

# NV Energy Solar PV Integration Study

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UWIG Solar Integration Workshop



# Study Team

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## Background

- Due to large number of pending interconnection requests for large-scale PV projects, NVEnergy submitted an application to the Public Utilities Commission of Nevada (PUCN) requesting approval for funding to evaluate the impacts of intermittent output of these PV facilities on NVE electrical system.
- NVE was concerned that the impacts of variable output of these PV facilities could potentially affect the NVE system to adequately “follow” these intermittent resources with NVE’s existing generators.
- Early 2010 the PUCN issued a Compliance Order approving a study of large-scale PV, and subsequently approved a second study to determine how much distributed PV generation (DG) could be installed on NV Energy’s existing system.
- The study was jointly funded by the United States Department of Energy (OE and EERE) and NV Energy, and conducted by a project team comprised of industry experts and research scientists from Pacific Northwest National Laboratories, Sandia National Laboratories, NV Energy and Navigant Consulting Inc..

# Objectives

The study objective was to quantify the impact of variable PV generation output on the NVE's system operations, including requirements for regulating and load-following reserves necessary to retain resource and demand balance, and to examine the ability of the existing conventional generation fleet to accommodate increasing amounts of PV generation. The scope of work was segmented into four specific tasks:

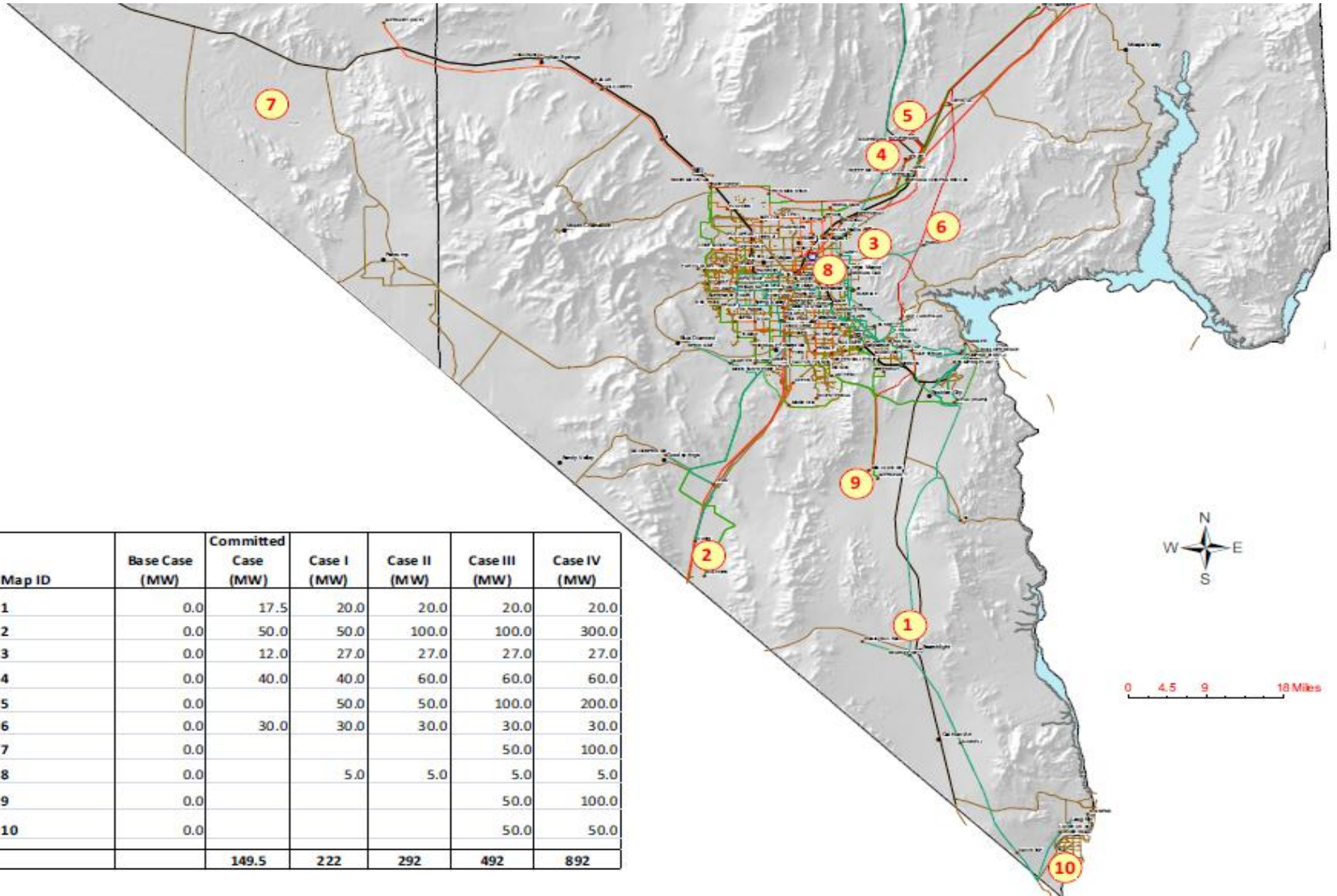
- Produce the likely generation profile of variable solar PV resources in southern Nevada on a one-minute time scale.
- Quantify increased within-hour balancing requirements.
- Evaluate the impacts of variable PV output on NV Energy's southern system operations, including
  - Ability of the existing generation fleet to accommodate PV
  - Cycling and movements of conventional generators to balance the system
- Quantify solar PV integration costs.

# Solar Integration Study Findings

**The results of studies completed to date indicate new PV and DG will impact generation performance and increase system costs.**

- Additional operating reserves are needed for increased regulation and load following.
- The level of variability for PV generation is lower when plants of the same size are distributed over a larger geographical area.
- Additional generating unit maintenance will be required due to the increased number of startups and movements.
- Generation displacement from PV & DG causes conventional units to operate less efficiently as penetration levels increase.
- For the cases studied, the annual cost to integrate large PV and DG ranges from \$2 to \$20 million or \$3 - \$8/MWh.
- Further, integration costs will increase under the following conditions but yet to be quantified and require additional study:
  - ✓ When the existing generation fleet has insufficient ramping capability to meet regulation and load following requirements, and if upgrades or other mitigation are needed.
  - ✓ Generation cycling and start-ups cause wear & tear and accelerated maintenance.

# Solar Integration Study Area



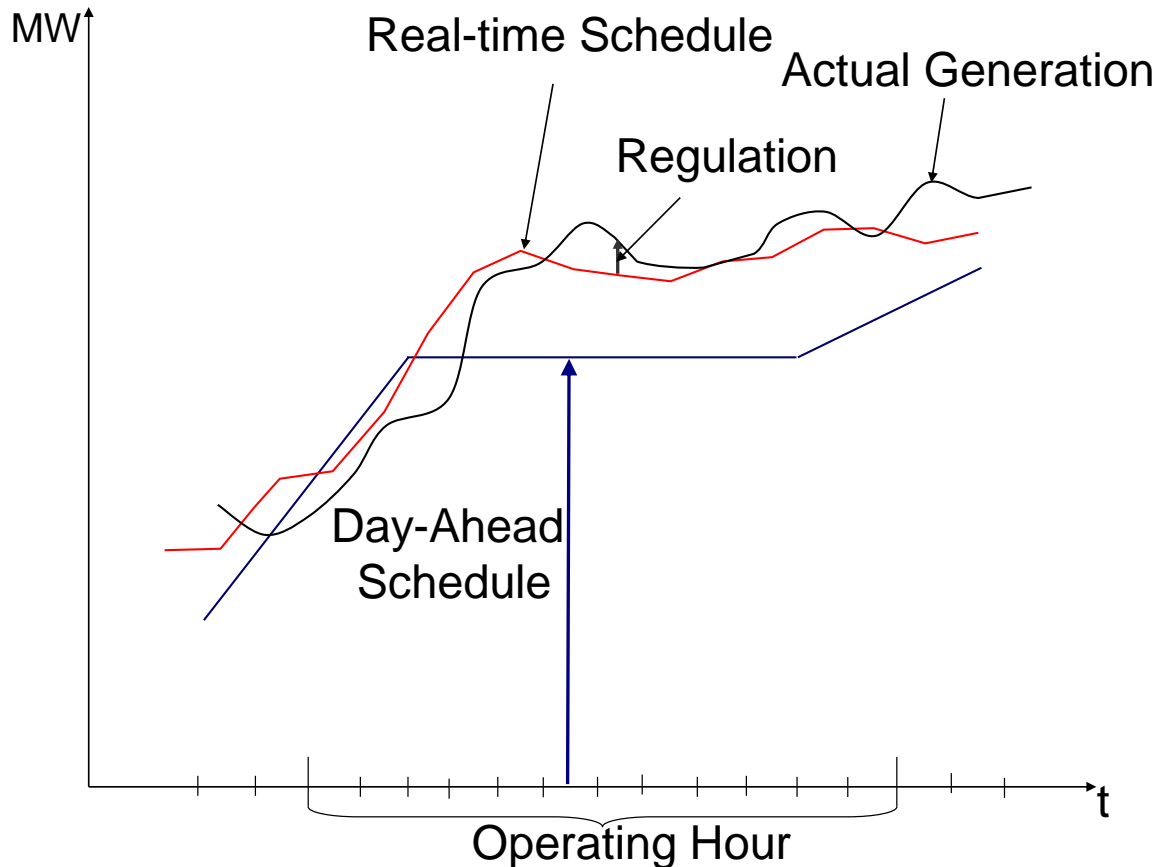
SolarPV Project Map ID	Base Case (MW)	Committed Case (MW)	Case I (MW)	Case II (MW)	Case III (MW)	Case IV (MW)
SolarPV Project 1	0.0	17.5	20.0	20.0	20.0	20.0
SolarPV Project 2	0.0	50.0	50.0	100.0	100.0	300.0
SolarPV Project 3	0.0	12.0	27.0	27.0	27.0	27.0
SolarPV Project 4	0.0	40.0	40.0	60.0	60.0	60.0
SolarPV Project 5	0.0	50.0	50.0	100.0	100.0	200.0
SolarPV Project 6	0.0	30.0	30.0	30.0	30.0	30.0
SolarPV Project 7	0.0				50.0	100.0
SolarPV Project 8	0.0		5.0	5.0	5.0	5.0
SolarPV Project 9	0.0				50.0	100.0
SolarPV Project 10	0.0				50.0	50.0
<b>Total:</b>		<b>149.5</b>	<b>222</b>	<b>292</b>	<b>492</b>	<b>892</b>

# Study Cases

PV/DG Cases		DG – Percent of Peak Load			
		0 MW	1% (50 MW)	9% (450 MW)	15% (750 MW)
Large PV	Case 0 – 0 MW	Base			
	Case 1 – 149 MW	1	1A	1B	1C
	Case 2 – 222 MW		2A		
	Case 3 – 292 MW		3A		3C
	Case 4 – 492 MW		4A	4B	
	Case 5 – 892 MW		5A		

# Scheduling and Dispatch Processes Simulated in the Study

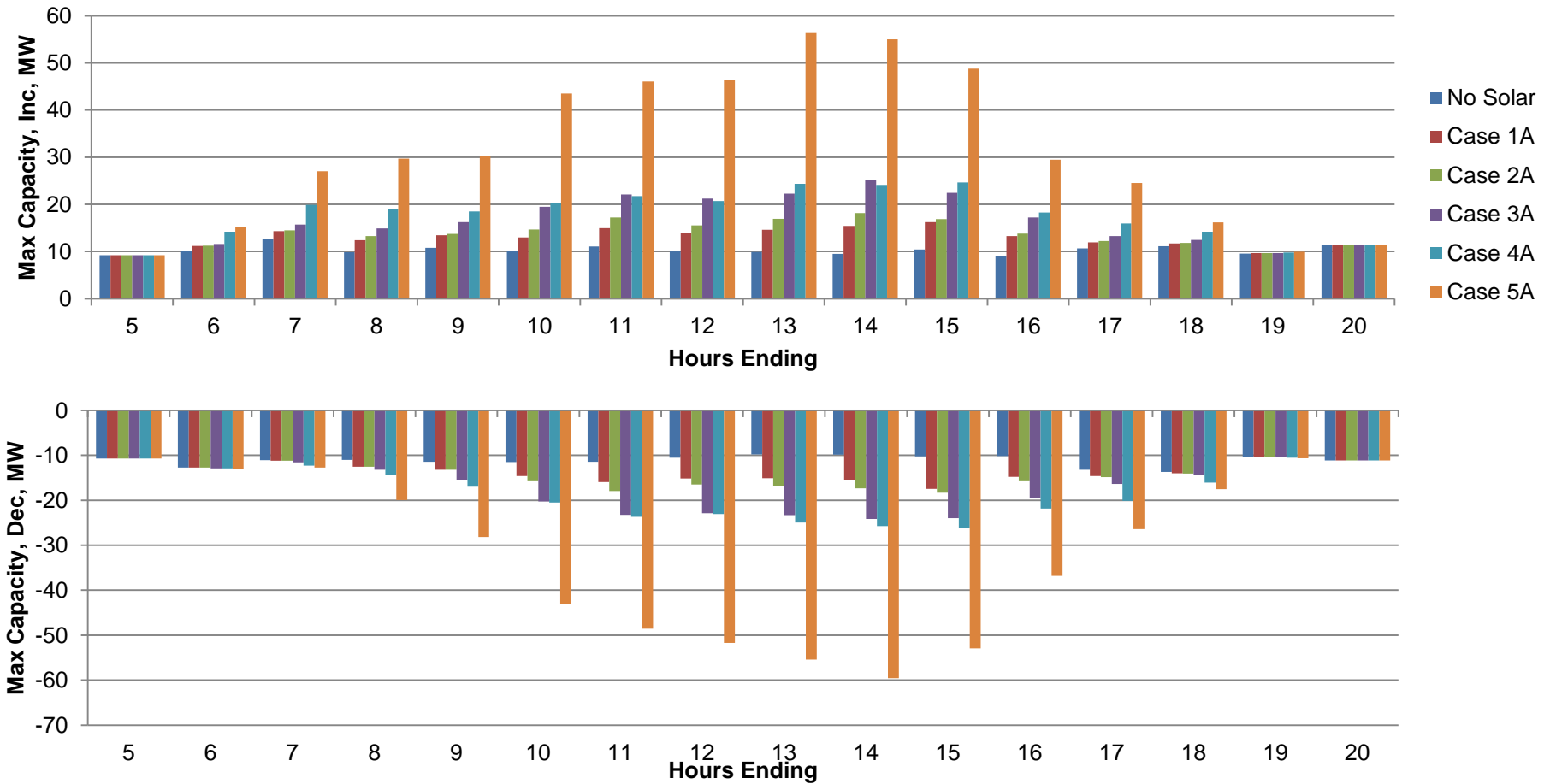
Perfect day-ahead and real-time forecasts are assumed so that PV impacts on the system are solely from its variability.



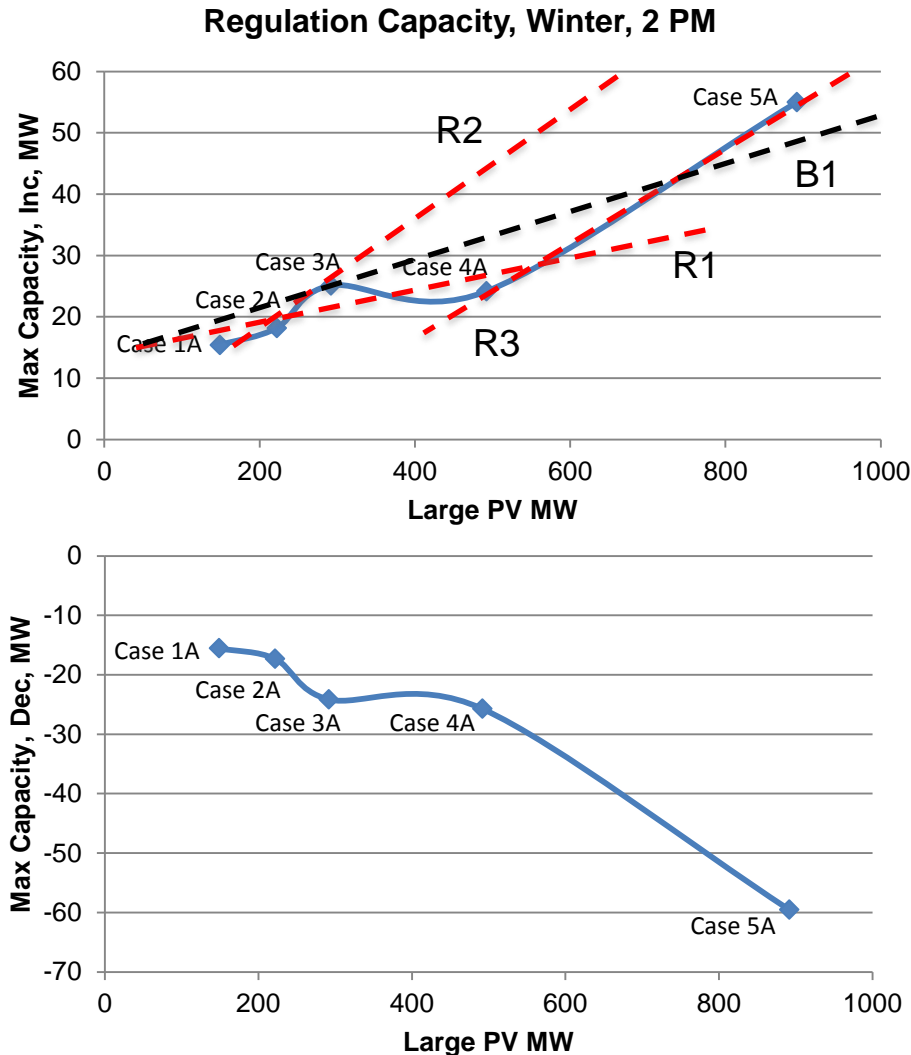
Process	Function in Meeting Demand
Hourly Schedule	Hourly average
Real-time Schedule	10-minute trend
Regulation	Minute-to-minute variations

# Regulation capacity requirements increase with PV penetration

## Regulation Capacity, Winter



# Regulation capacity and ramp requirements follow similar trends, affected by installed PV capacity and location diversity



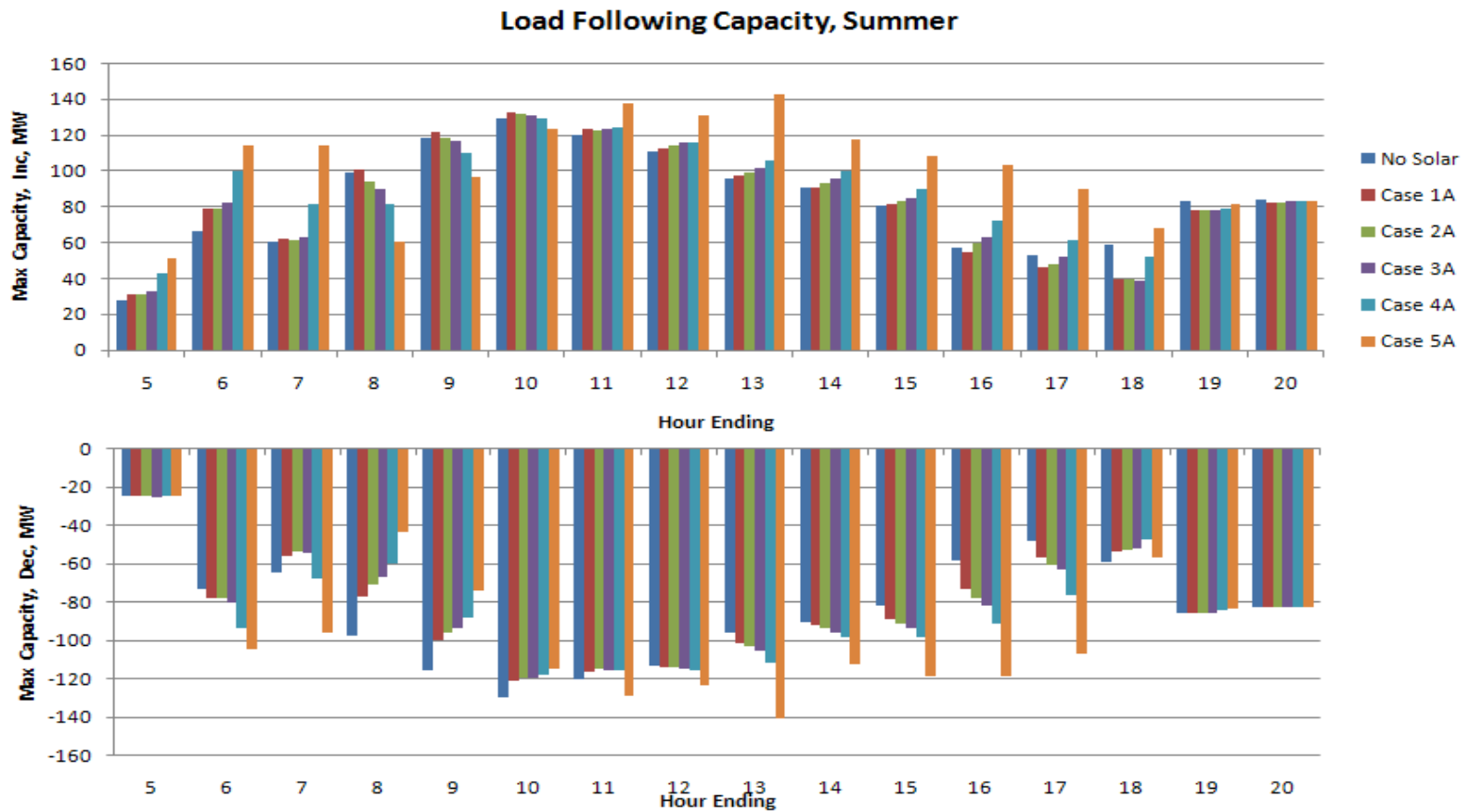
2 PM is one of the most challenging hours of the season

B1 is the average trend line depicting the relation between large PV and regulation capacity requirements. In average, about 25 MW large PV requires 1 MW of regulation increase.

R1 shows the trend when large PV increases with a larger diversity (refer to the PV case chart). About 35 MW large PV requires 1 MW regulation increase.

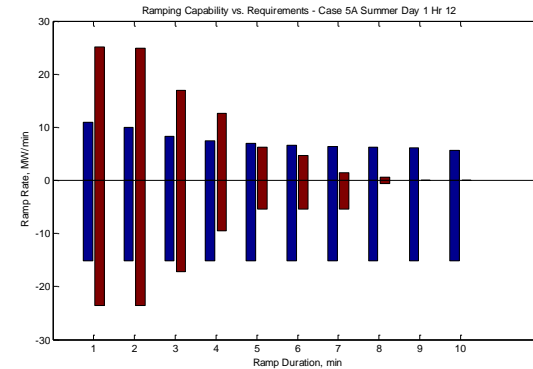
R2 and R3 are the trends when PV increases capacity on existing sites with no increased diversity (refer to the PV case chart). Every 10 to 15 MW PV would require 1 MW of regulation increase.

# Load Following: Requirements increase less significantly than regulation

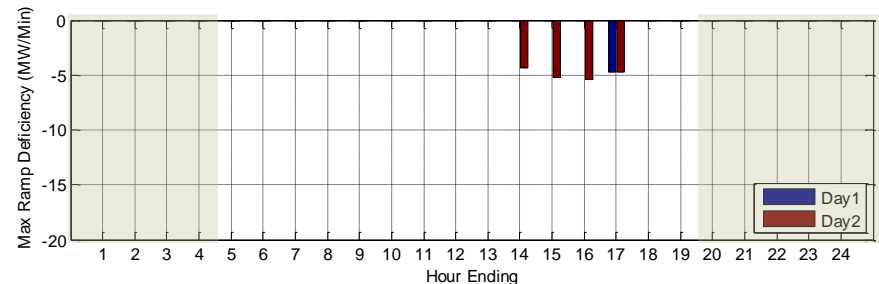
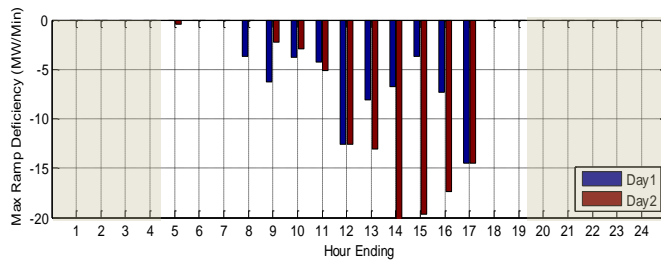
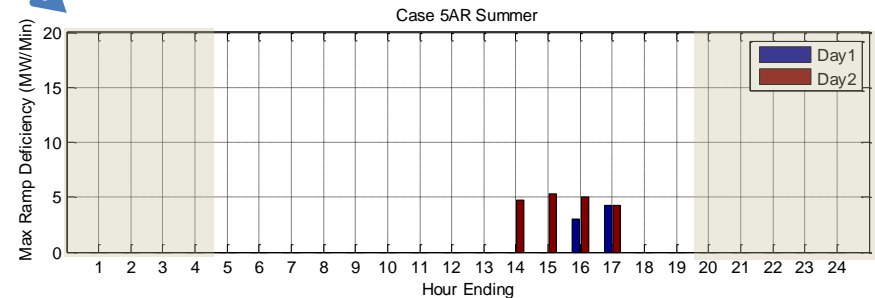
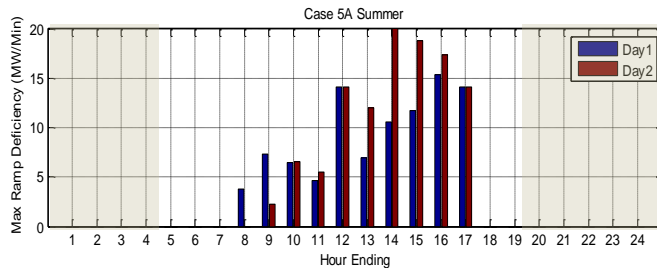


# Flexibility Evaluation: Large ramp deficiencies occur in high PV penetration cases but can be mostly removed after revised dispatch

Flexibility evaluation for a single hour →



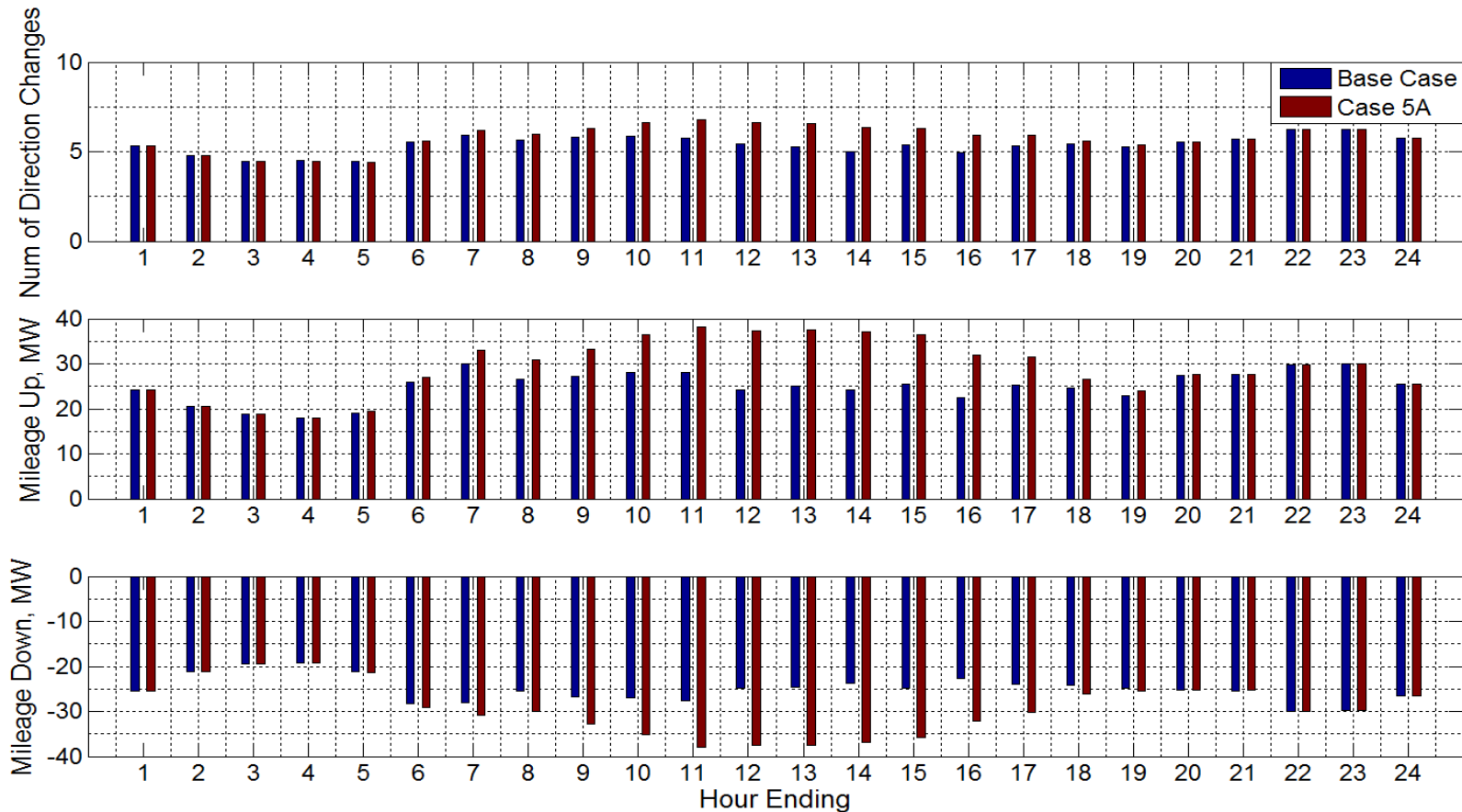
Flexibility evaluation for two days ↙ ↘



Before redispatch

After redispatch

# Cycling Analysis: Daily average of regulation mileage and direction changes increase with PV Penetration



Mileage: absolute sum of magnitude change between two turning points

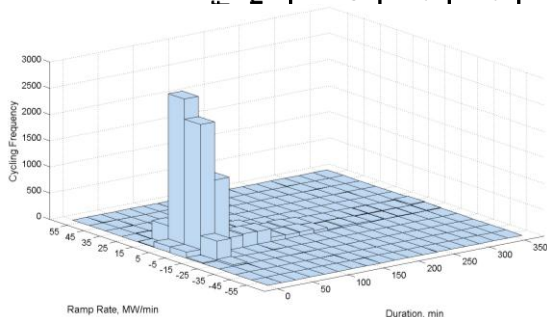
# Cycling Analysis: Regulation ramp rate and duration increase with PV penetration

## Base Case

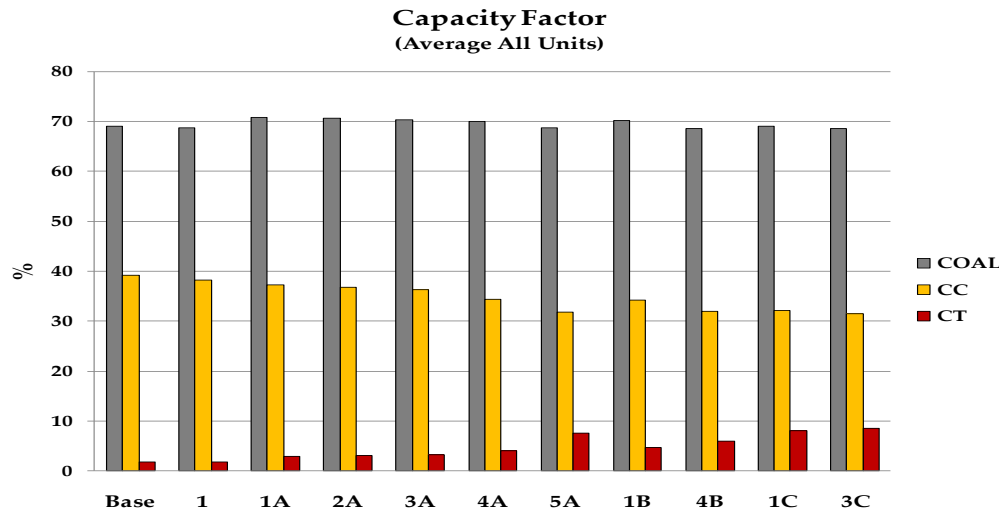
		Regulation half-cycle ramp rate in MW/min																		
		0	-45	-40	-35	-30	-25	-20	-15	-10	-5	5	10	15	20	25	30	35	40	45
Regulation half-cycle duration in minutes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	1	2	8	352	2261	2217	370	4	3	0	1	1	2	0	0
	3	0	0	0	0	0	1	1	19	1331	1348	15	1	1	0	0	0	0	0	1
	4	0	0	0	0	0	0	0	4	815	743	5	2	1	1	0	0	0	0	0
	5	0	0	0	0	0	0	0	2	400	409	2	0	1	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	223	188	1	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	1	0	0	74	86	1	1	0	0	0	0	0	0	0
	8	0	0	0	0	0	0	0	2	39	41	0	0	0	0	0	0	0	0	0
	9	0	0	0	0	0	0	0	0	20	31	1	0	0	0	0	0	0	0	0
	>=10	0	0	0	0	0	0	0	0	27	27	0	0	0	0	0	0	0	0	0

## Case 5A

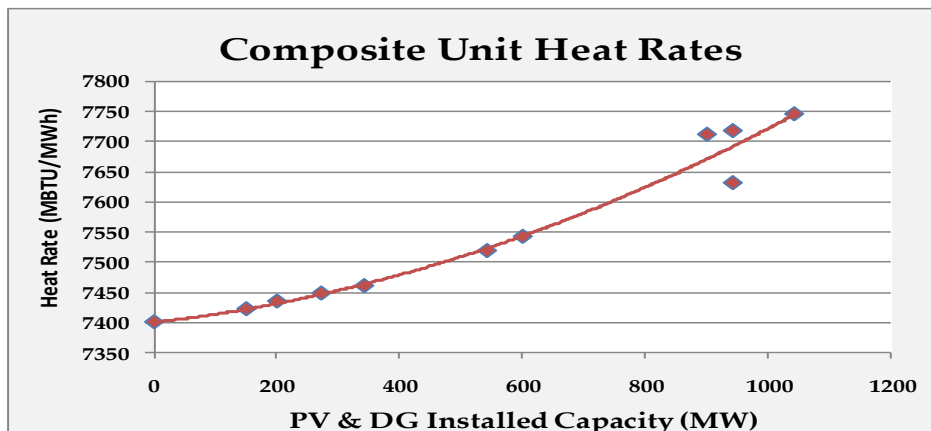
		Regulation half-cycle ramp rate in MW/min																		
		0	-45	-40	-35	-30	-25	-20	-15	-10	-5	5	10	15	20	25	30	35	40	45
i-cycle duration in minutes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	2	1	1	6	8	38	579	2466	2422	608	31	9	2	1	4	2	1	0
	3	0	2	1	0	6	16	46	212	1693	1747	207	51	13	5	2	3	3	3	0
	4	1	1	1	4	7	16	37	148	1186	1137	170	27	22	8	1	2	1	1	0
	5	0	0	0	4	4	19	26	108	867	855	107	32	22	8	5	0	0	0	0
	6	0	0	0	4	5	10	31	79	566	556	78	22	11	7	2	1	0	0	0
	7	0	0	0	2	6	16	54	385	345	60	20	7	2	0	0	0	0	0	0
	8	0	1	1	3	12	37	272	279	48	10	4	1	1	0	0	0	0	0	0
	9	0	0	0	3	8	25	189	201	31	5	3	0	0	0	0	0	0	0	0
	>=10	0	0	1	1	8	35	470	447	29	4	0	0	0	0	0	0	0	0	0



**Component of Integration Cost: Energy generated from PV and DG, as well as the additional balancing requirements, causes change in combustion turbine operation – lower capacity factor and efficiency.**

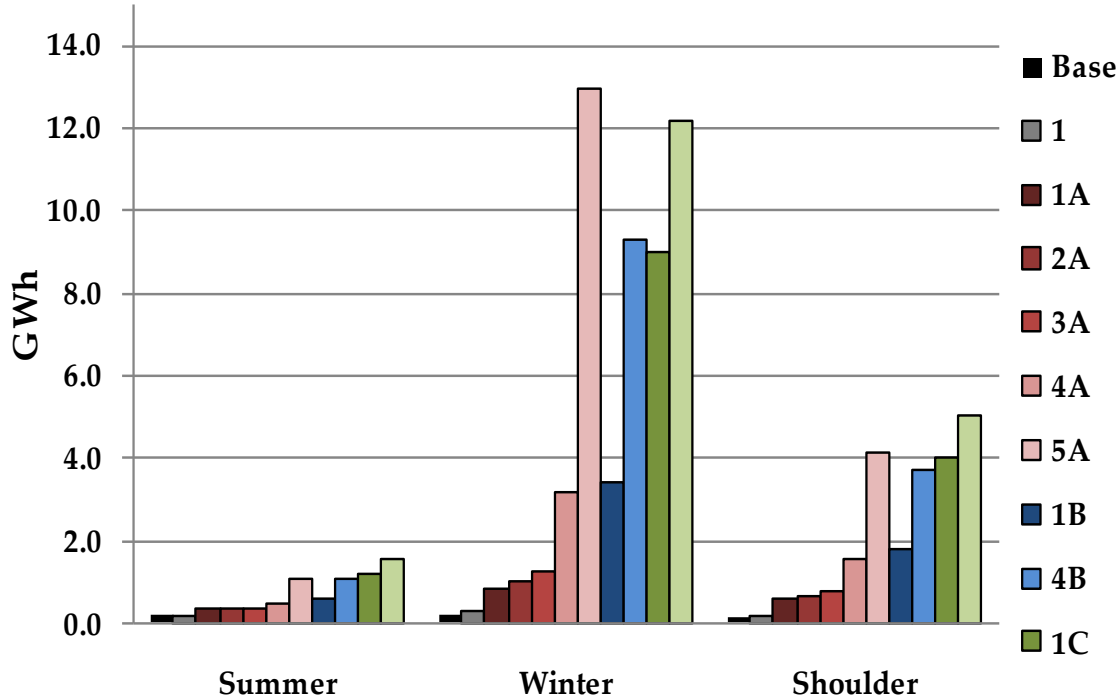


Case No.	Total PV & DG (MW)
Base	0
1	150
1A	200
2A	272
3A	342
4A	542
5A	942
1B	650
4B	942
1C	900
3C	1042



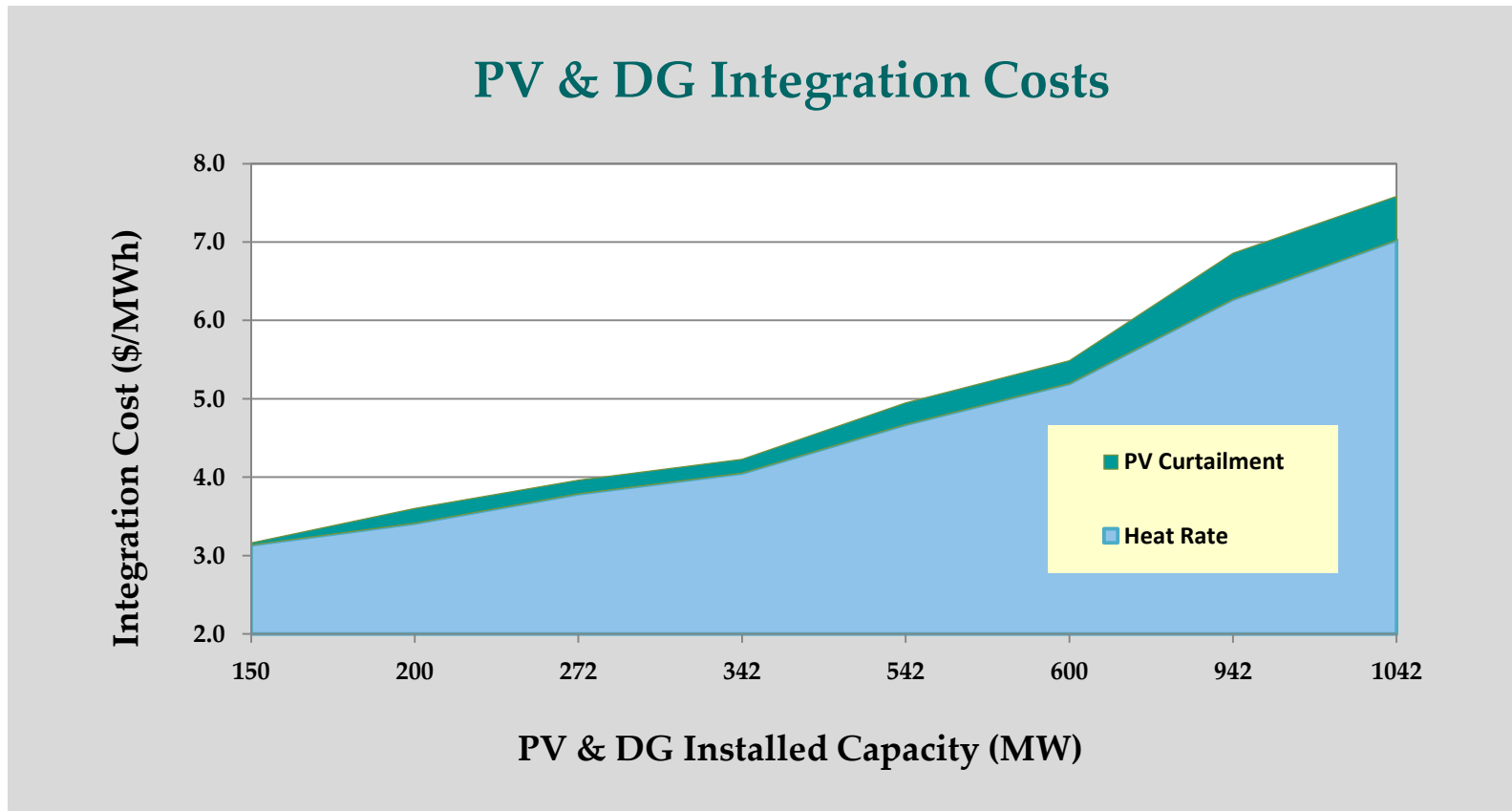
# Component of Integration Cost: Dumped energy increases with PV penetration, but only modestly as a percent of total energy produced

Dump Energy (NPC)



Scenario	Total PV & DG (MW)	Annual PV Curtailment (GWh)
Base	0	0.5
1	150	0.7
1A	200	1.7
2A	272	2.0
3A	342	2.4
4A	542	5.2
5A	942	18.2
1B	650	5.8
4B	942	14.0
1C	900	14.2
3C	1042	18.7

**Integration Cost: From a low of \$3/MWh to a high of just under \$8/MWh, excluding mitigation costs (additional dispatch of CT to cover rapid ramps, CT unit wear & tear, etc) that may be needed for higher PV penetration**



## Next Step

By using a new tool, the Renewable Integration Model (“RIM”), PNNL is continuing the study work. RIM will provide a detailed minute-by-minute “playback” of the behavior of a balancing area’s loads, renewable resources and conventional generation. The model allows for more accurate assessment of the flexibility of the generation fleet, balancing area control performance and renewable integration costs.

## Questions?

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