Demand Response Potential from the Bulk Grid Perspective

Dr. Brady Stoll
National Renewable Energy Laboratory

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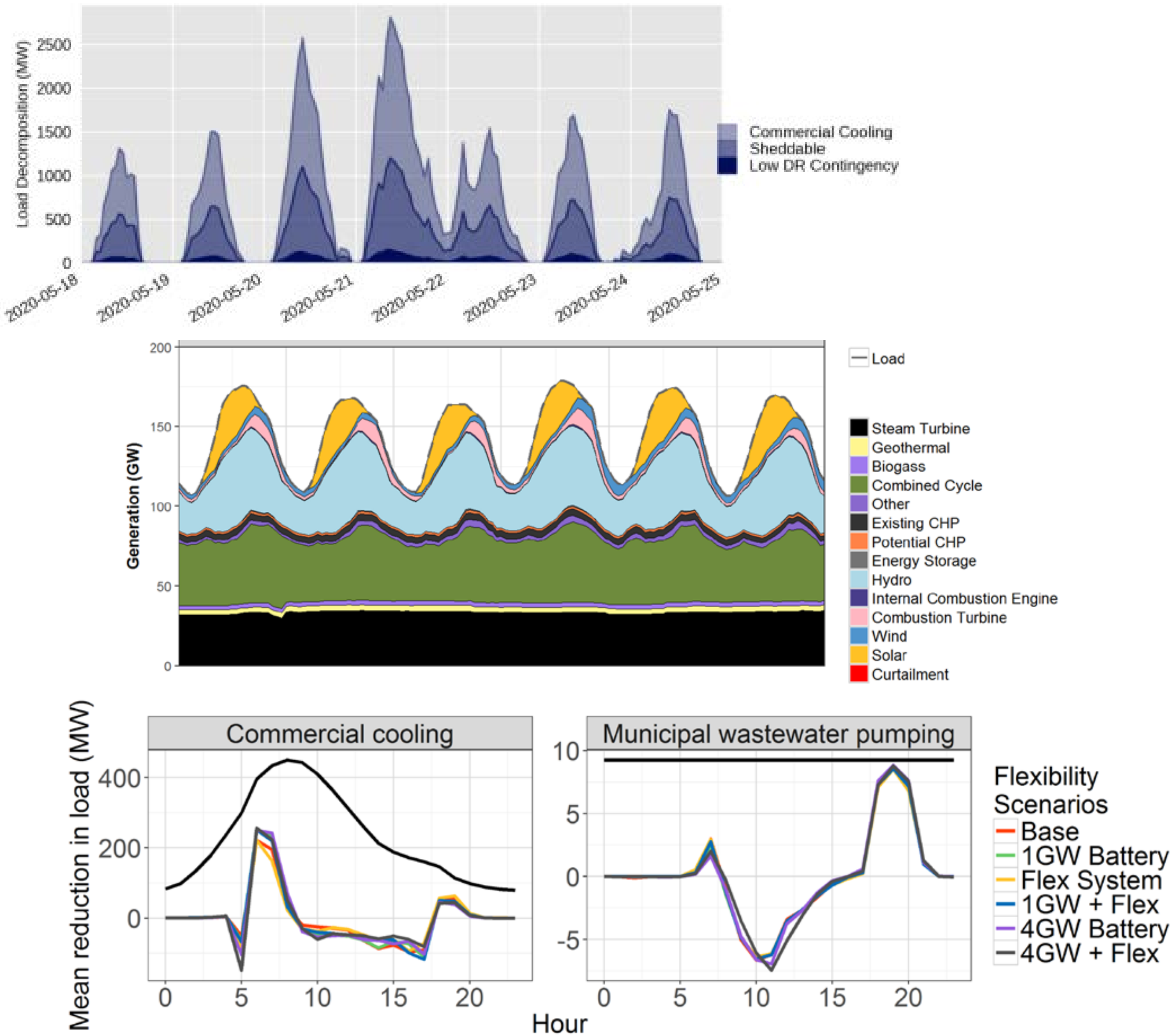
Overview

- Introduction
- Demand response input data andmodeling methods
- System impacts of demand response
- Value of demand response by end-use



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Introduction

Motivating Question: To what extent can demand response mitigate the increasing variability and uncertainty associated with variable generation?

Demand response

- Low capital cost
- Uncertain opportunity cost
- New communication and control technologies

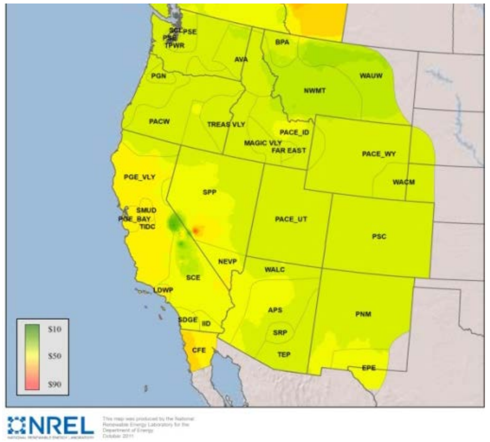
Current questions

- ➢ Potential depth of deployment?
- ➢ Ability to provide reserves and absorb curtailment?
- ➢ Value of these resources?

Production Cost Model

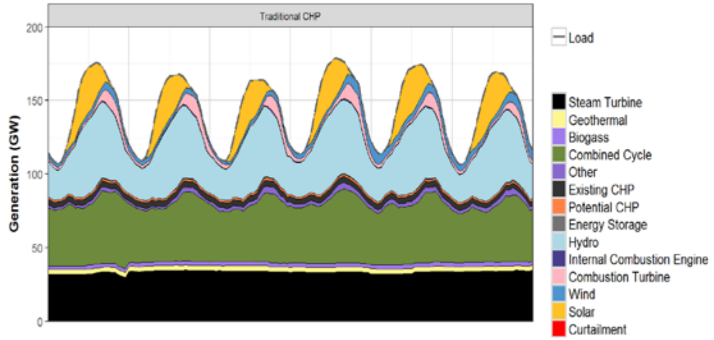
Simulate operation of electric power system

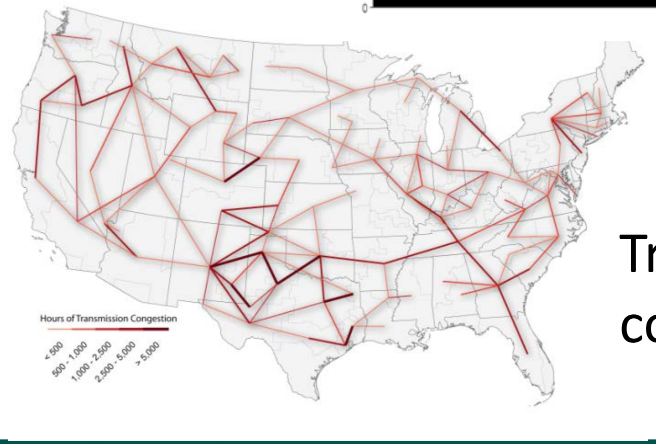
- Hourly or sub-hourly chronological dispatch
- Commits and dispatches generating units based on:
  - Electricity demand
  - Operating parameters of generators
  - Transmission grid parameters
- Used for system generation and transmission planning
  - Increasingly used for real-time operation



Locational prices, production cost

Dispatch information, fuel usage

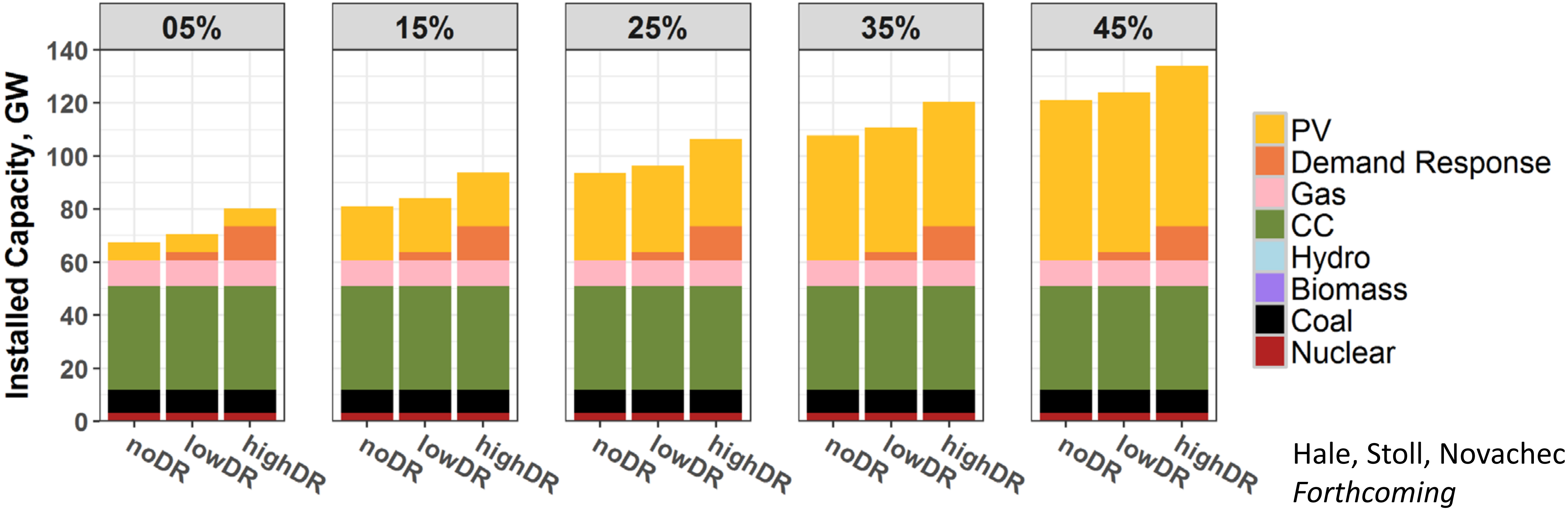




Transmission congestion

FRCC Production Cost Model Used in study

- Base model extracted from the Eastern Renewable Grid Integration Study
- PV Capacity added up to 45% PV



Hale, Stoll, Novacheck, *Forthcoming*

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Scenario Framework

(PV Level, DR Option, Flex Option, Gas Price)

PV Level	DR Option	Flex Option	Gas Price
5%	None	None	AEO 2014 Mid ($6.37-7.36/ MMBtu)
10%	Low DR	1GW Battery	AEO 2016 Low ($4.39-5.08/ MMBtu)
15%	High DR	Flex System	
20%		1GW + Flex	
25%		4GW Battery	
30%		4GW + Flex	
35%			
40%			
45%			

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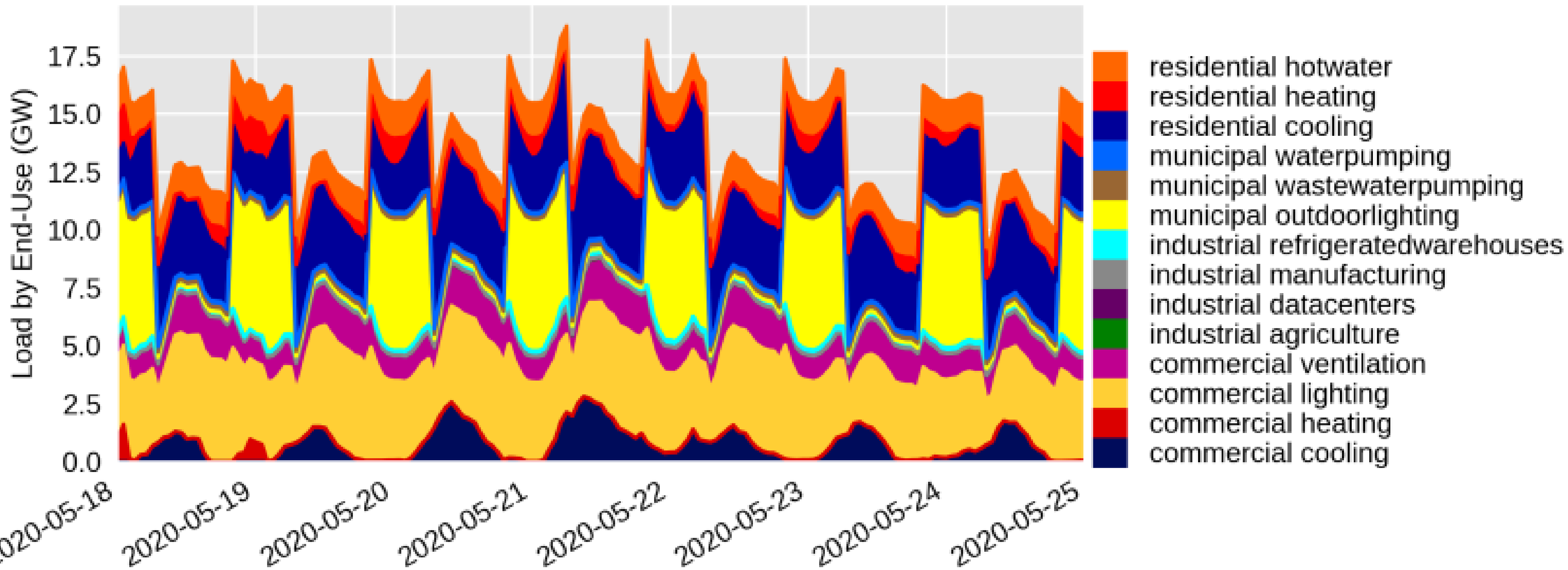
Demand Response
Input Data and Modeling Methods

Demand Response Resource

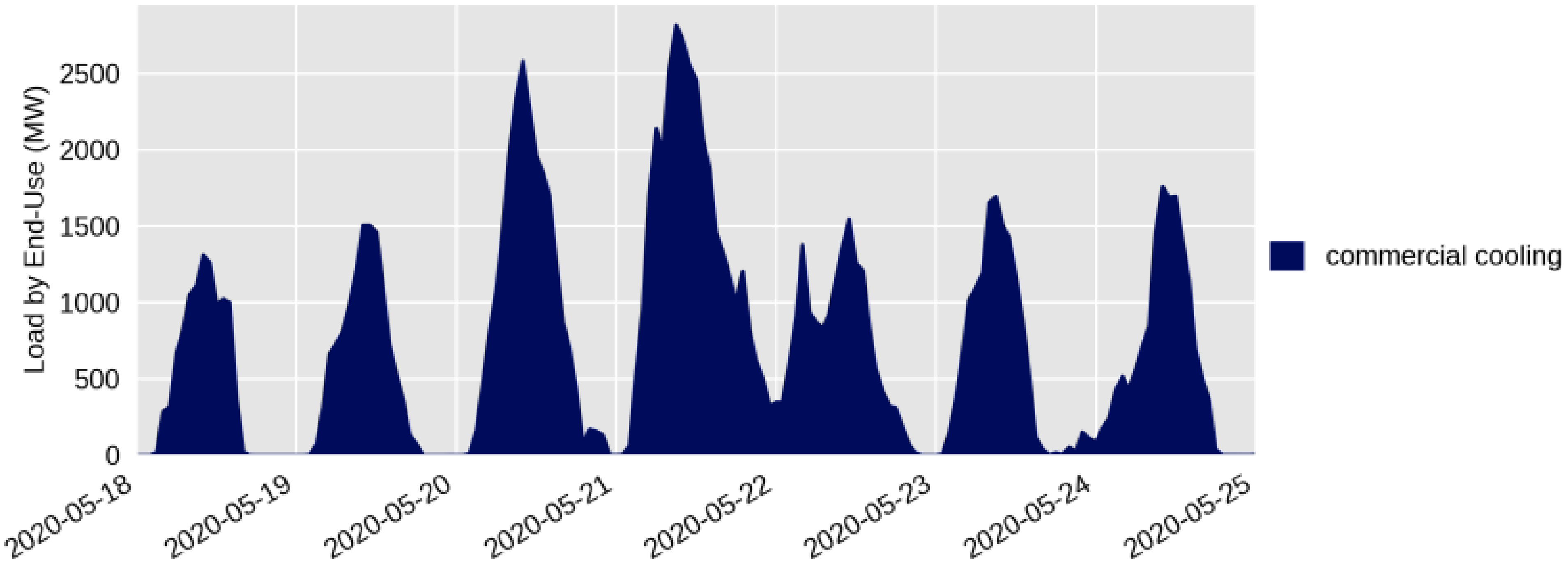


- Load shapes for end-uses that could participate in demand response are disaggregated by county

Methodology described in:

Olsen, Daniel J., et al. 2013. "Grid Integration of Aggregated Demand Response, Part 1: Load Availability Profiles and Constraints for the Western Interconnection." Technical Report LBNL-6417E.

Demand Response Resource

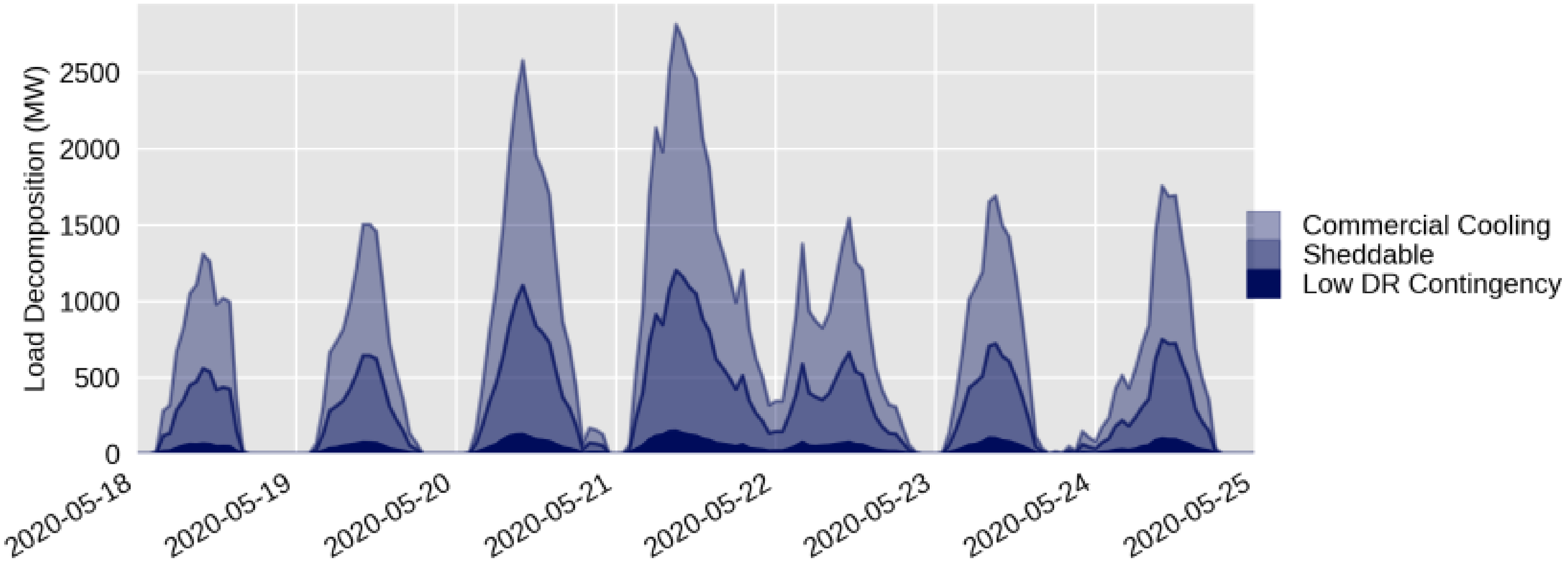


- Looking at one particular end-use: commercial cooling

Methodology described in:

Olsen, Daniel J., et al. 2013. "Grid Integration of Aggregated Demand Response, Part 1: Load Availability Profiles and Constraints for the Western Interconnection." Technical Report LBNL-6417E.

Demand Response Resource



- We apply 3 filters to this data
  - Fraction of the load that is sheddable
  - Fraction of the load that can be controlled
  - Fraction of the load that would be acceptable to customers to be shed

Grid Services Modeled

Energy – only a subset of end uses can provide energy shifting, must account for payback capacity and timing

Contingency – most inclusive service – capacity is held to respond to outages, peak (net) load conditions

Regulation – modeled like contingency in production cost model, but resource needs to be able to follow a fast signal, and performance needs to be measured

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Demand Response Resource Categories

Schedulable – *discrete decisions per end-use; little environmental coupling*

High Thermal Capacity Storage – *set-point-driven; moderate environmental coupling*

Storage – *often set-point-driven; potential for high environmental coupling*

Sheddable – *little tolerance for change in service levels; capacity-only resources*

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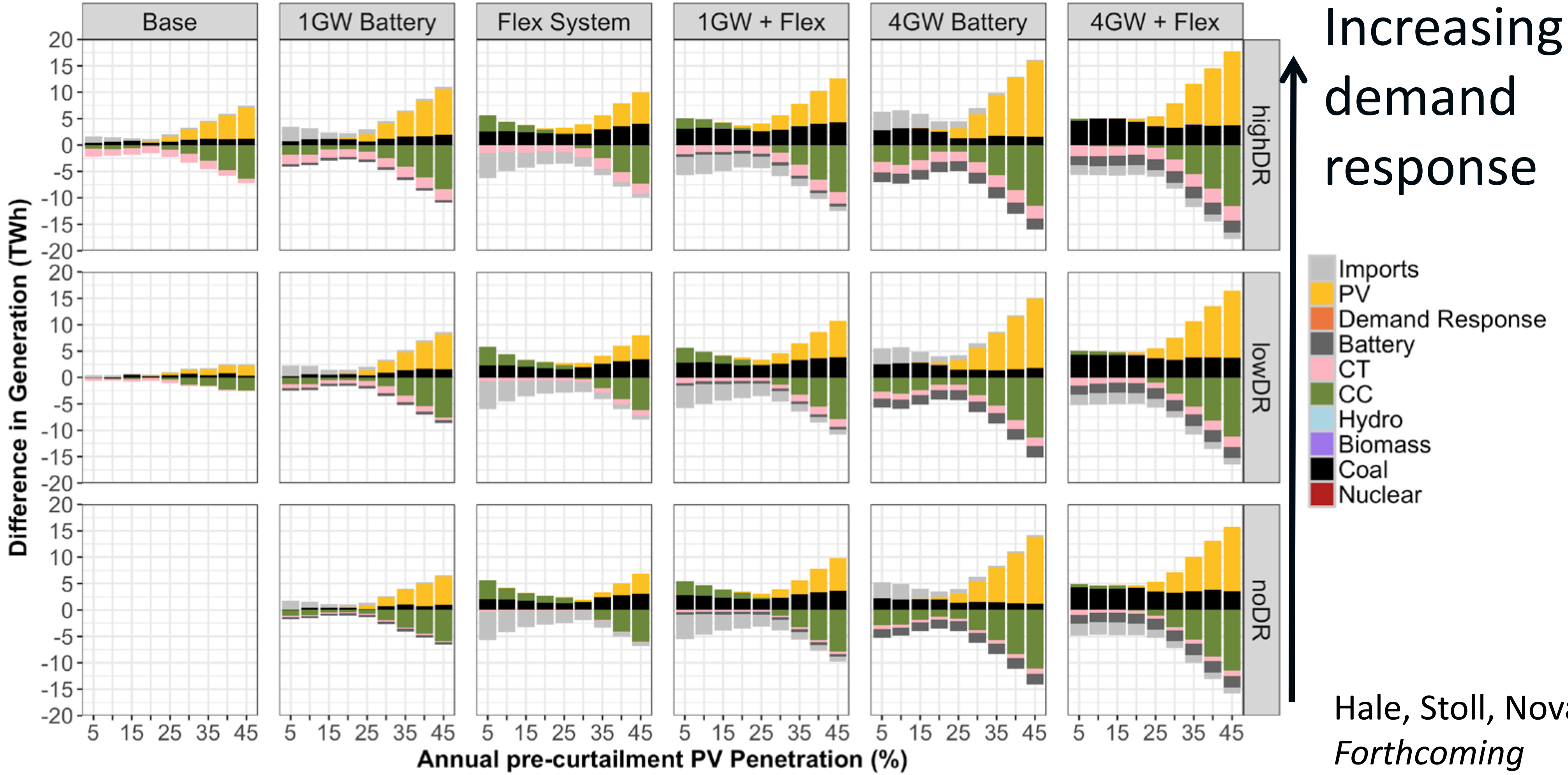
Modeling Demand Response in the bulk power system

- Constraints
  - Which grid services can be provided
  - How long each service can be used
  - When must the load be recovered by
  - Restrictions on timing of the load recovery
- Assumptions
  - Demand Response resource is given as input
  - Zero marginal cost
  - Centrally dispatched along with everything else to minimize system cost
- Allows us to measure the maximum value of the resource without insight into future market structures

System impacts of DR

Annual Generation differences from analogous Base scenario



Increasing demand response

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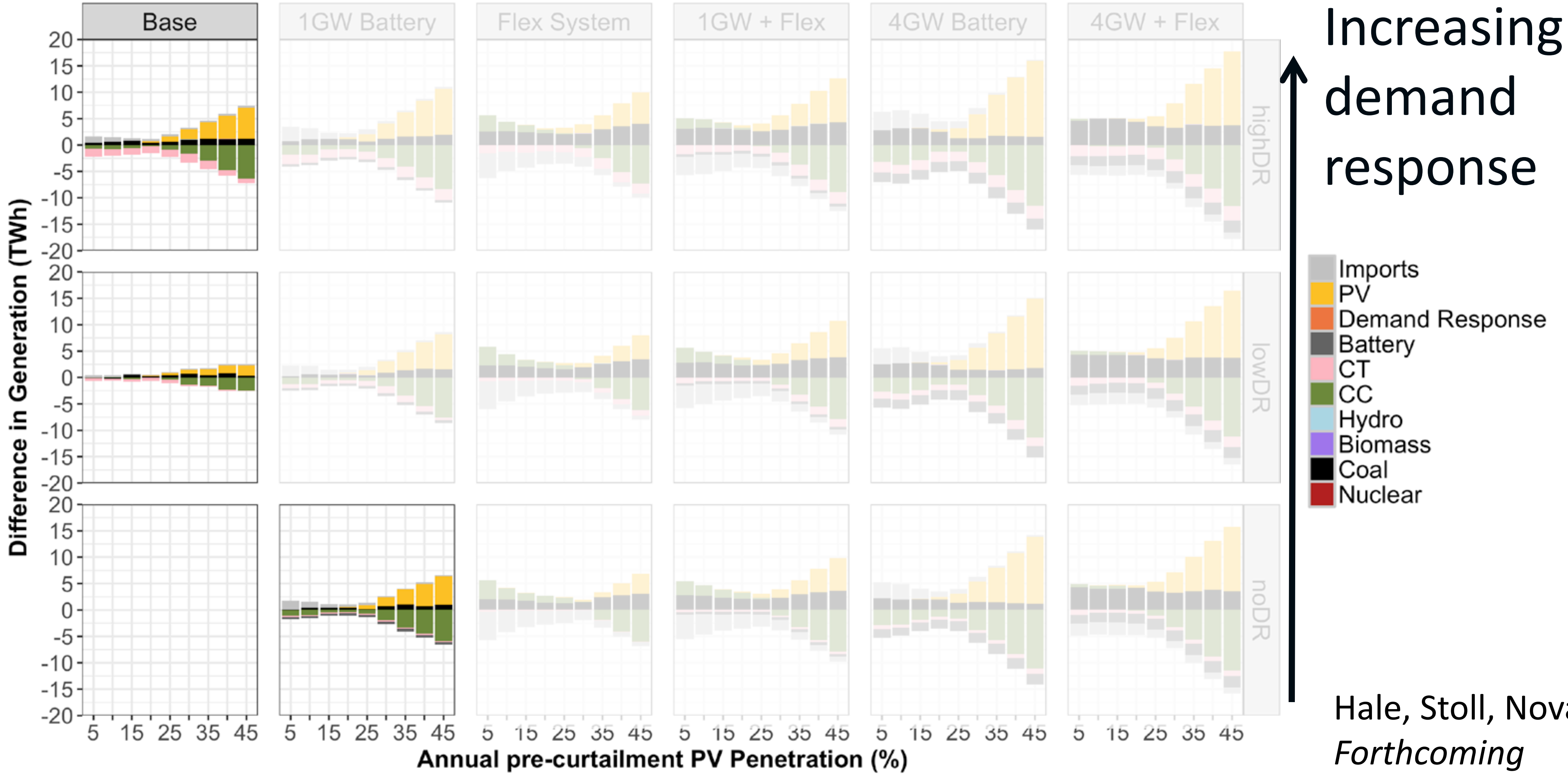
Impact of demand response is similar to 1 GW battery



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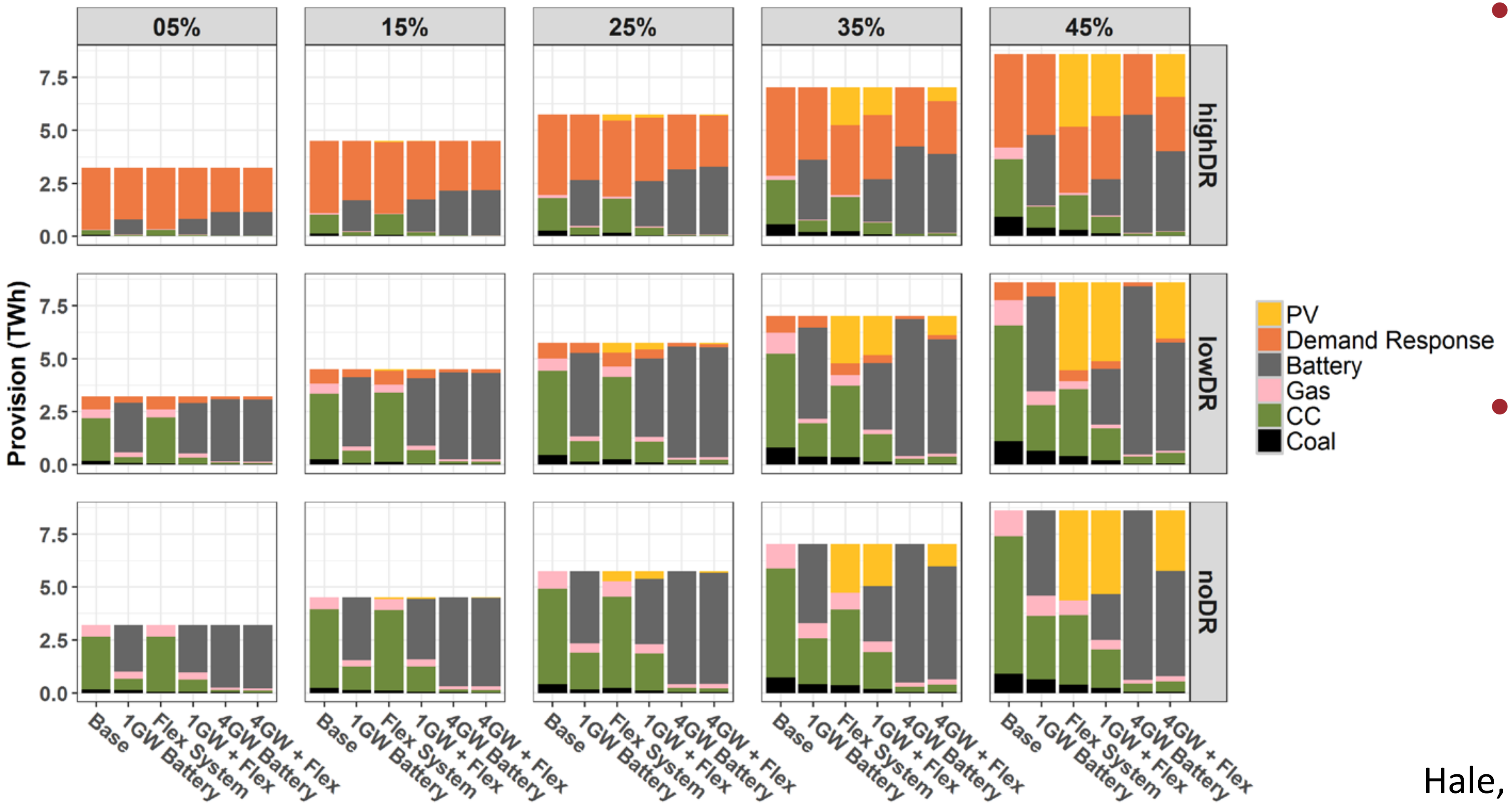
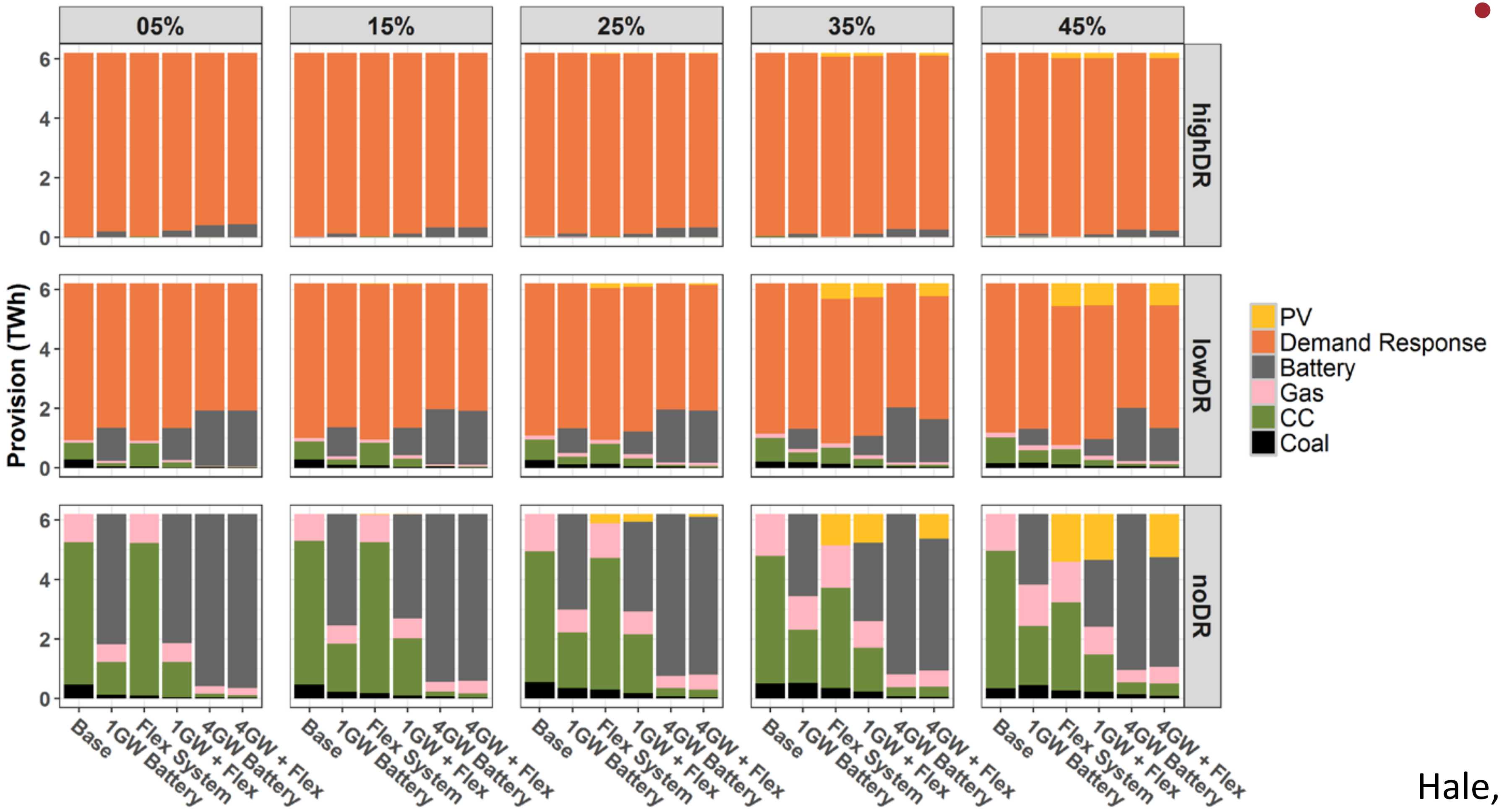
Demand response can provide significant portions of regulation reserves



- High DR scenario assumes a higher fraction of DR would have controls to enable reserve provision
- Regulations must be in place to allow such operation

Hale, Stoll, Novacheck, *Forthcoming*

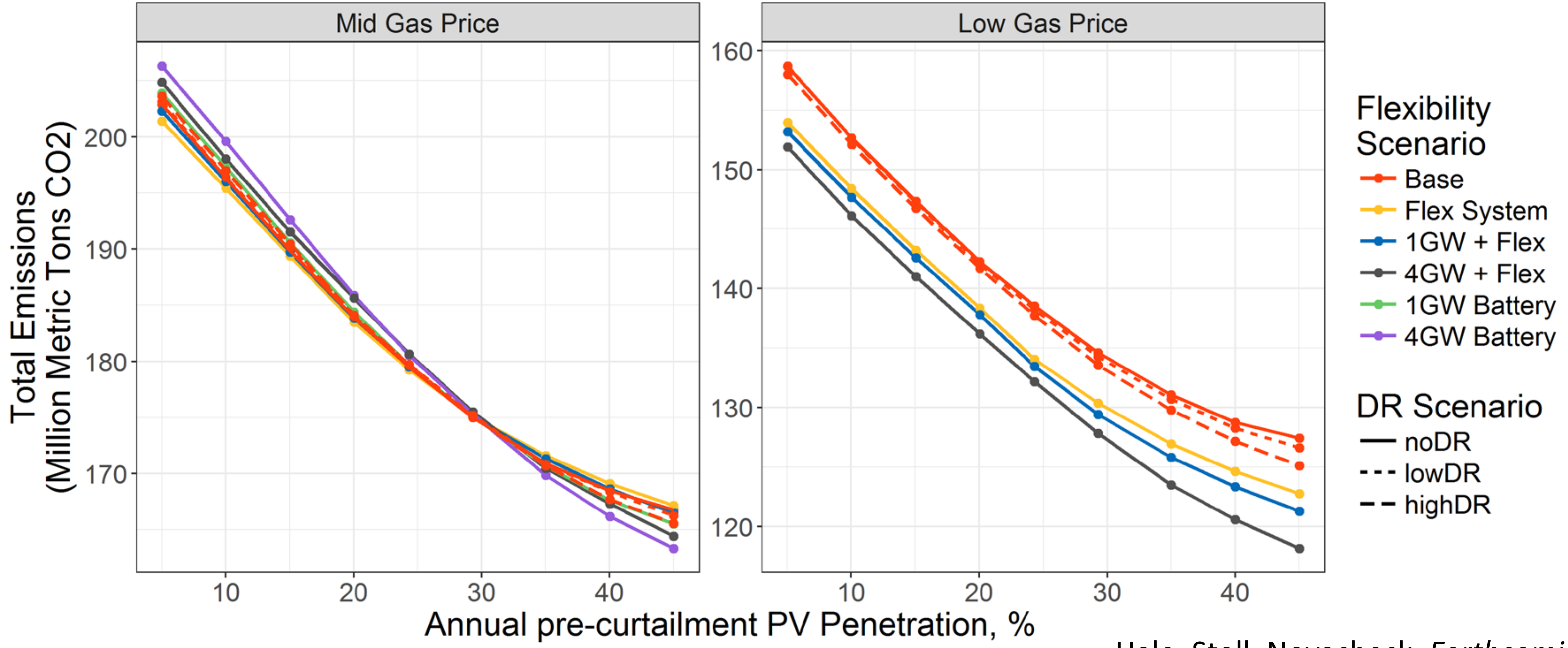
Demand response is very well suited to provide contingency reserves



- Again, regulations must be in place to allow such a high fraction of DR to provide reserves

Hale, Stoll, Novacheck, *Forthcoming*

Flexibility has a complex impact on emissions



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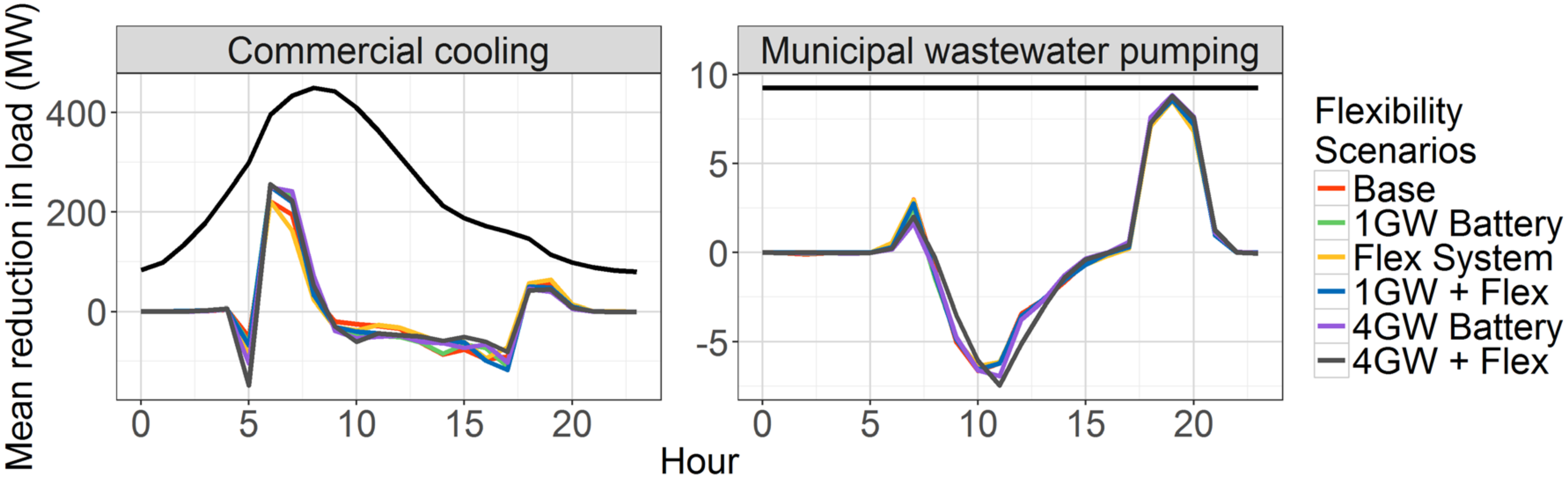
Value of DR by End-Use

Value of DR highly impacted by end-use availability

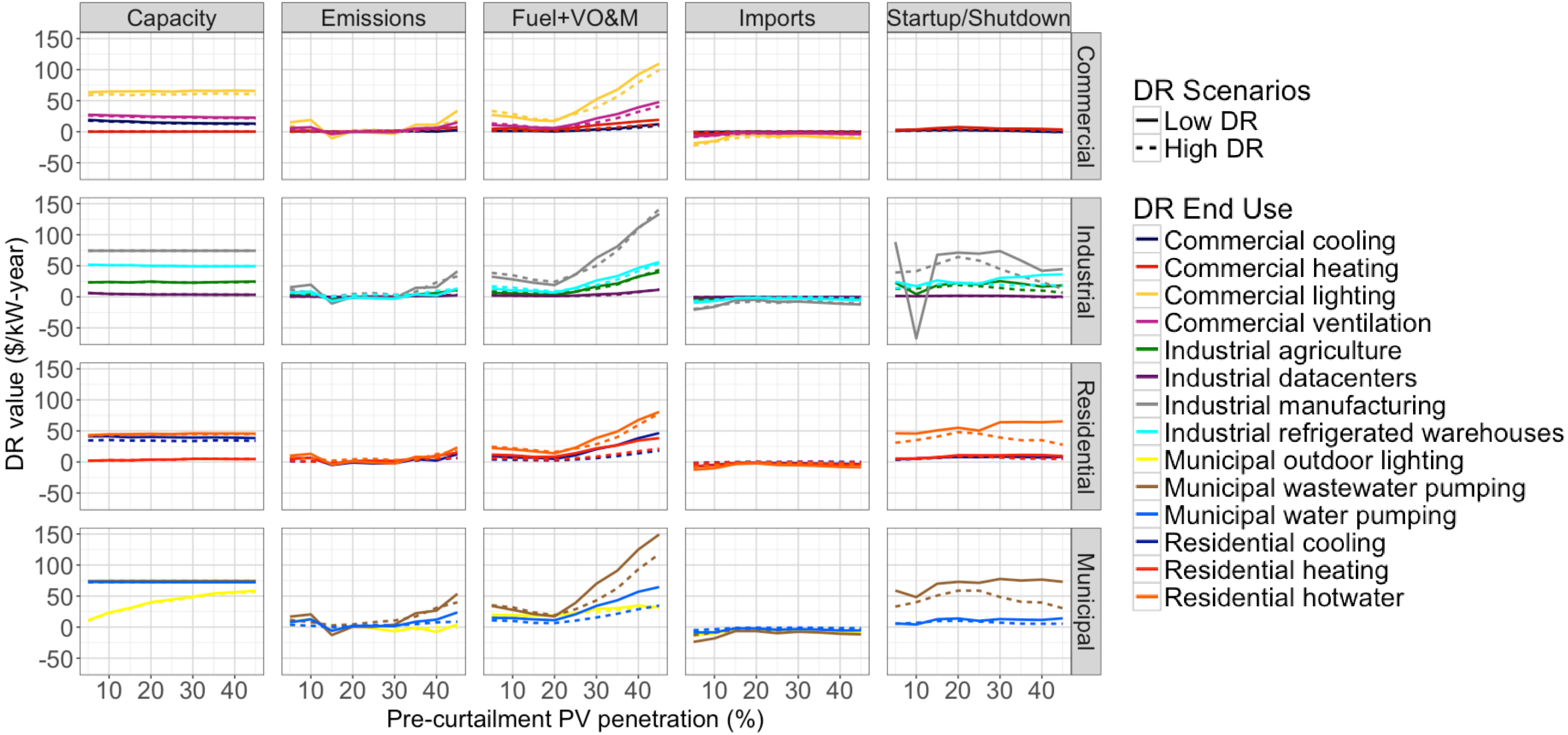
- Each end-use differs in load shape, operating constraints, and level of grid deployment. These all impact the amount of value they bring to the grid



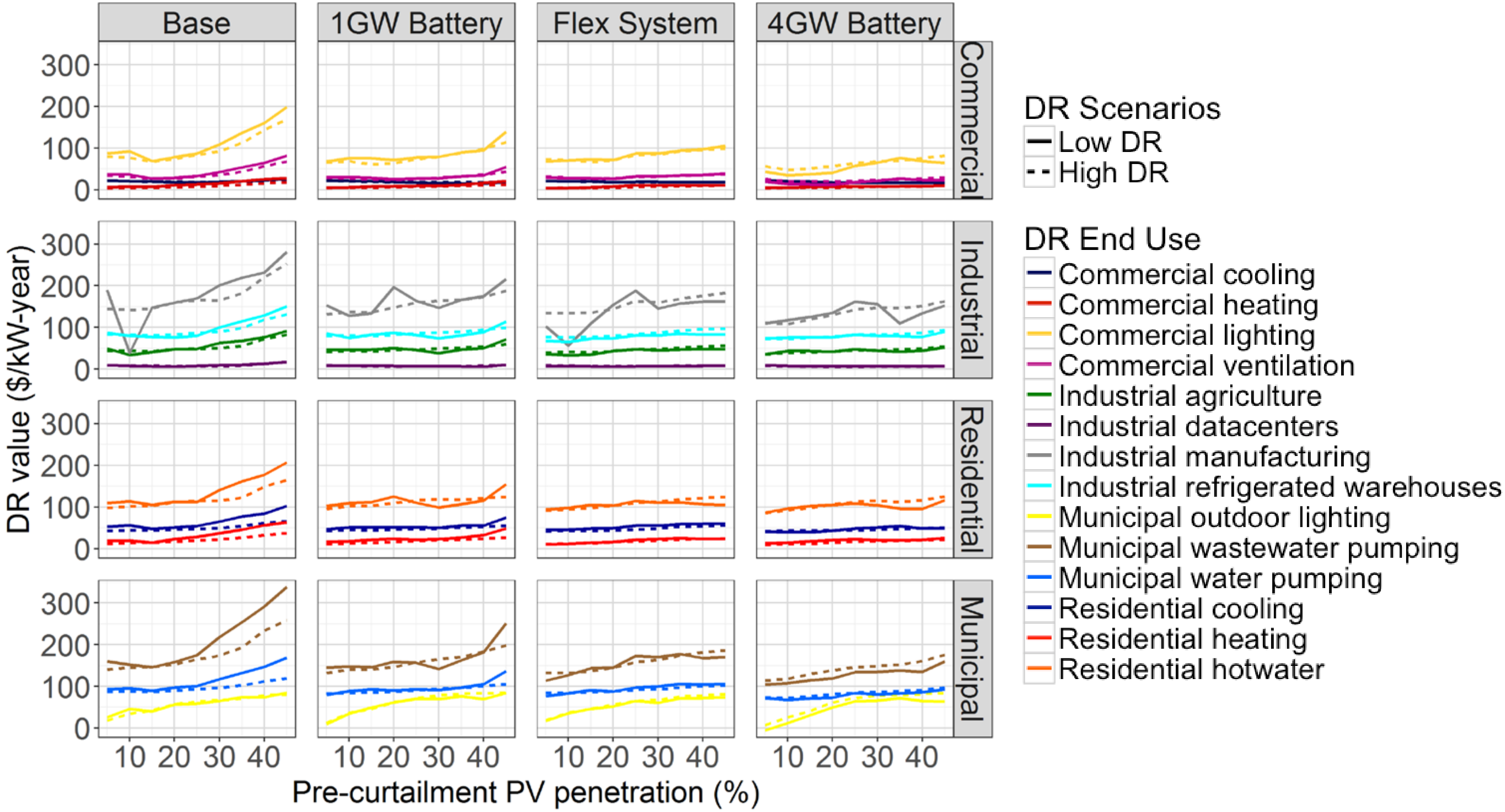
Value streams of Demand Response

- Capacity
- Emissions Reduction
- Fuel and VO&M Cost Reduction
- Import Cost Reduction
- Startup and Shutdown Cost Reduction

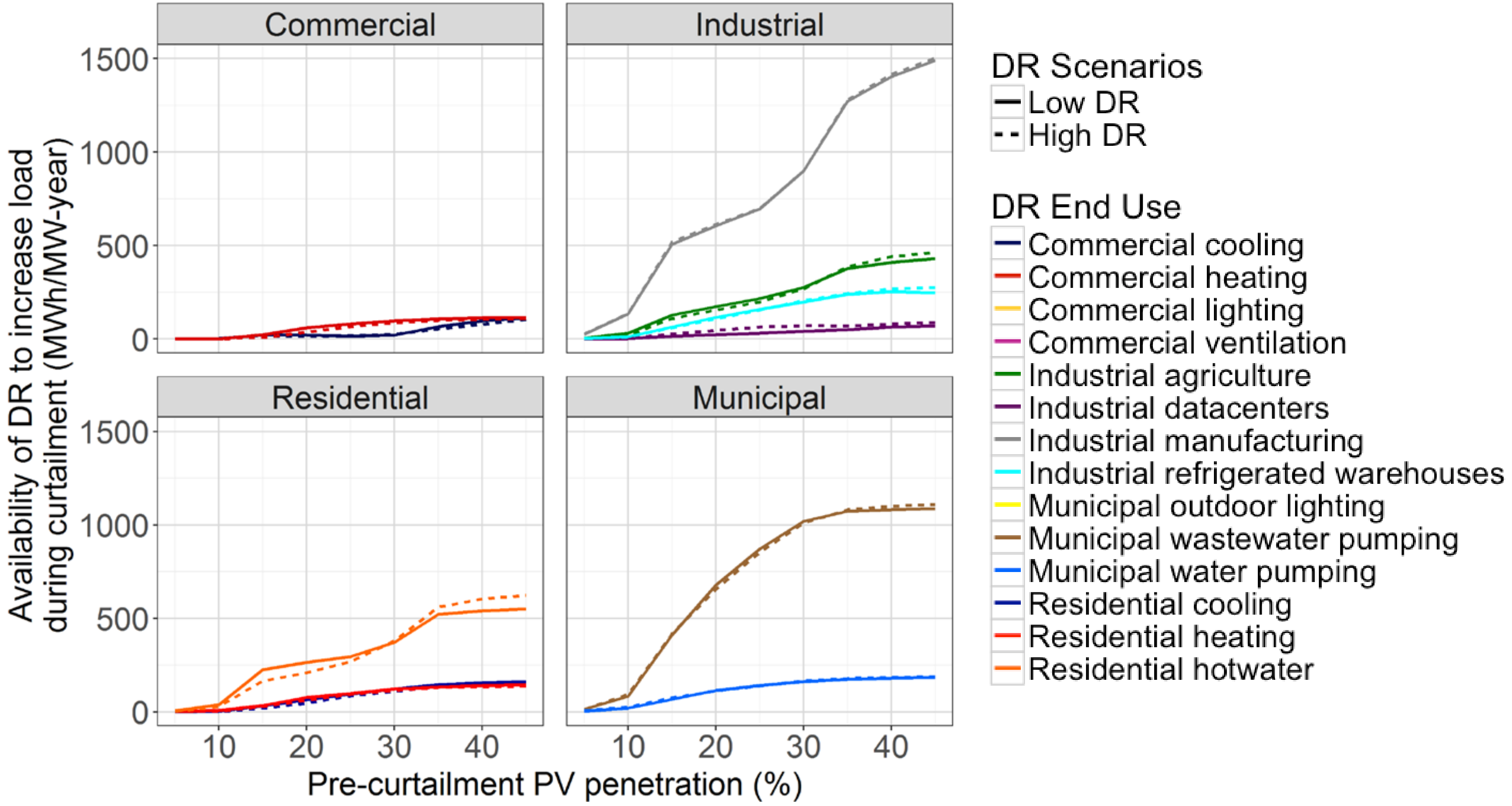
Value streams differ by end-use



Value of DR varies widely by end-use



Curtailment reduction potential increases with increasing PV



Conclusions

- Demand response can provide significant benefits to bulk power system operations, particularly by displacing peaking units and helping to balance variable generation
- Demand Response can provide much of the reserves needed by the system. In some jurisdictions, participation rules focused on ensuring grid reliability are the primary limitation on the fraction of reserves provided by load.
- The value of different end-uses vary dramatically based on their availability and constraints. The more flexible end-uses whose availability coincides with peak demand are most valuable

Questions?

Brady Stoll

brady.stoll@nrel.gov

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Sector	End-Use	Services Provided	Resource Type	Load Recovery Restrictions	T_{bal} (days)	T_{day} (hrs)
Residential	Cooling	E + C + R	Storage	5 am–6pm	1	1
	Heating	E + C + R	Storage	3 am–7 pm	1	1
	Water heating	E + C + R	Schedule	-	1	-
Commercial	Cooling	E + C + R	Storage	5 am–6 pm	1	2
	Heating	E + C + R	Storage	3 am–7 pm	1	2
	Lighting	C + R	Shed	-	-	-
	Ventilation	C + R	Shed	-	-	-
Municipal	Outdoor lighting	C + R	Shed	-	-	-
	Wastewater pumping	E + C	Schedule	-	1	3
	Water pumping	E + C	Schedule	-	1	2
Industrial	Agricultural pumping	E + C + R	Schedule	-	7	8
	Datacenters	E + C + R	Schedule	4 am–8 pm	1	4
	Manufacturing	E + C + R	Schedule	-	1	-
	Refrigerated warehouses	E + C + R	Storage	-	1	4

E = Energy, C = Contingency Reserves, R = Regulation Reserves

Scenario Framework

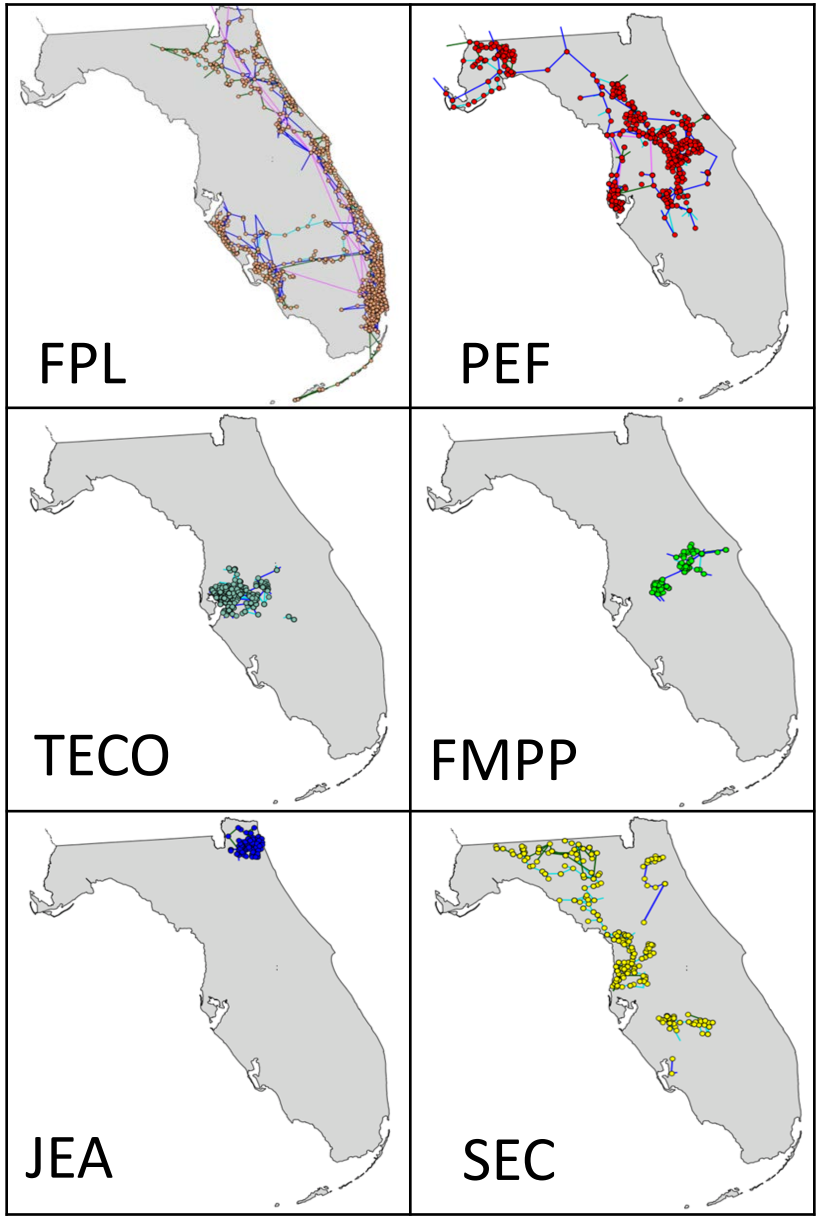
Flexibility Option	Modeling Description	Levels
Demand Response	LBNL + NREL resource data modeled with two virtual generators per region and end-use combination.	Low DR High DR
Battery Storage	20 batteries of equal size are deployed throughout FRCC. Each battery has 6 hours of storage.	Battery = 1 GW Large Battery = 4 GW
PV Reserve Provider	PV is allowed to provide regulation and contingency reserves.	Flex Scenario
40% CC Min Gen	The minimum generation for all CCs in FRCC are reduced from 50% of their maximum capacity to 40%.	
Reduced Regional Friction	Reserve products in FRCC are merged into single product rather than individual regional products. Hurdle rates to import power are also removed.	

FRCC Production Cost Model

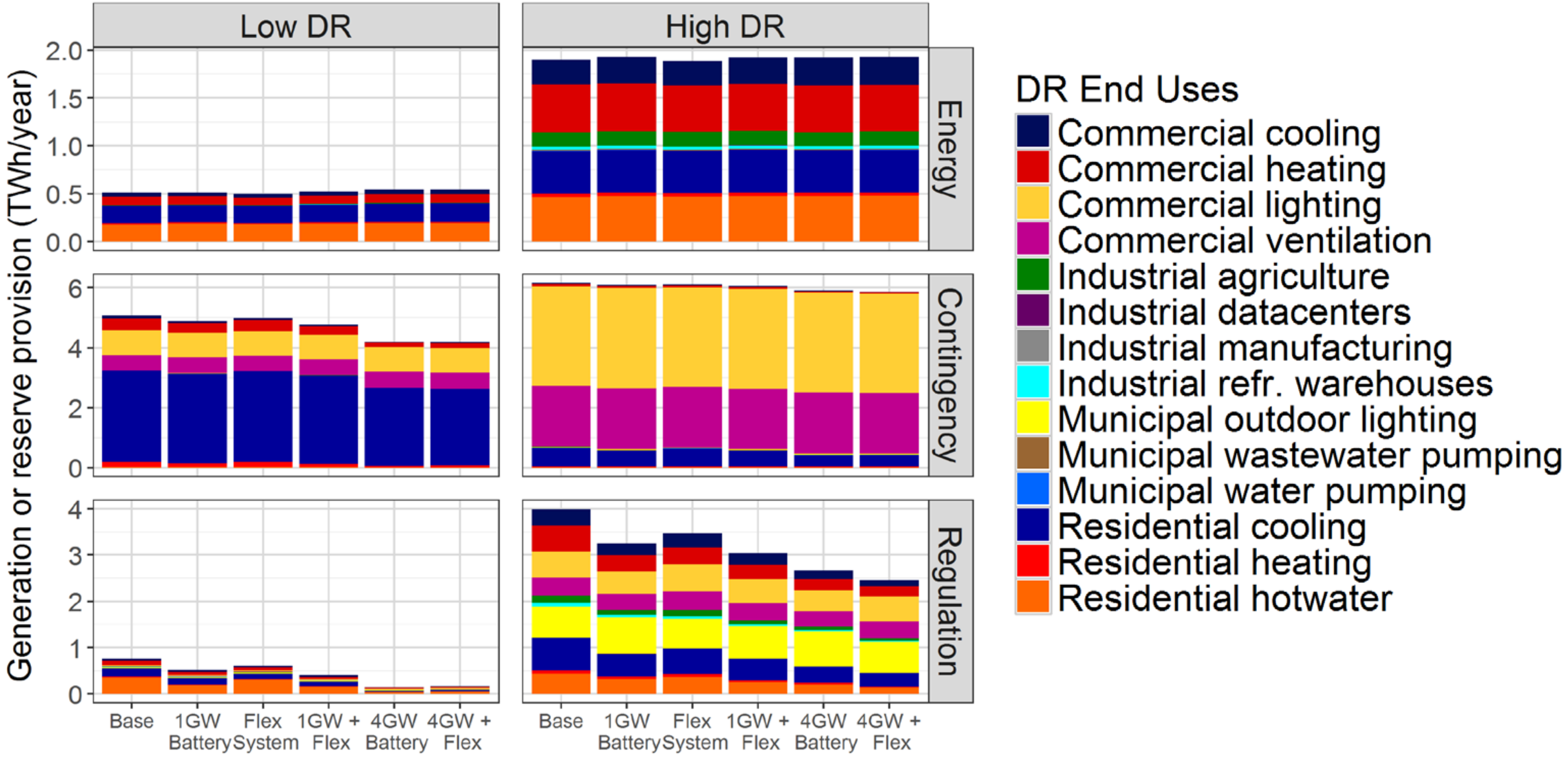
- Base model extracted from the Eastern Renewable Grid Integration Study (ERGIS)
- FRCC broken into 6 Balancing Areas
  - Captures major IOUs, Munis, and Co-ops
- Major connections to SERC captured

FRCC = Florida Reliability Coordinating Council

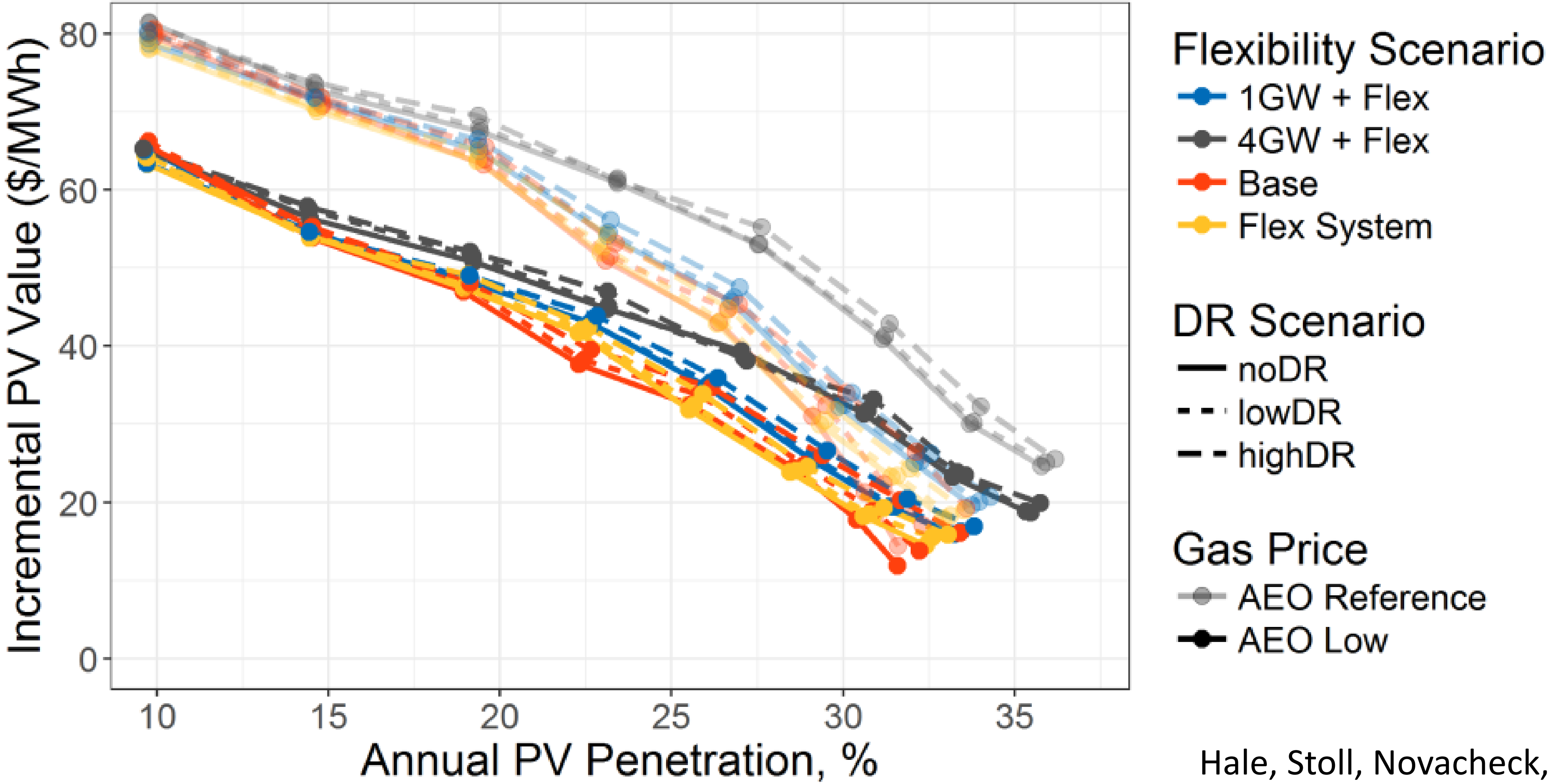
Denholm et. al, *Impact of Flexibility Options on Grid Economic Carrying Capacity of Solar and Wind: Three Case Studies*, NREL 2016



Provision of Energy increases with availability, however Reserves are becoming saturated



Demand Response increases the value of PV



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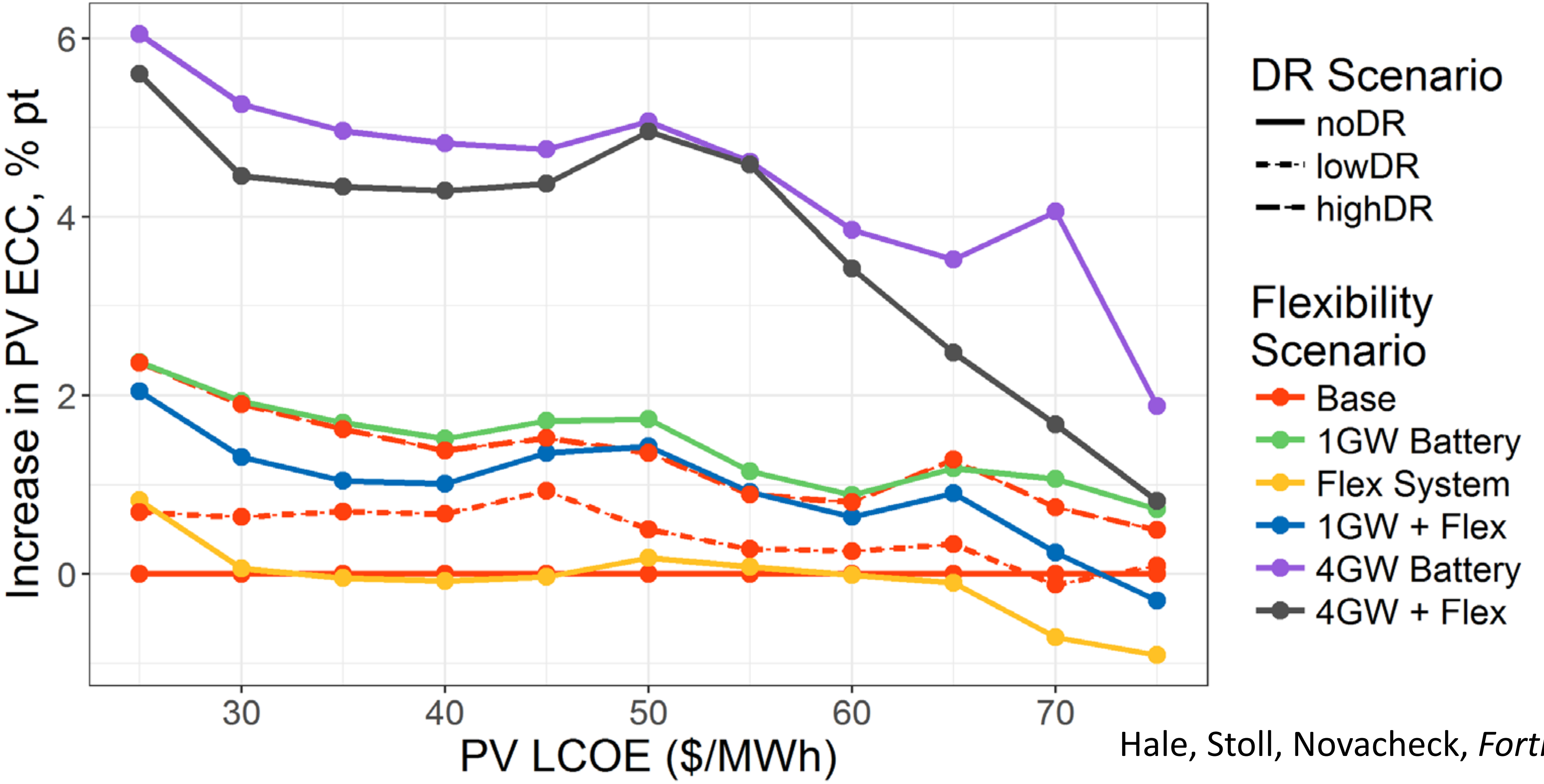
Demand Response can increase Economic Carrying Capacity of PV



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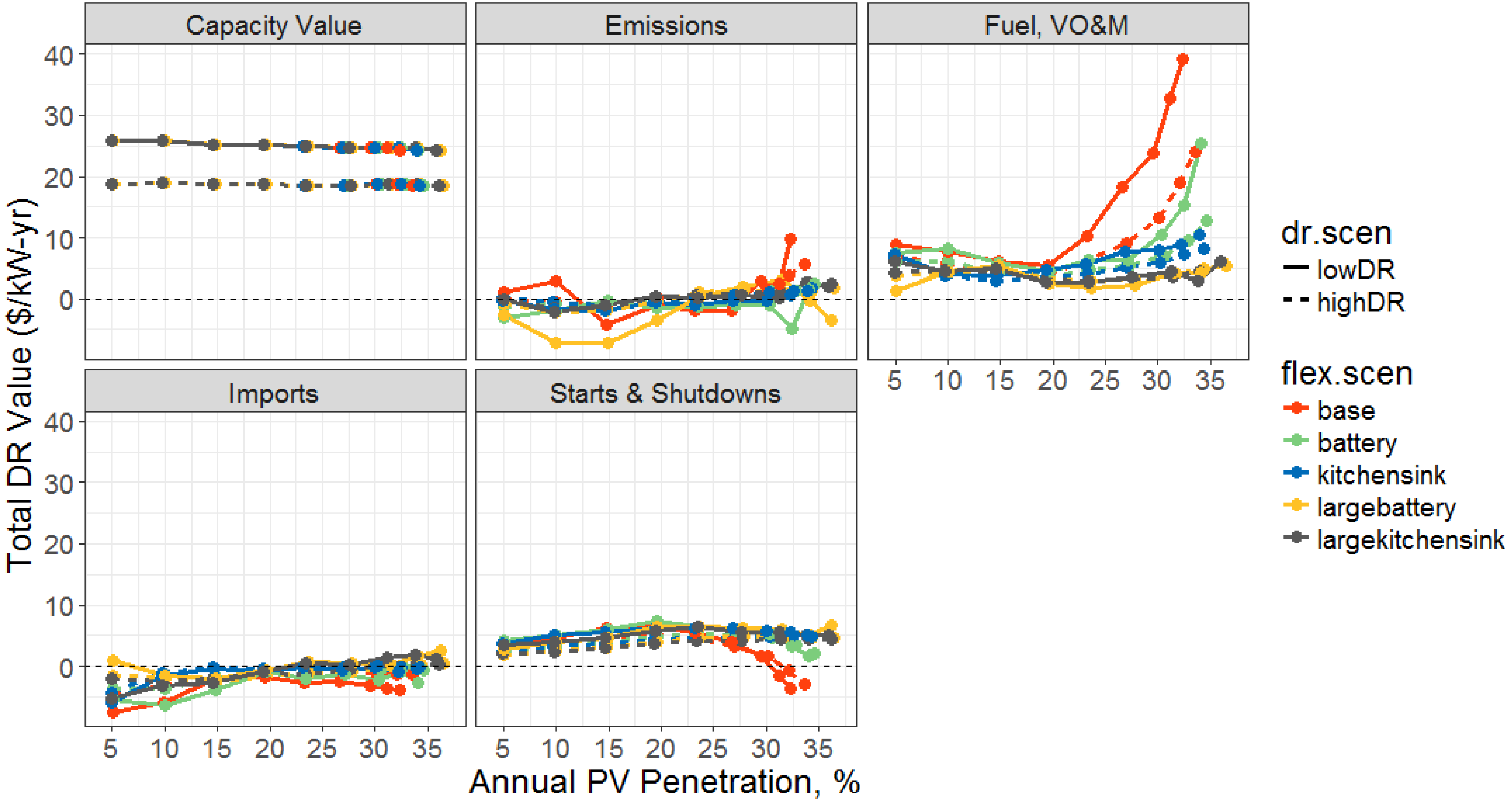
Total value of Demand Response



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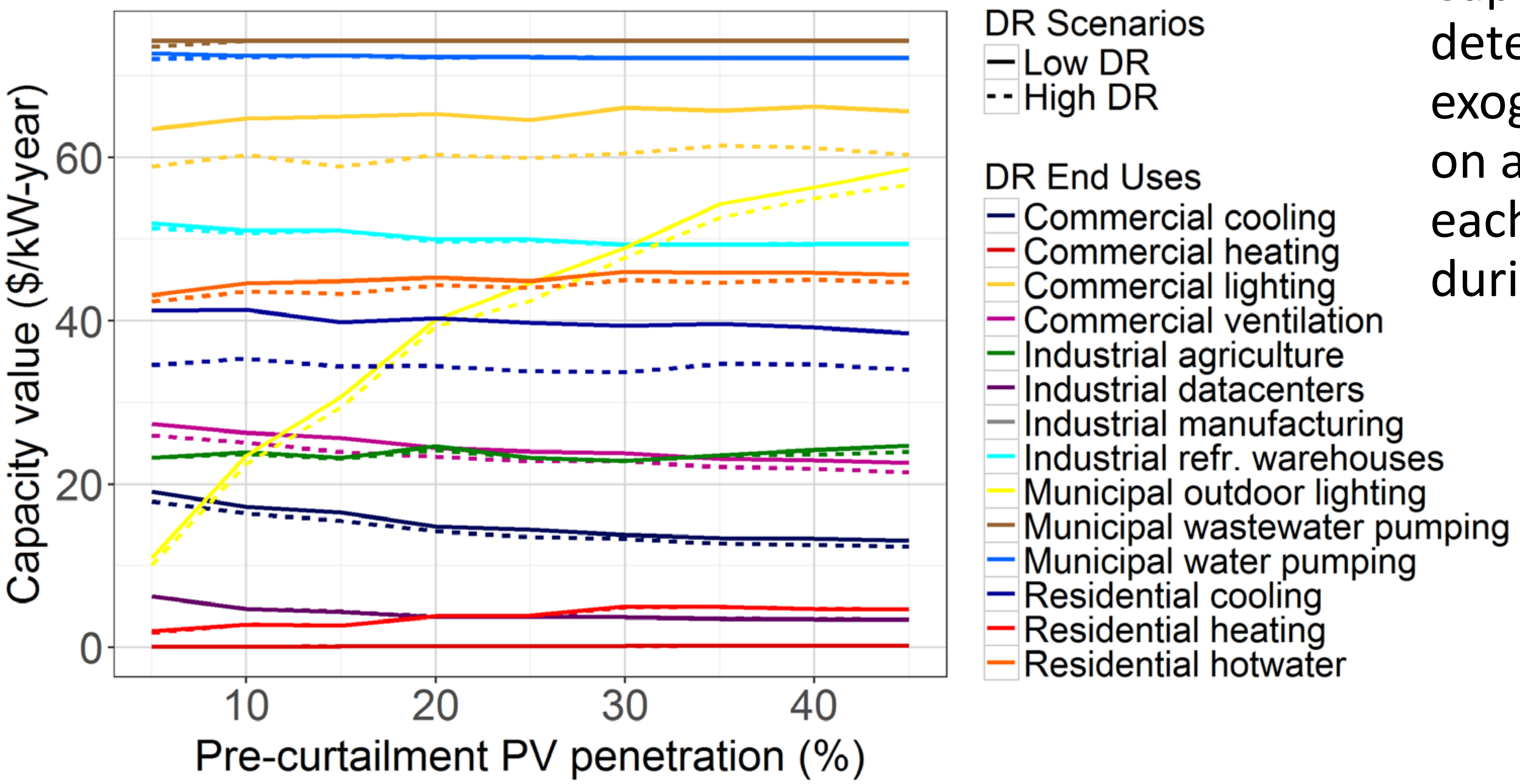
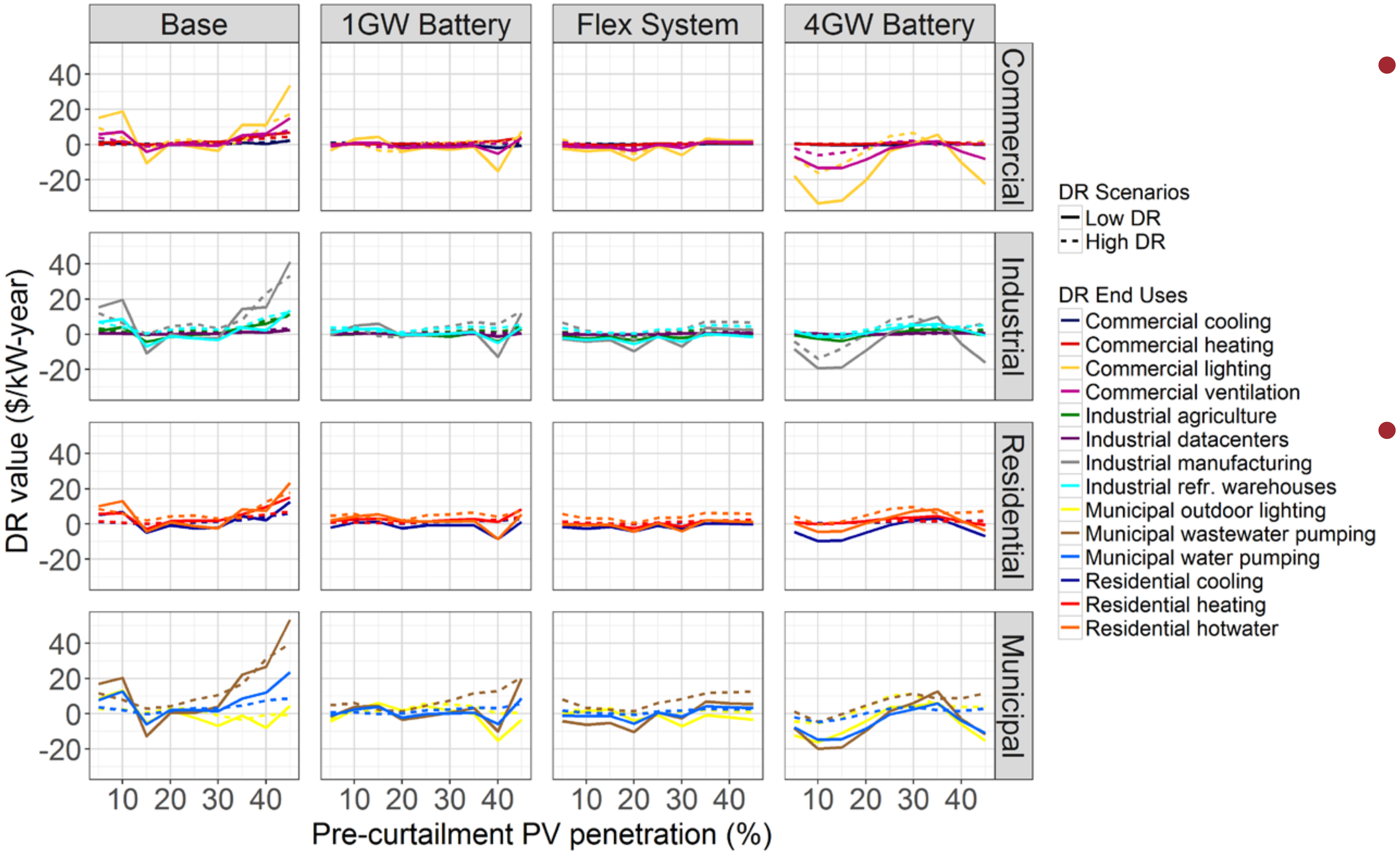
Capacity Value



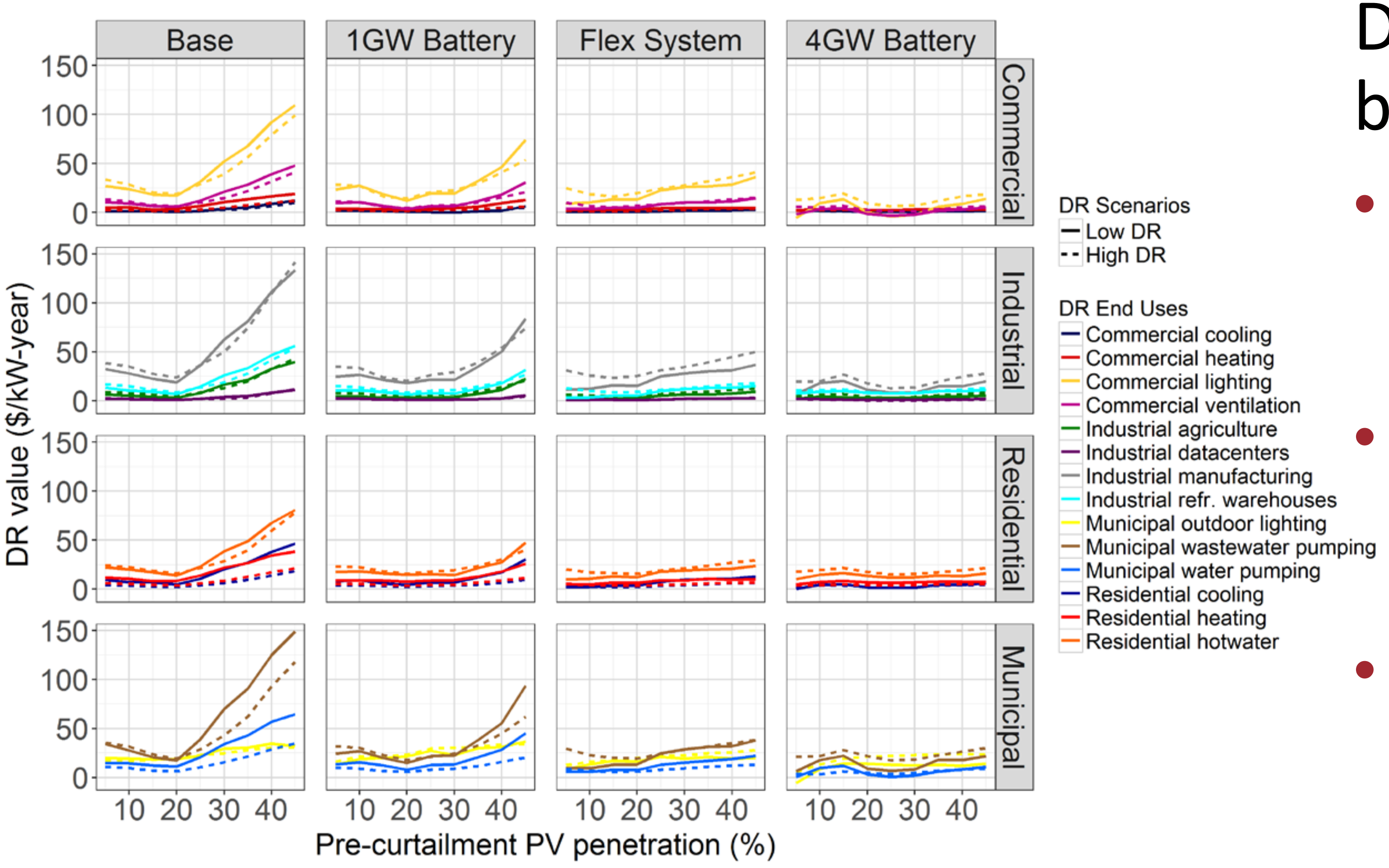
- Capacity value is determined exogenously based on availability of each end-use during peak hours

Emissions Reduction



- Based on post-processing fuel use changes and a social cost of carbon analysis, $50/ton
- Disaggregation of cost by end-use:
  - By fraction of energy displaced by each end use

Fuel and VO&M Reductions



Disaggregation of cost by end-use:

- By fraction of energy and reserves provided by each end use
- Performed on hourly basis to account for diurnal and seasonal variation in DR
- Does not account for second order effects

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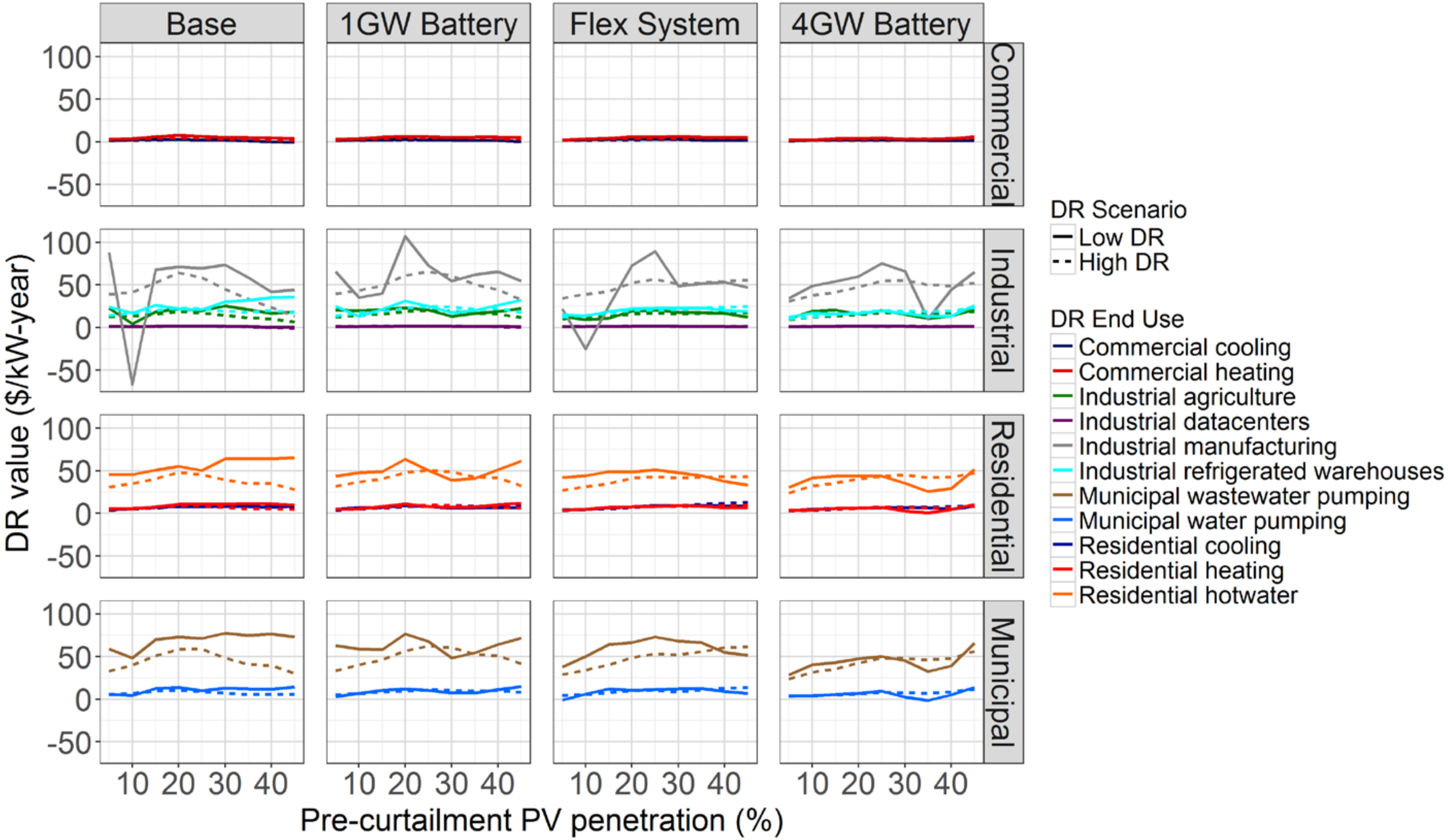
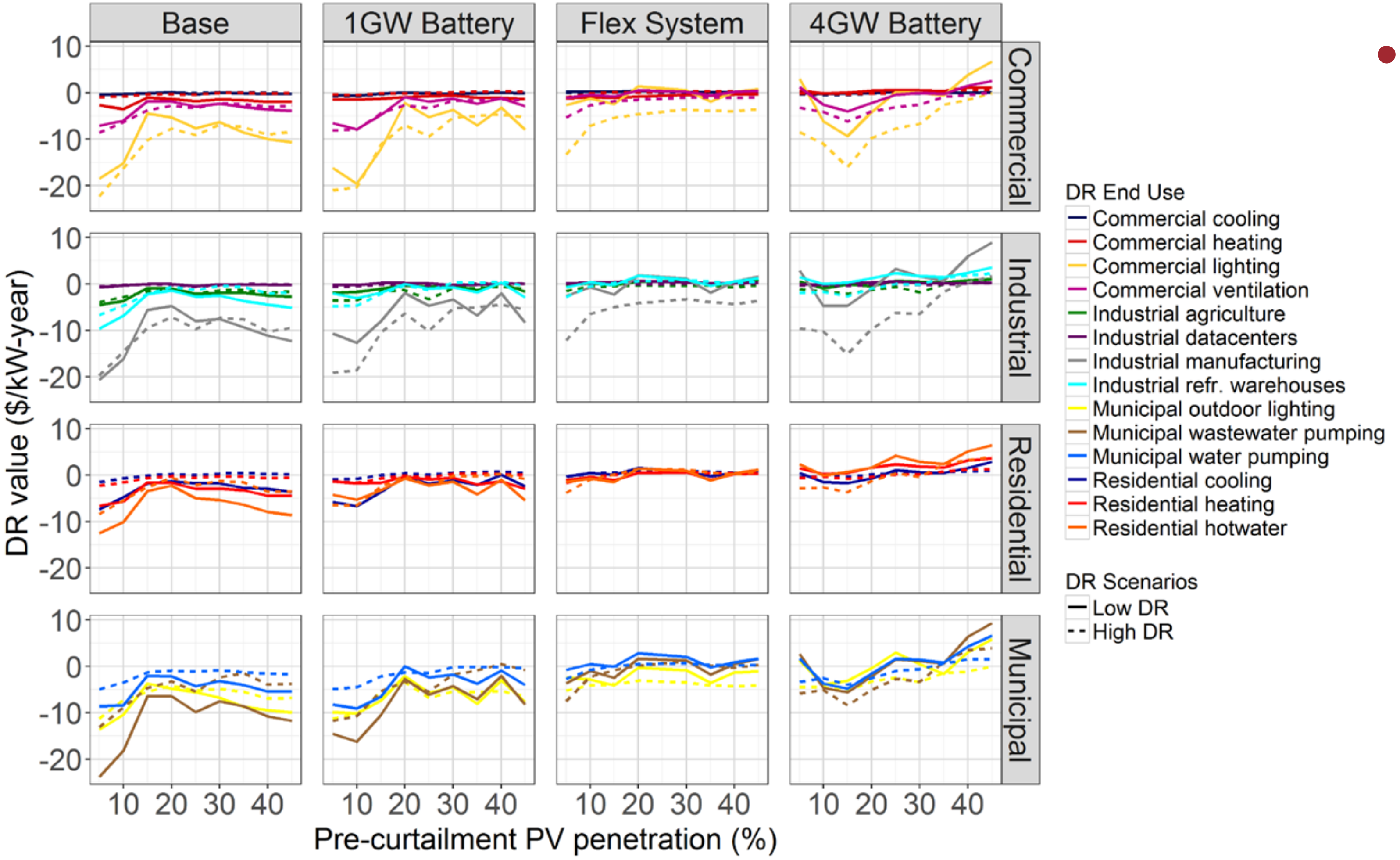
Generator Startup/Shutdown Cost Reduction



Imports



- DR generally reduces import costs for a brief period during the morning and evening peak loads, and increases costs during all other times of the day, resulting in a negative value to the system.

Generator Startup/Shutdown Cost Reduction