Use of Operating Agreements and Energy Storage to Reduce Photovoltaic Interconnection Costs

March 23, 2022

Clean Energy States Alliance

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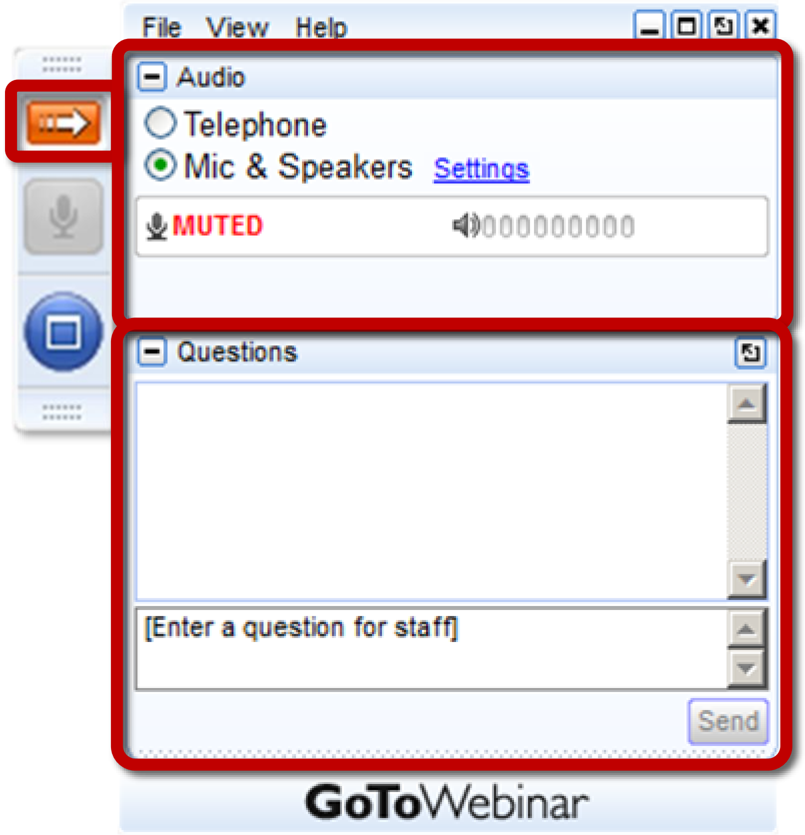

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EGLE Michigan Department of Environment, Great Lakes, and Energy

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Smart Electric Power Alliance

Webinar Speakers

- **Carrie Gill,** Rhode Island Office of Energy Resources
- **Shauna Beland**, Rhode Island Office of Energy Resources
- **Joyce McLaren**, National Renewable Energy Laboratory
- **Ryan Constable**, National Grid
- **Naim Darghouth**, Lawrence Berkeley National Laboratory
- **Sydney Forrester**, Lawrence Berkeley National Laboratory
- **Todd Olinsky-Paul**, Clean Energy States Alliance (moderator)

STATE OF RHODE ISLAND
OFFICE OF ENERGY RESOURCES

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CESA Webinar

March 23, 2022

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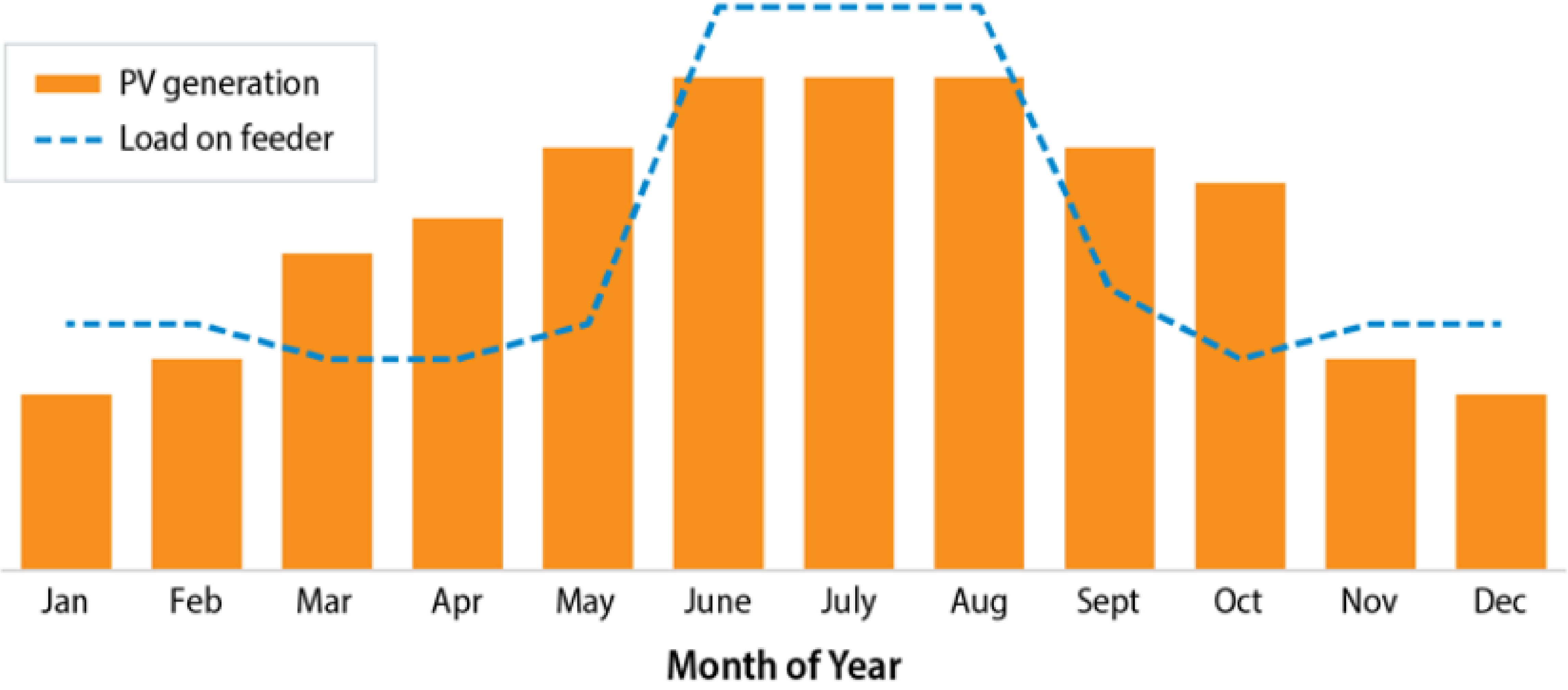
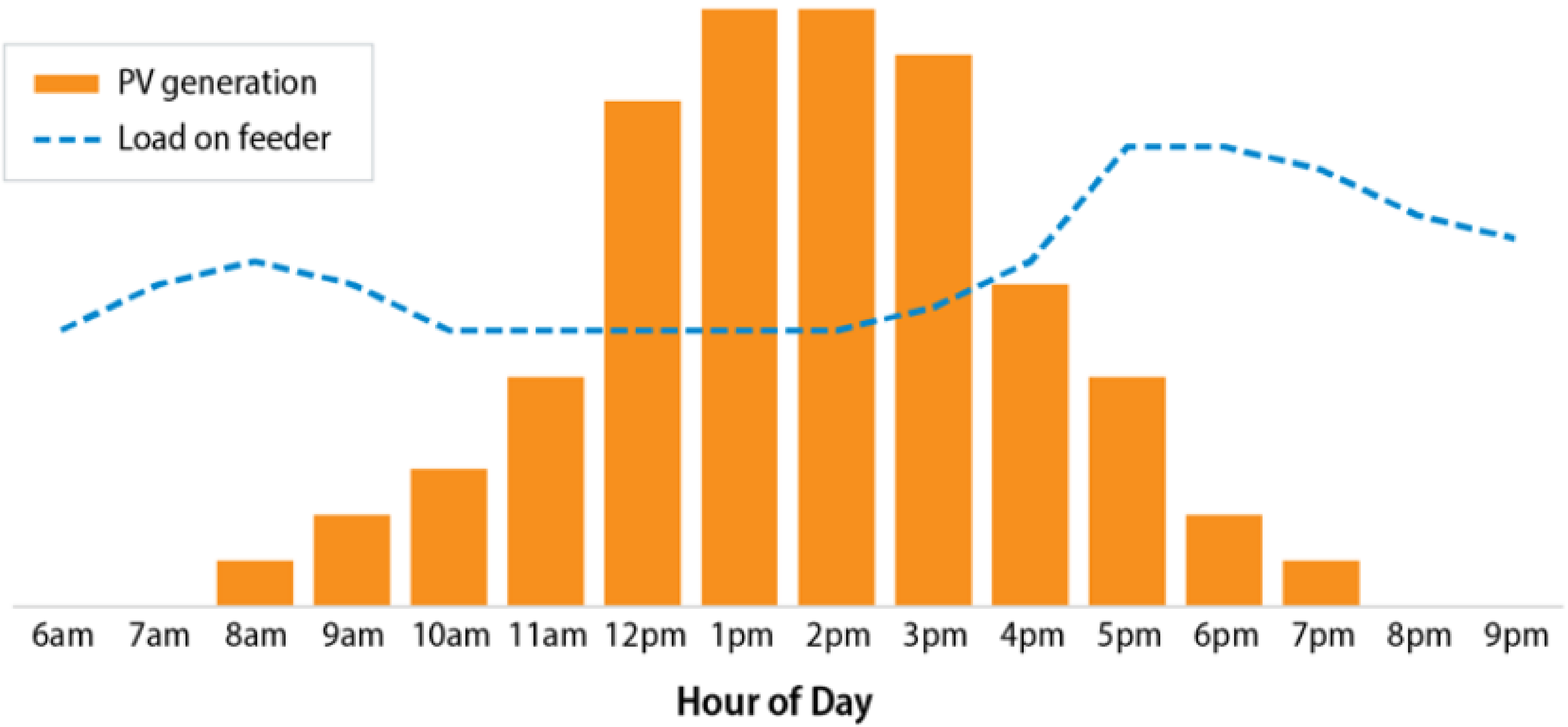
Operating Envelope Agreement

A contractual agreement between the utility and the system owner that defines a mutually agreeable set of time-based technical operating requirements (an “Operating Envelope”) for a PV and storage system that limits risk to neighboring customers and the utility’s infrastructure and provides certainty to both the utility and PV system owner.

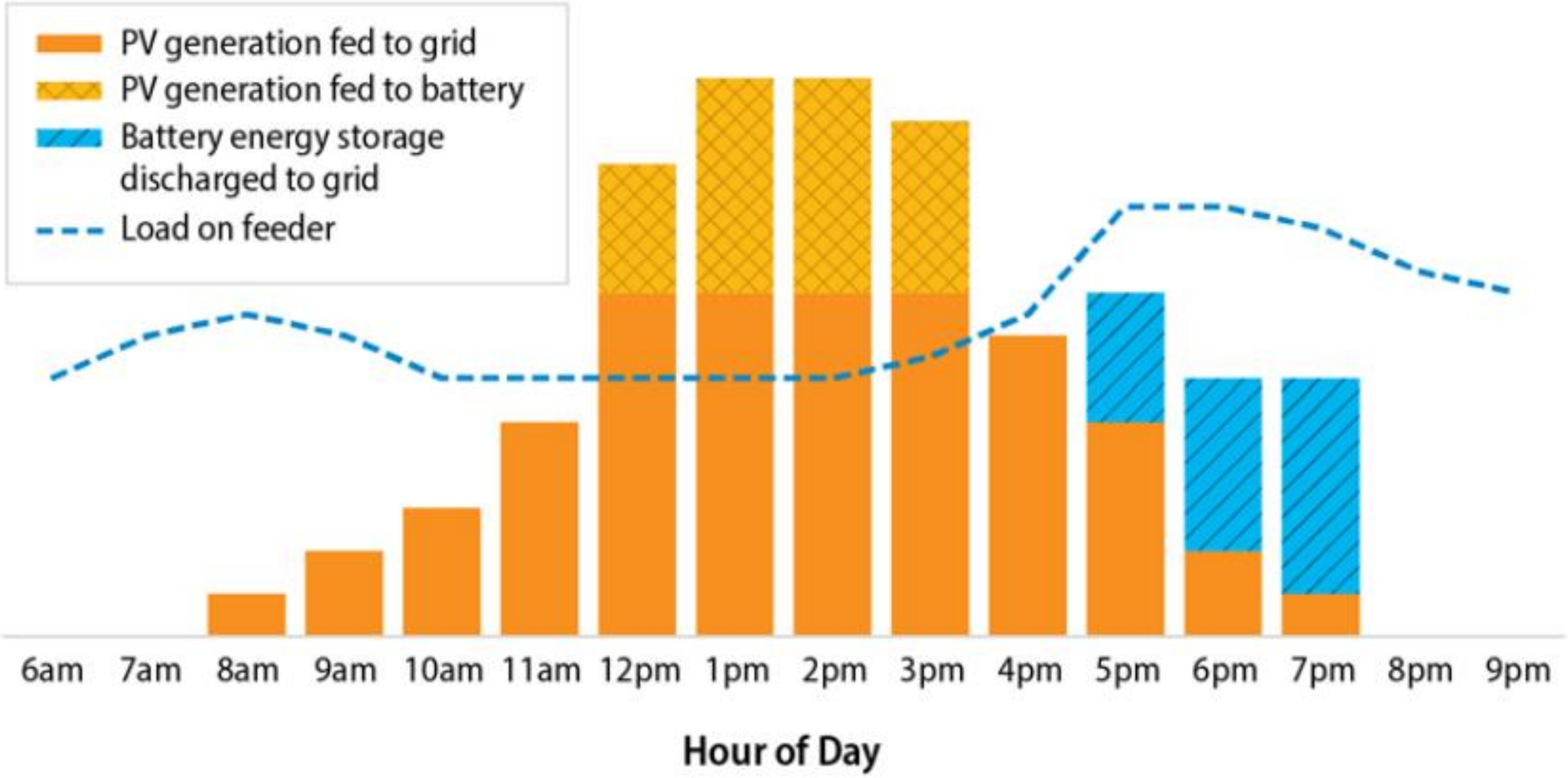
Conditions that can Trigger Grid Violations



Conditions that can Trigger Grid Violations



One Way to Remedy Grid Violations



Overview of the Analysis

TECHNICAL ANALYSIS

1 **IDENTIFY** grid violations →

- Overvoltage
- Undervoltage
- Line overloads
- Transformer overloads

2 **MITIGATE** grid violations →

- Infrastructure upgrades
- Reduction in PV system size
- Curtailment of PV
- Battery storage

3 **TECHNICAL PARAMETERS** of the OEA

- Maximum export for each hour of the year

ECONOMIC ANALYSIS

1 **COMPARE** the cost and revenue from the strategies that mitigate violations →

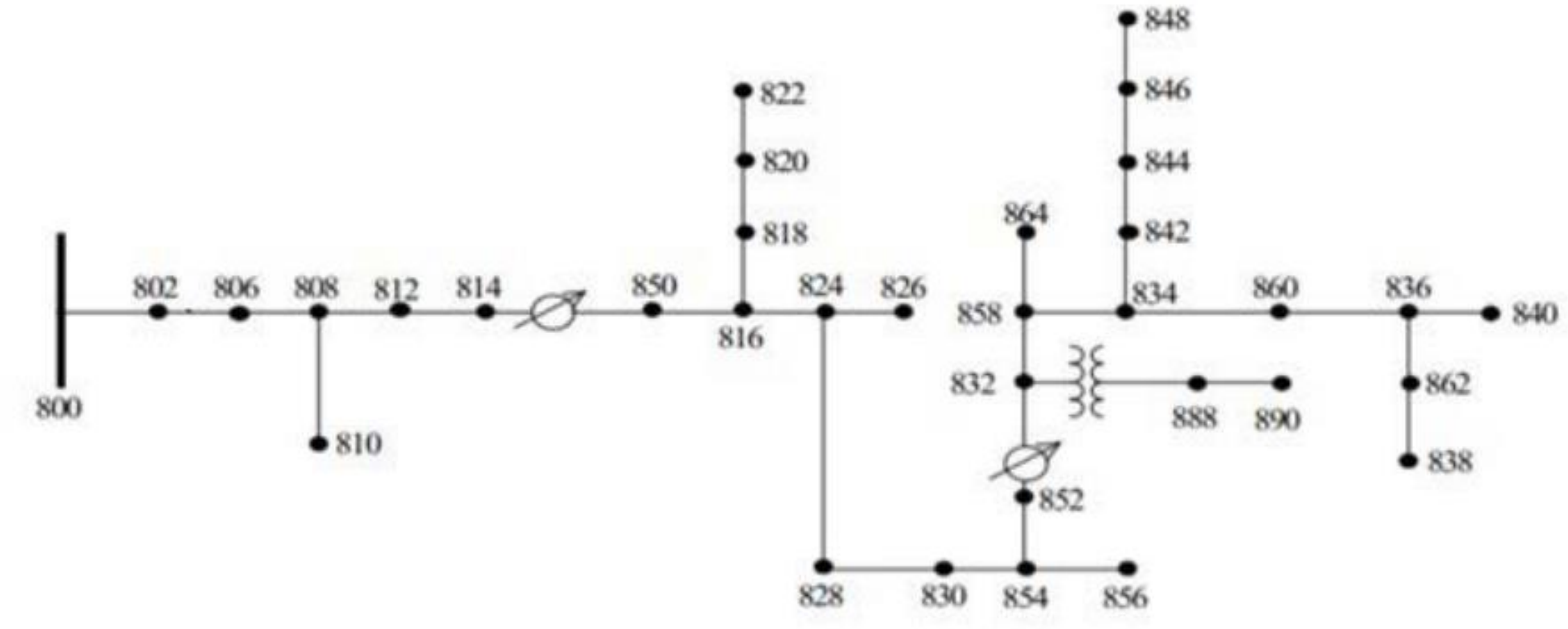
2 **CONDUCT** sensitivity analyses →

- Battery sizes
- Battery prices
- Future electricity market scenarios

3 **SELECT** economically preferred system design

- Net Present Value;
- Break-even infrastructure upgrade costs
- Break-even battery storage costs

IEEE Feeder Model Used in the Analysis



Identify violations for originally proposed PV size → Identify PV size that does not cause violations → Identify an export level that does not cause violations → Define OEA technical parameters

Output Metrics from Time-Series Analysis

	Time-Series Output Metrics	Description
M1	Maximum voltage (per unit)	Maximum voltage magnitude across all nodes in the network that experience overvoltage violations
M2	Minimum voltage (per unit)	Minimum voltage magnitude across all nodes in the network that experience undervoltage violations
M3	Maximum transformer loading (per unit)	Maximum loading observed across all transformers in the network that experience overloading
M4	Maximum line loading (per unit)	Maximum loading observed across all lines in the network that experience overloading
M5	Duration of occurrence of violations for each month in a year	This metric gives the total number of hours that the system experienced different kinds of violations for every month
M6	Duration of occurrence of violations for each week in a year	This metric gives the total number of hours that the system experienced different kinds of violations for every week
M7	Duration of occurrence of violations by hour of day	This metric gives the total number of hours that the system experienced different kinds of violations for every hour of the day, across the whole year

Power-Flow Modeling Scenarios

	SCENARIO	Description/Purpose
S1	Load-only	Tests the feeder model to ensure that there are no pre-existing violations or errors prior to beginning scenario analysis.
S2	Originally proposed PV size	Tests for violations due to the originally proposed PV system size, which represents the system as originally proposed by a PV developer in the interconnection request. For the purposes of this analysis, this scenario is designed to result in violations.
S3	Originally proposed PV size with smart inverter controls	Tests for violations due to the originally proposed PV system size, with advanced inverter controls enabled (volt-VAR), in accordance with IEEE Standard 1547. For this analysis, this scenario is designed to result in violations. The goal is to quantify the impact of advanced inverter controls in alleviating violations.
S4	Downsized PV system	This scenario is used to identify and verify the PV system size that does not cause violations on the feeder. A downsized PV system size is estimated, based on the violations from scenarios 2 and 3. An iterative process is used to identify and confirm the system size that does not cause violations in any hour of the year.
S5	Constant injection of generation to simulate a battery energy storage discharge to the grid	This scenario is used to ensure that the addition of a battery to mitigate PV violations will not cause additional violations by discharging to the grid (e.g., in hours of low PV production). It determines the maximum allowable constant injection at the point of interconnection. An iterative process identifies and confirms the battery size that does not cause violations in any hour of the year, despite when the battery is discharged.

Derived Operating Envelope (max allowable kW export)

	0:00–10:00	11:00	12:00	13:00	14:00– 23:00
January	990	990	1004	991	990
February	990	1015	1067	1034	990
March	990	1045	1088	1049	990
April	990	1042	1072	1023	990
May	990	1016	1041	995	990
June	990	990	1010	990	990
July	990	990	1017	990	990
August	990	1003	1037	995	990
September	990	1038	1062	1005	990
October	990	1009	1021	990	990
November	990	991	996	990	990
December	990	990	990	990	990

Variations of Operating Envelope Agreement

	Simple OEA →		Complex OEA
Month of Violation	**Enforcement during entire year**	**Enforcement during certain season(s)**	**Enforcement during specific months**
Analysis Indicators	*Violations occur in most months*	*Violations occur regularly during certain seasons*	*Violations are clustered in a few months*
Hours of Violation	**Enforcement 24-hours/day**	**Enforcement sunrise to sunset**	**Enforcement during specific hours of day**
Analysis Indicators	*Violations occur in most months*	*Violations occur throughout day*	*Violations are clustered during specific hours*
Magnitude of Violation	**Zero export to grid during enforcement**	**Single maximum export during enforcement**	**Maximum export limits may vary over the year**
Analysis Indicators	*Violations are large in magnitude*	*Violations are consistent in magnitude*	*Violations vary predictibly in magnitude across the seasons*

Terms and Conditions

Performance validation and data reporting

Term of the agreement and changes to the agreement

Non-compliance, enforcement, liability, and dispute resolution

Changes in ownership

Performance Validation

- How will performance be verified?
- Why, how, and when are systems treated differently?
- Must positively demonstrate compliance
- What are current and anticipated standards for inverters?
- If backstop compliance is needed, which technology is appropriate?
- What level of monitoring is appropriate?

Term and Changes

- Similar to ISA, OEA term is lifetime of system
- Changes may necessitate a restudy

- The utility can <u>require</u> a change if:
  - System size or components change
  - Repeat non-compliance

- The utility can <u>request</u> a change if:
  - Mutual benefit and system owner agrees (default to original OEA otherwise)

- The system owner can <u>request</u> a change if:
  - Changes in market conditions
  - Considering changes to the system
  - Changes in technology or resources

Non-Compliance

- Non-compliance
  - Discovered via investigation of a grid violation or through performance validation
  - Mis-operation
  - Inadvertent export
- Enforcement through disconnection
  - Immediate or planned, coupled with financial penalty for gross violations
- How will liability for damages will be assessed and compensated?
- How will dispute resolution be handled?

Changes in Ownership

- What are expectations and process for a change in system ownership?

- Examples of information that may be maintained:
  - Administrative contact information
  - Information required for tax purposes
  - Operations contact in case of emergency
  - Affirmation that the new system owner understands and agrees to the OEA, etc.

- May include clause describing penalties for lapsed information

Economic Analysis Methodology

Option (1) Downsized PV System

Option (2) 3.3 MW PV with infrastructure upgrade costs

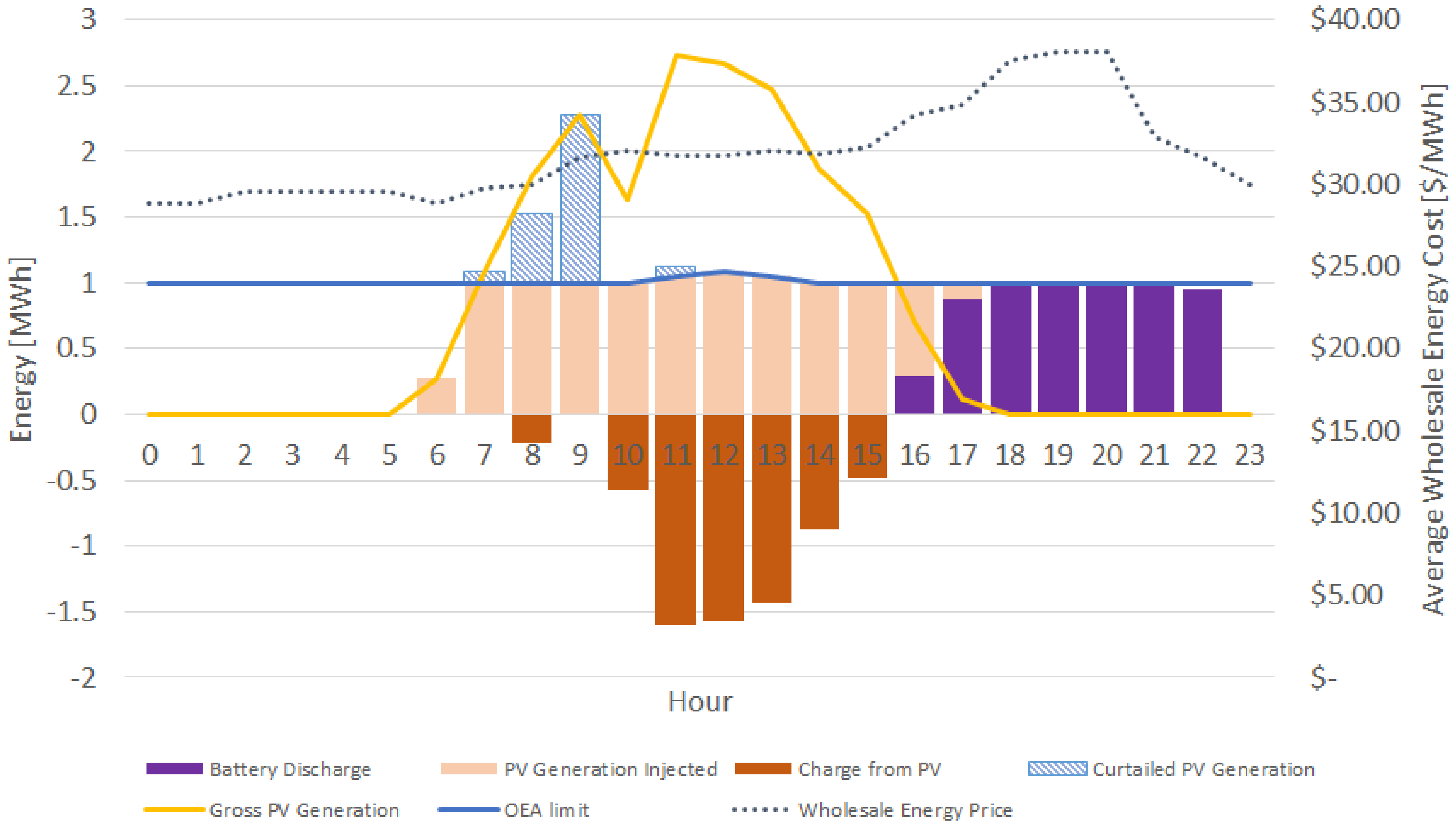
Option (3) 3.3 MW PV with curtailment to adhere to Operating Envelope

Option (4) 3.3 MW PV using battery and curtailment to adhere to Operating Envelope

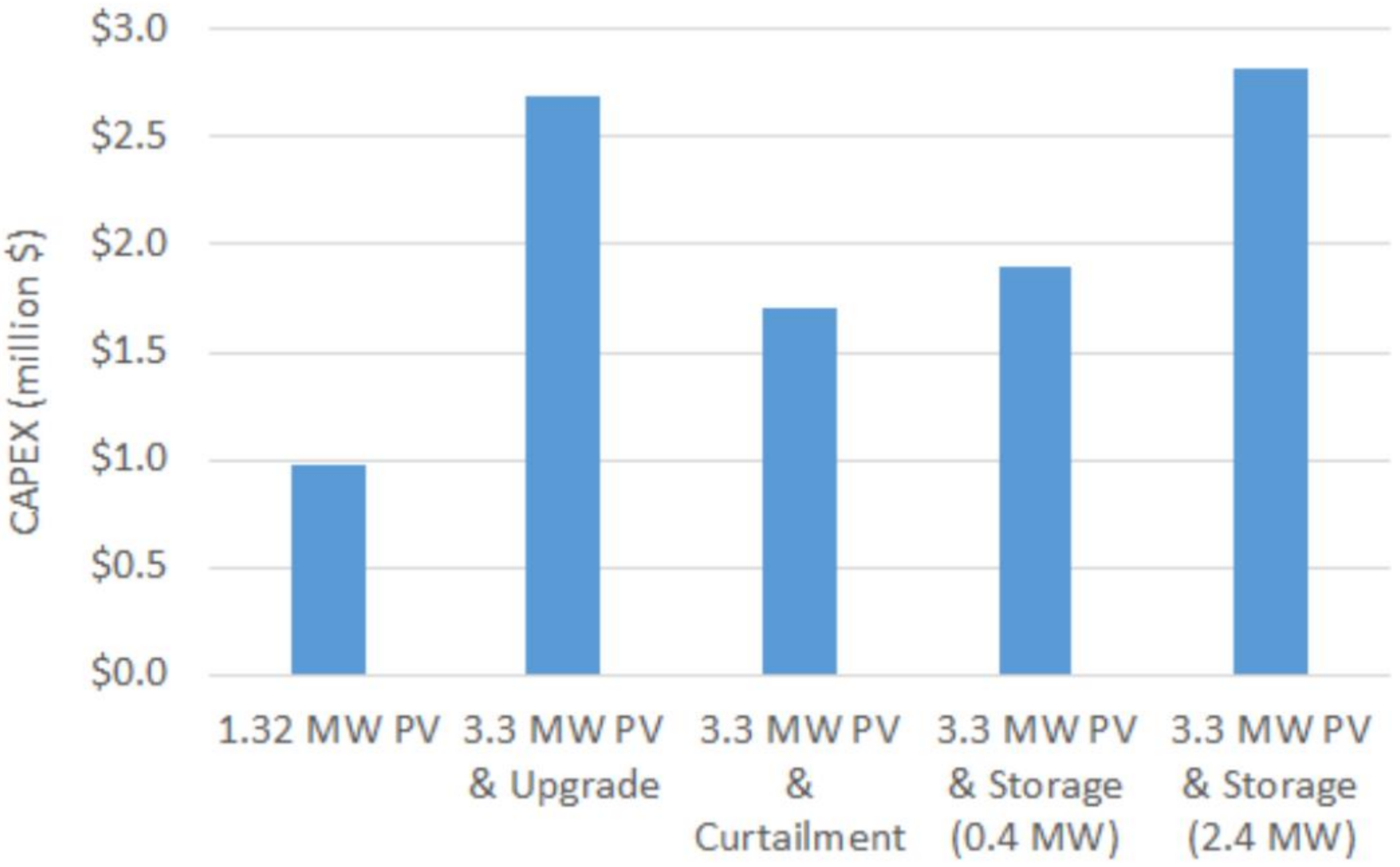
Assumptions

Variable	Base Case Value
Solar PV system size	*Option 1*: 1.32 MW *Options 2–4*: 3.3 MW
Storage size	*Option 4 only* Rated capacity: 0–2.4 MW Rated Power: 4x rated capacity (4-hour duration)
Solar PV capital costs	$1/W (DC STC)
Incremental storage costs	$1,250/kW (ATB 2021 battery storage CAPEX, 4-hour, advanced)
Discount rate	5%
PV degradation rate	0.5% per year
Battery degradation rate	3% per year
Battery depth of discharge	95%
Battery roundtrip efficiency	90%

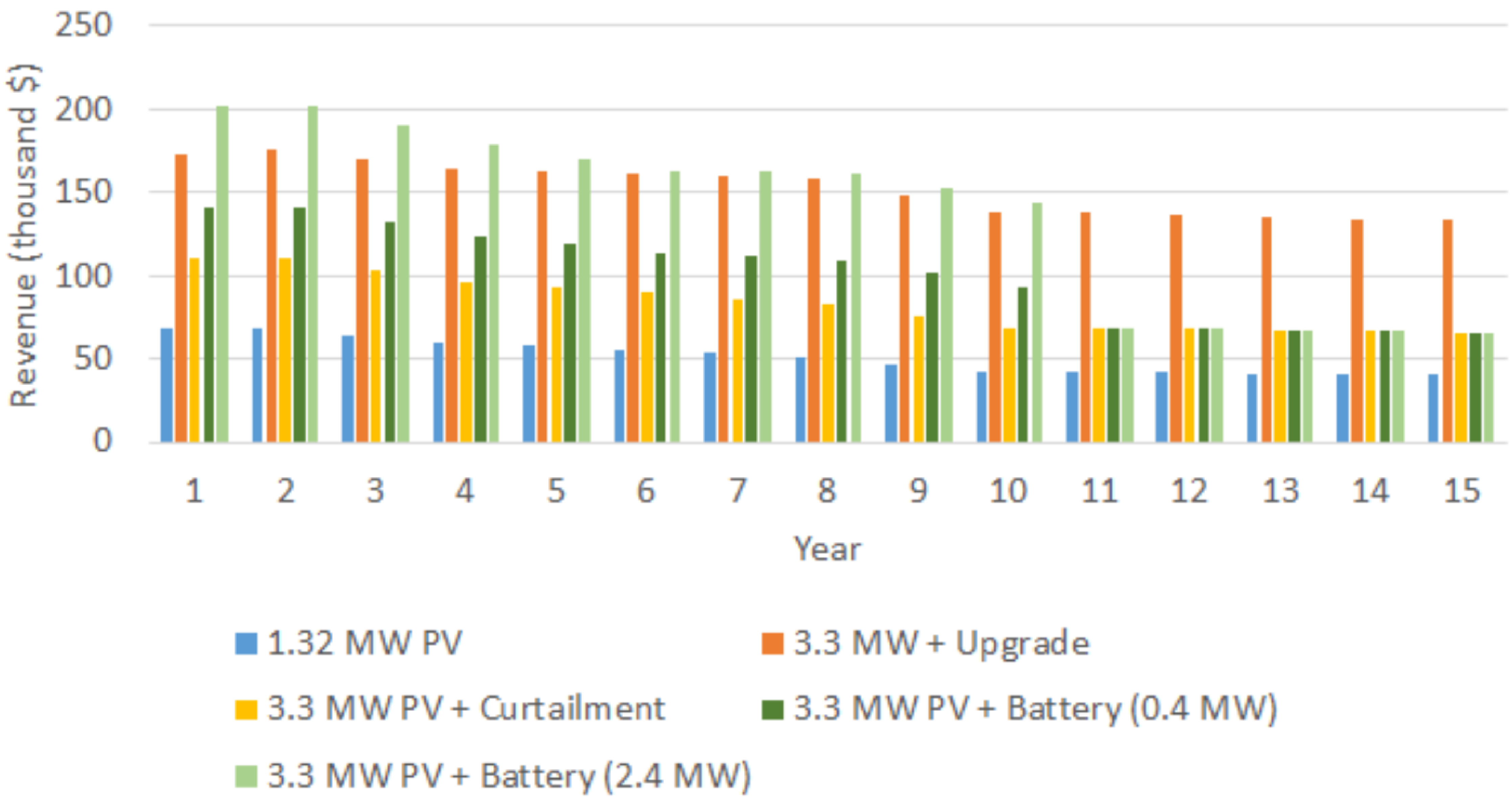
Example Output



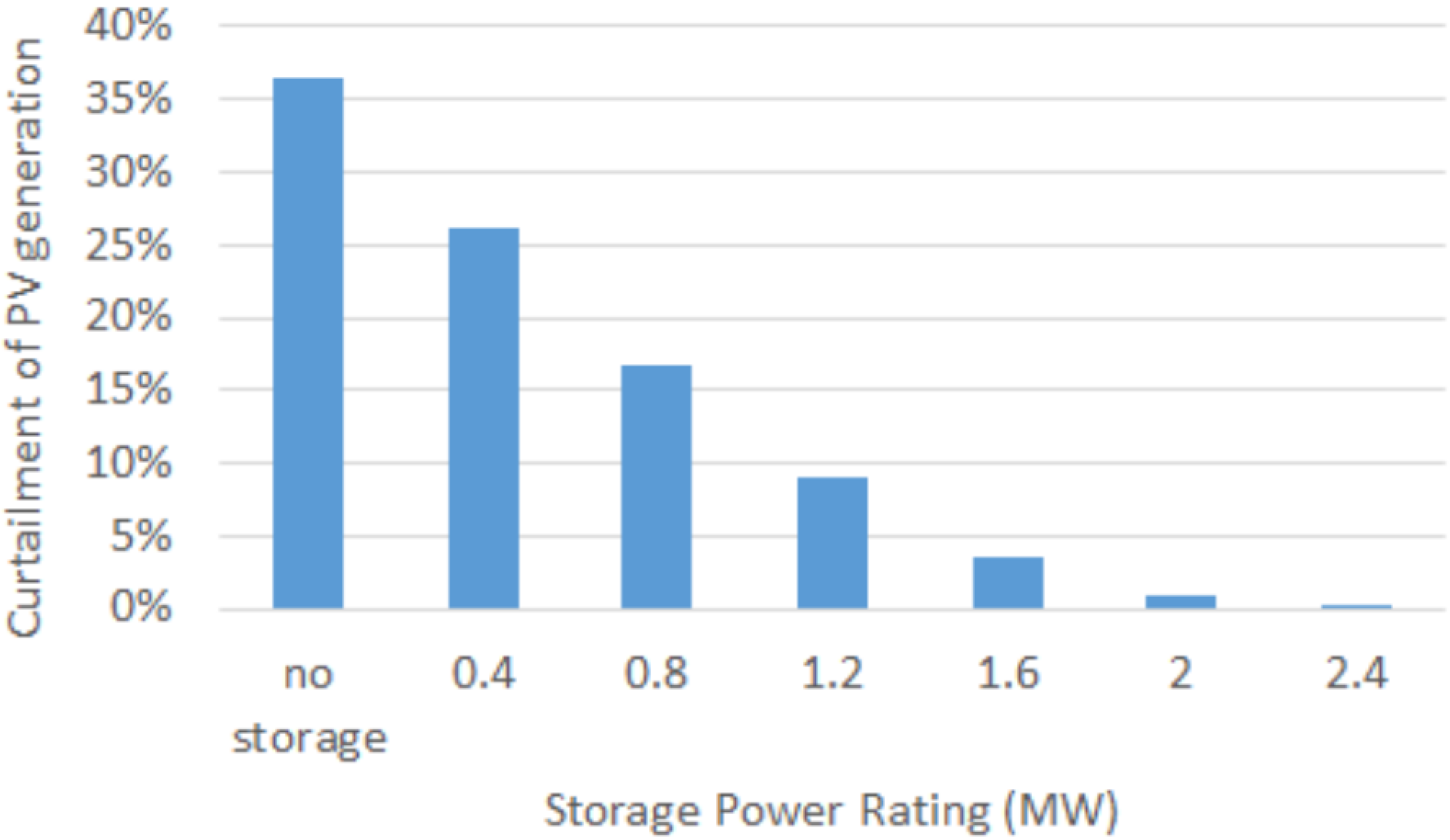
Upfront Costs



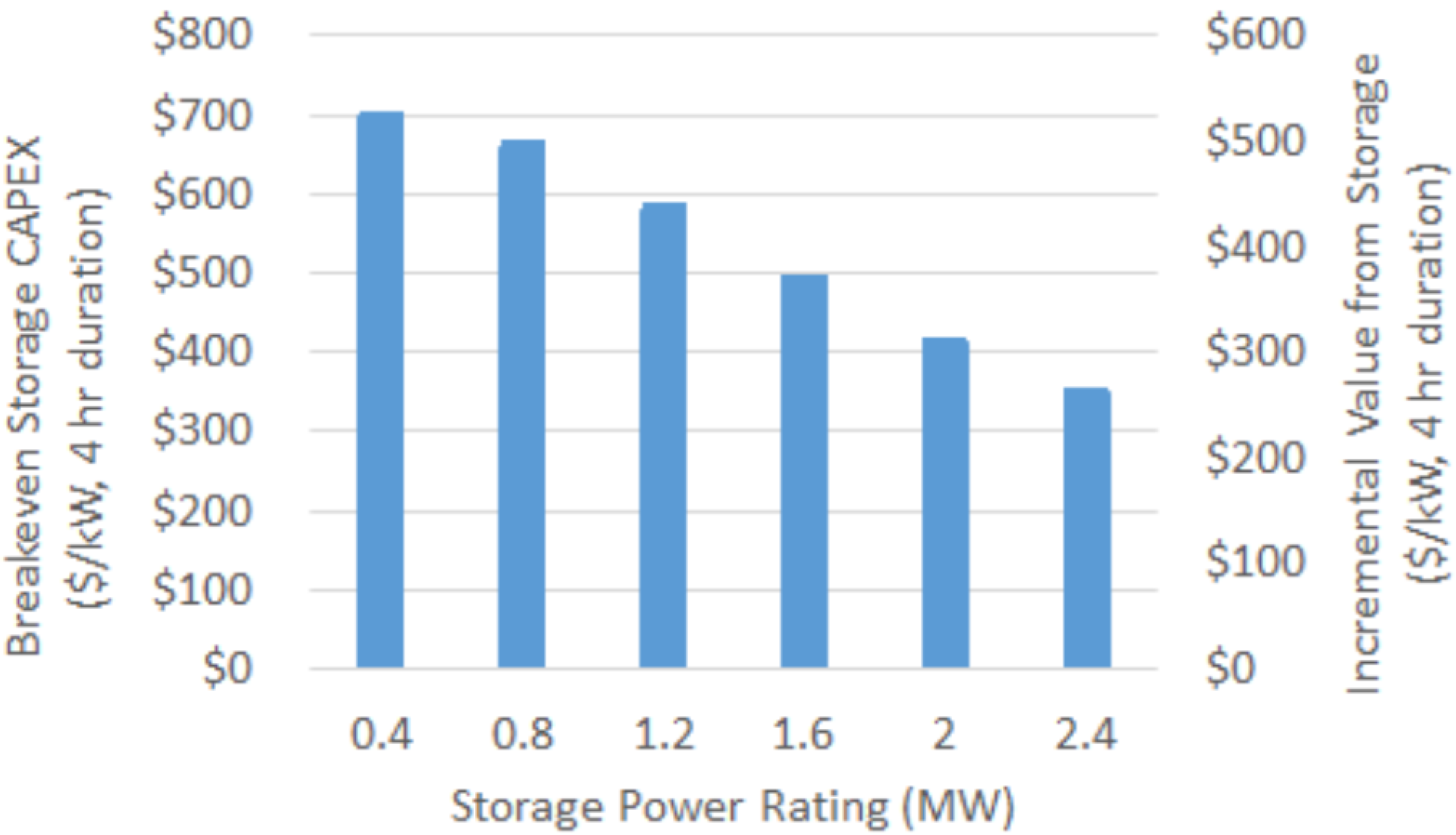
Annual Revenue



Curtailment of PV Generation by Storage Size



Breakeven Storage Costs



Revenues Under Sensitivity Cases

		CAPEX (million $)	Base Case		Renewable Cost Sensitivity		Storage Cost Sensitivity	
Option #	Description	PV cost $1/W 4 hr storage cost $1,250/kW	Revenue 2020 (thousand $)	Revenue 2030 (thousand $)	Revenue 2020 (thousand $)	Revenue 2030 (thousand $)	Revenue 2020 (thousand $)	Revenue 2030 (thousand $)
1	1.32-MW PV, downsized to avoid grid violations	0.98	68	55	67	47	68	56
2	3.3-MW PV + infrastructure upgrade costs of $148,500	2.69	171	139	167	119	170	140
3	3.3-MW PV + curtailment to avoid violations	1.71	111	90	108	76	110	91
4a	PV + 0.4-MW / 4-hour battery	1.89	141	123	137	111	140	121
4b	PV + 2.4-MW / 4-hour battery	2.82	203	190	197	185	200	185

Adopting this Concept

- Could future discussions about your interconnection tariff include these concepts?
- How might an existing interconnection service agreement be modified?
- Specify process for everyone:
  - Developer design
  - System impact study outputs
  - Final operating envelope technical parameters
  - Negotiate terms and conditions

Next Steps

- Are you considering implementing an operating envelope agreement?
- Please let us know!!
    - SEIN@NREL.gov

Citations

Gill, Carrie, Shauna Beland, Ryan Constable, Tim Roughan, Caitlin Broderick, Stephen Lasher, Joyce McLaren, Sherin Abraham, Anthony Teixeira, Naïm Darghouth, and Sydney Forrester. 2022. Use of Operating Agreements and Energy Storage to Reduce Photovoltaic Interconnection Costs: Conceptual Framework. Golden, CO: National Renewable Energy Laboratory. NREL/TP-7A40-81960. https://www.nrel.gov/docs/fy22osti/81960.pdf.

McLaren, Joyce, Sherin Abraham, Naïm Darghouth, and Sydney Forrester. 2022. Use of Operating Agreements and Energy Storage to Reduce Photovoltaic Interconnection Costs: Technical and Economic Analysis. Golden, CO: National Renewable Energy Laboratory. NREL/TP-7A40-80556. https://www.nrel.gov/docs/fy22osti/80556.pdf.

Thank you for attending our webinar

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Upcoming Webinars

How CEG and CT Green Bank are Helping Connecticut Affordable Housing Facilities Install Resilient Solar+Storage
Tuesday, March 29, 3-4:30pm ET

The Governance of Wholesale Power Markets
Tuesday, April 12, 2-3pm ET

An Introduction to the Solar Power in Your Community Guidebook
Thursday, April 14, 1-2pm ET

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