Behind-the-Meter Energy Storage Forecast

2019 Revised Forecast

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California Energy Commission
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Overview

- **Objective:** Describe the methodology used in the Energy Commission's behind-the-meter (BTM) energy storage forecast.

- **Methodology** for energy storage:

  1. Methodology for calculating historical storage adoption
  2. Methodology for forecasting storage adoption
  3. Methodology for estimating energy consumption due to storage
     – includes hourly charge and discharge behavior

- Any individual could replicate the Energy Commission's storage forecast
  – Data used in publically available and full methodology will be specified today

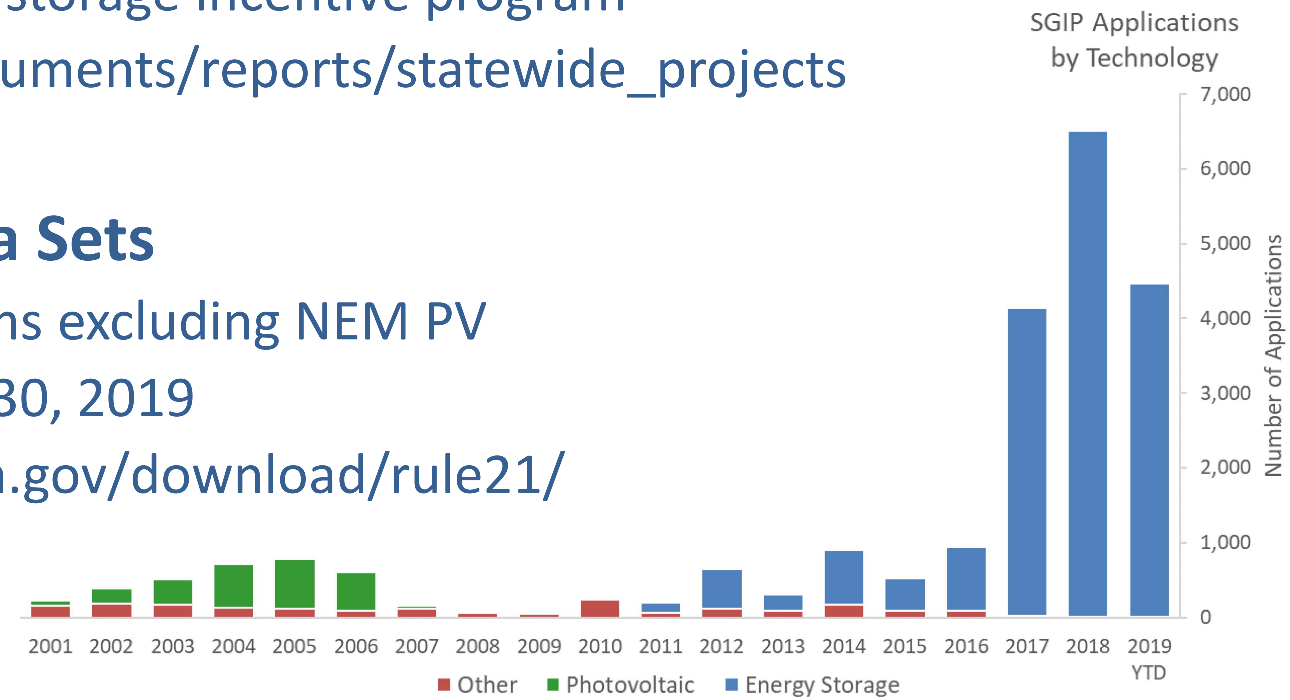
Methodology for Calculating Historical Storage Adoption

Potential Sources of Data

- **Self-Generation Incentive Program (SGIP)**
  - Publishes list of distributed generation systems that apply for incentives
  - Since 2016, over 15,000 applications for BTM energy storage projects;
    - Only 24 applications for all other technologies
    - SGIP effectively an energy storage incentive program
  - Link: www.selfgenca.com/documents/reports/statewide_projects

- **Rule 21 Interconnected Data Sets**
  - Rule 21 interconnected systems excluding NEM PV
  - Date of first availability: April 30, 2019
  - Link: www.californiadgstats.ca.gov/download/rule21/

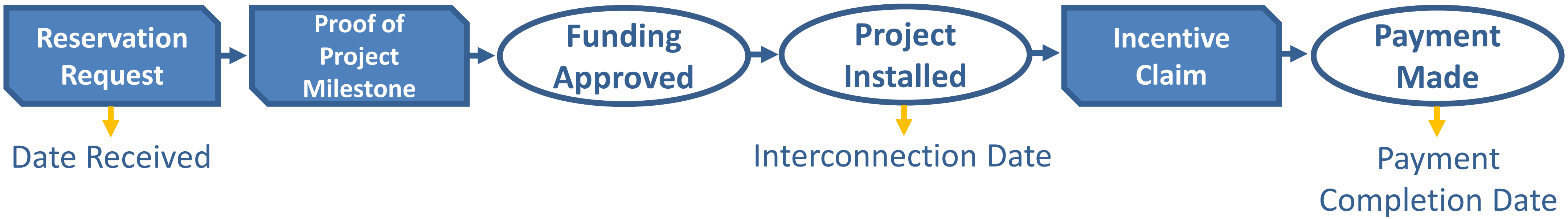
- Staff decided to use SGIP



Source: California Energy Commission analysis of SGIP Weekly Statewide Report (10/21/2019)

Methodology for Historical Data

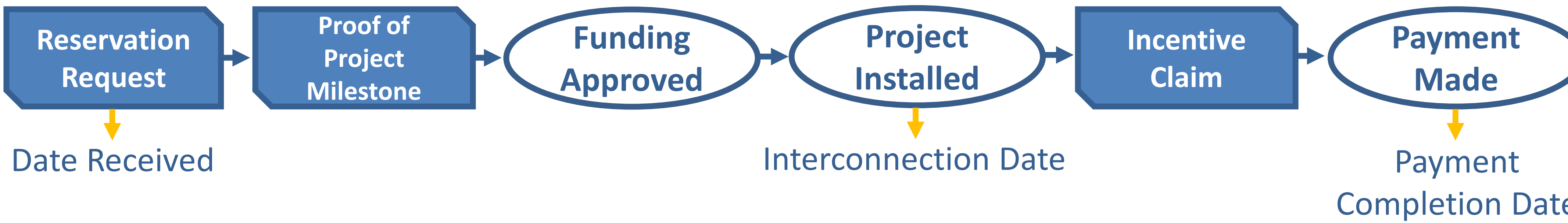
- SGIP application process



- Query to estimate installed storage systems in SGIP dataset
  1. Select "Equipment Type" = electrochemical, mechanical, or thermal storage.
  2. If the system has an interconnection date, then system is considered installed regardless of incentive status.
  3. If no interconnection date, filter out all cancelled projects.
  4. For remaining projects, consider projects that have either "payment completed", "payment in progress", or an "ICF" incentive status as installed.
     - SGIP handbook: "Completed **Incentive Claim Form** documents submitted to the Program Administrator once the system is installed, interconnected and operational."

Methodology for Historical Data

- SGIP application process



- Methodology to estimate date of installation
  - System must be considered installed in query
  - If system has interconnection date, then interconnection date = installation date
  - Otherwise, if system has payment completion date, payment completion date = installation date.
  - Otherwise, installation date = date received + avg. number of days (between date received and interconnection date)

Energy Storage Data Summary

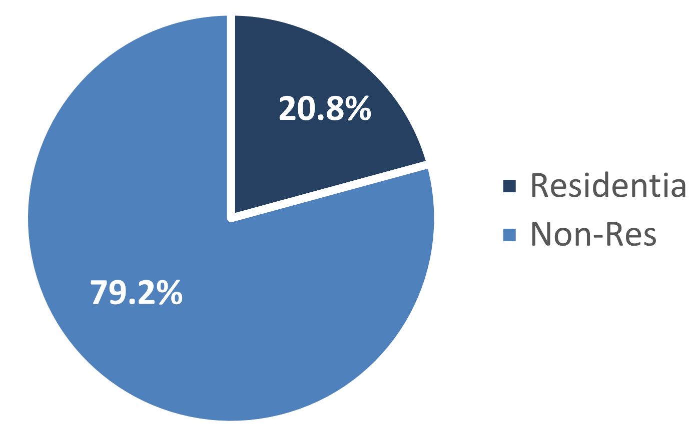
	Installed		Likely Installed*		Total	
Year	Count	Capacity (kW)	Count	Capacity (kW)	Count	Capacity (kW)
Pre 2011	2	19			2	19
2011	3	1,040			3	1,040
2012	3	24	1	600	4	624
2013	38	1,606			38	1,606
2014	255	5,134	1	18	256	5,152
2015	343	25,422	21	153	364	25,575
2016	174	27,540	14	1,604	188	29,144
2017	825	29,173	139	11,059	964	40,232
2018	4,726	75,229	351	26,161	5,077	101,390
2019 YTD	2,681	42,248	834	20,836	3,515	63,083
Total	9,050	207,435	1,361	60,430	10,411	267,865

* Based on SGIP Incentive Status

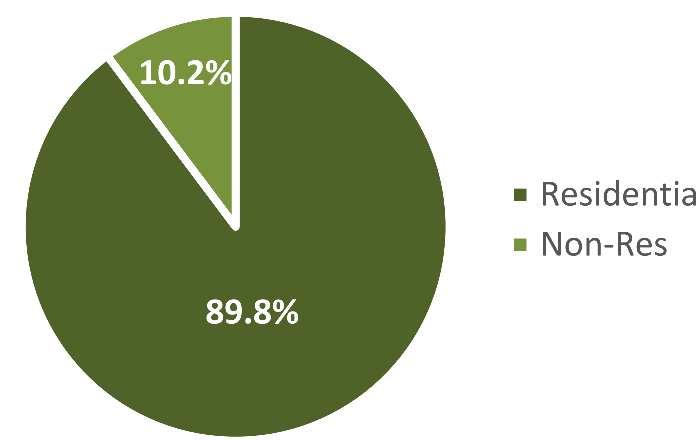
- Approximately another 108,000 kW of energy storage is in the SGIP application queue.

Source: California Energy Commission analysis of SGIP Weekly Statewide Report (10/21/2019)

Energy Storage Capacity by Sector



Number of Installed Systems by Sector



Methodology for Forecasting Storage Adoption

Approach to Forecasting Storage

- Continue to use trend / time series analysis, but with some changes
- Applied different methodology for residential and non-residential storage adoption forecasts due to different observed characteristics.
- Observations:

% of Energy Storage Rated Capacity (kW) by System Classification and Sector		
Classification	**Residential**	**Non-Residential**
Solar + Storage	96.6%	32.6%
Solar + Other	0.2%	4.0%
Stand Alone Storage	3.1%	63.4%

  – **Non-residential sector**: most storage systems are stand alone.
  – **Residential sector**: nearly all systems are paired with PV.

Source: California Energy Commission analysis of SGIP Weekly Statewide Report (10/21/2019)

Non-Residential Adoption Forecast

- Continue to base forecast on historical trend.
  - Most non-res storage systems are stand alone
  - Number of installations and system size can fluctuate from year to year

- Methodology:
  - $Capacity\ added\ in\ future\ year_{(MW)} = average\ of\ (2018\ capacity_{(MW)} + 2019\ capacity_{(MW)} + (SGIP\ program\ queue_{(MW)})\ x\ (likelyhood\ of\ installation\ ))$

- SGIP gives some visibility into the storage project pipeline.

Residential Adoption Forecast

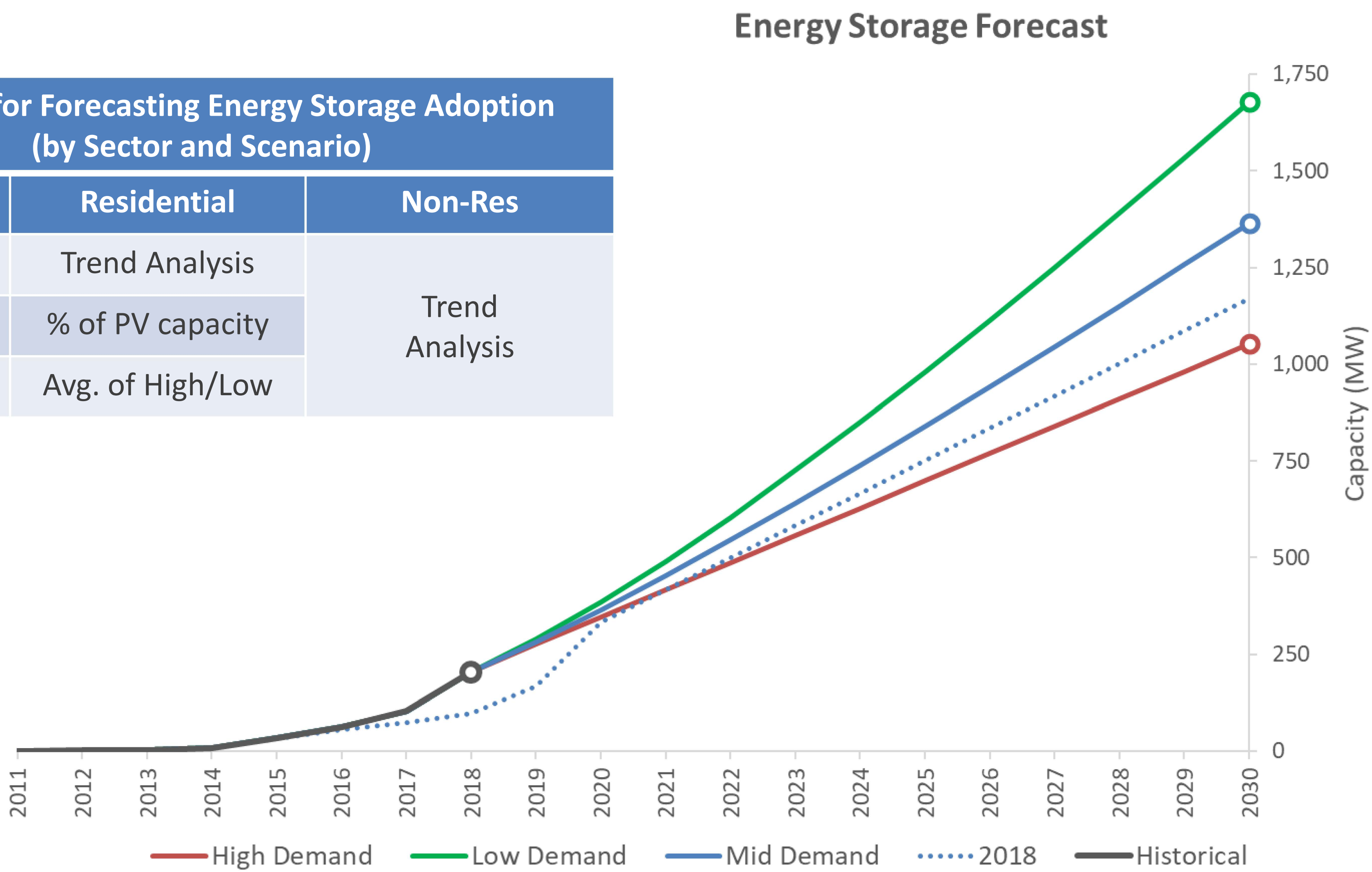
- Three adoption scenarios for residential storage
  - High energy demand (low storage adoption) – continue to use historical trend just like non-res storage forecast.
  - Low energy demand (high storage adoption) – residential storage adoption linked to PV
  - Mid energy demand – take average of high and low scenarios.

- Low scenario methodology:
  - $Adoption\ rate = \frac{Energy\ storage\ capacity\ added\ in\ 2018_{(MW)}}{Total\ installed\ PV\ Capacity_{\ (MW)}}$
  - $Storage\ adoption_{(year,MW)} = forecast\ of\ PV\ capacity_{(year,MW)}\ x\ adoption\ rate$

- Result: 3.4 times more storage capacity in low scenario vs. high by 2030.

Summary

Approach for Forecasting Energy Storage Adoption (by Sector and Scenario)		
Scenario	**Residential**	**Non-Res**
High Demand	Trend Analysis	Trend Analysis
Low Demand	% of PV capacity	
Mid Demand	Avg. of High/Low	



Forecasting Energy Consumption from Storage

Hourly Storage Forecast

- For 2019 revised forecast, developed hourly forecast for energy storage systems.
  - Better account for effect on non-coincident peak demand

- $Annual\ energy\ consumption_{storage} = \sum Hourly\ consumption_{storage}$

- Like storage adoption, staff used differing approaches for forecasting hourly energy consumption for residential and non-residential sectors.
  - Due to availability of data

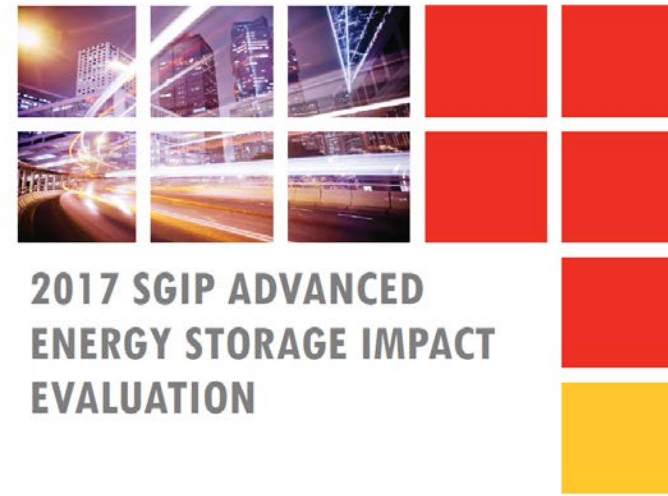
Non-Res Hourly Storage Forecast

- For non-residential sector, used charge / discharge profiles published in 2017 SGIP Storage Impact Evaluation.

- Report has observed charge / discharge profiles for different non-res building types
  - Industrial, food / liquor, hotel, retail, school, other
  - By system size (< 30 kW, 30 kW or greater)
  - Sample size: 150

- Profiles are published by month and hour
  - Profiles are statewide, not utility specific

- Average hourly charge / discharge (in kW) per rebated capacity (in kW)



Non-Res Hourly Storage Forecast

- Applied hourly charge / discharge profiles to forecast of storage capacity to get hourly storage charge and discharge information.
- Non-res systems mainly used to reduce demand charges
  - Peak discharge occurred during afternoon hours
  - Peak charging happens between 9 pm and 2 am.

FIGURE 4-30: AVERAGE HOURLY DISCHARGE (KW) PER REBATED CAPACITY (KW) FOR ALL NONRES PROJECTS

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hour	1	2	3	4	5	6	7	8	9	10	11	12
0	0.015	0.012	0.009	0.020	0.022	0.024	0.028	0.037	0.040	0.039	0.035	0.033
1	0.021	0.019	0.008	0.011	0.014	0.015	0.018	0.029	0.032	0.031	0.037	0.038
2	0.009	0.009	0.003	0.010	0.012	0.014	0.018	0.030	0.033	0.032	0.032	0.031
3	0.009	0.008	0.003	0.011	0.013	0.014	0.018	0.030	0.033	0.033	0.034	0.034
4	0.009	0.009	0.004	0.005	0.005	0.004	0.011	0.014	0.017	0.016	0.032	0.035
5	0.012	0.012	0.009	0.009	0.010	0.008	0.014	0.018	0.018	0.021	0.019	0.016
6	0.026	0.021	0.017	0.016	0.018	0.017	0.019	0.024	0.024	0.023	0.024	0.020
7	0.032	0.025	0.023	0.021	0.020	0.018	0.020	0.024	0.024	0.021	0.024	0.023
8	0.031	0.029	0.031	0.030	0.027	0.025	0.026	0.031	0.031	0.028	0.023	0.021
9	0.042	0.040	0.038	0.034	0.033	0.032	0.033	0.037	0.034	0.034	0.030	0.026
10	0.042	0.042	0.045	0.035	0.044	0.045	0.044	0.053	0.039	0.043	0.034	0.028
11	0.040	0.041	0.049	0.039	0.054	0.054	0.048	0.063	0.048	0.054	0.038	0.031
12	0.039	0.042	0.051	0.043	0.055	0.056	0.049	0.065	0.049	0.059	0.041	0.033
13	0.039	0.043	0.052	0.042	0.051	0.053	0.048	0.061	0.046	0.056	0.043	0.036
14	0.037	0.041	0.046	0.036	0.052	0.060	0.058	0.065	0.054	0.054	0.038	0.036
15	0.034	0.039	0.044	0.037	0.052	0.061	0.058	0.065	0.059	0.050	0.035	0.033
16	0.036	0.040	0.056	0.061	0.053	0.068	0.064	0.069	0.062	0.051	0.037	0.045
17	0.067	0.070	0.072	0.061	0.037	0.035	0.032	0.035	0.035	0.049	0.066	0.048
18	0.076	0.077	0.089	0.078	0.043	0.035	0.038	0.042	0.045	0.053	0.062	0.051
19	0.091	0.091	0.080	0.066	0.049	0.040	0.048	0.046	0.047	0.053	0.062	0.056
20	0.084	0.082	0.049	0.036	0.031	0.029	0.034	0.034	0.036	0.034	0.047	0.054
21	0.051	0.047	0.024	0.025	0.033	0.034	0.037	0.050	0.049	0.047	0.032	0.028
22	0.015	0.015	0.012	0.026	0.029	0.030	0.036	0.050	0.045	0.047	0.042	0.039
23	0.027	0.022	0.008	0.013	0.015	0.017	0.022	0.034	0.033	0.033	0.043	0.043

FIGURE 4-31: AVERAGE HOURLY CHARGE (KW) PER REBATED CAPACITY (KW) FOR ALL NONRES PROJECTS

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hour	1	2	3	4	5	6	7	8	9	10	11	12
0	-0.115	-0.109	-0.093	-0.095	-0.094	-0.097	-0.099	-0.113	-0.116	-0.104	-0.108	-0.101
1	-0.111	-0.105	-0.076	-0.072	-0.069	-0.073	-0.075	-0.091	-0.090	-0.079	-0.097	-0.094
2	-0.081	-0.077	-0.056	-0.055	-0.052	-0.055	-0.057	-0.069	-0.070	-0.066	-0.075	-0.073
3	-0.061	-0.058	-0.042	-0.044	-0.042	-0.043	-0.045	-0.058	-0.060	-0.058	-0.061	-0.059
4	-0.047	-0.046	-0.033	-0.033	-0.035	-0.034	-0.036	-0.045	-0.049	-0.047	-0.054	-0.054
5	-0.037	-0.037	-0.026	-0.024	-0.026	-0.023	-0.026	-0.030	-0.034	-0.031	-0.042	-0.043
6	-0.032	-0.032	-0.024	-0.025	-0.026	-0.023	-0.027	-0.028	-0.030	-0.032	-0.031	-0.030
7	-0.033	-0.030	-0.030	-0.025	-0.025	-0.024	-0.026	-0.026	-0.027	-0.028	-0.032	-0.031
8	-0.031	-0.032	-0.040	-0.035	-0.033	-0.030	-0.035	-0.039	-0.038	-0.039	-0.032	-0.029
9	-0.043	-0.044	-0.042	-0.033	-0.034	-0.031	-0.035	-0.041	-0.036	-0.038	-0.041	-0.037
10	-0.045	-0.044	-0.041	-0.035	-0.034	-0.034	-0.037	-0.041	-0.039	-0.039	-0.038	-0.038
11	-0.047	-0.043	-0.042	-0.033	-0.034	-0.037	-0.040	-0.041	-0.039	-0.040	-0.039	-0.038
12	-0.044	-0.040	-0.042	-0.033	-0.034	-0.037	-0.039	-0.042	-0.039	-0.039	-0.040	-0.034
13	-0.041	-0.040	-0.041	-0.036	-0.039	-0.041	-0.042	-0.049	-0.044	-0.045	-0.042	-0.033
14	-0.041	-0.041	-0.045	-0.037	-0.043	-0.044	-0.043	-0.054	-0.045	-0.049	-0.044	-0.034
15	-0.043	-0.042	-0.050	-0.043	-0.045	-0.046	-0.042	-0.058	-0.046	-0.053	-0.044	-0.037
16	-0.042	-0.046	-0.049	-0.037	-0.046	-0.045	-0.041	-0.059	-0.044	-0.056	-0.039	-0.036
17	-0.035	-0.038	-0.048	-0.045	-0.051	-0.057	-0.055	-0.069	-0.049	-0.056	-0.034	-0.036
18	-0.040	-0.042	-0.048	-0.040	-0.043	-0.052	-0.048	-0.054	-0.041	-0.047	-0.038	-0.037
19	-0.043	-0.044	-0.056	-0.053	-0.036	-0.045	-0.039	-0.046	-0.037	-0.041	-0.044	-0.036
20	-0.055	-0.061	-0.047	-0.039	-0.038	-0.036	-0.037	-0.040	-0.036	-0.041	-0.064	-0.033
21	-0.051	-0.051	-0.070	-0.091	-0.092	-0.087	-0.091	-0.101	-0.095	-0.107	-0.058	-0.052
22	-0.104	-0.098	-0.082	-0.083	-0.089	-0.089	-0.088	-0.107	-0.109	-0.101	-0.101	-0.096
23	-0.086	-0.083	-0.089	-0.102	-0.104	-0.102	-0.106	-0.125	-0.122	-0.117	-0.098	-0.086

Image from *2017 SGIP Advanced Storage Energy Storage Impact Evaluation*

Residential Hourly Storage Forecast

- For residential sector, SGIP Storage Impact Evaluation was not used.
  - Sample size of 28 systems, all on tiered (and not TOU) rates
  - Profiles unlikely to reflect the way the residential storage systems would be deployed
- Used the System Advisor Model (SAM) for modeling residential storage
  - SAM is able to model battery storage when coupled with a PV system
  - Provides hourly charge and discharge profiles
  - Developed by National Renewable Energy Laboratory
  - https://sam.nrel.gov/
- Approach: Model a single battery, then scale it to installed capacity.

Modeling Residential Storage in SAM

- Must specify characteristics for PV system and battery in SAM.

- Modeled PV System Size: 6 kW AC
  - Avg. statewide system size ~5.8 kW

- Battery Specs: modeled Tesla Powerwall
  - Tesla has over 50% market share in residential sector
  - Specs: 13.5 kWh capacity, 5 kW rated power
  - Observed avg. residential battery size: 13.6 kWh, 12.9 kWh, 13.5 kWh in 2017, 2018, and 2019 respectively according to analysis of SGIP data
  - Limitation: could not incorporate Li-ion battery self-discharge

Modeling Residential Storage in SAM

1 | Select PV system and battery characteristics

2 | Select a region within each utility service territory
- To capture regional variance solar production (and thus battery charging)
- Staff modeled 32 different regions across the state

3 | Used default hourly household electricity load profiles in SAM
- Annual household consumption adjusted to match for each forecast zone.

4 | Input utility rates and rate structures

5 | Specify battery charging and discharging behavior

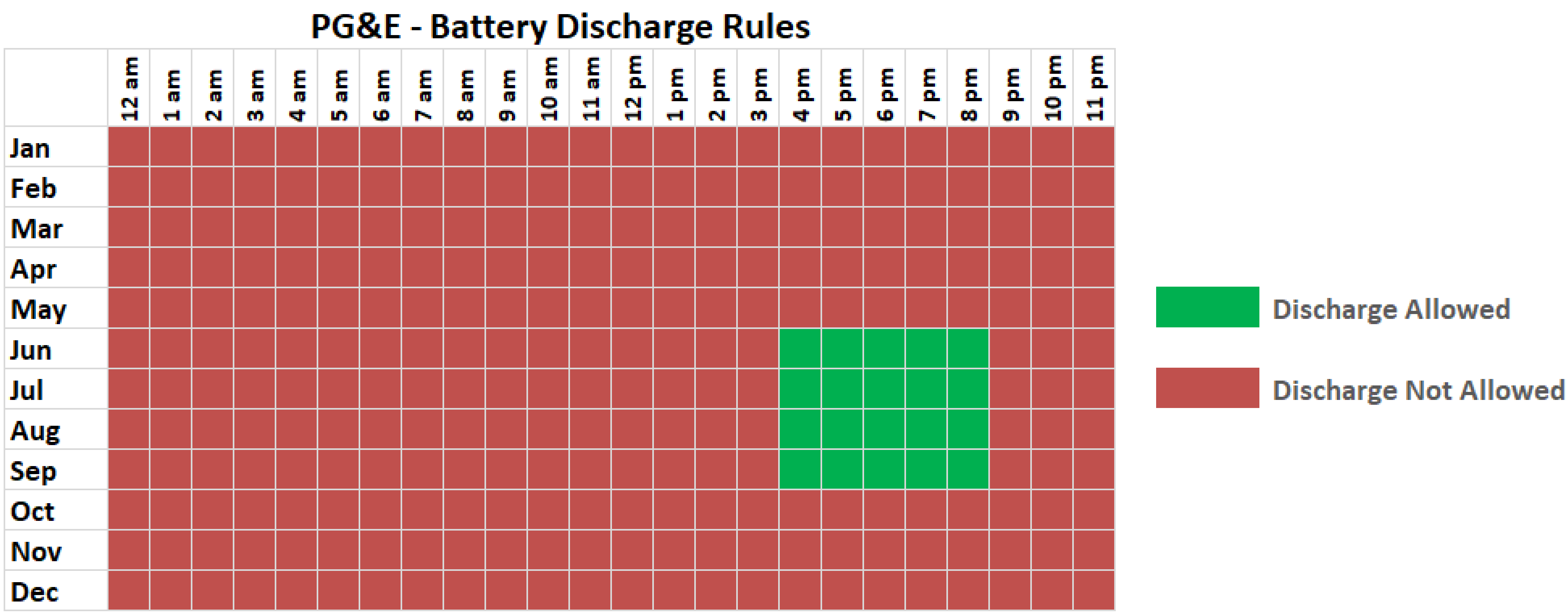
6 | Run SAM
- SAM generates hourly charging and discharge data for 5kW/13.5 kWh battery

Charge / Discharge Behavior

- Use "Manual Dispatch Model" with in SAM's battery storage module.
- Meet all incentive requirements
  - **Federal Incentive Tax Credit:** Battery must charge from solar / renewables
  - **SGIP Program Requirement:** battery must fully charge and discharge at least 52 times, or 687 kWh, per year
- Assume customers maximize bill savings
  - Battery charged and discharged in a way that maximizes bill savings
  - Charge during daytime using solar
  - Discharge only during hours which make sense financially
- Minimum State of Charge
  - Battery does not discharge below 20% (reserved for backup power)
  - Consistent with deployment of battery storage systems

Discharge Behavior – PG&E

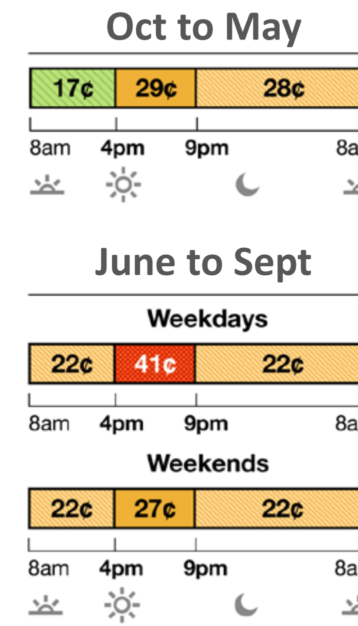
- Battery allowed to discharge in summer months during peak hours
  - PG&E TOU rate difference between peak / off-peak winter months only ~1.5 cents
  - Equivalent full charge / discharge cycles: 72 – 90



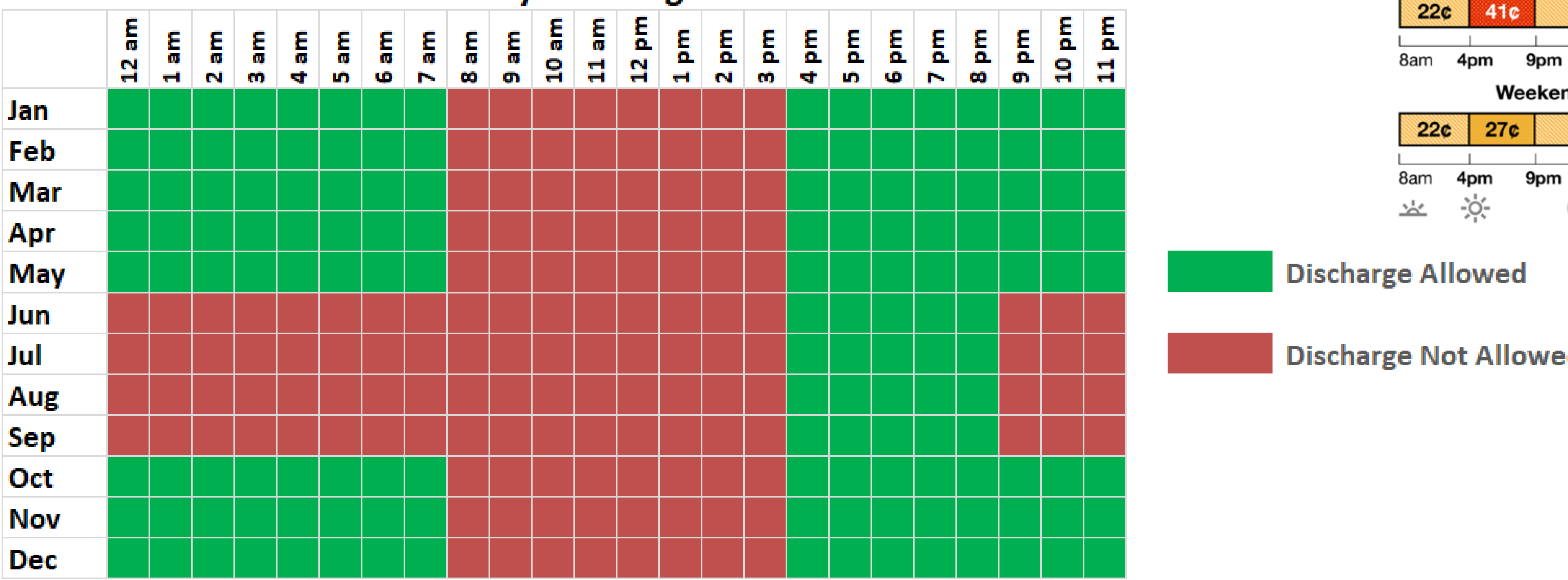
Note: Battery can only charge using PV System

Discharge Behavior - SCE

- Battery allowed to discharge year round
  - SCE TOU rate structure incentivizes arbitrage during winter months
  - Equivalent full charge / discharge cycles: ~ 250



SCE - Battery Discharge Rules



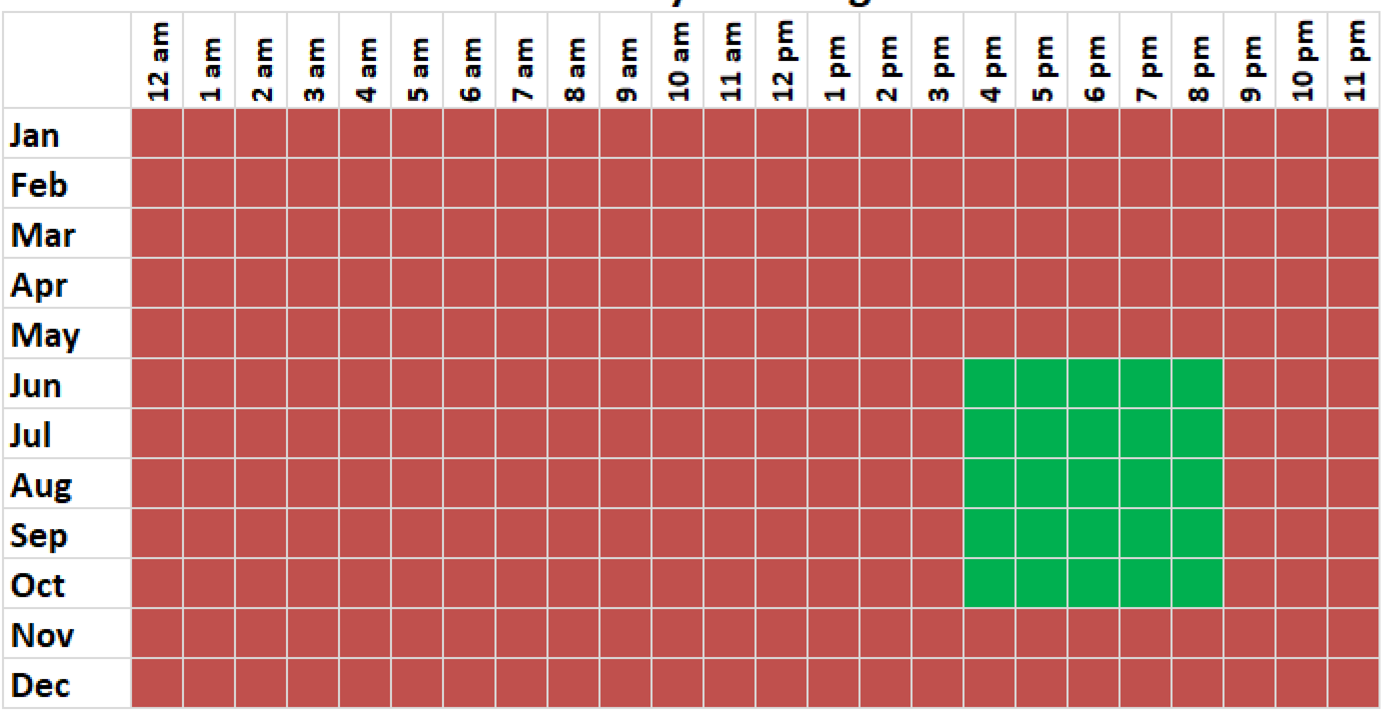
Note: Battery can only charge using PV System

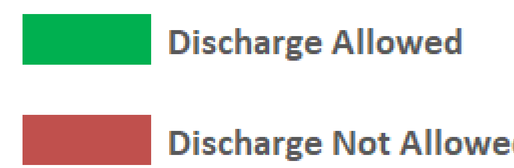
Discharge Behavior SDG&E

- Battery allowed to discharge during peak hours in summer months
  - Small TOU rate difference between peak / off-peak in winter months
  - Equivalent full charge / discharge cycles: ~100

Nov to May

SDG&E - Battery Discharge Rules





Note: Battery can only charge using PV System

Modeling Residential Storage – Final Steps

6 | Run SAM

– SAM generates hourly charging and discharge data for 5kW/13.5 kWh battery

7 | Convert SAM hourly charge / discharge data for Powerwall to charge / discharge profiles per kW of rated capacity.

8 | Combine charge / discharge profiles for 32 regions to create charge / discharge profiles for PG&E, SCE, and SDG&E

9 | Apply per kW charge / discharge profiles to forecast energy storage capacity (in MW) to corresponding forecast zones.

– Hourly forecast of charge / discharge from energy storage for the residential storage systems

Next Steps

- Energy storage forecast will continue to evolve.
- Expect incremental improvements over time including:
  - More data on charge / discharge behavior of battery systems
  - Changes to methodology as more data becomes available
- All future changes in assumptions and methodology will be communicated.
- Staff welcomes feedback, suggestions, and ideas.