Exploring the Benefits of Demand Response in the PJM Wholesale Energy Market: **A Cost-Benefit Perspective**

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Grid of the Future

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Outline

Current Demand Response in PJM Wholesale Markets

Issues With the Current Demand Response

Methodology and Assumptions

- Methodology
- Scenario Design

Simulation Results

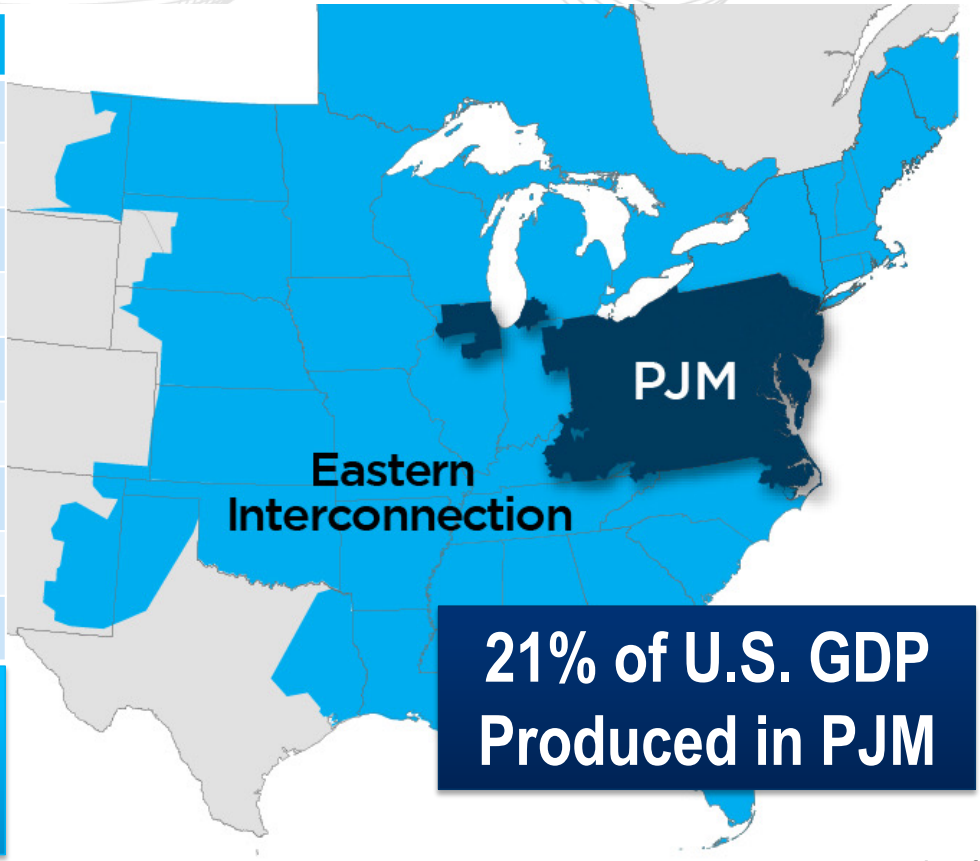
Observations & Next Steps

Questions

PJM as Part of the Eastern Interconnection

Key Statistics	
Member companies	1,110+
Millions of people served	65+
Peak load in megawatts	165,563
Megawatts of generating capacity	183,254
Miles of transmission lines	88,115
Gigawatt hours of annual energy	795
Generation sources	1,419
Square miles of territory	368,906
States served	13 + DC

- 26% of generation in Eastern Interconnection
- 25% of load in Eastern Interconnection
- 20% of transmission assets in Eastern Interconnection



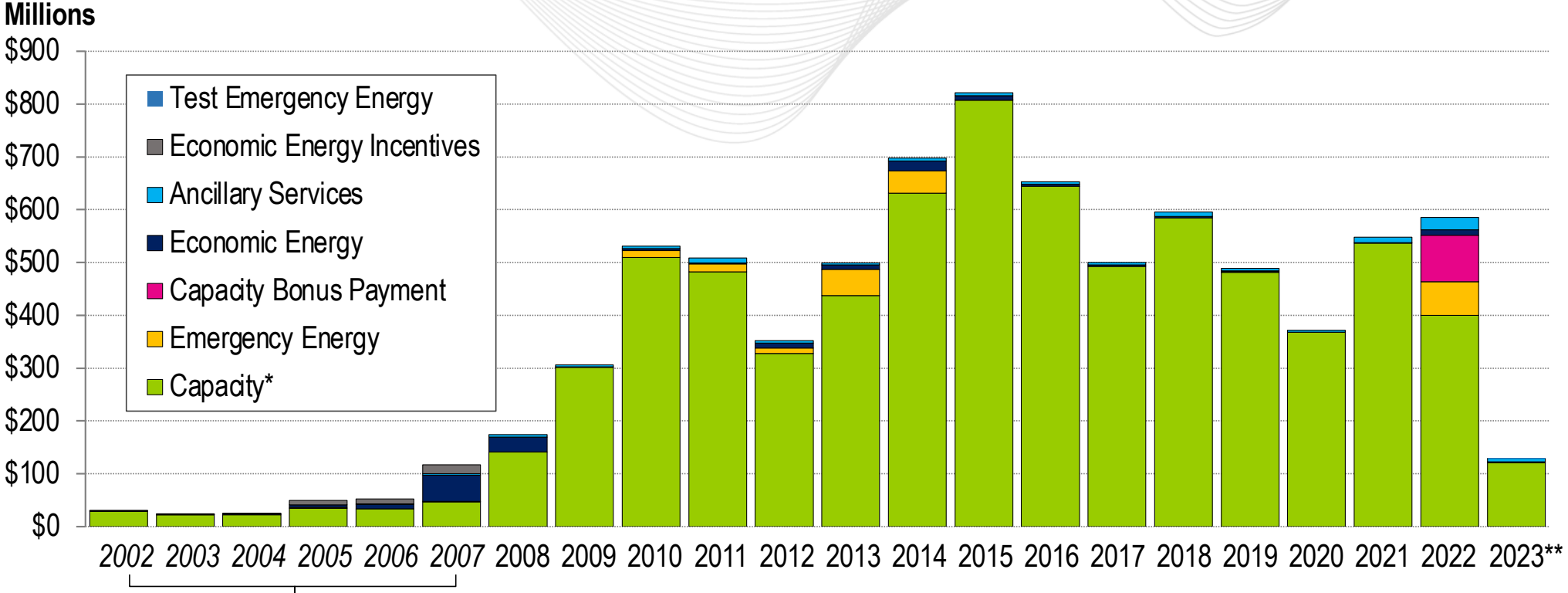
As of 2/2023

PJM Demand Response (DR) Programs:

Load management	Economic DR
(Pre-Emergency and Emergency DR) providers make a commitment in the **capacity market** to reduce load when required by the system or receive a financial penalty.	providers participate in the **energy and ancillary services markets** when it is economic for them. If the Economic DR offer price is less than the marginal price, they will be deployed similar to a generator.

- The choice to participate in DR programs is voluntary.
- Curtailment Service Providers (CSPs) act as brokers for eligible consumers.
- CSPs aggregate customer bids and offer them into PJM wholesale electricity markets.

PJM Demand Response Revenue by Wholesale Service



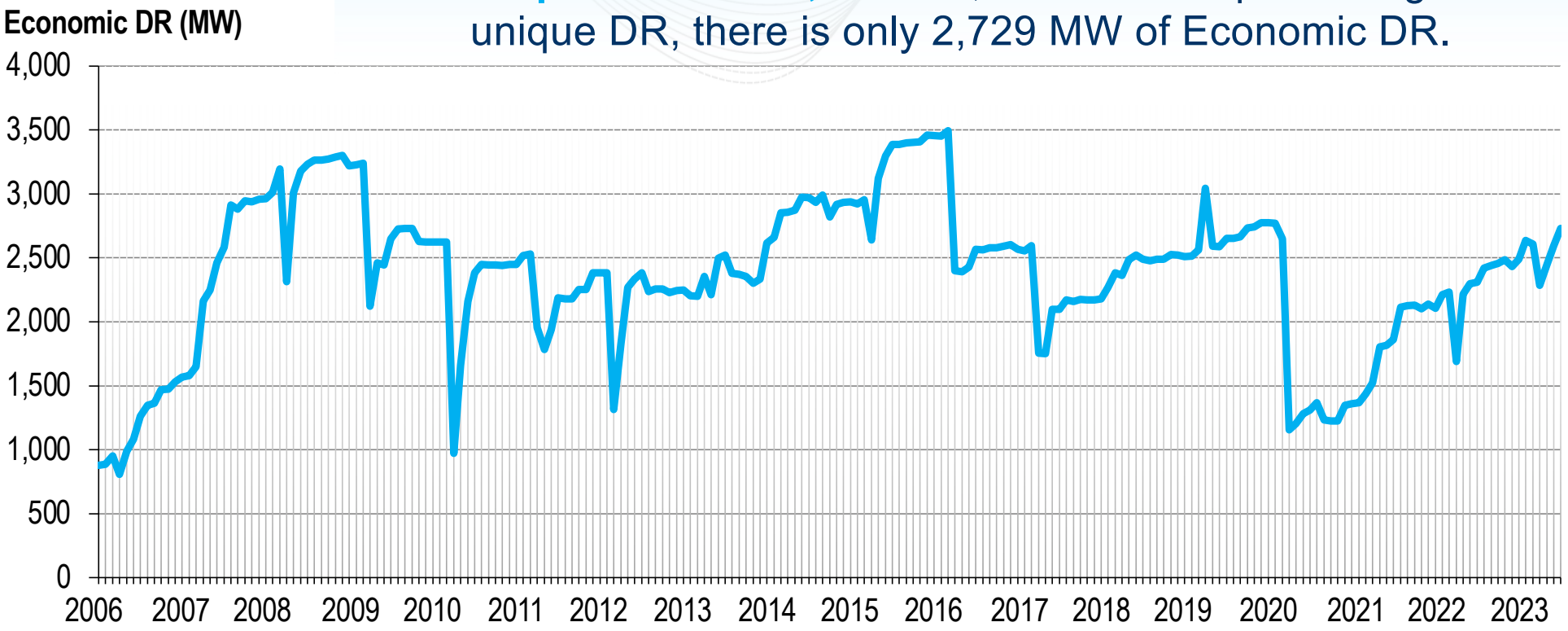
PJM assumes capacity value at $50/MW-day (PJM does not know the value of capacity credits in the forward market prior to RPM; only a portion of capacity was purchased through the daily capacity market at the time).

* Capacity Net Revenue inclusive of Capacity Credits and Charges. From 2020 on, this value also includes Price Responsive Demand Credits.

** As of Sept. 11, 2023

Economic Demand Response in PJM

As of September 2023, out of 9,423 MW of reported registered unique DR, there is only 2,729 MW of Economic DR.



What Are the Issues With PJM's Demand Response?

There is a significant difference in participation in the Load Management program compared to the Economic DR program.

There are a few reasons for this difference, such as:	
• **Compensation:** Historically, the capacity market has offered a more stable and attractive compensation mechanism for DR resources.	• **Operational Certainty:** Participating in the capacity market offers DR resources more predictability.
• **Risk:** The energy market can be more volatile than the capacity market, and it might be riskier for DR providers who have to coordinate with end-users to reduce consumption.	• **Duration of Events:** DR events in the capacity market can be of shorter duration than in the energy market.

What Are the Aims of This Study?

1. Quantify the net benefits of Economic DR in the PJM Real-Time Energy Market.
2. Investigate the impacts of Economic DR on the various revenue streams for generators, prices and uplift payments.
3. Evaluate the added value of more participation in PJM's Economic DR program.

Methodology

A simulation-based approach was used to simulate the PJM RTM under various DR scenarios.

PROBE Perfect Dispatch (PD) simulation tool was used:

PROBE PD replicates the PJM RTM clearing process, assuming all system conditions are known in advance (i.e., no forecast uncertainty or unexpected generator outages).

Net benefits derived from implementing DR are quantified by the difference between the cost to load associated with dispatching DR and the benefits (savings) to load achieved through DR implementation.

- **Total DR costs to load** are the sum of DR payments and the increase in total system uplift.
- **Total DR benefits (savings) to load** are the differences between the base case and the DR cases in generator energy revenue, synchronized reserve revenue and primary reserve revenue.

Scenario Design

Three DR scenarios were simulated in addition to a base case:

- DR equivalent to 1%, 2% and 5% of the base system load.
- DR is deployed only during PJM peak load hours, which are defined as HE 8 through HE 23.

Historical data from the year 2022 was simulated, excluding 13 days.

Total amount of DR in TWh

Month	DR = 1%	DR = 2%	DR = 5%
Jan	0.58	1.16	2.93
Feb	0.46	0.93	2.32
Mar	0.45	0.91	2.28
Apr	0.39	0.79	1.97
May	0.41	0.82	2.06
Jun	0.49	0.98	2.44
Jul	0.58	1.16	2.90
Aug	0.58	1.16	2.90
Sep	0.43	0.87	2.18
Oct	0.42	0.84	2.11
Nov	0.44	0.88	2.21
Dec	0.53	1.06	2.65

Simulation Results – Generator Energy Revenue

Decrease in generator energy revenue:

Difference between the Base Case and the 5% DR Case in 2022: $8.4 billion (15.7%)

Month	Base Case ($B)	DR = 1% ($B)	DR = 2% ($B)	DR = 5% ($B)
Jan	4.04	3.88	3.72	3.39
Feb	2.76	2.69	2.62	2.46
Mar	2.54	2.46	2.40	2.24
Apr	3.17	3.06	2.96	2.74
May	4.13	4.01	3.90	3.60
Jun	5.60	5.40	5.21	4.72
Jul	7.04	6.72	6.43	5.74
Aug	7.69	7.34	7.01	6.22
Sep	4.39	4.28	4.15	3.84
Oct	2.98	2.89	2.79	2.53
Nov	3.04	2.99	2.87	2.64
Dec	6.04	5.81	5.52	4.92
2022	**53.42**	**51.53**	**49.58**	**45.03**

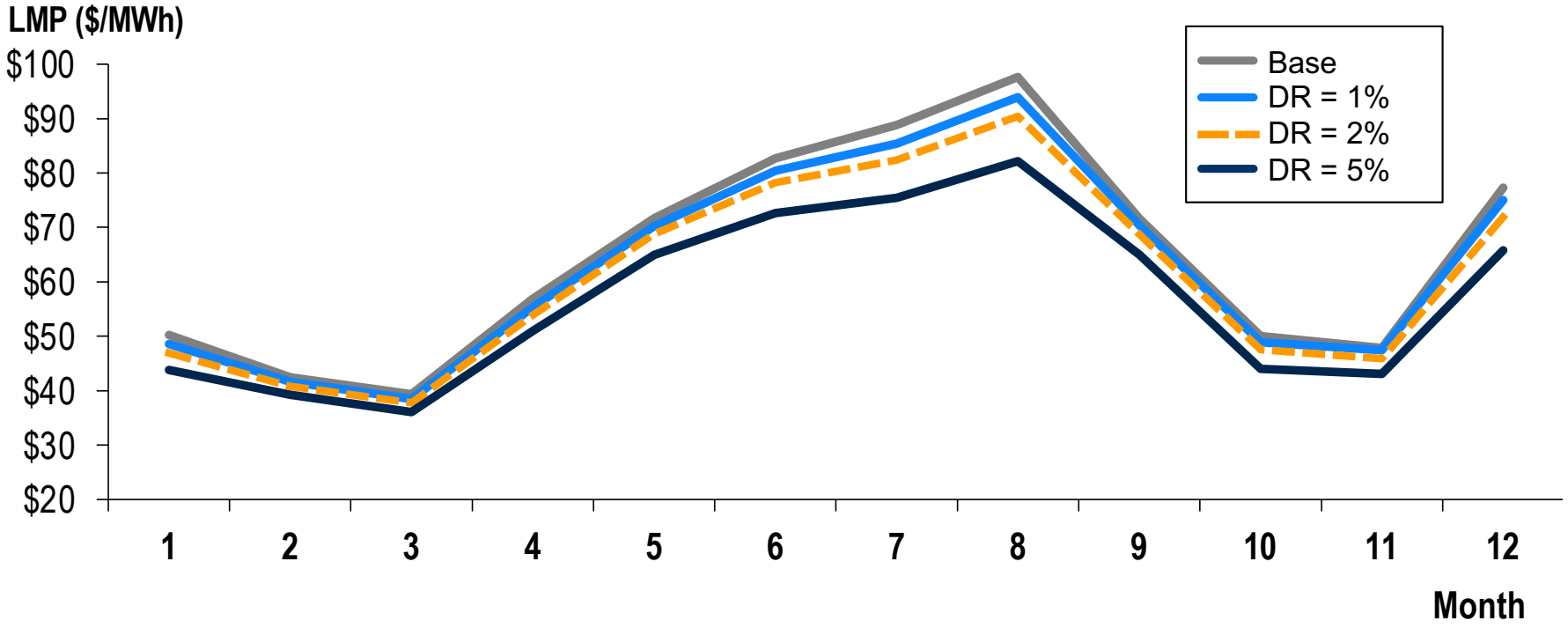
Simulation Results – Load Savings

Increase in savings to load when the DR participation increases:

Month	DR = 1% ($M)	DR = 2% ($M)	DR = 5% ($M)
Jan	162.0	320.1	648.2
Feb	72.3	143.0	300.3
Mar	75.0	136.9	296.5
Apr	113.3	213.7	438.0
May	117.6	229.7	528.7
Jun	200.0	384.5	878.2
Jul	326.5	616.7	1,304.8
Aug	353.3	686.0	1,478.0
Sep	109.5	239.0	551.0
Oct	91.0	189.5	458.1
Nov	47.4	165.9	394.0
Dec	224.2	512.7	1,113.5
2022	**1,892.0**	**3,837.5**	**8,389.1**

Simulation Results – LMP Change

Decrease in the system's average generation-weighted LMP:



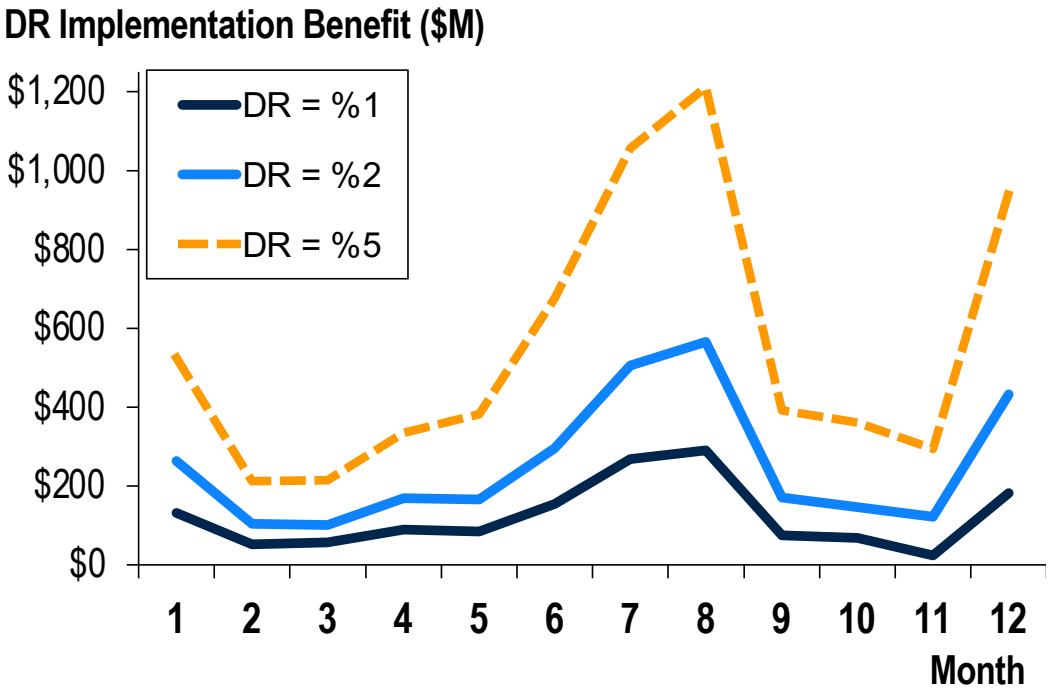
Simulation Results – Change in System Dispatch

Change in the system dispatch for each unit type:

Unit Type	DR = 1%		DR = 2%		DR = 5%	
	MWh Change	Percentage Change (%)	MWh Change	Percentage Change (%)	MWh Change	Percentage Change (%)
Diesel	-17,261	-6.60	-38,824	-14.85	-91,823	-35.12
CT	-1,051,150	-5.74	-2,055,408	-11.22	-4,441,599	-24.25
Coal, CC, Oil	-4,700,750	-1.02	-9,461,909	-2.06	-24,412,057	-5.30
Landfill	-906	-0.09	-1,853	-0.19	-3,421	-0.35
Hydro	-106	-0.01	-156	-0.01	-4,419	-0.03
Nuclear	51	0.00	-39	0.00	-468	0.00
Solar	0	0	0	0	0	0
Wind	0	0	0	0	0	0

Simulation Results – Net Benefits of Demand Response

Potential Net Benefits of DR: Net benefits ranging from $1.5B with 1% DR implementation to $6.6B with 5% DR implementation



Month	DR = 1%	DR = 2%	DR = 5%
Jan	132.4	263.7	524.4
Feb	52.5	104.7	212.3
Mar	56.4	101.0	214.7
Apr	89.8	168.3	335.3
May	85.0	165.9	381.2
Jun	153.7	295.2	675.5
Jul	268.4	505.5	1,056.3
Aug	290.4	565.4	1,211.1
Sep	74.2	170.5	391.6
Oct	68.2	145.6	360.5
Nov	23.9	121.4	293.8
Dec	181.3	432.2	943.6
2022	**1,476.1**	**3,039.4**	**6,600.2**

Observations

- Implementation of DR offers enhanced reliability, efficiency and cost-effectiveness to the system.
- Dispatch of inefficient and typically more pollution-intensive units is reduced.
- DR plays a crucial role in alleviating system pressure during high load demand months in the summer and winter.
- Simulation results show the potential net benefits range from $1.5 billion for 1% DR implementation to $6.6 billion for 5% DR implementation.
- Reduction in generator energy revenues results in significant load savings, especially in the summer and winter months.

Potential areas for future research:

- Advantages of DR at a zonal granularity to provide more locale-specific insights
- Determination of the optimal DR deployment strategies across diverse geographic locations and specific temporal intervals considering both daily and seasonal variations
- Developing strategies to enhance participation in Economic DR