Tucson Electric Power

October 17th, 2019

IRP Advisory Council Presentation

Distributed Energy Resources and Customer-Sited Energy Resource Alignment

CONTENT

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- Customer Energy Resource Alignment (CERA): Solution Overview
- Project RAIN
  - Background & Objectives
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  - CERA Roadmap Considerations
- Conclusion & Next Steps

OVERVIEW

The Utility Impacts

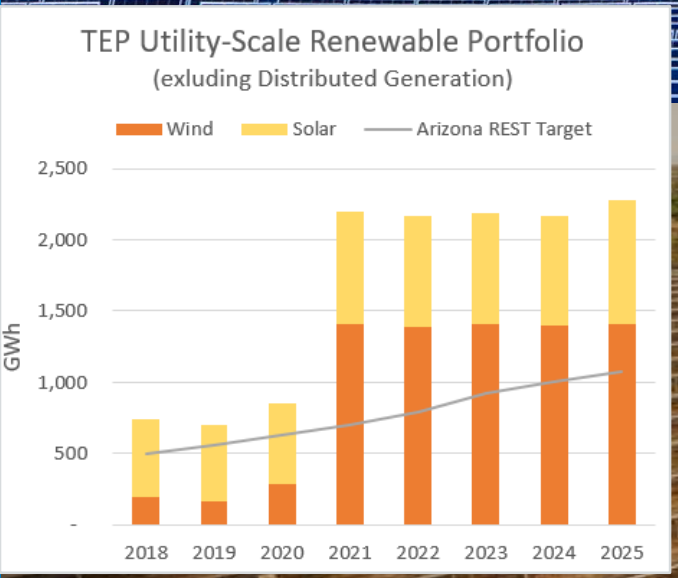
Related to Distributed Energy Resources

Utility-Sited & Large Scale DER at TEP

Currently

- 474 MW Solar
- 80 MW Wind
- 21 MW Energy Storage
- 34 MW DR

630 MW new renewable capacity planned by end of 2030

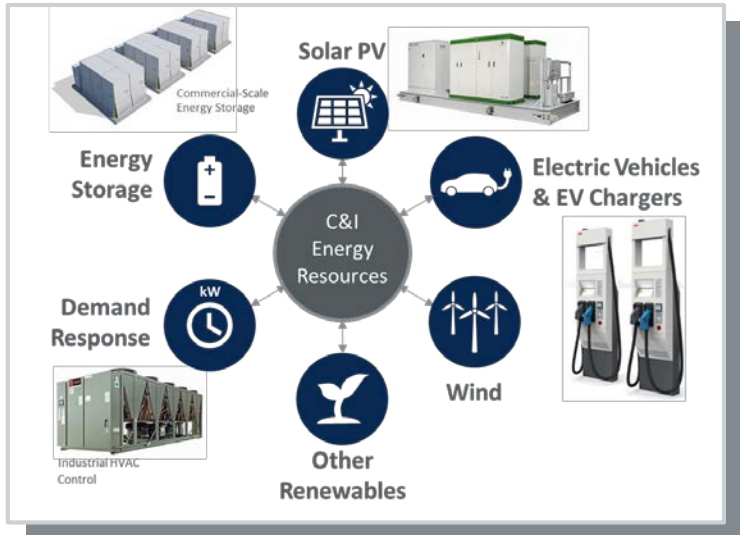


A diverse ecosystem of Customer-Sited Energy Resources (CERs) are increasingly common, presenting challenges & opportunities to utilities

- The vendor landscape is increasingly complex as the number of CER devices & manufacturers grows
- Each CER device has unique comms protocols, impacts on the local grid, and vendors/aggregators
- Without monitoring & control, CERs represent uncertain generation and load at the grid edge

RESIDENTIAL CERS

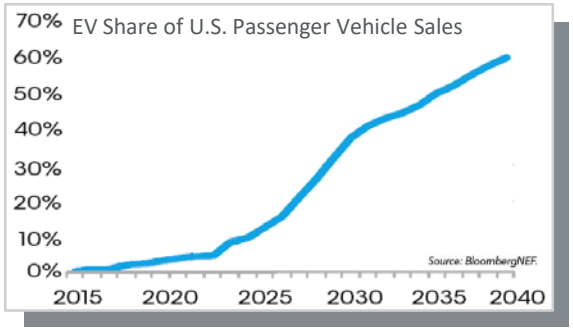
COMMERCIAL CERS



CERs continue to increase in penetration and impact across the grid

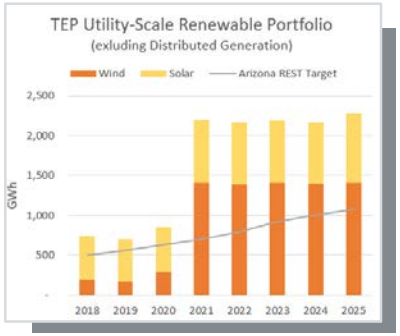
1

ELECTRIC VEHICLE PEAK LOAD FORECASTED TO GROW SIGNIFICANTLY



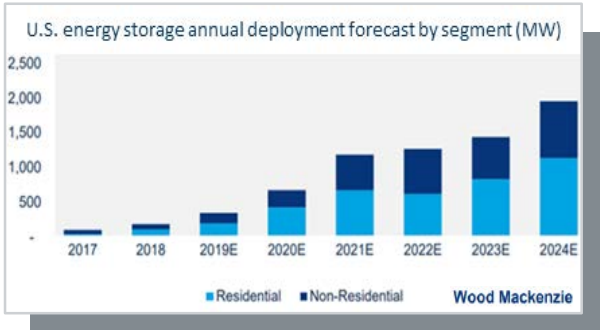
2

SOLAR CONTINUES TO INCREASE AS A SHARE OF GENERATION



3

BATTERY STORAGE GROWTH ACCELERATES



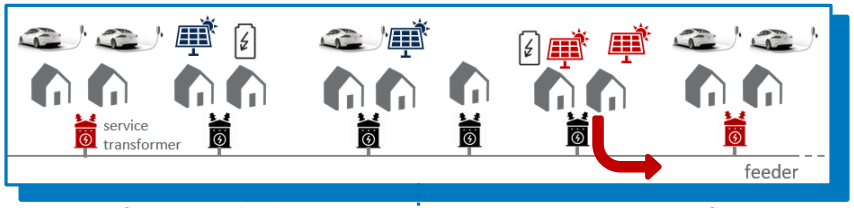
…and, Smart Thermostat market (~5M installed): estimated 20% avg. annual growth through 2024

As CERs proliferate they can cause a variety of grid issues

PROBLEM: When uncontrolled, CERs can cause local and system-level reliability issues

LOCAL ISSUES

High penetration can overwhelm service transformers, cause reverse power flow, and create power quality issues



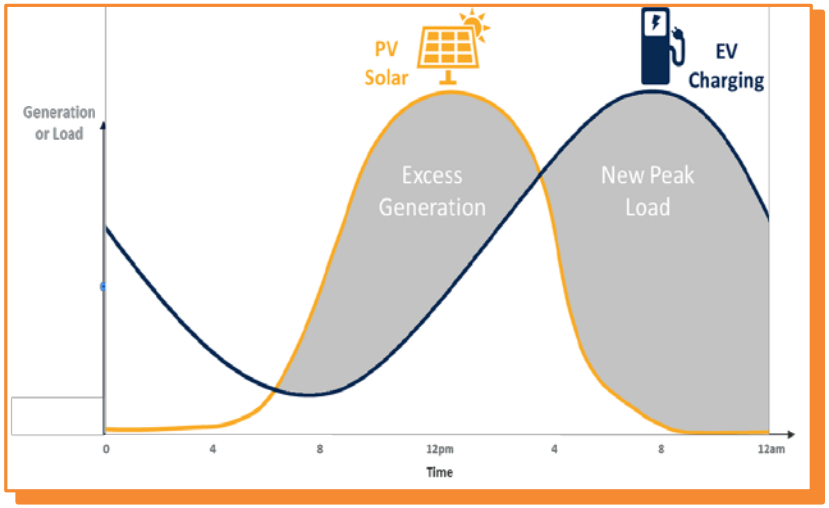
transformer overload
voltage sag

reverse power flow
high voltage

In 2019, 4% of TEP feeders experience these local issues

SYSTEM-LEVEL

Solar generation is not aligned with new Electric Vehicle load, creating over-generation mid-day and driving higher system peaks



Issues begin in pockets but will spread system-wide as CER penetration increases

Utilities have 3 ways to address Customer-Sited Energy Resources (CERs)

1. System Hardening

Benefits

- Known, proven approach
- Long-term, reliable solution
- Minimum Customer Impact

Drawbacks

- Significant grid investment
- May decrease grid utilization
- Feeder-by-Feeder Solution

2. Utility-Owned DER

Benefits

- A viable approach
- Improves grid utilization
- Minimum Customer Impact

Drawbacks

- Significant DER investment
- Feeder-by-Feeder Solution

3. CER Control & Alignment

Benefits

- Potentially economic solution
- Leverages existing CER assets
- Improves grid utilization& supports reduction of grid investment
- Scalable system-wide

Drawbacks

- Requires technical development to advance beyond system-level DR
- Highest customer impact

TEP Project RAIN

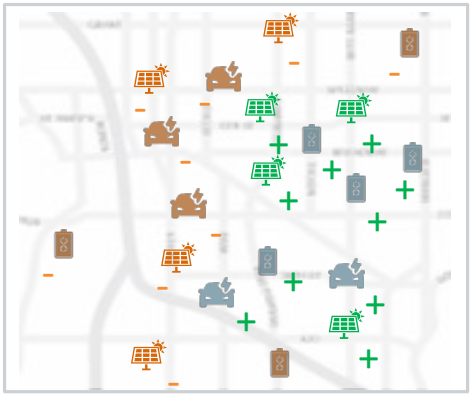
- A blended approach leveraging each solution is likely most economic, practical
- Project RAIN demonstrated CER Alignment is technically viable, but has challenges
- TEP will continue to evaluate all options and pursue the most cost-effective portfolio

Customer Energy Resource Alignment (CERA)

Solution Overview

CERs bring customer complexities beyond traditional Utility DER control

- CERs spread across the grid may be helping or hurting grid operations at any time
- It is a critical organizational decision to develop a strategy for aligning CERs to the grid



CER Customer Considerations

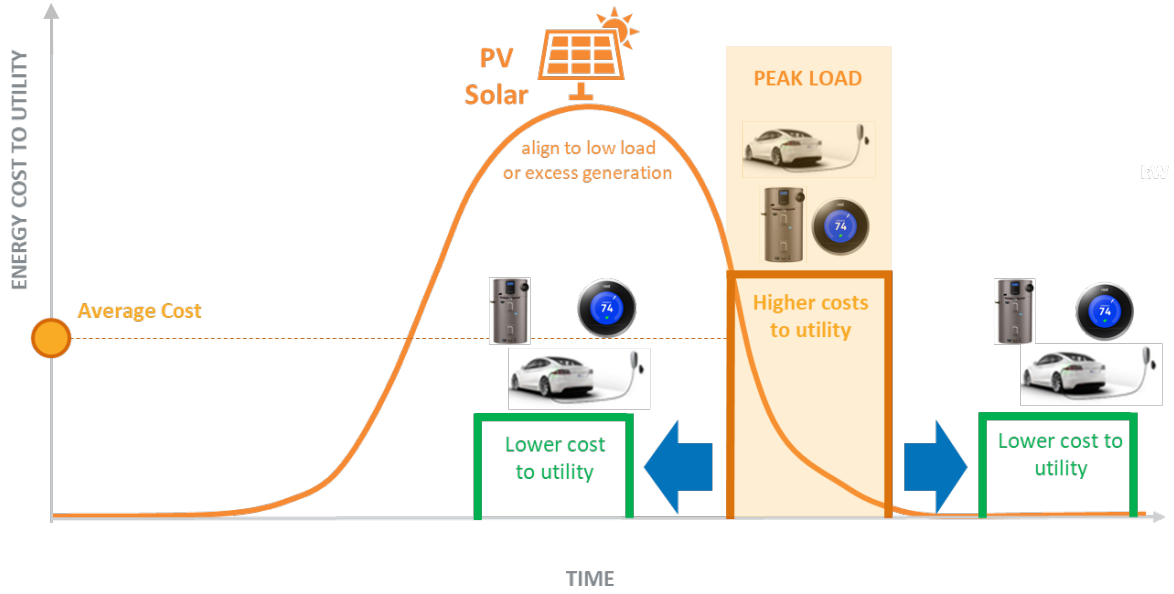
- **Customer owns the asset** and TEP must engage customers and gain consent to control their devices.
- **Customer experience** must be maintained and their objectives, like lower bills, must be considered.
- **Third-party vendors** may own, install or maintain devices or their communications.

Proliferating CERs necessitate customer engagement and alignment between customer, aggregator & utility objectives

For this reason, Project RAIN evaluated the customer experience of participants in addition to technical factors

Aligning CER operation could benefit both customers and the utility

- Improve grid utilization, reduce peaks and potential to defer infrastructure investment
- Shift electric use, like EV charging, to low load periods or times of excess solar generation



KEY CHALLENGE: Designing a system to perform multiple operational DER/CER Management objectives while interfacing with a diverse set of CER Aggregators & Devices

Project RAIN positions TEP to progress from "Walk" to "Jog"

Project RAIN: Focus on controlling devices via aggregators for local and system-level impact

"Explore"—Current

- System-wide Commercial & Industrial Demand Response only
- CER in most cases managed by the customer without direct utility control

"Walk"—Near Term

- System-wide Demand Response & Generation Curtailment
- Dispatch through separate aggregator portals
- Explore CERA solutions to centralize dispatch, test local CER control (pilot)
- Prelim Measurement & Verification (M&V) of control events

"Jog"—Mid Term

- ADMS derives dispatch needs, but grid operators manually dispatch in CERA
- Dispatch through centralized CERA
- Localized dispatch enabled
- Explore CERA dispatch optimization & advanced use-case functionality (pilot)
- M&V of control events

"Run"—Long Term

- ADMS derives dispatch needs and automatically dispatches CERA
- CERA integrated to ADMS to prioritize, address constraints
- CERA CER dispatch optimization enabled
- Automated CER response
- Autonomous CER behavior
- Micro-grid type enablement at some customers
- Near real-time M&V of control events

Years to Achieve:	1-3 Years	3-7 Years	7+ Years

Technical complexity & industry nascency drive long implementation timelines and necessitate staged testing, development, and deployment.

Project RAIN

(Resource Aggregation and Integration Network)

Project RAIN—Overview

One of the first projects globally to explore how Customer-owned distributed generation, energy storage and flexible loads can be controlled to respond optimally to dynamic requests from a CERA platform.

Test control & optimization of diverse devices & locations

45 Devices

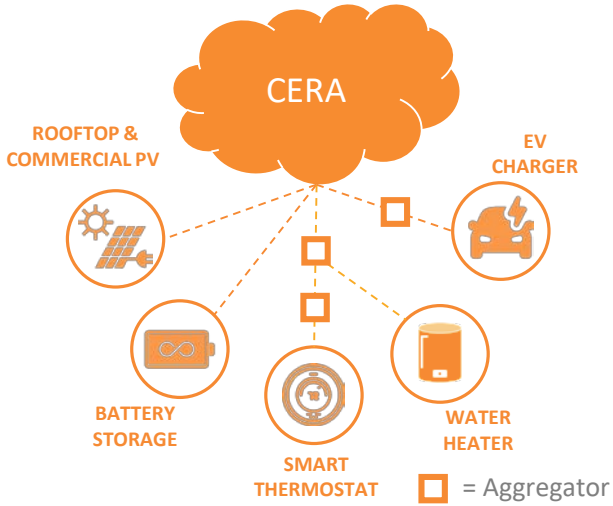
13* Locations

146 Test Days

11 Event Types

* Does not include two additional backup test-sites which were not utilized for testing

Single platform managed DERs and Behind the Meter CERs



Enabled strategic learnings

- State of the industry with respect to CER aggregation
- Practical capabilities of individual and aggregated CER
- Potential for **customer engagement** in supporting the grid
- Practical challenges of communication and coordination
- Strategies for applying CER management to TEP grid operations

TEP partnered with EPRI and Smarter Grid Solutions to control a variety of CERs

EPRI ELECTRIC POWER RESEARCH INSTITUTE

smarter grid solutions

TEP

Project RAIN- Achievement Summary

- Validated technical ability to control and align CERs to grid needs
- Uncovered and resolved practical challenges
- Gained understanding of the state of the industry
- Learnings will inform CERA Roadmap, future implementations

CERA Capabilities	Project RAIN Validation
Peak Reduction & Load Shifting	✓
Curtail Capacity & Prevent Reverse Power Flow	✓
Local Balancing	✓
CER Dispatch via Aggregators	✓
CER Dispatch- Direct to Device	✓
Real-time CER dispatching	✓

Project RAIN Validates CERA's potential to solve utility & customer CER challenges

Project RAIN provided TEP with a critical understanding of how CER devices can be aligned to support local and system-level objectives

Each device has benefits and drawbacks for CERA utilization

Battery Storage

+ Can be dispatched in either direction at any time
+ Minimal comfort impact
- Requires awareness of battery state of charge

Solar PV

+ No comfort impact
- Can only curtail (increasing load)
- Peak does not line up with utility peak

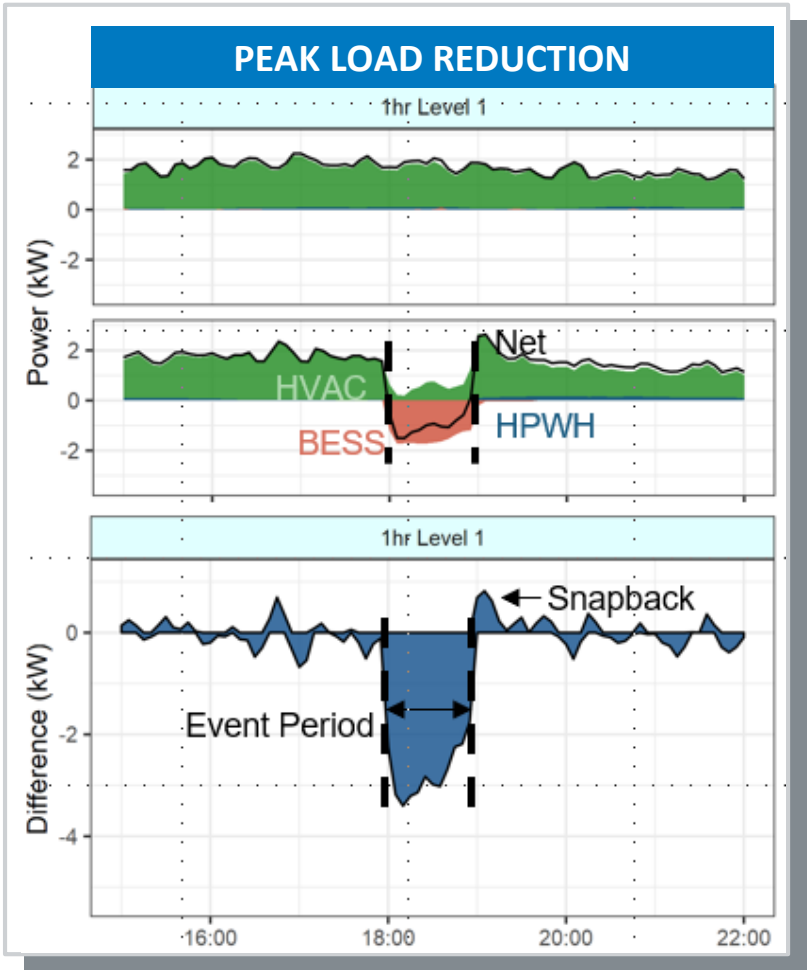
Smart Thermostat

+ Large portion of customer load
+ Peak HVAC correlates with peak utility load
- High customer impact
- Impact fades as degree target reached

Water Heater

+ Minimal comfort impact
- Unpredictable usage pattern
- Minimal impact on total load

CERs were successfully controlled to provide grid benefits

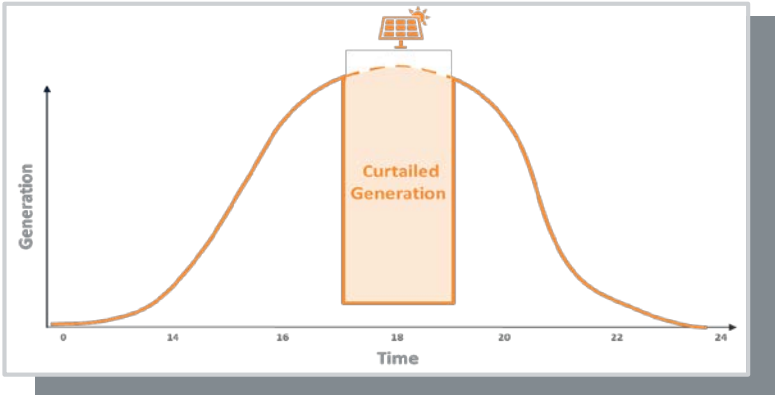


ACHIEVED LOAD REDUCTION DURING PEAK PERIODS

- Smart Thermostat temperature setpoints increased
- Water Heater avoids heating, maintains lower water temperature
- Battery storage systems dispatched to fulfill remaining demand or provide energy to the grid
- **Collectively, the CERs were coordinated to provide 3kW of peak demand reduction**

CERs were successfully controlled to provide grid benefits

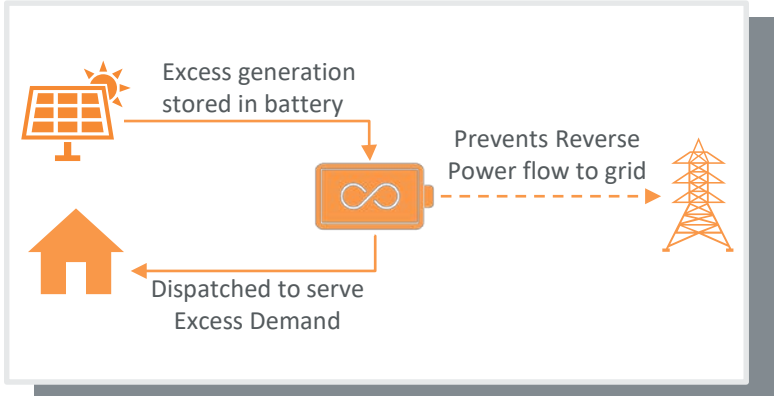
Solar PV Curtailment



CURTAILED OVERGENERATION

- Solar PV generation curtailed by 90% of nameplate capacity (~55kw) during overgeneration events

Exported Energy Reduction



MAXIMIZED LOCAL CONSUMPTION & REDUCED REVERSE POWER FLOW

- Battery storage aligned to improve self-consumption of Solar PV and minimize exports to the grid
- Reduced Reverse power flow up to almost 80%

Project RAIN—Implementation Challenges

Numerous challenges (both technological and philosophical) were encountered. While some were overcome, others remain to address in future implementations

PROTOCOL ISSUES

1. Proprietary standards still pervasive, introduce complication & potential vendor lock-in
2. Signals limited to set of 4, predefined SIMPLE commands
3. No defined means of cancelling/updating an event
4. Open ADR to API conversion required
5. Some definitions of events still reside with vendors

DATA ISSUES

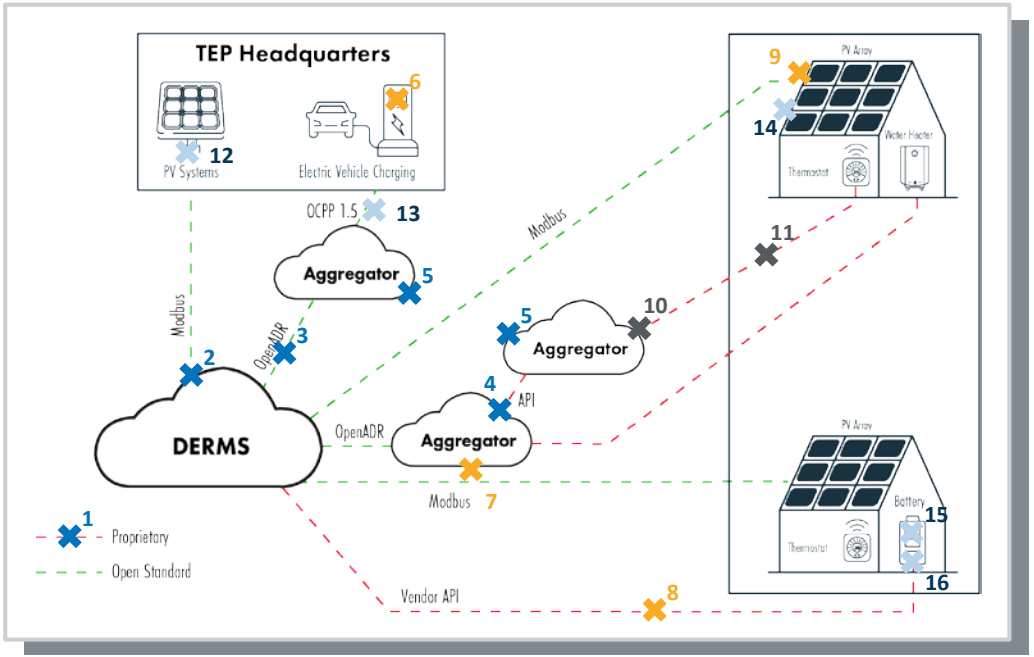
6. No indication of shed event
7. Reports idle shed when should report idle heightened
8. No awareness of device state
9. No DERMS awareness of inverter kVA (real vs. reactive) power limit

PROCEDURAL ISSUES

10. Alerts sent for every hour of multi-hour event
11. Signals take up to 3 minutes to reach some t-stats

HARDWARE/SOFTWARE FAILURES

12. Comms/control board failure
13. Cellular link to parking garage frequently breaks
14. Comm board failures
15. Stops dis/charging arbitrarily
16. ECO6 units disconnect permanently if SoC drops too low



Other Challenges

- Current approach to device connectivity is data-intensive
- Customer comfort impacted by t-stat events
- Contractor education & installation issues

Project RAIN Key Findings

Standardize Protocols, Minimize Customization

Even with open standards, differences between vendors necessitate costly customization

Balance Local & Centralized CER Control

Local control can achieve static local goals, but centralized CERA required for dynamic grid needs

Minimize Communication Data Intensity

High intensity requires high bandwidth networks, increase costs of implementation

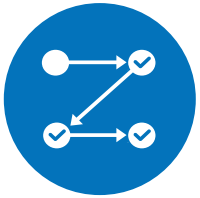
Prioritize Customer Experience & Contractor Engagement

Customer engagement & experience, proper CER installation / maintenance are critical to effectiveness

Develop Dispatch Optimization Capabilities

Effective optimization is critical to enabling full value of long-term ADMS/CERA integration.

Key Finding Roadmap Considerations



Standardize Protocols, Minimize Customization

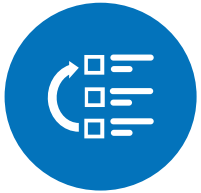
- Advocate CER communications standardization in legislative, regulatory, and utility policy
- Leverage common aggregation platforms
- Limit the number of supported devices types in program design

Prioritize Customer Experience & Contractor Engagement

- Prioritize customer comfort/experience in program design
- Engage manufacturers, installation & maintenance contractors to ensure awareness of CERA programs/equipment

Balance Local & Centralized CER Control

- Centrally controlled CERA will be required to align to dynamic needs
- Evaluate local control to add customer value (e.g. bill reduction)



Develop Dispatch Optimization Capabilities

- Prioritize Optimization capabilities in Distributed Energy Resource Management System/CERA selection
- Utilize a phased implementation & testing roadmap to develop & validate capabilities

Minimize Communication Data Intensity

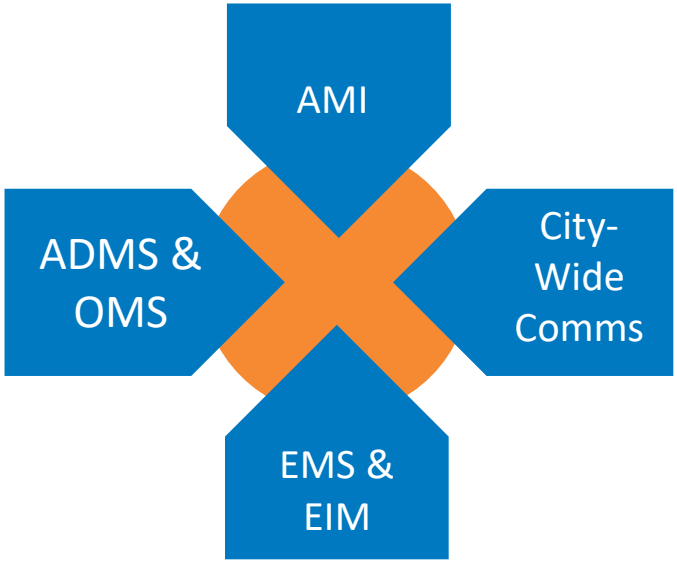
- Evaluate alternative, “push” based communication approaches
- Consider network bandwidth needs in technology roadmap

Conclusion

& Next Steps

CERA is part of a system wide Distribution Modernization effort at TEP

Distribution Modernization drives 4 key pillars of operational advancement



- Situational awareness and real-time response is the TEP roadmap
- These 4 pillars are in-flight
- Once completed, the infrastructure to achieve CERA is in place

AMI – Automated Metering Infrastructure
ADMS – Advanced Distribution Management System
OMS – Outage Management System
EMS – Energy Management System
EIM – Energy Imbalance Market

TEP Current & Near-Term CERA Programs

TEP's Energy Efficiency & Demand Side Management Plans are increasingly promoting managed CERs

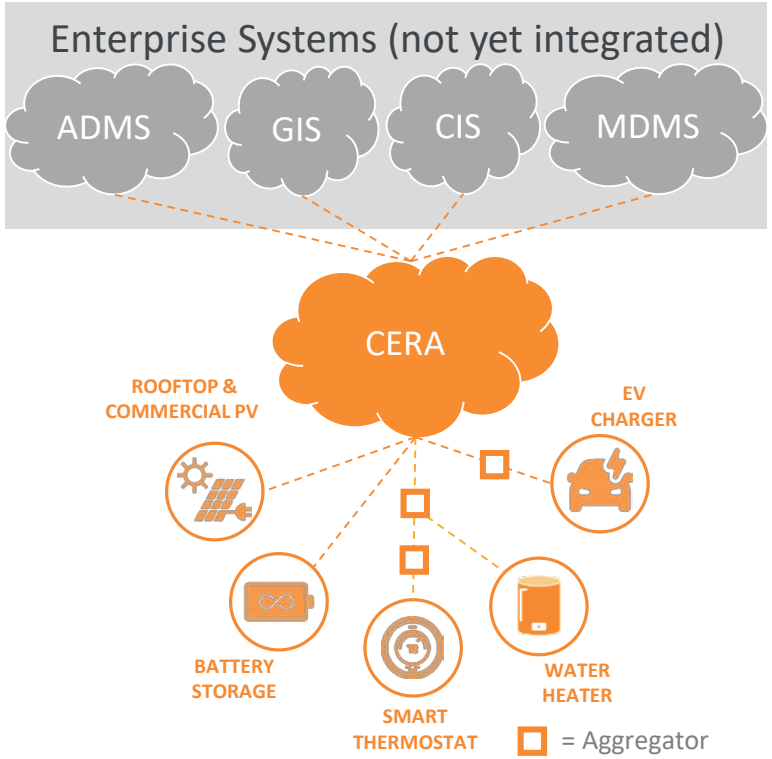
Residential Load Management Pilot Program	Electric Vehicle (EV) Infrastructure Program	Customer Incentive Programs
◆ Demand Response & Thermal Storage: Smart Thermostats and Controlled Water Heaters ◆ Feeder level Storage via large-scale battery units	◆ Smart City EV Buildout ◆ Smart Home EV Pilot ◆ Smart School EV Bus Pilot ◆ Regional EV Plan ◆ Managed Charging	◆ Smart Thermostat Incentives ◆ EV Charger Program ◆ Grid Interactive Water Heater Program

Programs are incentivizing CER adoption, including utility control of CERs

Project RAIN—steppingstone towards a full, system-integrated CERA

- Project RAIN focused on control of end-point CERs – more functionality remains to be tested

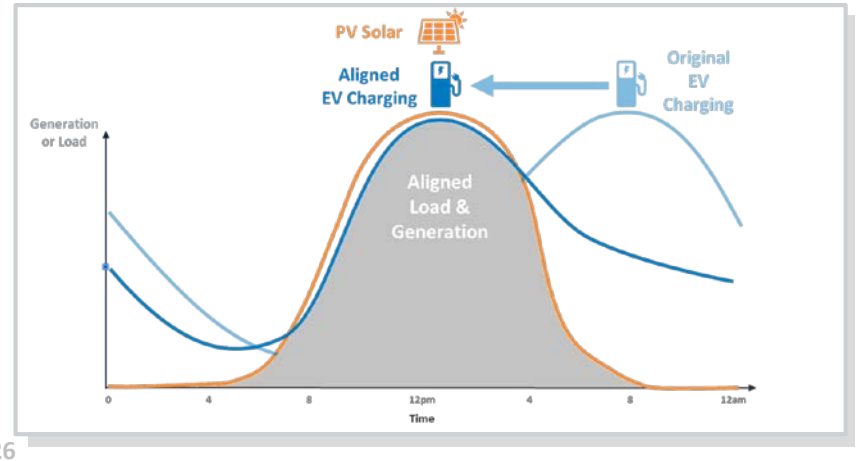
Long-Term CERA Capabilities	Project RAIN
CER monitoring & control	✓
Real-time CER dispatching	✓
CER scheduling	✓
CER Aggregation	✓
Dispatch/Schedule Optimization	✗
CER Forecasting	✗
Fail-safes	✓
Market Participation	✗
Real/Reactive power control	✓ real power only
Volt Var Optimization	✗



GIS – Geographical Information System
CIS – Customer Information System
MDMS – Meter Data Management System

PROJECT RAIN—Conclusion

- **Challenges across** technology, process, vendor and customer engagement **to be solved**
  - **CERA as a scalable solution** will require incremental validation and testing
- Aggregator vendor ecosystem for CERs is nascent but **rapidly evolving**
- CER growth combined with long lead-time for solution implementation **necessitate:**
  - **continued planning & evaluation**
  - **incremental development & testing of CERA capabilities**
- Alignment of CERs presents a key opportunity to **benefit TEP grid operations**



NEXT STEPS

- Design incremental field deployments
- Continue process of learning
- A roadmap that aligns **CERA** with **ADMS**

THANK YOU!