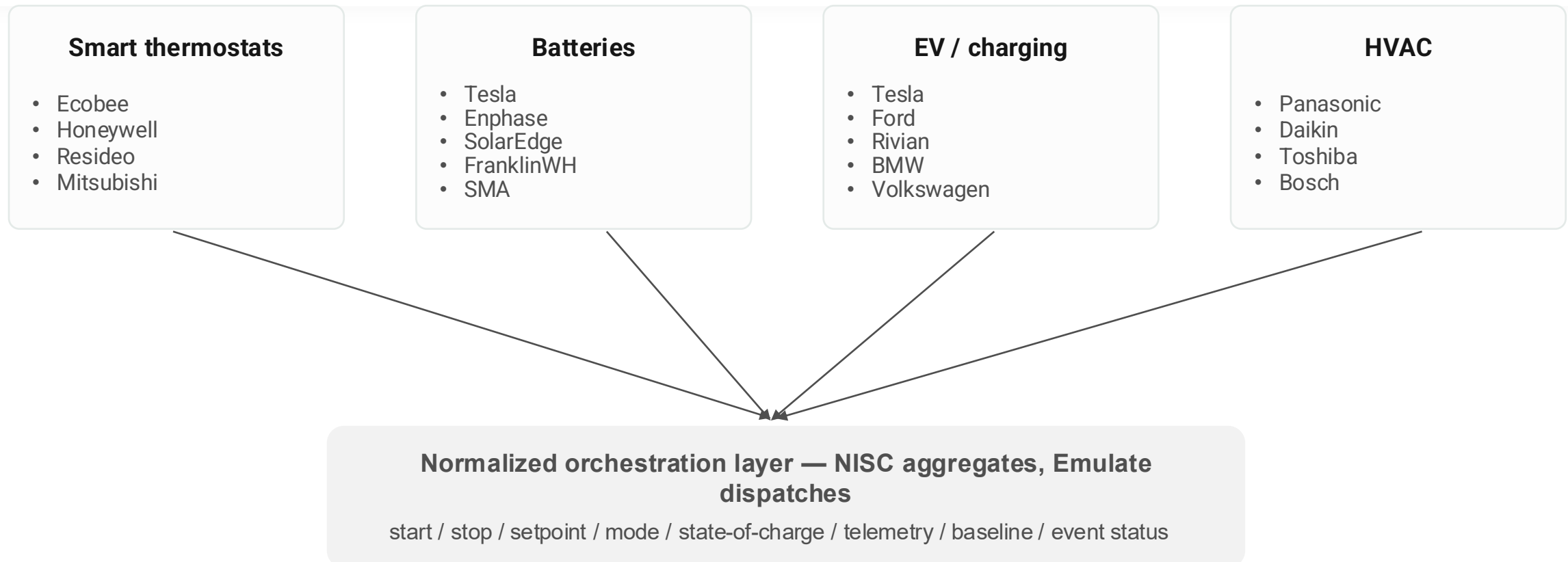
The screen shows a "Select a Device" header. The text says "Charging Station Brands" and "Charge Amp". There is a search bar and a list of "Charging Station Brands" with options: Charge Amps Down, Charge Amps Halo, and Charge Amps Aura.

The screen shows an "Add a Device" header. The text says "Connect Your Device to Our Optimization Engine" and "Your device data is transmitted over secure, end-to-end encrypted connections. We cooperate with Emulate Energy to optimize your energy consumption." There is a "Continue" button.

The screen shows a "Your Charging Station is Added Successfully" header. There is a "Open Device Details" button and an "Add Another Device +1" button. At the bottom, there is a "Go to My Devices" button.

Abstraction Layer to Coordinate Dispatch Over Dozens of Device Types

- Platform expanded across leading US OEM brands — thermostats, batteries, EVs and HVAC
- One API aggregation model delivers extreme OEM coverage — NISC aggregates the loads, Emulate dispatches them



API Coverage Expanded to EVs, Charging stations, Thermostats and BESS



ELECTRIC VEHICLES

- | | |
|------------|-------------|
| 1. Tesla | 10. Toyota |
| 2. VW | 11. Seat |
| 3. Audi | 12. Volvo |
| 4. BMW | 13. Kia |
| 5. Jaguar | 14. Hyundai |
| 6. Skoda | 15. Citroen |
| 7. Porsche | 16. Peugeot |
| 8. Mini | 17. Nissan |
| 9. Ford | 18. Renault |
| | 19. VW |



CHARGING STATIONS

1. Easee
2. Zaptech
3. Wallbox
4. EV Box



HVAC

1. Ecobee
2. Mitsubishi
3. Honeywell
4. Resideo
5. Mitsubishi
6. Panasonic
7. Daikin
8. Toshiba
9. Bosch



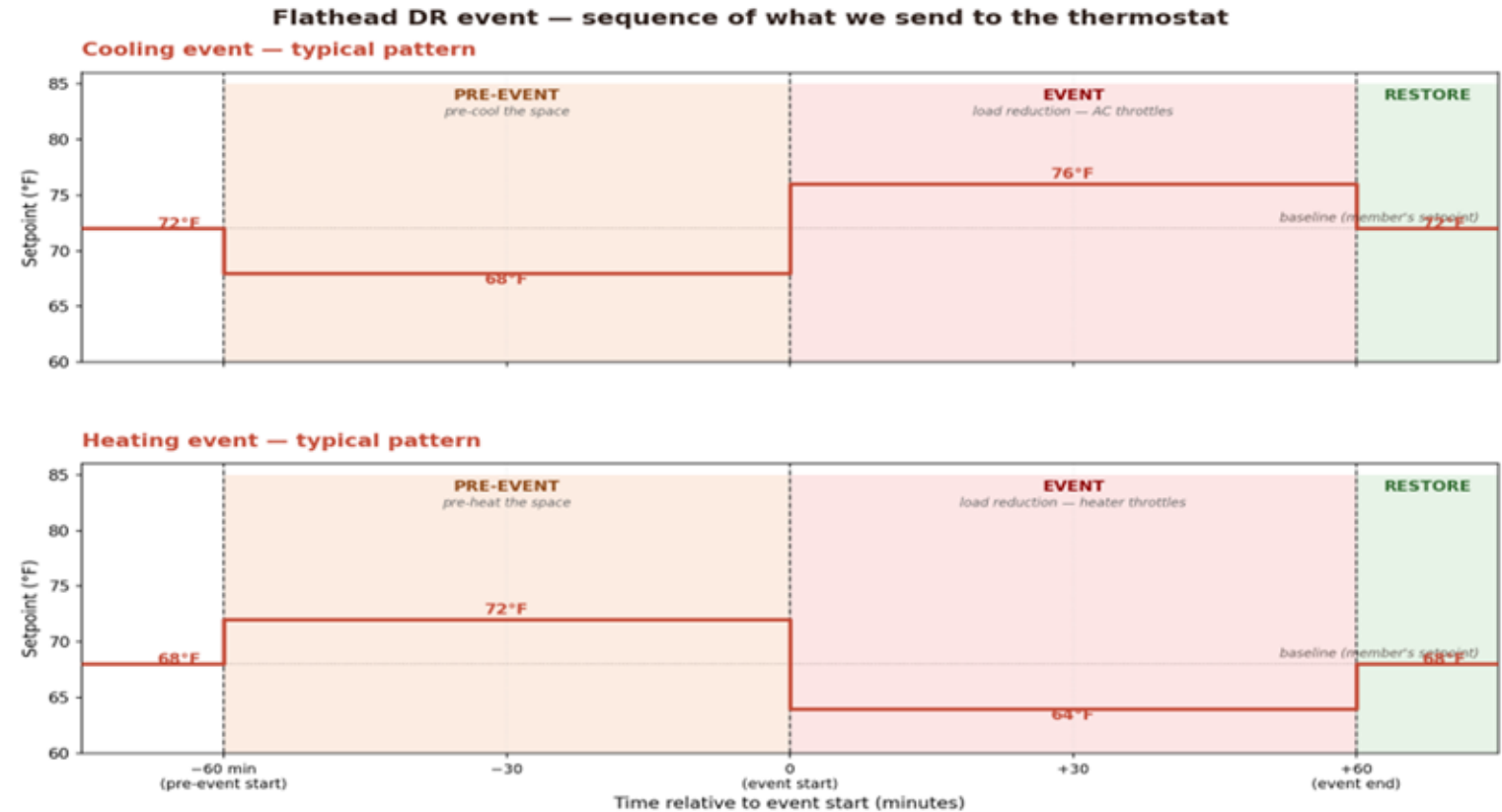
BATTERIES

1. Tesla
2. Solar Edge
3. Enphase
4. FranklinWH
5. SMA

Why this matters: The value of a DERMS to a cooperative increases as OEM device coverage grows, and when API integration fees are avoided; Emulate provides broad OEM coverage and no API fees.

Thermostat Control Keeps Members in Their Comfort Band

- Sequence of setpoint actions DERMS sends to a T-Stat across a DR event.
- The same shape applies whether the DR event is a cooling or a heating event — only the direction of the setpoint shift changes.
- If a Member overrides the thermostat setting during the DR event, Emulate detects the override and releases DR control for that device.
- If a Member overrides, Member's setpoint takes over and device returns to normal operation.
- No further DR commands are sent to that unit for the rest of the DR event.

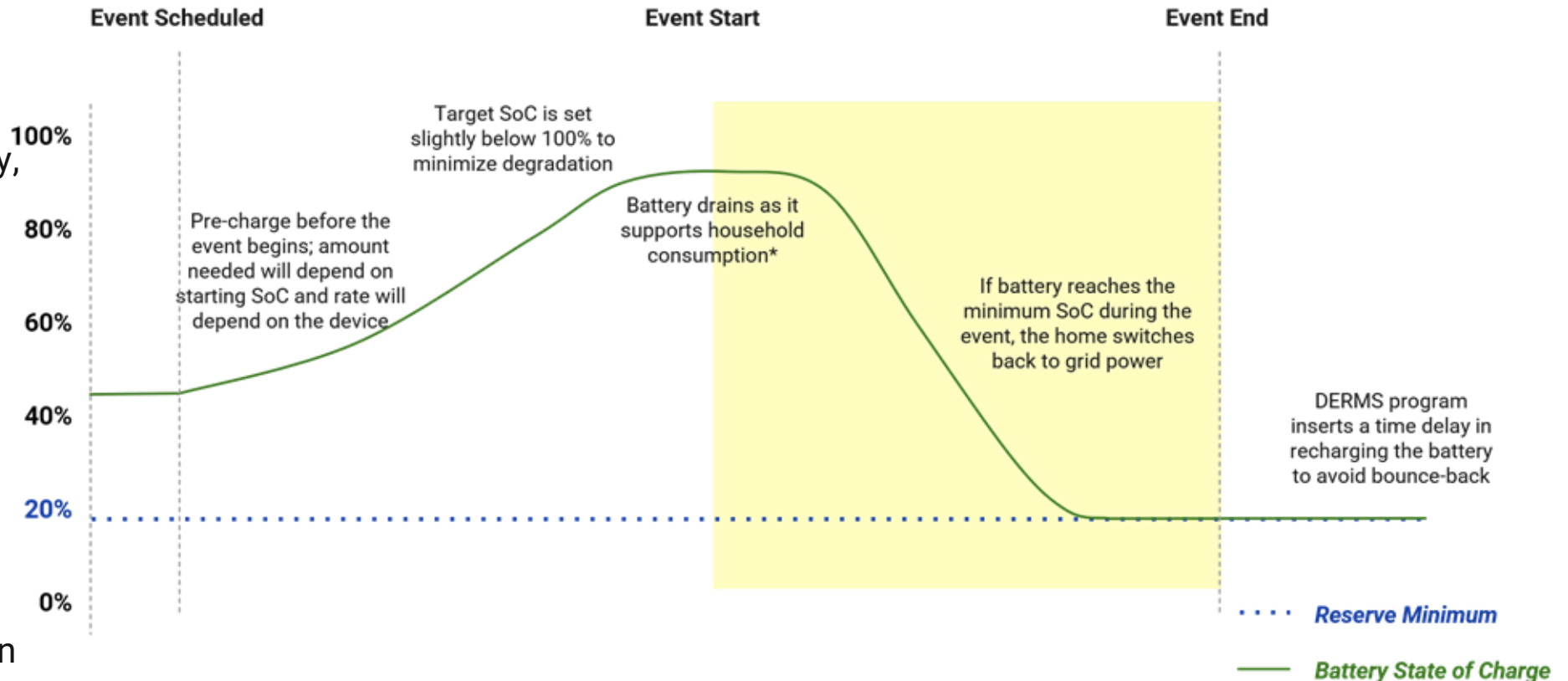


Why this is important: Co-ops and their Members need to know what to expect during a DR event.

Battery Control Methodology, Verified in the Field

Tasks 3.1, 3.2, 3.3

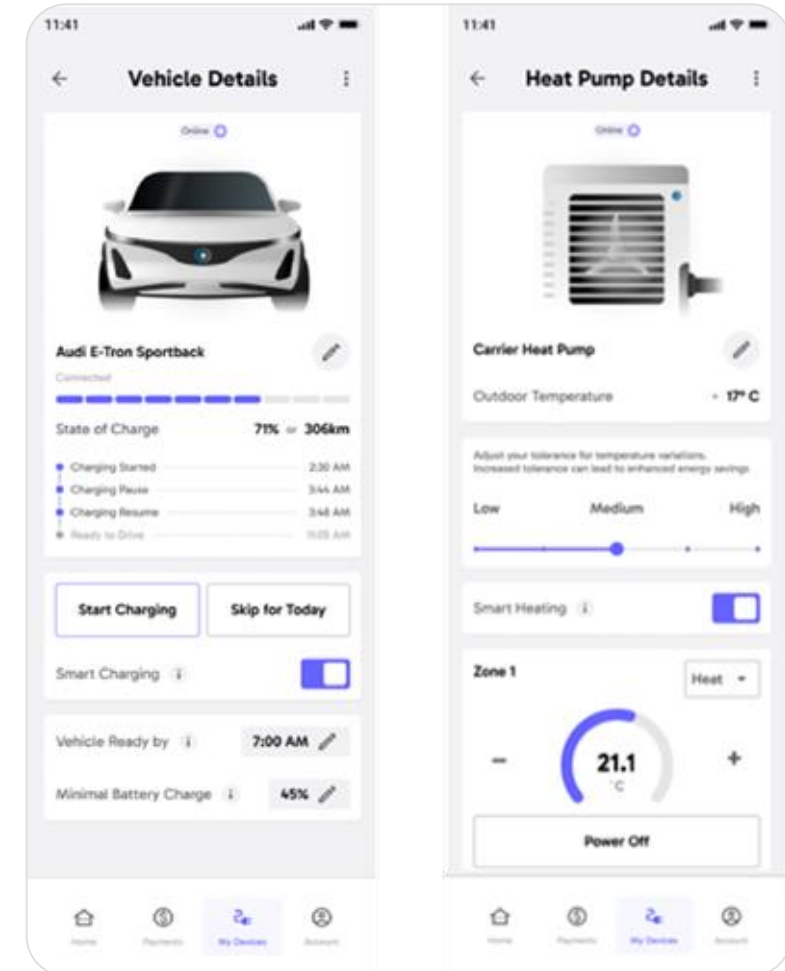
- To ensure co-ops can control batteries properly, Emulate arranged for 3 co-ops to receive li-ion batteries from FranklinWH, at no cost.
- Two battery systems have been installed and will be included in DR events using the control scheme on the right.
- The third battery is scheduled for installation in Summer 2026.



Why this is important: Battery storage is a highly effective asset increasingly used in DERMS projects. Control requirements differ markedly from T-Stats, and co-ops need specific advice on how to include them in DR events.

The Optimization Engine Cuts Member Bills with Time-Varying Prices

- Emulate's updated WebView enables Members to actively manage energy usage through a NISC-integrated mobile app.
- Beyond simple Demand Response, the system acts as an automated optimization engine responding to time-varying prices.
- Users can customize battery charge levels, set deadlines, and control smart HVAC or EV charging settings.
- Members choose between maintaining comfort ranges or opting for wider setpoint ranges for maximum savings.

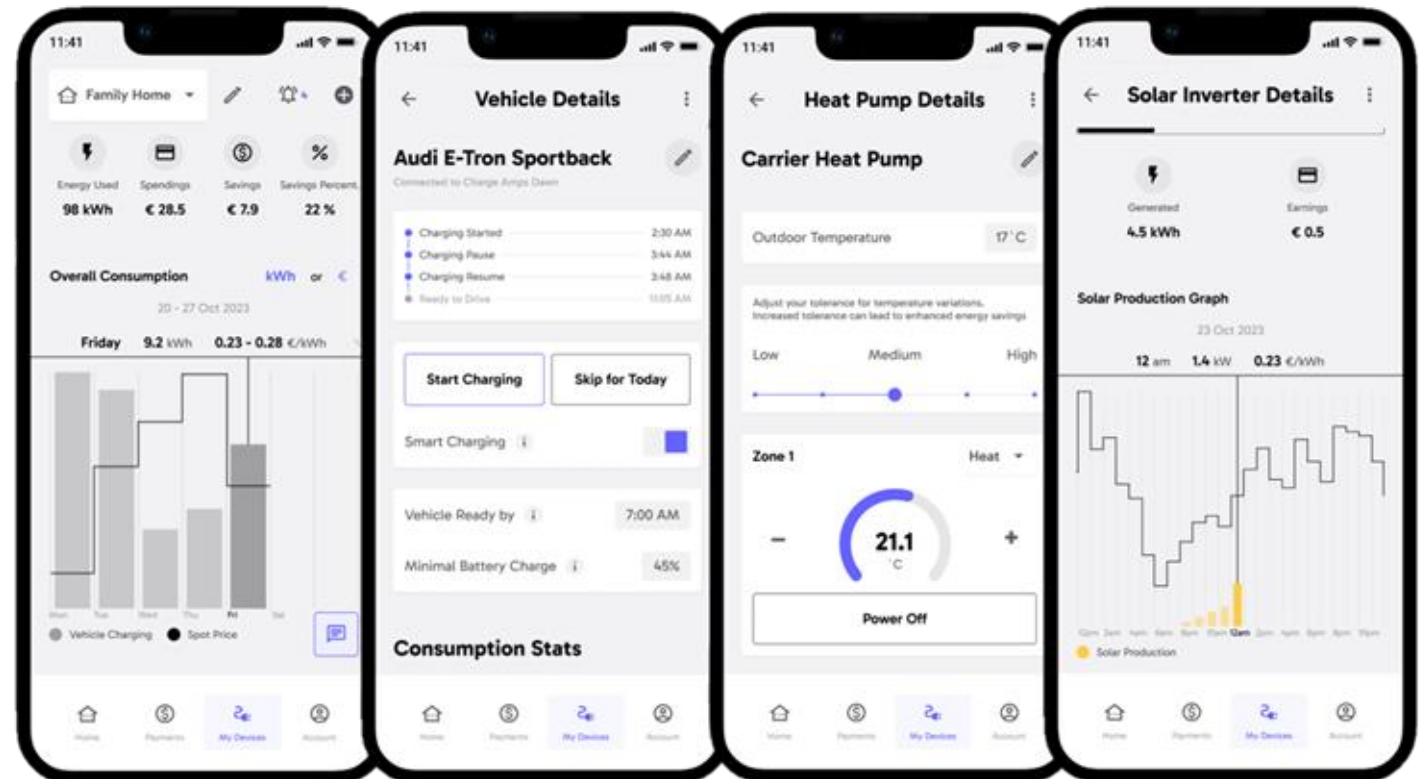


Why this matters: Advanced DERMS features and automated optimization make it easier and more rewarding for Members to save money while participating in grid services.

WebView Gives Members Deep Insight into Device Performance

The WebView transforms utilities into active energy management providers by giving users direct insights into device behavior.

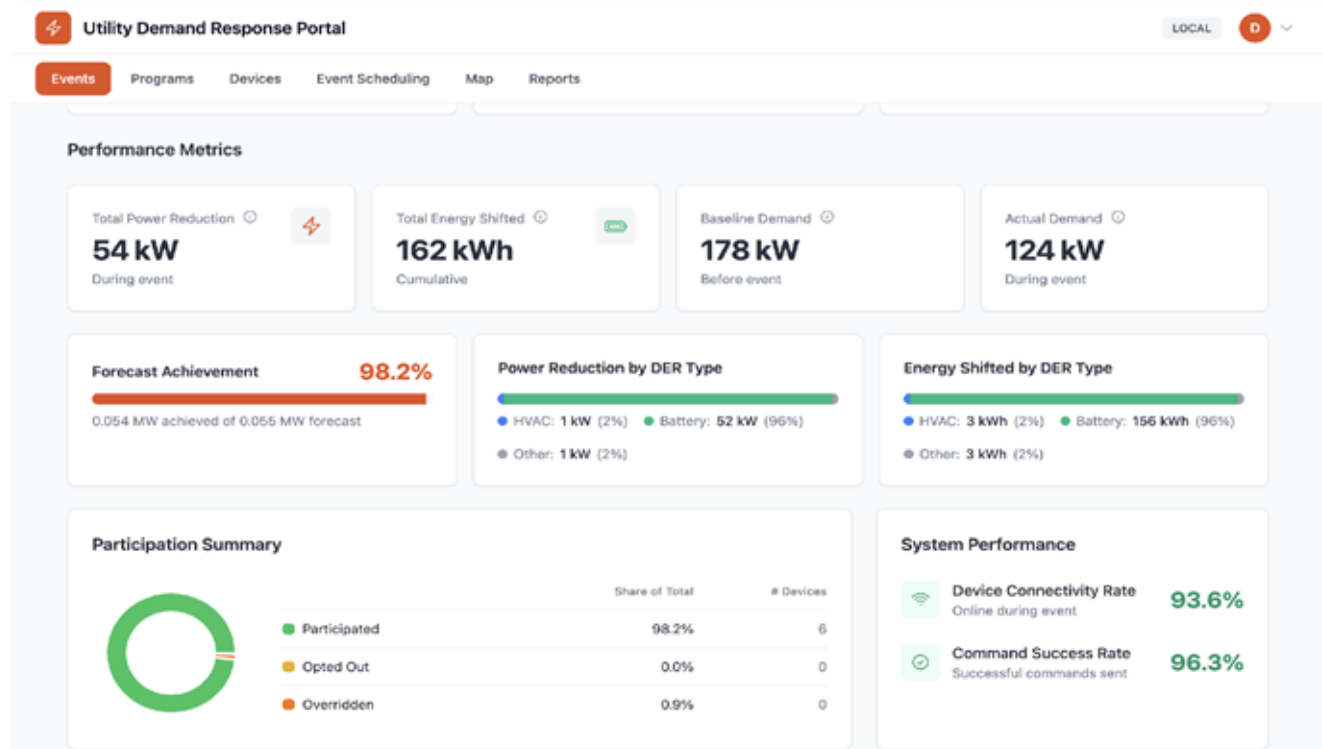
- Enables granular monitoring of all connected Distributed Energy Resources.
- Optimizes performance for future time-varying tariffs.
- On track for testing before the end of the Pilot.



Why this matters: Emulate's WebView available will add world class functionality to the DERMS platform and increase the value of DERMS for co-ops and their Members.

M&V Turns Every DR Event into Utility-Level Proof

- Measurement and verification (M&V) turns DR dispatch events into auditable evidence
- M&V is the reporting layer that turns DER control capability into board-ready proof of performance



UDR Portal screenshot

Baseline comparison

Compare with actual demand reduction during event

Portfolio performance

Actual kW, shifted kWh, participation and opt-out data across DER fleet

Exportable reporting

Event reports for internal review, board materials, regulatory filings

54 kW

Power reduction

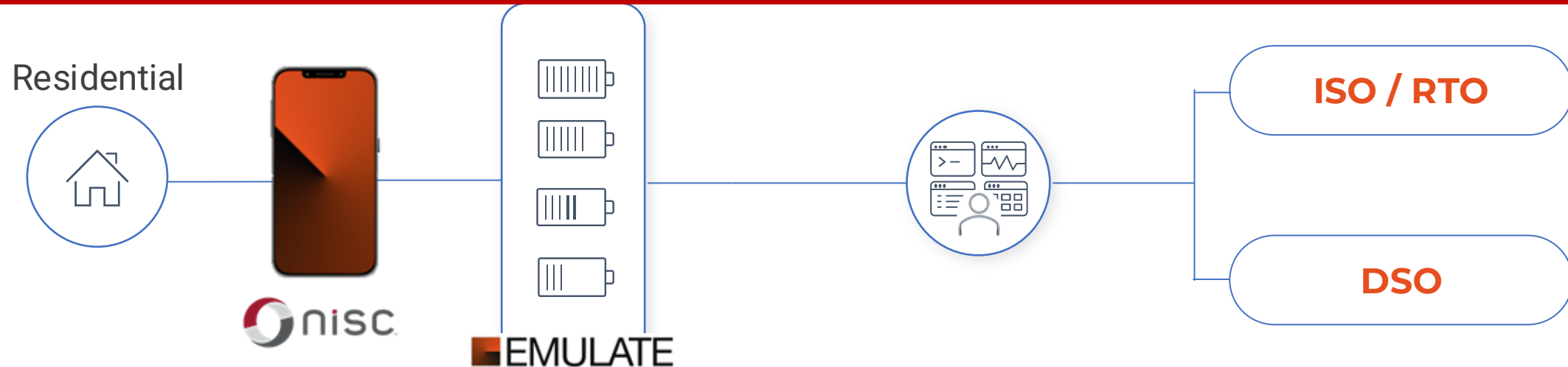
162 kWh

Energy shifted

Co-ops Can Bid Flexibility into Markets under FERC 2222

- 01 Residential devices connected and optimized
- 02 Creation of Emulate virtual batteries
- 03 Virtual batteries plugged into VPP
- 04 Flexibility monetized on Energy markets

Beyond peak shaving — aggregated flexibility is monetized in wholesale energy & ancillary-services markets

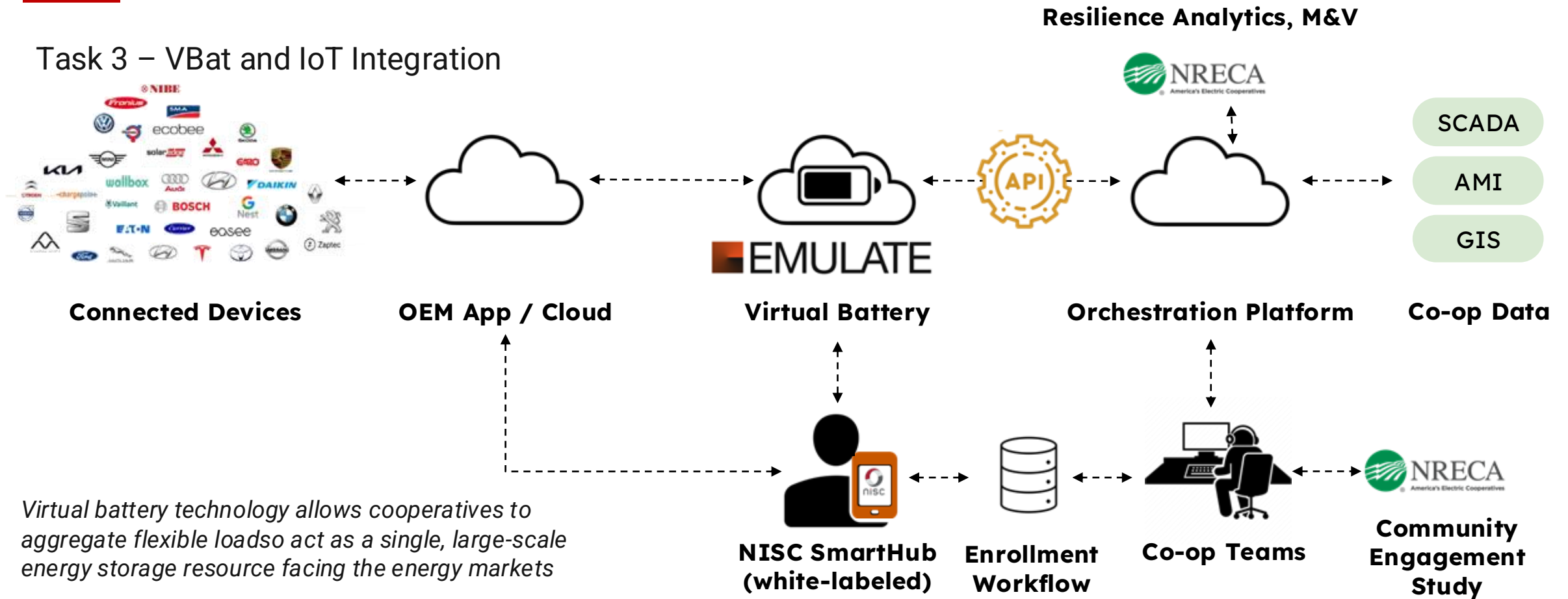


FERC ORDER 2222 — THE BREAKTHROUGH NEXT STEP

Aggregated DERs can now bid directly into U.S. RTO/ISO wholesale markets. Emulate already delivers ancillary services across Europe today — the same engine gives co-ops a first-ever wholesale revenue path.

Virtual Battery Dispatch Connects Co-ops to Markets

Task 3 – VBat and IoT Integration

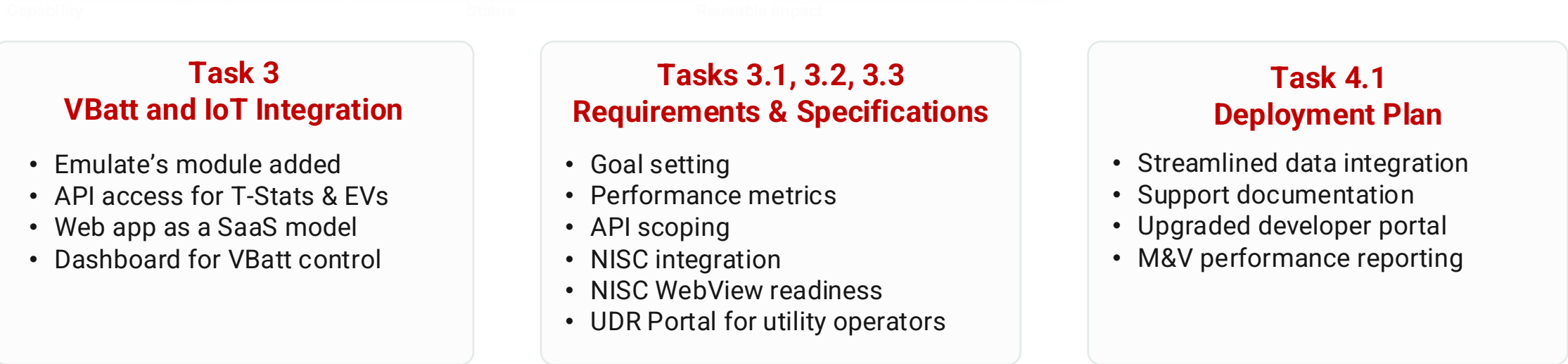


Virtual battery technology allows cooperatives to aggregate flexible load so act as a single, large-scale energy storage resource facing the energy markets

Why this is important: Integrating Virtual Battery technology into market-facing platforms enables co-ops to monetize member flexibility directly in energy markets while reducing infrastructure investment.

Summary: An Affordable DERMS Co-ops Run Themselves

- Friction points in DERMS adoption by co-ops, including non-integration with NISC IT, high acquisition and operating costs, limited co-op staff, and API integration complexity – were greatly reduced.
- CIDER produced a reusable and scalable software suite specifically optimized for cooperative utilities that can efficiently deploy, control and orchestrate DERs, even for relatively small co-ops.



Final Assessment:

CIDER accelerated technology development, proved deployment readiness, and created a pathway for scalable commercial DERMS adoption in the US cooperative market.

Key Achievements Under CIDER

- CIDER produced a set of reusable software innovations beyond a single pilot deployment
- Value derives from reusable capabilities that can be applied across the larger co-op market

Capability	Status	Reusable impact
NISC integration	Completed	Lower administrative burden, faster enrollment
UDR Portal	Developed	Self-service dispatch and event reporting
DER Economics Model	Developed	Co-op-specific investment case
OEM abstraction	Expanded	Support for multiple device categories and vendors
M&V framework	Enhanced	Event proof and portfolio performance
Battery framework	Advanced	Foundation for virtual battery dispatch
Commercial pathway	Under way	First commercial customer and co-op pipeline

Overview – ReNORM Planning Analytics

ReNORM is a set of 4 tools used together to support the deployment and operation of a DER management system (DERMS) at an electric cooperative distribution utility.

ReNORM - Resilience and Neighborhood Outage Restoration Modelset

- **omf.models.restoration** - identify switching orders and DER controls to restore an outage
- **omf.models.resilientCommunity** - calculate outage effects on individual consumers
- **omf.models.derUtilityCost** - calculates net utility benefits from a group of DER
- **omf.models.derConsumer** - calculate benefits to consumers from DER

Overview of Restoration Model

The Restoration Model informs control decisions to support loads during outages and events when generation cannot meet demand.

- Uses the PowerModelsONM optimization library from Los Alamos National Laboratory to find optimal series of control actions to support loads given available centralized and distributed energy resources.
- Can ingest and consider user-defined load priorities, as well as load criticalities generated with the Resilient Community model.
- Provides an interactive outage map for easy understanding of device actions during simulation.
- Creates charts to show how different generation sources contribute to meeting demand, lost kWh sales during the simulation, and various other metrics summarizing system information and outage impacts on consumer-members.
- Multiple instances of Restoration can be used to compare potential equipment additions and upgrades.

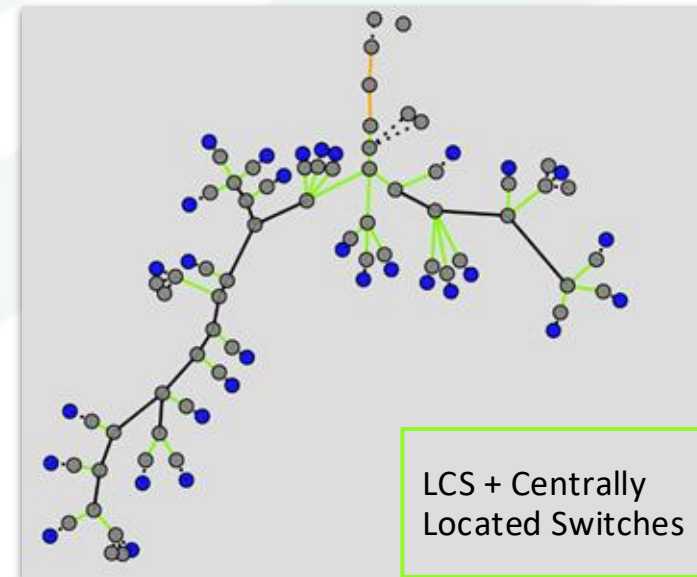
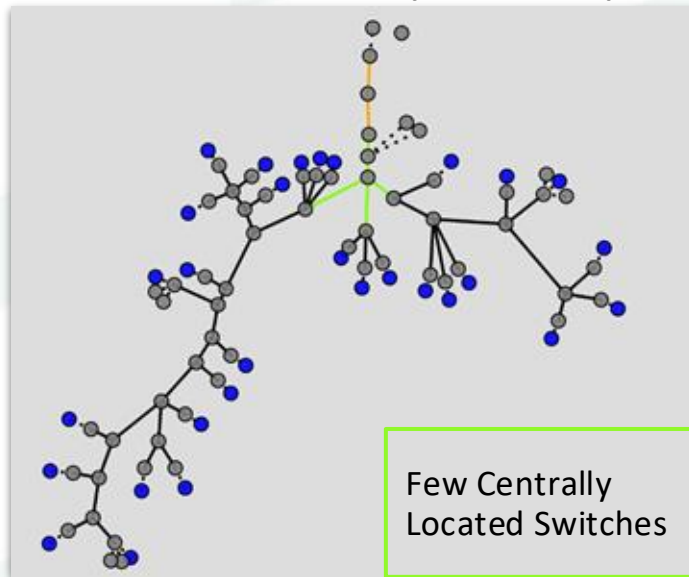
The screenshot shows the 'Open Modeling Framework > restoration > "Restoration Demo"' interface. It is divided into several sections:

- Model Input:** Contains fields for Model Type (restoration), Model Name (Restoration Demo), User (admin), Created (2026-01-23 13:12:50.568059), and Run Time (0:04:06).
- Model Specifications:** Includes a Feeder section with an 'Open Editor' button, and three file upload sections: Customer Information (.csv file) with 'customerInfoExample.csv', Event Information (.json file) with 'iowa240_dwp_22.events.json', Load Priorities (.json file) with 'iowa240_dwp_22.loadPriority.bas', and Microgrid Tagging (.csv file) with 'iowa240_dwp_22.microgridTaggi'.
- Solution Fidelity:** A dropdown menu set to 'Medium'.
- Include Locational Data in Analysis:** Includes a 'Load LCI Data (.json file)' section with 'rescomOutputForIowa240.json', a 'Use LCI' dropdown set to 'Yes', and an 'Impact of LCI' dropdown set to 'High'.
- Buttons:** At the bottom right, there are buttons for 'Delete', 'Run Model', 'Share', and 'Duplicate'.

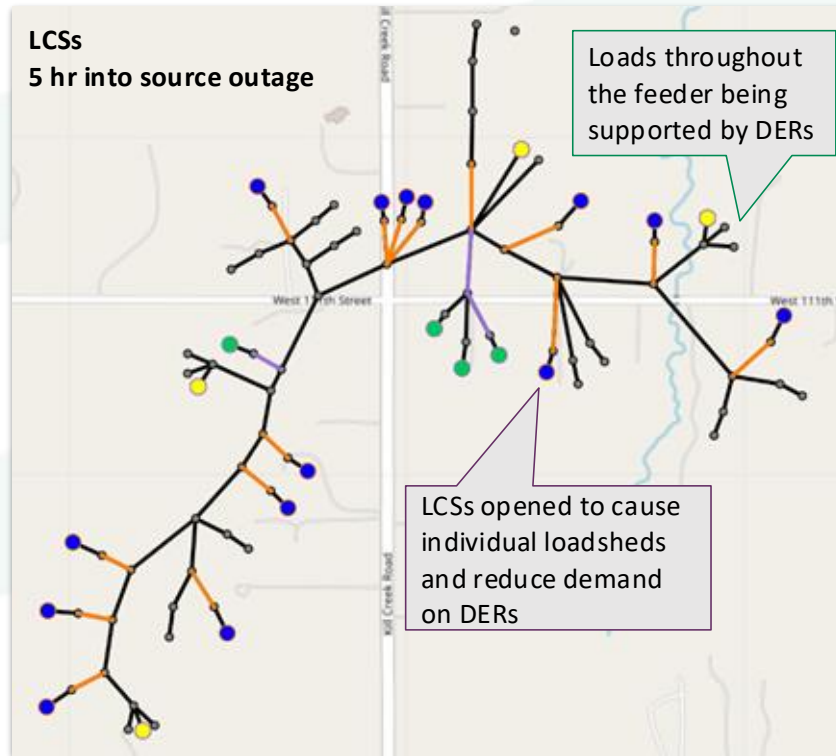
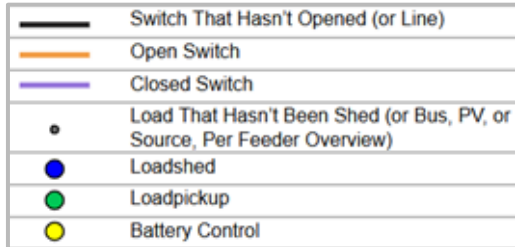
Using Restoration to Evaluate Switch Locations

One of the many ways to use Restoration is to evaluate new potential switch locations.

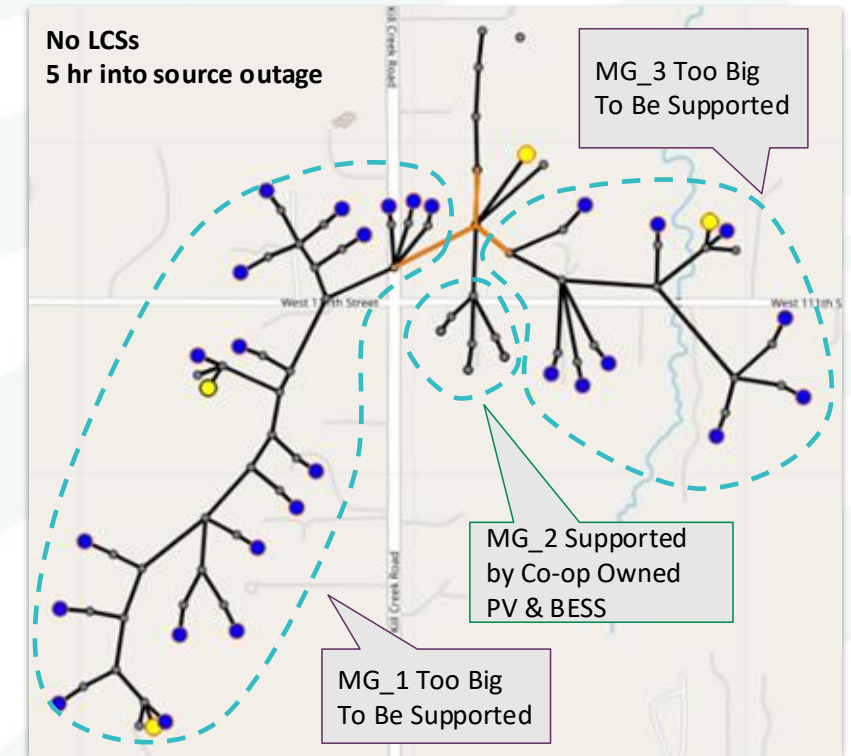
- We will use Restoration to demonstrate the benefits during a simulated outage gained from implementing load-controlling switches (LCSs) at the point of load.
- LCSs allow for more fine-tuned control of load shed and behind the meter (BTM) DERs which can:
 - Improve uptime for customers
 - Help save time and money for co-ops



Benefits of LCSs: Maximum Loads Supported



LCS: As many loads as possible can be supported by power from DERs by keeping some LCSs closed while opening as many as necessary to match demand to the DERs' output.



No LCS: For a load to be supported, there needs to be enough power from DERs to support the entire microgrid containing it.

Benefits of LCSs: Analyzing Tradeoffs

Metric (Simulation- Constrained)	Description	No LCSs	LCSs	Difference w/ LCSs
SAIFI	Number of interruptions for an average member.	1.0	0.63	0.37
SAIDI	Total minutes of interruption for an average member.	348	268	80
CAIFI	Number of interruptions for an average member who experienced at least one interruption.	1.0	1.06	-0.06
CAIDI	Minutes of duration for an average interruption.	348	423	-75
Mean Outage Incidence	Percent of loads experiencing an outage during the average simulation timestep.	48.33%	37.22%	11.11%

In exchange for significantly lower interruption frequency and durations across the entire feeder...

...Individual interruptions lasted longer and were slightly more frequent for those who experienced them

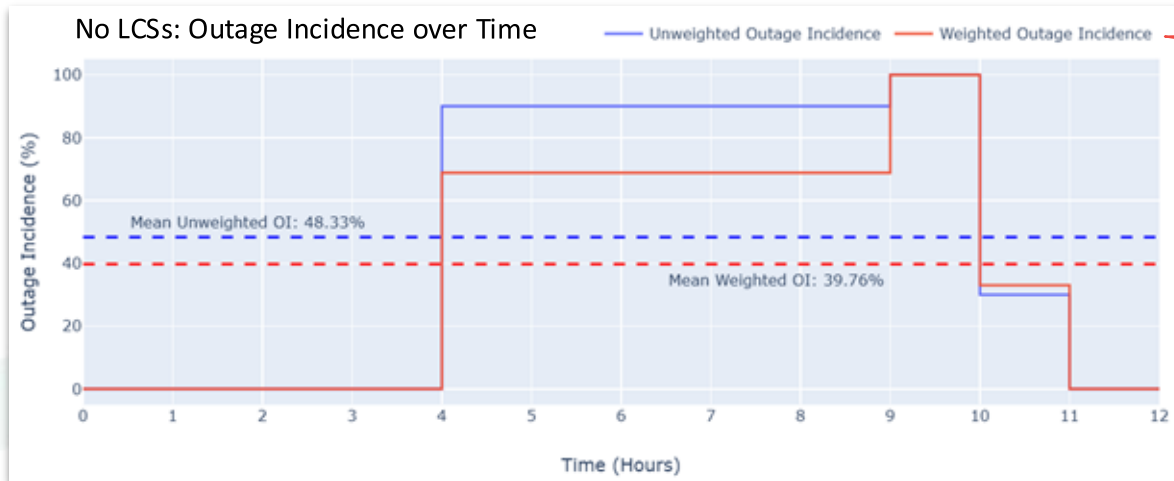
Simulation-Constrained Metrics by Microgrid

Microgrid ▲ ▼	SC-SAIDI ▲ ▼	SC-SAIFI ▲ ▼	SC-CAIDI ▲ ▼	SC-CAIFI ▲ ▼
Whole System	348.0	1.0	348.0	1.0

Simulation-Constrained Metrics by Microgrid

Microgrid ▲ ▼	SC-SAIDI ▲ ▼	SC-SAIFI ▲ ▼	SC-CAIDI ▲ ▼	SC-CAIFI ▲ ▼
Whole System	268.0	0.63	423.16	1.06

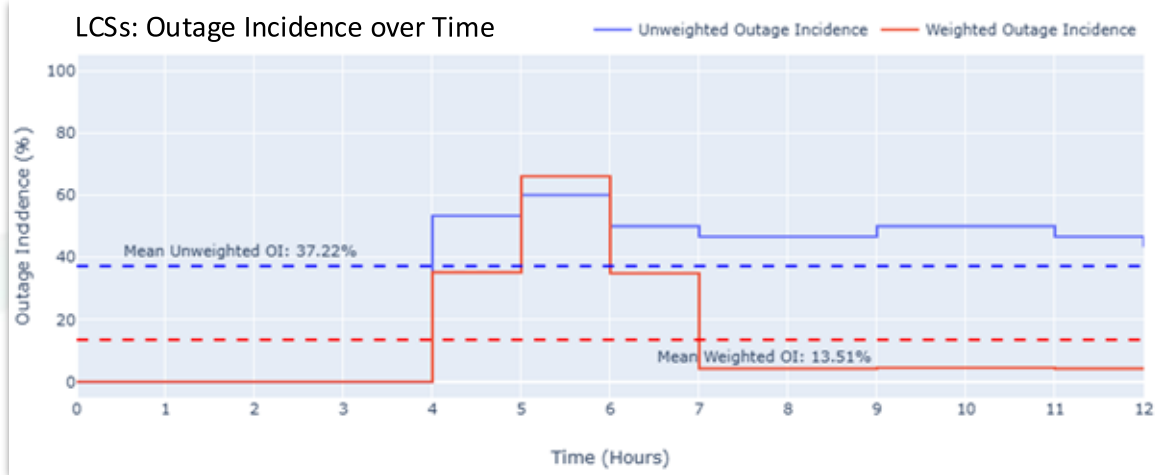
Benefits of LCSs: Prioritizing Critical Loads



Weighted by load criticality.
 $w_{crit} = 100$
 $w_{noncrit} = 1$

8.57%

The larger difference between mean weighted and unweighted Outage Incidence indicates greater prioritization of critical loads when LCSs are used

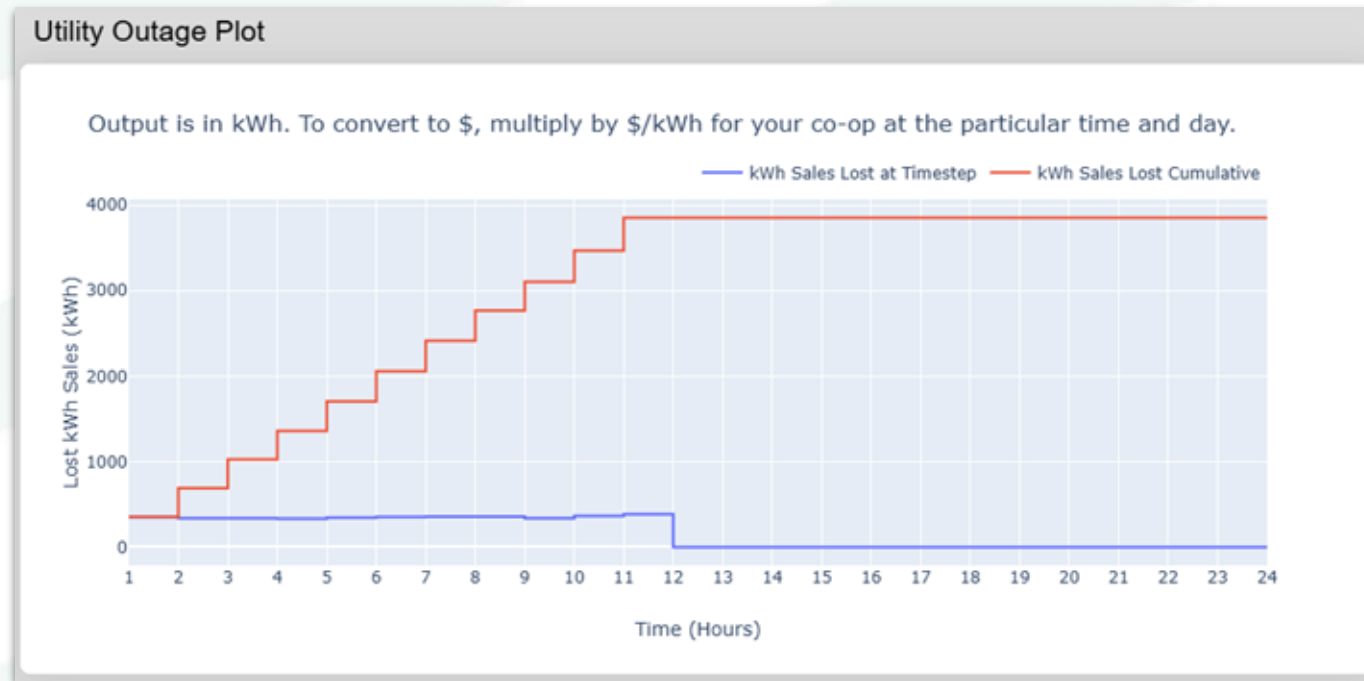


23.71%

Both means are also lower with LCS versus without, indicating an overall decrease in OI!

Restoration Function: Utility Outage Cost

The restoration model also generates a graph of lost kWh sales for co-ops to use in their analysis of potential value saved by adding or upgrading equipment to support resilience.



Restoration Model Conclusion

In this analysis, the Restoration model was able to show the benefits of LCSs through:

- Improved SAIFI, SAIDI, and Outage Incidence in exchange for slightly worsened CAIFI and CAIDI
- Outage map visualizations
- An increase in the difference between mean weighted and unweighted Outage Incidence
- A much lower weighted outage incidence overall

This highlights just one of the ways that `omf.models.restoration` can be used by co-ops to perform analyses based on:

- Generation resource spread
- Outage costs
- Critical load prioritization
- Sections of service area impacted

Overview of Resilient Community Model

Description

Evaluates co-op chosen customer and weather hazard statistics to determine the relative impact of outages on individual loads, and uses this to identify the pieces of distribution system equipment that are most critical to their service area. This supports the incorporation of outage impact severity and recovery ability into resilience considerations.

User Stories

1. A cooperative distribution engineer or analyst wants to understand how outages impact their members to prioritize those who experience the most negative effects. The tool shows the criticality of each piece of equipment to the community's outage survivability, allowing them to be prioritized in resilience planning and recovery operations.
2. A researcher is investigating the connections between customer statistics and the resilience planning and operation process.

Locationally-Aware Restoration

Resilient Community can also be used to inform other models with locational data.

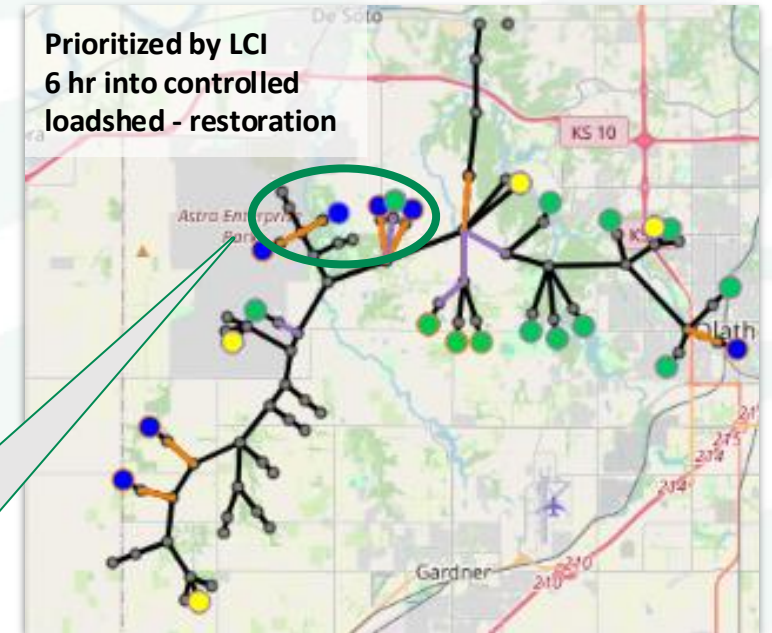
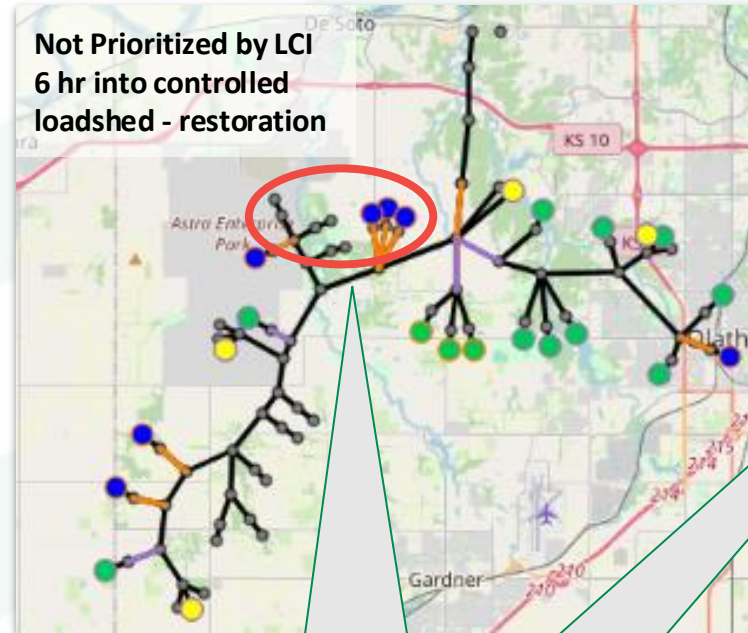
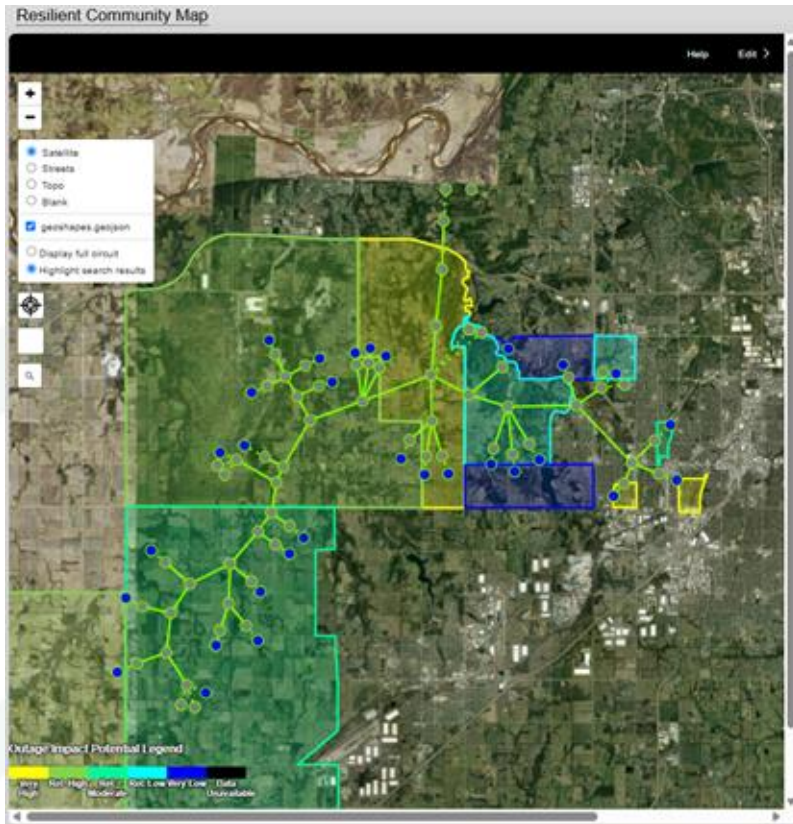
- In the Restoration model, Locational Criticality Index (LCI) information provided by Resilient Community can allow for impact-potential-aware analysis and simulation of outage responses.

Scenario:

A cooperative distribution engineer or analyst wants to understand how prioritizing members who experience the most negative effects from outages could impact restoration approaches and outcomes.

1. They analyze their feeder with Resilient Community to get a sense of the vulnerability of different loads on the feeder.
2. They set up their feeder in the Restoration model with a controlled loadshed scenario identical to the one in the restoration section and run it twice:
 - Once without any load priorities
 - Once using LCI information given by Resilient Community to inform the simulation
3. Once their simulations are done running in Restoration, they compare the outputs of both, considering performance weighed by LCI.

Locationally-Aware Restoration



When prioritizing by LCI:
Relatively Low LCI load
shed in favor of Very High
LCI load supported

—	Switch That Hasn't Opened (or Line)
—	Open Switch
—	Closed Switch
•	Load That Hasn't Been Shed (or Bus, PV, or Source, Per Feeder Overview)
•	Loadshed
•	Loadpickup
•	Battery Control

Locationally-Aware Restoration

Restoration Prioritized by LCI

Simulation-Constrained Metrics by LCI Quartiles

LCI Quartile ▲ ▼	SC-SAIDI ▲ ▼	SC-SAIFI ▲ ▼	SC-CAIDI ▲ ▼	SC-CAIFI ▲ ▼	Loads Served ▲ ▼	Est. Household Residents Served ▲ ▼	LCI of Average Residential Load ▲ ▼
Low LCI	↑ 142.5	↑ 0.75	↑ 190.0	1.0	8	349.8	16.67
Low-Medium LCI	↓ 145.71	0.86	↓ 170.0	↑ 1.2	7	574.67	40
High-Medium LCI	94.29	0.14	660.0	1.0	7	500.96	66.67
High LCI	↓ 270.0	1.0	↓ 270.0	1.0	8	1148.78	93.33

Restoration Not Prioritized by LCI

Simulation-Constrained Metrics by LCI Quartiles

LCI Quartile ▲ ▼	SC-SAIDI ▲ ▼	SC-SAIFI ▲ ▼	SC-CAIDI ▲ ▼	SC-CAIFI ▲ ▼	Loads Served ▲ ▼	Est. Household Residents Served ▲ ▼	LCI of Average Residential Load ▲ ▼
Low LCI	↓ 90.0	↓ 0.62	↓ 144.0	1.0	8	349.8	16.67
Low-Medium LCI	↑ 171.43	0.86	↑ 200.0	↓ 1.0	7	574.67	40
High-Medium LCI	94.29	0.14	660.0	1.0	7	500.96	66.67
High LCI	↑ 300.0	1.0	↑ 300.0	1.0	8	1148.78	93.33

Prioritizing restoration by LCI results in comparatively higher outage severity metrics for loads in the lowest LCI quartile and comparatively lower metrics for loads in the highest LCI quartile.



Less intense outages for loads that have higher potential outage impact

Full Customizability

- Priorities for defining outage impact are likely to vary between service areas.
- To address this, we created a fully-customizable metric called Outage Impact Potential (OIP) that omf.models.resilientCommunity implements.
- OIP is designed to be the aggregate of 12 customer variables and 13 weather hazard variables, each weighted by the user and optionally excluded by using a weight of 0.
- OIP is combined with technical data about loads and equipment on the feeder to create the Locational Criticality Index (LCI) for each feeder object, which is what can be passed to omf.models.restoration.

Open Modeling Framework • resilientCommunity • "Demo resCom mostly ag After OIP"

Model Input

Model Type Help?	Model Name	User
resilientCommunity	Demo resCom mostly ag After OIP	admin
Created	Run Time	
2025-11-04 11:59:15.932522	0:00:10	

System Parameters

Feeder	Customer Information (.csv file)	Equipment Lifetime (.csv file)
Open Editor	Choose File restorationLoads ORIGINAL.csv	Choose File equipLifeExampleEMPTY.csv
Feeder Map Coloring By	Average Peak Demand (kva)	Average Number of Occupants
Base Criticality Index	2.0	4.0

Include in Analysis

Lines	Transformers	Fuses
Yes	No	No

Outage Impact Potential (OIP)

Aggregation Method

Average of Min-Max Normalized

Outage Impact Potential - Customer Variables

% Age 16+ Employed	Weight	1
% Age 65+	Weight	1
% Crowding	Weight	1
% Individuals Below Poverty Level	Weight	1
% Individuals Disabled	Weight	1
% Limited English Speaking Households	Weight	1
% Mobile Home	Weight	1
% Multi-Unit Structure	Weight	1
% No Vehicle	Weight	1
% Non-HS Grads	Weight	1
% Non-Institutionalized Below Age 19	Weight	1
Avg Aggregate Household Income (USD)	Weight	1

Outage Impact Potential - Weather Hazards Annualized Frequency

Avalanche	Weight	1
Cold Wave	Weight	1
Drought	Weight	1
Earthquake	Weight	1
Hail	Weight	1
Heat Wave	Weight	1
Hurricane	Weight	1
Ice Storm	Weight	1
Landslide	Weight	1
Lightning	Weight	1
Strong Wind	Weight	1
Wildfire	Weight	1
Winter Weather	Weight	1

[Delete](#) [Run Model](#) [Share](#) [Duplicate](#)

DERMS Program Design Overview

derUtilityCost Scenario 1: “Base Case”

Run an initial Base Case (no subsidies or upfront costs) to determine the value that can be extracted from each technology, annually. **For the BESS tech, this can be viewed as either a fleet of residential batteries under a DER sharing agreement, or a single utility-owned BESS.**

Outputs:

Annual Savings for Technology

Determine Initial “Break-even” Monthly Subsidies

$$\text{Monthly Subsidy for Technology} = \frac{\text{Annual Savings for Technology}}{\text{Total \# of devices} \div 12 \text{ Months}}$$

derUtilityCost Scenario 2: “Adjusted Subsidies”

Run an Adjusted Subsidies case, consisting of the Base Case including the Initial “Break Even” monthly technology subsidies. This provides a “break-even case” where the DER subsidy costs = DER savings.

derConsumer

Run derConsumer with the monthly subsidies calculated from derUtilityCost Scenario 1. This shows how the subsidies provided by the utility affect the member-consumer’s savings.

Subsidy Modification

There are two subsidy inputs in the models: an upfront (one-time only) subsidy, and an ongoing monthly subsidy. The user may want to apply a combination of these subsidies for their program. Here is how the results from derUtilityCost can be used to identify an upfront subsidy and determine the remaining monthly subsidy amount for a break-even situation.

1. Run derUtilityCost to determine the total annual savings for each device.
2. Use the equation below to split the annual savings into the two subsidy amounts. This is your break-even case where the subsidy costs = savings from the DER.

Monthly Subsidy = (Annual Savings ÷ Total Number of Devices - **Upfront Subsidy**) / 12 Months

Example

- Assume that the derUtilityCost output indicates that the BESS annual savings = \$1,000
- A co-op is confident that they will be able to enroll at least 10 BESS devices in their program, and wants to pay no more than \$10 upfront to get those batteries enrolled.

For the subsidies to break-even with those savings, the monthly subsidy would have to be less than or equal to:

BESS Monthly Subsidy = (\$1,000 annual savings ÷ 10 total devices - \$10 upfront subsidy) / 12 Months = **\$7.50 monthly subsidy**

How to Consider Upfront + Ongoing Costs

“The Approach” in this analysis considers \$0 upfront startup costs and \$0 ongoing operational costs to obtain the net benefit from all DER. A utility ultimately wants to know if the program will pay itself off in a reasonable amount of time.

The following method can be used to adjust the break-even subsidies per technology to consider the payback of any startup and ongoing costs:

1. **Run the base case approach** and obtain break-even subsidies per technology (see slide “The Approach - Overview”)
2. **Reduce the break-even subsidies** by some fractional amount depending on the total costs and the individual technology subsidy amount according to:

Adjusted Monthly Subsidy, per tech = Break-Even Monthly Subsidy, per tech - X(Ongoing Monthly Costs)

where X = (Break-Even Monthly Subsidy, per tech / Sum of all Break-Even subsidies across all tech)

The annual ongoing cost is the sum of all monthly costs in the first year of analysis.

1. Consider the upfront and ongoing costs

~~Upfront Costs~~ = SPP(annual savings - annual subsidies - annual ongoing costs)

The utility determines an acceptable SPP (e.g. 5 years)

OR

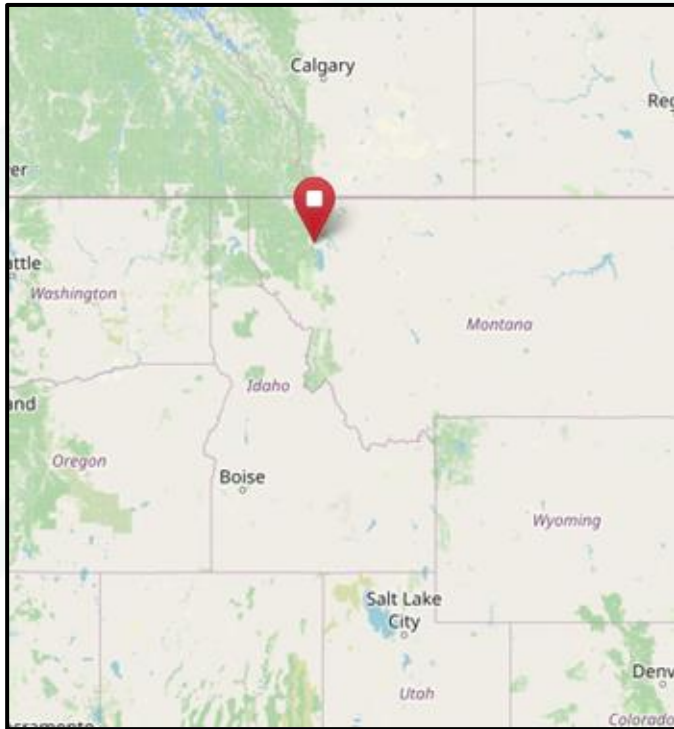
Upfront Costs = SPP(annual savings - annual subsidies)

If the utility has already factored in the ongoing costs when calculating its annual subsidies, they do not need to include it again here. Instead, they would use this equation instead of the one above it, without the extra annual ongoing costs term.

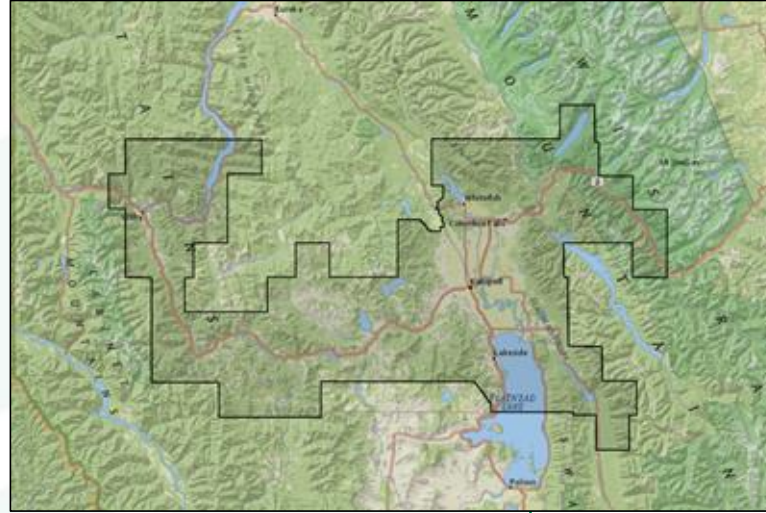
Detailed Results: Flathead



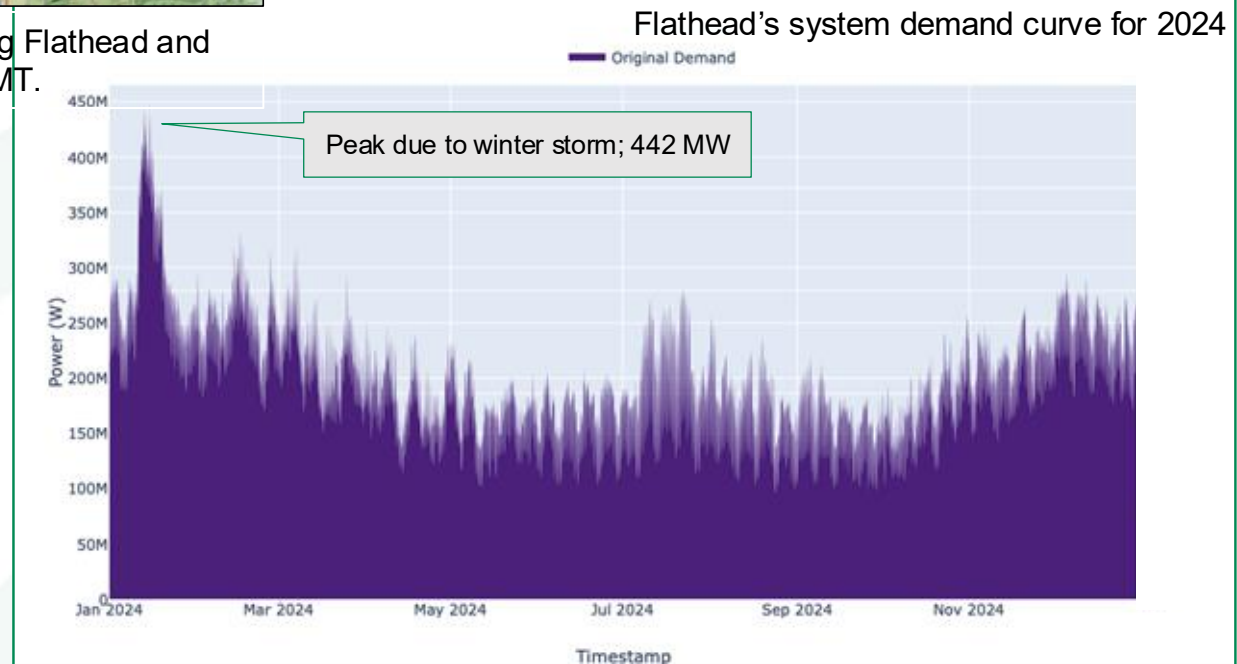
FLATHEAD ELECTRIC
COOPERATIVE



Flathead's service area approximate centroid located at (48.197777, -114.316109).



Flathead's service area spanning Flathead and Lincoln counties in MT.

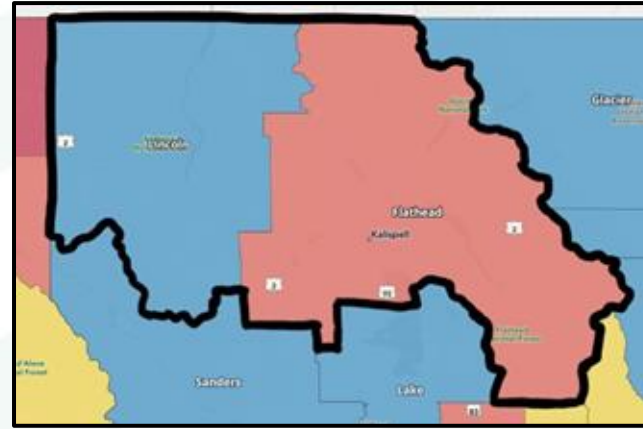


Detailed Results: Flathead

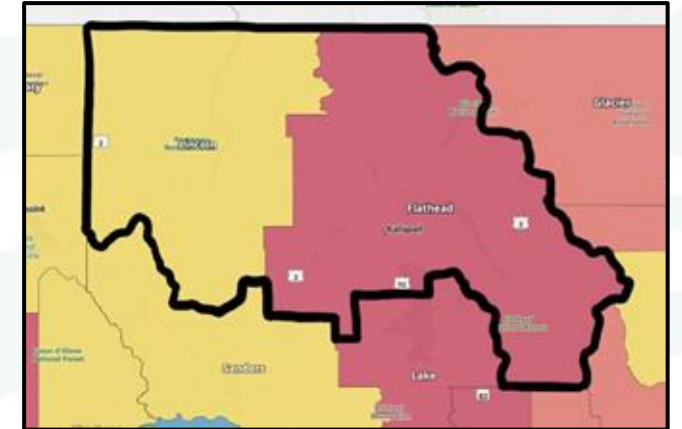
Flathead EC serves rural Montana areas that experience grid-stressing weather events:



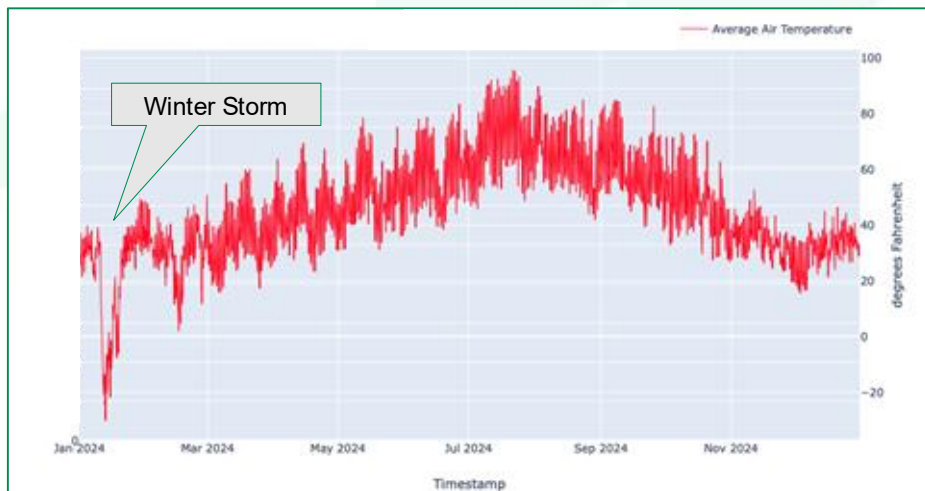
Wildfires



Landslides



Cold Waves



Flathead's regional climate is considered **"Very-Cold/Cold"** by the EERE's Building America data sets.

<https://www.energy.gov/eere/buildings/building-america-climate-map>

Reliability Metrics w/ Major Event Days:

- SAIDI: 692.240
- SAIFI: 2.720
- CAIDI: 254.500

Reliability Metrics w/out Major Event Days:

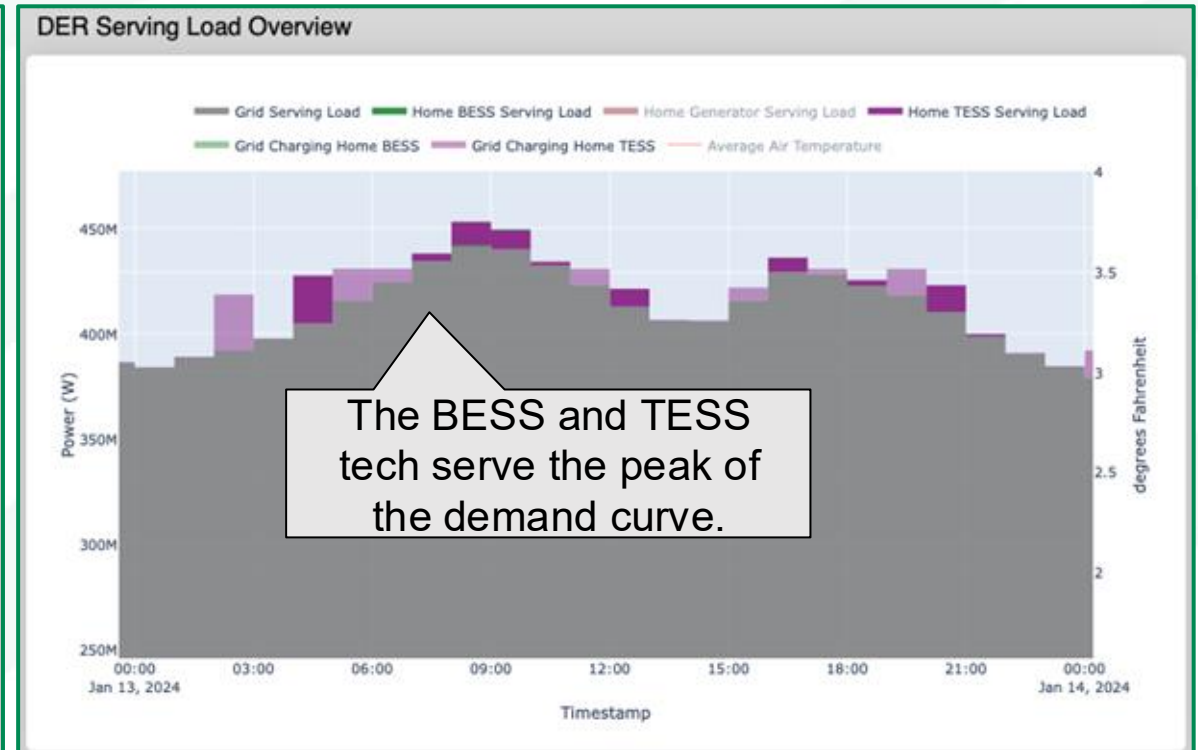
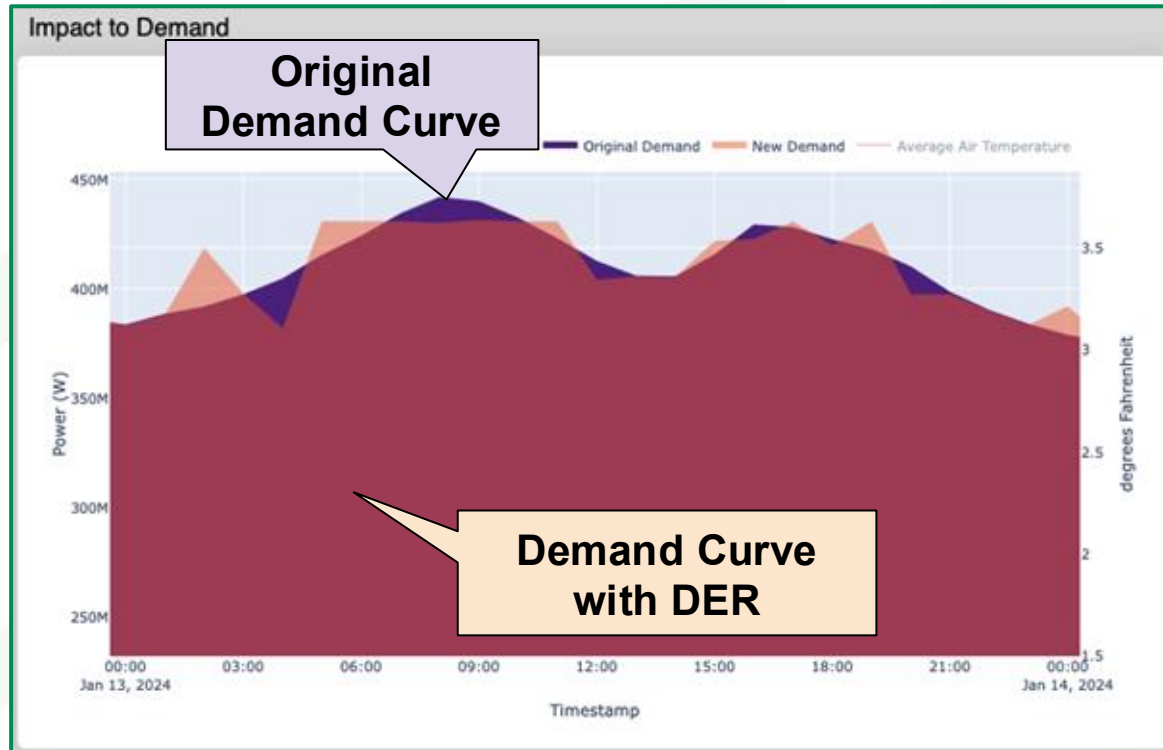
- SAIDI: 222.950
- SAIFI: 1.820
- CAIDI: 122.500

Flathead – Wholesale Energy & Demand Tariffs

	Wholesale Energy Rate (\$/kWh)		Wholesale Demand Rate (\$/kW)
Month	<i>Heavy Load Hours</i> (6am–10am Mon–Sat)	<i>Light Load Hours</i> (10pm–6am Mon–Sat, all day on Sundays)	
Jan	0.04356	0.04380	11.88
Feb	0.04543	0.04918	12.339
Mar	0.02919	0.03454	7.97
Apr	0.02233	0.02709	6.09
May	0.00860	0.01273	2.35
Jun	0.01510	0.01608	4.12
Jul	0.05098	0.04806	13.91
Aug	0.05380	0.05032	14.67
Sep	0.06051	0.05906	16.51
Oct	0.05063	0.04885	13.81
Nov	0.03953	0.04164	10.78
Dec	0.04763	0.04879	12.99

Flathead – Scenario 1 derUtilityCost Outputs

Winter peak – January 13, 2024



Flathead – Scenario 1 derUtilityCost Outputs

Tech	Total Annual Savings (kW Demand Savings + kWh Consumption Savings)	Number of Devices	Annual Value of DER per Device	Monthly Subsidy (Total Annual Savings / Number of Devices / 12 months)
BESS	\$57,880	652	\$89	\$7.40
Air Conditioner	\$117,899	38,236	\$3	\$0.26
Water Heater	\$969,020	22,441	\$43	\$3.60
Heat Pump	\$28,644	2,088	\$14	\$1.14

Annual value per device not including subsidies

These monthly subsidies will be used as inputs in Flathead's derUtilityCost Scenario 2 and derConsumer

Example Monthly Subsidy calculation:

If Water Heaters saved \$969,020 for the year, then the annual value of water heaters per device would be $\$969,020 / 22,441 \text{ water heaters} = \$43 \text{ per water heater per year}$. That value could be used to determine a monthly subsidy = $\$43 / 12 \text{ months} = \$3.60/\text{month}$ (assuming no upfront subsidies).

Flathead – Scenario 2: Adjusted Subsidies

Scenario 2 considers a program where the participation levels remain the same, but the subsidies are adjusted based on the results from Scenario 1.

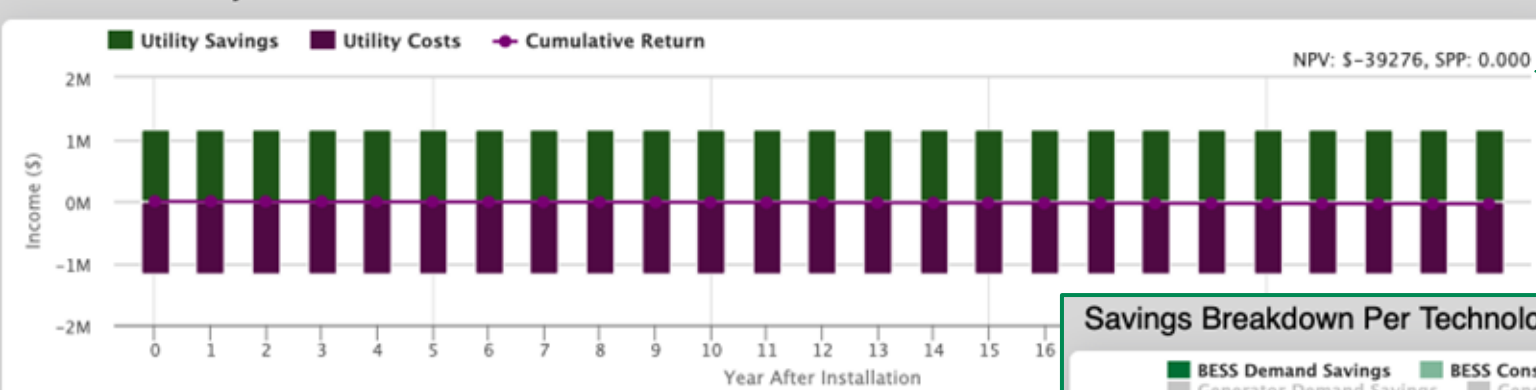
	Upfront Subsidy (\$)	Ongoing Subsidy (\$/month)	Participation Level (out of 65,236 residential meters)
BESS	0	\$7.40	1% (652)
Air Conditioner	0	\$0.26	59% (38,236)
Water Heater	0	\$3.60	34% (22,441)
Heat Pump	0	\$1.14	3% (2,088)
GEN	-	-	-

The monthly subsidies calculated from Scenario 1 are used as the starting inputs for Scenario 2.

The participation levels are kept the same

Flathead – Scenario 2 derUtilityCost Outputs

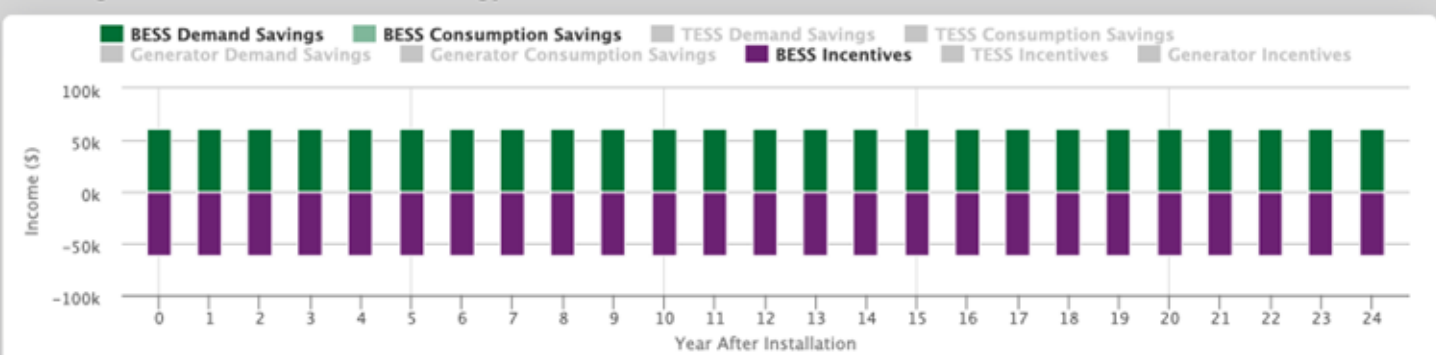
Cash Flow Projection



The SPP is 0 since the subsidy costs are roughly equal to the DER savings, and there are no other initial costs. The NPV, however, is expected to be close to zero for this break-even scenario, but it is nonzero due to the number of decimal places in the subsidy input values.

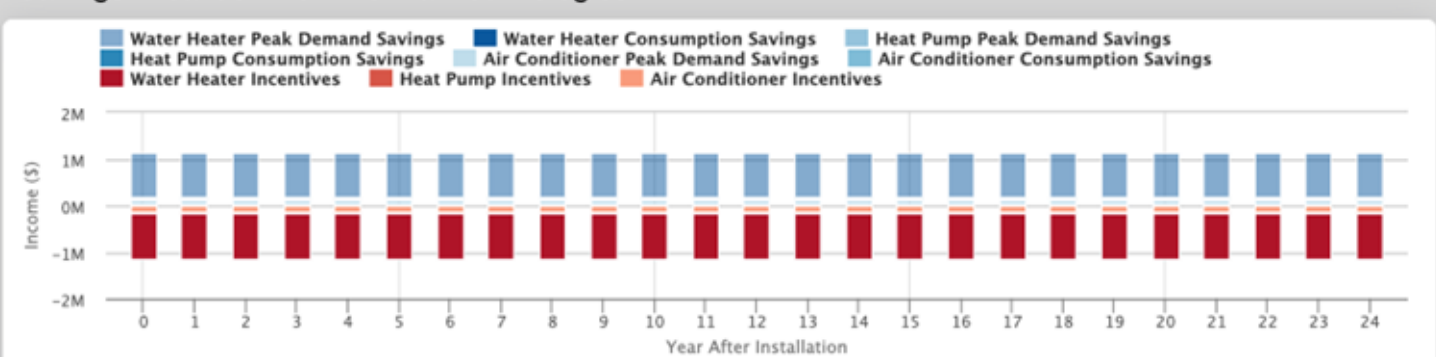
The annual BESS subsidies are roughly comparable to the annual BESS savings

Savings Breakdown Per Technology



The annual TESS subsidies are roughly comparable to the annual TESS savings

Savings Breakdown of Thermal Technologies



Flathead – derConsumer Inputs

The derConsumer model considers the same subsidies that were used in Scenario 2 derUtilityCost to show the member-consumer point of view.

	Upfront Subsidy (\$)	Ongoing Subsidy (\$/month)	Consumer Retrofit Costs (\$)
BESS	0	\$7.40	0
Air Conditioner	0	\$0.26	150 (Nest Thermostat)
Water Heater	0	\$3.60	175 (Aquila Controller)
Heat Pump	0	\$1.14	0
Generator	-		-

Approx. cost to equip the device to respond to the utility's load control signals. (e.g. Smart Thermostat, Wi-Fi enabled smart plug, etc.)
Note: The companies listed here are only examples, not endorsements.

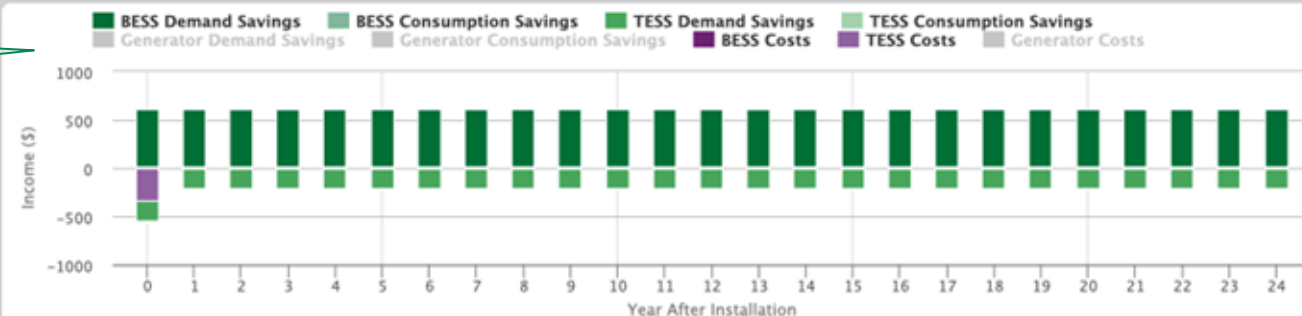
These are the same subsidies used in the derUtilityCost Adjusted Subsidies case. Using them in derConsumer will show how these subsidies look from the perspective of a hypothetical member-consumer.

The Heat Pump retrofit cost is \$0 because it's the same smart thermostat that is used for the Air Conditioner.

Flathead – derConsumer Outputs

Most of the DER savings come from the BESS, whereas most of the costs come from the TESS technologies

Savings Breakdown Per Technology



Cash Flow Projection



The SPP is positive, meaning the program will pay the consumer back in just over 7 months since the only costs here are the retrofit device costs.

Cash Flow Projection



Flathead – derConsumer Outputs

BESS Savings vs. Incentives

Annual BESS Demand Savings + Consumption Savings = \$596/yr

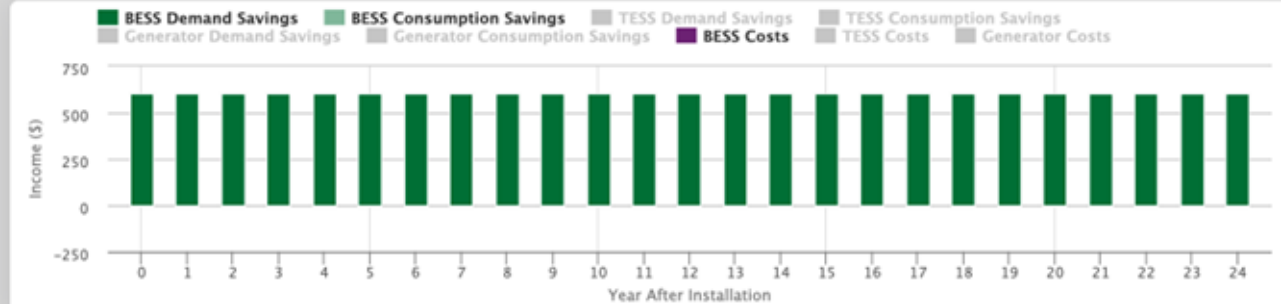
- ★ The consumer can consider enrolling their existing BESS in with the utility's DER sharing program, or consider a new installation. The consumer can also see how quickly a new installation could be paid off over time.

All TESS Savings vs. Incentives

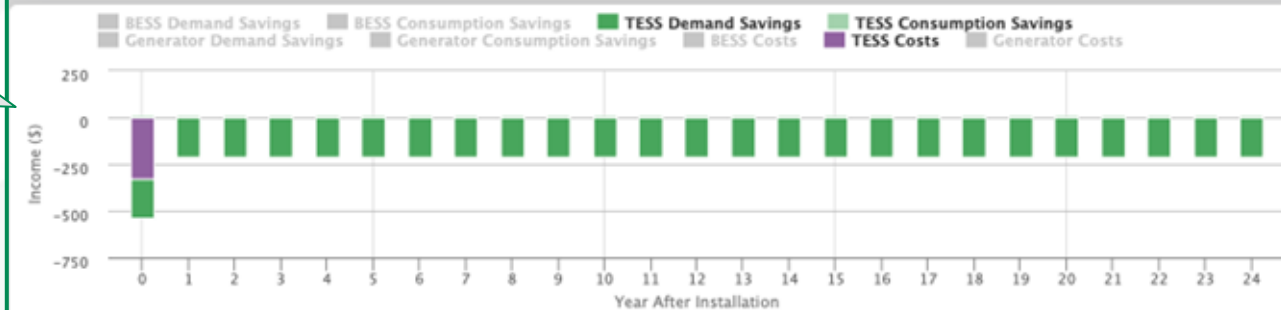
Annual TESS Demand Savings + Consumption Savings = -\$195/yr

- ★ The consumer can consider installing a Smart Thermostat and other load control devices and enroll in the utility's DER sharing program, but these results suggest that it may be more expensive for the consumer.

Savings Breakdown Per Technology

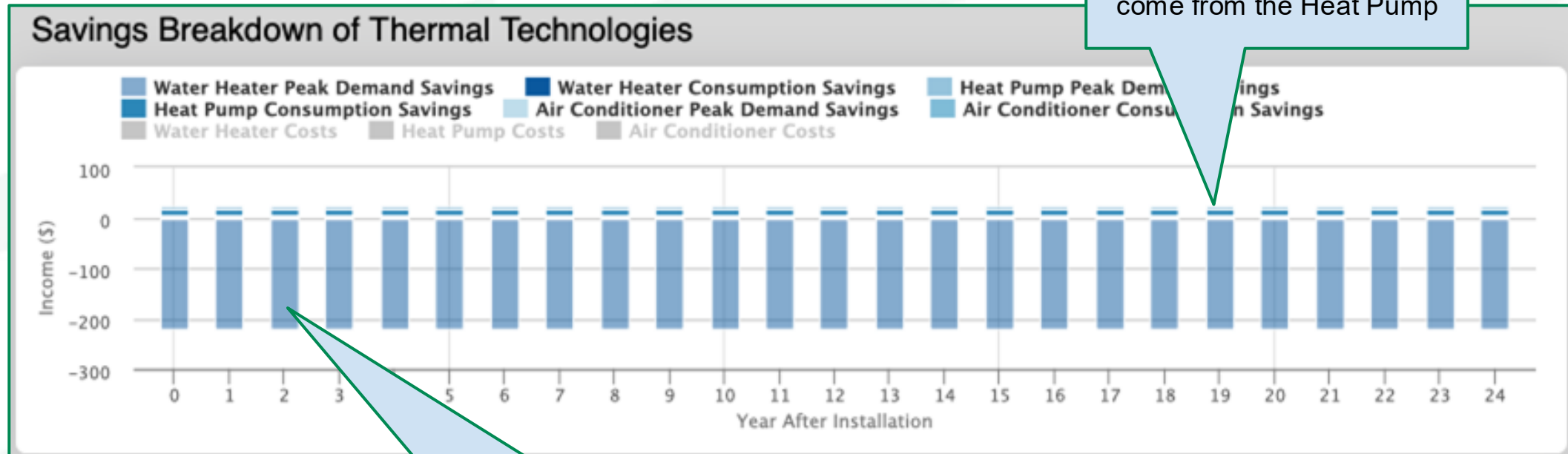


Savings Breakdown Per Technology



Note: The Y axis scale is not the same between the two plots. See the previous slide for a better side-by-side comparison between TESS and BESS.

Flathead – derConsumer Outputs



Water Heaters were listed as Flathead's #2 technology preference, but provided the least amount of savings to the consumer out of all the thermal DER.

Flathead's Tech Preferences

- #1 = Central Air Conditioner
- #2 = Water Heater
- #3 = Heat Pump
- #4 = BESS
- #5 = GEN