GRID SERVICE REQUIREMENTS ON A CHANGING GRID

NATIONAL COUNCIL ON ELECTRICITY POLICY

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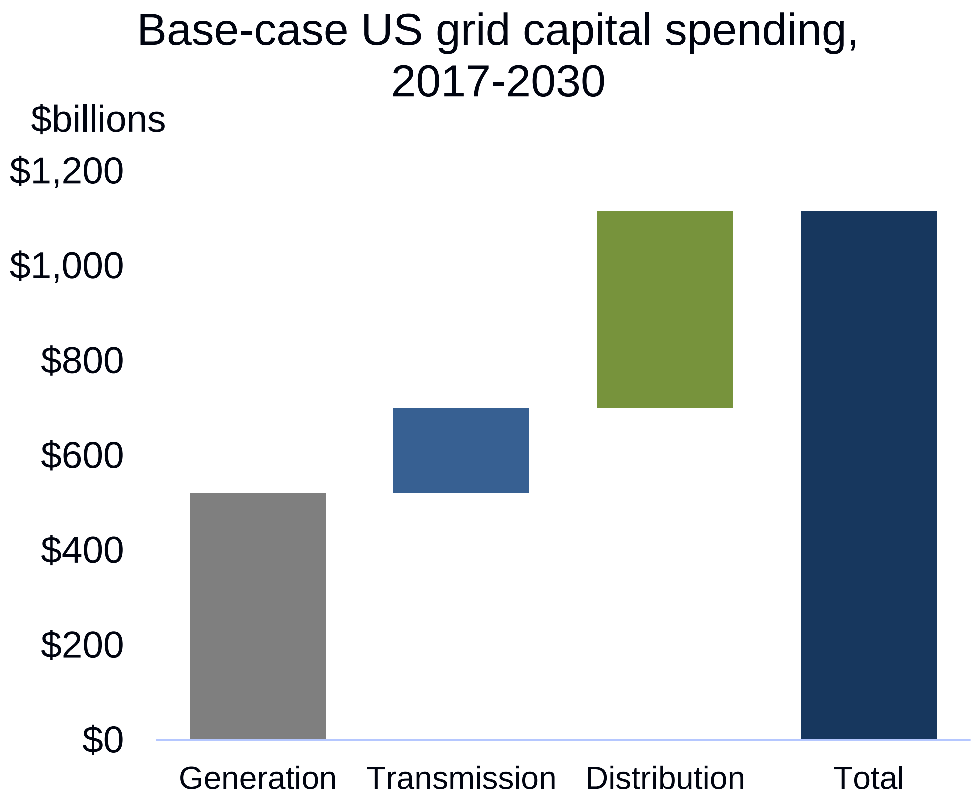
ROCKY MOUNTAIN INSTITUTE

Transforming global energy use to create a clean, prosperous, and secure low-carbon future.

The U.S. grid is aging and a business-as-usual reinvestment would require >$1 trillion in capital investment through 2030



- Forecasts of **transmission and distribution** investment needs suggest a combined $500-600 B on network investment

- Replacing retiring generators on a like-for-like basis would require ~$500 B through 2030

Source: RMI analysis of EEI, SNL, IEA, EIA data

DER capabilities can be applied to reduce both capital expenditures and energy costs

DER Application	How It's Monetized
Operating Cost Savings	Reduced peak kW demand to lower utility demand charges Electricity generation to reduce commodity costs
Distribution Capacity Deferral	Reduced peak demand allows for reduced capacity infrastructure (e.g., substation transformers) Power quality capabilities reduce need for dedicated infrastructure (e.g., capacitors)
Transmission Capacity Deferral	(Same as distribution)
Generation Capacity Deferral	Lower peak demand resulting in reducing generation capacity required Reduced quantity and size of backup gensets required

Source: RMI analysis of EEI, SNL, IEA, EIA data

New technologies are already cost competitive

Alternatives are increasingly cost-effective in terms of energy, capacity, and ancillary service provision

Energy costs

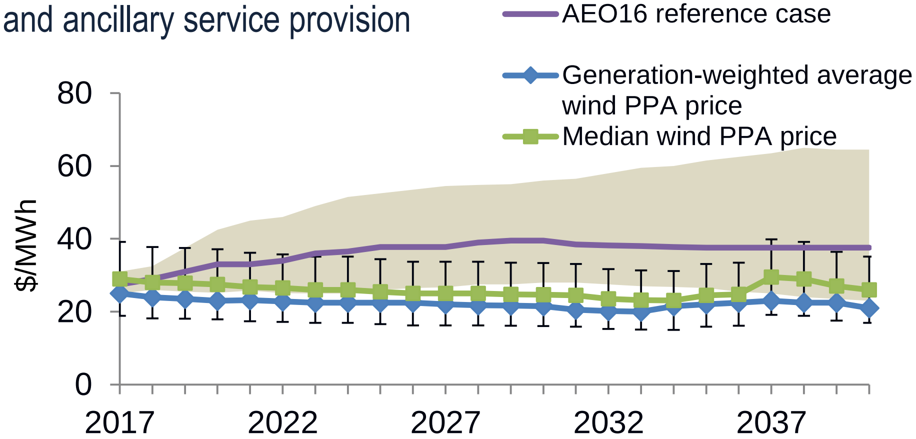
- Recent wind PPAs routinely beat energy costs from coal and gas plants (right)
- Solar costs are following suit
- Renewable energy avoids price volatility exhibited by natural gas

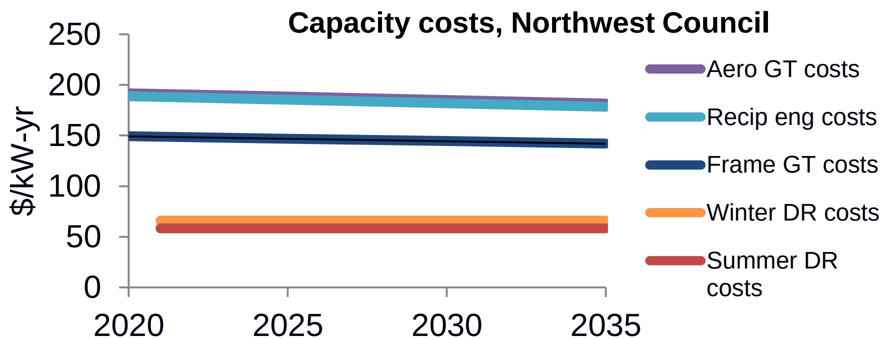
Capacity costs

- Costs of procured DR for peak reduction is often lower than new NG peaker plants, including Northwest states (right)
- Significant entry of DR into RTO markets, especially where capacity payments provided

Ancillary services

- Increasing participation of alternatives in ancillary service markets
- PJM ancillary service markets show capabilities for demand response for synchronous reserves (534 MW in 2016) and regulation (38 MW)





Capacity Cost Reduction Capabilities Have Been Demonstrated by a Growing Number of Projects

Puget Sound Electric Reliability Plan
BPA

Fort Churchill initiative
NV Energy

Advanced Reliability from Utility-Scale PV
CAISO, NREL

Delta Project; transmission cancellations
Pacific Gas & Electric

Diablo Canyon retirement
Pacific Gas & Electric

San Onofre retirement & Preferred Resource Pilot (PRP)
Southern California Edison

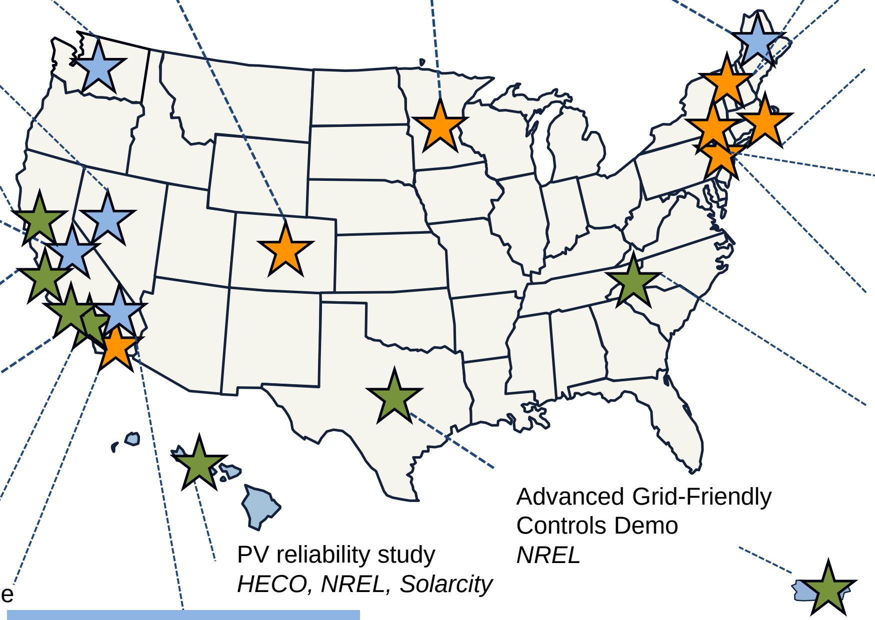
Aliso Canyon Response Plan
Southern California Edison

Oceanside Substation Alternative
San Diego Gas & Electric

Distribution Non-Wires Alternatives Project
Xcel Energy CO

Solar + storage substation upgrade deferral
Xcel Energy MN

Boothbay transmission alternatives
Central Maine Power



Borrego Springs Microgrid
San Diego Gas & Electric

PV reliability study
HECO, NREL, Solarcity

Advanced Grid-Friendly Controls Demo
NREL

Mad River Valley Project
Green Mountain Power

Geo-Targeted DSM
Efficiency Vermont

Load Curtailment Pilots (Nantucket, Tiverton)
National Grid

Brooklyn-Queens Neighborhood Program
ConEd

Thermostats for distribution upgrade deferral
Central Hudson

Asheville gas power plant deferral
Duke Energy

Distribution
Transmission
Generation

Note: This list is not comprehensive

Distribution Case Study #1: **Brooklyn-Queens Neighborhood Program**

NEED

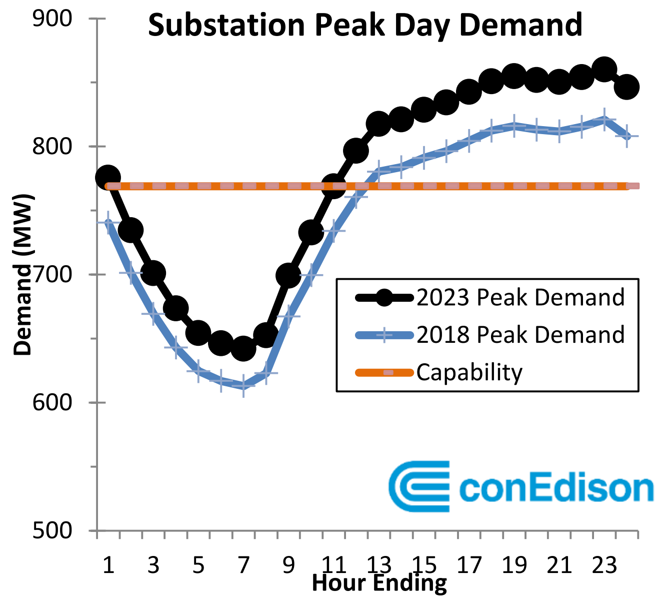
- ConEd in New York is spending $200 M on DERs to defer a $1.2 B substation upgrade under the program
- The substation was expected to be overloaded by 69 MW by 2018 for 40–48 hours per year in the summer

SOLUTION

- Including EE upgrades, PV systems, demand response and management systems, storage systems, and microgrids.
- Program to provide 52 MW peak drop
  - 41 MW from DERs
  - 11 MW non-traditional utility-side projects
- Also includes 17 MW of traditional infrastructure investment

COST SAVINGS

- The project will save $1.0 B in costs if the substation is completely obviated.
- If simply deferred until 2026, the savings will be $300 M.



Goals	2016	2017	2018	Total
Customer-side Solutions	9 MW	23 MW	9 MW	41 MW
Utility-side Solutions	3 MW	8 MW	-	11 MW
Total	**12 MW**	**31 MW**	**9 MW**	**52 MW**

Distribution Case Study #2:
Xcel Energy Colorado Non-wires Alternative Project

NEED

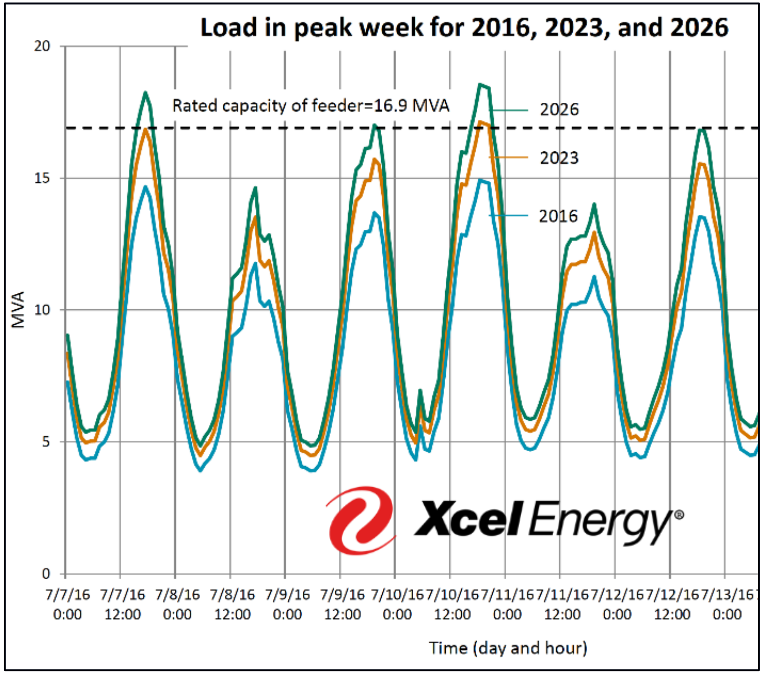
- Load growth is expected to begin exceeding substation capacity of 16.9 MVA in 2023, growing to a 10% overload by 2027
- The conventional solution would be a transformer upgrade costing $1.9 M

SOLUTION

- Xcel's program will deliver 2 MVA of peak reduction using DER technology deployed through residential customers
- DERs used will include smart thermostats, controllable A/C switches, and efficiency upgrades (insulation, air sealing, and A/C units)

COST SAVINGS

- The project would save $1.4 M in capital expenditures
- Net savings, including marketing and on-going participation payments, would be $200,000



Transmission Case Study #1:
Borrego Springs Microgrid

NEED

- SDG&E identified frequent outages and reliability concerns serving the small town of Borrego Springs (pop. 3,500), located at the end of a 69 kV transmission line in a remote area
- Conventional solution: add a second, parallel transmission line

SOLUTION

- SDG&E elected to build a microgrid to leverage DER capabilities to provide reliability and avoid building new transmission
- The microgrid assets include:
  - Diesel gensets (two 1.8 MW units)
  - Substation batteries (1.5 MW/4.5 MWh)
  - Distributed batteries (75 kW/150 kWh)
  - Rooftop PV (700 kW)
  - Residential DR via smart thermostats

Borrego Springs

COST SAVINGS

- The total capital cost of the microgrid was $18 M, which was just 30% of the capital cost of a new transmission line

Transmission Case Study #2:
Boothbay Non-Transmission Alternatives

NEED

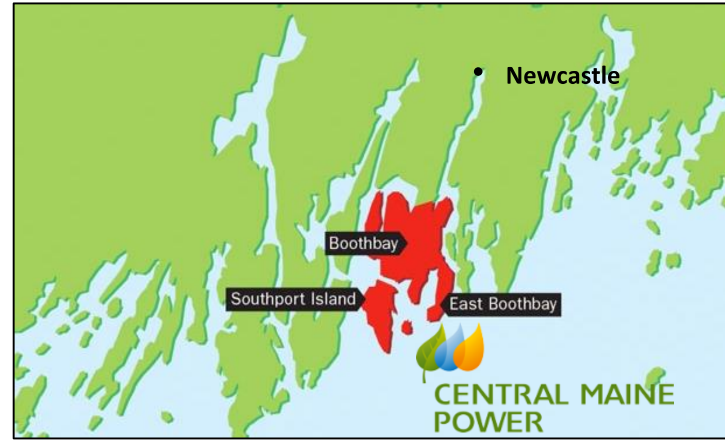
- Central Maine Power identified grid performance violations that would require an estimated $18 million rebuild of a 34.5 kV transmission line from Newcastle to Boothbay Harbor

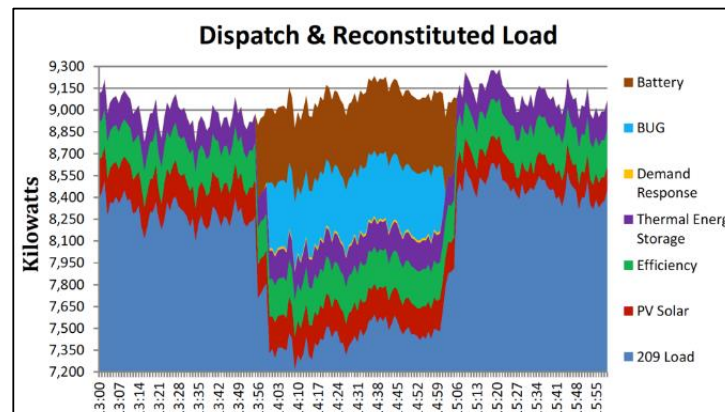
SOLUTION

- A non-transmission alternative was created to provide 2 MW of peak load relief
- The program included:
  - 500 kW of battery storage
  - 500 kW of diesel back-up
  - 308 kW of PV
  - 243 kW of energy efficiency upgrades
  - 254 kW of demand response

COST SAVINGS

- The net cost was less than 1/3 of the conventional transmission project, saving $18.7 M over a ten-year life



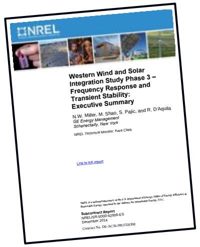


Change is possible

Studies show that power quality and grid stability will not necessarily suffer in a high renewable future

MN Renewable Energy Integration and Transmission Study, GE Energy Consulting, 2014

- 40% variable generation can be integrated onto Minnesota grid without loss of reliability
- Assumes new wind and PV provide regulation, reactive support and have zero-voltage ride through capability
- Further analysis required to evaluate 50% penetration



Western Wind and Solar Integration Study, NREL, 2015

- Western Interconnection can withstand loss of largest generators (N-1-1) under 50% renewable penetration (Phase 3 study)
- Local dynamic stability can be maintained if renewables are modeled to have advanced controls and inverter features (Phase 3A study)

Advanced Grid-Friendly Controls Demonstration Projects, CAISO, ERCOT, FirstSolar, NREL, 2016/17

- Recent field testing of utility-scale PV with advanced inverters to provide power quality and network stability services
- 300 MW plant in California, 20 MW plants in Texas and Puerto Rico
- High performance for services including automatic generation control (AGC) and frequency regulation, droop response, and reactive power/voltage/power factor controls

New technologies can provide most or all stability services

Large-scale, fossil-fueled synchronous generators have traditionally provided the majority of these services

		Synchronous						Inverter-Based					Demand Response	
		Coal	Gas–Simple Cycle	Gas–CCGT	Nuclear	Hydro	Synchronous Condenser	Wind	Centralized PV	Distributed PV	Centralized Storage	Distributed Storage	Industrial	Small / Aggregated
Volt/Var		4	4	4	4	4	4	4	4	2	3	2	0	0
Short Circuit Contribution		4	4	4	4	4	3	0	0	0	0	0	0	0
Frequency Support	Inertial Response	4	2	4	4	4	4	3	2	0	4	4	0	0
Frequency Support	Primary Frequency Response	3	3	3	0	4	0	3	3	2	4	4	1	2
Frequency Support	Regulation	3	4	4	0	4	0	2	2	2	3	3	1	2
Frequency Support	Load Following	1	4	4	0	3	0	1	1	1	3	3	1	1
Frequency Support	Spinning Reserve	2	4	4	0	4	0	1	1	0	3	3	4	4
Short-term availability		4	3	3	4	3	4	2	1	1	2	2	3	2
Long-term availability		3	3	3	4	4	3	3	3	3	2	2	3	2
Black Start		1	3	3	0	4	0	0	0	0	4	0	0	0

0	1	2	3	4
No service provision		Partial service provision		Full service provision

4	4	4
Demonstrated in commercial deployment	Demonstrated in pilots but faces market/regulatory barriers	Demonstrated in limited trial or lab settings

Source: *Contributions of Supply and Demand Resources to Required Power System Reliability Services*, EPRI 2015; RMI Analysis

New technologies can provide most or all stability services

Portfolios of alternative resources can provide synthetic replacement of synchronous resources to enable low-inertia grids in the future

		Synchronous						Inverter-Based					Demand Response	
		Coal	Gas–Simple Cycle	Gas–CCGT	Nuclear	Hydro	Synchronous Condenser	Wind	Centralized PV	Distributed PV	Centralized Storage	Distributed Storage	Industrial	Small / Aggregate d
Volt/Var		4	4	4	4	4	4	4	4	2	3	2	0	0
Short Circuit Contribution		4	4	4	4	4	3	0	0	0	0	0	0	0
Frequency Support	Inertial Response	4	2	4	4	4	4	3	2	0	4	4	0	0
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Black Start		1	3	3	0	4	0	0	0	0	4	0	0	0

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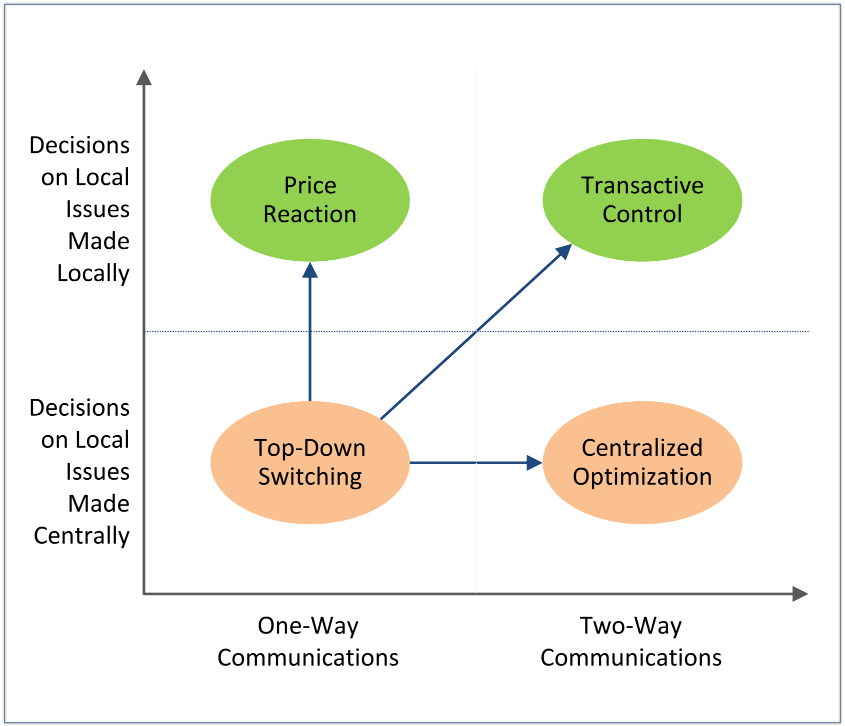
Distributed Capabilities versus Distributed Control

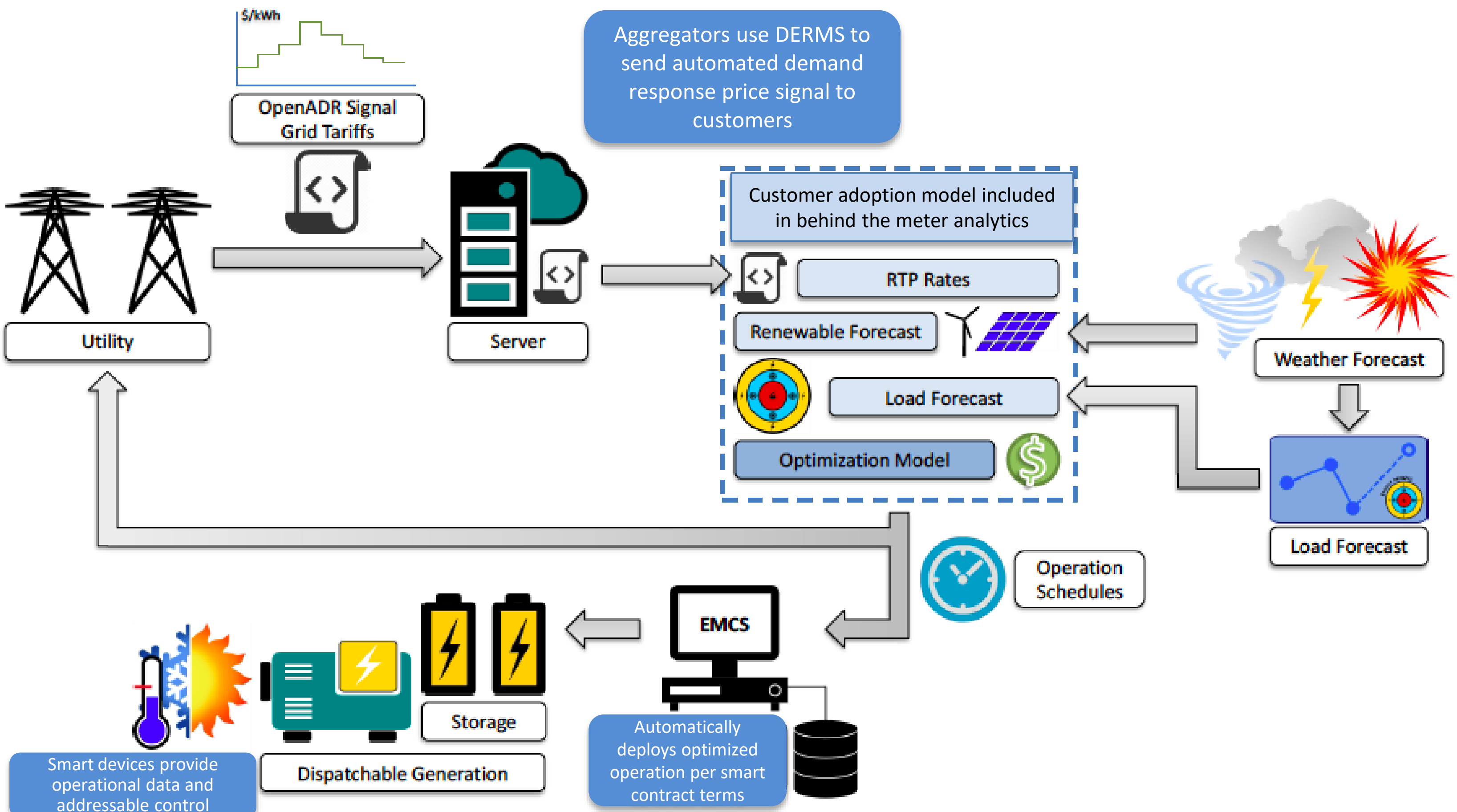
A system with enhanced DER capabilities will likely require distributed approaches to system control for maximum efficiency

Distribution-level energy management approaches
(from Kok and Widegren, 2016)



	One-Way Communications	Two-Way Communications
Decisions on Local Issues Made Locally	**Price Reaction** + Full Use of Response Potential – Uncertain System Reaction – Market Inefficiency + No Privacy Issues	**Transactive Control** + Full Use of Response Potential + Certain System Reaction + Efficiency Market + No Privacy Issues
Decisions on Local Issues Made Centrally	**Top-Down Switching** – Partial Use or Response Potential – Uncertain System Reaction – Autonomy Issues	**Centralized Optimization** + Full Use of Response Potential + Certain System Reaction – Privacy and Autonomy Issues – Low Scalability

The Distributed Technology Ecosystem of the future



Adapted from "Electric Grid Transactions Modeling with DER-CAM", Michael Stadler, Microgrid Reearch Group, LBNL, June 2015

Key questions to consider today: How can we…

1. Understand and test the capabilities of new technologies to provide grid services?

- Take advantage of resources that are coming online anyway
- Start small and learn by doing, but plan for scale

2. Update market rules to leverage new capabilities

- Encourage aggregation to allow distributed resources to compete fairly
- Revisit “baseline” rules to accommodate new capabilities of demand response

3. Integrate new service capabilities into long-term planning?

- Plan for long-term system evolution, rather than 1:1 replacements of current assets
- Recognize value provided by smaller, modular resources, versus major projects

THANK YOU

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lguccione@rmi.org

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