CO2 Emissions Implications of Using Electricity Storage in California

Proposed Evaluation Methodology

The California Energy Storage Alliance (CESA) with Jim Eyer

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Background

» Project Purpose
  - Estimate CO2 emissions implications of storage use, as operated in the Bulk Peaker modeling by EPRI in the AB2514 Cost Effectiveness proceeding
  - Create a CO2 evaluation methodology based upon clear principals of operation for existing assets versus a generic storage device.
  - Open a discussion about CO2 reduction potential due to storage operation when operated as capacity, regulation, and/or spinning reserve.

» Project Scope
  - ☐ Spinning Reserve Service Evaluation
  - ☐ Frequency Regulation Service Evaluation
  - ☐ Generation (energy) Service Evaluation
  - ☐ Combined Results

» Presentation Objective
  - Convey approach used to evaluate CO2 emissions implications of storage use
  - Request comments on approach

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Clarifications and Assumptions

- Evaluation has not been completed at a system level. We propose a methodology based upon simplified substitution of traditional grid asset capacity with energy storage.
- Charging and discharging emissions are currently based on the marginal grid heat rate.
- Evaluation does not include the additional CO2 reduction benefit which could be allocated to a storage device due to increased renewable deployment expected in the future.
- Evaluation does not cover non-CO2 GHG benefits provided by an energy storage resource deployed on the grid.
- Current evaluation only includes operation of the storage device as modeled by EPRI with the ESVT tool in the Bulk Peaker Base Case.
- Inputs and approach have not been validated through public comment or review; we do invite such comment.

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Approach Overview

» Three complementary, separate evaluations
  - Two generic ancillary services evaluations
    1. spinning reserves
    2. frequency regulation
       - two resource configurations: with and without storage
       - generic generation resources (state-of-the-art CT and CCGT)
  - Production cost modeling for actual energy dispatch using marginal grid heat rate from DER model

» Combine evaluations into one framework using dispatch profile from Bulk Peaker Base Case as modeled by EPRI using ESVT

» Intended Results: high level estimate of CO2 emissions implications of storage use

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Ancillary Services Evaluation: Assumptions

Generation Assumptions

Criterion	CT	CCGT	Note
Model	LMS100 SAC	Frame 7FA?	LMS100 SAC from E3.
Rated Power (MW)	100	500	Assumed.
Heat Rate (Btu/kWh, ISO)	8,628	6,940	From E3.
Ambient Operating Temp. (^{o}F)	77	59	Average during operation.
Temp.-related Penalty (%)	3.66%	0.00%	Increased fuel use per kWh for avg. temp > 59 ^{o}F.
Temp.-adjusted Heat Rate (Btu/kWh)	8,944	6,940	ISO heat rate plus efficiency penalty
Part Load Penalty (%)	1.14%	1.14%	For 90% loading: average of 80% & 100% from E3.
Adjusted Heat Rate 2 (Btu/kWh)	9,046	7,019	Adjusted for temperature and part load.
Ramping Penalty	0.30%	0.30%	For 5% per hour ramp, so probably conservative.
Adjusted Heat Rate 3 (Btu/kWh)	8,971	6,961	Adjusted for temperature and ramping.
Adjusted Heat Rate 4 (Btu/kWh)	9,073	7,040	Adjusted for temperature, part load and ramping.

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Spinning Reserves: Evaluation Assumptions

		CT	CCGT	Storage
Generation Only	Rated Capacity (MW)	50	500	
	Service Type 1	Peaking	Baseload	
	Service Power (MW)	50	450	
	Loading[1] (%)	100%	90%	
	Service (Hours/year)	240	8,760	
	Ramping?	no	no	
	Operation (Hours/year)	240	8,760	
	Service Type 2		Reserves	
	Service Power (MW)		50	
	Loading[1] (%)		0.23%[2]	
	Service (Hours/year)		8,760	
	Ramping?		no	
	Operation (Hours/year)		20	

		CT	CCGT	Storage
Generation Plus Storage	Rated Capacity (MW)		500	50
	Service Type 1		Baseload	Reserves
	Service Power (MW)		450	50
	Loading[1] (%)		100%	0.23%[2]
	Service (Hours/year)		8,760	8,760
	Ramping?		no	n/a
	Operation (Hours/year)		8,760	20
	Service Type 2		Peaking	
	Service Power (MW)		50	
	Loading[1] (%)		100%	
	Service (Hours/year)		240	
	Ramping?		no	
	Operation (Hours/year)		240	

1. Loading of the portion of capacity allocated to service power.
2. Reflects 20 hours/year for spinning reserves service during 8,760 hours/year.

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Spinning Reserves Evaluation Results

Emissions Results Summary				
	000 Lbs/Year	Tons/Year	Tons/MW-yr	
Difference	-34,578	-17,289	**-346**	<= value used for the analysis.
Net Change	-1.1%	=> a reduction.		

Resource Configuation1 -- Spinning Reserve Resource: CC, Baseload Gen. Resource: CC, Peaker Type: CT									
Service	Service	Operation	Resource	Power	Heat Rate	*Energy*	*Emissions*		
Type	Hours/Year	Hours/Year	Type	MW	Btu/kWh	MWh/Year	Lbs/kWh	000 Lbs/Year	Tons/Year
Peak	240	240	CT (full load)	50	10,000	12,000	1.17	14,040	7,020
Spinning Reserve	8,760	20	CC (part load)	50	6,450*	1,000	0.75	755	377
Baseload	8,760	8,760	CC (part load)	450	6,515	3,942,000	0.76	3,004,579	1,502,289
Totals		9,020		550	6,525	3,955,000	0.8	3,019,373	1,509,687

*Assume energy for Spinning Reserve service is provided by a CC operating at full load.

Resource Configuation2 -- Spinning Reserve Resource: Storage, Baseload Gen. & Peaking Resource: CC									
Service	Service	Operation	Resource	Power	Heat Rate	*Energy*	*Emissions*		
Type	Hours/Year	Hours/Year	Type	MW	Btu/kWh	MWh/Year	Lbs/kWh	000 Lbs/Year	Tons/Year
Peak	240	240	CC (full load)	50	6,450	12,000	0.75	9,056	4,528
Spinning Reserve	8,760	20	Storage	50	7,771*	1,000	0.91	909	455
Baseload	8,760	8,760	CC (full load)	450	6,450	3,942,000	0.75	2,974,830	1,487,415
Totals		9,020		550	6,450	3,955,000	0.8	2,984,795	1,492,398

*Assume energy for Spinning Reserve service is provided by a CC operating at full load. Includes adjustment for 17.0% storage losses.

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Regulation Evaluation Assumptions

- 50 MW of storage
  - 4x efficacy
    - 2x the range – storage can be operated at 50 MW up *and* 50 MW down
    - 2x the benefit – fast response storage has been recognized as providing an equivalent regulation value to multiple traditional CTs
  - Avoided generation
    - 200 MW of CT (peaking)
    - CCGT part-load operation (90%)
- 8760 hours (to be consistent with EPRI results)

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Regulation Evaluation Assumptions

	Resource Type	CT	CCGT	Storage
	Rated Power (MW)	200	2,000	
Generation Only	Service Type 1	Peaking	Baseload	
	Service Power (MW)	200	1,800	
	Loading (%)	100%	90%	
	Service (hours/year)	240	8,760	
	Ramping?	no	yes	
	Service Type 2		Regulation	
	Service Power (MW)		200	
	Loading (%)		50%	
	Service (hours/year)		8,760	
	Ramping?		yes	

	Resource Type	CT	CCGT	Storage
	Rated Power (MW)		2,000	50
Generation Plus Storage	Service Type 1		Baseload	Regulation
	Service Power (MW)		1,800	200*
	Loading (%)		100%	25%
	Service (hours/year)		8,760	8,760
	Ramping?		no	n/a
	Service Type 2		Peaking	
	Service Power (MW)		200	
	Loading (%)		100%	
	Service (hours/year)		240	
	Ramping?		no	

*Storage is assumed to be 4x as effective as generation for frequency regulation service: 2x up plus 2x down.

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Regulation Evaluation

Resource Configuation 1 -- Generation Only Frequency Response Service										
Service Type	Resource Type	Name-plate Power (MW)	Service Power (MW)	Average Loading During Service	Annual Operation Hours	Energy (MWh/Yr)	Heat Rate (Btu /kWh)	CO2 Emissions		
								Lbs. /MWh	Tons /Year	Tons /MWh
Peaking	LMS100 SAC	2 @ 100	200	90%	240	43,200	9,073	1,061.5	22,929	0.530770
Baseload	CC @ Part Load	4 @500	1800	90%	8,760	14,191,200	7,040	823.7	5,844,438	0.411835
Reg Up			100	50%	8,760	438,000	7,040	823.7	180,384	0.411835
Reg Down			100	50%	8,760	438,000	7,040	823.7	180,384	0.411835

Service		Nameplate Power	Service Power		Energy To Grid		CO2 Tons /Year	
Generation		2,000	2,000	Energy from peaking and baseload gen output.	14,234,400		5,867,367	Tons
Regulation		200	200		876,000		360,768	Per MWh
Total		**2,200**	**2,200**		**15,110,400**		**6,228,135**	**0.4122**

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Regulation Evaluation

» Generation & Storage (with storage losses)

Resource Configuation 2 -- S ation Frequency Respo										
Service Type	Resource Type	Name-plate Power (MW)	Service Power (MW)	Loading During Service	Annual Operation Hours	Energy To Grid (MWh/Yr)	Heat Rate	CO2 Emissions Lbs. /MWh	CO2 Emissions Tons /Year	CO2 Emissions Tons /MWh
Peaking	CC @ Full Load	4 @ 500	200	90%	240	43,200	7,040	823.7	17,791	0.411835
Baseload			1,724 *	100%	8,760	15,104,430	6,940	812.0	6,132,248	0.405990
Reg Up	Storage	1 @ 50[1]	100 [2]	25% [3]	8,760	n/a	n/a	n/a	n/a	n/a
Reg Down			100 [2]	25% [3]	8,760	-37,230 [4]	7,040 [5]	823.7	15,333	0.411835

* For ENERGYgeneration. Provides a total of 1,800 MW of CAPACITY.
1. The same capacity provides both up and down.
2. Reflects 2.0x efficacy of storage as a regulation resource, both up and down.
3. This value is applied to the SERVICE power, not nameplate.
4. "Make-up" energy to offset storage losses.
5. Energy from CC, includes penalty for part load and ramping, if any.

energy for storage losses, if any, assumed to be from CC at part load w/ramping

CO2 for reg down due to storage losses

Service		Nameplate Power (MW)	Service Power (MW)		Energy To Grid (MWh)		CO2 Tons /Year	
Generation		2,000	1,924*	Energy from peaking and baseload gen output.	15,147,630		6,150,039	Tons
Regulation		50	200 [1]		-37,230		15,333	/MWh
Total		**2,050**	**2,124**		**15,110,400**		**6,165,371**	**0.4080**

* For ENERGYgeneration. Provides a total of 2,000 MW of CAPACITY.
1. Same capacity provides 50 MW up AND down. Also reflects 2.0x efficacy of storage as a regulation (up and down) resource.

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Regulation Evaluation

» Generation & Storage (without storage losses)

Resource Configuation 2 -- S ... ation Frequency Response Service										
								CO2 Emissions		
Service Type	Resource Type	Name-plate Power (MW)	Service Power (MW)	Loading During Service	Annual Operation Hours	Energy To Grid (MWh/Yr)	Heat Rate	/MWh	/Year	s /MWh
Peaking	CC @ Full Load	4 @ 500	200	90%	240	43,200	7,040	823.7	17,791	0.411835
Baseload			1,720 *	100%	8,760	15,067,200	6,940	812.0	6,117,133	0.405990
Reg Up	Storage	1 @ 50 [1]	100 [2]	25% [3]	8,760	n/a	n/a	n/a	n/a	n/a
Reg Down			100 [2]	25% [3]	8,760	n/a [4]	n/a [5]	n/a	n/a	n/a

* For ENERGYgeneration. Provides a total of 1,800 MW of CAPACITY.

1. The same capacity provides both up and down.
2. Reflects 2.0x efficacy of storage as a regulation resource, both up and down.
3. This value is applied to the SERVICE power, not nameplate.
4. "Make-up" energy is not included.
5. Energy from CC, includes penalty for part load and ramping, if any.

energy for storage losses, if any, assumed to be from CC at part load w/ramping

CO2 for reg down due to storage losses

Service		Nameplate Power (MW)	Service Power (MW)		Energy To Grid (MWh)		CO2 Tons /Year	
Generation		2,000	1,920*	Energy from peaking and baseload gen output.	15,110,400		6,134,924	Tons
Regulation		50	200 [1]		0		0	/MWh
Total		**2,050**	**2,120**		**15,110,400**		**6,134,924**	**0.4060**

* For ENERGYgeneration. Provides a total of 2,000 MW of CAPACITY.

1. Same capacity provides 50 MW up AND down. Also reflects 2.0x efficacy of storage as a regulation (up and down) resource.

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Regulation Results

» Net CO2

– Generation Only including storage losses

Emissions Results Summary			
	Tons/year	Tons/MW-yr	
Emissions Reduction	-62,763	-1,255*	
Net Change	-1.01%	=> a reduction.	
* For 50 MW.			

Versus

– Generation & Storage without storage losses

Emissions Results Summary			
	Tons/year	Tons/MW-yr	
Emissions Reduction	-93,211	-1,864*	**<= value used for the analysis.**
Net Change	-1.50%	=> a reduction.	
* For 50 MW.			

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Production Cost Evaluation

- EPRI ESVT Bulk Peaker Base Case
- 8760 hours
- Energy input to and output from storage
  - regulation service
  - “generation” service
    - apparently spinning reserves implications are trivial?
- Related emissions based on hourly energy use/production and heat rate
- Incorporate results from the two separate ancillary services evaluations, emissions

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Production Cost Results

	Energy (from/to grid)							
	Regulation Service				*Generation Service*			
	Charging		*Discharging*		*Charging*		*Discharging*	
Energy (MWh/year)	29,281		13,786		74,701		70,950	
Capacity Factor	0.067		0.031		0.171		0.162	
Usage (hrs./yr)	6,942		1,586		1,616		1,700	
	Energy Stored (MWh)	Tons Emitted	Energy to Grid (MWh)	Tons Offset	Energy Stored (MWh)	Tons Emitted	Energy to Grid (MWh)	Tons Offset
Avg.–Service Hrs.	4.22	1.93	8.7	4.03	46.23	21.02	41.7	19.85
Avg.– Annual Hrs.	3.34	1.53	1.57	0.73	8.53	3.88	8.10	3.85
	Total	13,419	Total	6,393	Total	33,971	Total	33,739

	Energy to Grid (MWh)	Annual Tons
Storage Charging*	-103,982	-47,390
Storage Discharging	84,736	40,131
Net Increase (Tons)		-7,258

* Negative MWh values indicate charging energy into storage (from the grid) and negative emission value indicates tons of CO2 output for generation of charging energy.

Discharge Hours (full load equivalent)	1,695	=> 19.3% capacity factor
Energy Losses (MWh)	-19,246	=> 81.5% storage efficiency

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Ancillary Services Results

» The two ancillary services evaluations' results were combined with production cost results

	Ancillary Services					
	Spin		*Reg Up*		*Reg Down*	
Avoided Emissions (tons/MW/year)	374		932		932	
(tons/MW-service-hour)	0.04269		0.10639		0.10639	
Service (MW-service hours)	131,532		223,418		338,299	
"Service Factor"	0.300		0.510		0.772	
Usage (hrs./yr)	6,420		5,049		8,026	
	MW Service	Tons Avoided	MW Service	Tons Avoided	MW Service	Tons Avoided
Avg.–Service Hrs.	20.5	0.87	44.2	4.71	42.2	4.48
Avg.–Annual Hrs.	15.0	0.64	25.5	2.71	38.6	4.11
	Total	5,616	Total	23,770	Total	35,992

Avoided Emissions (tons/MW/year) / Annual Hours

Regulation avoided CO2 emissions total = 1,864 tons/MW -year.

Sum of annual hourly MW (of) Service values

MW Service Hours	Tons Avoided
693,248	65,378

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Results Summary

Results Summary	
	tons/year
Avoided Emissions for Ancillary Services	65,378
Net Increase for Energy (from/to grid)	-7,258
Net Reduction	58,120

Totals	Annual	Per MWh Discharged*	Per MW-year**
Emissions Reduction (Tons)	58,120	1.458	1,162
Automobile Equivalent (Auto-years)	10,338	8.20	207

* Total Energy to Grid = 84,736 MWh: 13,786 MWh for Regulation, + 70,950 MWh for Energy.

** Storage power = 50 MW

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Observations and Conclusions

» Based on results as-is…

- Based upon the current assumptions in this case, storage used for spinning reserves and for frequency regulation will reduce C02 emissions when compared to generic, state-of-the art natural gas fueled generation resources on the margin (state-of-the-art CTs and CCGTs).
- Where energy generation involves less efficient, older, or fossil-fueled generation (especially coal-based), storage may result in increased emissions given higher emissions per kWh generated and storage losses.
- If it is assumed that charging emissions are based upon the grid average heat rate, the CO2 benefits of storage increase. If additional renewables or other non-CO2-emitting resources are deployed on the grid, the CO2 reduction benefits of storage further increase.

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Supporting Slides

- Generation Details
- Summary Results – Ancillary Services
- Summary Results – Energy
- Regulation Evaluation Inputs
- 8760 Data Summary

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Generation Details

	#1	#2	#3	#4
Derate Temperature (°F)	32	50	68	86
Loading Level (%)	40%			
CC Ramping Penalty	0.30%			
Aero CT Ramping Penalty	0.30%			

Blue values are from E3

From GE for LM6000 -PC SPRINT
49.6 MW power output has
8,531 Btu/kWe -Hr heat rate .
That is probably LHV basis?
If so, convert to HHV:
8,513 LHV * 1.108 = 9,455 HHV?

Technology	Default CT	Hybrid CT	Hybrid Sprint	Hybrid "High" Case	LM6000	LM6000 Sprint	LM6000	LM6000 Sprint	LMS100 SAC	CCGT
Year	2015	2015	2015	2015	2015	2015	2020	2020	2020	2020
Rated Power (ISO STC)	--	100	100	100	50	50	50	50	100	500
Rated Heat Rate (HHV, ISO STC)	9,300	9,447	9,387	--	9,447	9,387	9,447	9,387	8,628	6,940
Derated Capacity #1 (32°F)		100	100	--	50	50	50	50	100	500
Derated Capacity #2 (50°F)		92	98	--	46	50.5	46	50.5	101	505
Derated Capacity #3 (68°F)		78	96	--	39	48	39	48	103	515
Derated Capacity #4 (86°F)		64	88	--	32	44	32	44	98	490
Derated Capacity, Average*	--	83.5	95.5	--	41.75	48.125	41.75	48.125	100.5	502.5
Efficiency #1 (32°F)	--	96.9%	100.3%	--	96.9%	100.3%	96.9%	100.3%	100.3%	100.3%
Efficiency #2 (50°F)	--	99.4%	101.7%	--	99.4%	101.7%	99.4%	101.7%	101.7%	101.7%
Efficiency #3 (68°F)	--	104.1%	102.5%	--	104.1%	102.5%	104.1%	102.5%	102.5%	102.5%
Efficiency #4 (86°F)	--	109.7%	104.8%	--	109.7%	104.8%	109.7%	104.8%	104.8%	104.8%
Efficiency "Penalty," Average*	--	2.52%	2.33%	--	2.52%	2.33%	2.52%	2.33%	2.33%	2.33%
Heat Rate Average* (Btu/kWh, HHV)	--	9,685	9,606	--	9,685	9,606	9,685	9,606	8,829	7,102
Part Load 40.0% Loading	--	140.0%	140.0%	--	140.0%	140.0%	140.0%	140.0%	121.6%	121.6%
Fuel 50.0% Loading	--	128.5%	128.0%	--	128.5%	128.0%	128.5%	128.0%	112.5%	112.5%
Use 80.0% Loading	--	105.0%	106.5%	--	105.0%	106.5%	105.0%	106.5%	102.3%	102.3%
100.0% Loading	--	100.0%	100.0%	--	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Part Load 40.0% Loading	--	13,559	13,449	--	13,559	13,449	13,559	13,449	10,738	8,638
Heat 50.0% Loading	--	12,445	12,296	--	12,445	12,296	12,445	12,296	9,933	7,990
Rate 80.0% Loading	--	10,169	10,230	--	10,169	10,230	10,169	10,230	9,030	7,263
(HHV) 90% Loading**	--	9,927	9,918	--	9,927	9,918	9,927	9,918	8,930	7,183
100.0% Loading	--	9,685	9,606	--	9,685	9,606	9,685	9,606	8,829	7,102
Adjusted Heat Rate Average (Btu/kWh, HHV)***	--	9,957	9,948	--	9,957	9,948	9,957	9,948	8,957	7,204

* After accounting for a range of ambient temperatures, average: 59.0°F.
** Average of values for 80% and 100%.
***Accounts for temperature, part load and ramping.

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Summary Results Presentation

» Ancillary Services

AncillaryServices				
ServiceType	Avoided Emissions (Tons/ MW-yr)	Avoided Emissions (Tons per MW/ service hour)	Annual Service Hours EPRI Base Case	Avoided Emissions (tons/yr)
Spin	374	0.0427	131,532	5,616
Reg Up	932	0.1064	223,418	23,770
Reg Down	932	0.1064	338,299	35,992
			Subtotal (tons)	65,378
			Tons/MW*	1,308

* Storage power = 50 MW

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Summary Results Presentation

» Energy to/from Grid

Energy (from/to grid)			
Service/Operation Type		Energy (MWh /Year)	Annual Emissions (tons/yr.)***
Regulation-related Storage Charging		-29,281	-13,419
Regulation-related Storage Discharging		13,786**	6,393
Energy-related Storage Charging		-74,701	-33,971
Energy-related Storage Discharging		70,950**	33,739
	Subtotal	-19,246	-7,258
	Per MW*	-385	-145

* Storage power = 50 MW

** Total Energy to Grid = 84,736 MWh: 13,786 MWh for Regulation, + 70,950 MWh for Energy.

***Negative values indicate 1) energy into storage or 2) CO2 emissions associated with generation of that energy.

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Regulation Evaluation Inputs (1)

Frequency Response Service				
	Override	Default	Value Used	Notes
Service Type Designator	default	Frequenc	Frequency Response	
Generation Type Designator	default	CC	CC	
Operation (Hours/Year)	default	8,760	8,760	
Power, Gen-Only, Reg Up (MW)	default	100	100	CC power allocated to regulation up service
Power, Gen-Only, Reg Down (MW)	default	100	100	CC power allocated to regulation down service
Generation-only Average Loading	default	50.0%	50.0%	for CC power allocated to regulation service
Storage Average Loading	default	25.0%	25.0%	for regulation service, applies to **SERVICE** power

Peaking Generation Service				
	Override	Default	Value Used	Notes
Service Type Designator	default	Peaking	Peaking	
Generation Type Designator	default	LMS100 SA	LMS100 SAC	
Operation (Hours/Year)	240	500	240	20 hours per month, 12 months per year.
Service Power (MW per Unit)	default	100	100	LMS100 CT
Peaking Unit Count	2			
Heat Rate (Btu/kWh)	default	9,073	9,073	LMS100 "adjusted" for temp., part load & ramping
Generation Average Loading	default	90.0%	90.0%	

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Regulation Evaluation Inputs (2)

BaseloadGenerationService	Override	Default	Value Used	Notes
Service Type Designator	default	Baseload	Baseload	
Generation Type Designator	default	CC	CC	
Operation (Hours/Year)	8,760	8,760	8,760	
Service Power (MW per Unit)	default	500	500	
Baseload Unit Count	4			
Heat Rate, Rated (Btu/kWh)	default	6,940	6,940	Full load, at ISO STC. From E3's data.
Temp-related Fuel Efficiency Penalty	0.00%	2.33%	0.00%	Assume 0% based on avg ambient temp = ISO STC.
Heat Rate, Temp-Adjusted (Btu/kWh)	default	6,940	6,940	On average, no temperature-related heat rate penalty.
Generation-only Average Loading	default	90.0%	90.0%	While baeload gen is used for regulation service.
Part Load Fuel Efficiency Penalty	default	1.14%	1.14%	@ 90.0% loading. Derived from E3's data.
Heat Rate, Part Load (Btu/kWh)	default	7,019	7,019	After applying 1.14% part load efficiency penalty.
Ramping Fuel Efficiency Penalty	default	0.30%	0.30%	
Heat Rate Part Load w/Ramping	default	7,040	7,040	After applying 0.30% efficiency penalty for ramping.
Do Energy Balancing	TRUE			i.e., use goal seek for equal scenario energy
Gen-with-Storage Average Loading	100.0%			If storage provides regulation service.

Storage for Frequency Response Service	Override	Default	Value Used	Notes
Storage Type Desingator	default	Storage	Storage	
Storage Power (MW)	default	50	50	Provides 50 MW reg up AND 50 MW down.
Storage Efficiency (%)	83.0%	83.0%	83.0%	
Storage Efficacy Factor	default	2.0	2.0	i.e., 2.0x as effective as gen. NOTE: Up + Down = 4.0x.
Include Storage Energy Losses?	FALSE	TRUE	FALSE	=> FALSE if production cost modelling doesn't account for it.
Show "Value Used" Label?	FALSE	TRUE	FALSE	

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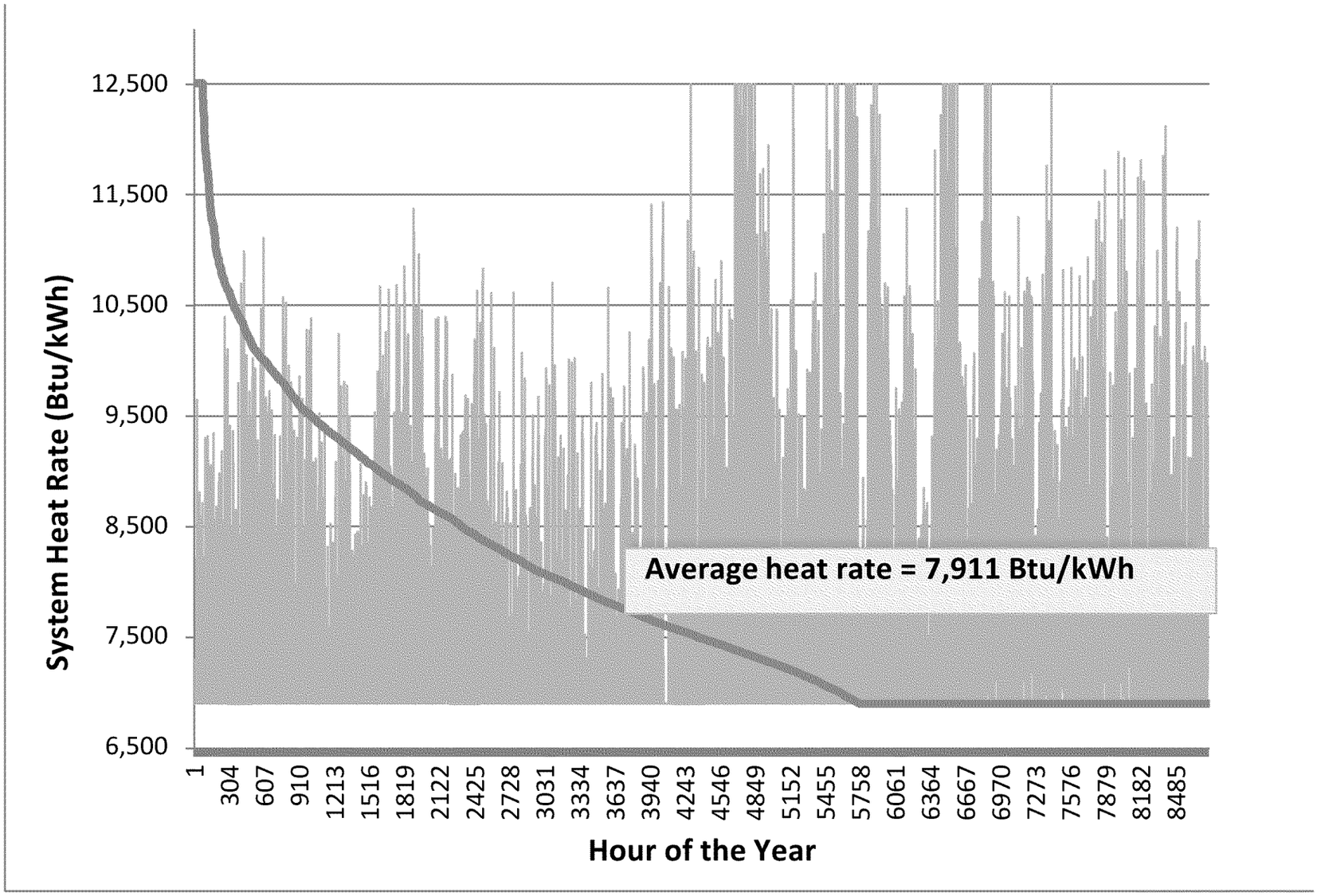
System Heat Rate Plot



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8760 Data Summary

From respective column in data sheet

Spinning Reserves Bid (Discharging)

Regulation Up Bid (Discharging)

Regulation Down Bid (Charging)

From "Regulation Dispatch (kWh)" column in Bid/Dispatch Data sheet.

From "Energy Dispatch (kWh)" Column in Bid/Dispatch Data sheet.

NOTE that 8,754

	Ancillary Service						Heat Rate	Emission Factors		Energy (from/to grid)							
										Charging Reg		*Discharging Reg*		*Charging Gen.*		*Discharging Gen.*	
Hour #	MW	Tons Avoided	MW	Tons Avoided	MW	Tons Avoided	Btu /kWh	Lbs /MWh	Tons /MWh	MWh	Tons Offset	MWh	Tons Offset	MWh	Tons Offset	MWh	Tons Offset
1	50	2.13	0	0.00	0	0.00	7,300	854	0.4270	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
2	28	1.18	22	2.39	50	5.32	6,900	807	0.4037	-4.2	-1.68	0.0	0.00	0.0	0.00	0.0	0.00
3	0	0.00	50	5.32	0	0.00	6,900	807	0.4037	0.0	0.00	11.3	4.58	-50.0	-20.18	0.0	0.00
4	0	0.00	50	5.32	50	5.32	6,900	807	0.4037	-1.0	-0.42	0.0	0.00	0.0	0.00	0.0	0.00
8757	0	0.00	50	5.32	50	5.32	7,583	887	0.4436	-1.0	-0.46	0.0	0.00	0.0	0.00	0.0	0.00
8758	48	2.06	2	0.17	50	5.32	7,249	848	0.4241	-6.5	-2.77	0.0	0.00	0.0	0.00	0.0	0.00
8759	0	0.00	50	5.32	50	5.32	7,468	874	0.4369	-1.0	-0.46	0.0	0.00	0.0	0.00	0.0	0.00
8760	0	0.00	50	5.32	50	5.32	7,124	833	0.4167	-1.0	-0.44	0.0	0.00	0.0	0.00	0.0	0.00

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