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Demand Response Potential from the Bulk Grid Perspective

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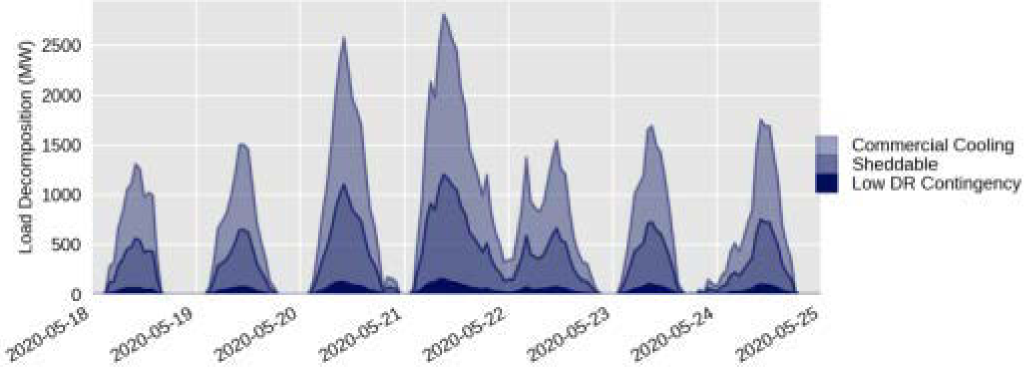
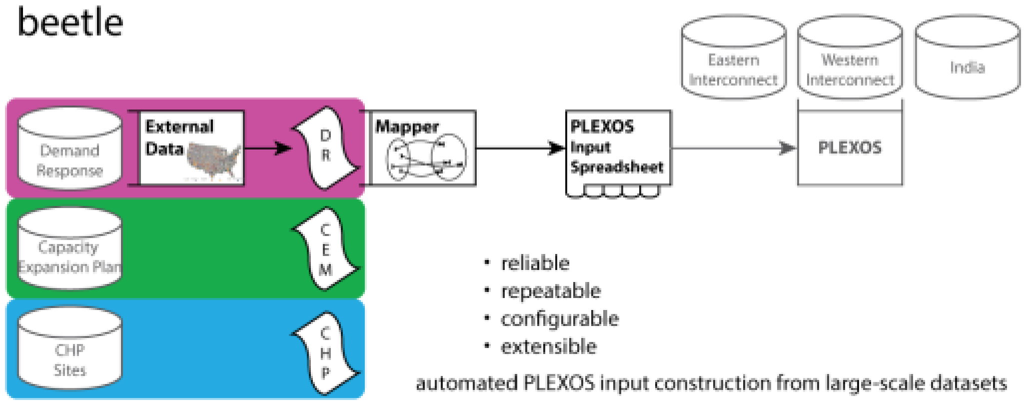
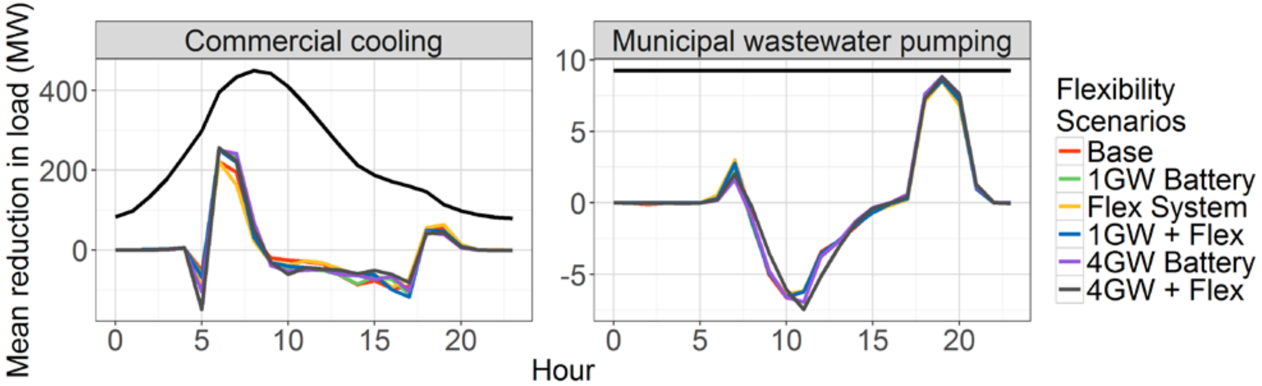
Outline

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







Introduction

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

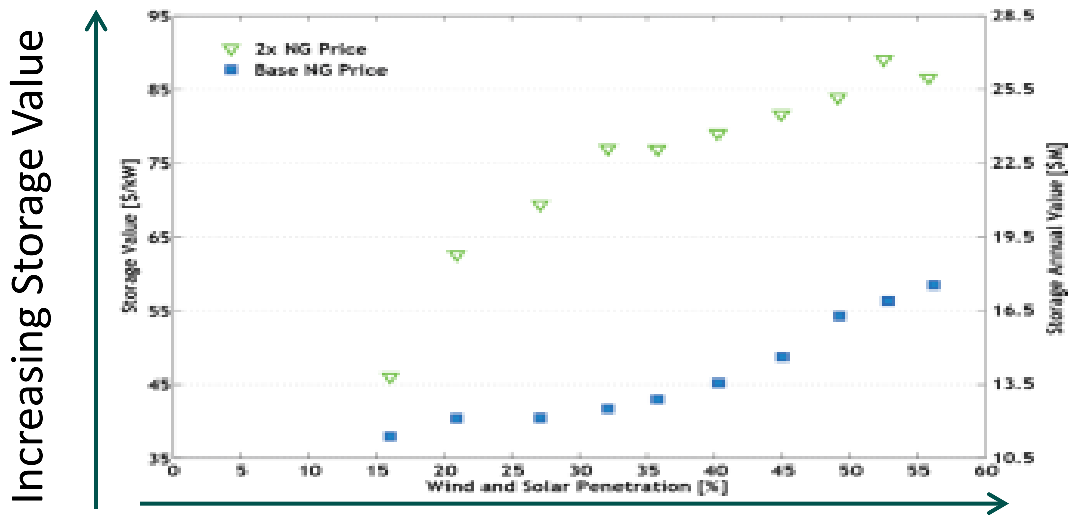
Demand response

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

➢ Potential depth of deployment?

➢ Ability to provide reserves and absorb curtailment?

Analogy with Storage

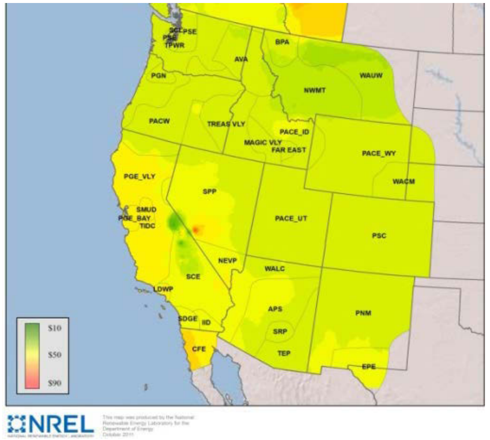


Increasing VG Penetration

Production Cost Model

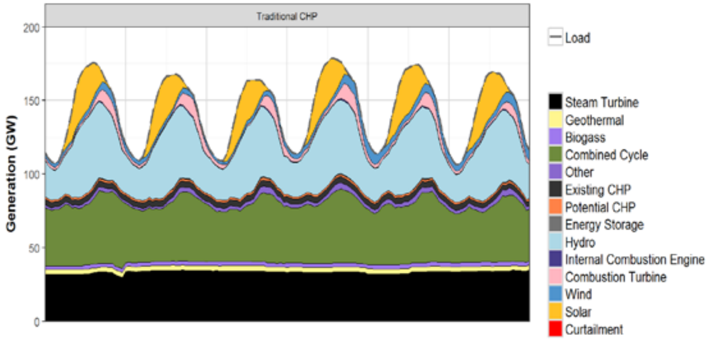
Simulate operation of electric power system

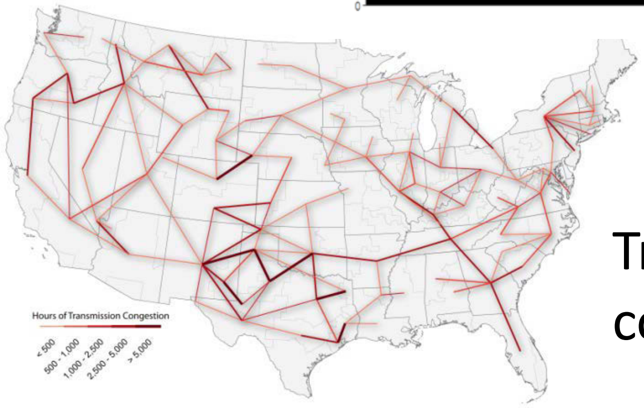
- Hourly or sub-hourly chronological dispatch
- Commits and dispatches generating units based on:
  - Electricity demand
  - Operating parameters of generators
  - Transmission grid parameters
- Used for system generation and transmission planning
  - Increasingly used for real-time operation



Locational prices, production cost

Dispatch information, fuel usage

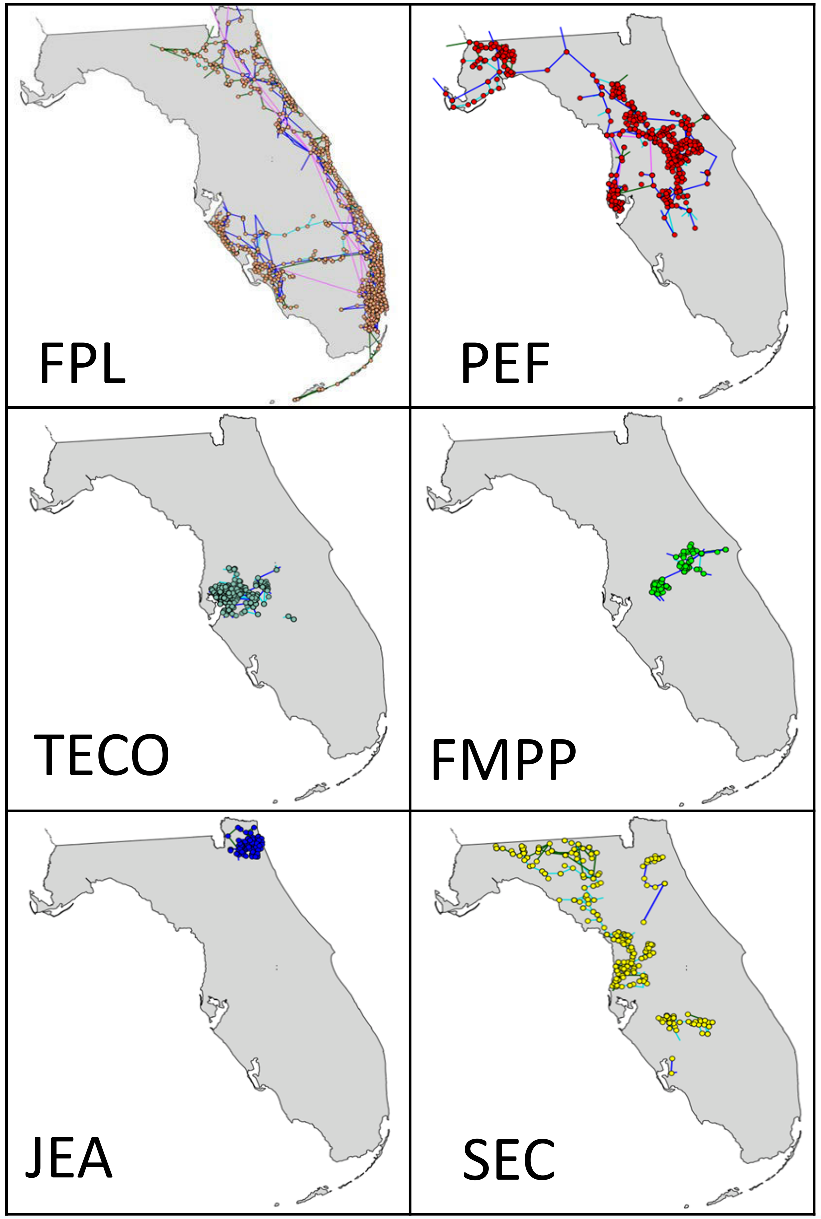




Transmission congestion

FRCC Production Cost Model

- Base model extracted from ERGIS
- FRCC broken into 6 Balancing Areas
  - Captures major IOUs, Munis, and Co-ops
- Major connections to SERC captured



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

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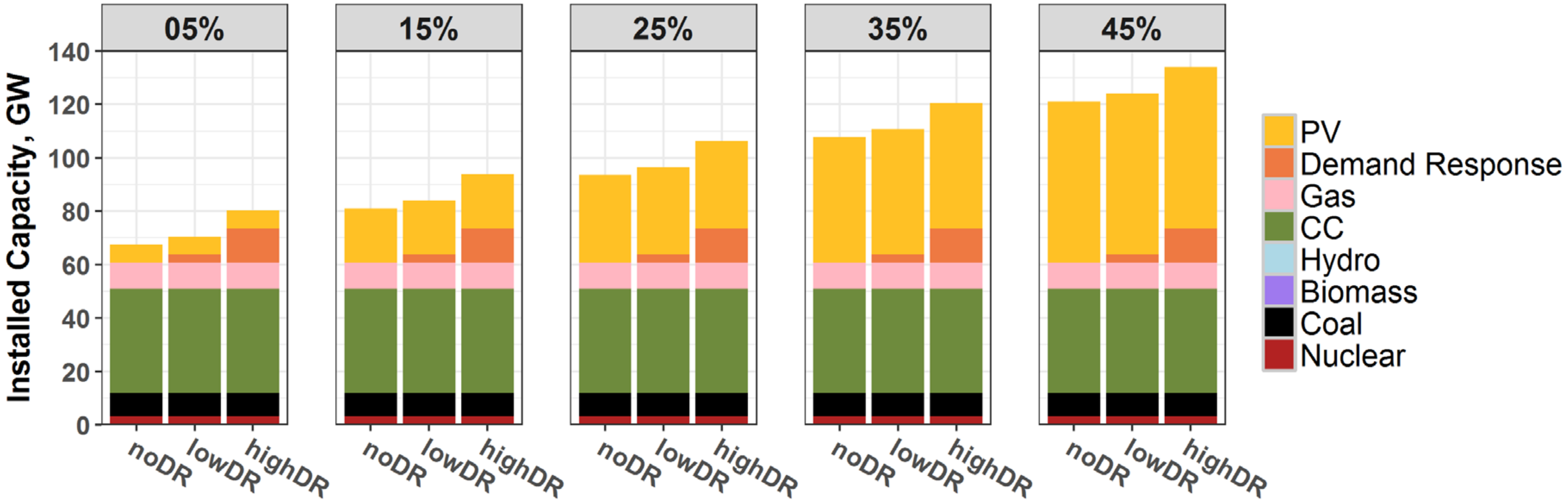
FRCC Capacity



Hale, Stoll, Novacheck, *Forthcoming*

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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
40% CC Min Gen	The minimum generation for all CCs in FRCC are reduced from 50% of their maximum capacity to 40%.	
Reduced BA Friction	Reserve products in FRCC are merged into single product rather than individual products for each BA. Hurdle rates to import power are also removed.	

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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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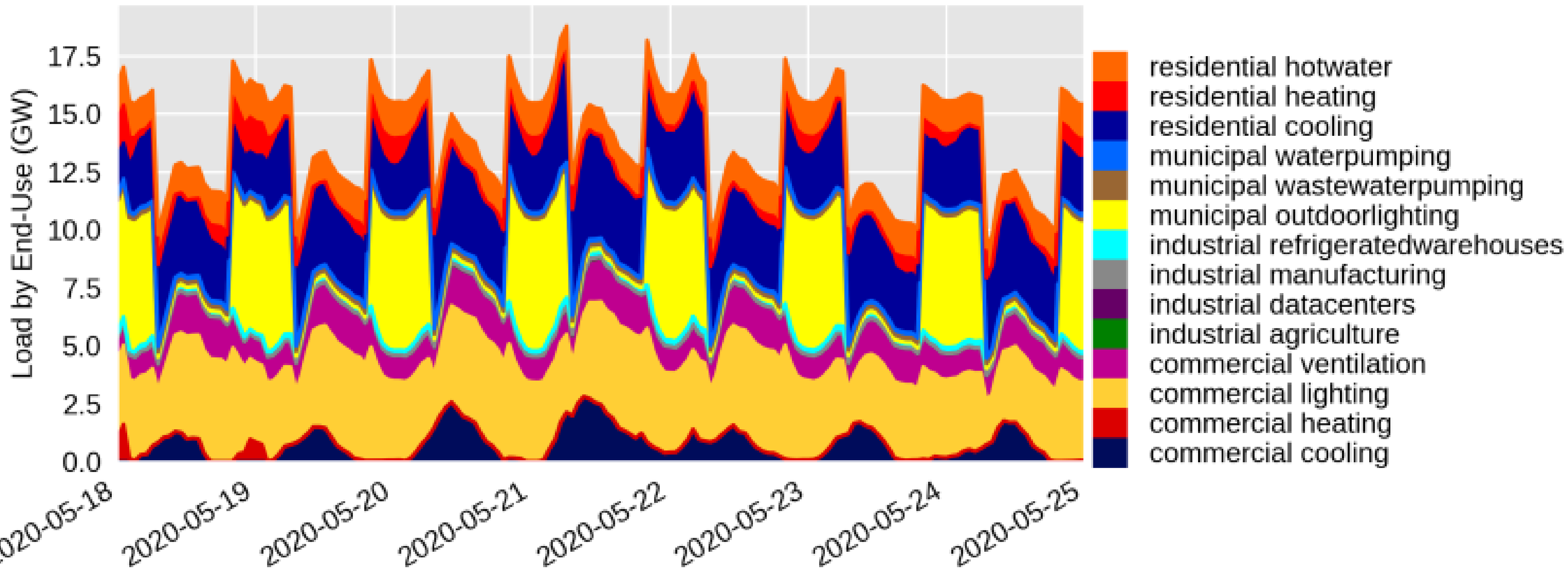
Demand Response
Input Data and Modeling Methods

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.

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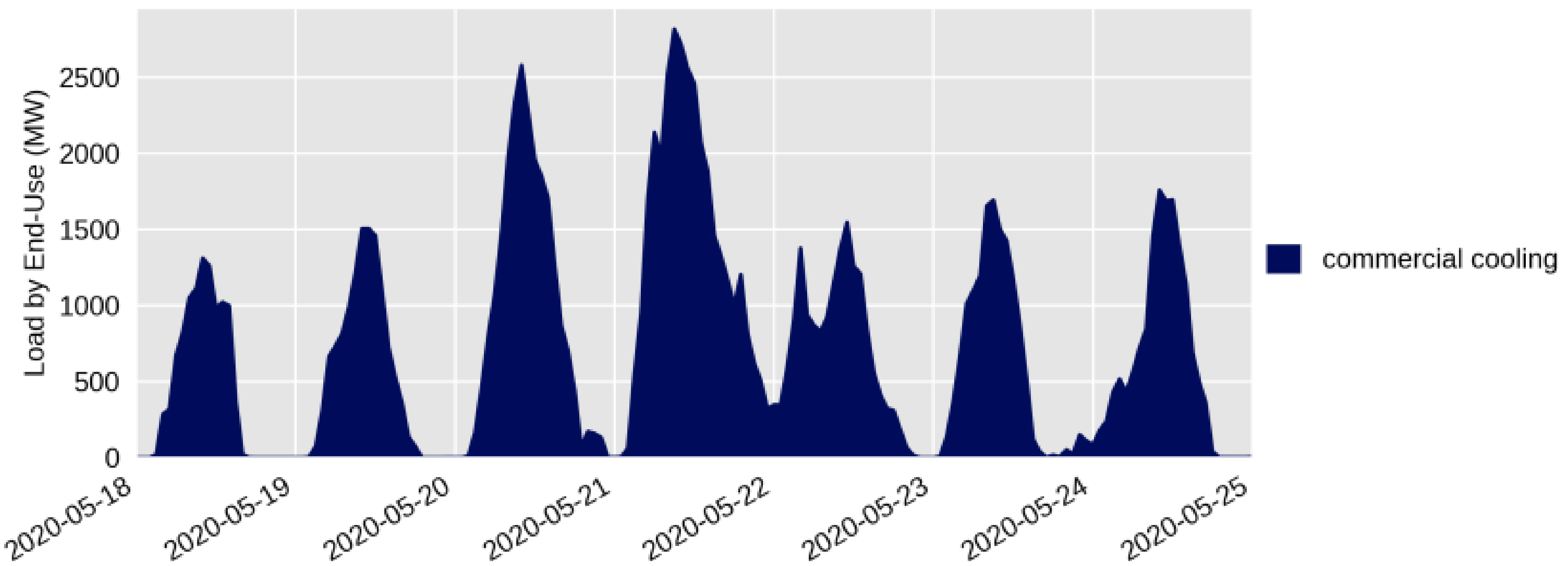
Demand Response Resource



- 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.

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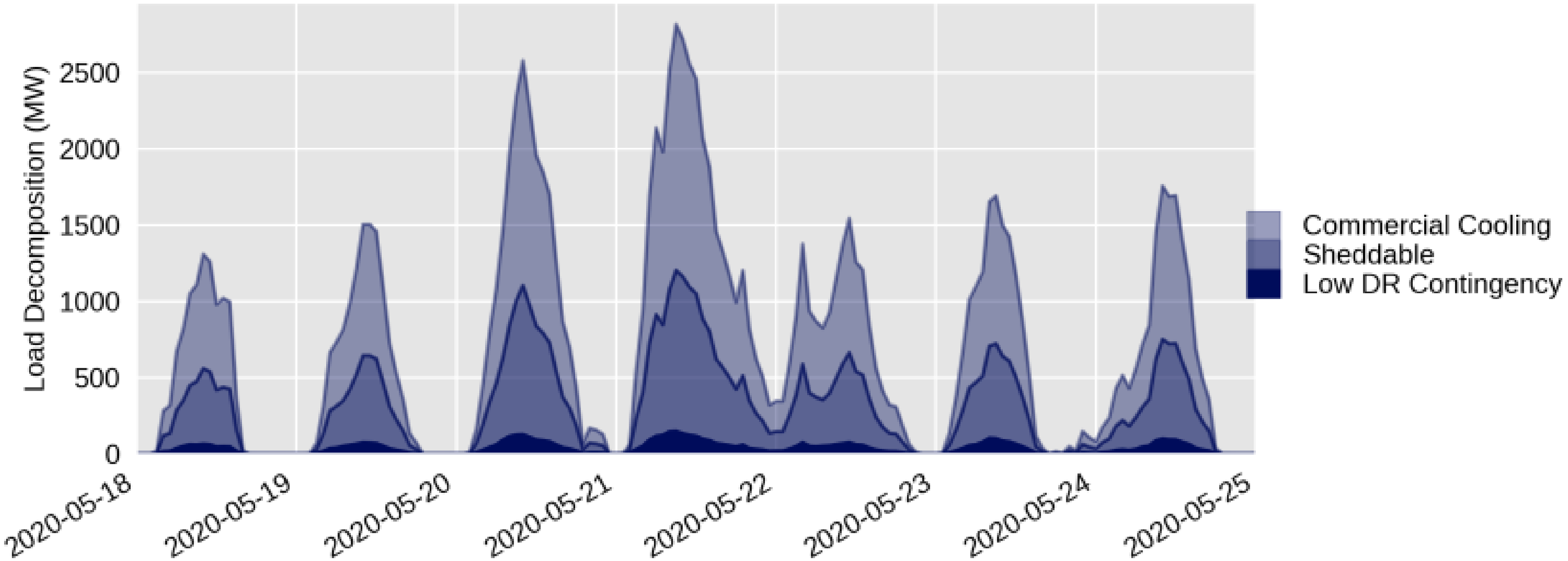
Demand Response Resource



- Three filters are applied 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

Demand Response Resource Categories

Schedulable

High Thermal Capacity Storage

Storage

Sheddable

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*

Demand Response Resource Categories

Schedulable – e.g. *pumping, manufacturing*

High Thermal Capacity Storage – *e.g. refrigeration*

Storage – *e.g. heating & cooling*

Sheddable – *e.g. lighting & ventilation*

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 PCM, but resource needs to be able to follow a fast signal, and performance needs to be measured

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
  - 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

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System impacts of DR

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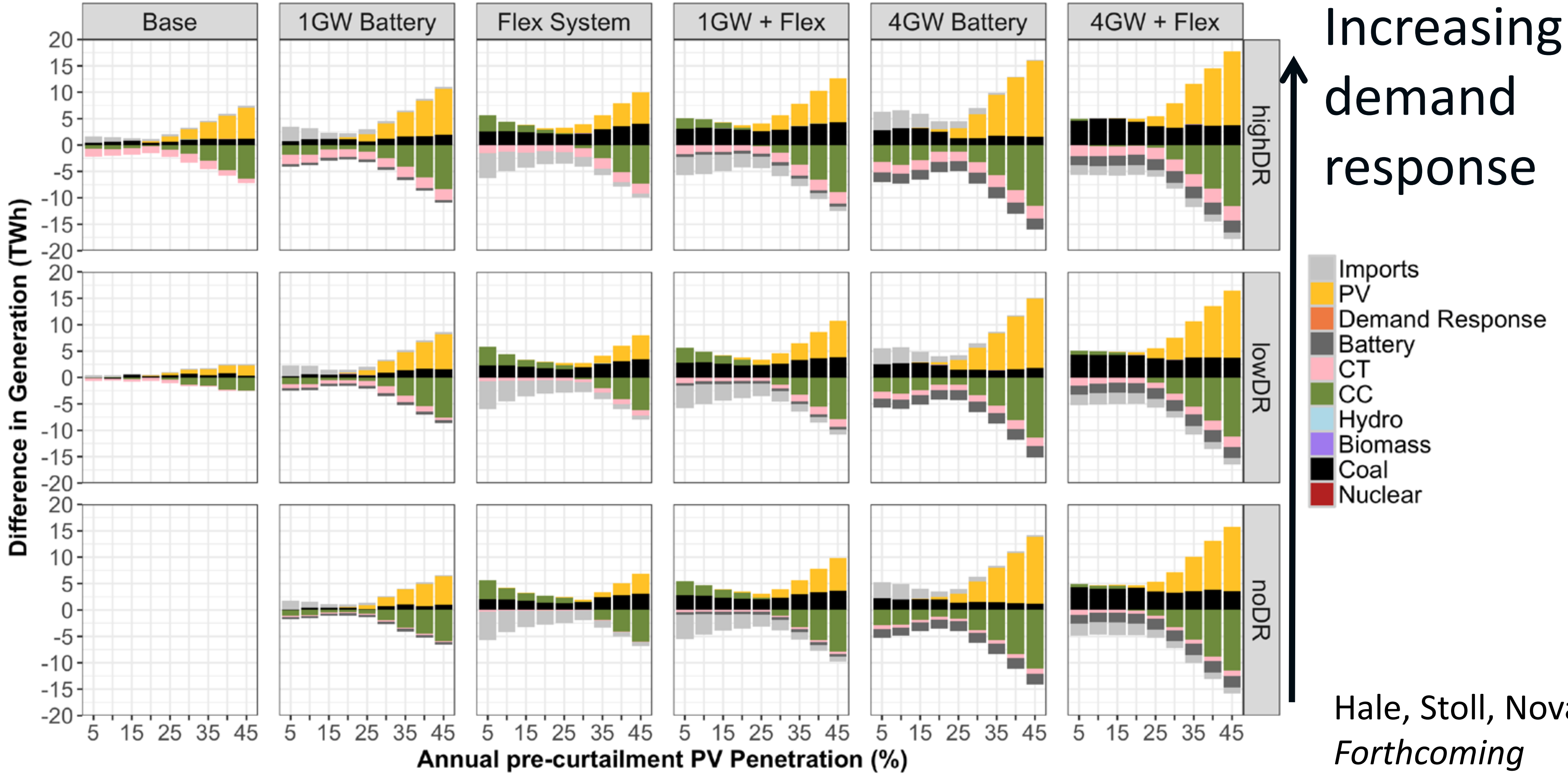
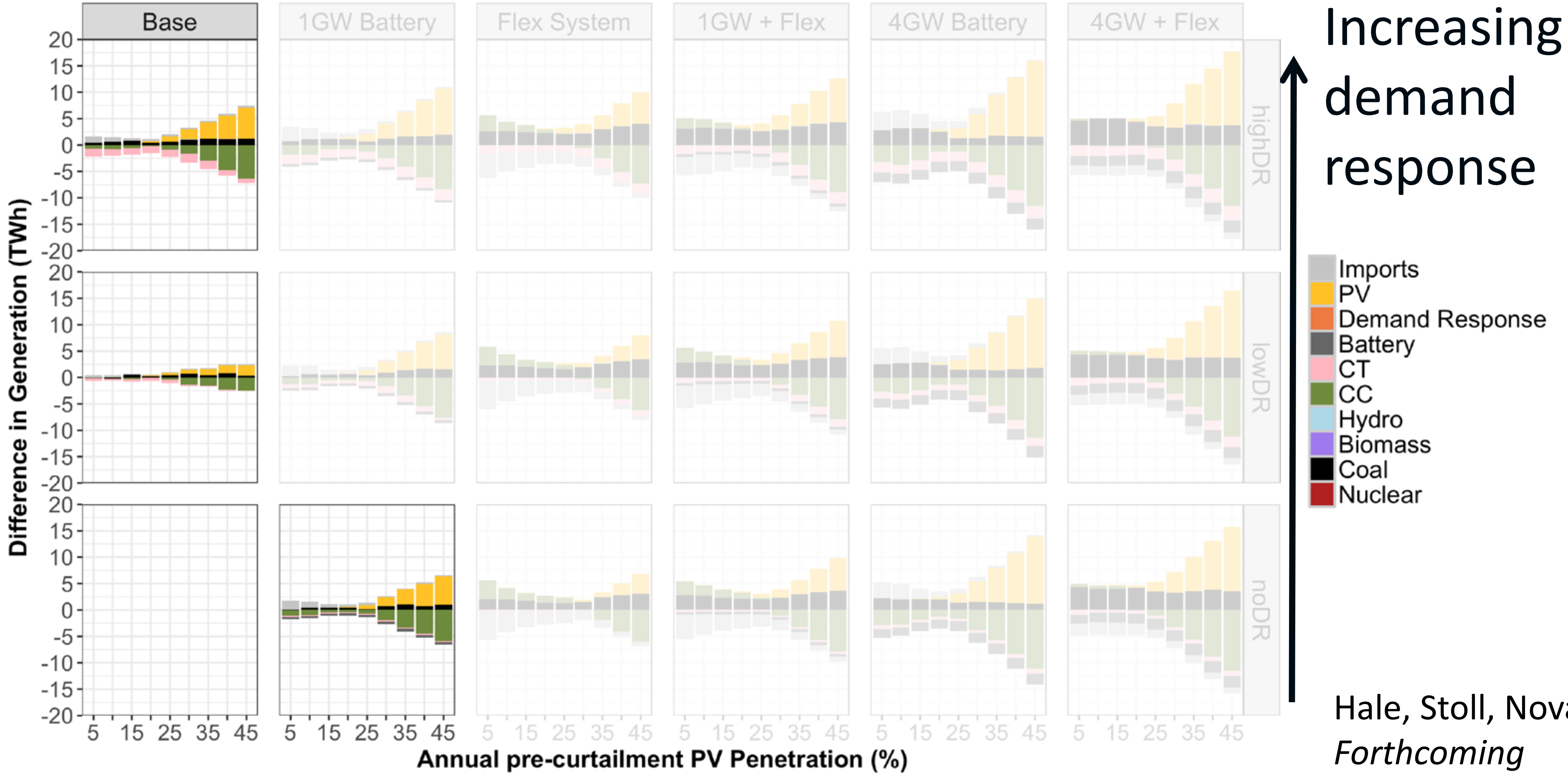
Annual Generation differences from analogous Base scenario



Increasing demand response

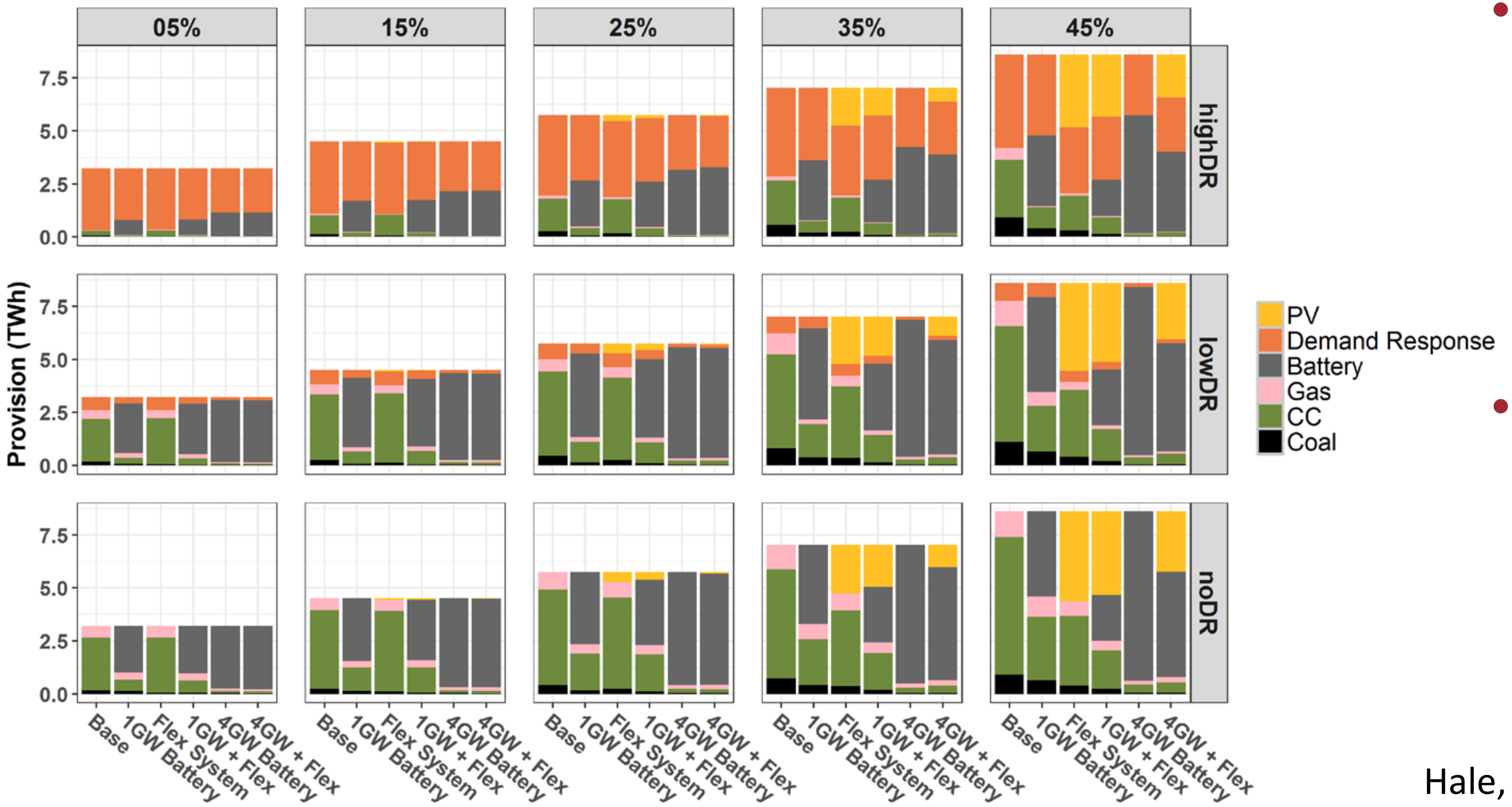
Hale, Stoll, Novacheck, *Forthcoming*

Impact of demand response is similar to 1 GW battery



Hale, Stoll, Novacheck, *Forthcoming*

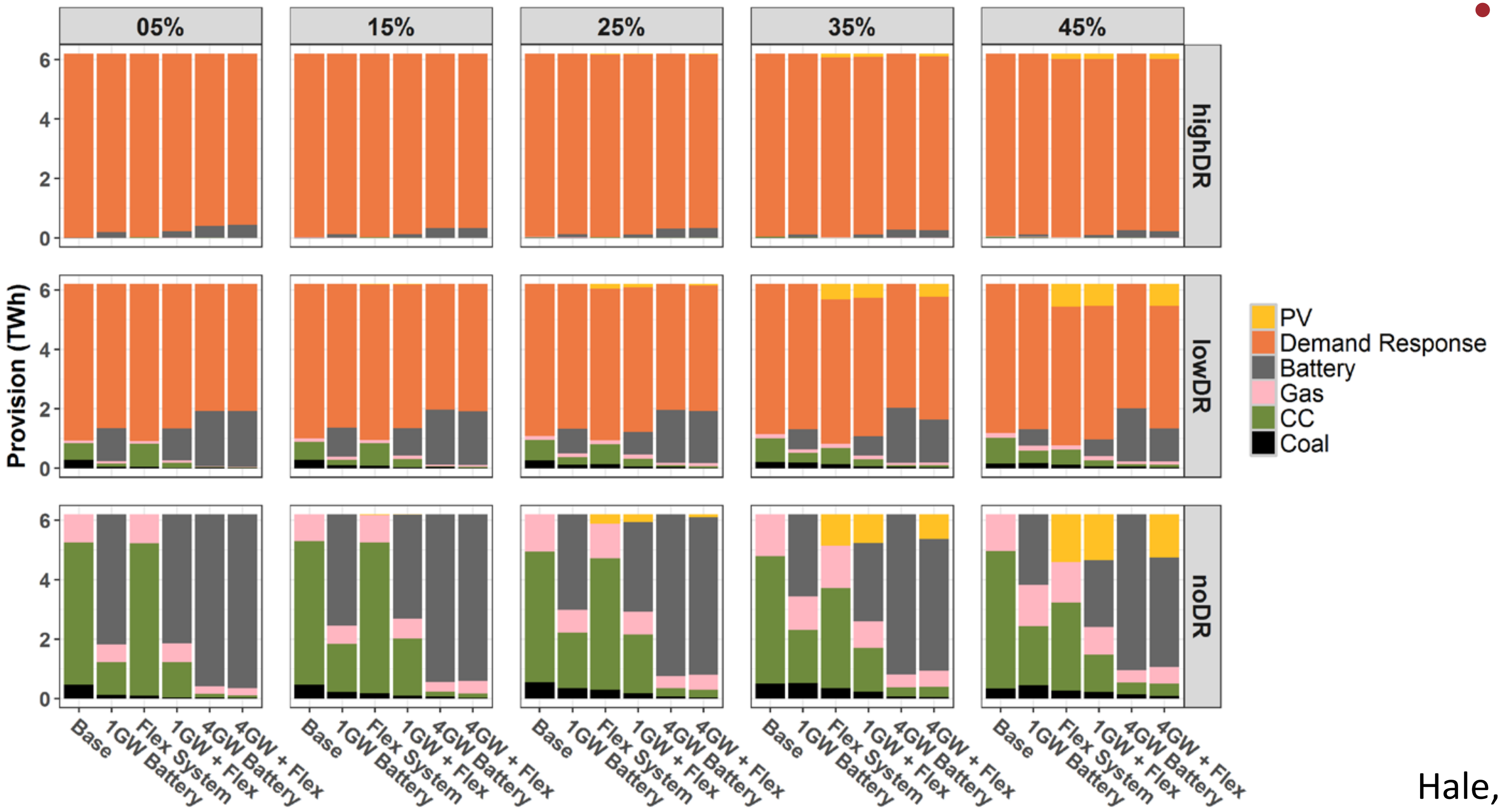
Demand response can provide significant portions of regulation reserves



- 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*

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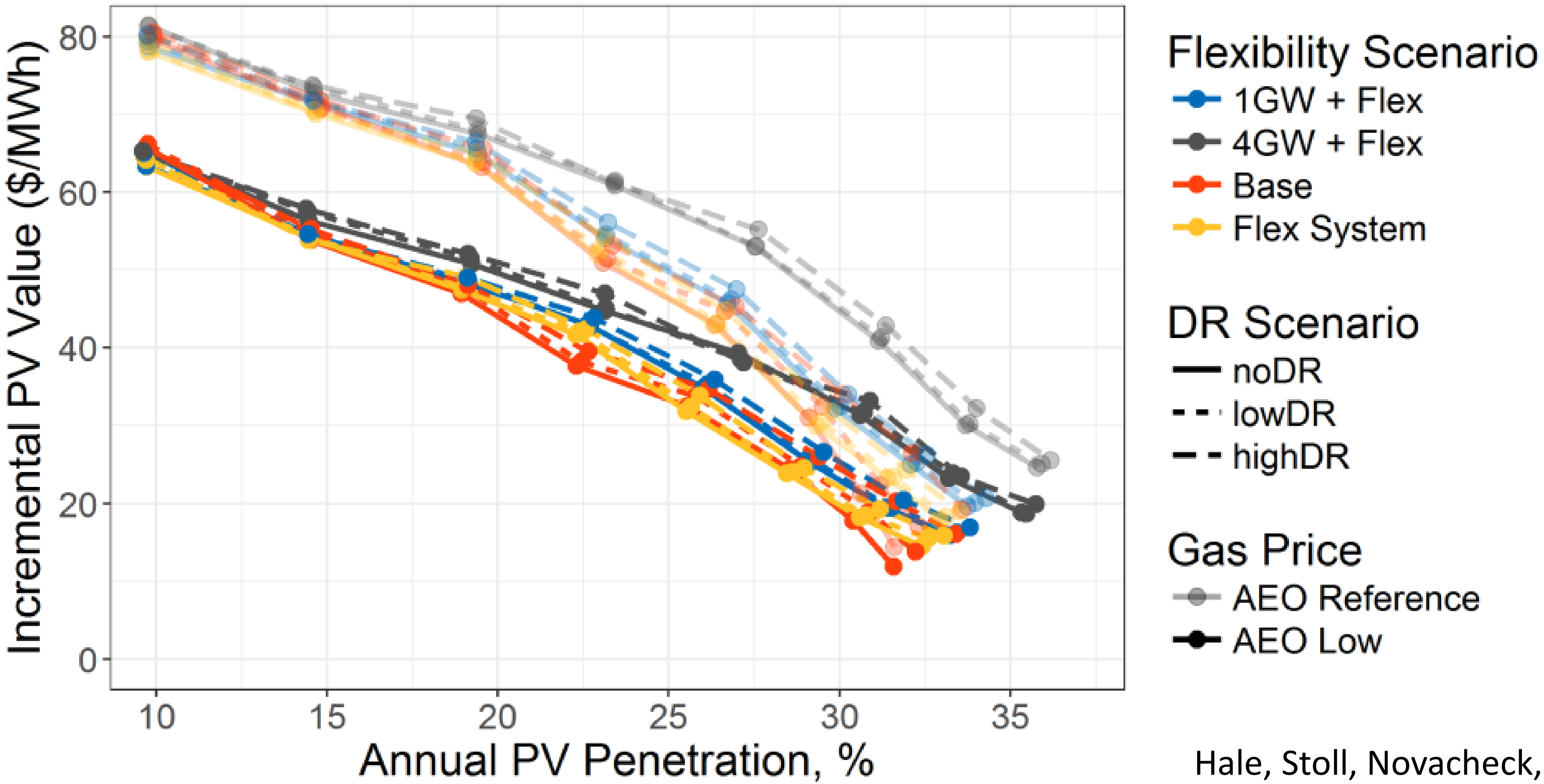
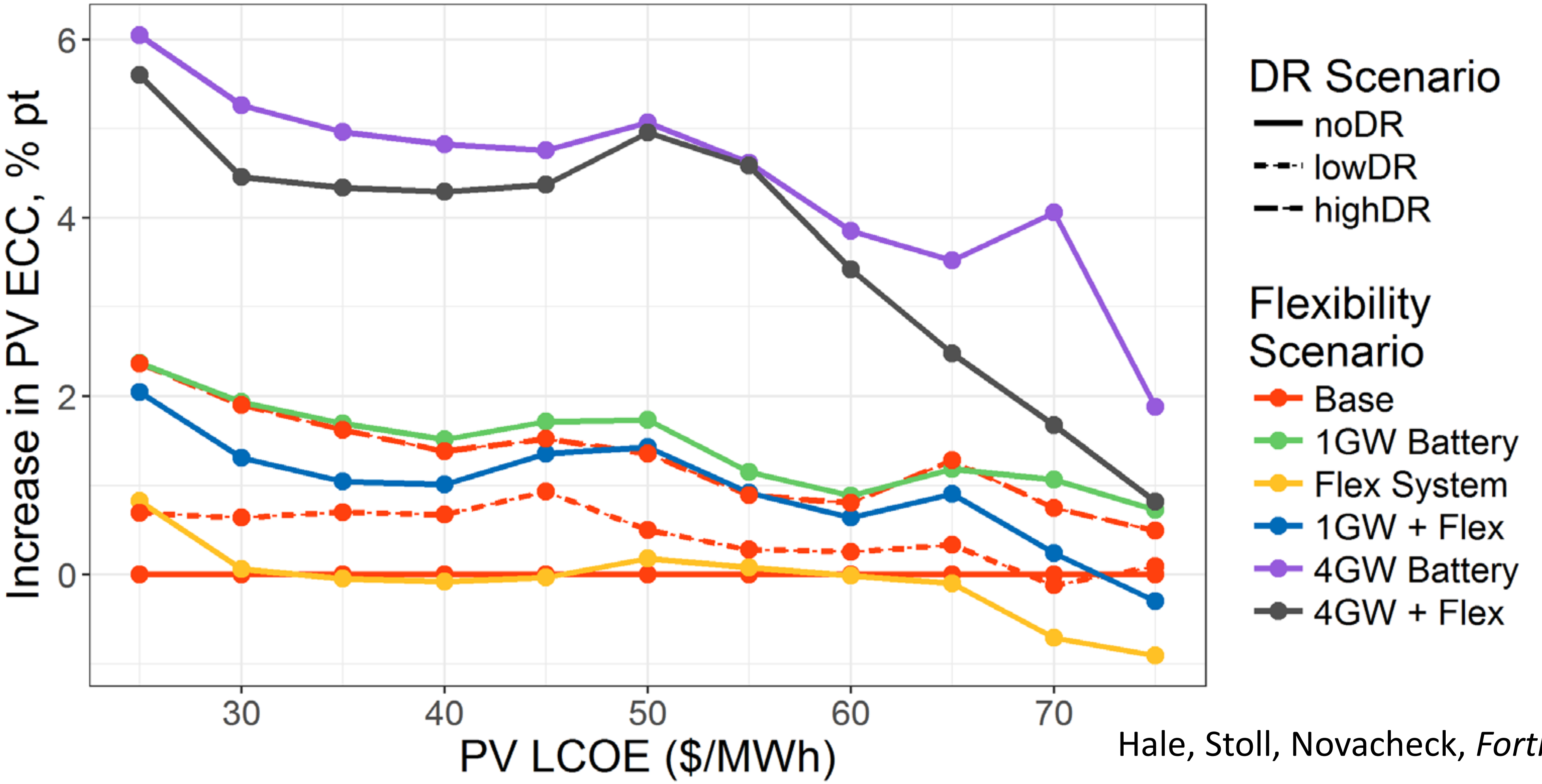
Demand Response increases the value of PV



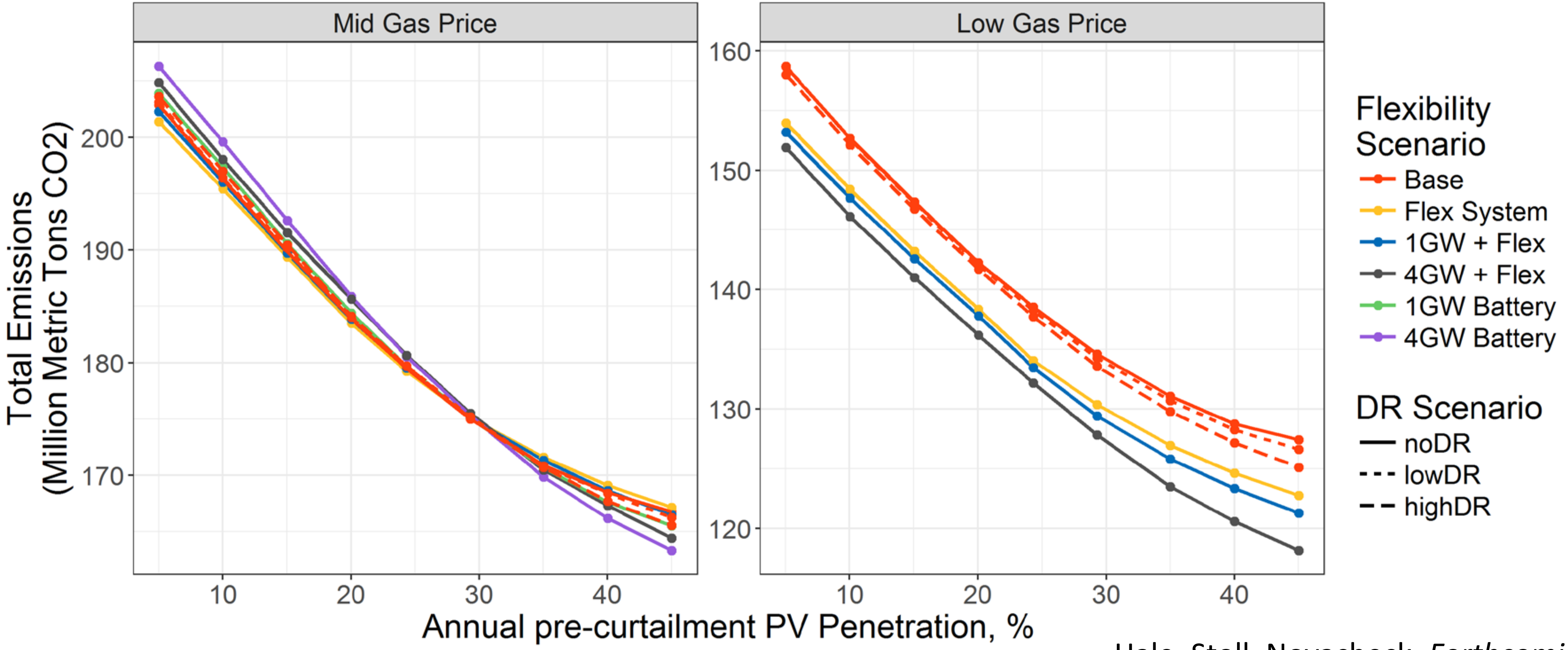
Hale, Stoll, Novacheck, *Forthcoming*

Demand Response increases Economic Carrying Capacity of PV



Hale, Stoll, Novacheck, *Forthcoming*

Flexibility has a complex impact on emissions



Hale, Stoll, Novacheck, *Forthcoming*

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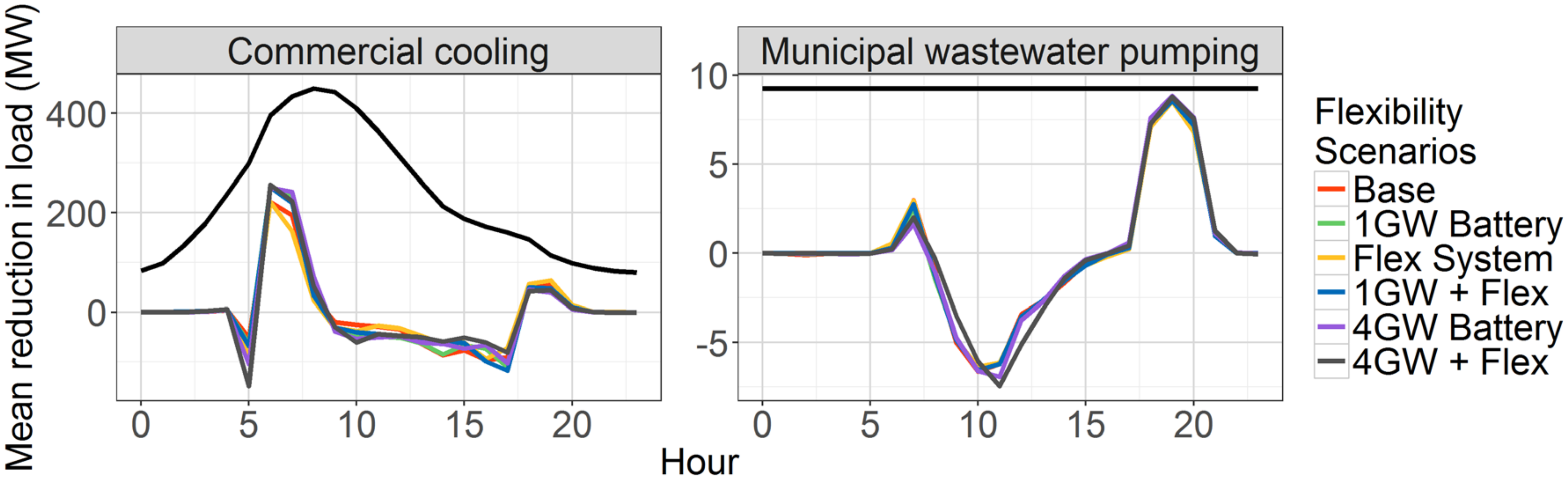
Value of DR by End-Use

Value of DR

- 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



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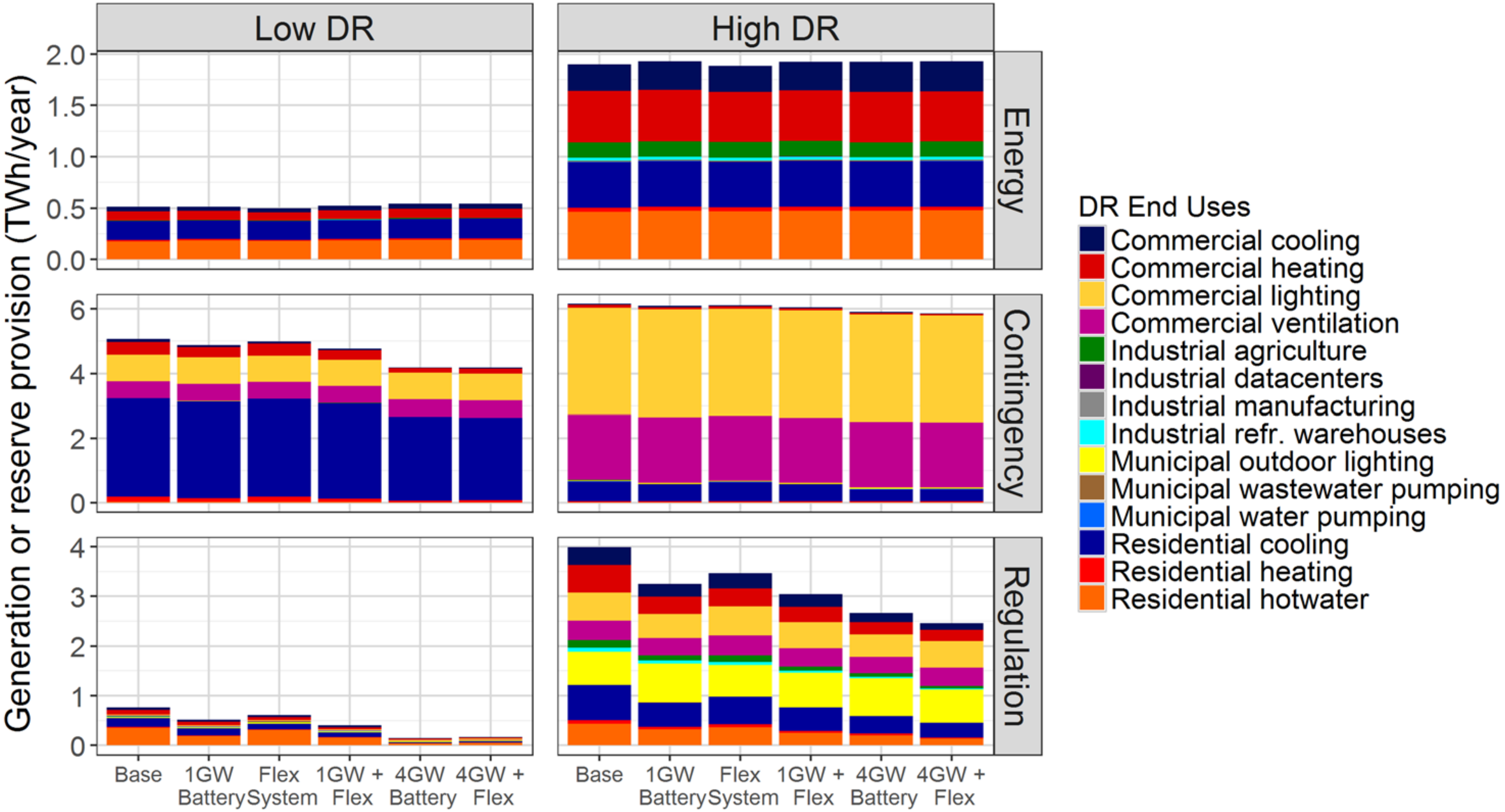
Grid Service Provision by End-Use



End-use Value by Component

- Capacity
- Emissions
- Fuel and VO&M
- Imports
- Startup & Shutdown Costs

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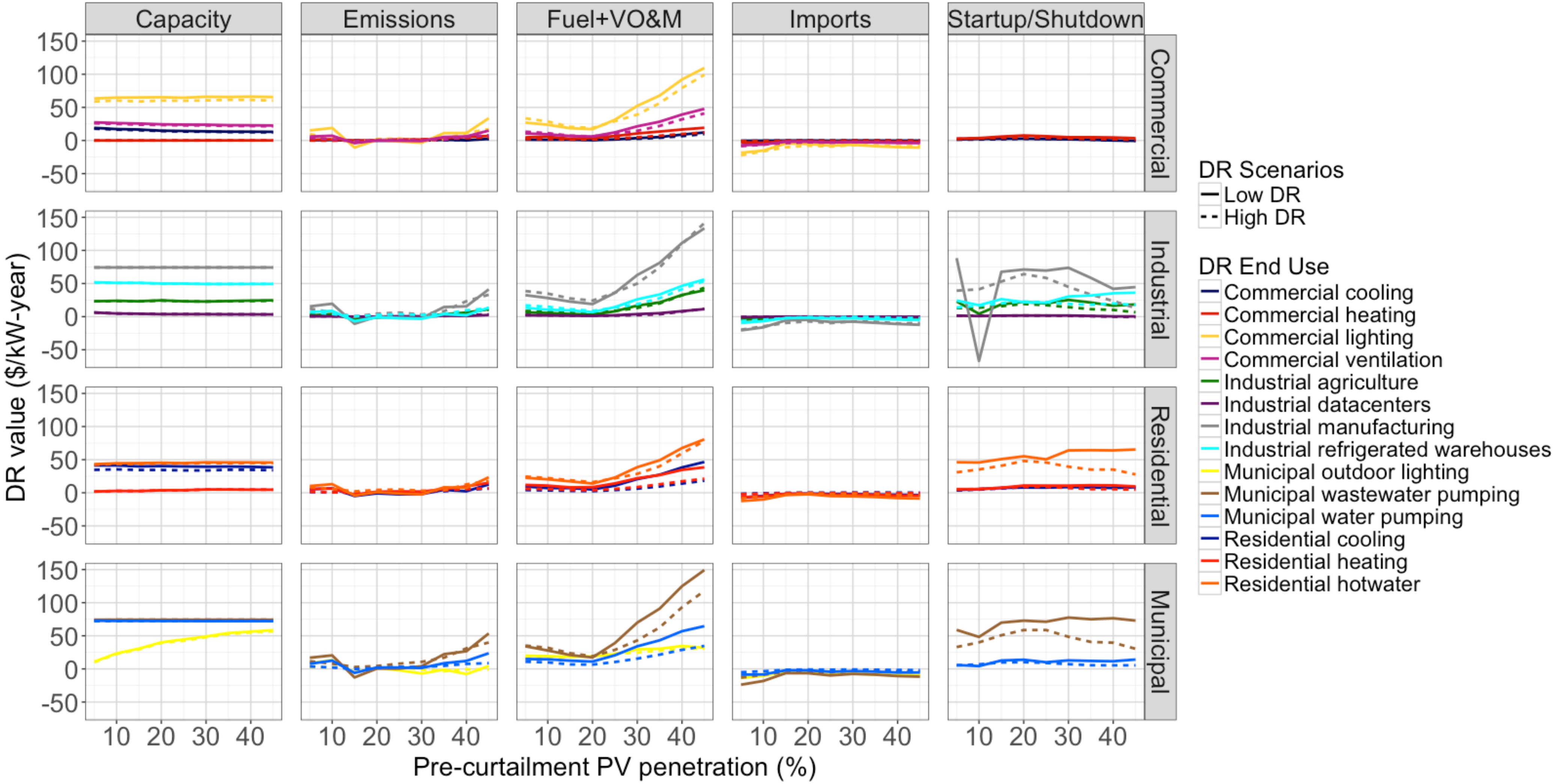
End-use Value by Component, Base scenario



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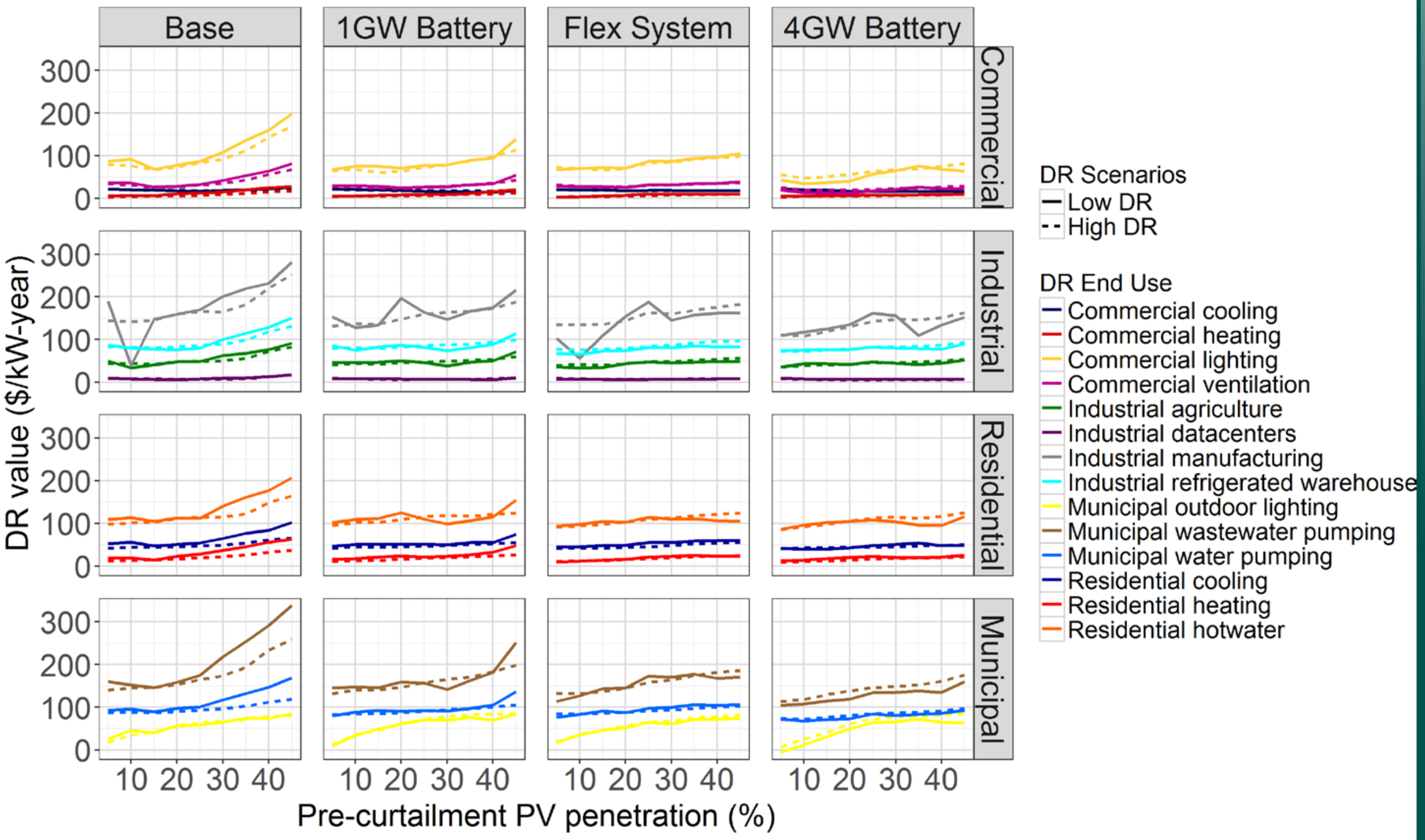
Total Value

- The total system value of DR ranges from -5.43 to 338.37 $/kW-year
- DR value is not saturated in these scenarios
- Additional flexibility impacts value of DR



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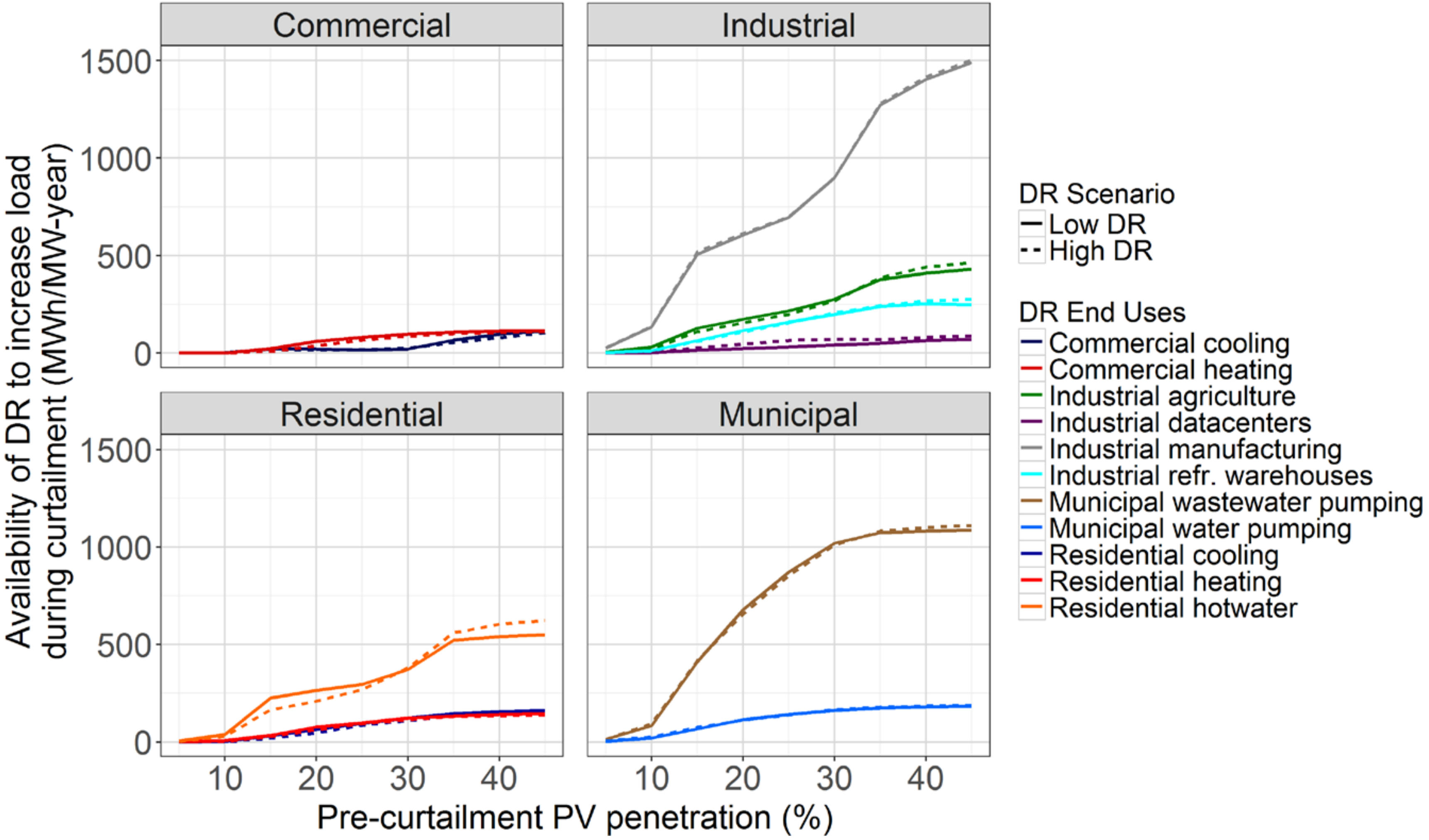
Curtailment Reduction



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

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Questions?

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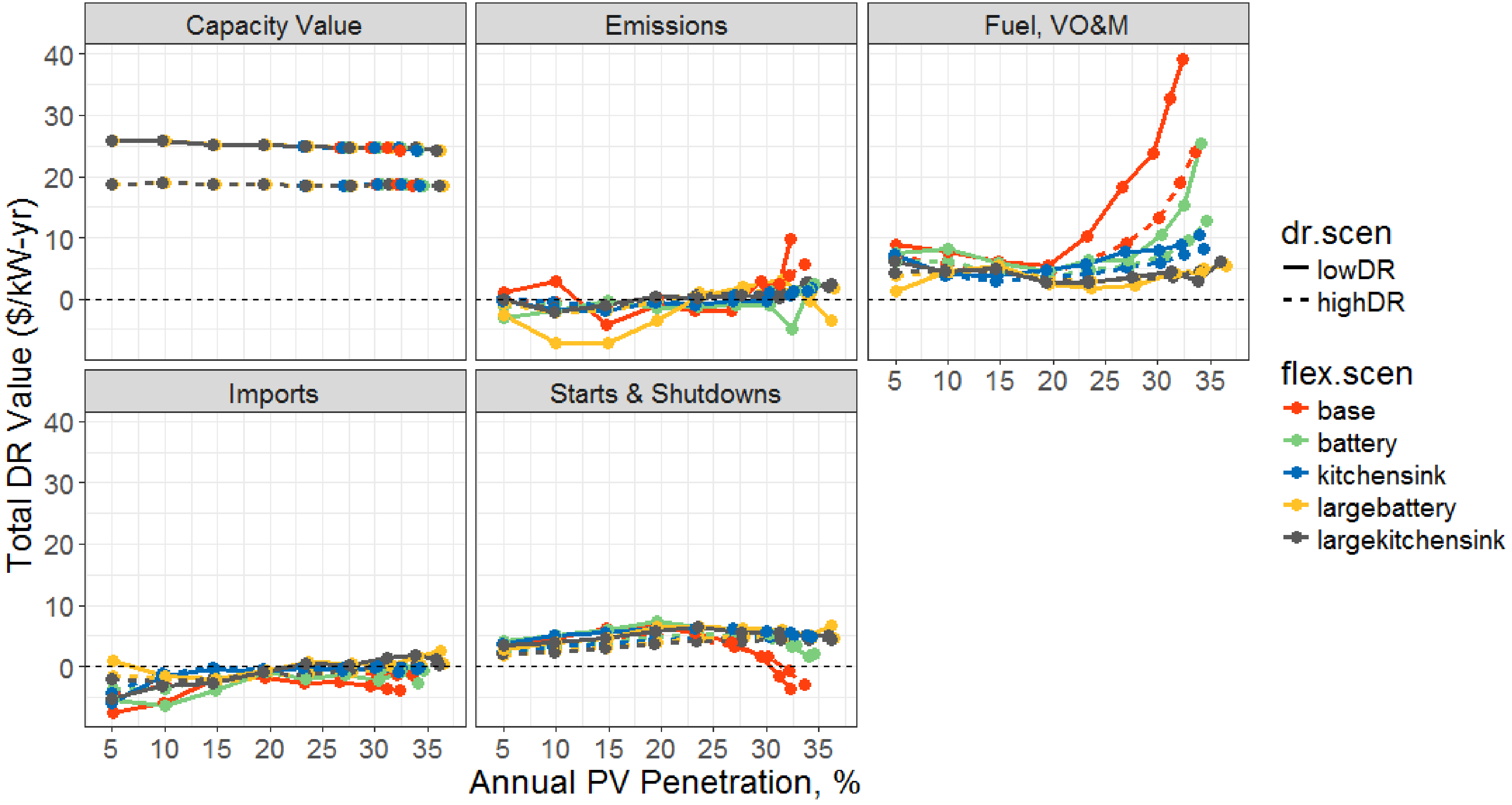
Total value of Demand Response



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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

Schedulable Resource Example: Agricultural Pumping

discrete decisions per end-use, little environmental coupling

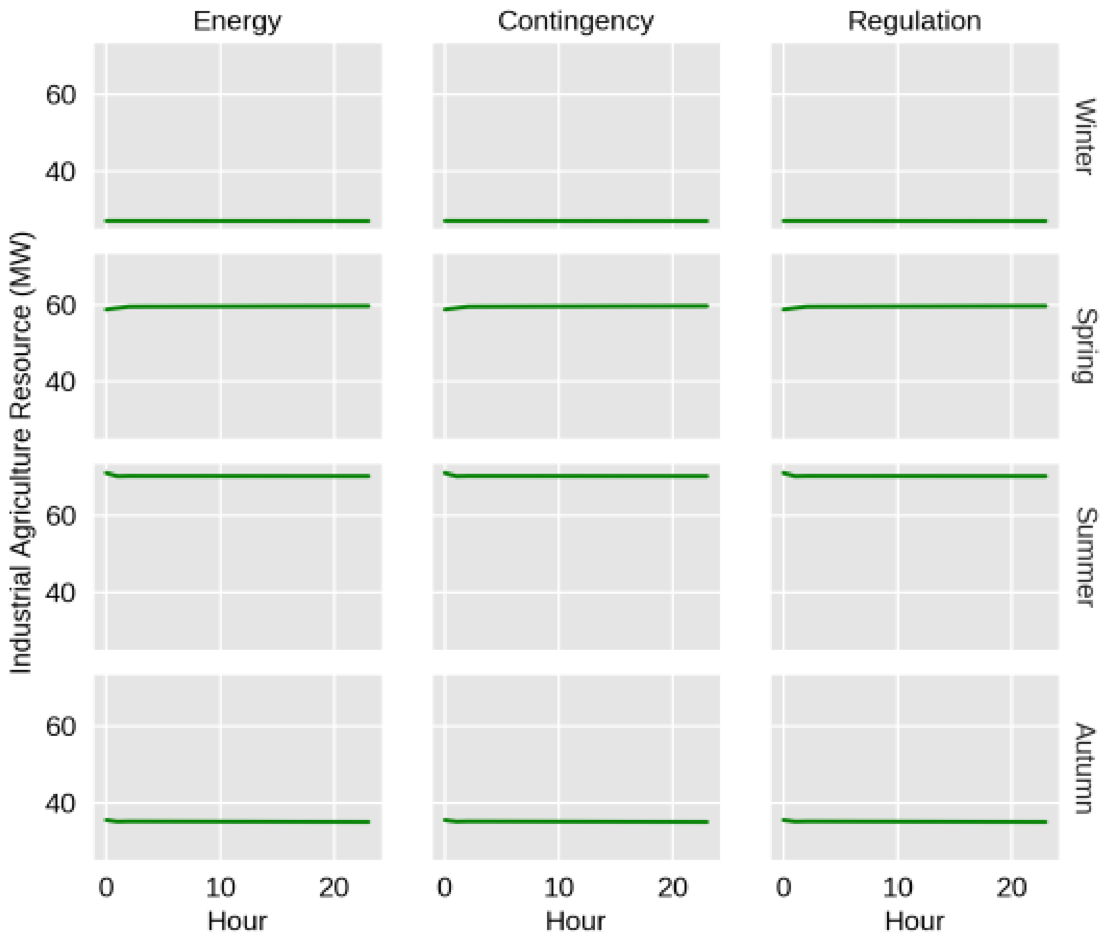
Modeled as a Generator with Storage Reservoirs

- Generation capacity is maximum over all services

- Pumping Capacity(i) = min(2*Energy(i), max(Energy)) - Energy(i)

- Storage must hit a weekly target (daily for other schedulable end-uses)

Average Daily Profiles for High DR Scenario



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Storage Resource Example: Commercial Heating

often set-point-driven, potential for high environmental coupling

Modeled as a Generator with Storage Reservoirs

- Generation capacity is maximum over all services

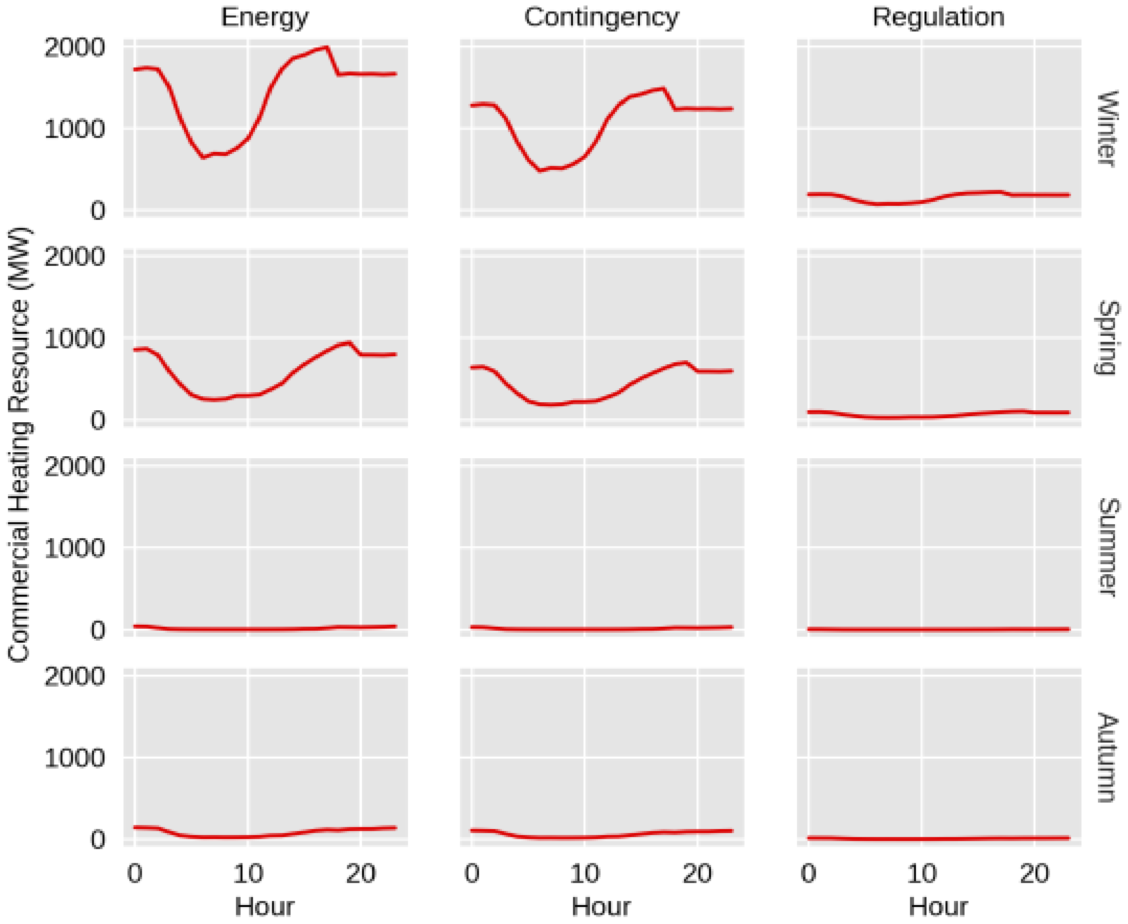
- Pumping Capacity(i) = min(max(Energy) - Energy(i), max(Energy(day))

- Storage must hit a daily target

- Pumping is restricted to 3am – 7pm (make up during occupied hours)

- Energy shifting is limited to a total of 2 use-hours (sum(Generation(i) / Energy(i)) ≤ 2)

Average Daily Profiles for High DR Scenario



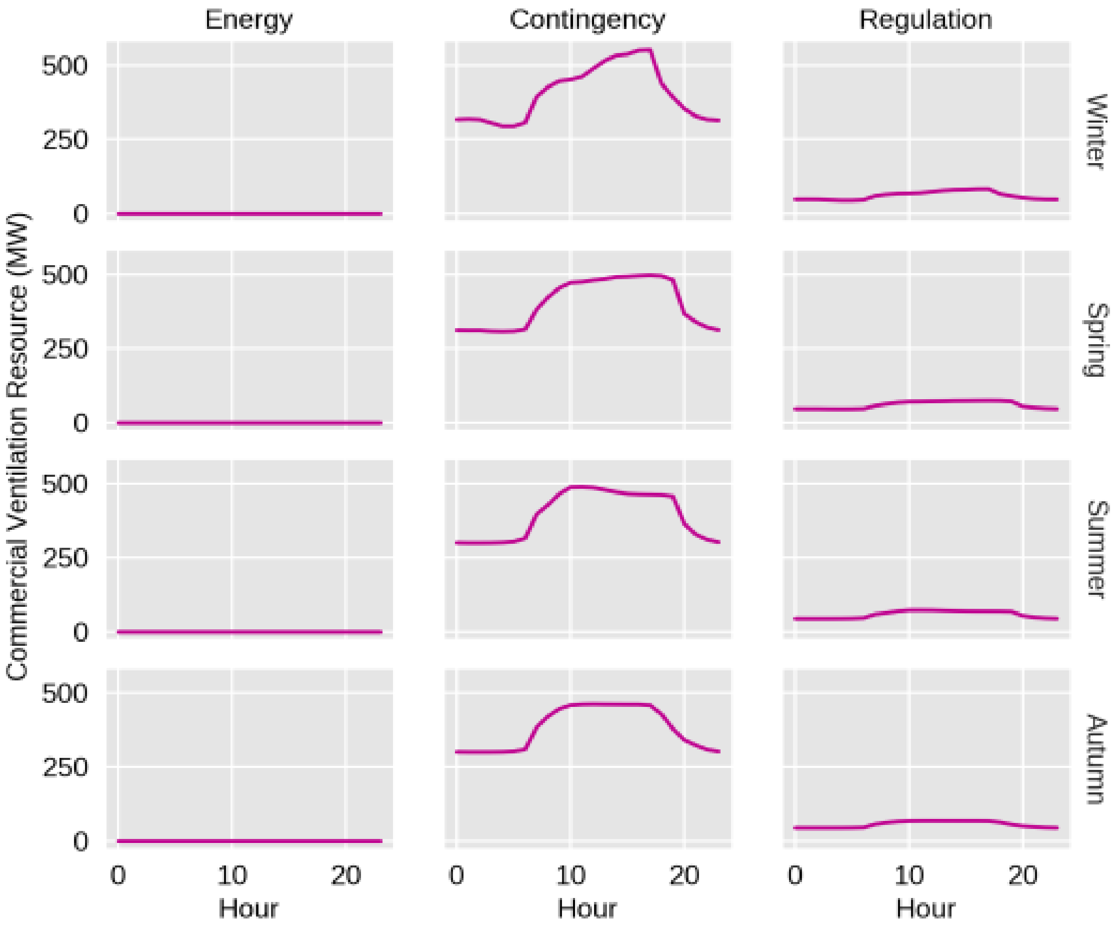
Sheddable Resource Example: Commercial Ventilation

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

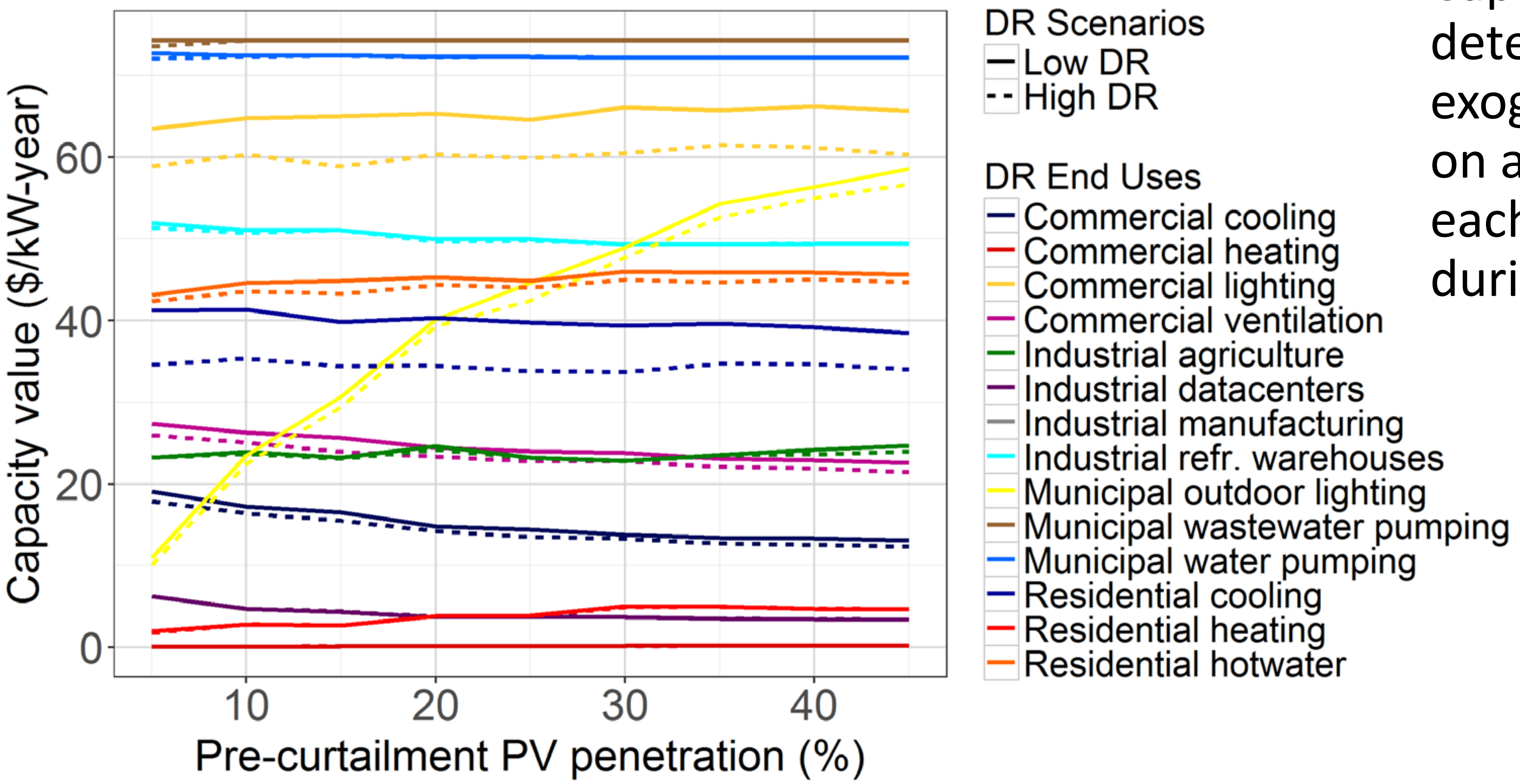
Modeled as a Plain Generator

- Generation is restricted to zero
- Reserves provision restricted to the appropriate profile

Average Daily Profiles for High DR Scenario

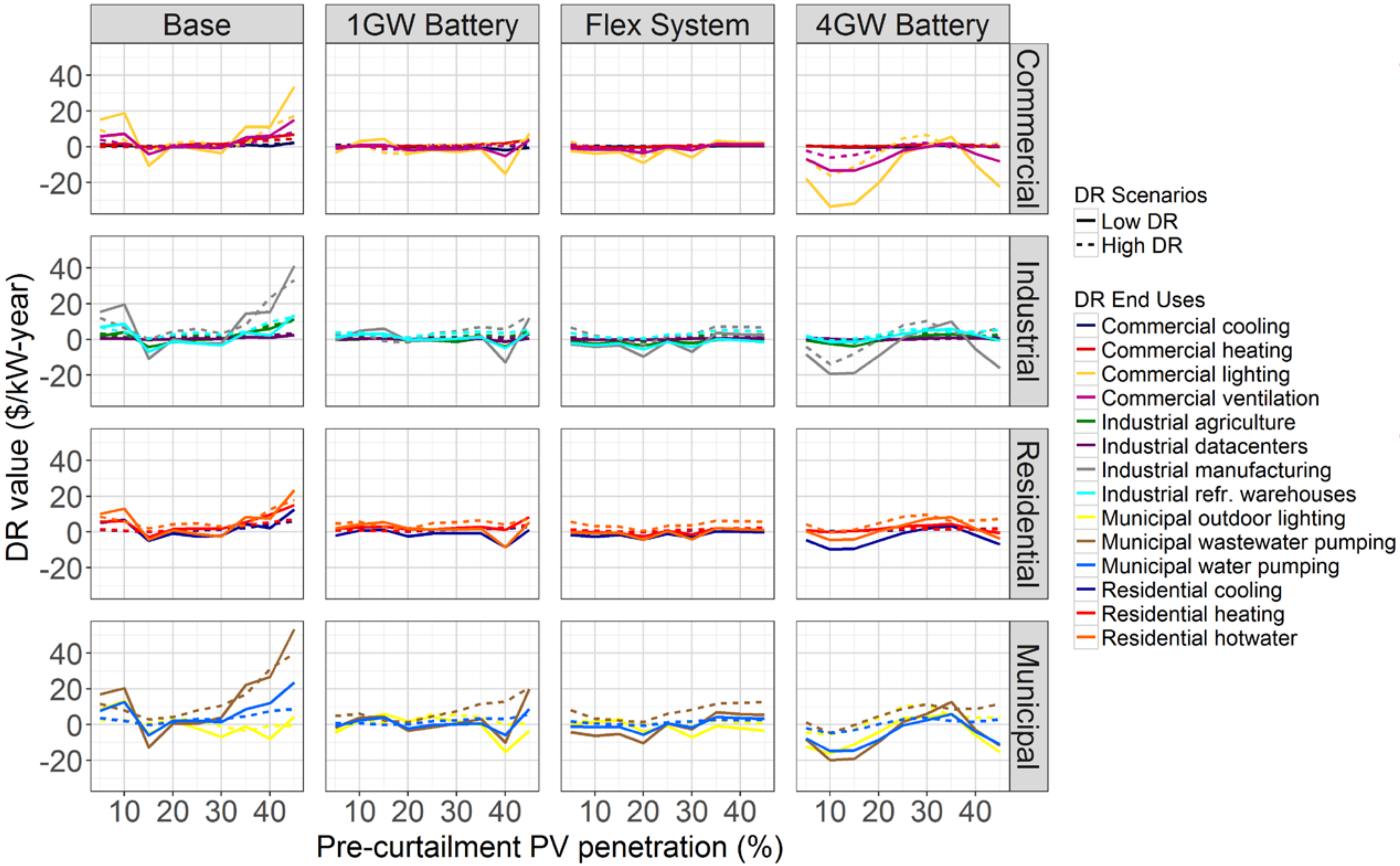


Capacity Value



- 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

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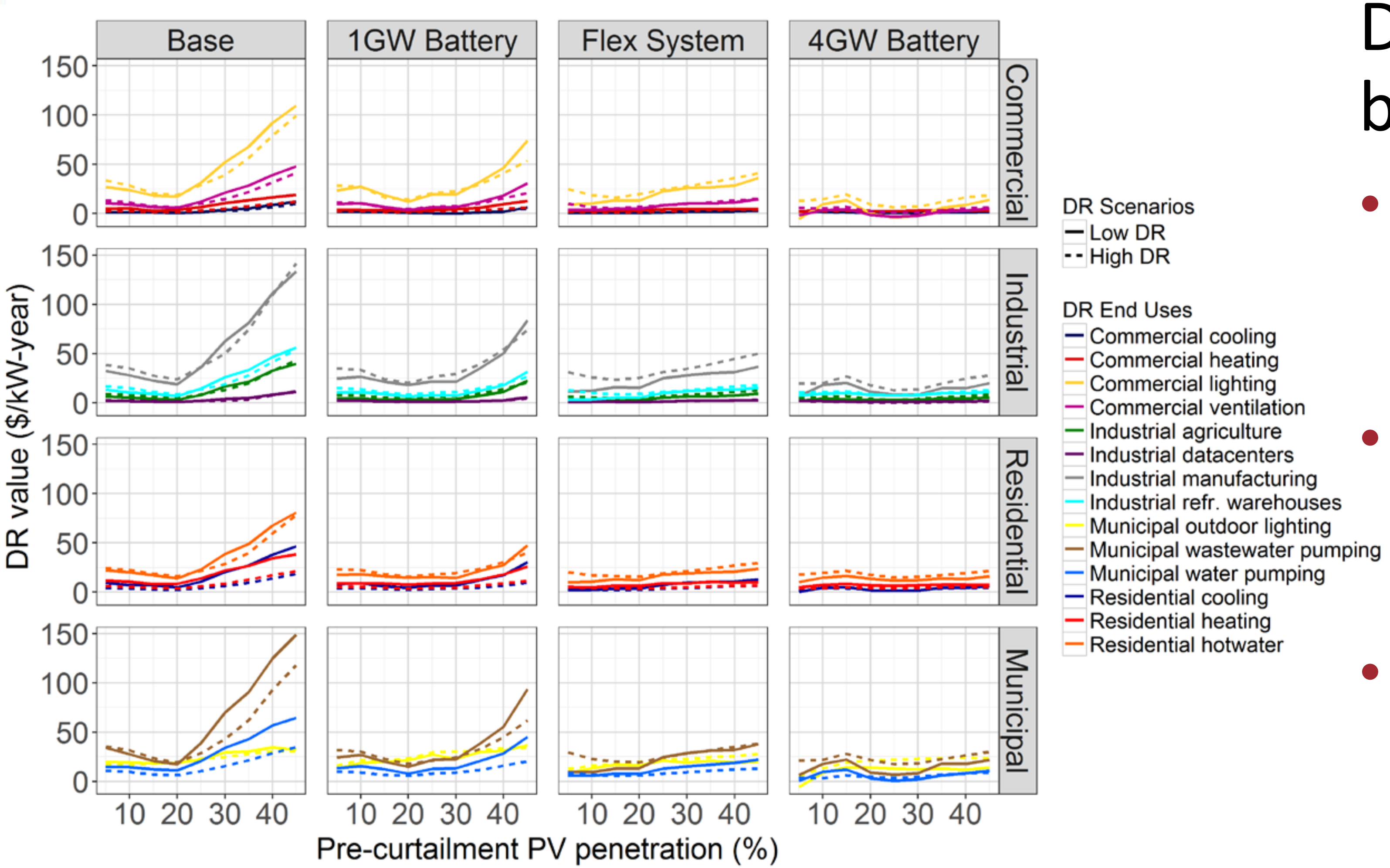
Fuel and VO&M Reductions



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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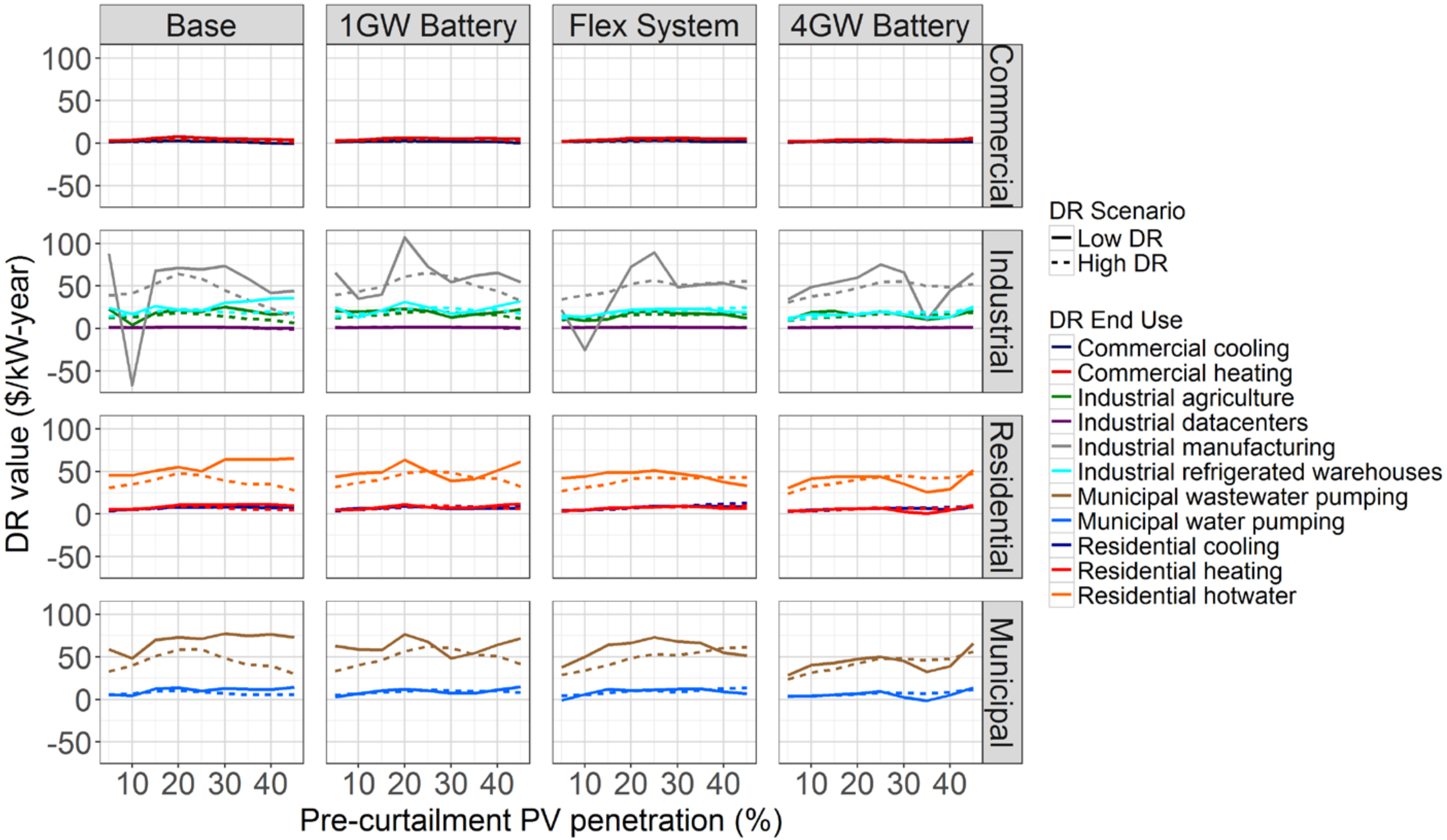
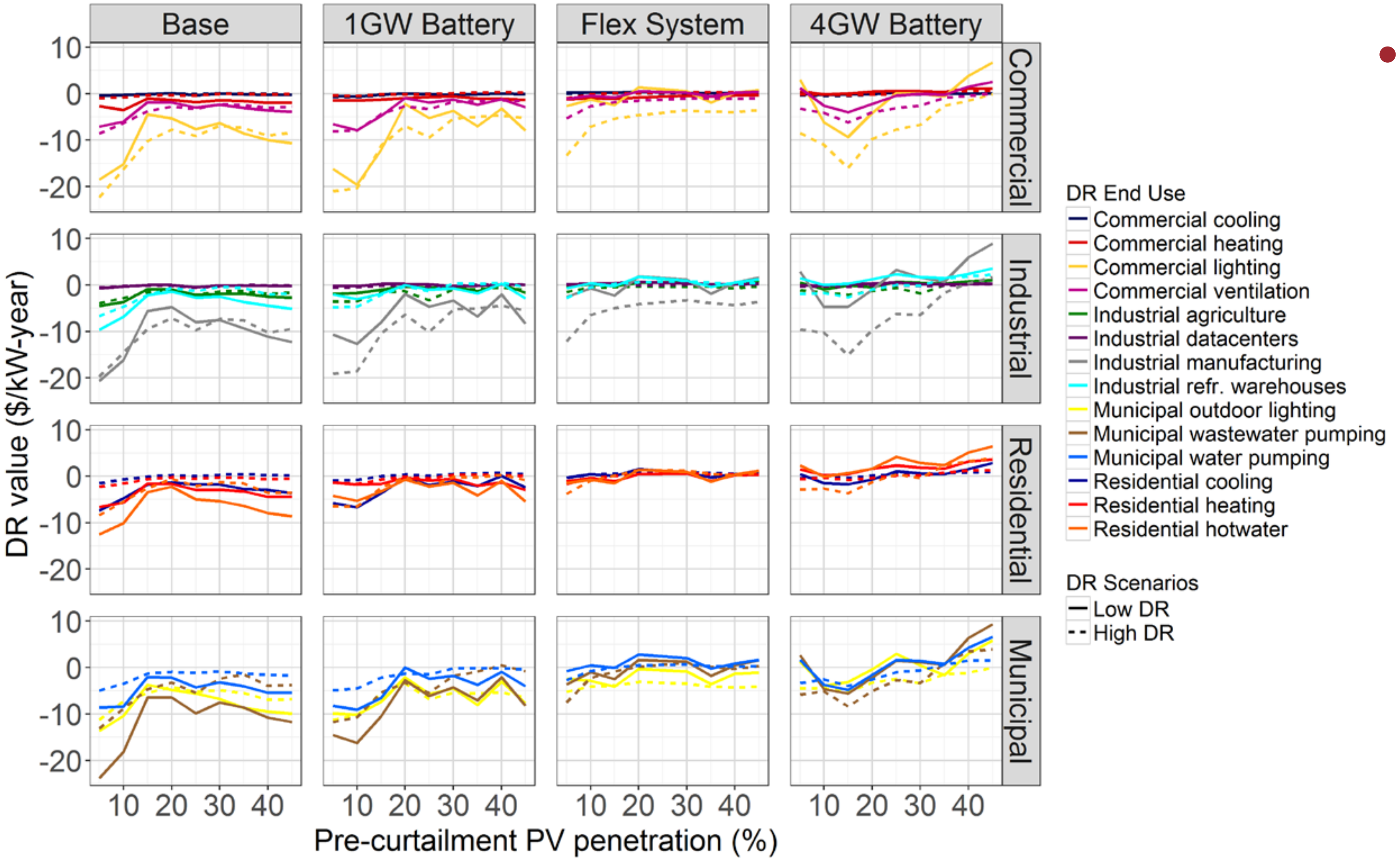
Generator Startup/Shutdown Cost Reduction



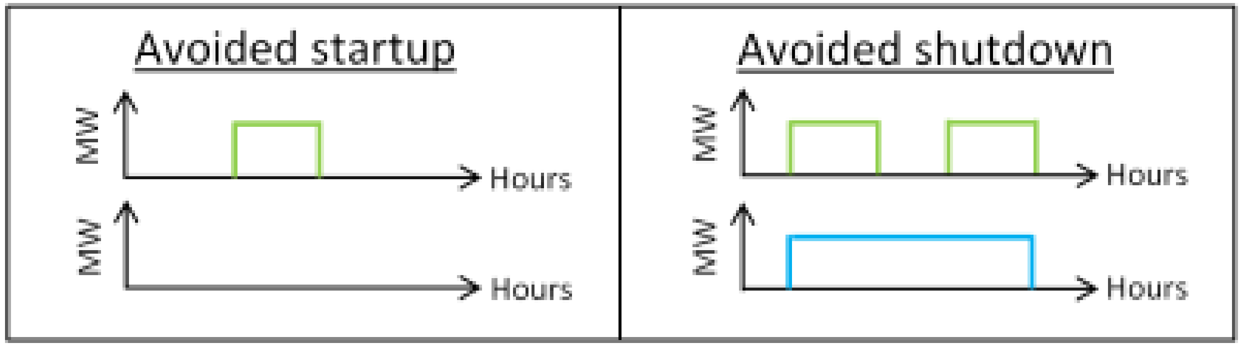
Imports



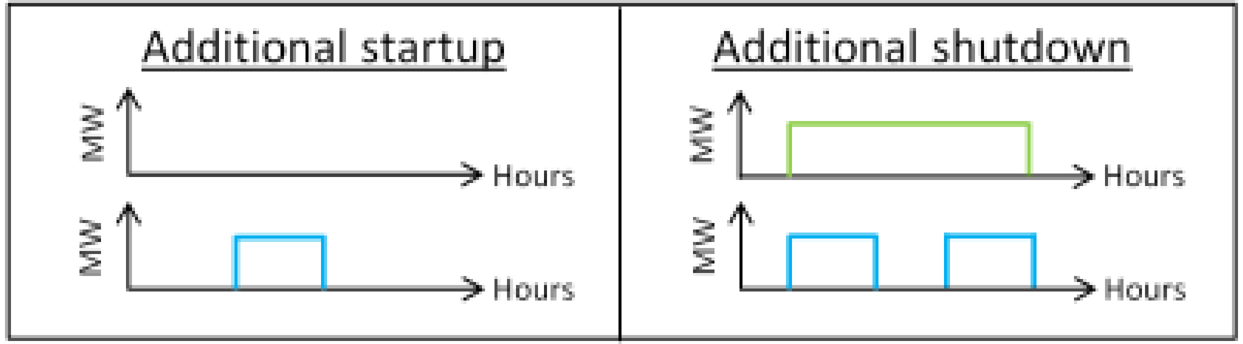
- DR generally reduces import costs for a brief period during the morning and evening peak loads, and increases costs during all other times of the day, resulting in a negative value to the system.

Generator Startup/Shutdown Cost Reduction

DR **reduces** generator startups and shutdowns:



DR **increases** generator startups and shutdowns:



No DR scenario — DR scenario