Demand Response Advanced Controls Framework and Assessment of Enabling Technology Costs

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Overview

- Background
- Current Demand Response Opportunities
- Intersection of Demand Response Opportunities and Bulk Power System Services
- Categorization of End-uses and Enabling Technologies
- Framework for Enablement Costs
- Enabling Technology Cost Assessment

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Objective of Research

- ◆Define a suite of services based on bulk power system operational needs that could be provided by local resources;
- ◆Identify existing and future DR opportunities' ability to provide these bulk power system services; and
- ◆Provide a framework and quantitative assessment of enabling technology costs for end-use DR enabling technologies

Not your father's Demand Response

- **Demand Response:** A mechanism through which an end-use's load profile is changed (by the user, a third party, or a utility) in response to system needs, often in return for economic compensation (e.g., payments or a different rate structure).
- **Universal questions for DR:**
  - What does the bulk power system need?
  - What role can DR resources play in meeting that need?
  - How much does it cost to enable DR resources to meet that need?
  - What is the value proposition for a DR resource to do so?
- The process of asking questions and analyzing data revealed results that were a break from conventional thought – what the electric grid needs may not be peak capacity DR

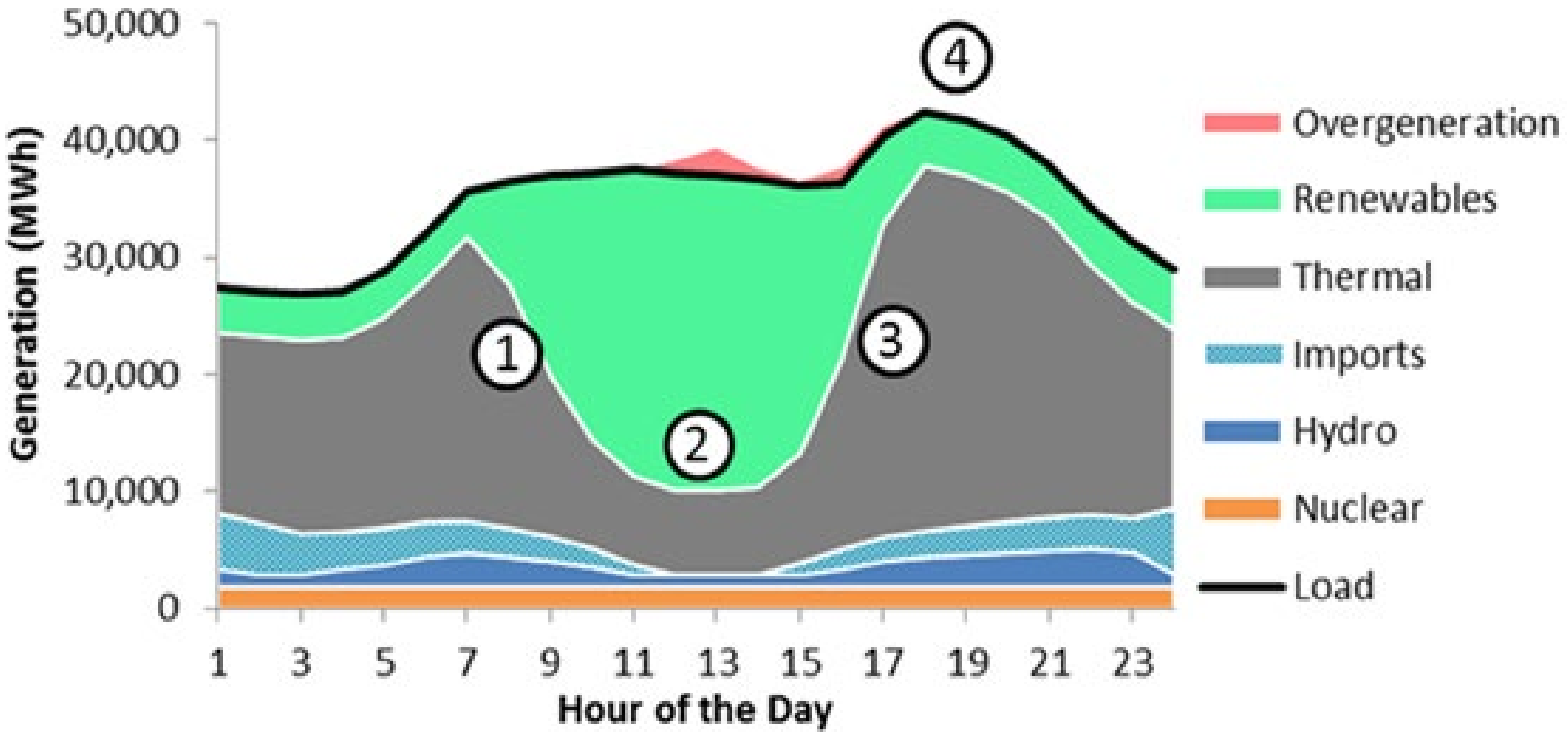
Driven by the Challenges of an Increasingly Dynamic Grid

Ramping ① ③

Minimum Generation
& **Curtailment** ②

Evening **Peak** ④

Intra-hour **Variability**
& Short-duration Ramps
① ② ③ ④ (All day)



Source: E3 (2014). Investigating a Higher Renewables Portfolio Standard in California.

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Time-Based Rates DR Opportunities

Title	Description
Time-of-Use (TOU)	Rates provide different but predetermined prices over specific temporal periods (e.g., summer weekdays between 4 PM and 9 PM).
Critical Peak Pricing (CPP)	Rates institute a single or variable predetermined price for electricity during a narrowly defined period (e.g., summer weekday between 4 PM and 7 PM) that is only applied during specific system operating or market conditions and generally limited in the number of times it can be dispatched (e.g. twelve times per year).
Variable Peak Pricing (VPP)	Rates provide different prices over specific temporal periods (e.g., summer weekdays between 4 PM and 9 PM) that vary daily based on system operating and/or market conditions.
Real-Time Pricing (RTP)	Rates where price can differ by hour of day. There are two common forms of RTP: one that provides twenty-four hour price schedule a day in advance (DA-RTP) and another that provides hourly price within 60 minutes after consumption has occurred (RT-RTP).

Incentive-Based Programs DR Opportunities

Title	Description
Controllable	Provides a utility or ARC with the opportunity to directly control a customer's various electricity consuming end-uses or some portion of their load which could be increased, decreased or even physically disconnected from the grid with little to no notice.
Configurable	Similar to Controllable programs in that the utility has the ability to control the electricity consumption of one or more customer devices for a specified period of time **but the customer can configure the control technology** to override whatever DR signals are received under certain conditions.
Manual	Do not provide any automated control technology to participating customers, leaving them to alter their electricity consumption through purely manual changes in response to a discrete event signal in exchange for a defined financial payment.
Behavioral	Intended to produce a change in electricity consumption, but are voluntary and do not provide any explicit performance payments.

Typology of Dispatchable DR Opportunities

- Interest is in understanding costs of advanced controls for DR
- Thus, focus on rates and programs that frequently include them

Demand Response Opportunity	Time Scale		
	Advance Notice of Response	Duration of Response	Frequency of Response
Time-Based Retail Rates			
VPP	2 – 24 hrs.	Length of peak period (e.g., ~4-15 hrs.)	Daily, seasonal, etc.
CPP	2 – 24 hrs.	Length of critical peak period (e.g., ~2-8 hrs.)	Typically <100 hrs./year
Incentive-Based Programs			
Controllable	5 sec. – 30 mins.	5 mins. – 4 hrs.	Sometimes limited in tariff
Configurable	30 – 60 mins.	2-8 hrs.	Sometimes limited in tariff

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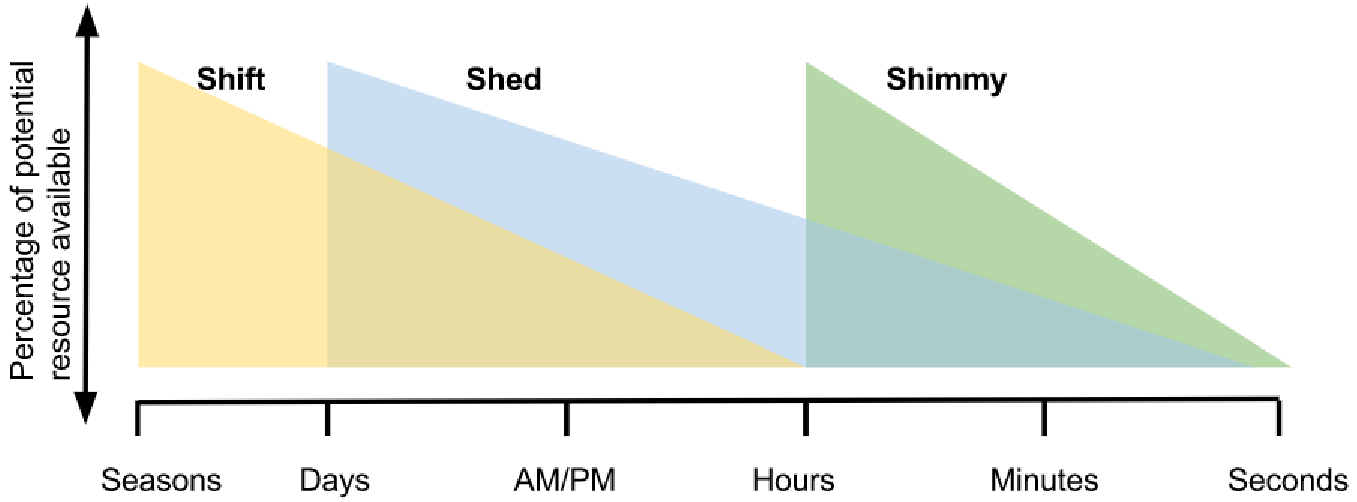
Intersection of DR Opportunities and Bulk Power System Services

Bulk Power System Operations	Time Scale									
	Procurement or Schedule	Control Signal	Advance Notice of Deployment	Duration of Response	Frequency of Response	VPP	RTP	CPP	Configurable	Controllable
Spinning Reserves	Days ahead	<1 min	~1 min	~30 min	~20-200 times per year					●
Supplemental Reserves	Days ahead	<10 min	~10-30 min	~Multiple hours	~20-200 times per year					●
Regulation Reserves	Days to hours ahead	~1 min to 10 min	None	< 10-min in one direction	Continuous					●
Imbalance Energy	5 min to 1 hr.	5 min to 1 hr.	5 min to 1 hr.	5 min to 1 hr.	Depends on position in bid stack					●
Hour-ahead Energy	1-2 hrs.	5 min to 1 hr.	1-2 hrs.	>1 hr.	Depends on position in bid stack				●	●
Multi-hour-ahead Energy	None*	1 hr.	1-36 hrs.	>1 hr	As frequent as daily				●	●
Day-ahead Energy	24-36 hrs.	1 hr.	24-36 hrs.	>1 hr.	Depends on position in bid stack	●	●	●	●	●
Resource Adequacy	Years	1 hr.	Day ahead	Multiple hrs.	Seasonal	●	●	●	●	●

Introducing DR Service Types

- An expansion of the portfolio of services that DR resources can be considered for creates additional complexity
- To simply, introduce a more generalized and friendly nomenclature (i.e., less jargon)



Mitigate Ramps and Capture Surplus Renewables

Manage contingency events and coarse net load following

Fast DR to smooth net load and support frequency

Service Type Mapping to DR Opportunities and Bulk Power System Services

Shimmy	Shift	Shed	Bulk Power System Service	VPP	CPP	Configurable	Controllable
		•	Spinning Reserves				•
		•	Supplemental Reserves				•
•			Regulation Reserves				•
•			Imbalance Energy				•
	•		Multi-hour-ahead Energy			•	•
		•	Hour-ahead Energy			•	•
		•	Day-ahead Energy	•	•	•	•
		•	Resource Adequacy	•	•	•	•

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End-uses and DR Enabling Technologies Considered in this Assessment

Sector	End-Use	Enabling Technology Summary
Commercial and Residential	Battery-electric & plug-in hybrid vehicles	Automated Demand Response (ADR)
All	Behind-the-meter batteries	ADR
Residential	Air conditioning	Direct load control (DLC), programmable communicating thermostats (PCT).
	Electric hot water heaters	DLC or ADR
	Pool pumps	DLC
Commercial	HVAC	Depending on site size, energy management system ADR, DLC, and/or PCT.
	Lighting	A range of luminaire, zonal & standard control options.
	Electric hot water heaters	ADR
	Refrigerated warehouses	ADR
Industrial	Processes & Large facilities	Automated load Shedding & process interruption.
	Agricultural pumping	Base Switch & ADR
	Wastewater treatment	ADR

Residential Sector Enabling Technologies and End-use Combinations

End Use	Enabling Technology Component	Shift	Shed	Shimmy
HVAC	Direct load control switches (DLC)		●	
	Programmable Communicating Thermostat (PCT)	●	●	
Electric Hot Water Heaters	Direct load control switches (DLC)	●	●	●
	Automated demand response (ADR)	●	●	●
Pool Pumps	Direct load control switches (DLC)		●	
Residential Battery Storage	Automated demand response (ADR)	●	●	●
Residential Battery Electric Vehicles	Level 2 charging ADR	●	●	●
	Level 1 charging ADR	●	●	●

Commercial Sector Enabling Technologies and End-use Combinations

End Use	Commercial Size (kW demand)	Enabling Technology Component	Shift	Shed	Shimmy
HVAC	Small	Direct load control switches (DLC)		●	
		Smart thermostats	●	●	
	Medium	Direct load control switches (DLC)		●	
		Automated demand response (ADR)	●	●	● w/VFD
	Large	Automated demand response (ADR)	●	●	● w/VFD
Lighting	All Commercial	Office Luminaire (ADR)		●	●
		Office Zonal (ADR)		●	●
		Office Std. (ADR)		●	
		Retail Luminaire (ADR)		●	●
		Retail Zonal (ADR)		●	●
		Retail Std. (ADR)		●	

Commercial Sector Enabling Technologies and End-use Combinations

End Use	Commercial Size (kW demand)	Enabling Technology Component	Shift	Shed	Shimmy
Electric Hot Water Heaters	Small and Medium	Automated demand response (ADR)	●	●	●
Refrigerated warehouses	All Commercial	Automated demand response (ADR)	●	●	●
Battery Storage	All Commercial	Automated demand response (ADR)	●	●	●
Electric Vehicles	All Commercial	Charging Level 2 Automated demand response (ADR)	●	●	●

Industrial Sector Enabling Technologies and End-use Combinations

End Use	Customer Type	Enabling Technology Component	Shift	Shed	Shimmy
Pumping	Agricultural	Direct load control switch (DLC)		●	
		Automated demand response (ADR)	●	●	● w/VFP
	Waste Water Treatment Pumping	Automated demand response (ADR)	●	●	● w/VFP
Process	Industrial	Automated demand response (ADR)	●	●	● w/VFD
	Waste Water Treatment	Automated demand response (ADR)	●	●	
Battery	Any	Industrial. Battery (ADR)	●	●	●

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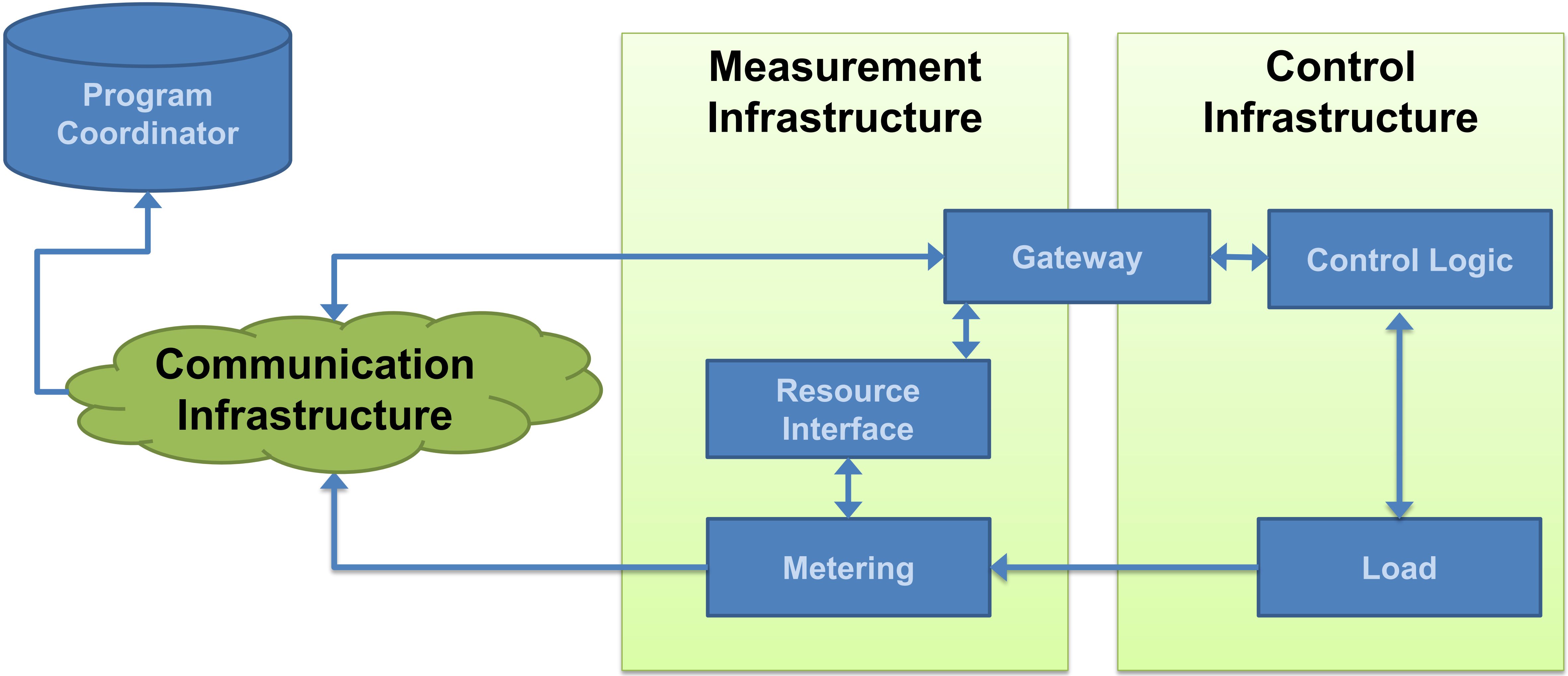
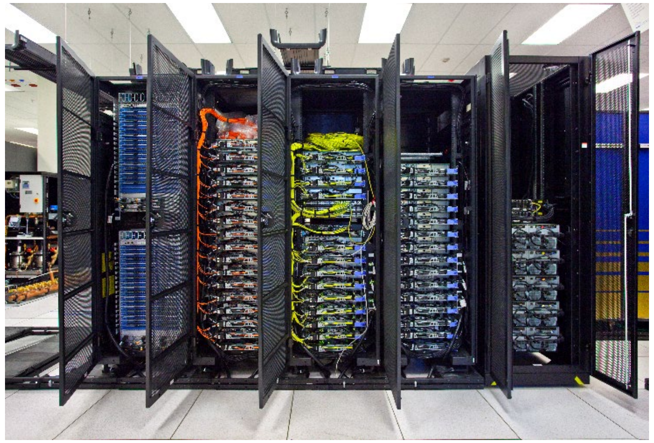
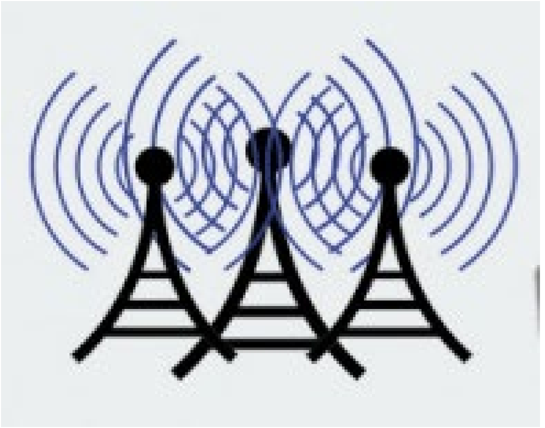
Key Elements Driving Enablement Costs



Communications Infrastructure Options

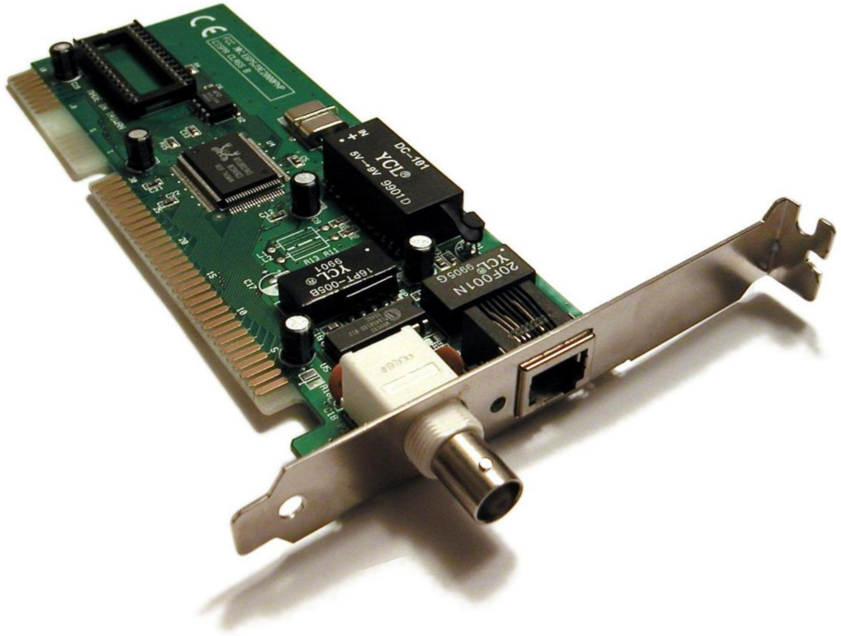
- FM Radio or pager based communication solution
- Wi-Fi or Broadband communication solution
- Cellular communication solution
- Advanced metering infrastructure (AMI) network communication solutions





Energy Measurement Infrastructure Options

Electricity Meter



Network Interface Card (NIC) embedded in a AMI meter

Gateway used to connect end use controls to NIC, meter and communication infrastructure

Control Infrastructure Options

- ◆Advancement of ADR control logic and sophisticated algorithms can convert DR signals into actionable load control that enable real-time response to signals.
- ◆DLC switches
- ◆Smart Inverters

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Assessing Enablement Costs for DR

- Costs not included in assessment
  - Variability in technology costs and in site-specific costs
  - Operational costs
- Attribution of enablement costs
- Technology solutions for site enablement
  - Fast response DR services (Shimmy)
  - Energy DR services (Shift)
  - Conventional DR services (Shed)

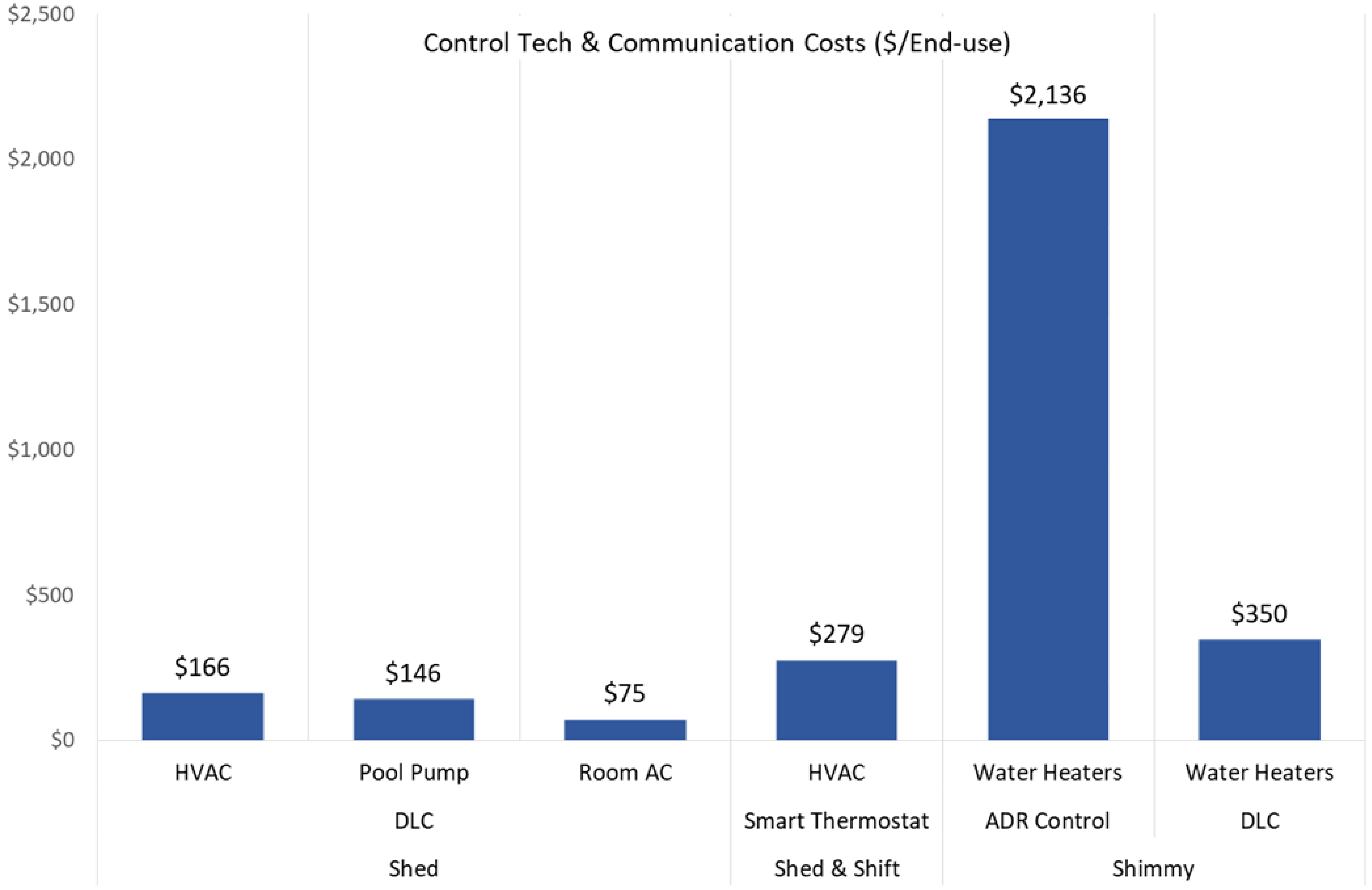
DR Site Enablement Cost Categories

- Fixed initial **communication and hardware costs** for achieving controllability "per site" for the given end-use or customer premise. Costs included in this category are telemetry, communication resource interface, and installation costs. Reported in **$ per site**.

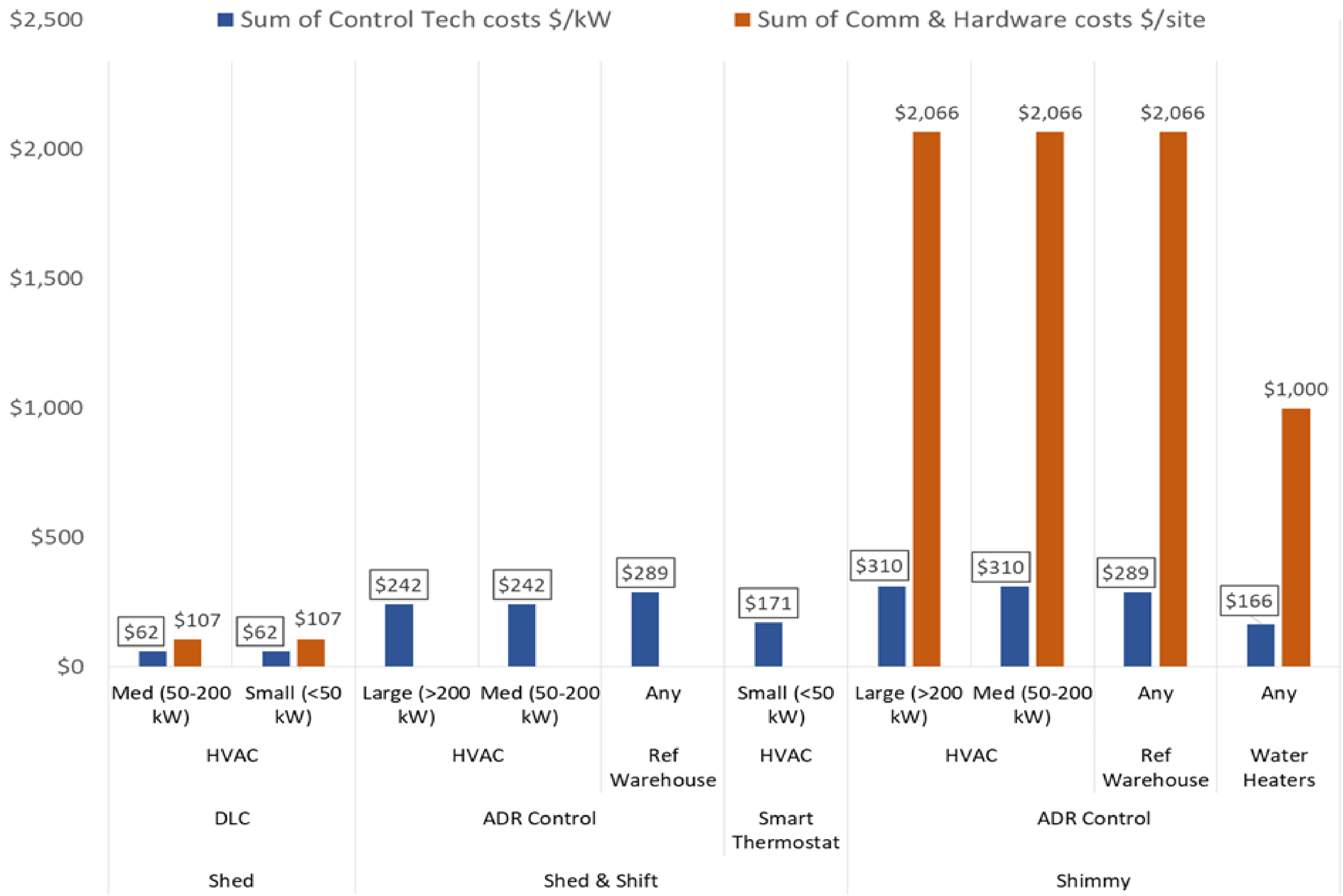
- Variable initial **costs for the control technology** for achieving controllability "per kW" (e.g., HVAC and retail lighting controls). Reported as **$ per kW** enabled for DR services.

- Fixed initial **end-use control technology and communication costs** for achieving controllability "per end-use". Costs are specific to Electric Vehicles and the Residential sector end-uses and are reported as **$ per end-use** enabled for DR services.

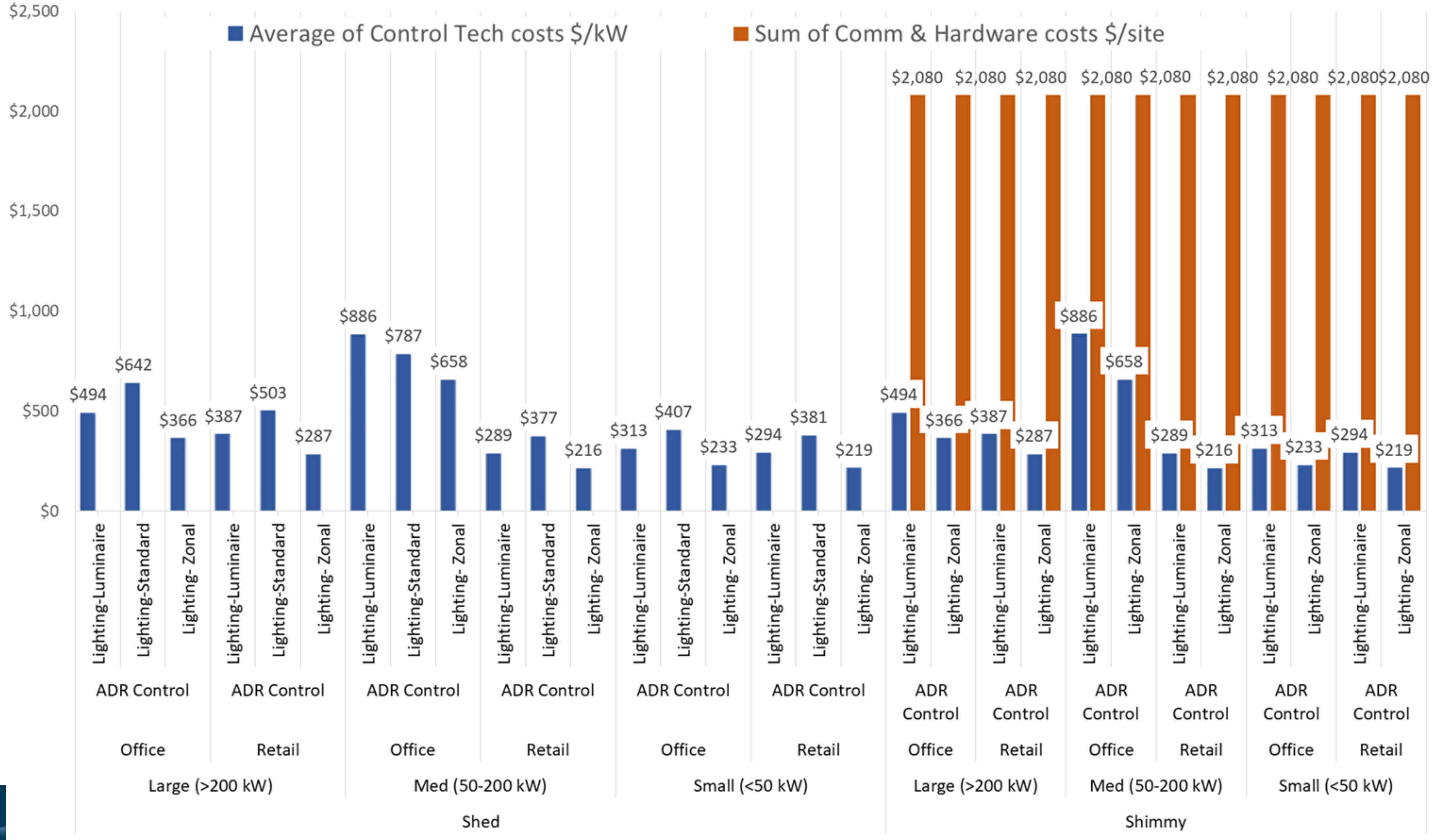
Residential DR Site Enablement Costs



Commercial DR Site Enablement Costs



Commercial Lighting DR Site Enablement Costs



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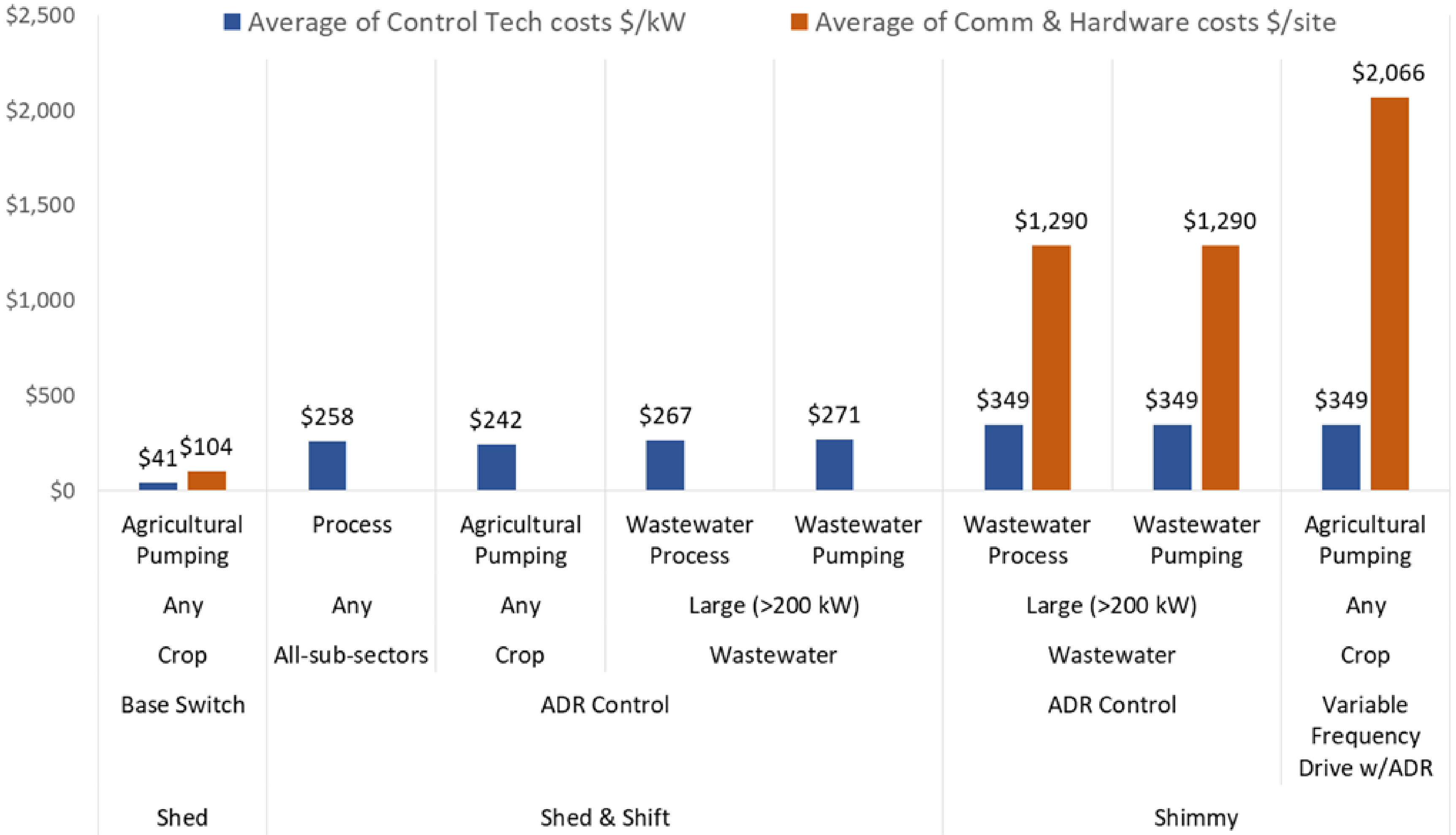
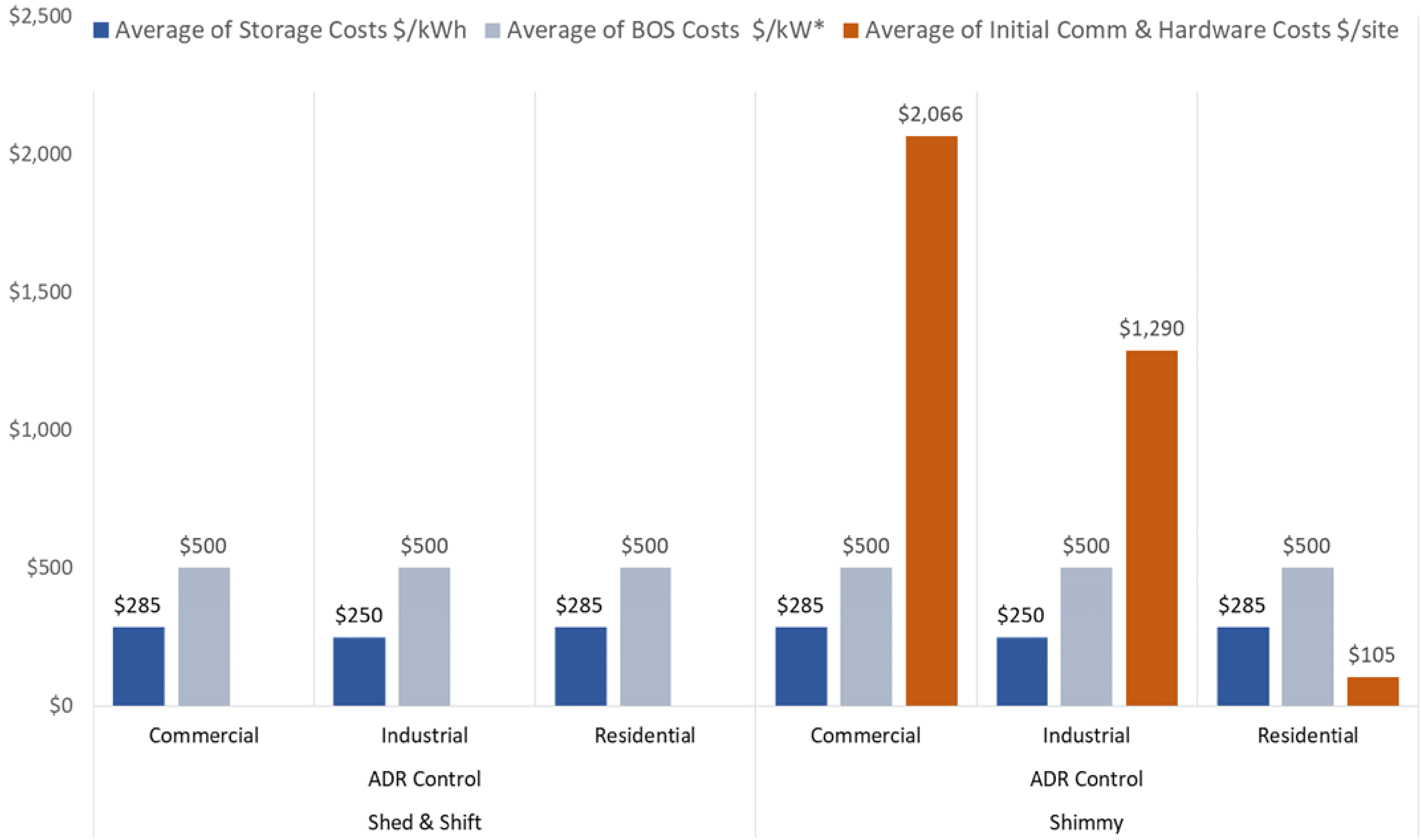
Industrial DR Site Enablement Costs



Behind-the-meter Battery DR Enablement Costs

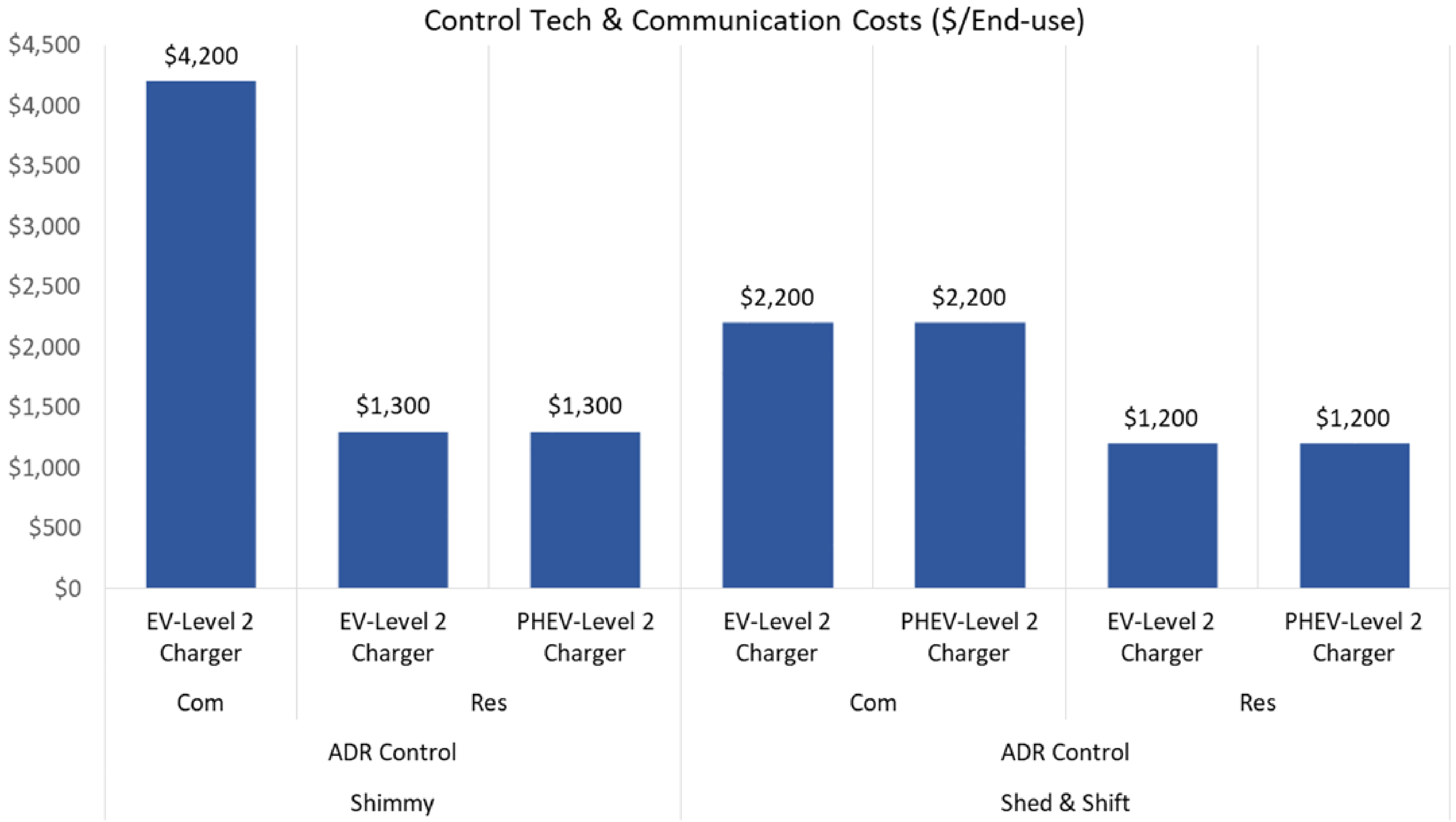


The costs breakdown:

- Storage costs in $/kWh (the actual battery stacks in case of a battery system),
- BOS costs in $/kW (inverter, utility interconnection, BMS, and installation)
- Communication and Energy Measurement

BOS stands for "Balance of System" in energy storage systems. BOS equipment include permitting and interconnection, inverters/converters, and specific power electronics. These costs are often not reported by manufacturers.

Electric Vehicle DR Enablement Costs



Parting Thoughts

- Energy Efficiency, Load-Modifying DR & Supply DR
  - EE & DR integration could be an overall increase in combined load-modifying & supply DR availability for meeting system capacity needs, with supply DR at lower cost compared to DR-only technology investments.
  - Energy-efficiency upgrades often present opportunities for cost-effective controls upgrades (either as part of an integrated project or as controls built into new equipment in an Internet-of-things approach) that can reduce enabling DR costs.
- Wholesale Market Design
  - Encourage broader participation of non-generator resources in wholesale markets

Parting Thoughts

- Policy Direction
  - Data-driven Energy Markets & Policy
  - Catalyze Shift Service Types
  - Future Rate Design for Residential & Non-Residential Customers
  - Developing Market Mechanisms for Market Entrance
  - Interoperability Standards for Plug & Play Grid
  - Distribution System Automation

Thank you!

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