

# DER-VET Task Force

10/05/2023

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- Sales territories, market shares, future product offerings;
- Confidential market strategies or business plans;
- Other competitively sensitive information;
- Advise or try to influence others on their business decisions (except to the extent that they are already public);
- Complaints or disparaging remarks concerning customers/suppliers/competitors.

## DO NOT AGREE...

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- To only do business on certain terms and conditions;
- To set (or fix) prices;
- To divide markets or technologies;
- To allocate customers/suppliers/territories;
- To suppress a technology;
- To the use, promotion or endorsement of particular vendors, contractors, consultants or products.

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- The webcast is being recorded along with all Q&A. Your participation provides consent to that recording.
  
- As a result, please make sure your phone is on mute throughout the webcast unless speaking. Do not place your phone on hold.

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# Agenda

- Question on Production Cost Modeling and DER-VET
- Understanding Frequency Regulation Results



# Question on Production Cost Modeling and DER-VET

# PCMs and DER-VET

- Production Cost Models (PCMs) are used to determine least-cost unit commitment and dispatch simulation based on operational costs over different timeframes, typically in hourly time-steps over a full year. For energy storage, they can be used for estimating system-wide costs and dispatch associated with large-scale projects.
- PCMs can provide locational marginal prices, which can serve as inputs to DER-VET. Depending on the scale of the storage dispatch, the operation of storage can potentially impact operation costs and commitment in the area.
- This potentially requires iterations between the PCM and DER-VET.
  
- Question: Does anyone here run Production Cost Models?
  - If so, what PCM tools are you (or your consultants) using?
  - Are you using these PCM tools with DER-VET, and can you share that experience?



# Understanding Frequency Regulation Results



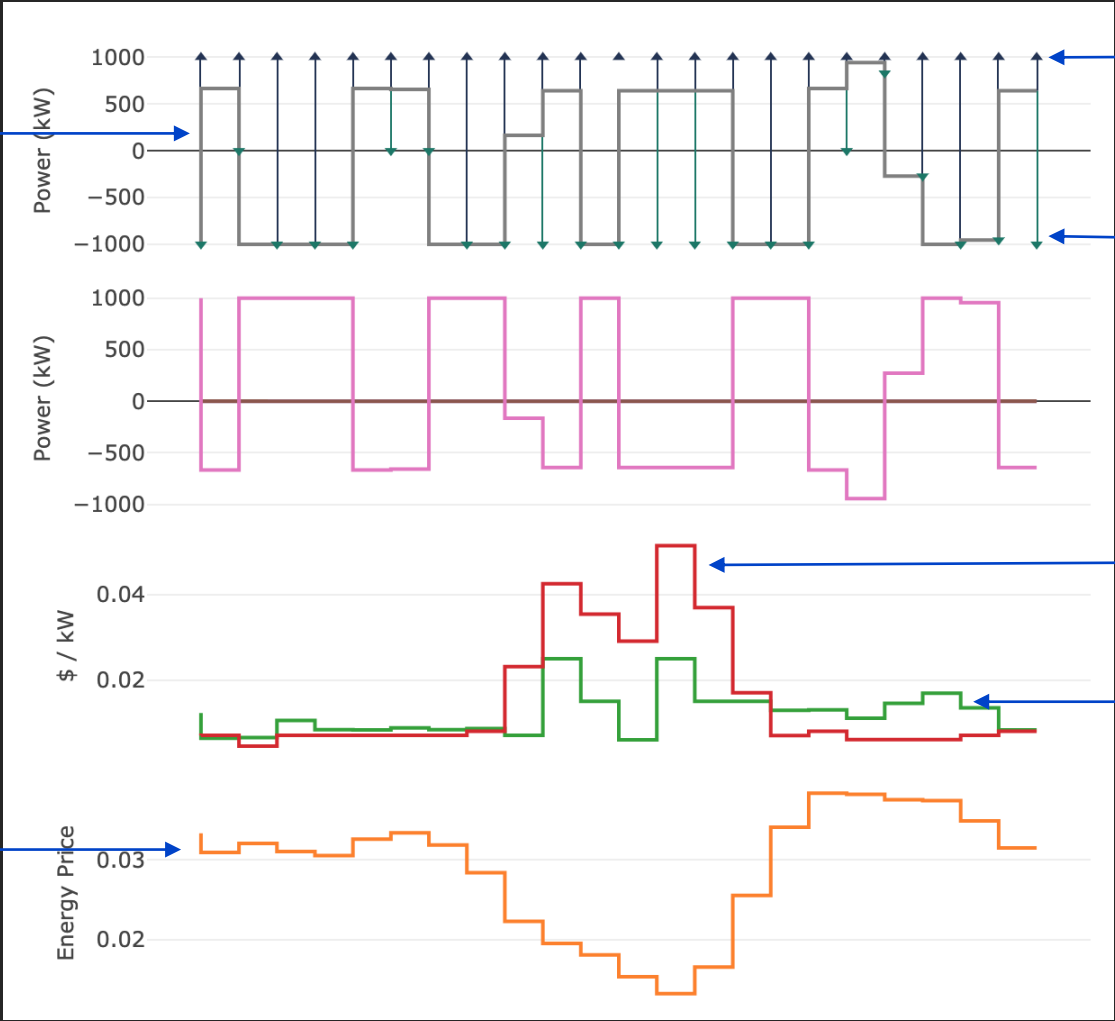
# Frequency Regulation

- What is Frequency Regulation (FR)?
  - Process of maintaining the grid's electrical frequency at a stable and consistent level (60 Hz)
- How do FR markets work?
  - ISO/RTOs send corrective Automatic Generation Control (AGC) signals to participating to increase/decrease supply
  - ~4/~6 s interval (depending upon ISO considered)
- How does this work for energy storage?
  - Regulation Up
    - Increase system discharge, curtail charging
  - Regulation Down
    - Increase system charge, curtail discharging
- FR in DER-VET
  - “eou”/”eod”
    - “This represents the extra energy that will be discharged or less energy that will be charged for providing 1 kW of regulation up for 1 hour. In reality, this parameter varies hour to hour and location to location but is fixed in DER-VET.”
    - kWh/kW-h
  - “CombinedMarket” binary
    - Some markets (MISO) require equal quantity of Reg Up and Reg Down
  - “u\_ts\_constraints”/”d\_ts\_constraints”
    - User defined maximum and minimum Reg Up and Reg Down participation in Timeseries Input File

[https://storagewiki.epri.com/index.php/DER\\_VET\\_User\\_Guide/Services/Frequency\\_Regulation](https://storagewiki.epri.com/index.php/DER_VET_User_Guide/Services/Frequency_Regulation)

# Dispatch Results from DER-VET's GUI

Energy Time-shift



Reg Up

Reg Down

Reg Down Price

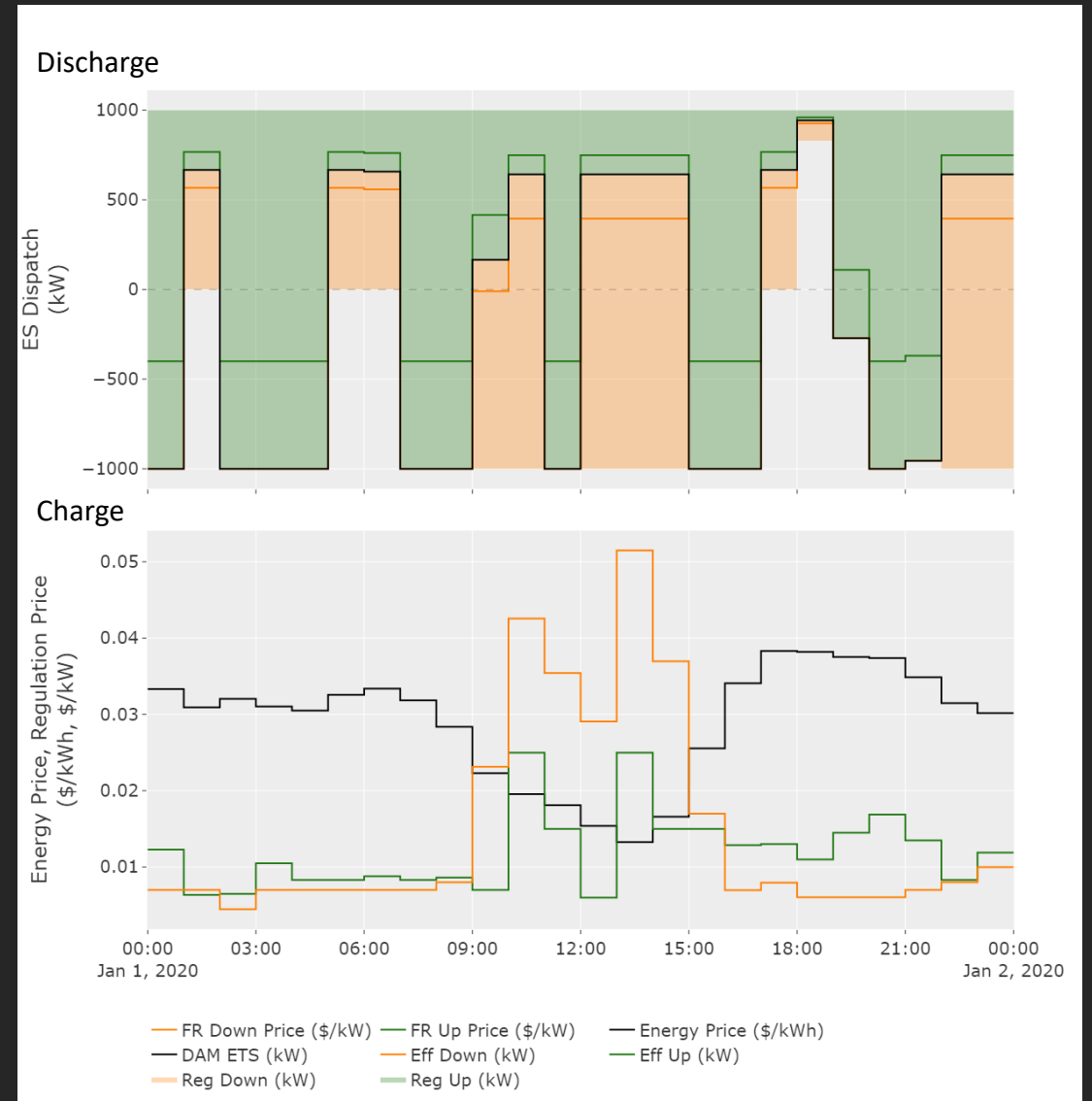
Reg Up Price

Energy Price

<https://www.der-vet.com/referencecases/> (CAISO Market Case)

# Dispatch Results Example

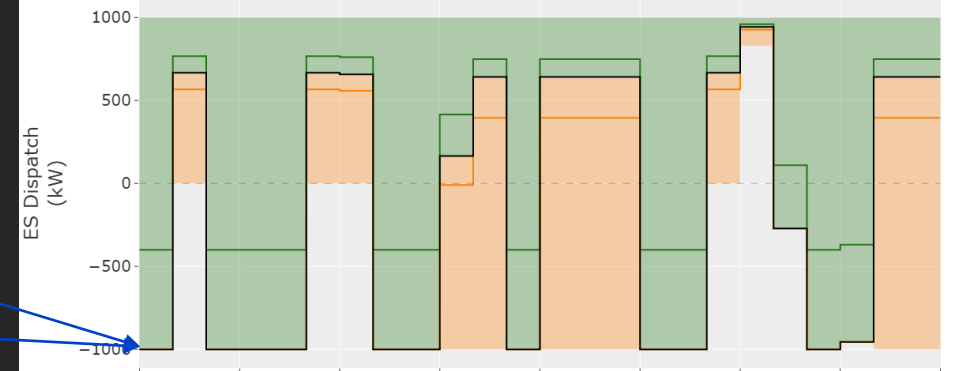
- $eou=0.3$ 
  - E.g. 00:00-01:00
  - DAM ETS, 1000 kW (charging)
  - Reg Up, 1000 kW (curtailed charging)
  - Reg Up, 1000 kW (discharging)
  - Eff Up: “Levelized Reg Up Impact”
    - $(2000 \text{ kW}) * (0.3 \text{ kWh/kW-h}) = 600 \text{ kWh}$
- Separating charging/discharging is needed for energy/Round Trip Efficiency (RTE) calculations



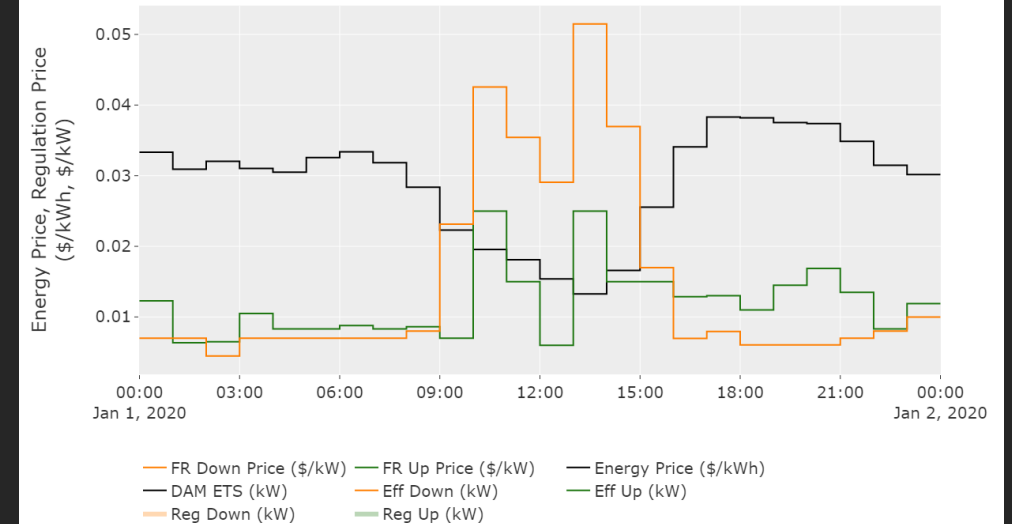
# Timeseries Output ETS

	A	B	C	D	E	F	G	H	I	J	K
	Start Datetime (hb)	Aggregated State of Energy (kWh)	BATTERY: 4-hr li-ion Charge (kW)	BATTERY: 4-hr li-ion Charge Option (kW)	BATTERY: 4-hr li-ion Discharge (kW)	BATTERY: 4-hr li-ion Discharge Option (kW)	BATTERY: 4-hr li-ion Energy Option (kWh)	BATTERY: 4-hr li-ion Power (kW)	BATTERY: 4-hr li-ion SOC (%)	BATTERY: 4-hr li-ion State of Energy (kWh)	BATTERY: Energy Price (\$/kWh)
1	1/1/2020 0:00	0	-1000	-300	0	300	-45	-1000	0	0	0.033311
2	1/1/2020 1:00	805	0	0	666.666667	0	0	666.666667	0.20125	805	0.030916
3	1/1/2020 2:00	138.333333	-1000	-300	0	300	-45	-1000	0.824583	138.3333	0.03203
4	1/1/2020 3:00	943.333333	-1000	-300	0	300	-45	-1000	0.235833	943.3333	0.031034
5	1/1/2020 4:00	1748.333333	-1000	-300	0	300	-45	-1000	0.437083	1748.333	0.030509
6	1/1/2020 5:00	2553.333333	0	0	666.666667	0	0	666.666667	0.638333	2553.333	0.032566
7	1/1/2020 6:00	1886.666667	0	0	657.673509	4.046920821	-4.0469208	657.673509	0.471667	1886.667	0.033373
8	1/1/2020 7:00	1224.946237	-1000	-300	0	300	-45	-1000	0.306237	1224.946	0.031845
9	1/1/2020 8:00	2029.946237	-1000	-300	0	300	-45	-1000	0.507487	2029.946	0.028372
10	1/1/2020 9:00	2834.946237	0	0	150	165.0537634	225.7258065	-353.22581	165.053763	2834.946	0.022292
11	1/1/2020 10:00	2316.666667	0	0	150	641.666667	11.25	-138.75	641.666667	0.579167	0.019551

Discharge



Charge



L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
FR Down Price (\$/kWh)	FR Energy Settlement Price (\$/kWh)	FR Energy Throughput (kWh)	FR Energy Throughput Down (Charging) (kWh)	FR Energy Throughput Down (Discharging) (kWh)	FR Energy Throughput Up (Charging) (kWh)	FR Energy Throughput Up (Discharging) (kWh)	FR Up Price (\$/kWh)	Frequency Regulation Down (Charging) (kW)	Frequency Regulation Down (Discharging) (kW)	Frequency Regulation Up (Charging) (kW)	Frequency Regulation Up (Discharging) (kW)	Net Load (kW)	Total Generation (kW)	Total Load (kW)	Total Storage Power (kW)
0.00699	0.03331091	-600	0	0	-300	-300	0.01227058	0	0	1000	1000	1000	0	0	-1000
0.007	0.03091634	-2.84E-14	0	100	0	-100	0.00634	0	666.666667	0	333.333333	-666.667	0	0	666.666667
0.004485	0.03203	-600	0	0	-300	-300	0.00649	0	0	1000	1000	1000	0	0	-1000
0.007	0.03103427	-600	0	0	-300	-300	0.01049358	0	0	1000	1000	1000	0	0	-1000
0.007	0.03050917	-600	0	0	-300	-300	0.00832396	0	0	1000	1000	1000	0	0	-1000
0.007	0.03256636	-2.84E-14	0	100	0	-100	0.00830585	0	666.666667	0	333.333333	-666.667	0	0	666.666667
0.007	0.0337319	-4.04692082	0	98.65102639	0	-102.697947	0.00877318	0	657.673509	0	342.326491	-657.674	0	0	657.673509
0.007	0.0318448	-600	0	0	-300	-300	0.00832396	0	0	1000	1000	1000	0	0	-1000
0.00799	0.02837173	-600	0	0	-300	-300	0.00862262	0	0	1000	1000	1000	0	0	-1000
0.023133	0.0222923	-75.7258065	150	24.75806452	0	-250.483871	0.007	1000	165.053763	0	834.946237	-165.054	0	0	165.053763
0.042552	0.01955078	138.75	150	96.25	0	-107.5	0.02499	1000	641.666667	0	358.333333	-641.667	0	0	641.666667

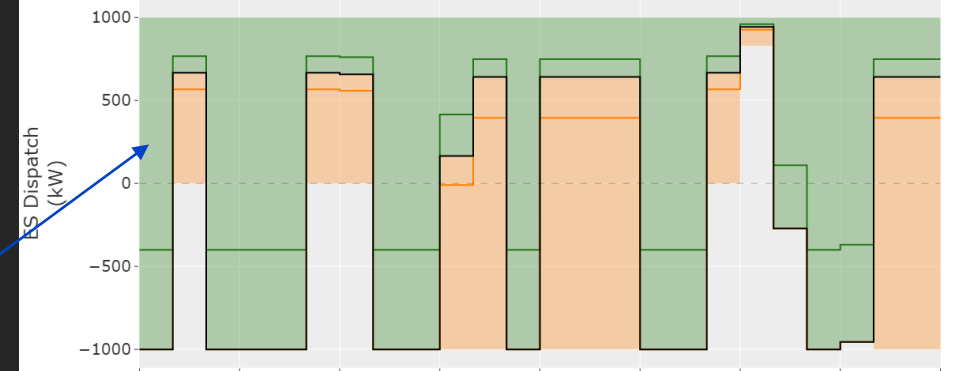
Take note of sign

# Timeseries Output FR Up

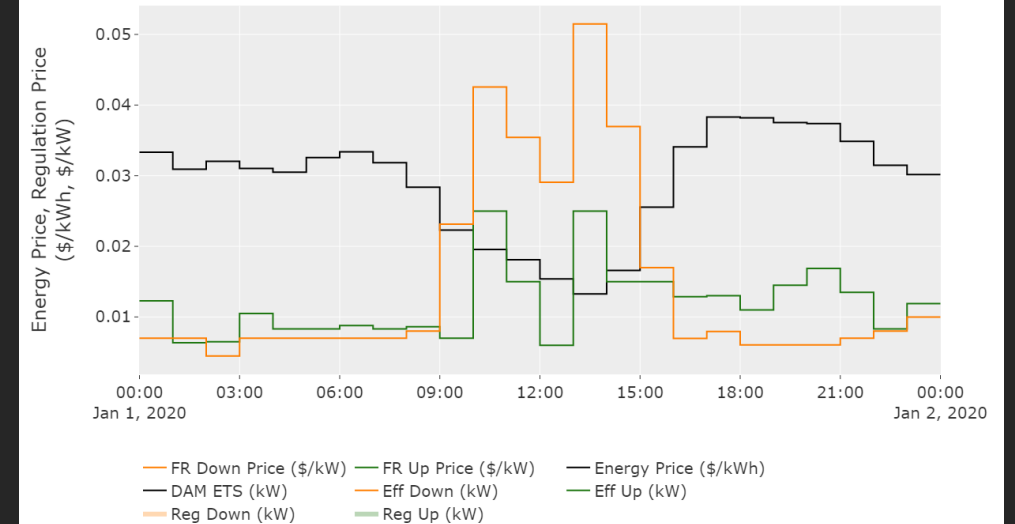
	A	B	C	D	E	F	G	H	I	J	K
	Start Datetime (hb)	Aggregated State of Energy (kWh)	BATTERY: 4-hr Li-ion Charge (kW)	BATTERY: 4-hr Li-ion Charge Option (kW)	BATTERY: 4-hr Li-ion Discharge (kW)	BATTERY: 4-hr Li-ion Discharge Option (kW)	BATTERY: 4-hr Li-ion Energy Option (kWh)	BATTERY: 4-hr Li-ion Power (kW)	BATTERY: 4-hr Li-ion SOC (%)	BATTERY: 4-hr Li-ion State of Energy (kWh)	BATTERY: 4-hr Li-ion Energy Price (\$/kWh)
1	1/1/2020 0:00	0	-1000	-300	0	300	-45	-1000	0	0	0.033311
2	1/1/2020 1:00	805	0	0	666.666667	0	0	666.666667	0.20125	805	0.030916
3	1/1/2020 2:00	138.333333	-1000	-300	0	300	-45	-1000	0.034583	138.3333	0.03203
4	1/1/2020 3:00	943.333333	-1000	-300	0	300	-45	-1000	0.235833	943.3333	0.031034
5	1/1/2020 4:00	1748.333333	-1000	-300	0	300	-45	-1000	0.437083	1748.333	0.030509
6	1/1/2020 5:00	2553.333333	0	0	666.666667	0	0	666.666667	0.638333	2553.333	0.032566
7	1/1/2020 6:00	1886.666667	0	0	657.6735093	4.046920821	-4.0469208	657.673509	0.471667	1886.667	0.033373
8	1/1/2020 7:00	1224.946237	-1000	-300	0	300	-45	-1000	0.306237	1224.946	0.031845
9	1/1/2020 8:00	2029.946237	-1000	-300	0	300	-45	-1000	0.507487	2029.946	0.028372
10	1/1/2020 9:00	2834.946237	0	150	165.0537634	225.7258065	-353.22581	165.053763	0.708737	2834.946	0.022292
11	1/1/2020 10:00	2316.666667	0	150	641.6666667	11.25	-138.75	641.666667	0.579167	2316.667	0.019551

L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
FR Down Price (\$/kW)	FR Energy Settlement Price (\$/kWh)	FR Energy Throughput (kWh)	FR Energy Throughput Down (Charging) (kWh)	FR Energy Throughput Down (Discharging) (kWh)	FR Energy Throughput Up (Charging) (kWh)	FR Energy Throughput Up (Discharging) (kWh)	FR Up Price (\$/kW)	Frequency Regulation Down (Charging) (kW)	Frequency Regulation Down (Discharging) (kW)	Frequency Regulation Up (Charging) (kW)	Frequency Regulation Up (Discharging) (kW)	Net Load (kW)	Total Generation (kW)	Total Load (kW)	Total Storage Power (kW)
0.00699	0.03331091	-600	0	0	-300	-300	0.01227058	0	0	1000	1000	1000	0	0	-1000
0.007	0.03091634	-2.84E-14	0	100	0	-100	0.00634	0	666.666667	0	333.333333	-666.667	0	0	666.666667
0.004485	0.03203	-600	0	0	-300	-300	0.00649	0	0	1000	1000	1000	0	0	-1000
0.007	0.03103427	-600	0	0	-300	-300	0.01049358	0	0	1000	1000	1000	0	0	-1000
0.007	0.03050917	-600	0	0	-300	-300	0.00832396	0	0	1000	1000	1000	0	0	-1000
0.007	0.03256636	-2.84E-14	0	100	0	-100	0.00830585	0	666.666667	0	333.333333	-666.667	0	0	666.666667
0.007	0.0337319	-4.04692082	0	98.65102639	0	-102.697947	0.00877318	0	657.673509	0	342.326491	-657.674	0	0	657.673509
0.007	0.0318448	-600	0	0	-300	-300	0.00832396	0	0	1000	1000	1000	0	0	-1000
0.00799	0.02837173	-600	0	0	-300	-300	0.00862262	0	0	1000	1000	1000	0	0	-1000
0.023133	0.0222923	-75.7258065	150	24.75806452	0	-250.483871	0.007	1000	165.053763	0	834.946237	-165.054	0	0	165.053763
0.042552	0.01955078	138.75	150	96.25	0	-107.5	0.02499	1000	641.666667	0	358.333333	-641.667	0	0	641.666667

### Discharge



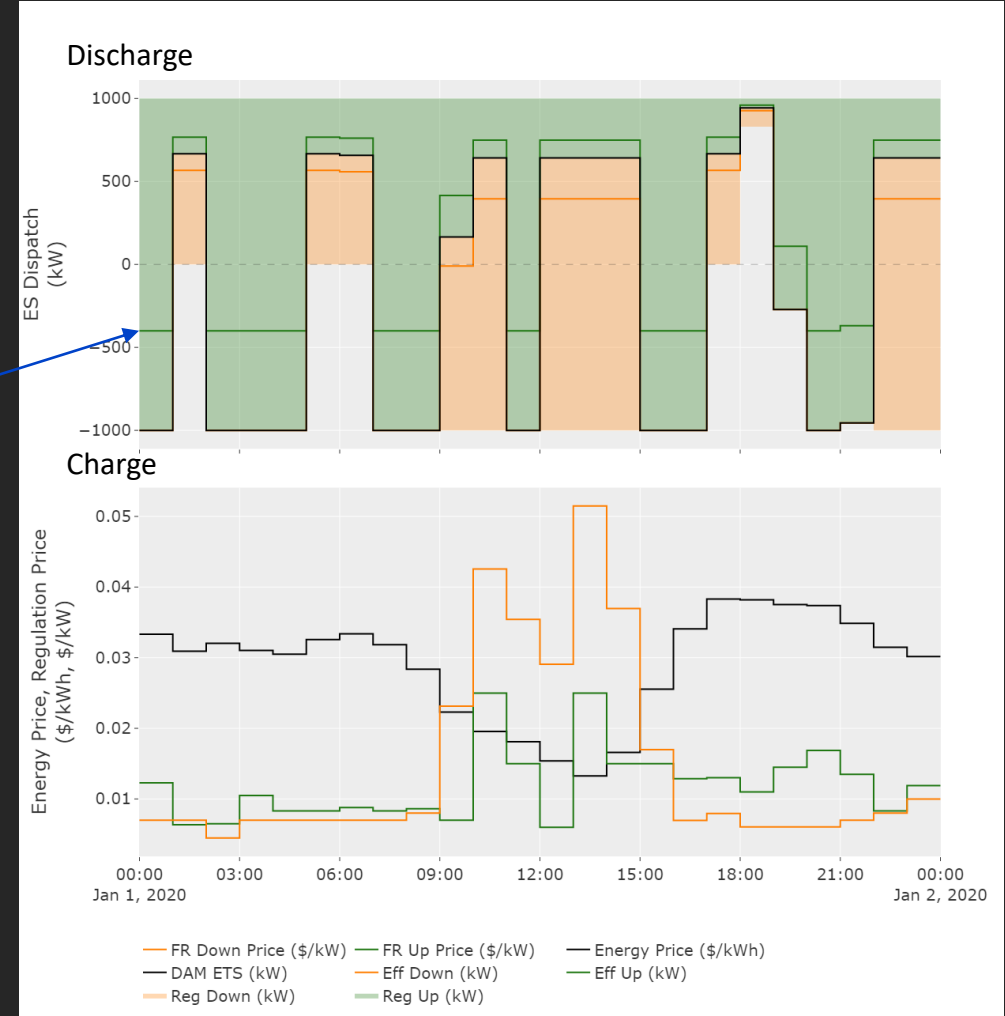
### Charge



# Timeseries Output FR Up Throughput

	A	B	C	D	E	F	G	H	I	J	K
		Aggregated State of Energy (kWh)	BATTERY: 4-hr Li-ion Charge (kW)	BATTERY: 4-hr Li-ion Charge Option (kW)	BATTERY: 4-hr Li-ion Discharge (kW)	BATTERY: 4-hr Li-ion Discharge Option (kW)	BATTERY: 4-hr Li-ion Energy Option (kWh)	BATTERY: 4-hr Li-ion Power (kW)	BATTERY: 4-hr Li-ion SOC (%)	BATTERY: 4-hr Li-ion State of Energy (kWh)	BATTERY: 4-hr Li-ion Energy Price (\$/kWh)
1	Start Datetime (hb)										
2	1/1/2020 0:00	0	-1000	-300	0	300	-45	-1000	0	0	0.033311
3	1/1/2020 1:00	805	0	0	666.666667	0	0	666.666667	0.20125	805	0.030916
4	1/1/2020 2:00	138.333333	-1000	-300	0	300	-45	-1000	0.034583	138.3333	0.03203
5	1/1/2020 3:00	943.333333	-1000	-300	0	300	-45	-1000	0.235833	943.3333	0.031034
6	1/1/2020 4:00	1748.333333	-1000	-300	0	300	-45	-1000	0.437083	1748.333	0.030509
7	1/1/2020 5:00	2553.333333	0	0	666.666667	0	0	666.666667	0.638333	2553.333	0.032566
8	1/1/2020 6:00	1886.666667	0	0	657.673509	4.046920821	-4.0469208	657.673509	0.471667	1886.667	0.033373
9	1/1/2020 7:00	1224.946237	-1000	-300	0	300	-45	-1000	0.306237	1224.946	0.031845
10	1/1/2020 8:00	2029.946237	-1000	-300	0	300	-45	-1000	0.507487	2029.946	0.028372
11	1/1/2020 9:00	2834.946237	0	150	165.0537634	225.7258065	-353.22581	165.053763	0.708737	2834.946	0.022292
12	1/1/2020 10:00	2316.666667	0	150	641.666667	11.25	-138.75	641.666667	0.579167	2316.667	0.019551

L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
FR Down Price (\$/kW)	FR Energy Settlement Price (\$/kWh)	FR Energy Throughput (kWh)	FR Energy Throughput Down (Charging) (kWh)	FR Energy Throughput Down (Discharging) (kWh)	FR Energy Throughput Up (Charging) (kWh)	FR Energy Throughput Up (Discharging) (kWh)	FR Up Price (\$/kW)	Frequency Regulation Down (Charging) (kW)	Frequency Regulation Down (Discharging) (kW)	Frequency Regulation Up (Charging) (kW)	Frequency Regulation Up (Discharging) (kW)	Net Load (kW)	Total Generation (kW)	Total Load (kW)	Total Storage Power (kW)
0.00699	0.03331091	-600	0	0	-300	-300	0.01227058	0	0	1000	1000	1000	0	0	-1000
0.007	0.03091634	-2.84E-14	0	100	0	-100	0.00634	0	666.666667	0	333.333333	-666.667	0	0	666.666667
0.004485	0.03203	-600	0	0	-300	-300	0.00649	0	0	1000	1000	1000	0	0	-1000
0.007	0.03103427	-600	0	0	-300	-300	0.01049358	0	0	1000	1000	1000	0	0	-1000
0.007	0.03050917	-600	0	0	-300	-300	0.00832396	0	0	1000	1000	1000	0	0	-1000
0.007	0.03256636	-2.84E-14	0	100	0	-100	0.00830585	0	666.666667	0	333.333333	-666.667	0	0	666.666667
0.007	0.0337319	-4.04692082	0	98.65102639	0	-102.697947	0.00877318	0	657.673509	0	342.326491	-657.674	0	0	657.673509
0.007	0.0318448	-600	0	0	-300	-300	0.00832396	0	0	1000	1000	1000	0	0	-1000
0.00799	0.02837173	-600	0	0	-300	-300	0.00862262	0	0	1000	1000	1000	0	0	-1000
0.023133	0.0222923	-75.7258065	150	24.75806452	0	-250.483871	0.007	1000	165.053763	0	834.946237	-165.054	0	0	165.053763
0.042552	0.01955078	138.75	150	96.25	0	-107.5	0.02499	1000	641.666667	0	358.333333	-641.667	0	0	641.666667



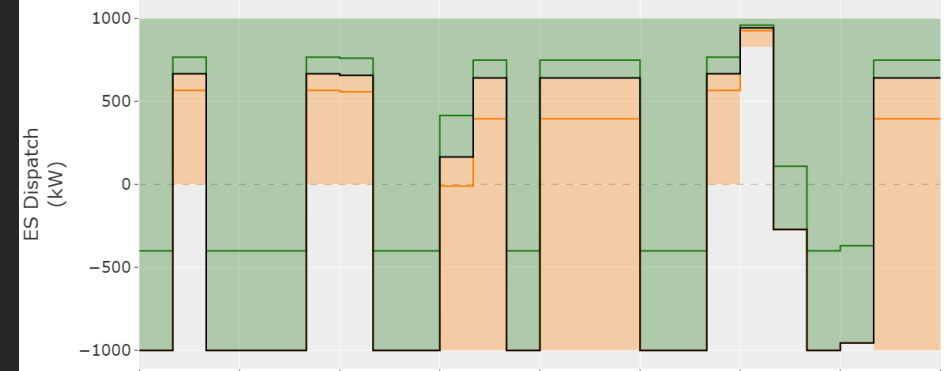
**Note, if performing SOE accounting, consider RTE**

# Timeseries Output FR Up

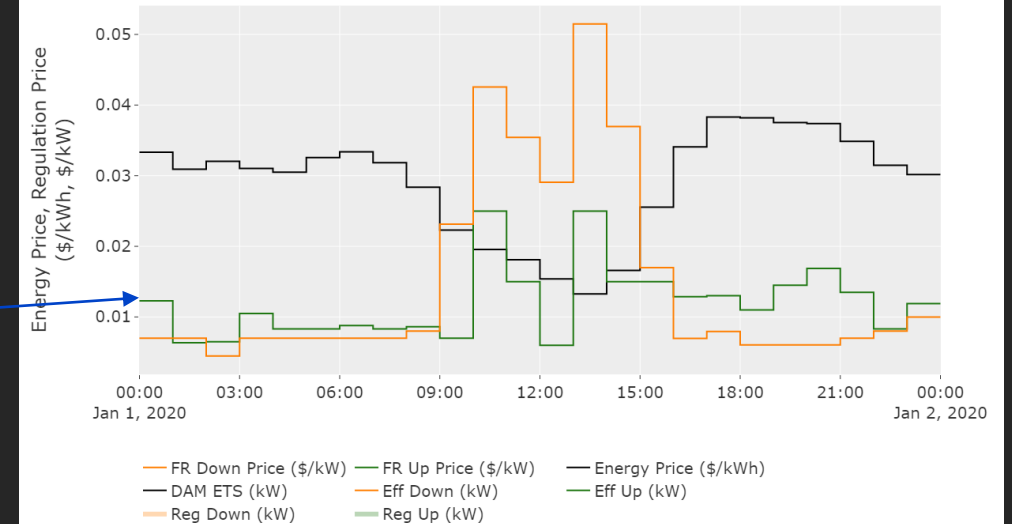
	A	B	C	D	E	F	G	H	I	J	K
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1	1/1/2020 0:00	0	-1000	-300	0	300	-45	-1000	0	0	0.033311
2	1/1/2020 1:00	805	0	0	666.666667	0	0	666.666667	0.20125	805	0.030916
3	1/1/2020 2:00	138.333333	-1000	-300	0	300	-45	-1000	0.034583	138.3333	0.03203
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10	1/1/2020 9:00	2834.946237	0	0	165.0537634	225.7258065	-353.22581	165.053763	0.708737	2834.946	0.022292
11	1/1/2020 10:00	2316.666667	0	0	150	641.666667	11.25	-138.75	0.579167	2316.667	0.019551

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0.00699	0.03331091	-600	0	0	-300	-300	0.01227058	0	0	1000	1000	1000	0	0	-1000
0.007	0.03091634	-2.84E-14	0	100	0	-100	0.00634	0	666.666667	0	333.333333	-666.667	0	0	666.666667
0.004485	0.03203	-600	0	0	-300	-300	0.00649	0	0	1000	1000	1000	0	0	-1000
0.007	0.03103427	-600	0	0	-300	-300	0.01049358	0	0	1000	1000	1000	0	0	-1000
0.007	0.03050917	-600	0	0	-300	-300	0.00832396	0	0	1000	1000	1000	0	0	-1000
0.007	0.03256636	-2.84E-14	0	100	0	-100	0.00830585	0	666.666667	0	333.333333	-666.667	0	0	666.666667
0.007	0.0337319	-4.04692082	0	98.65102639	0	-102.697947	0.00877318	0	657.673509	0	342.326491	-657.674	0	0	657.673509
0.007	0.0318448	-600	0	0	-300	-300	0.00832396	0	0	1000	1000	1000	0	0	-1000
0.00799	0.02837173	-600	0	0	-300	-300	0.00862262	0	0	1000	1000	1000	0	0	-1000
0.023133	0.0222923	-75.7258065	150	24.75806452	0	-250.483871	0.007	1000	165.053763	0	834.946237	-165.054	0	0	165.053763
0.042552	0.01955078	138.75	150	96.25	0	-107.5	0.02499	1000	641.666667	0	358.333333	-641.667	0	0	641.666667

## Discharge



## Charge



**Note, Energy Price (\$/kWh), Reg Price (\$/kW)**



# Questions and Discussion





**Together...Shaping the Future of Energy®**