THE ROLE OF DISTRIBUTED ENERGY RESOURCES IN TODAY'S GRID TRANSITION

GRIDWORKS

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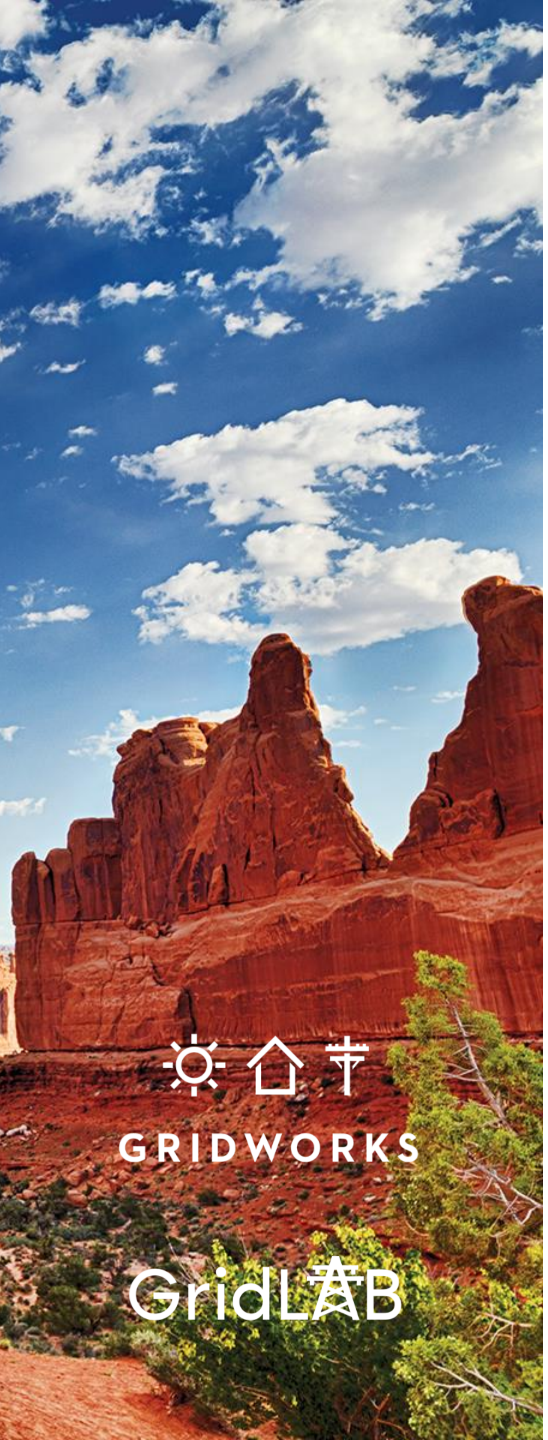


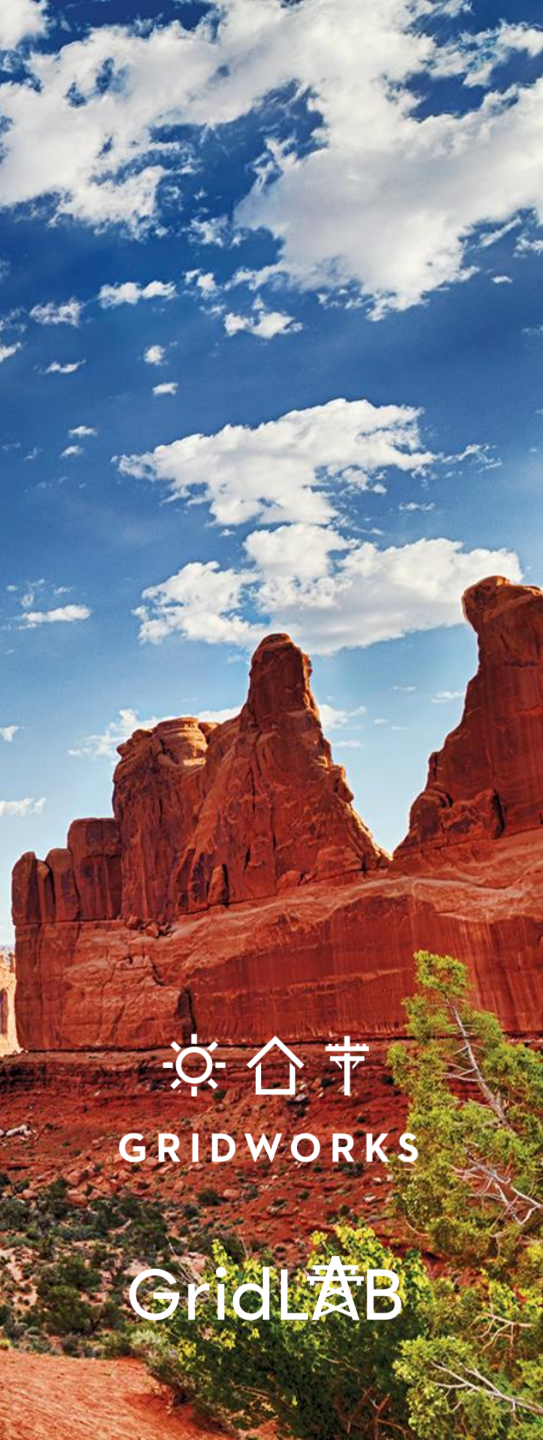
1 | INTRODUCTION

TWO MOST SIGNIFICANT TRENDS IN US ENERGY MARKETS

1. Adoption of large, central renewable generation by utilities and policy-makers
2. Adoption of distributed energy resources by customers

QUESTION | *Do these trends complement or frustrate one another?*

CONCLUSION | *Distributed Resources increasingly seen as a complement to large, scale renewables, because they deliver unique benefits to customers AND flexibility to the grid.*



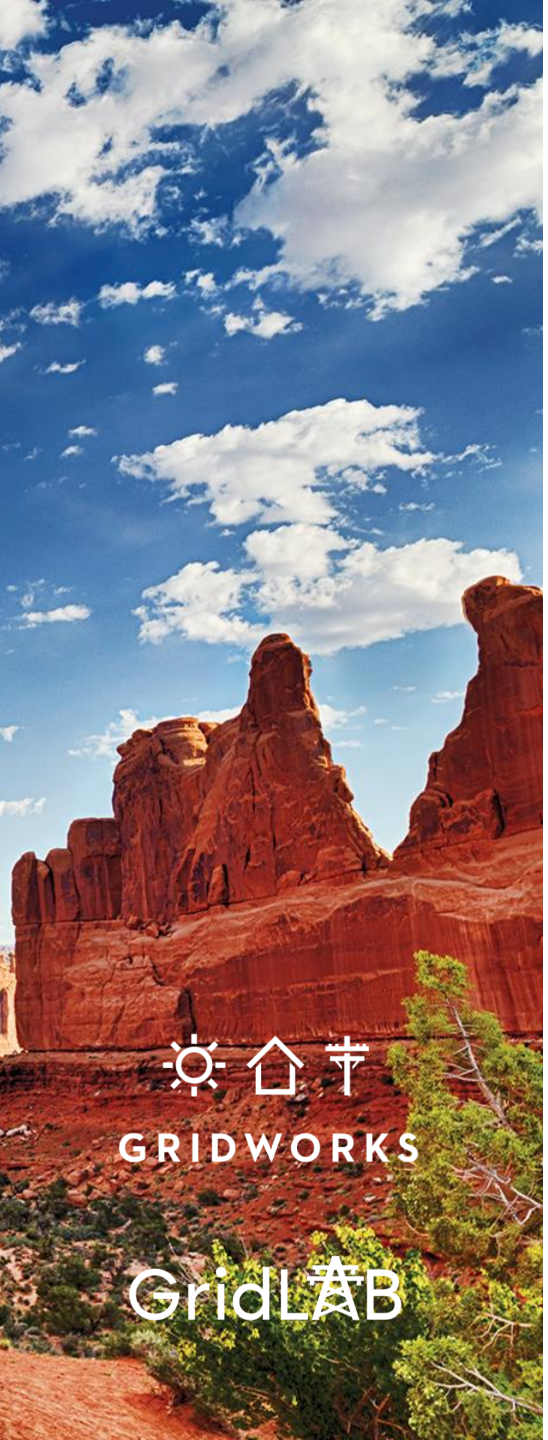
2 | DEFINITION AND CAPABILITIES

DISTRIBUTED GENERATION

- small-scale power generators
- decentralized and typically connected to the distribution grid; behind- or in-front-of customer meter
- Technologies: solar photovoltaics (PV), small wind systems, cogeneration/ Combined Heat and Power systems, and fuel cells

CAPABILITIES

- *the ability to generate energy locally, closer to end users compared to traditional generators*
- *reduce demand for costly, large-scale utility infrastructure, such as high- voltage transmission lines*
- *Reduce line-losses*



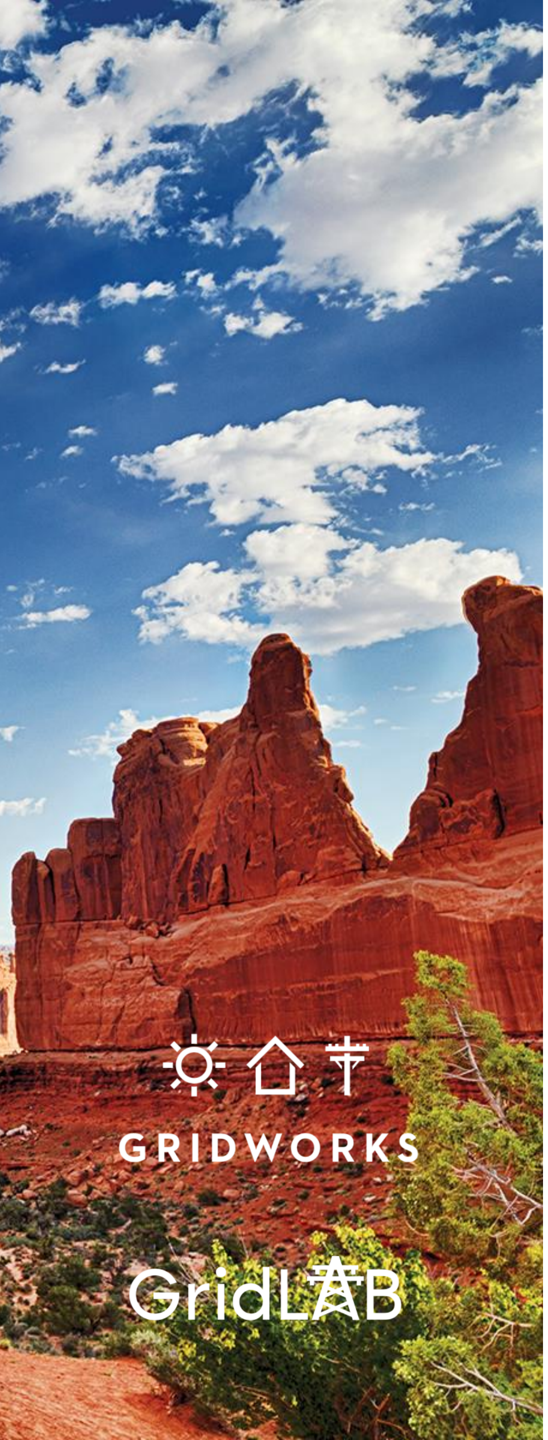
2 | DEFINITION AND CAPABILITIES

BATTERY STORAGE

- used to both store and discharge energy; both a generator and a source of load
- Behind- or in-front-of the customer meter
- Technologies: primarily lithium ion

CAPABILITIES

- *shift energy from times of plenty to times of scarcity*
- *respond to price signals in order to both meet grid needs and reduce customer bills*
- *provide important voltage regulation and frequency regulation services to improve power quality*



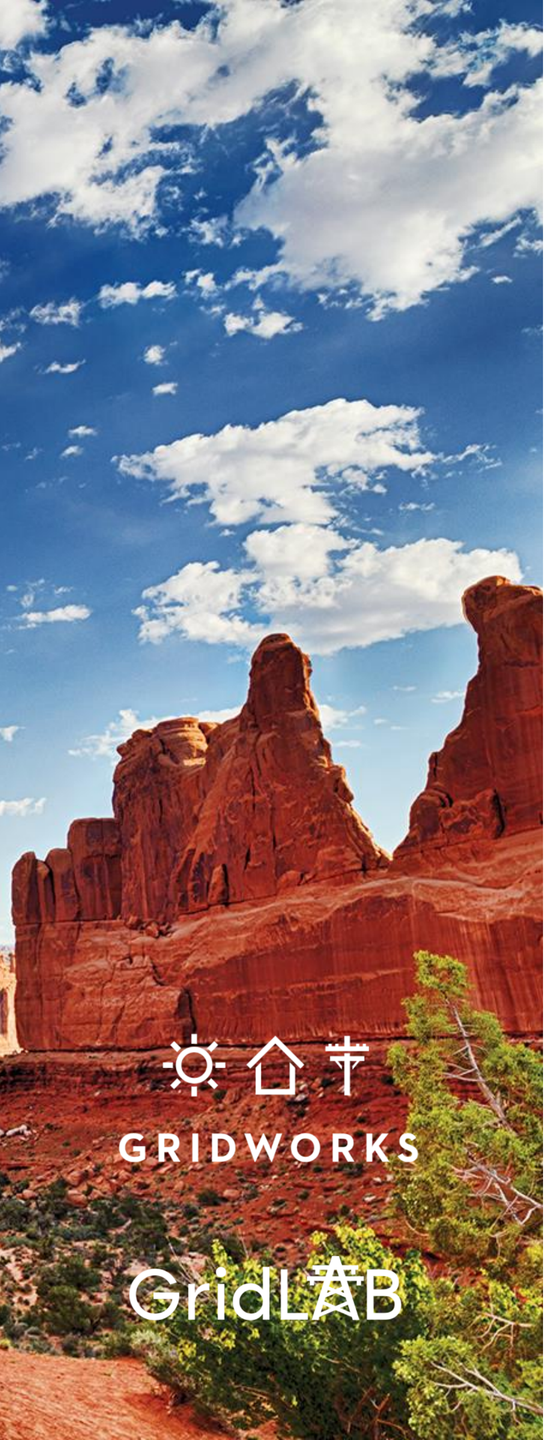
2 | DEFINITION AND CAPABILITIES

SMART INVERTERS

- devices that convert direct current produced by a generator to alternating current used by the grid

CAPABILITIES

- *intelligently manage the output of the DG system*
- *provide voltage support, frequency regulation, and ramp rate control*
- *stabilize voltage and frequency on the grid, and to "ride through" a minor voltage or frequency disturbance*



Source: ACEEE

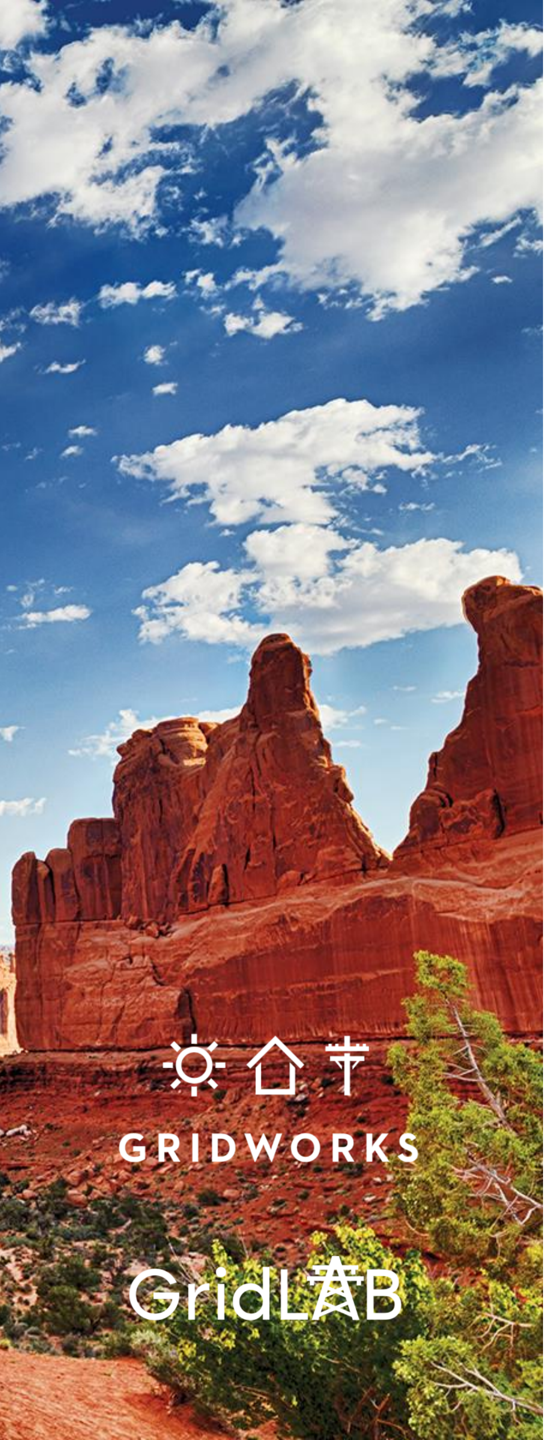
2 | DEFINITION AND CAPABILITIES

ENERGY EFFICIENCY

- customer-sited technologies and behaviors that reduce a consumer's end-use energy consumption
- Technologies: lighting or insulation improvements, mechanical improvements of heating, cooling, appliance, and industrial systems, or passive measures that monitor and control energy consumption

CAPABILITIES

- *primarily provides load and demand reductions by enabling and encouraging consumers to use less energy*
- *Targeted energy efficiency can reduce system peak load and grid constraints*



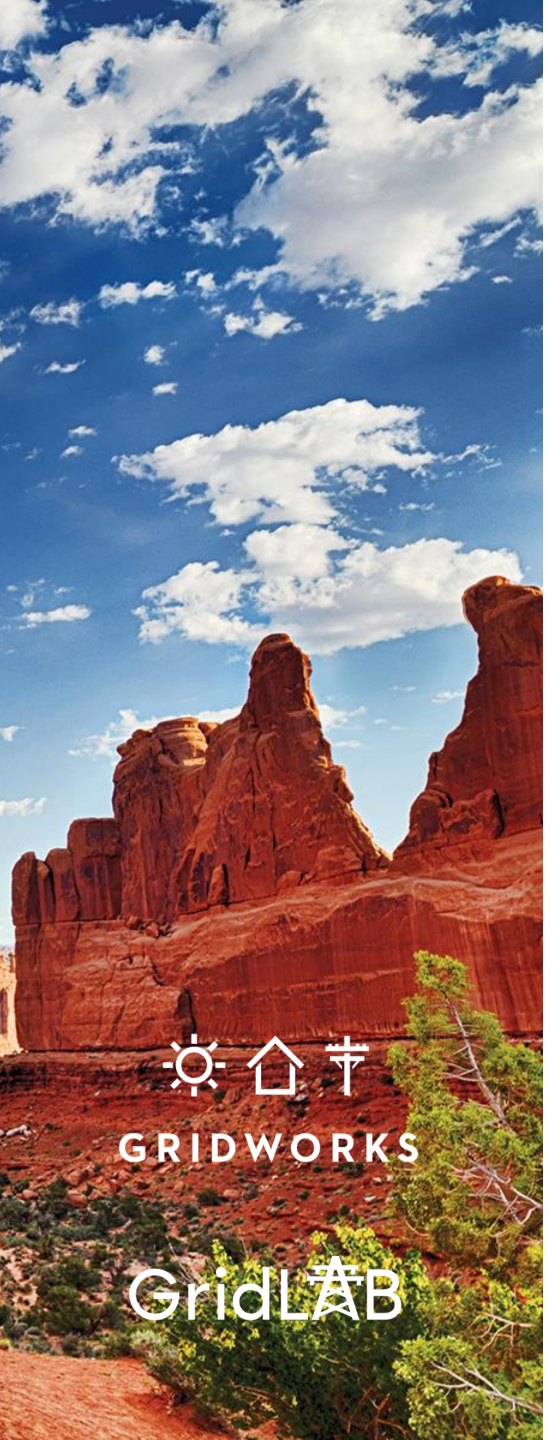
2 | DEFINITION AND CAPABILITIES

DEMAND RESPONSE

- a coordinated reduction in electric load in response to specific system conditions or market incentives
- controlled by a customer, an aggregator or directly by the utility
- Technology: smart thermostats, battery storage, EV chargers, pool pumps, electric space and water heaters, and more…

CAPABILITIES

- *used to shape and shift load*
- *shed load during peak load events; shift load to periods of oversupply*
- *provide ancillary grid services, such as rapidly smoothing load or regulating voltage in response to sudden grid disturbances*



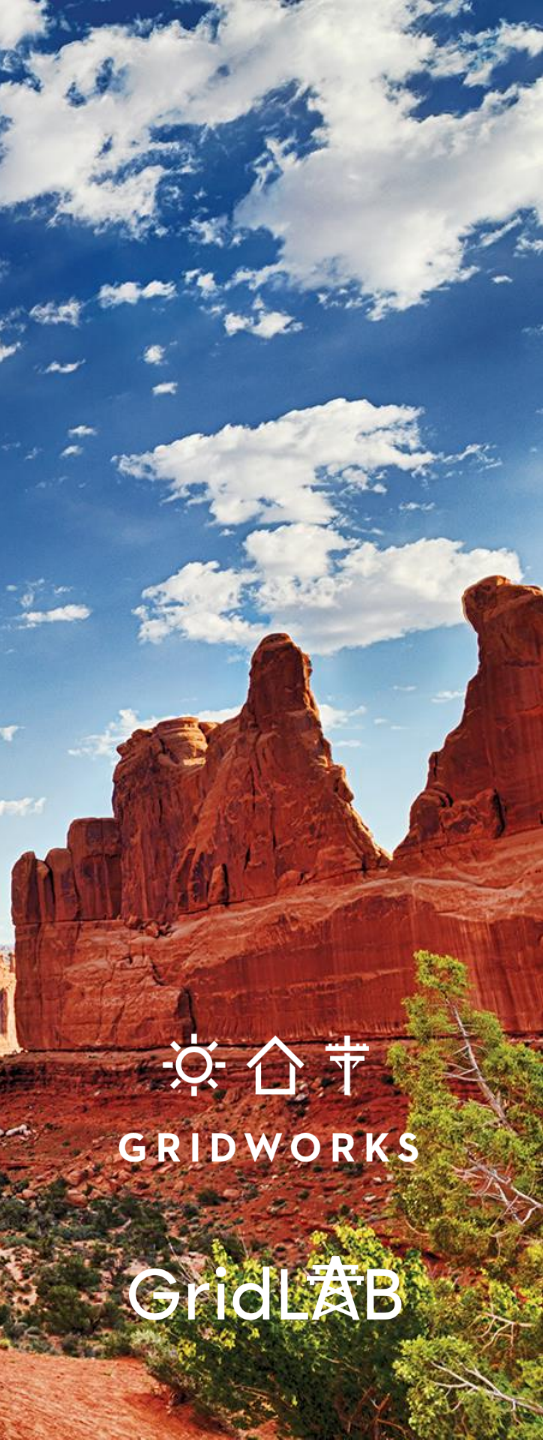
2 | DEFINITION AND CAPABILITIES

ELECTRIC VEHICLES

- primarily provide mobility, and consumers rarely (if ever) purchase them for the additional grid services they can provide
- Flexible load that can be shaped and shed

CAPABILITIES

- *Mobile demand response: used to shape and shift load*
- *particularly effective customer engagement tool*



2 | DEFINITION AND CAPABILITIES

DER: GOOD ALONE, BETTER TOGETHER

Distributed energy resources can be combined to maximize their value to the grid and the adopting customer

Customer-sited
- Solar + Storage + Smart Inverter + EV

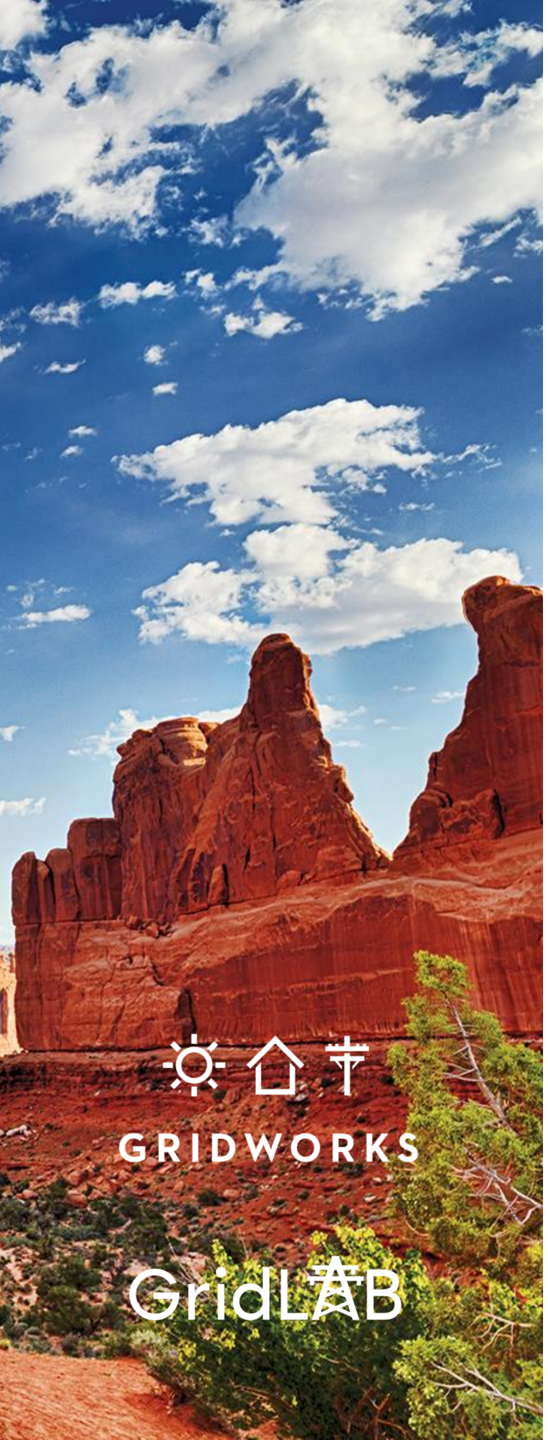
Microgrids
- Coordinate resources across locations

Portfolios
- drawing on the relative strengths of different technologies
- risk management strategies that are not possible for single DER resources.

Source: GE

A portfolio of interconnected distributed energy resources can provide enhanced value and services compared to each resource in isolation.

Image Courtesy of GE



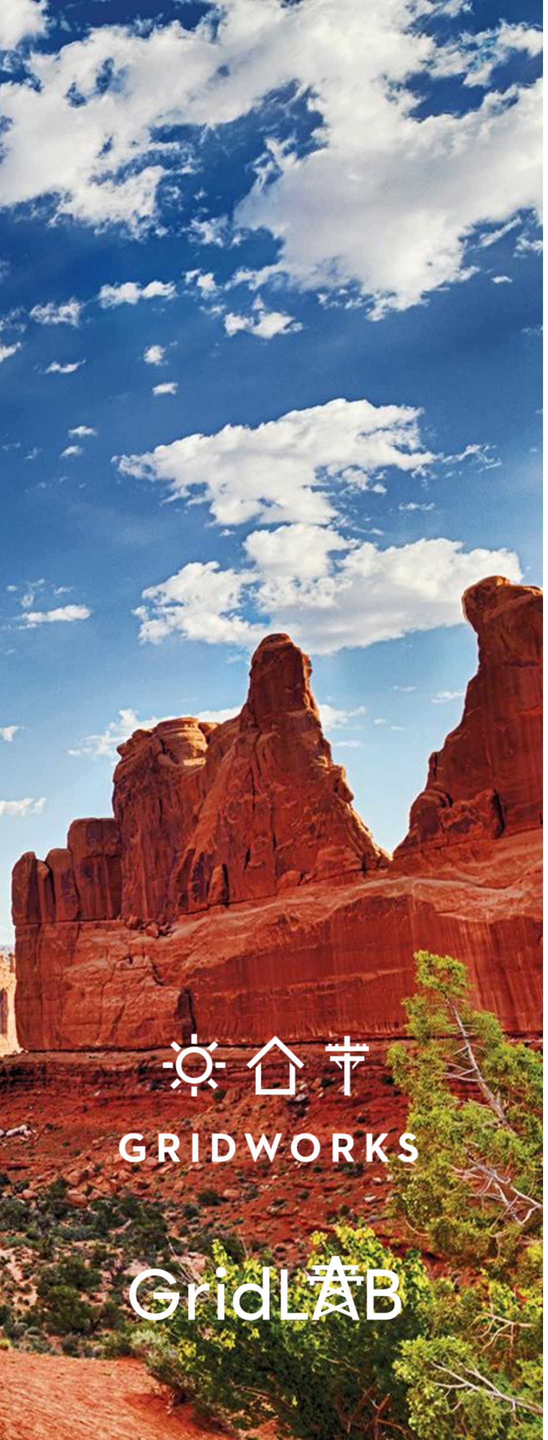
3 | DER SERVICES

- **AVOIDED GENERATION**
- **AVOIDED TRANSMISSION AND DISTRIBUTION INFRASTRUCTURE**
- **FLEXIBILITY**

WHAT IS FLEXIBILITY?

The flexibility the grid requires can be described as:

- **Ramp** - the ability to respond rapidly and over sustained periods to changes in load or generation.
- **Overgeneration** - the grid needs to be able to absorb or shift excess generation.
- **Frequency** - the grid needs to keep generation and load in balance at all times.
- **Voltage** - maintain voltage within acceptable limits. While the other flexibility needs are required at a larger system level, voltage is a local requirement and must be managed at a circuit level.



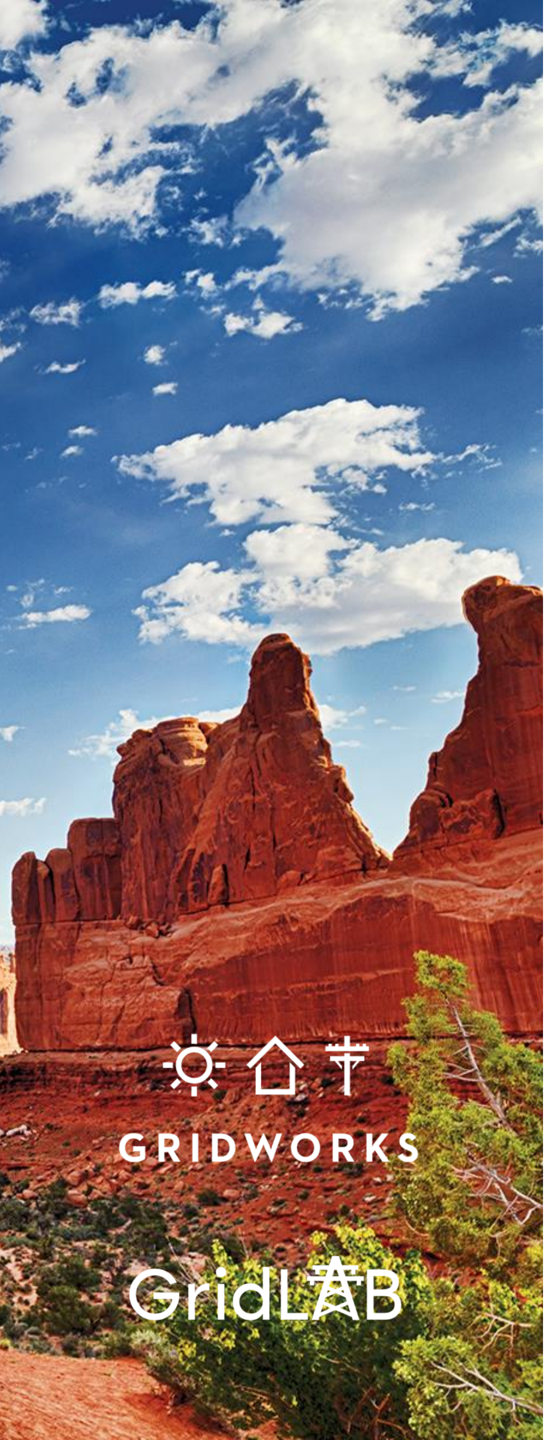
4 | CASE STUDIES: EMBRACING DER SERVICES

NEW YORK REV

ConEd was forced to consider $1.2 billion of grid upgrades, including a new substation, in order to mitigate the overload.

Instead, ConEd pursued a mix of traditional grid upgrades and distributed solutions that in total cost one-fifth of the traditional “wires” solution.

The solution included a portfolio of DER such as distributed generation, energy efficiency, demand response, and battery storage.



4 | CASE STUDIES: EMBRACING DER SERVICES

NEW YORK Reforming Energy Vision (REV)

Source: SEIA

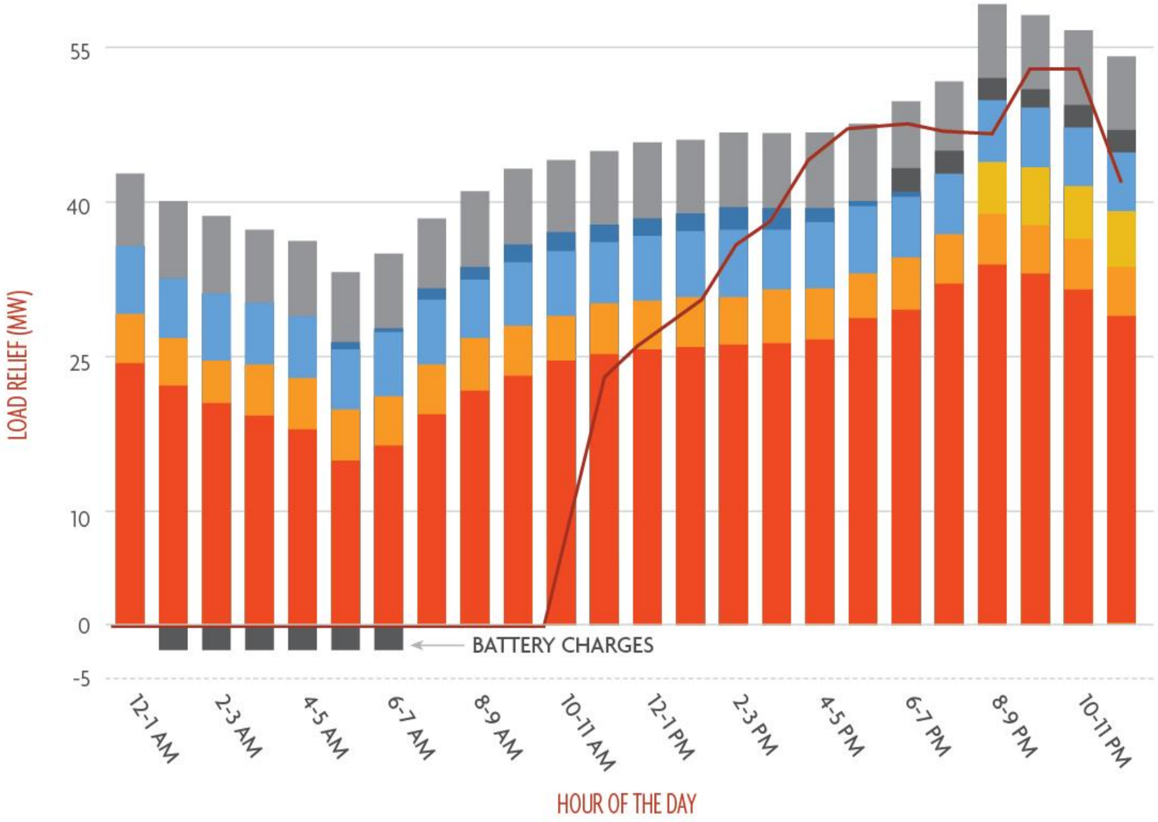
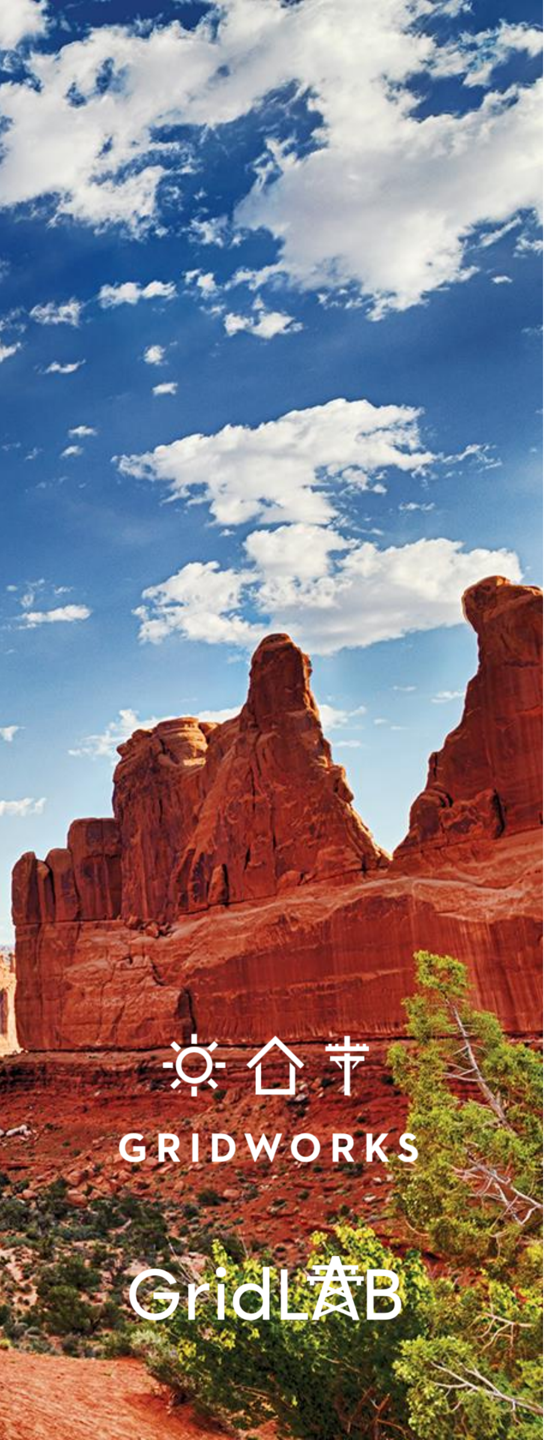


FIGURE 4. BQDM SOLUTION PORTFOLIOS

The Brooklyn Queens Demand Management Program used a portfolio of a variety of DER to provide significant needed load relief and avoid $1.2 billion in grid upgrades.

Image courtesy of SEIA

- VOLTAGE OPTIMIZATION
- DISTRIBUTED ENERGY STORAGE SYSTEM (BATTERY)
- SOLAR
- FUEL CELL
- DEMAND RESPONSE
- DISTRIBUTED GENERATION (GAS-FIRED)
- ENERGY EFFICIENCY
- TOTAL 2018 NON-TRADITIONAL LOAD RELIEF NEED



4 | CASE STUDIES: EMBRACING DER SERVICES

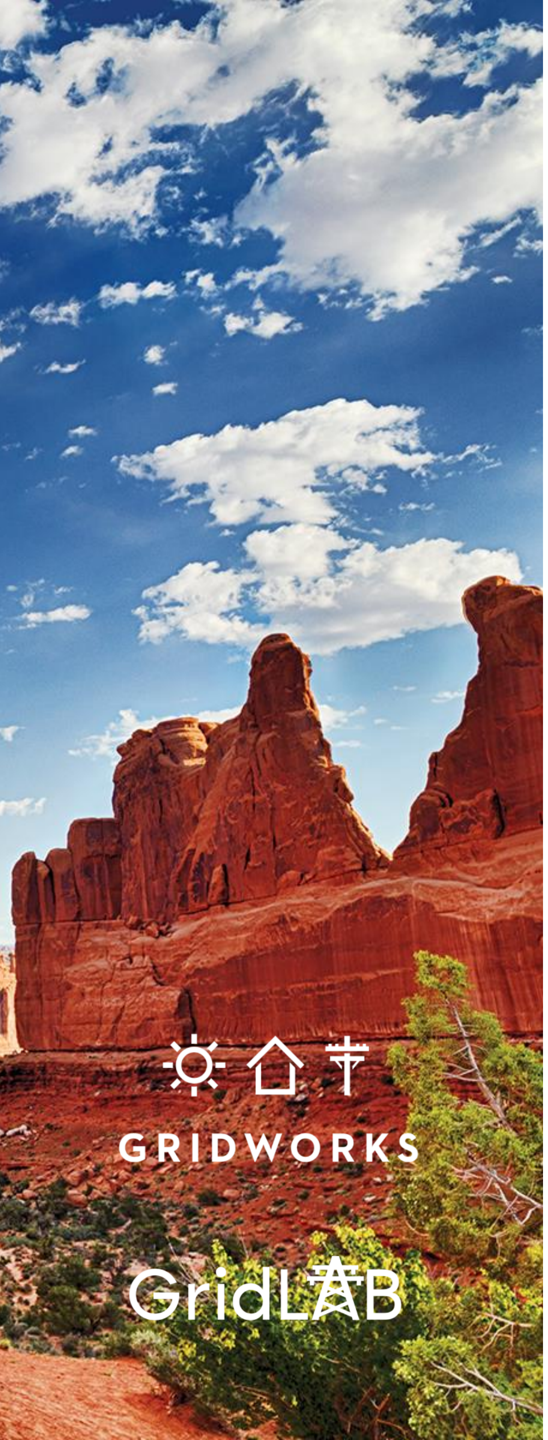
OAKLAND CLEAN ENERGY INITIATIVE

The retirement of a 40-year old peaking plant in Oakland, California posed risks to local transmission reliability.

the California grid operator (CAISO) and local utility (PG&E) evaluated whether a portfolio of DER could replace traditional investment options, such as building new gas turbines or transmission lines.

The resulting proposal, approved by CAISO, allows PG&E to procure 20- 45 MW of clean energy and DER. The resource portfolio includes at least 19.2 MW of demand response, 10 MW
of battery storage, a mix of local generation and energy efficiency upgrades, and some traditional grid upgrades to transformers and substations

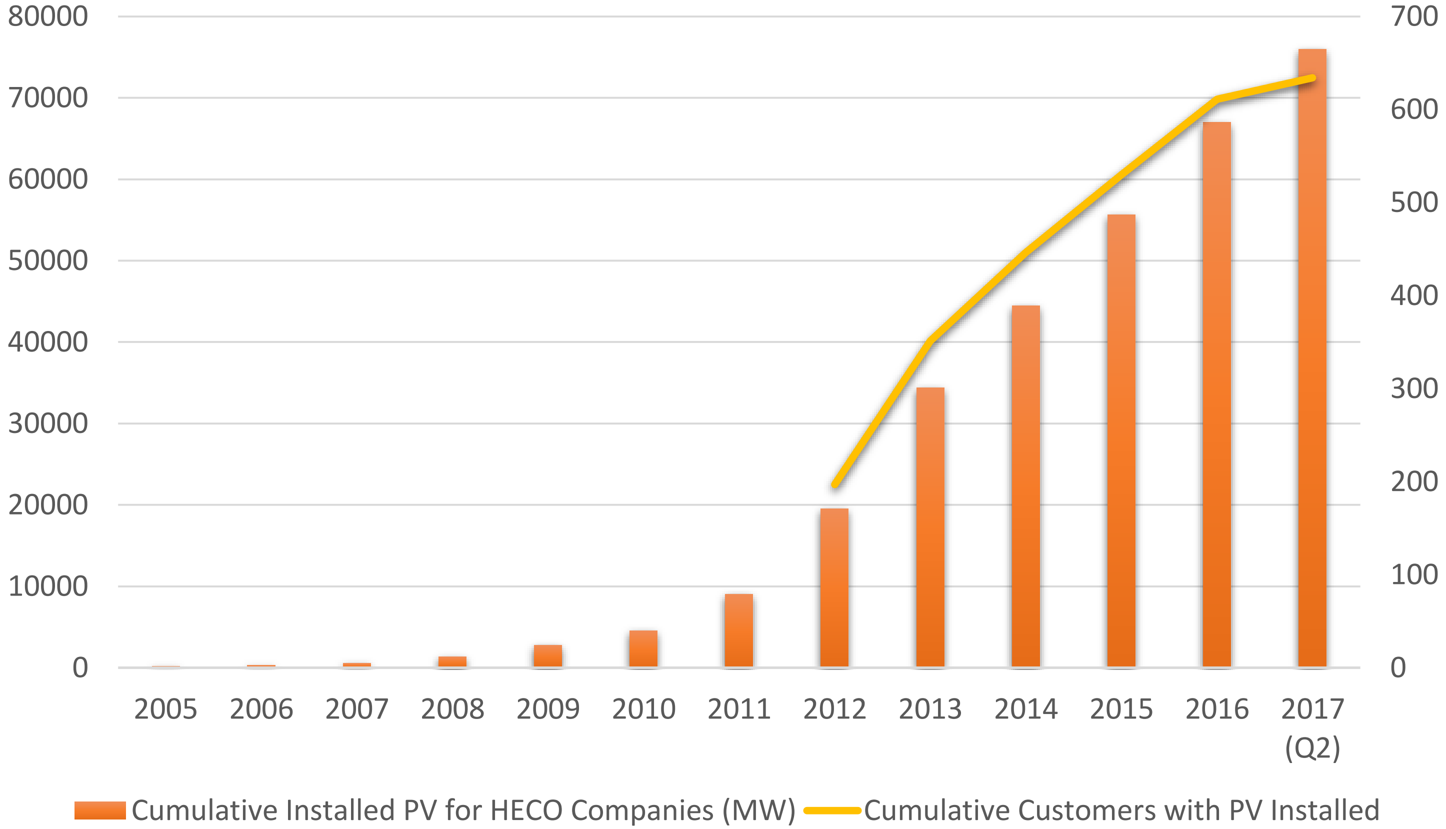
total cost of $102 million — a significantly lower cost than the traditional wires upgrade of $537 million for a 230 kV transmission upgrade.

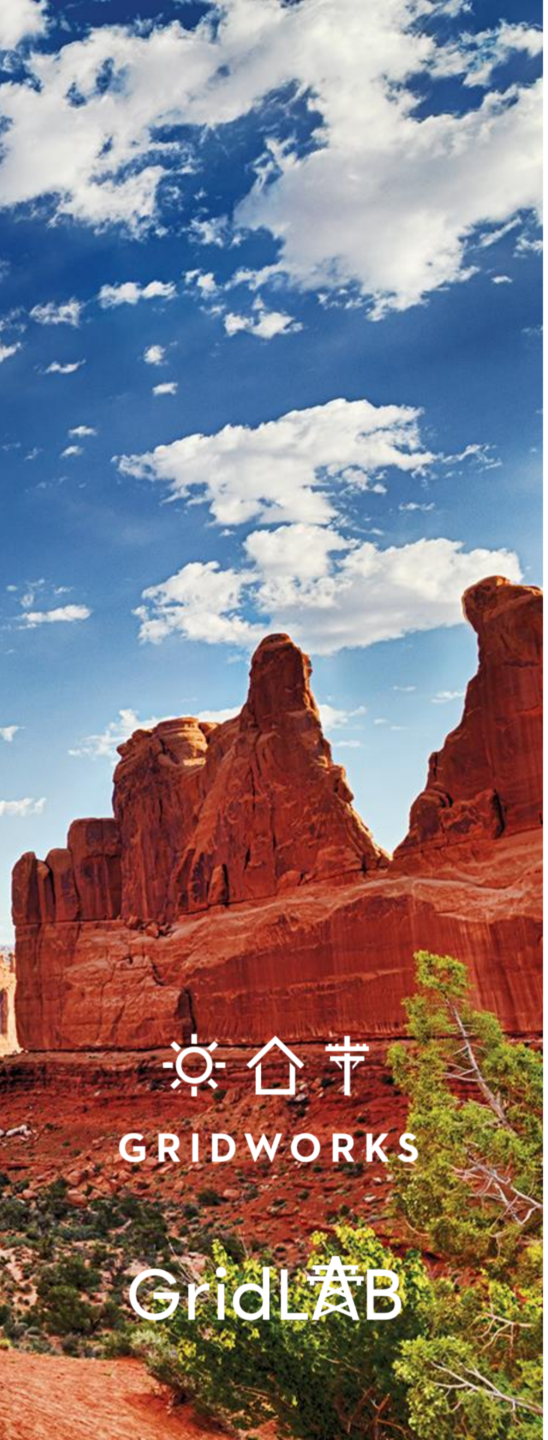


4 | CASE STUDIES: EMBRACING DER SERVICES

HAWAIIAN ELECTRIC COMPANY'S SOLAR SURGE

Source: Gridworks





4 | CASE STUDIES: EMBRACING DER SERVICES

HAWAIIAN ELECTRIC COMPANY

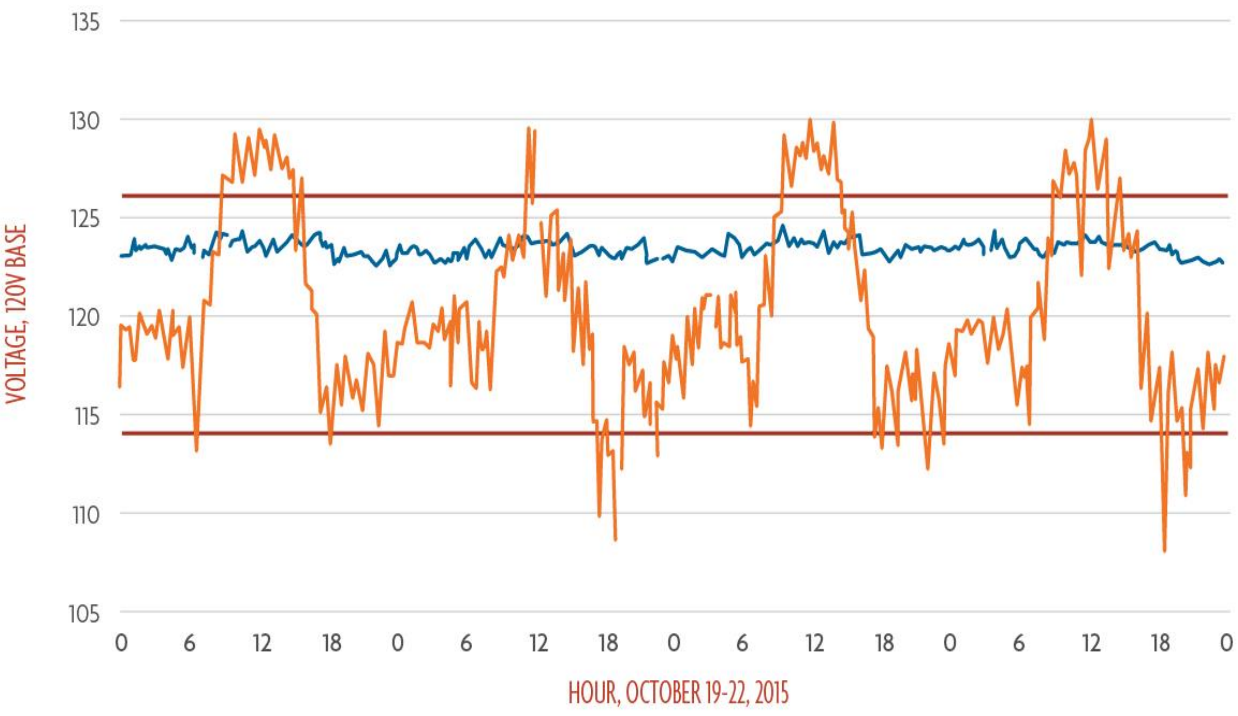


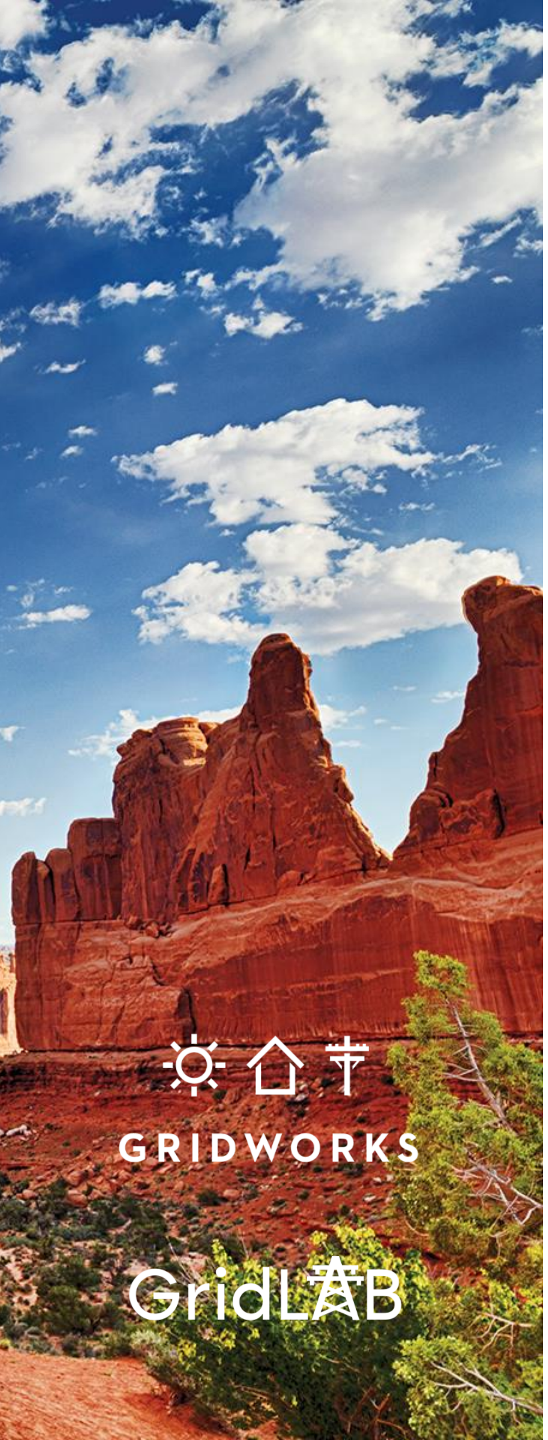
FIGURE 5. CUSTOMER METER VOLTAGE READINGS AND SERVING DISTRIBUTION TRANSFORMER

High penetration of distributed solar PV on some Hawaiian Electric Company distribution circuits drove voltage beyond design limits, prompting policy-makers to adopt smart inverter standards.

Image Courtesy of HECO

- DISTRIBUTION TRANSFORMER VOLTAGE
- CUSTOMER VOLTAGE
- UPPER VOLTAGE LIMIT
- LOWER VOLTAGE LIMIT

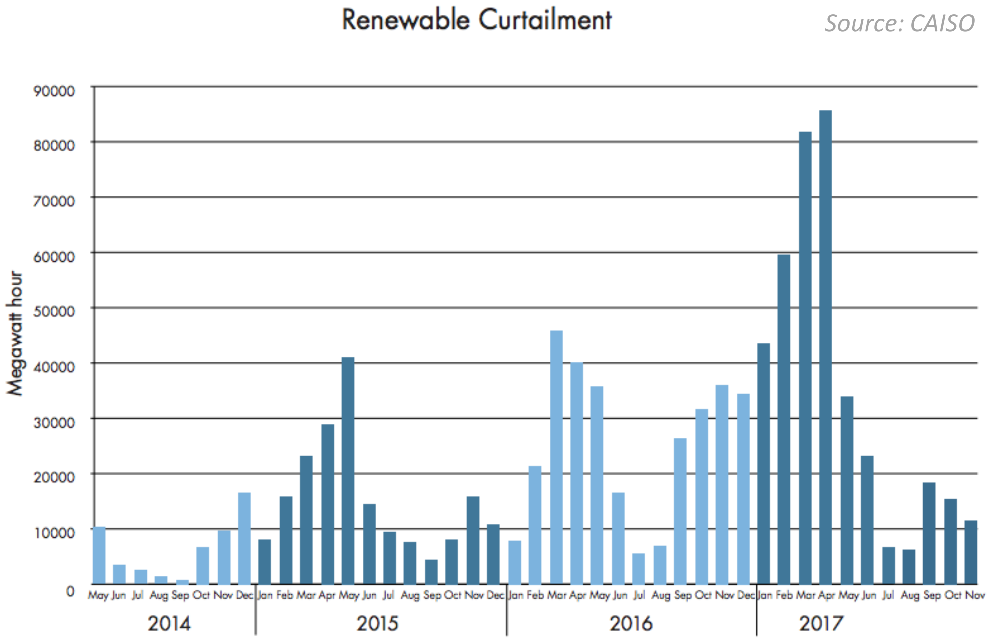
Source: HECO

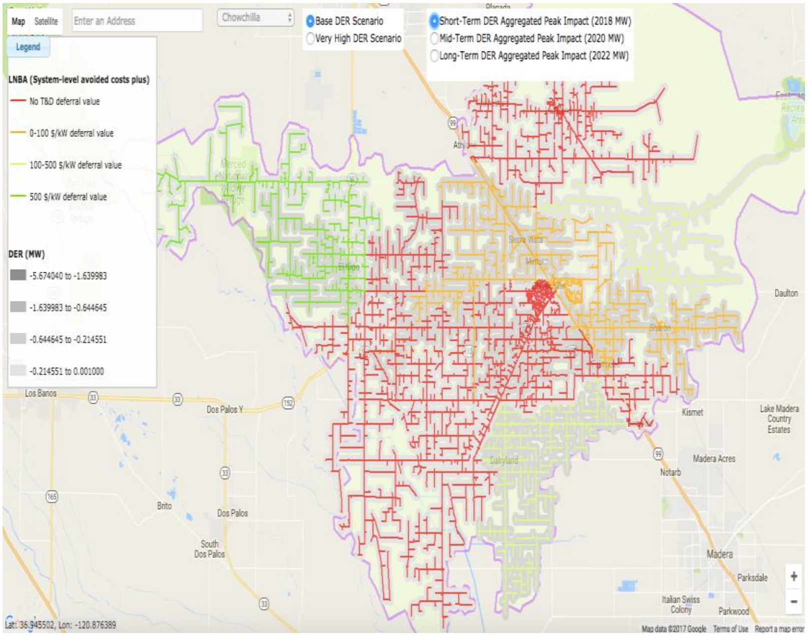


5 | RECOMMENDATIONS

Time and Location Are Very Important!!

Source: PG&E

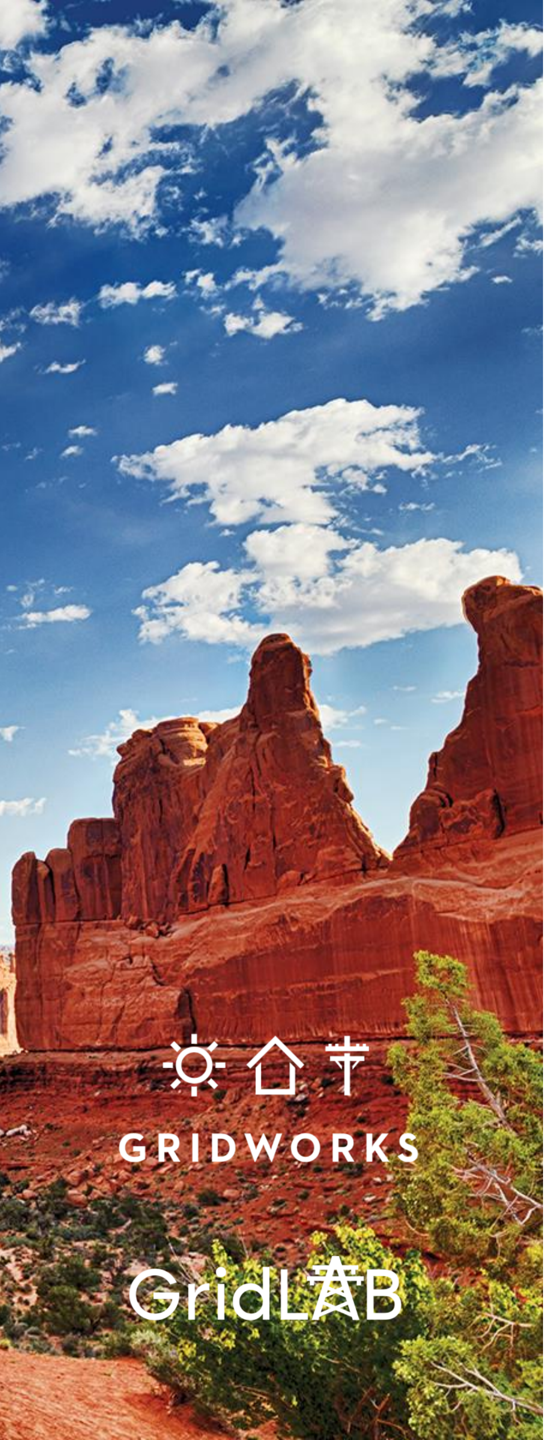




California ISO

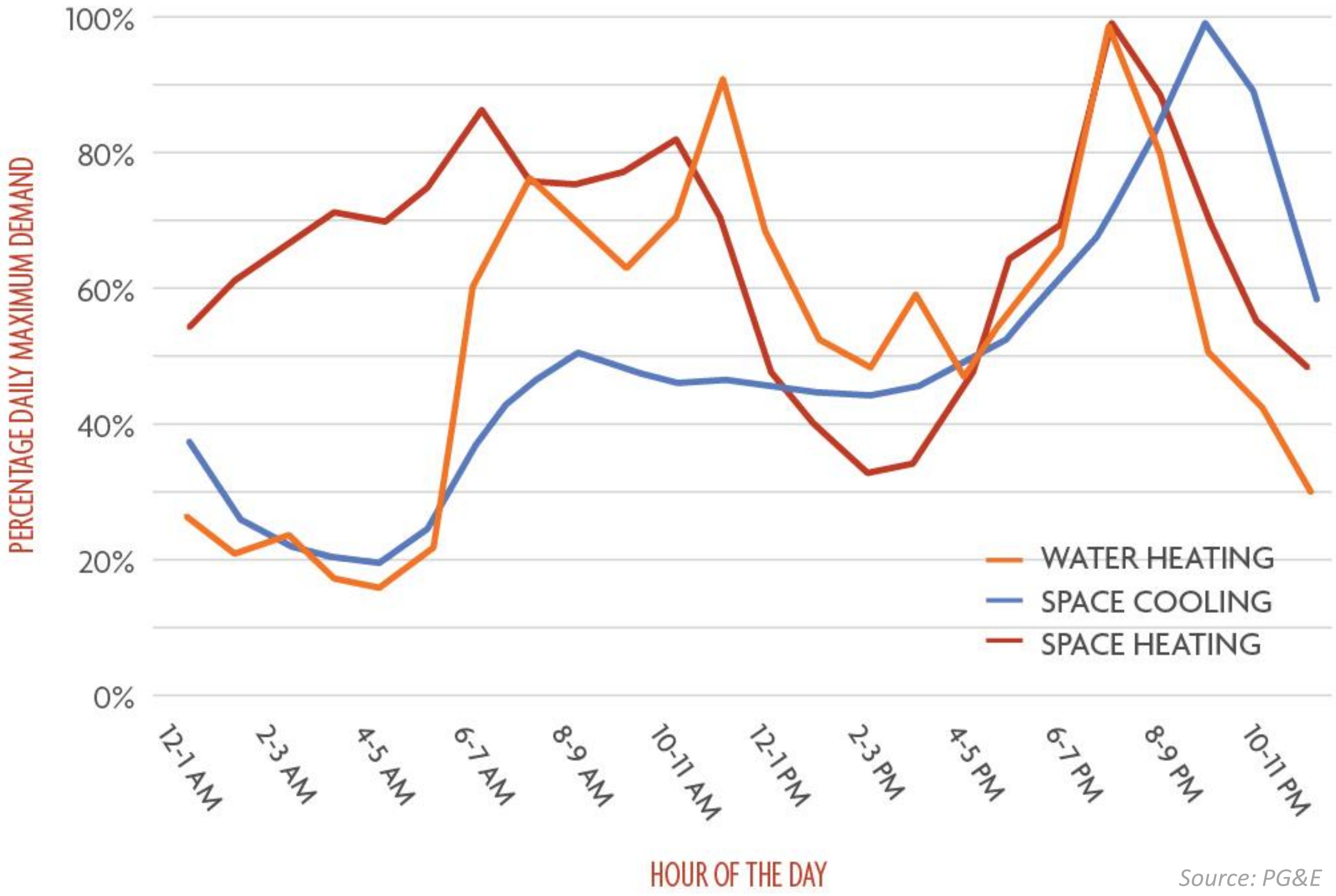
CAISO PUBLIC

Utilities can see wasted power and money or good service and cost savings. The difference is largely attributable to when and where the DER serve the grid and customer.

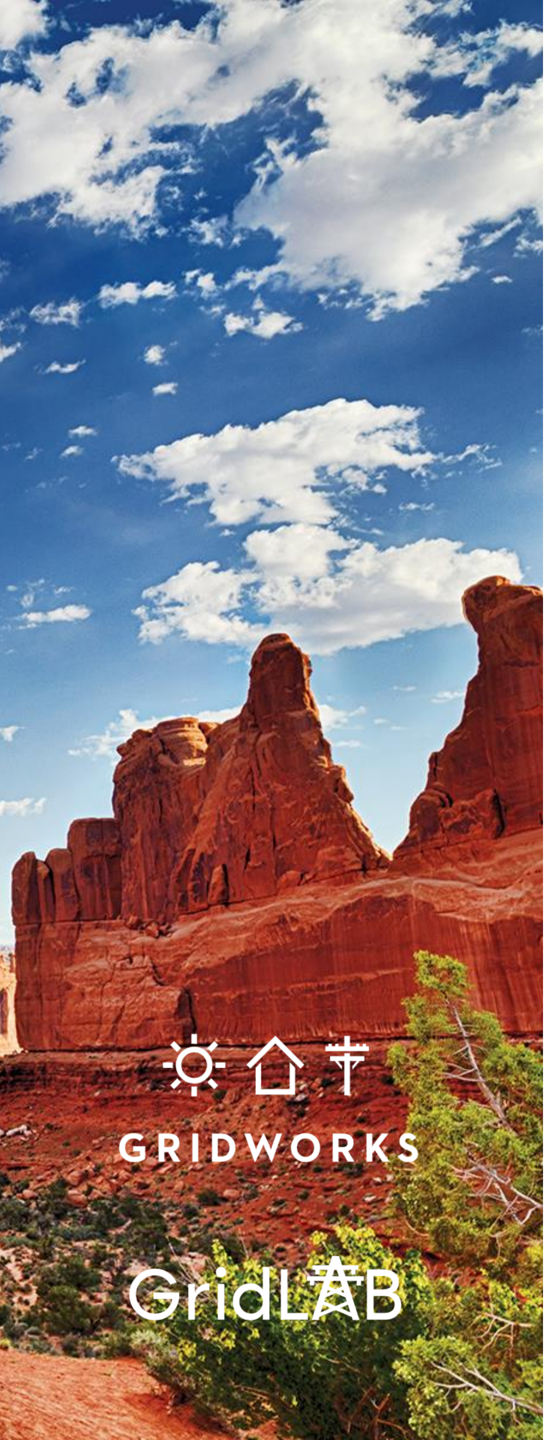


5 | RECOMMENDATIONS

For example, different Energy Efficiency meet different grid needs



Source: PG&E



5 | RECOMMENDATIONS

DER can and should provide flexibility

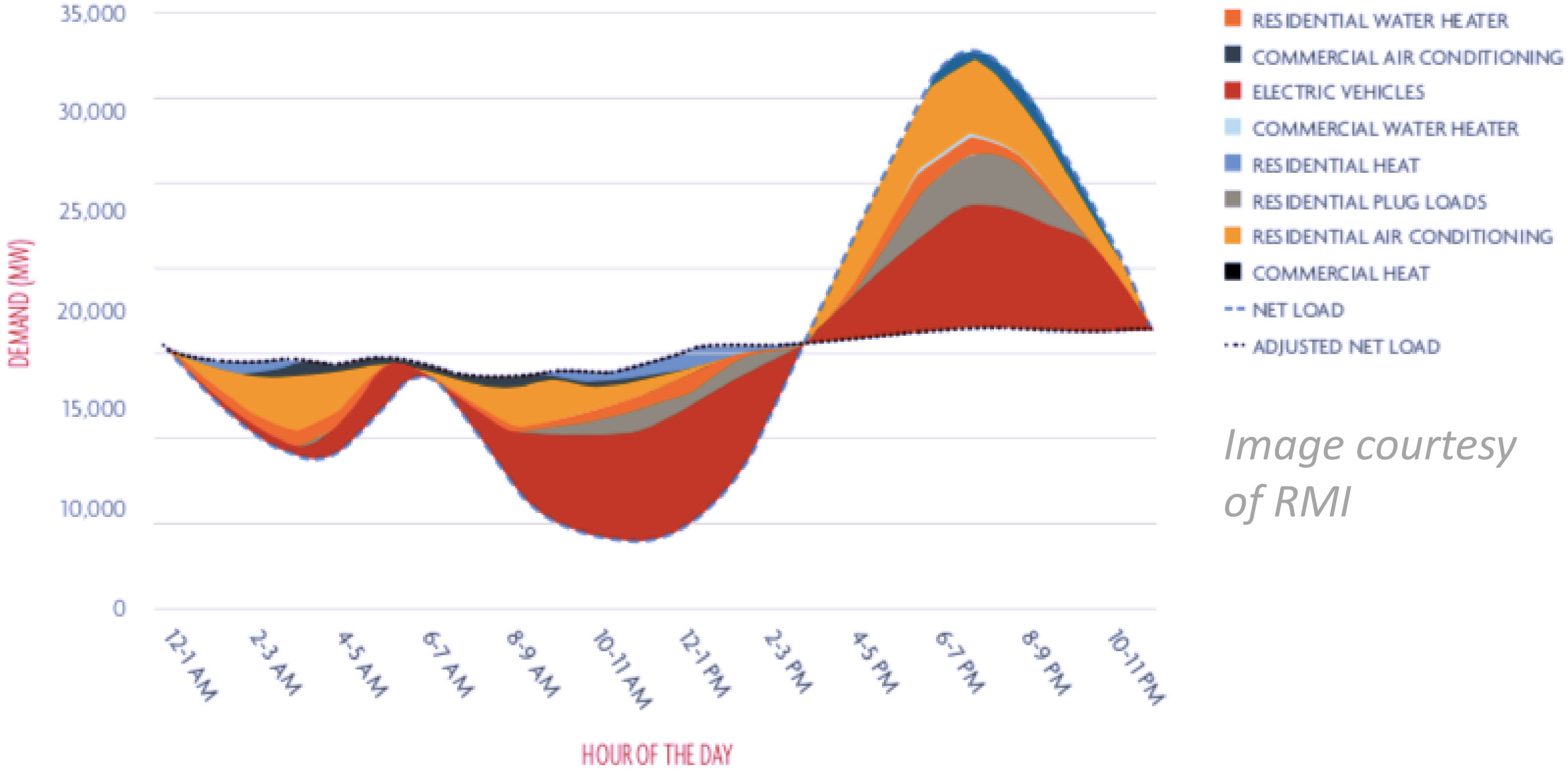


Image courtesy of RMI

FIGURE 3. FLEXIBLE RESOURCES CAN BE USED TO REDUCE SYSTEM PEAKS AND FLATTEN NET LOAD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