Residential Battery Storage

Technology, Performance and Trends

September 16, 2020

Sonoma Clean Power

Speakers

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Programs Manager
Sonoma Clean Power

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Agenda

3:00pm – Welcome

3:05pm – Introduction

3:10pm – Residential Battery Storage

- Overview
- Market trends
- Rates
- Performance and efficiency
- Technology (installation, capacity, safety)

4:00pm – Financing and Incentives

4:15pm – Q&A

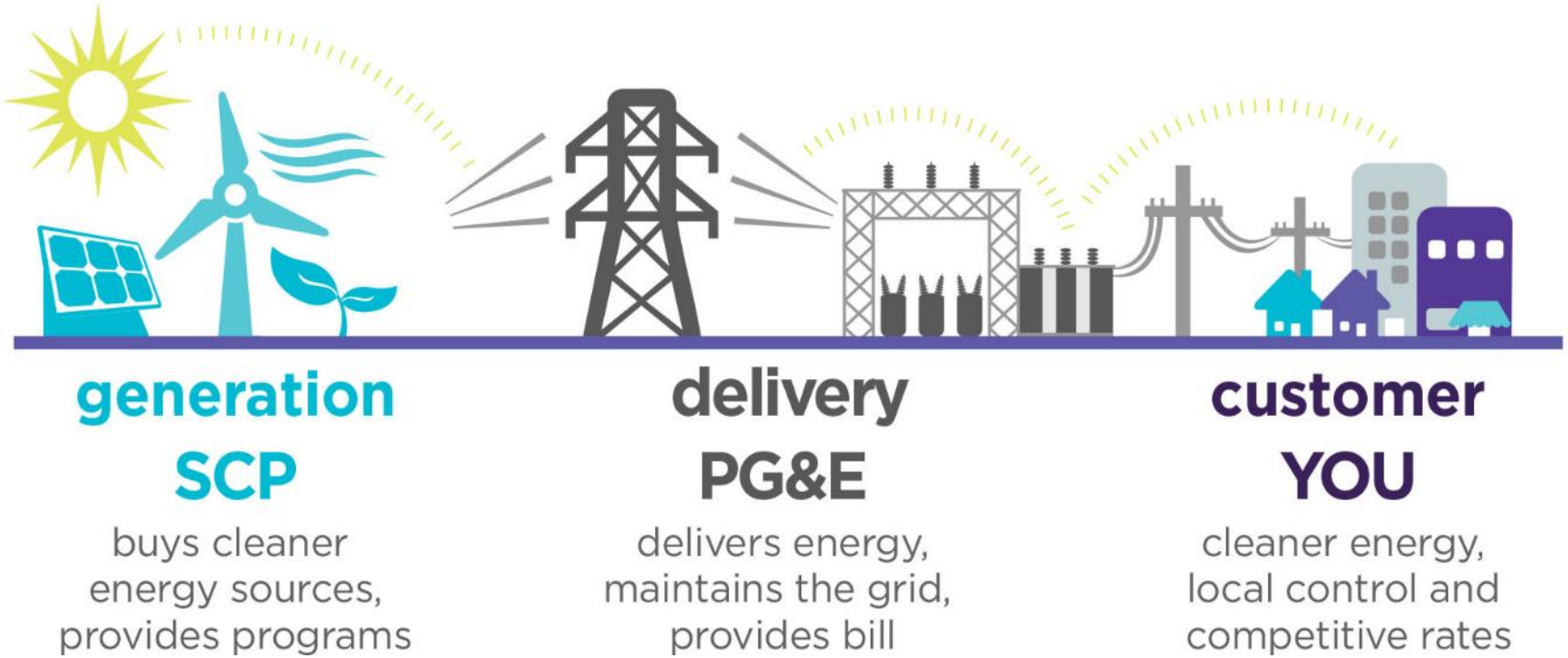
Webinar Logistics

- All attendees are in listen only mode
- We will be answering questions after the presentation
- Please send us questions using the Q&A feature
- You may also use the chat function
- Webinar is being recorded
  - The recording and slides will be shared after the webinar

Who is Sonoma Clean Power?

- Not-for-profit public agency that serves Sonoma and Mendocino Counties
- Started service in 2014, expanded in 2017
- Community Choice Aggregator (CCA)
- Default service provider (opt-out model)
- Self-funded through revenues – no tax dollars
- Run by a Board of Directors and Community Advisory Committee
- Generates electricity for approximately 600,000 customers
- 25 employees

How Community Choice Works



SCP’s Mission

Sonoma Clean Power is turning the tide on the climate crisis, through bold ideas and practical programs.

- Provide higher percentages of renewable energy and reduce greenhouse gas emissions
- Help solve the climate crisis at a local level
- React and respond to local needs
- Deliver customer programs that make a difference

Service Territory

Mendocino County (excluding Ukiah)

- Willits, Point Arena, Fort Bragg
- Unincorporated Mendocino County

Sonoma County (excluding Healdsburg)

- Cloverdale, Cotati, Petaluma, Rohnert Park, Santa Rosa, Sebastopol, Sonoma, Windsor
- Unincorporated Sonoma County

CleanStart Service

50% Renewable

97% Carbon-Free

- Default service
- Competitive rates
- Mix of renewables, carbon-free energy, and general system power

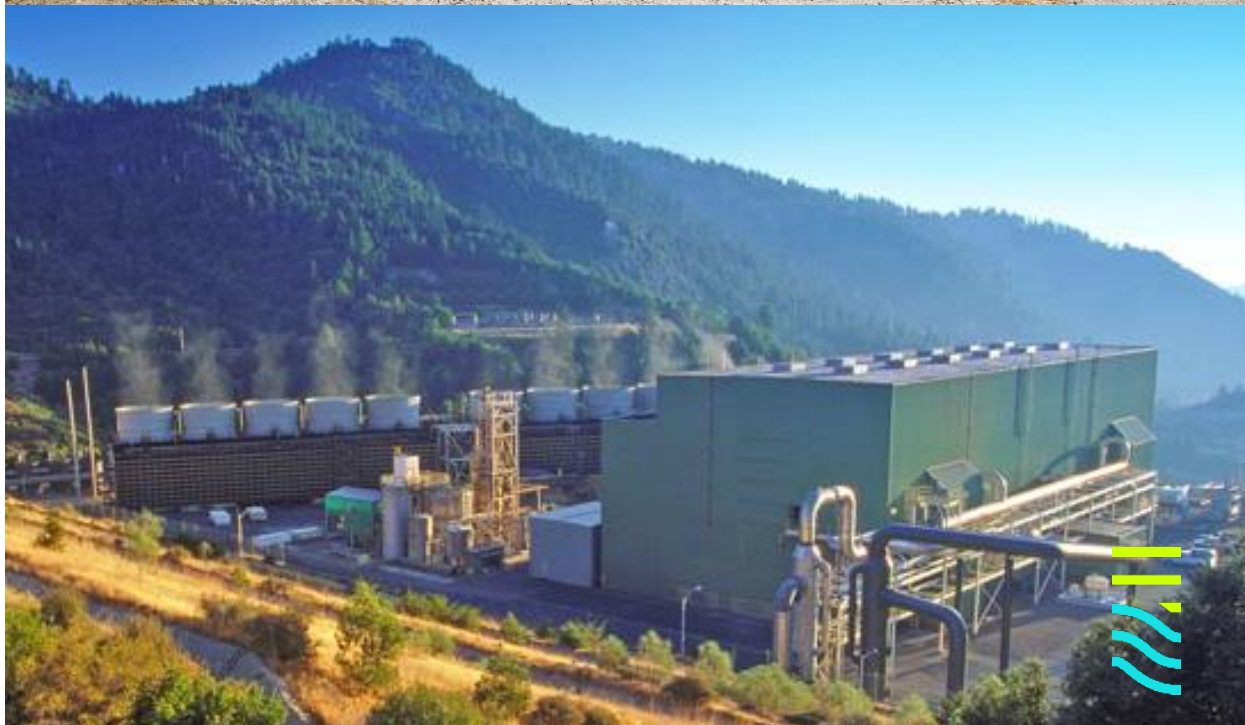
EverGreen Service

- Optional program available to residential and commercial customers
- Premium of $0.025/kWh (about $13 more per month than CleanStart for avg. home)

24/7 Renewable

100% Local

Solar & Geothermal



Advanced Energy Center

SCP is building a 10,000 square foot energy store and training center that will open later in 2020.

Showcase for electric home appliances and equipment for keeping power on during Public Safety Power shutoffs.

Customers and building professionals can:

- Take classes on advanced energy topics
- Request contractor bids
- Purchase equipment and controls with incentives using zero interest loans paid back on their electric bill
- Learn about all of SCP customer programs in one place
- Try cooking in SCP’s zero carbon kitchen

An Introduction to Residential Energy Storage Systems

Chris Calwell

On behalf of:
Sonoma Clean Power
September 16, 2020

Background

- Ecos Research is a small consulting firm based in San Luis Obispo, CA focused on how best to achieve breakthrough reductions in greenhouse gas emissions through technology and policy-driven improvements to consumer products.
- Most of our work to date has focused on energy efficient consumer electronics and appliances, residential energy storage and PV, and electric vehicles.
- I joined the research team at CSIRO in Newcastle, Australia to conduct testing and research on residential energy storage research efforts in Feb-March 2019 through Fulbright Specialist funding from the US State Department.
- This presentation is a distillation of my findings from that research, some parallel findings from Germany, and our subsequent work for EPA ENERGY STAR, Pacific Gas & Electric, and Portland General Electric on the residential energy storage topic.

Key topics we’ll cover

- Batteries 101
- Market trends - what’s happening to sales?
- Why residential battery sales are rising and how they're typically used
- Key challenges in understanding their installation issues, performance claims, specifications and warranties
- The good, the bad and the ugly from early measurements of battery performance and efficiency
- Safety considerations
- Economics - Why it is challenging to get them to pay for themselves now, but won’t be in the future

As residential PV installations have grown and designs have matured, costs have fallen steadily. Next frontiers: EVs and energy storage.

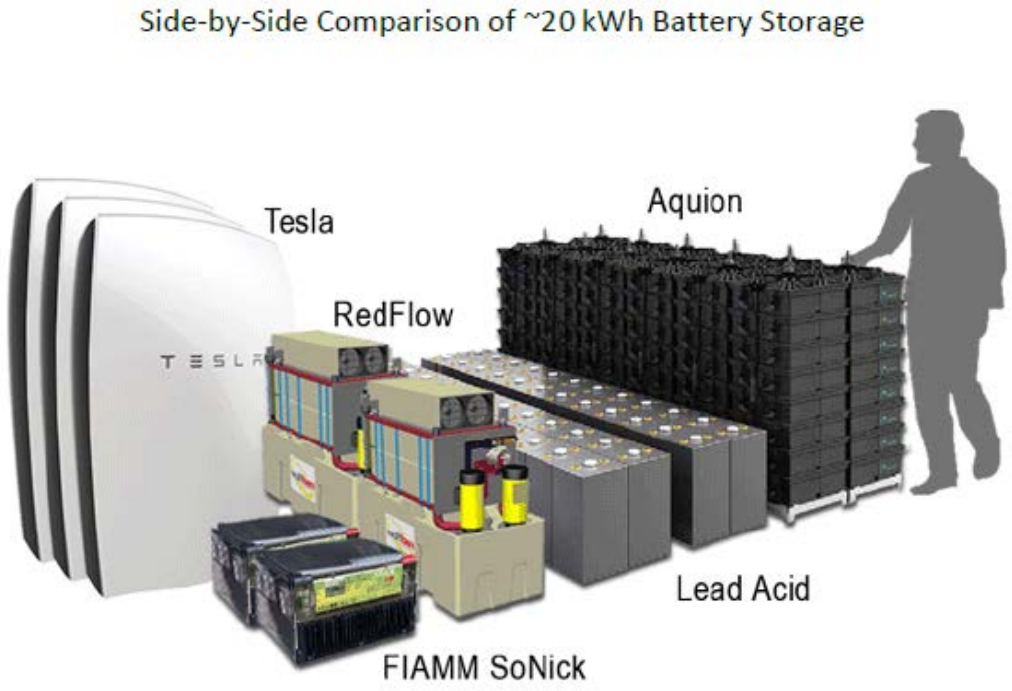
Photo source: Redwood Energy, A Zero Emissions All-Electric Single-Family Construction Guide, 2020.

Early home battery designs were very limiting

- A dedicated room or shed to house everything
- Banks of heavy lead acid batteries that often required water to be added, or other maintenance, and could only utilize about half of their capacity to ensure a reasonable lifetime
- Many of these systems were strictly off-grid, and intended to power a small number of basic loads with a gasoline generator backup
- If they allowed a grid connection, significant extra hardware was needed

Why are home batteries getting more popular?

- Early systems mostly used costly, bulky, difficult-to-maintain lead acid batteries coupled with solar (and often backup diesel generators) to allow people to live off-grid
- Newer designs connect to solar *and* the grid using mostly low maintenance lithium ion technology that was first developed for consumer electronics, electric vehicles, and utility-scale energy storage



Source: FIAMM

Each Tesla Powerwall 2 stores 13.5 kWh, so 1.5 of them would hold as much energy as the systems on the left

Lithium ion batteries represent a major advance from lead acid and nickel chemistries.

But there are key differences among lithium ion chemistries too:

Specifications	Lead Acid	NiCd	NiMH	Li-ion[1] Cobalt	Li-ion[1] Manganese	Li-ion[1] Phosphate
Specific energy Wh/kg)	30–50	45–80	60–120	150–250	100–150	90–120
Internal resistance	Very Low	Very low	Low	Moderate	Low	Very low
Cycle life[2] (80%DoD)	200–300	1,000[3]	300–500[3]	500–1,000	500–1,000	1,000–2,000
Charge time[4]	8–16h	1–2h	2–4h	2–4h	1–2h	1–2h
Charge tolerance	High	Moderate	Low	Low. No trickle charge		
Self-discharge/ month (room temp)	5%	20%[5]	30%[5]	<5% Protection circuit consumes 3%/month		
Cell voltage nominal	2V	1.2V[6]	1.2V[6]	3.6V[7]	3.7V[7]	3.2–3.3V
Charge cutoff voltage (V/cell)	2.40 Float 2.25	Full charge detection by voltage signature		4.20 typical Some go to higher V		3.60
Discharge voltage	1.75V	1.0V		2.5–3.0V		2.5V
Peak load current Best result	5C[8] 0.2C	20C 1C	5C 0.5C	2C <1C	>30C <10C	>30C <10C
Charge temperature	–20 to 50°C (–4 to 122°F)	0 to 45°C (32 to 113°F)		0 to 45°C[9] (32 to 113°F)		
Discharge temperature	–20 to 50°C (–4 to °F)	–20 to 65°C (–4 to 49°F)		–20 to 60°C (–4 to 140°F)		
Maintenance requirement	3-6 months[10] (toping chg.)	Full discharge every 90 days when in full use		Maintenance-free		
Safety requirements	Thermally stable	Thermally stable, fuse protection		Protection circuit mandatory[11]		
In use since	Late 1800s	1950	1990	1991	1996	1999
Toxicity	Very high	Very high	Low	Low		
Coulombic efficiency[12]	~90%	~70% slow charge ~90% fast charge		99%		
Cost	Low	Moderate		High[13]		

Table source: Cadex Electronics, *Batteries in a Portable World: A Handbook on Rechargeable Batteries for Non-Engineers,* 2017.

Germany and Australia are the early leaders in home battery installation; US sales modest so far but rising fast

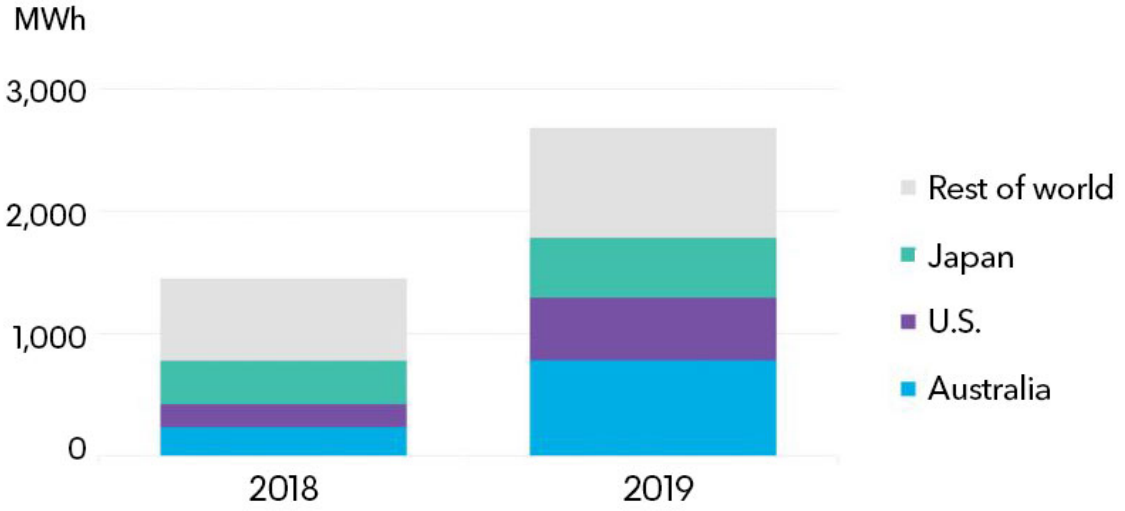
Global Market Volume for Residential Energy Storage Systems, by Region, Through 2023
(Units)

Region	2017	2018	2023	CAGR% 2018-2023
North America	38,500	72,350	123,432	11.3
Europe	67,000	131,000	247,230	13.5
Asia-Pacific	29,100	82,000	130,790	9.8
ROW	1,000	4,600	7,176	9.3
Total	135,600	289,950	508,628	11.9

Source: BCC Research

Annual residential storage deployments by country

Estimated and forecast residential storage installations in Australia

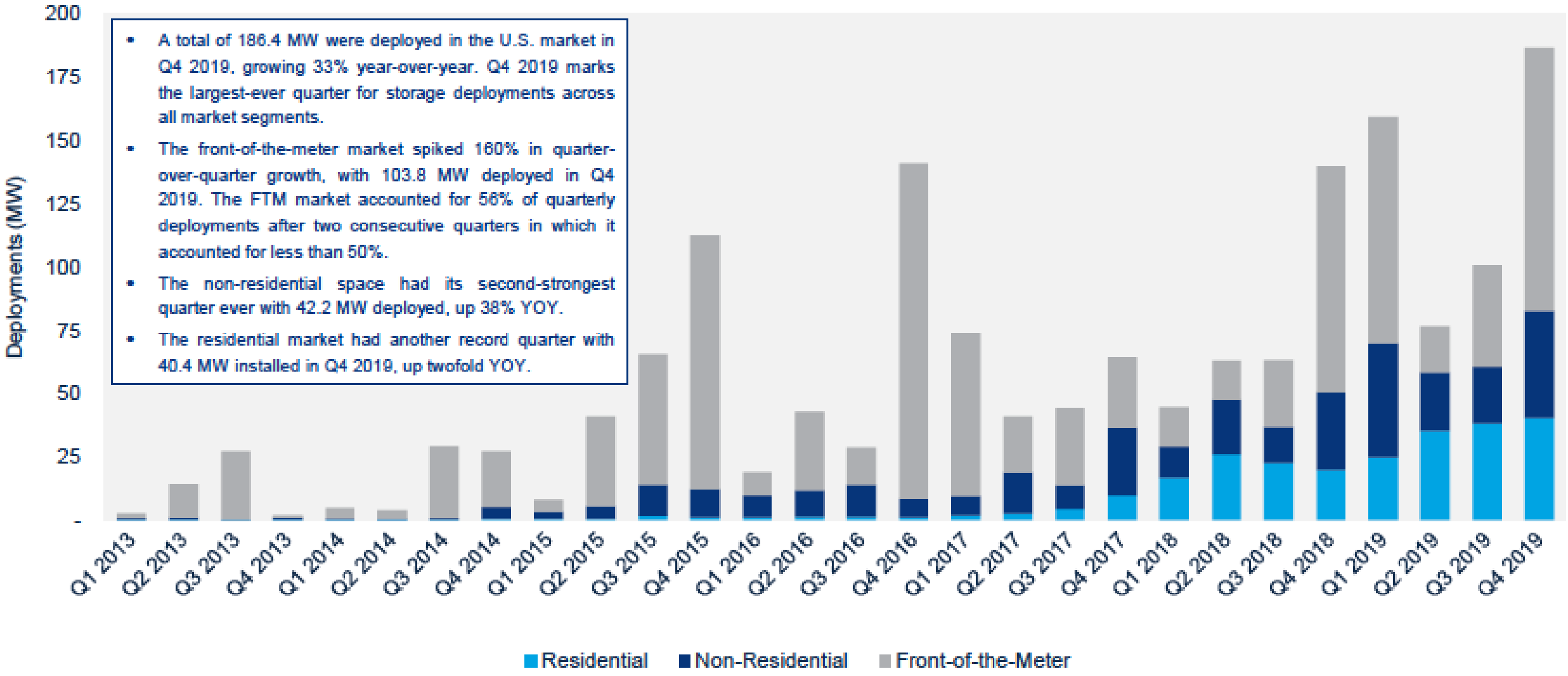


Source: BloombergNEF, 2018 Long-Term Energy Storage Outlook

U.S. Q4 2019 deployments reached a record 186 MW

Q4 2019 breaks previous record for total quarterly deployments by 17%

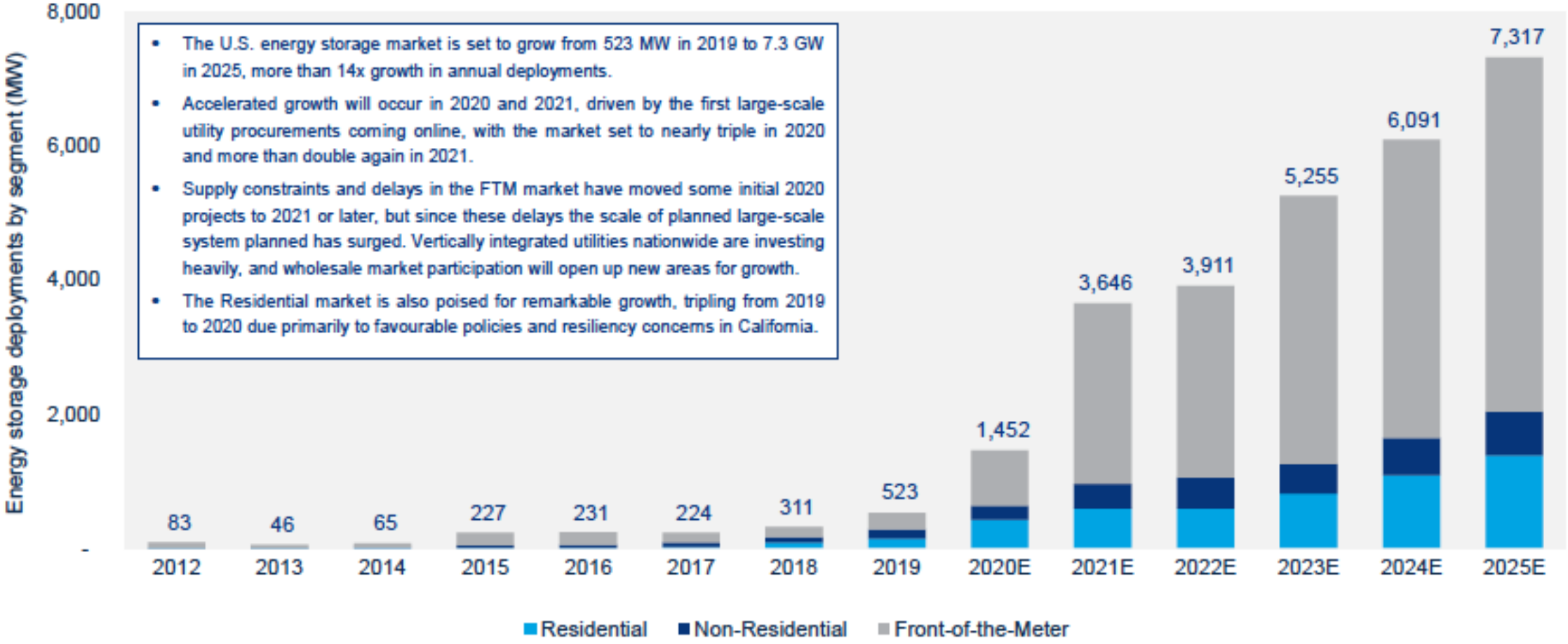
- A total of 186.4 MW were deployed in the U.S. market in Q4 2019, growing 33% year-over-year. Q4 2019 marks the largest-ever quarter for storage deployments across all market segments.
- The front-of-the-meter market spiked 160% in quarter-over-quarter growth, with 103.8 MW deployed in Q4 2019. The FTM market accounted for 56% of quarterly deployments after two consecutive quarters in which it accounted for less than 50%.
- The non-residential space had its second-strongest quarter ever with 42.2 MW deployed, up 38% YOY.
- The residential market had another record quarter with 40.4 MW installed in Q4 2019, up twofold YOY.



U.S. energy storage annual deployments will reach 7.3 GW annually in 2025

Sharp scale-ups are being driven by utility procurements and the accelerating residential market

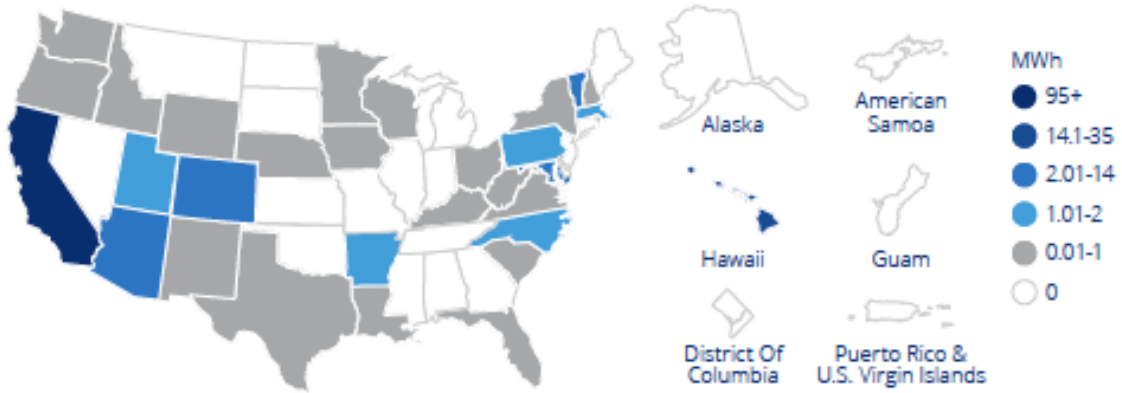
U.S. energy storage annual deployment forecast, 2012-2025E (MW)



- The U.S. energy storage market is set to grow from 523 MW in 2019 to 7.3 GW in 2025, more than 14x growth in annual deployments.
- Accelerated growth will occur in 2020 and 2021, driven by the first large-scale utility procurements coming online, with the market set to nearly triple in 2020 and more than double again in 2021.
- Supply constraints and delays in the FTM market have moved some initial 2020 projects to 2021 or later, but since these delays the scale of planned large-scale system planned has surged. Vertically integrated utilities nationwide are investing heavily, and wholesale market participation will open up new areas for growth.
- The Residential market is also poised for remarkable growth, tripling from 2019 to 2020 due primarily to favourable policies and resiliency concerns in California.

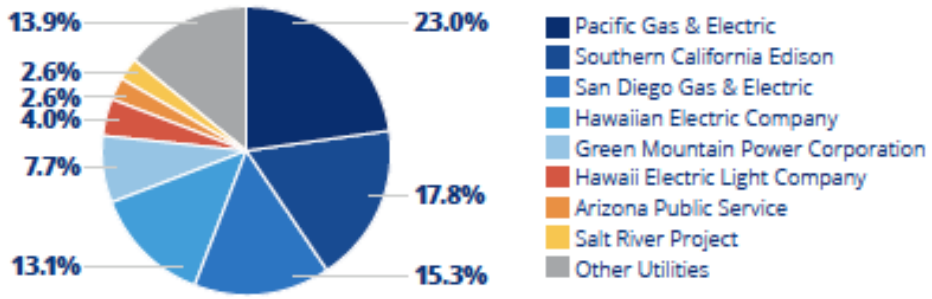
Residential Storage Market

Figure 3: 2018 Annual Residential Deployment (MWh)



Source: Smart Electric Power Alliance, 2019

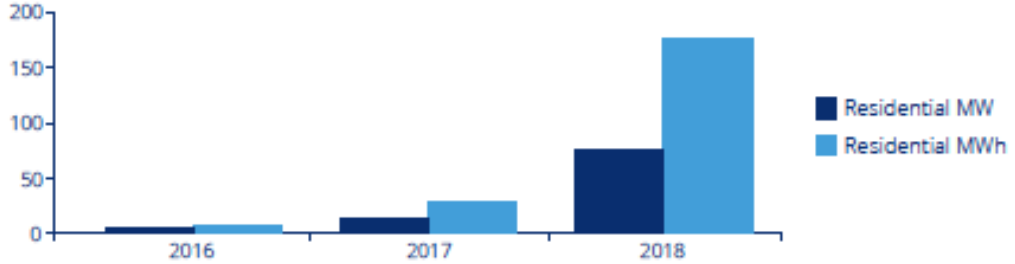
Figure 4: Top Utilities by 2018 Annual Residential Deployment (MWh)



Source: Smart Electric Power Alliance, 2019

MW = Megawatts-ac

Figure 5: Annual Residential Deployment



Source: Smart Electric Power Alliance, 2019

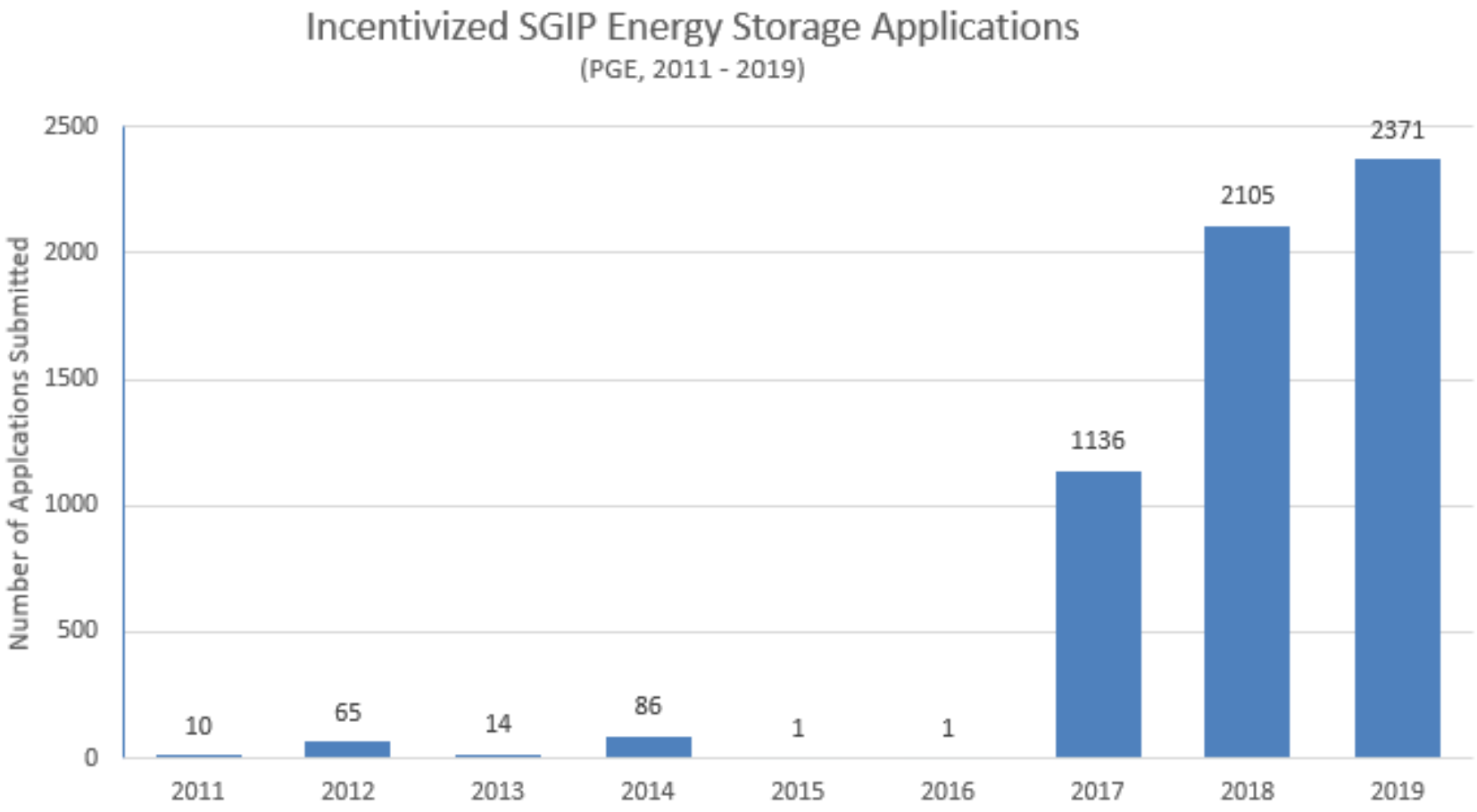
175.5 MWh of residential storage was added in 2018, an increase of 500.1% over 2017.

- **California** interconnected 99.9 MWh across 7,344 residential battery storage systems, an increase of 629.2% in MWh and 506.4% in systems over 2017. This continued growth is the result of the state's Self Generation Incentive Program (SGIP).[3]
- **Hawaii** interconnected 33.6 MWh across 1,975 residential battery storage systems in 2018, an increase of 278% in MWh and more than doubled the number of systems deployed over 2017. This increase was primarily driven by net metering changes that offered a self-consumption option to customers.[4]
- **Vermont** interconnected 13.5 MWh across 1,000 residential battery storage systems, an increase of 526.2% in MWh and 549.4% in systems over 2017. Green Mountain Power was the sole driver of residential storage growth in Vermont in 2018.

3 California Public Utilities Commission (CPUC) (n.d.). Self-Generation Incentive Program. Retrieved from https://www.cpuc.ca.gov/sgip/

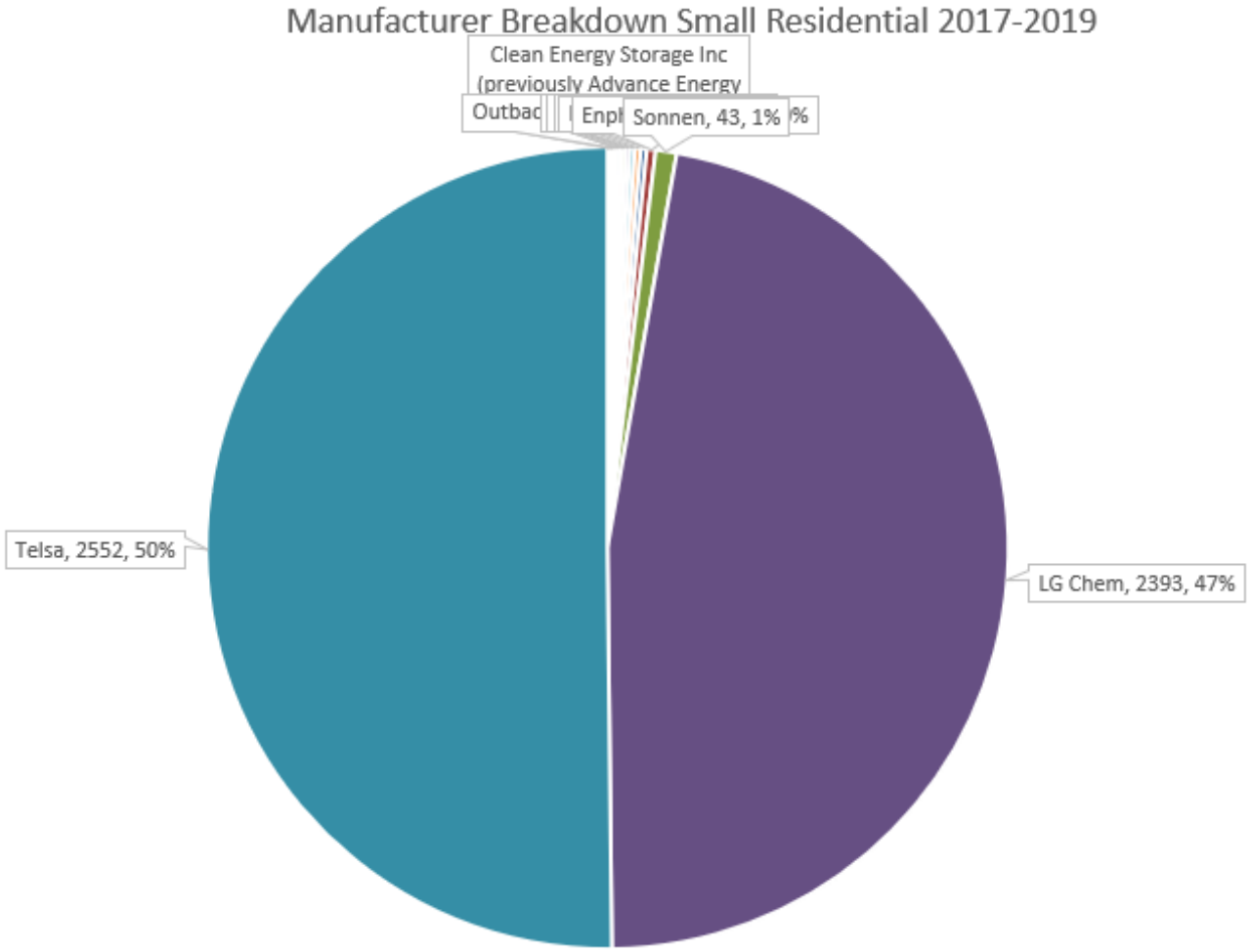
4 Hawaiian Electric Company (HECO) (2018). Net Energy Metering Plus. Retrieved from https://www.hawaiianelectric.com/products-and-services/customer-renewable-programs/private-rooftop-solar/net-energy-metering-plus

California's battery incentives (SGIP) are rising fast: 2,000+ systems per year in northern California claiming rebates



The data shows electrochemical energy storage projects that submitted incentive applications through the Self-Generation Incentive Program (SGIP) in PG&E's service territory, in the small residential storage category (≦ 10 kW).

Two battery makers dominate California's rebated residential systems

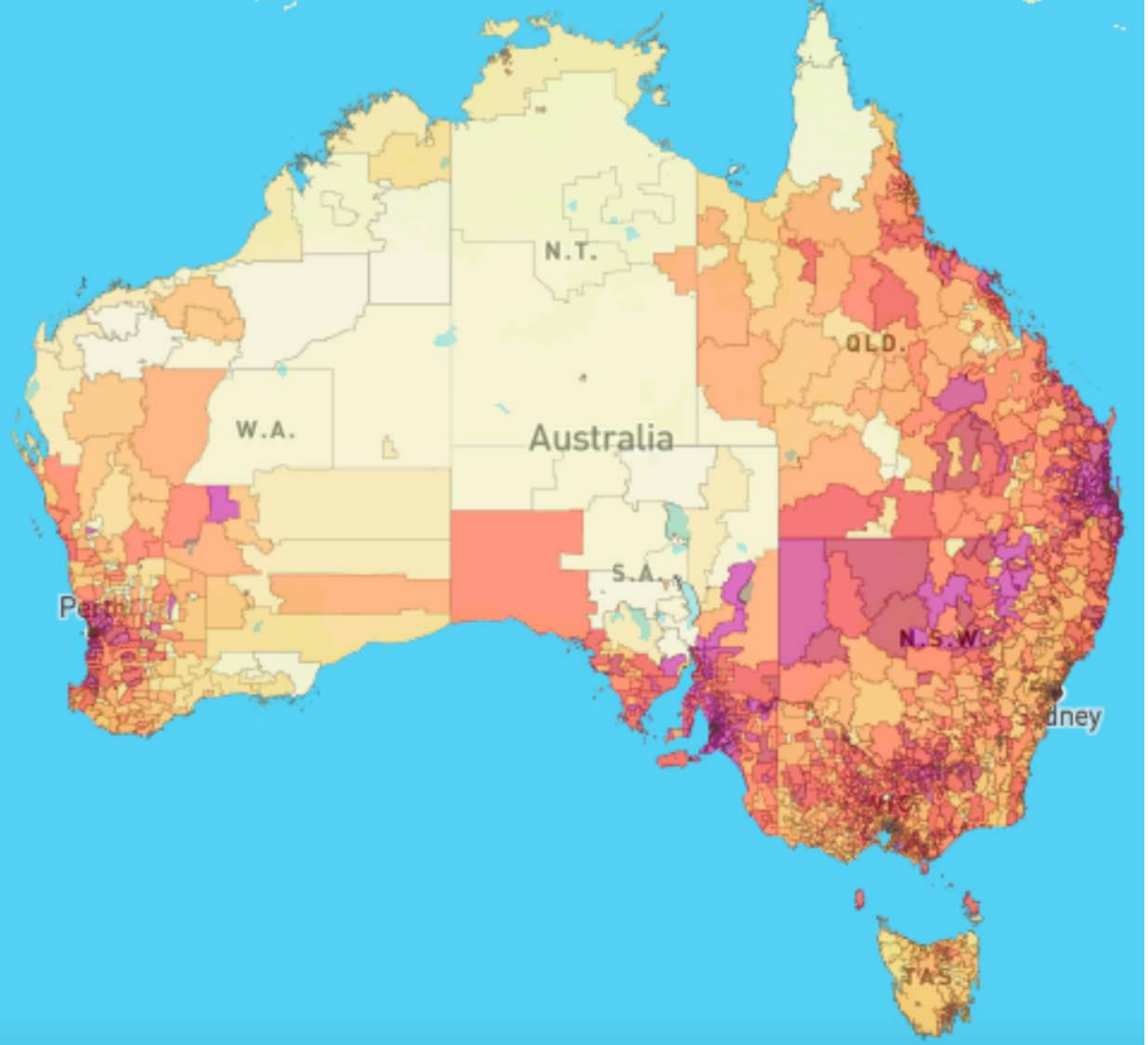


Manufacturer	Count
BMZ	1
Clean Energy Storage Inc (previously Advance Energy Storage)	1
Concorde	1
Discovery	1
LG Solar	1
NEOVOLTA	1
Solaredge	1
US Battery	1
LG Electronics	2
Outback Power Systems	2
JLM	3
Enerdel	4
Simpliphi	6
Sunverge	6
Tabuchi	7
Pika Energy	8
Adara Power	10
Energport Inc	12
Mercedes Benz	12
Enphase Energy	18
Sonnen	43
LG Chem	2393
Telsa	2552

2020 results so far: 78% of SGIP rebates to Tesla, 15% to LG Chem, and 7% to all other manufacturers combined.

Market status

- At present, in the more mature Australian marketplace, 25% of homes have solar on the roof. There are nearly 250 competing residential models for sale representing at least 66 distinct brands of home energy storage systems.
- Good list of available models: www.smartenergy.org.au/batteryfinder
- Fewer models are presently available in the US market (where 2% of homes have solar on the roof), but three key categories of competitors are seen here:
  - *Standalone battery makers*: Samsung, LG Chem, BYD, PylonTech, Simpliphi, etc.
  - *Inverter manufacturers* offering branded matching batteries: Enphase, SolarEdge, Generac, Outback, etc.
  - *Full system manufacturers* offering various combinations of solar panels, inverters, batteries, and control/monitoring systems: SunPower, Tesla, Sonnen, etc.



Percentage of homes with rooftop PV by post code

- 0%
- 1%
- 2.5%
- 5%
- 10%
- 15%
- 20%
- 25%
- 30%
- 35%
- 40%+

Some of the Available US Models

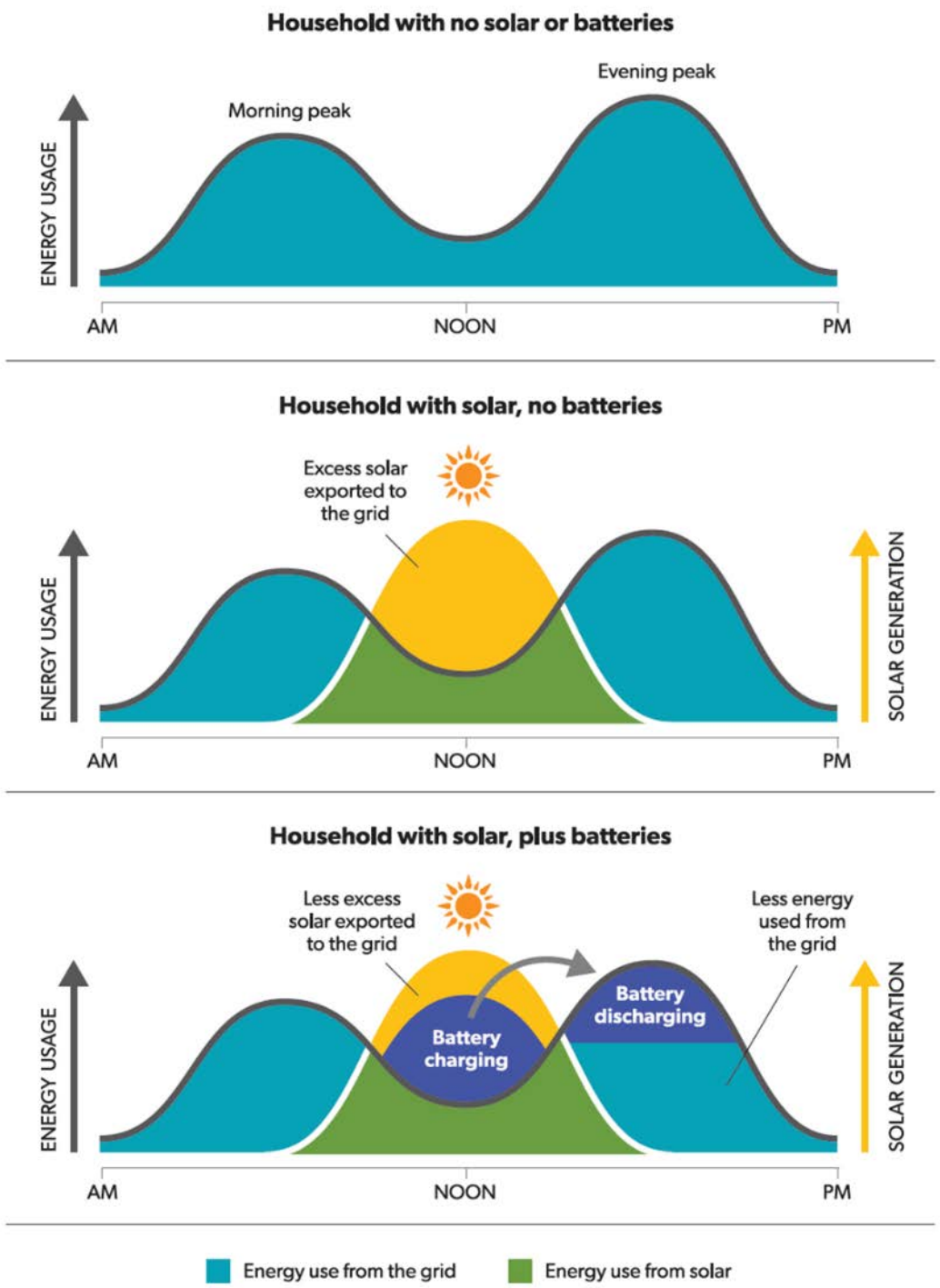
	DC Batteries			AC Batteries		
DC Battery	**Blue Planet** Energy	**LG** RESU 10H	**SimpliPhi** Power 2.4	**Tesla** Powerwall	**Panasonic** EVDC-105	**Sonnen** EcoLinx
						
Capacity (kWh)	8, 12, 16	9.3	2.4	13.5 (up to 135)	5.7, 11.4, 17.1	10, 12, 14, 16, 18, 20
Round Trip Eff.	98%	94.5%	98.0%	98%	89%	86%
Chemistry	Lithium Iron Phosphate	Lithium-ion	Lithium Iron Phosphate	Lithium Nickel Manganese Cobalt Oxide	Lithium-ion	Lithium Iron Phosphate

Key market drivers for residential storage systems (in rough order of importance for US customers)

1. **Backup of whole house or critical loads** for early adopters that have the money to keep the lights on when the grid goes down. Otherwise, grid-connected solar-powered homes shut off automatically during outages to protect utility line workers.
2. **Solar self-consumption**: make extra electricity while the sun is shining and use it from batteries when the sun isn’t shining to minimize environmental impact or avoid net metering limitations
3. **Arbitrage:** *consumers* buy power at cheap times of day under time of use (TOU) rates and sell it back to the utility or consume it at expensive times of day
4. **Virtual power plant (VPP)**: support *utility* grid by consuming or providing power when and where needed to balance loads

The fundamental premise or value propositions of residential batteries

- Reduce the height of peaks in demand
- Increase the height of valleys in demand
- Minimize sale of power *to the grid* at low prices
- Minimize purchase of power *from the grid* at high prices during times of peak consumption
- **Basic goal: buy power when it's cheap and sell power when it's expensive**



SCP
Billing and Rates

Sonoma
Clean Power

SCP Billing (non-solar)

Your Account Summary

Amount Due on Previous Statement	$417.01
Payment(s) Received Since Last Statement	-418.01
Previous Unpaid Balance	$0.00
Current PG&E Electric Delivery Charges	$120.39
Sonoma Clean Power Electric Generation Charges	75.69
Current Gas Charges	208.92

Automatic Payment Service (APS)
to be applied 02/24/2020 **$406.00**

Details of PG&E Electric Delivery Charges

01/04/2020 - 02/03/2020 (31 billing days)

Service For:
Service Agreement ID:
Rate Schedule: E1 X Residential Service

01/04/2020 – 02/03/2020	Your Tier Usage	1	2

Tier 1 Allowance	325.50	kWh	(31 days x 10.5 kWh/day)	
Tier 1 Usage	325.500000	kWh	@ $0.23581	$76.76
Tier 2 Usage	325.500000	kWh	@ $0.29675	96.59
Generation Credit				-76.67
Power Charge Indifference Adjustment				17.56
Franchise Fee Surcharge				0.44
Santa Rosa Utility Users' Tax (5.000%)				5.71

Total PG&E Electric Delivery Charges **$120.39**

2014 Vintaged Power Charge Indifference Adjustment

- CleanStart rates match PG&E's rates as of March 1, 2020.
  - SCP's Generation Rate
    - Generation-Total + PCIA + FF
  - PG&E Generation Rate
    - Generation Credit

Details of Sonoma Clean Power Electric Generation Charges

01/04/2020 - 02/03/2020 (31 billing days)

Service For:
Service Agreement ID: ESP Customer Number:

01/04/2020 – 02/03/2020

Rate Schedule: E-1

EverGreen	651.000000	kWh	@ $0.02500	$16.28
Generation - Total	651.000000	kWh	@ $0.08544	55.62
		Net Charges	71.90	
Utility Users Tax				3.59
Energy Commission Surcharge				0.20

Total Sonoma Clean Power Electric Generation Charges **$75.69**

SCP Billing (solar and solar plus)
NetGreen 2.0

Roles of Responsibility:

PG&E	Sonoma Clean Power
Approves Installation & Interconnection	
Maintains Meters & Wires	
Bills delivery charges annually + monthly minimum bill charges	Bills generation charges monthly
Annual True-Up for delivery charges/credits	Annual Cash Out for generation exported to the grid

NetGreen +

- NetGreen + is SCP’s net energy metering (NEM) program.
- NetGreen is available to any SCP customer with solar.
- NetGreen credits customers the retail rate plus a bonus penny for any over-generation during a TOU period.
- Each spring, SCP does a cash-out for customers that exported more energy (kWh) than consumed on an annual basis at double PG&E’s net compensation rate or about 6 cents.

More information available at:
sonomacleanpower.org/programs/netgreen

Residential Rate Options

Rate	Description
E-1 (Tiered Rate)	Flat rate, same price for all hours
E-TOU-C (Peak Pricing 4-9pm everyday)	Time of Use (TOU) rate with 19 hours of off-peak pricing and 5 hours of peak pricing
E-TOU-D (Peak Pricing 5-8pm weekdays)	TOU rate with 21 hours of off-peak pricing and 3 hours of peak pricing on weekdays, weekends are all off-peak.
EV2A (Home Charging Rate)	Peak period 4-9pm, part-peak 3-4pm and 9pm-12am, all other hours are off-peak

E-TOU-A, E-TOU-B, E-6, and EVA rate options are closed to new customers

Rate Options with a Battery

Customers with …	Available rates
Battery only	EV2A
Battery + Solar	Any TOU rate, except EV2A
Battery + Solar + EV	Any TOU rate

Rate comparisons can be done at pge.com/myenergy

More information

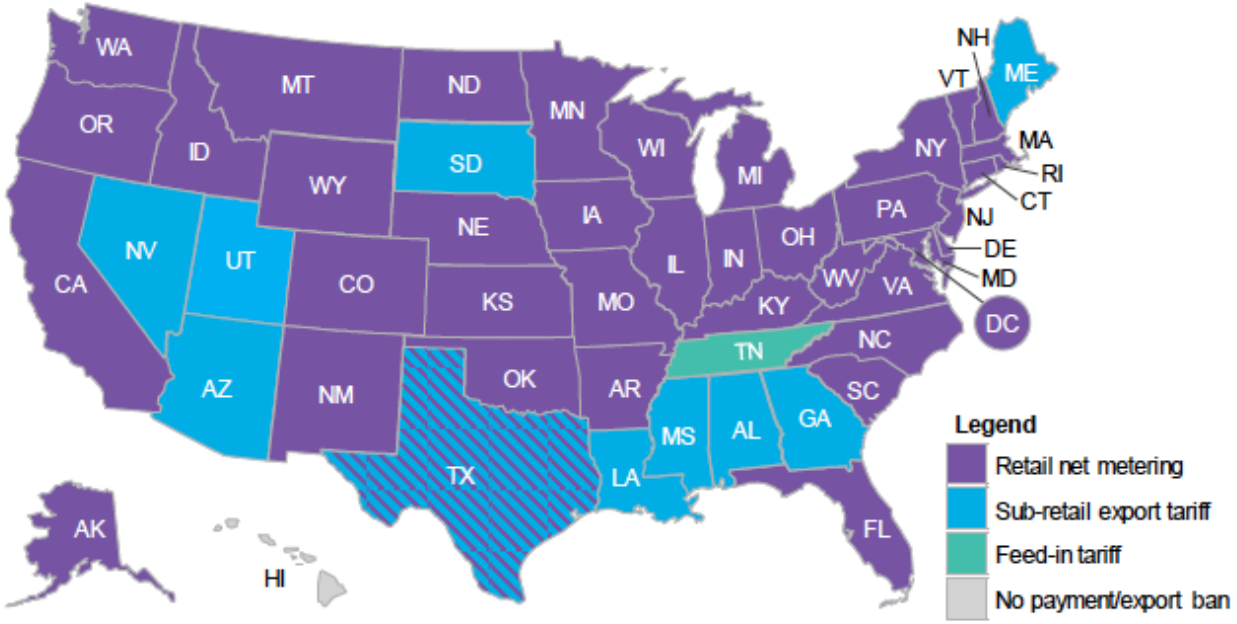
Online: sonomacleanpower.org/billing
sonomacleanpower.org/programs/netgreen

Email: info@sonomacleanpower.org (billing)
programs@sonomacleanpower.org

Local Contact Center: 1 (855) 202-2139, M-F 8am-5pm

True net metering is waning: Increasingly common that utilities pay less for self-generated electricity on sunny days than they charge for it at night

Policy: Net metering state policies as of December 2018

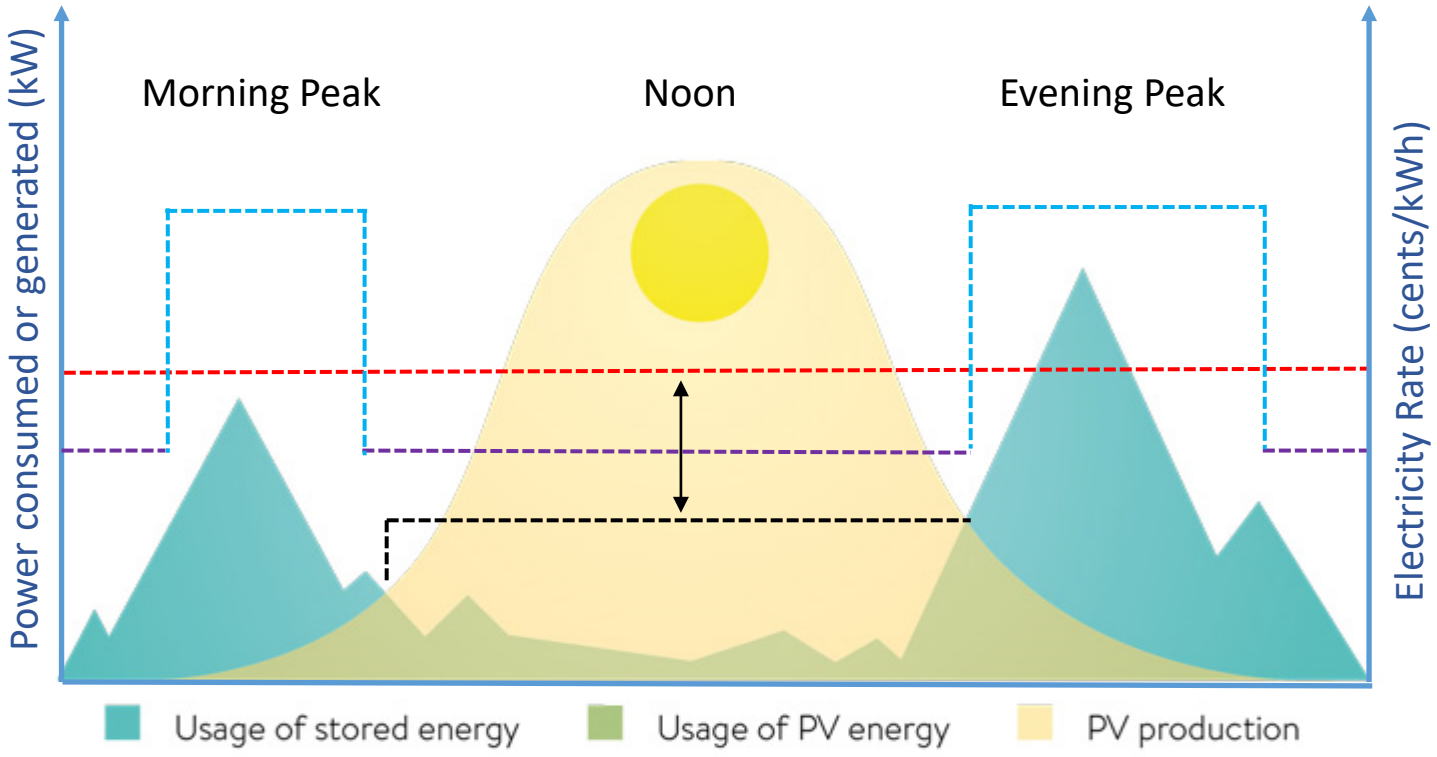


- As of December 2018, net metering at the full retail rate was available to most customers within 38 states and Washington, D.C.
- The rooftop solar markets were once again threatened in 2018 by regulators' willingness to dismantle net metering regimes at low adoption levels. Maine became the first state in the Northeast to compensate residential solar generation below the retail rate. Several other states are set to follow. Connecticut, Michigan, and Utah are among the states that enacted suspensions or phase-outs in the past year.
- Net metering successor schemes vary widely. Several states, including Nevada and Maine, are phasing down the value of net metering credits over time; Arizona will compensate small-scale PV systems at the five-year-average utility-scale PPA price, and only for 10 years; and Indiana will only offer net metering to systems connected before 2022. New York's commercial PV market has transitioned from net metering to a *Value of Distributed Energy Resources* tariff that varies by location, system, and time of generation. NY mass market customers will transition to the complex scheme in 2020.

Source: BloombergNEF, DSIRE. Note: the map displays the mechanism offered to the majority of residential customers where the incentives vary within a state.

  BloombergNEF

Batteries don't generally save money under flat rates, but can with time of use (TOU) rates or some kinds of net metering rates



On peak rate paid by consumer

Flat electricity rate paid by consumer

Off peak rate paid by consumer

Wholesale rate paid to consumer

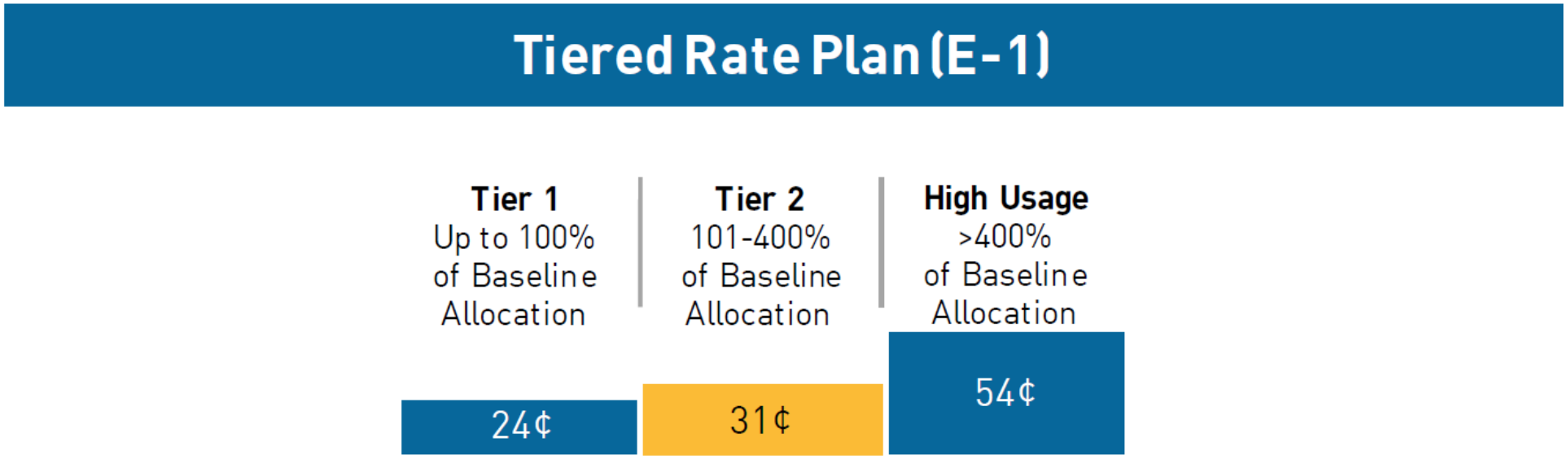
Morning: minimal energy production, high energy needs.

Midday: highest energy production, low energy needs.

Evening: low energy production, high energy needs.

How does this work with PG&E's rates?

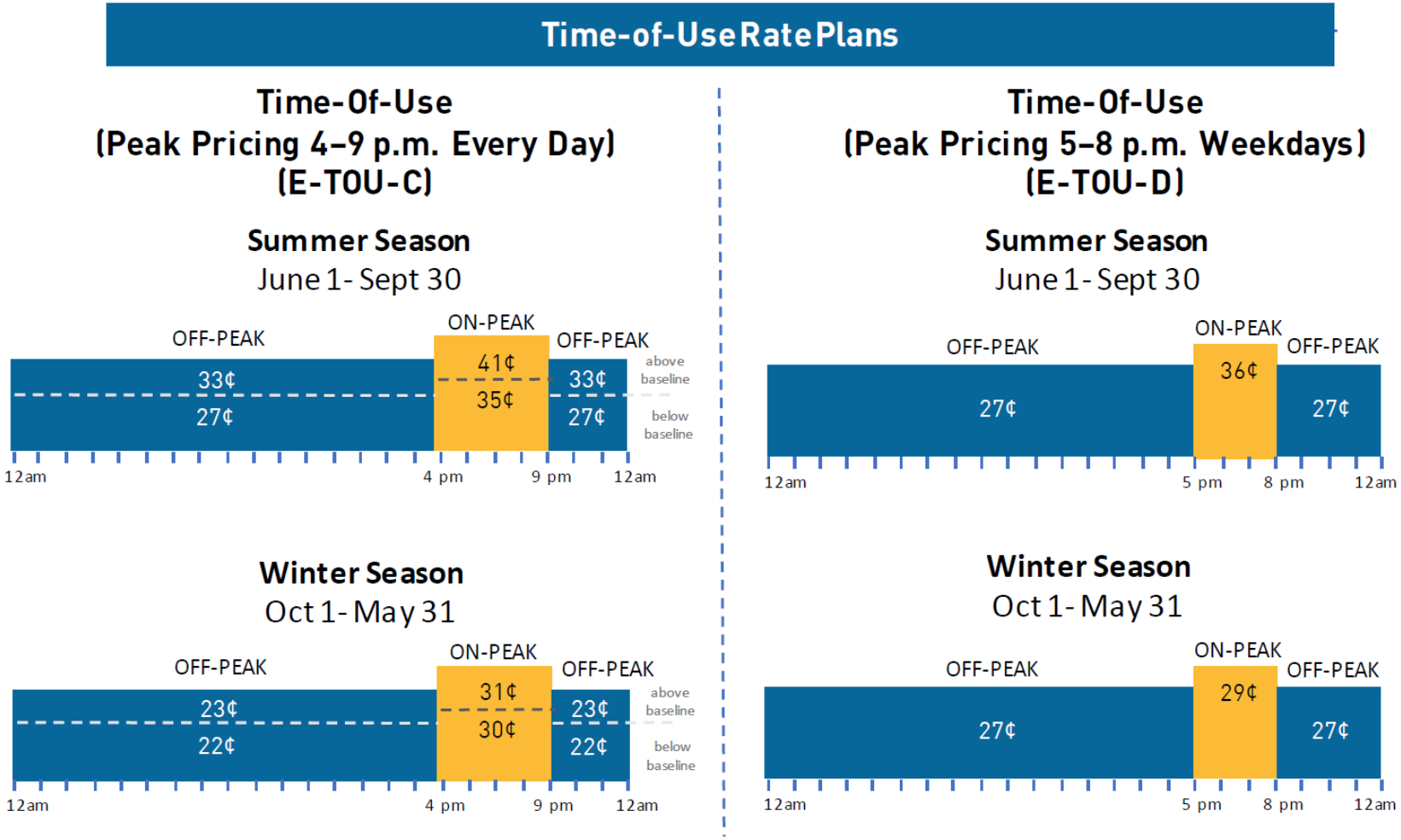
- PG&E has progressively tiered rates by default, where you pay more for each unit of electricity as you use more. This is intended to help encourage conservation, because any electricity you save on the margin can be at a very high price:



Time of Use (TOU) rates from PG&E

It can make sense to arbitrage electricity between cheap and inexpensive times of day if the price difference is at least 20 to 30 cents/kWh.

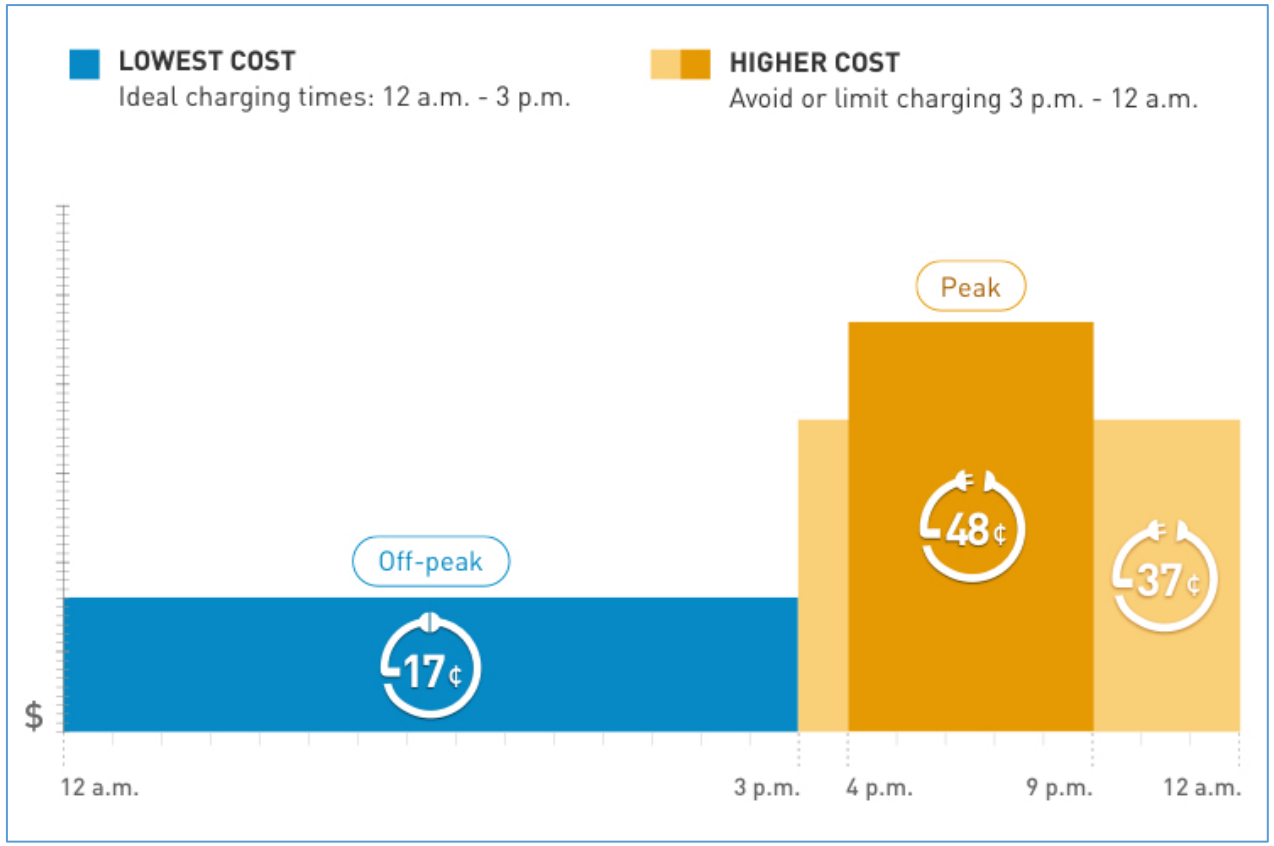
With PG&E's TOU rates, the price differences between peak and off peak times are much smaller than that (2 to 9 cents/kWh).



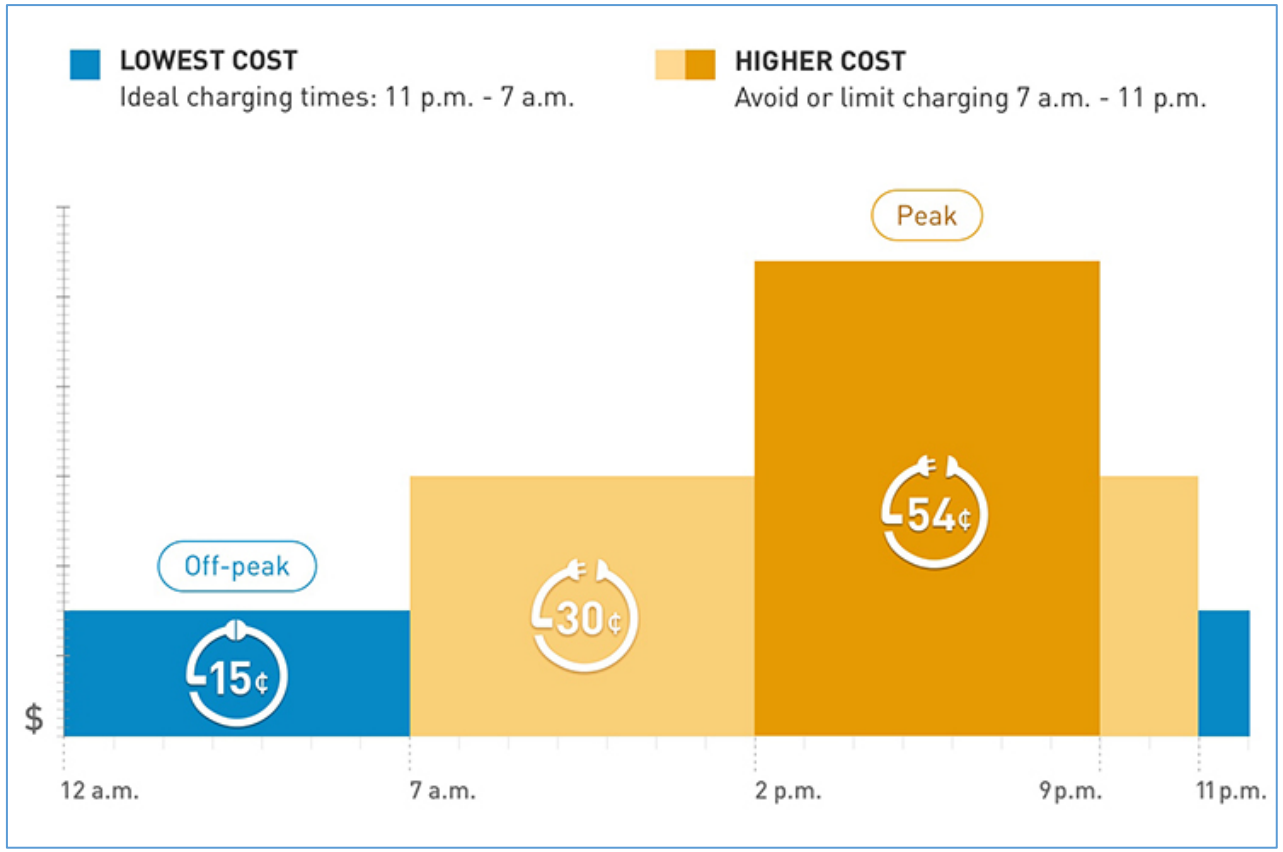
Source: www.pge.com/pge_global/common/pdfs/rate-plans/how-rates-work/Residential-Rates-Plan-Pricing-2020.pdf

PG&E's EV rates are the most promising for shifting power between different times of day

EV2A rate (cheaper peak but more expensive off-peak)



EVB rate (bigger price differences between peak and off-peak)

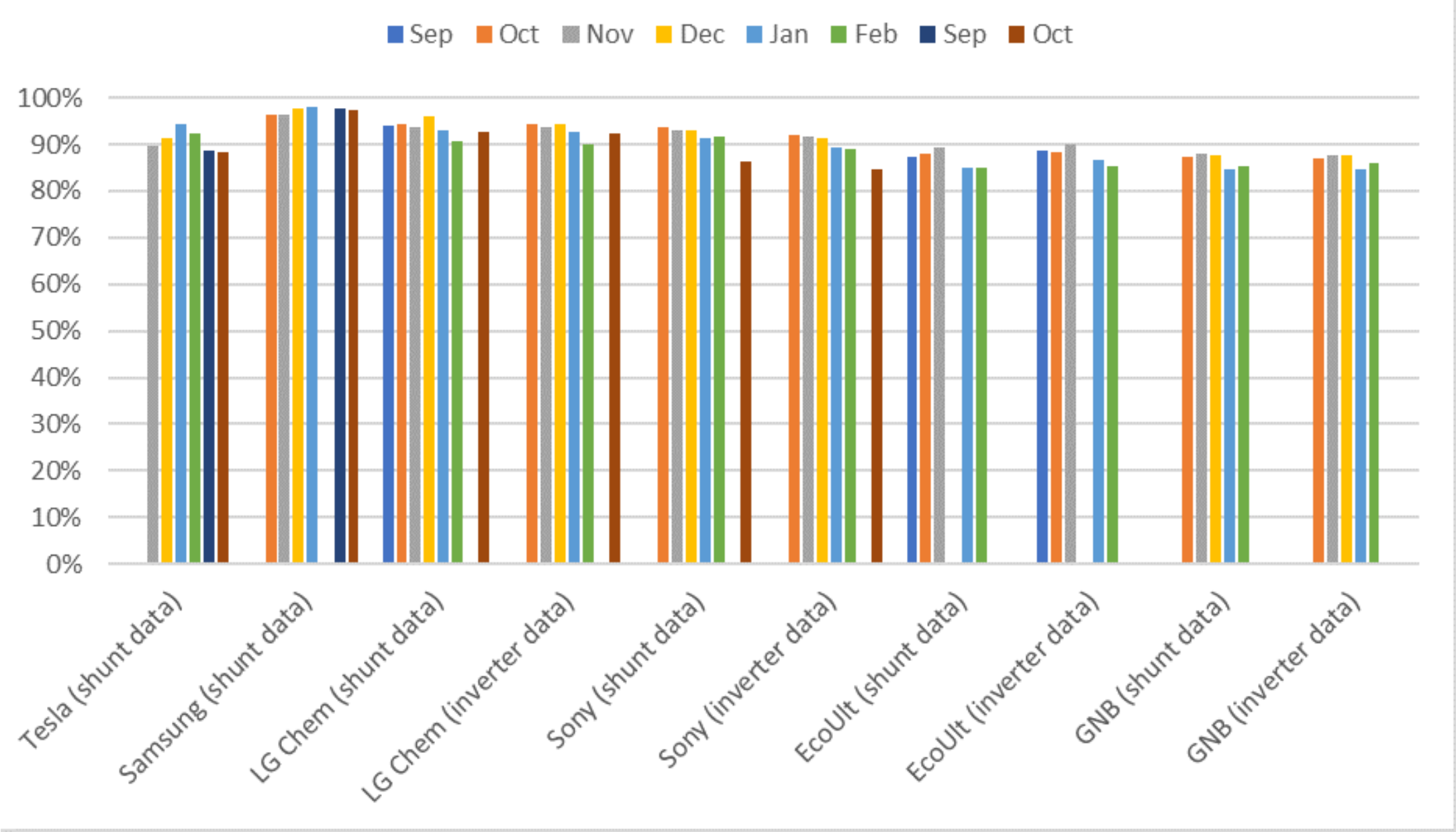


source: www.pge.com/en_US/residential/rate-plans/rate-plan-options/electric-vehicle-base-plan/electric-vehicle-base-plan.page

Why not encourage storage in all homes?

- Round trip energy conversion losses can be 15 to 20%, or more, and the paired inverters have high standby losses, **so adding batteries increases a home's total electricity use**.
- If most of the home's electricity consumption passes in and out of the battery before use, overall home energy use rises by as much as having another refrigerator in the home, or more.
- The best system designs may have half of the energy losses of the least efficient inverter/battery systems
- Performance, longevity, safety, and warranty coverage differ dramatically among available products, which greatly affects whether they will be cost-effective to purchase.

Round trip efficiencies often decline gradually with use



Source: https://batterytestcentre.com.au/

How much does round trip efficiency matter?

The difference between a 94% and 87% round trip efficiency battery system over the course of its lifetime is not small. Assume:

- 10 kWh average lifetime capacity
- One charge and discharge cycle per day from 100 to 20% DOD
- 10 years of use
- The inefficient product loses 3,796 kWh over its lifetime.
- The efficient product loses 1,402 kWh over its lifetime.
- **Lifetime savings potential from a better battery system is about 2,400 kWh, not counting standby losses in the inverter.**

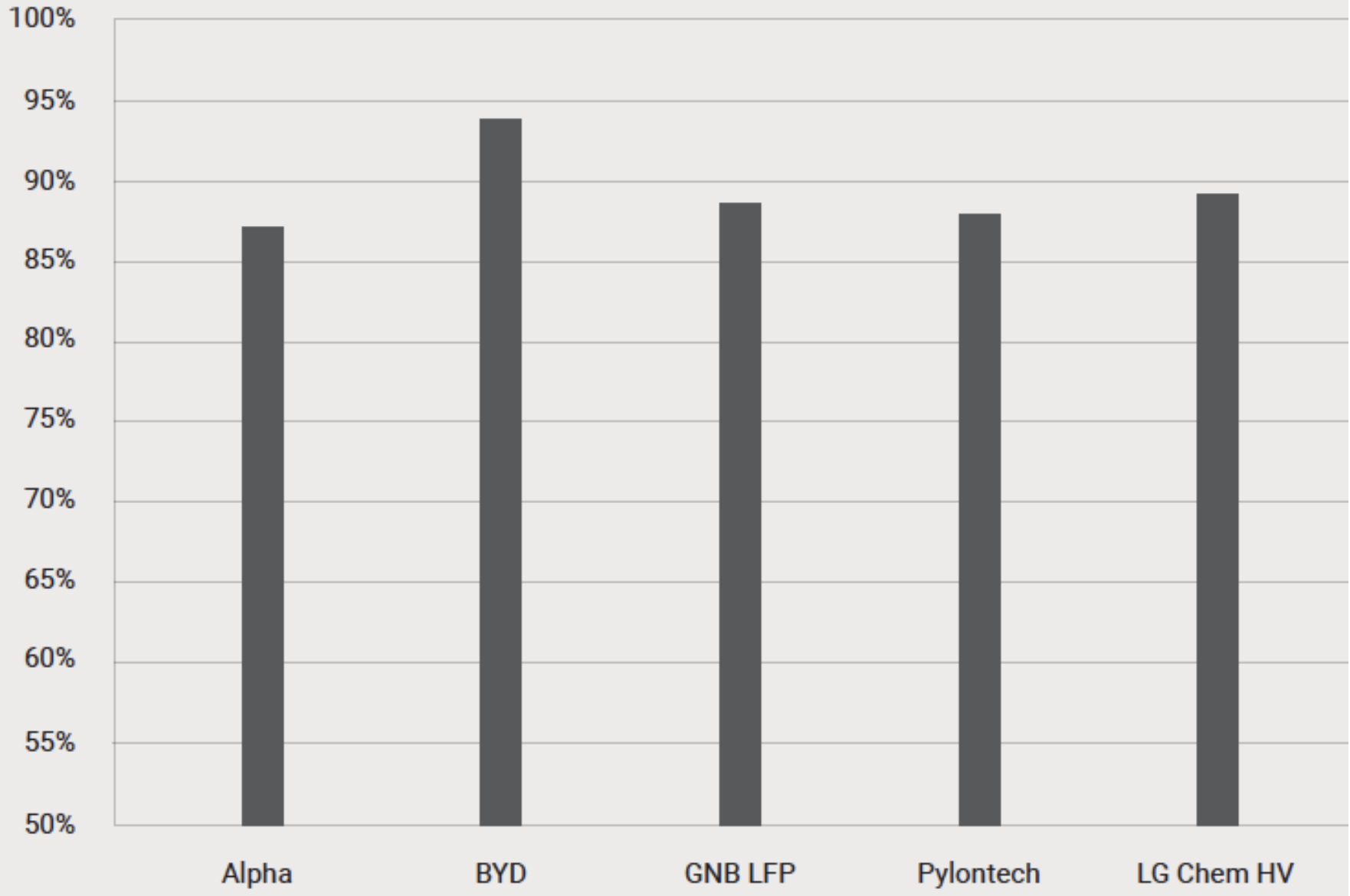


Figure 22. Lifetime round-trip efficiency of various battery packs

Source: https://batterytestcentre.com.au/

Where do most of the energy losses occur?

- I conducted testing of competing systems in partnership with CSIRO in Australia earlier this spring and found four key sources of losses in residential energy storage systems:
  - Power conversion losses within **the inverters** were the largest source of losses in the overall HESS -- often about 6% when charging and 8% when discharging. That's an average of 200 watts being lost of the 3000 watts that might be sent to or from the battery by the inverter.
    - **Inverters** can also waste significant energy when idling, waiting to charge or discharge connected batteries.
  - Wiring between the batteries and their inverter accounted for a surprisingly high share of losses, often 1 to 2% in each direction.
  - The losses inside the **battery** itself when charging and discharging (coulombic losses) or when sitting idle (self-discharge losses and battery management system overhead) were typically only 1% or less. So lithium ion batteries themselves are very efficient.

Manufacturers and installers routinely show exterior installation in their marketing materials, but exterior temperatures can vary widely

Marketing Photos May Not Resemble Your Actual Installation

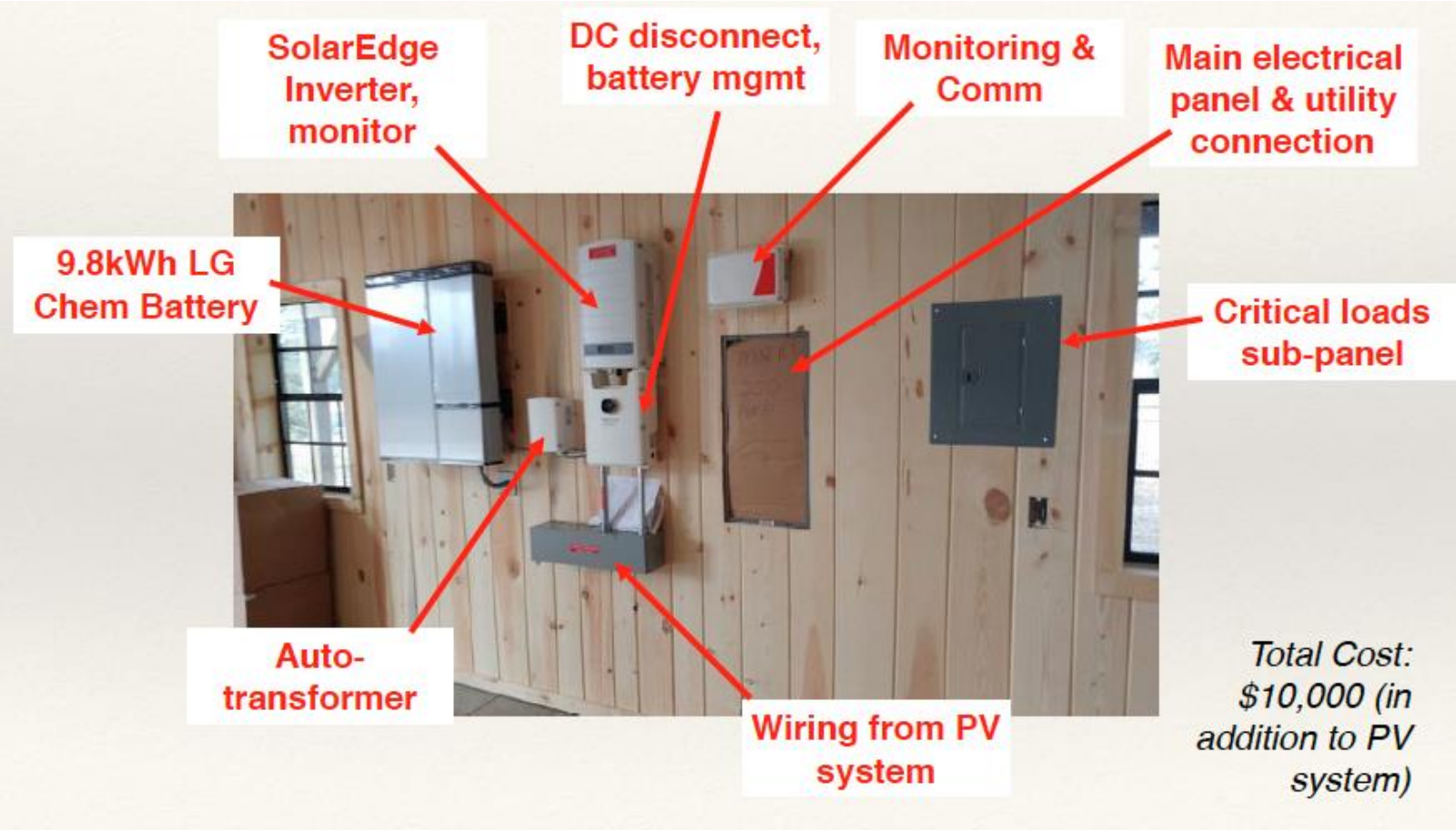


Image sources: Sonnen and Shaw Solar

Physical requirements

Where can the battery be located? Noise and safety considerations often argue for garages or utility rooms.

Need enough adjacent wall space for more electrical boxes, good ventilation, and clearance around current hardware.

Installation more costly if meter and main service panel are in one housing (backed up circuits need to be moved to another load panel by an electrician):

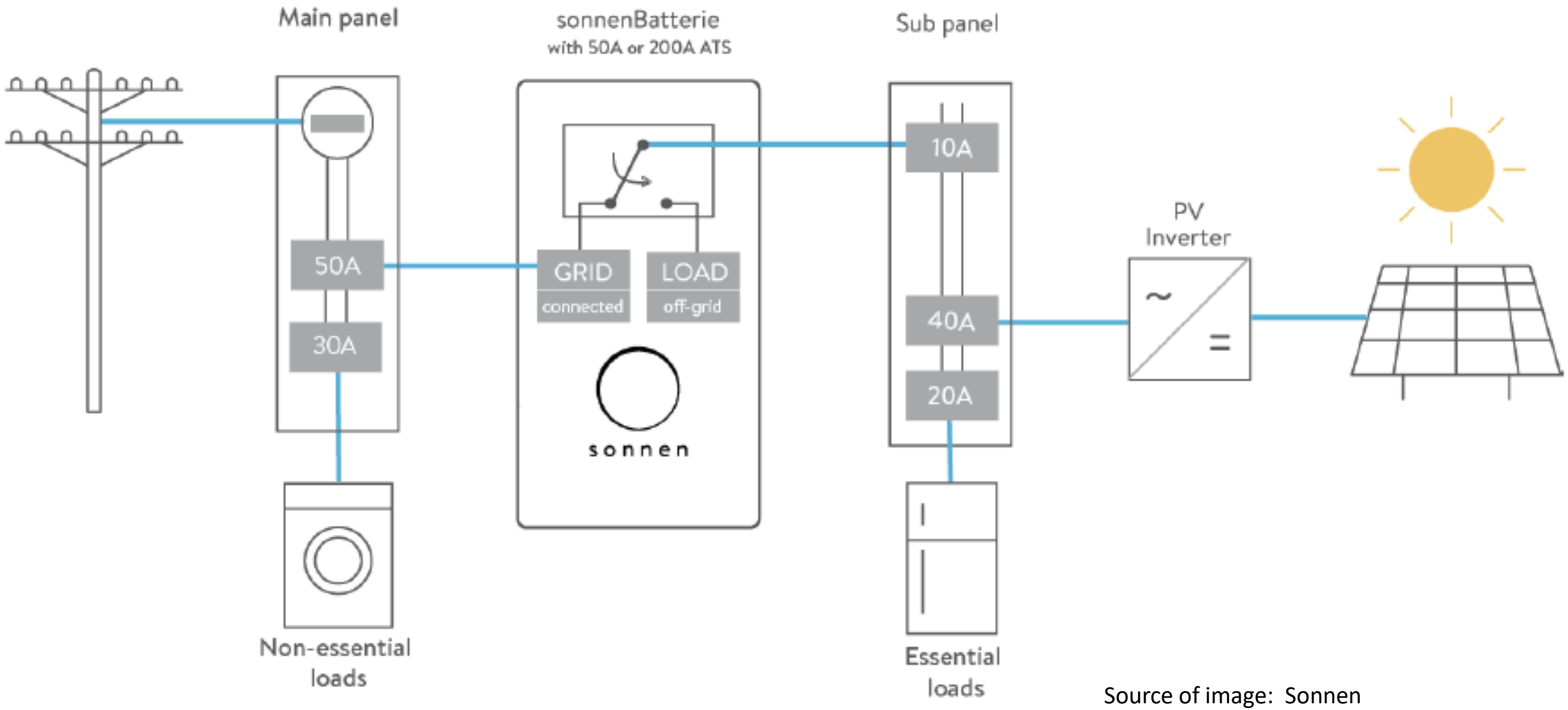
What’s involved in backing up your whole house with batteries?

- Multiple battery banks that can store a total of 25 to 40 kWh worth of energy.
- Peak power output may need to be 12 to 20 kW to handle HVAC systems, water heaters, cooking, clothes dryer, etc. Even then, homeowners need to be careful about what they try to run simultaneously.
- Multiple new load panels, often with all breakers moved out of old panel.
- Additional electrical boxes mounted to wall for gateway, power monitoring, disconnects, etc.

Main panel is typically on AC-disconnect side of the battery. So all loads you wish to backup have to be relocated to a critical loads sub-panel.

Challenging to find a battery with enough peak current capability to drive loads like AC, space heating, water heating, pool pumps, or EV charging

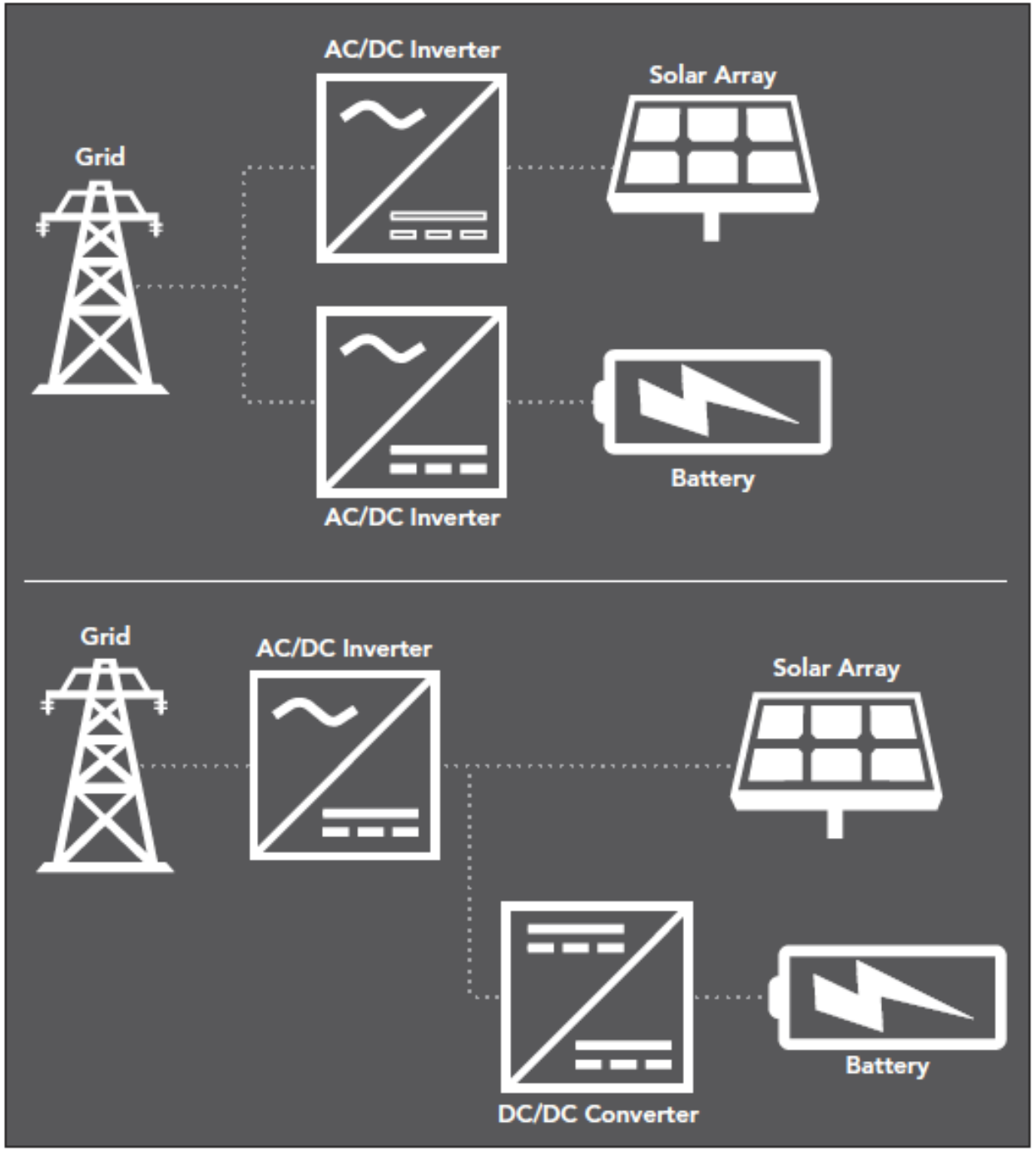
Critical loads sub-panel usually must be physically proximate to main panel, inverter and battery in retrofits, so need significant wall space for all of the hardware. Safety concerns lead to garage or exterior installs, where temperatures can be unfavorable.



Source of image: Sonnen

Which architecture will win out: AC-coupled or DC-coupled?

- AC-coupled advantages:
  - Can retrofit to existing solar home
  - Flexible battery placement location
  - Can be higher combined solar + battery power output to grid or home
- DC-coupled advantages
  - More energy efficient
  - Lower cost in new construction (don't have to buy two inverters)
  - Simpler installation
  - Less inverter clipping at peak solar output (extra charges battery)



Less than $1,400 to put your toe in the water with a small residential energy storage system for backing up fridge, wi-fi router computer and phones

Photos by Chris Calwell, Ecos Research. See https://ecoflow.com/ for more info on the EcoFlow Delta 1300

Results from long term lab testing of batteries: IT Power's measurements

- 18 different lead acid and lithium ion battery systems being tested over a three year period (split into two phases) to determine how much capacity they lose with age, heavy usage, and temperature cycling
- Testing being conducted in Canberra under $1.4 million of grants from Australian government
- Live data streamed to web (http://batterytestcentre.com.au/) from individual round trip measurements.
- Reports published every six months summarizing key findings to date
- Most of the batteries it has tested have either experienced problems in installation/setup/commissioning, or operation, or both
- Impacts on capacity, efficiency, and performance over time can be significant

IT Power Testing Approach: 3 Complete Charge and Discharge Cycles of 3 Hours Each Per Day with an Hour Rest In Between, While Cycling Between High Temps of Up to 97 Degrees and Lows Down to 50 Degrees F

Table 2: Daily temperature settings for summer and winter regimes

Time	Charging regime	Summer temperatures	Winter temperatures
02:00 - 05:00	Charge	Low	Low
05:00 - 06:00	Rest		
06:00 - 09:00	Discharge		
09:00 - 10:00	Rest	Transition to high	Transition to high
10:00 - 13:00	Charge	High	High
13:00 - 14:00	Rest		
14:00 - 17:00	Discharge		
17:00 - 18:00	Rest		Transition to low
18:00 - 21:00	Charge		Low
21:00 - 22:00	Rest		
22:00 - 01:00	Discharge		
01:00 - 02:00	Rest	Transition to low	

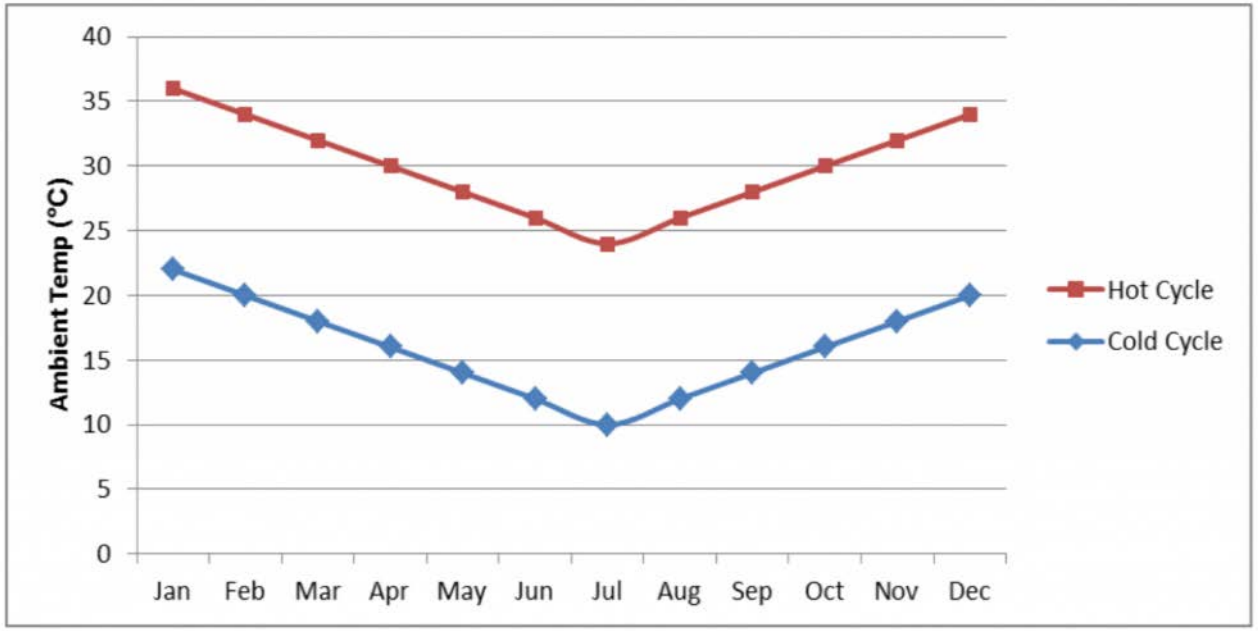


Figure 1: Daily hot and cold cycle temperatures throughout the year

Source: https://batterytestcentre.com.au/

How a fully sealed battery pack without liquid or convective cooling can degrade over time

Battery went from a usable capacity of about 7.7 kWh to about 6 kWh over 1,183 charge and discharge cycles before failing entirely. In the process, it would often de-rate for periods of time due to overheating.

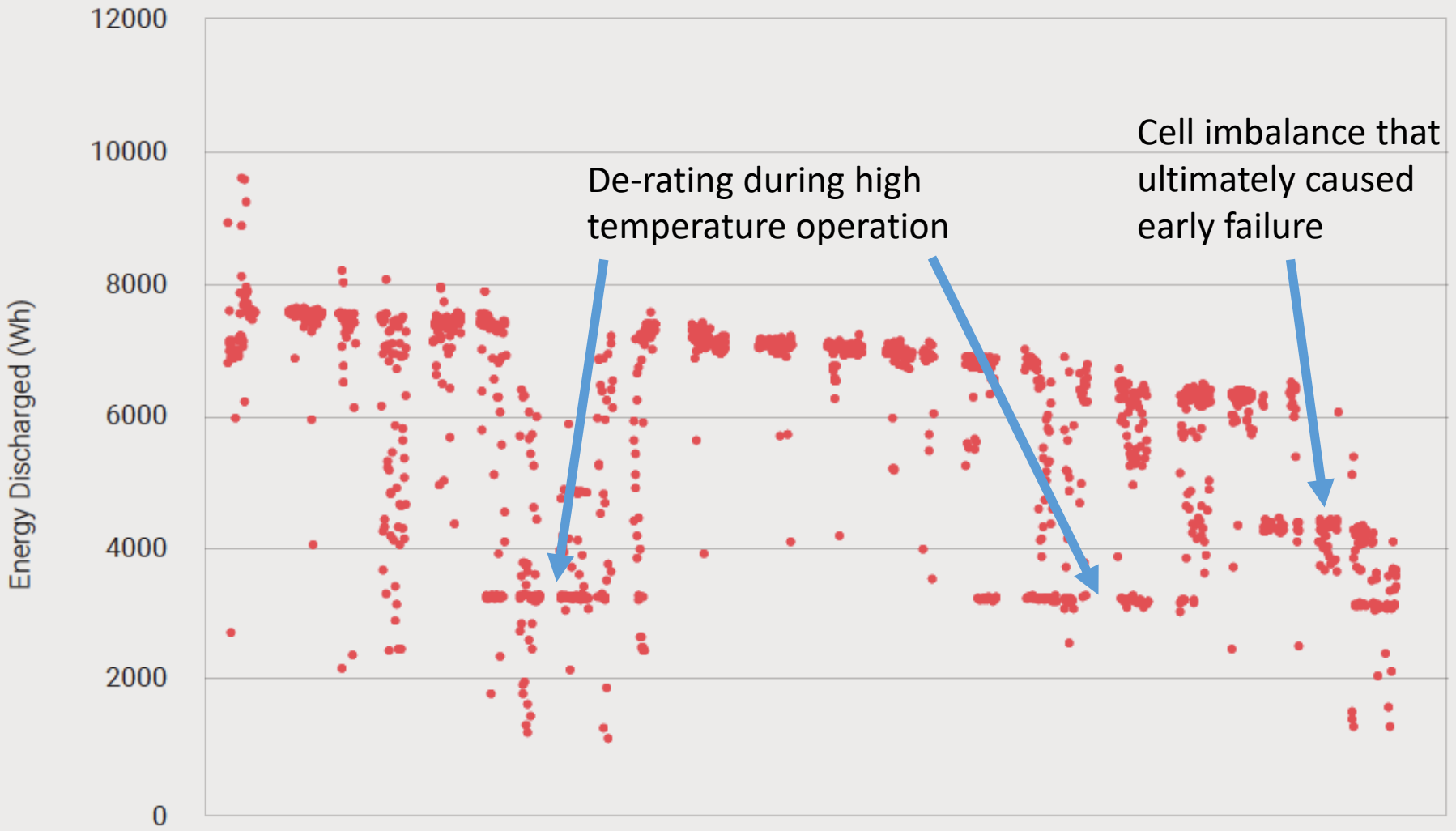


Figure 5. Energy discharged per cycle by the LG Chem RESU 1 battery pack

Source: https://batterytestcentre.com.au/

Some products lose very little capacity until used heavily for many hundreds of cycles

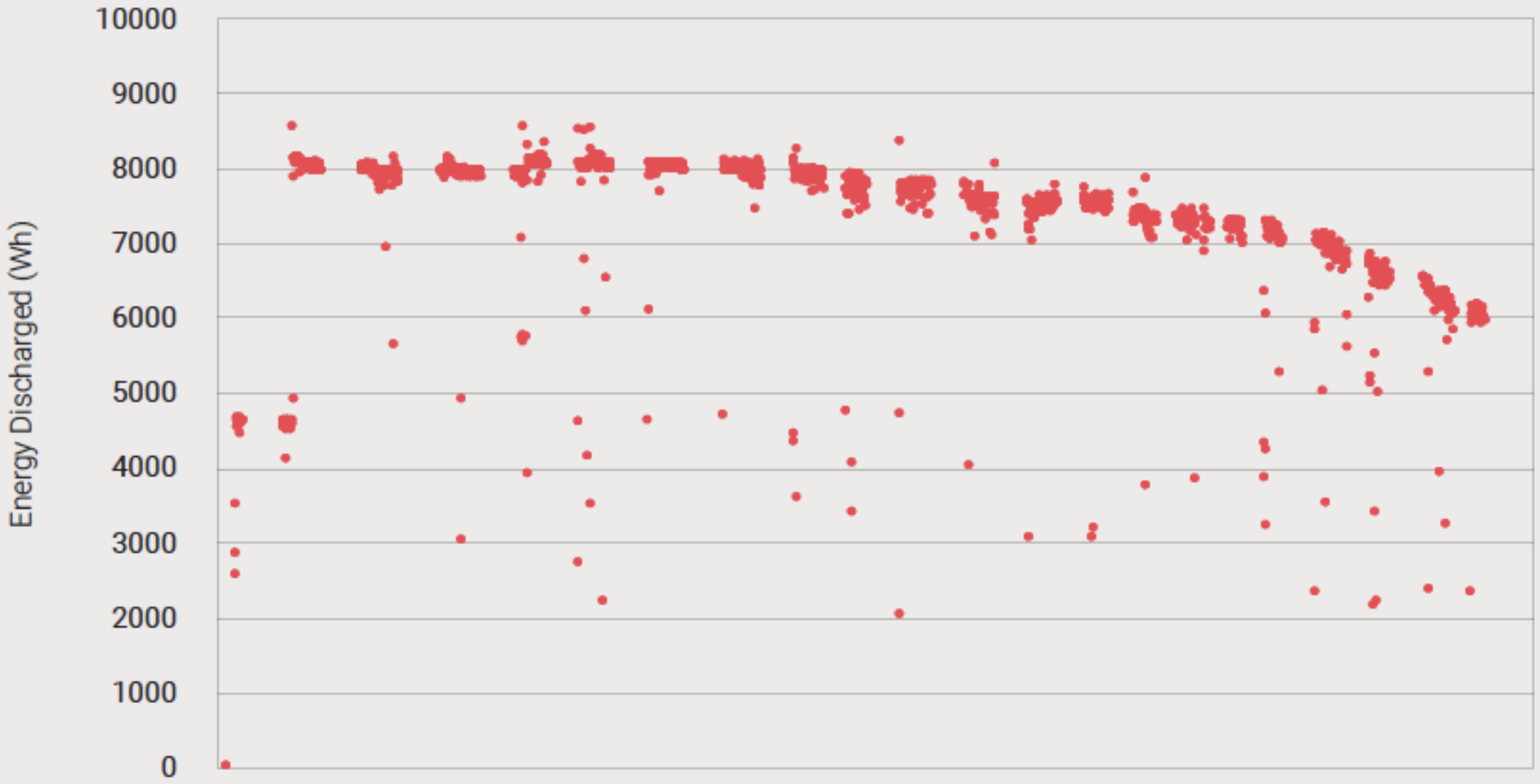


Figure 18. Energy discharged per cycle by the BYD battery pack

Source: https://batterytestcentre.com.au/

Capacity fade matters greatly to battery economics

Phase 1 testing suggests that the Tesla Powerwall 1 will fall to 60% of nominal capacity after 2200 charge and discharge cycles (about 6 years of normal use).

The Sony Fortelion may not reach that point until roughly 6000 charge and discharge cycles (about 16 years of normal use).

Faster discharge (0.5C vs. 0.33C) explains part of that difference, but not all.

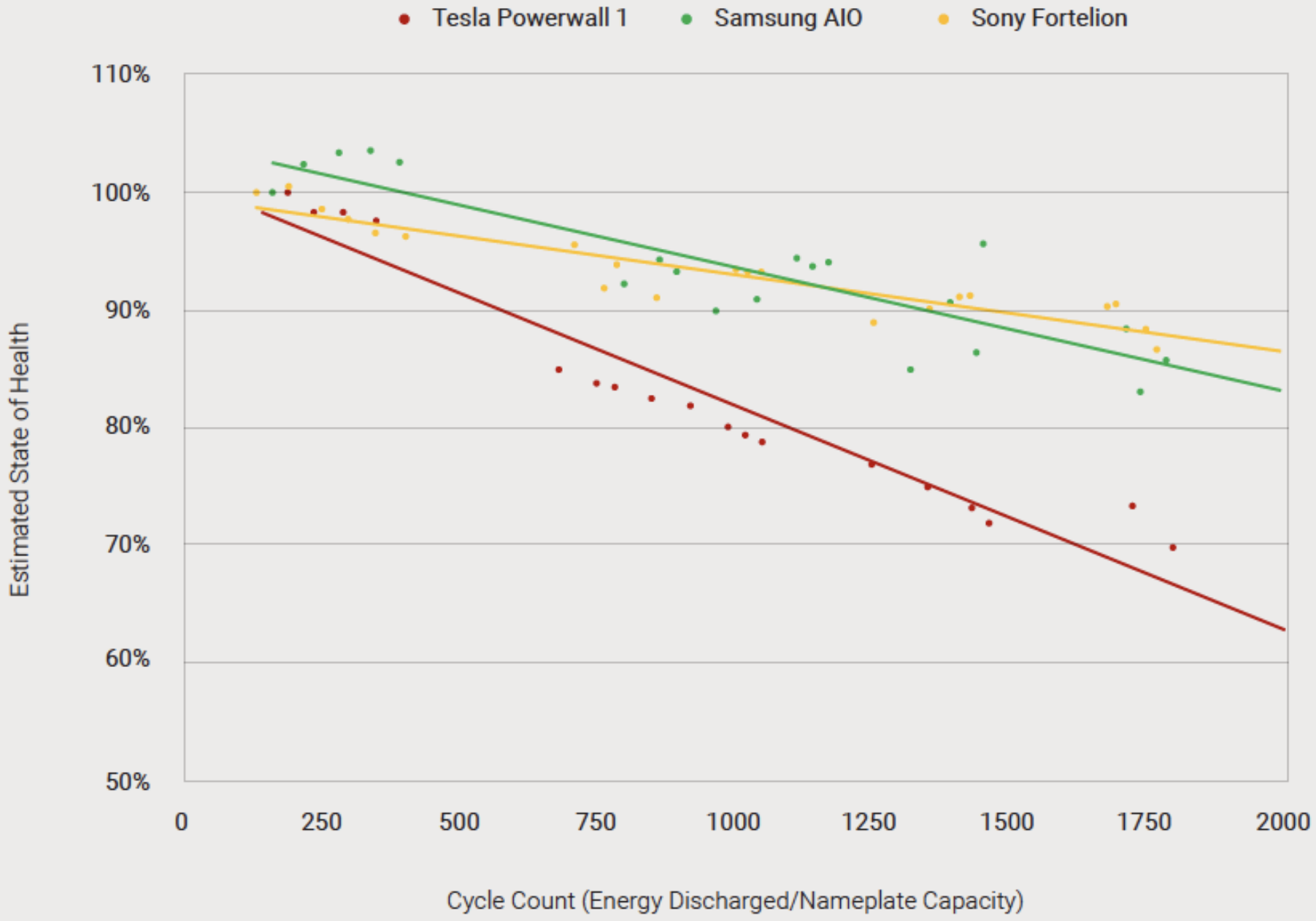
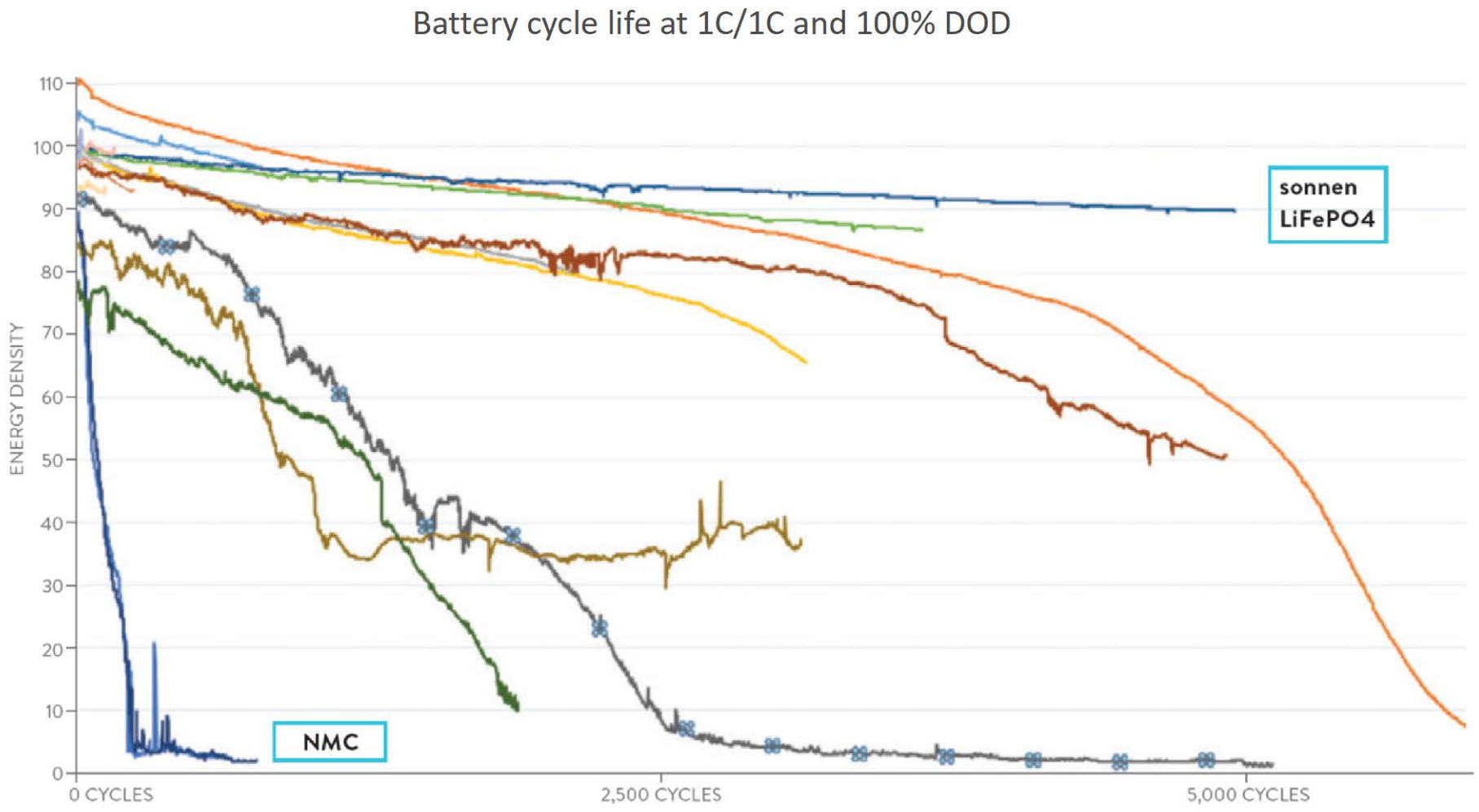


Figure 13. Capacity fade of Phase 1 battery packs based on monthly capacity tests

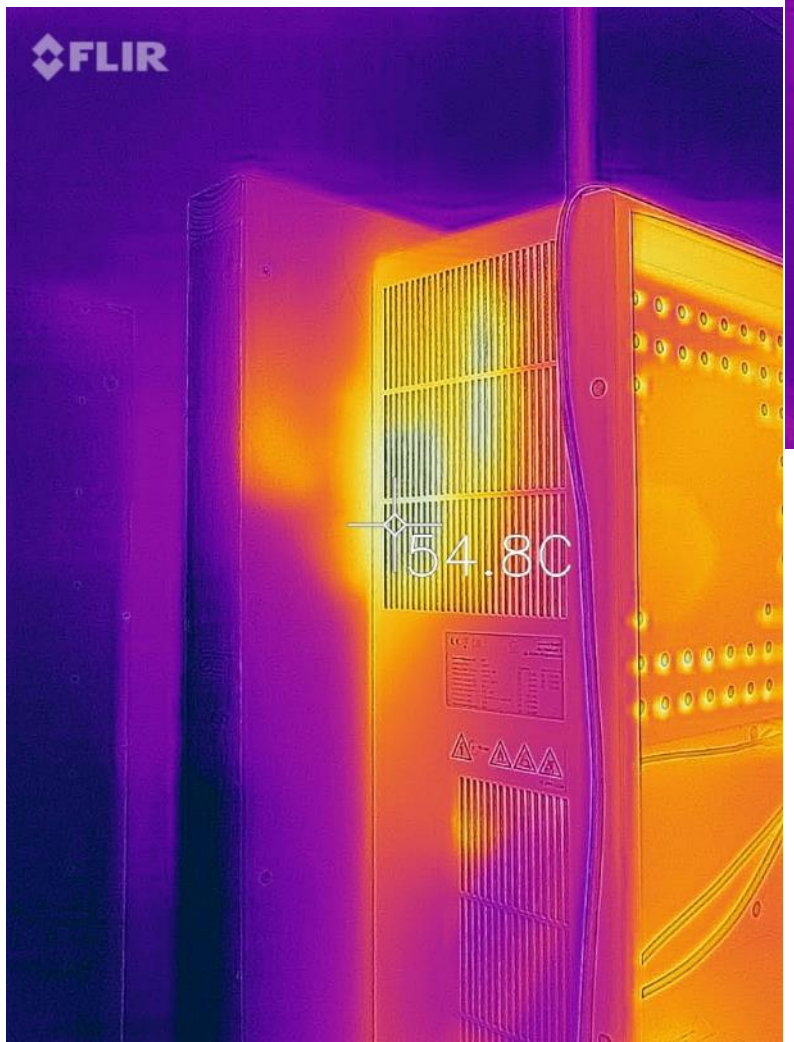
Source: https://batterytestcentre.com.au/

Sonnen makes particularly bold claims about its long term performance (based on Sony cells), but has convincing data to back them up



sonnen

Heat is the enemy of long term battery performance, and these systems run quite warm in sealed enclosures



Additional considerations

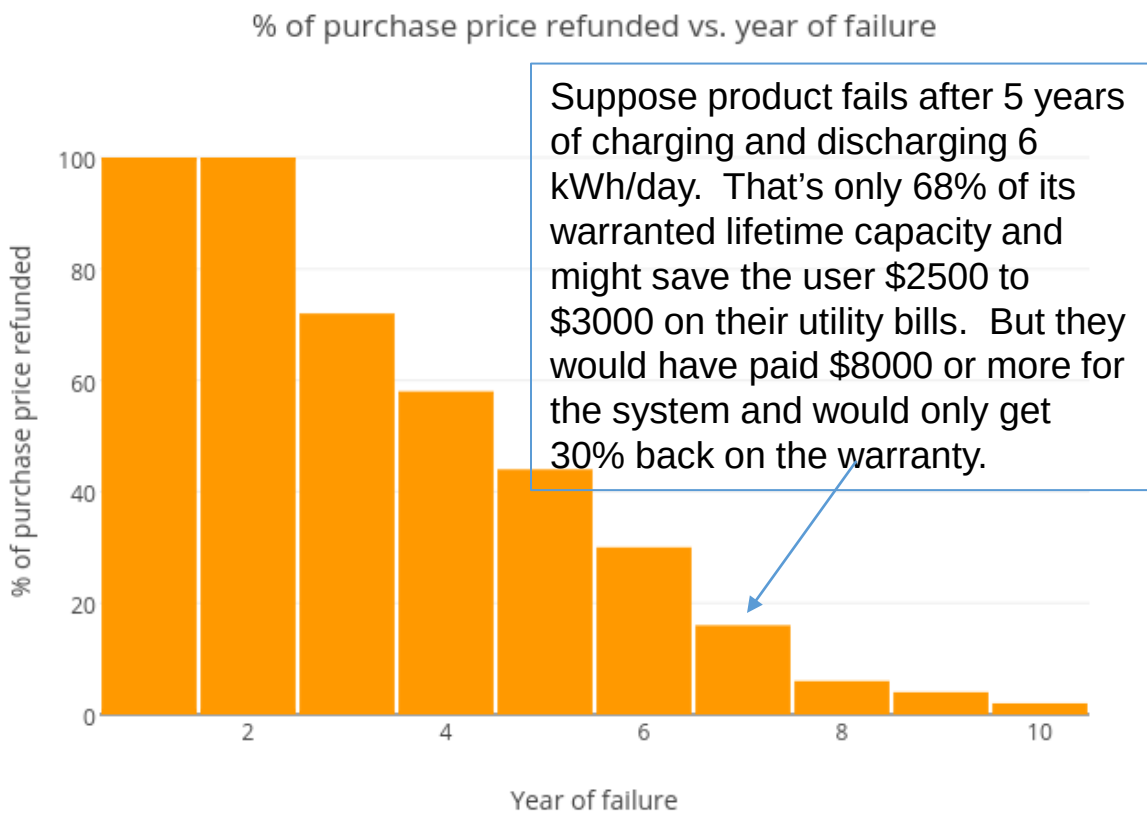
- Safety and Permitting
  - Products covered by an ANSI/UL safety standard but not their installation, which is left to electrical and building codes that vary regionally and locally. Most states encourage them to be installed outside or in garages, where higher temperatures can make them perform worse than they would in conditioned space.
- Energy vs. Power
  - Batteries can be optimized to deliver relatively lower power over long time periods (energy-prioritized) or high power over short time periods (power-prioritized), so both their energy and power ratings matter.
- Warranties
  - Batteries differ greatly not just in the duration of their warranties, but in whether they are framed on a calendar year basis, a number of charge and discharge cycles basis, or a total MWh throughput over time basis. Differences make it hard for consumers to fairly compare competing systems.

Lithium ion battery safety considerations

- A number of high-profile fires have occurred around the world in electric toys, skateboards, cellular phones, laptop computers, electric vehicles, and e-cigarettes. Residential energy storage systems have a good safety record to date (2 fires in Australia so far), but installation volumes have been modest.
- They don't catch fire very often, but can be explosive and tough to extinguish when they do
- Design and installation details are key:
  - Don't let batteries sit for more than 6 months before installing
  - Garage or exterior install might be safer than in the home, but subjects battery to more extreme temperatures
  - Protect battery from being impacted or damaged by a car backing up in garage
  - Set maximum charge and discharge limits carefully
- Sources for more information:
  - Lingxi Kong, Chuan Li, Juchun Jiang, and Michael G. Pecht, "Li-Ion Battery Fire Hazards and Safety Strategies," *energies,* 08/22/18.
  - https://batterytestcentre.com.au/

Example of the fine print of lithium ion battery warranties

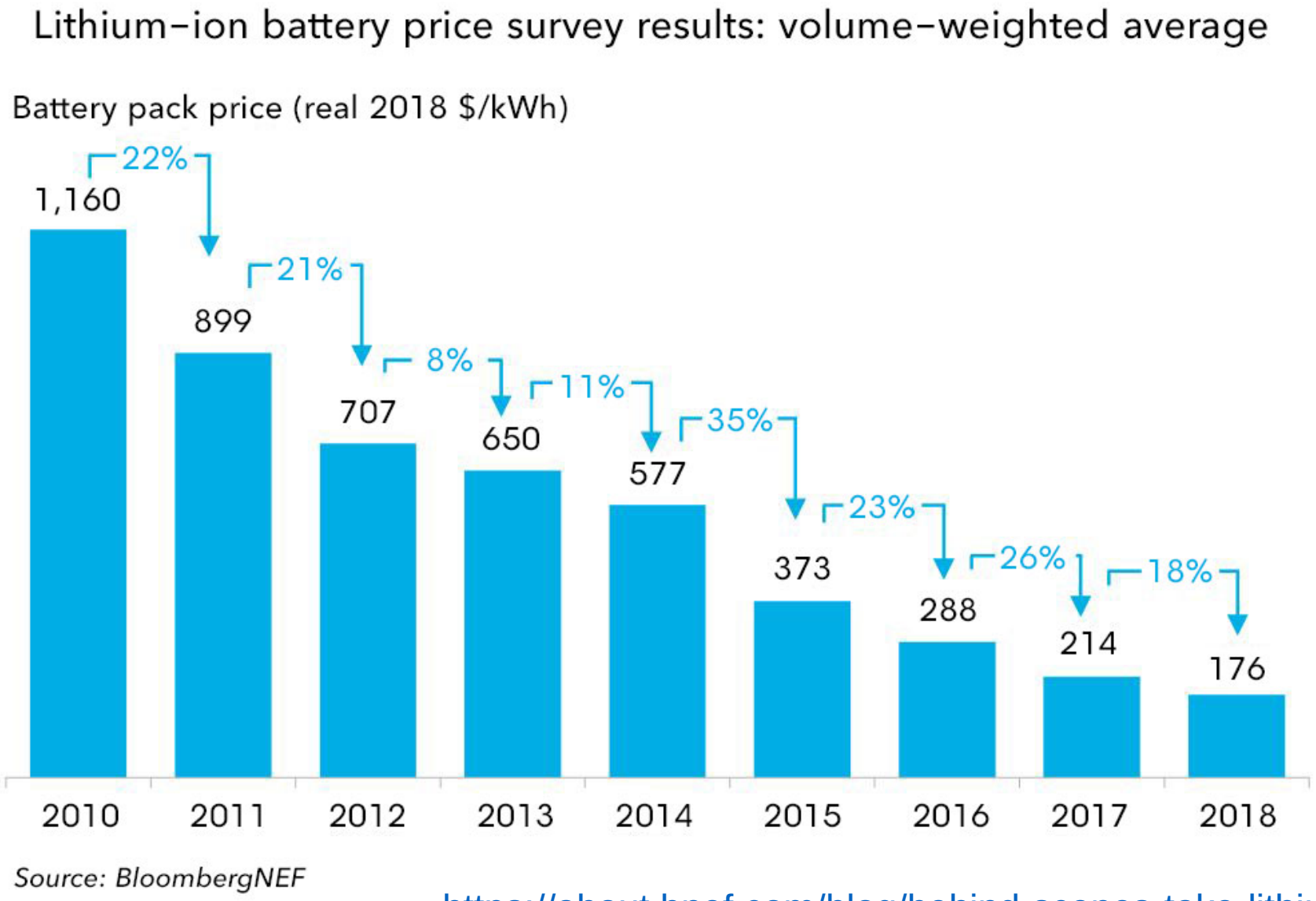
- LG Chem warranty states 10 years, but the system is only warranted to deliver 60% of its capacity at that point.
- Likewise, they will only warranty 16,100 kWh of total lifetime storage in their 6.5 kWh nominal pack.
- Warranty payout drops sharply with age:
  - 0-2 years: 100% of purchase price
  - 2-3 years: 72% of purchase price
  - 3-4 years: 58% of purchase price
  - 4-5 years: 44% of purchase price
  - 5-6 years: 30% of purchase price
  - 6-7 years: 16% of purchase price
  - 7-8 years: 6% of purchase price
  - 8-9 years: 4% of purchase price
  - 9-10 years: 2% of purchase price



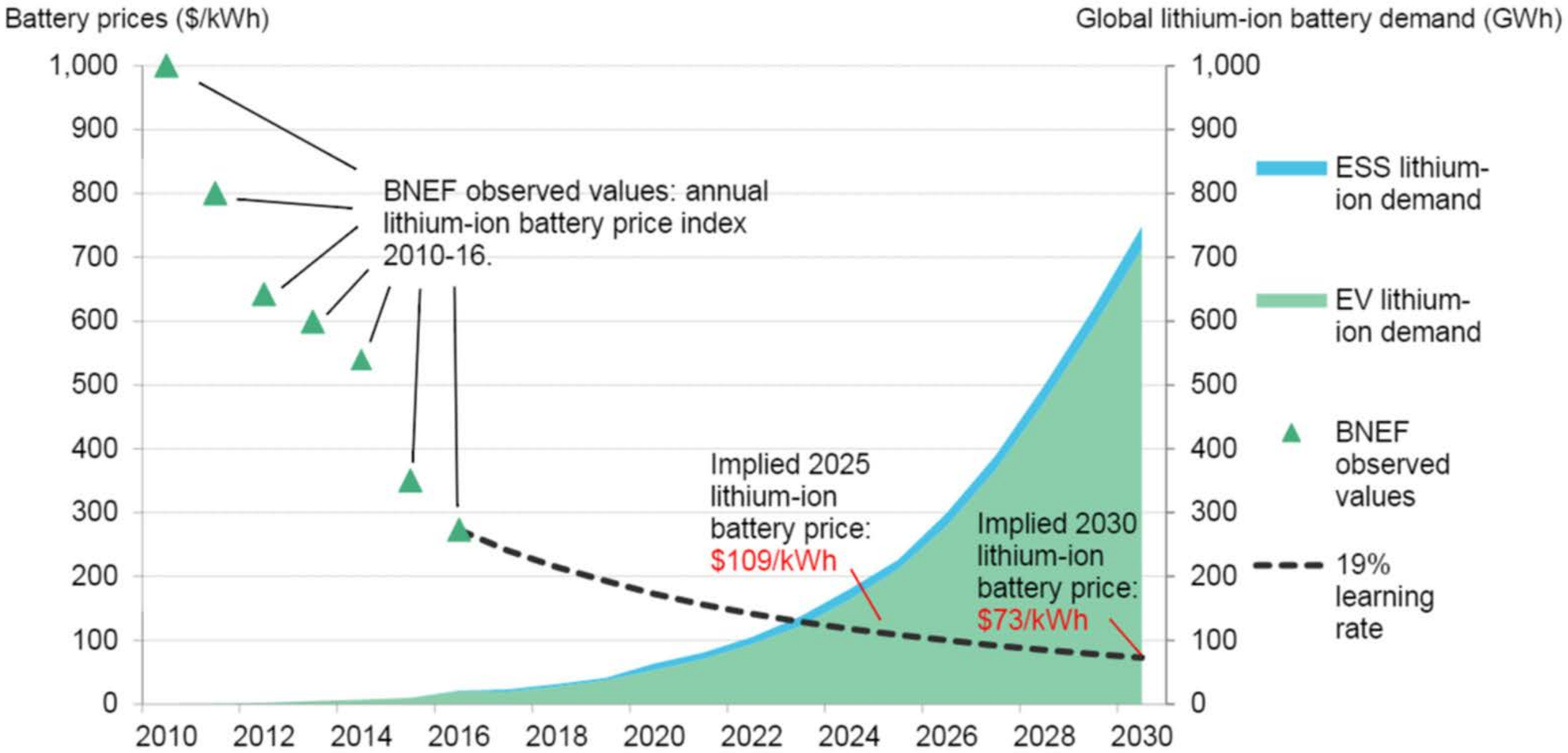
Suppose product fails after 5 years of charging and discharging 6 kWh/day. That's only 68% of its warranted lifetime capacity and might save the user $2500 to $3000 on their utility bills. But they would have paid $8000 or more for the system and would only get 30% back on the warranty.

Source: https://www.solarquotes.com.au/blog/new-lg-chem-resu-batteries-smaller-powerful-cheaper-

The good news: battery prices dropping rapidly, so no urgency to buy immediately



https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/



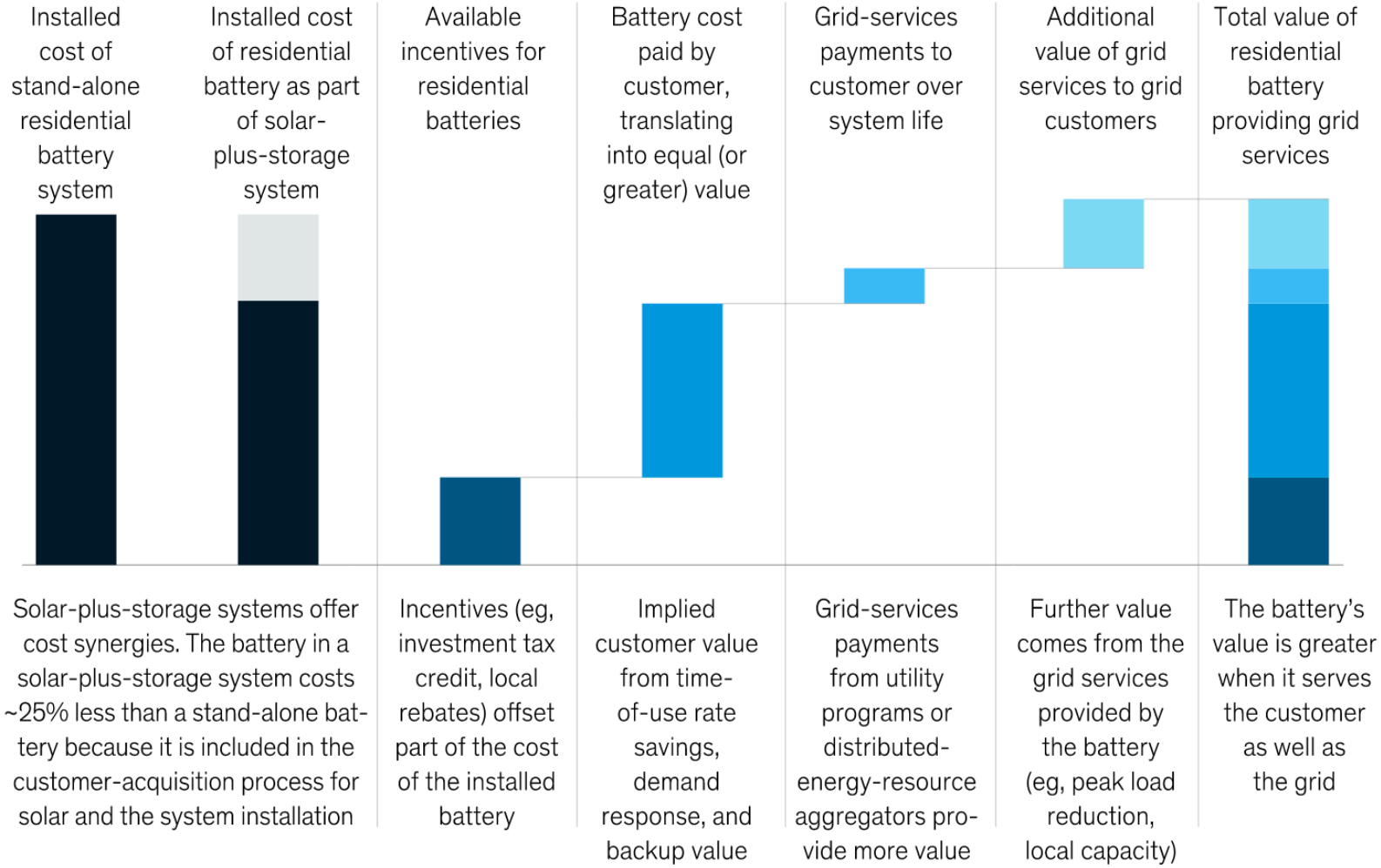
Bloomberg New Energy Finance

Battery economics are still challenging in the US unless costs (and benefits) are split among the consumer, the utility, and government rebates

- Assume installed battery system costs of about $10,000 to $20,000, depending on system size and whether solar is being added simultaneously.
- Federal tax credit can save 26% of cost if batteries charged from solar.
- SGIP incentive is $250/kWh, or about 20-25% of system cost.

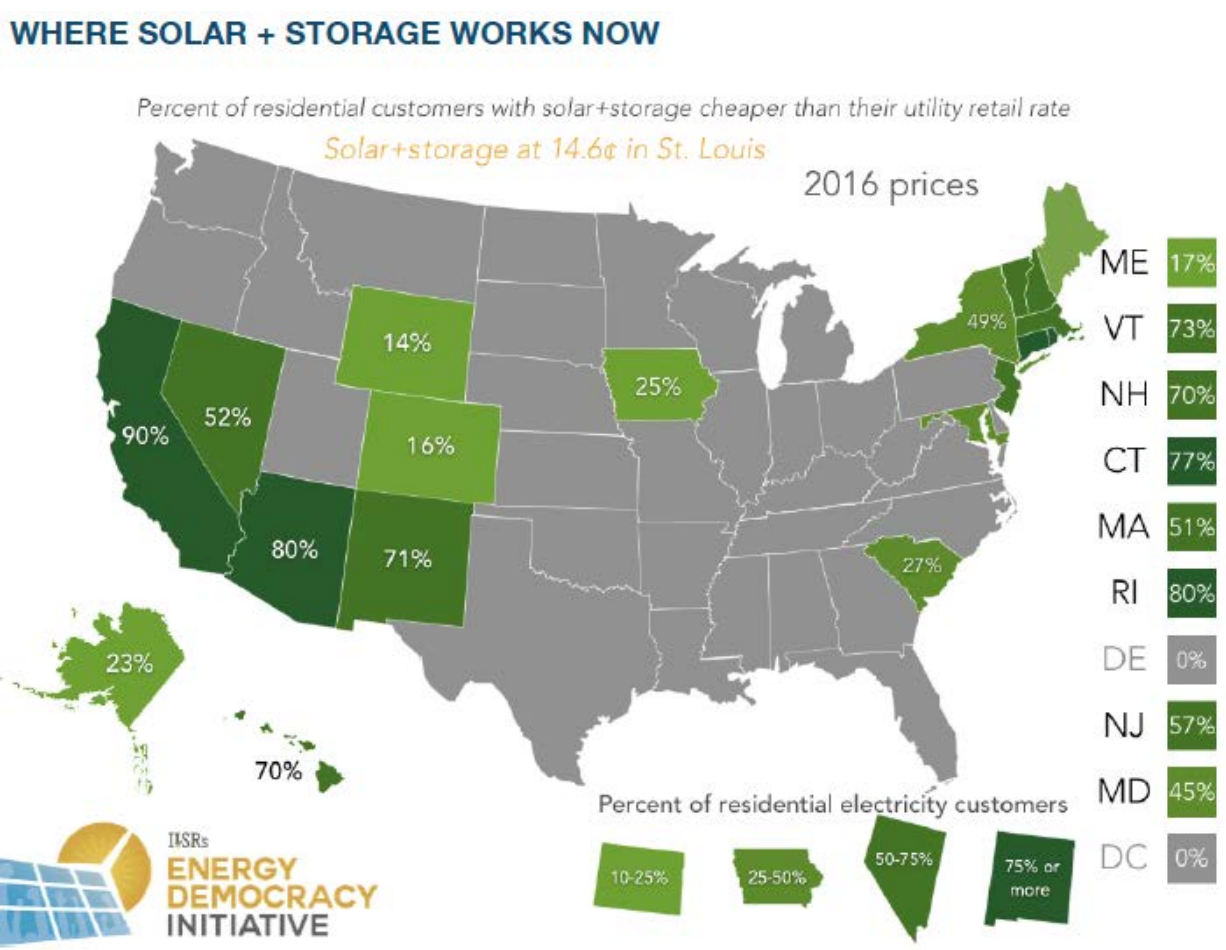
Grid-services payments can encourage battery owners to make their batteries available to system aggregators, thereby creating additional value for the battery owners as well as other grid users.

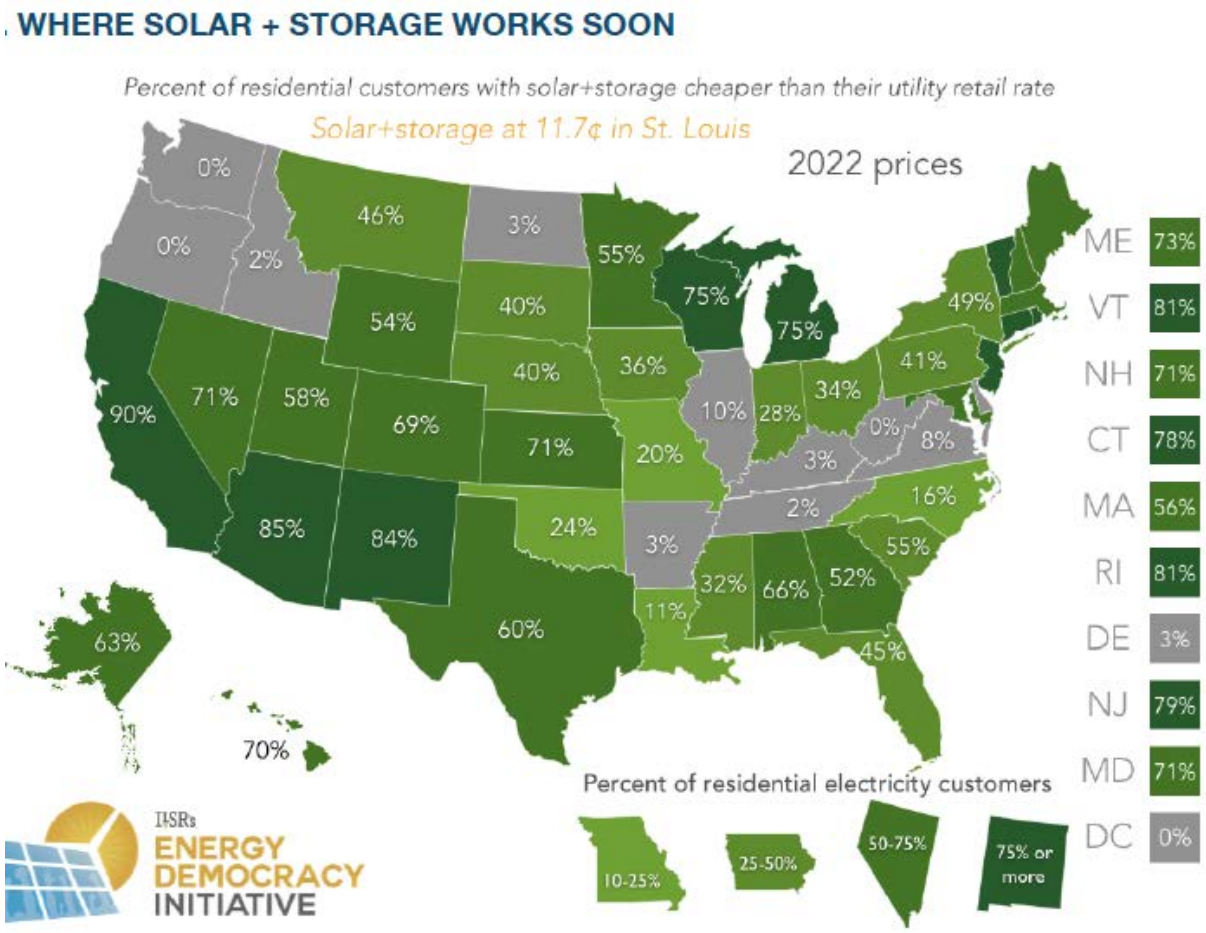
Battery value build-up, illustrative example of solar-plus-storage system with grid-services compensation



Sources: https://news.energysage.com/california-energy-storage-incentives-sgip-explained/ and www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/how-residential-energy-storage-could-help-support-the-power-grid

The likely consequence of residential utility rates rising while solar and storage costs drop over time: grid defection





Source: Institute for Local Self Reliance, July 2018

One more option to consider: V2G

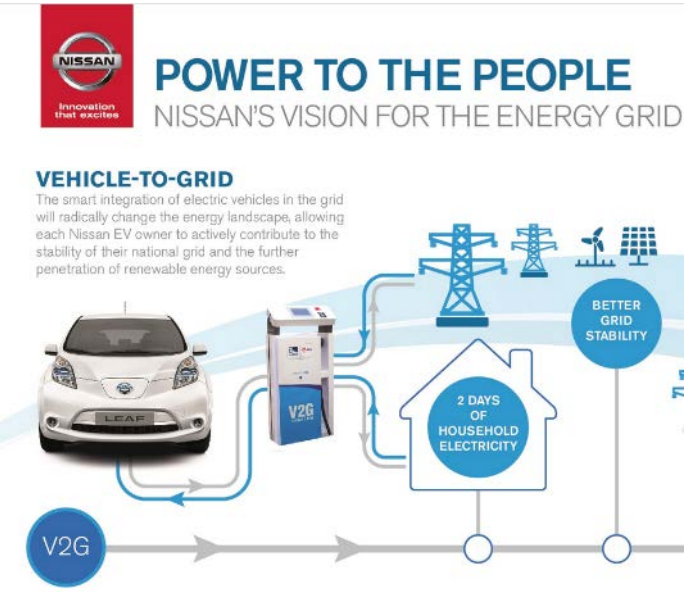
- If you’re planning to buy a residential battery primarily for backup power, why not use an electric vehicle for that purpose instead?
- The technology is called V2G (vehicle to grid) or V2H (vehicle to home).
- It essentially substitutes a bi-directional charger for the standard one, and feeds DC power from your EV batteries back through your inverter to power loads in your home when the grid is down or at times of day when electricity is expensive.
- Like PV, it can also sell power to the grid.

Why V2G?

- An electric vehicle represents about 1/3 of a house in terms of annual electricity consumption.
- But on a *power* basis, most electric vehicles are able to discharge far more kW instantaneously than is needed to power all of the electrical equipment in your home simultaneously.
- Each EV contains 3-10x the battery capacity of a typical home battery, already bought or leased by the customer, and sitting unused 70-90% of the time.
- It’s nice that EVs can absorb extra renewables at times of day when they would otherwise be wasted, but their ability to discharge large amounts of power and energy to the grid on short notice when needed by the customer or utility is even more valuable.

Bidirectional power flow capability increasingly available in EVs and chargers

- Hardware capability to send power in both directions has existed in EVs for awhile; software now being increasingly enabled, starting with the current generation Nissan Leaf
- V2G chargers now available from Nuvve, Ossiaco and others
- Most promising use case: large employers provide free charging to employees in exchange for being able to use their EV batteries bidirectionally during the work day for minimizing demand charges and grid support



Conclusions

- Residential energy storage systems are tremendously promising, but don’t automatically save money, pay for themselves, or reduce greenhouse gas emissions.
- There are big differences between the best and worst-designed battery systems, and more systematic testing and labeling is needed to help consumers buy the best products
- It’s worth promoting the most efficient systems with good incentives that ensure charging and discharging occurs when most beneficial to society (primary) and the user (secondary).
- Products need to last a long time and continue performing well to eventually pay for themselves.

Thank you!

Chris Calwell

ccalwell@ecosresearch.com

(970) 759-9737

Thanks also to August Goers for furnishing key visuals. He works at Luminalt -- a leading solar and battery system installer in CA: august@luminalt.com

Incentives and Financing

Federal Tax Credits

- 26% Federal Tax Credit is available until end of 2020
- Solar and Battery Installations
- Steps down to 22% in 2021
- Reduced to 10% in 2022

Talk to a tax professional for more information and tax advice.

California Self-Generation Incentive Program (SGIP)

- California Public Utilities Commission Program
- Offers rebates for energy storage technologies
- Senate Bill 700 (2018) created new incentive levels for resiliency projects

www.cpuc.ca.gov/sgipinfo

SCP Residential SGIP Assistance

- Helps participating contractors with SGIP paperwork and the application process
- Provides an upfront payment to help reduce out of pocket expenses
- Accepting General market residential projects over 10 kilowatts (kW) and Equity Resiliency*
- Upfront Incentives
  - General Market residential projects over 10 kW
    - 100% of SGIP incentive received upfront
  - Equity Resiliency
    - 60% of the SGIP incentive received upfront

*As of 9/18/2020, the Equity Resiliency budget has been expended and new applications are no longer being accepted.

www.sonomacleanpower.org/programs/sgipassistance

Current SGIP Rebates

	Small Residential Storage	Large-Scale Storage
General Market	$0.25/watt-hour $250/kilowatt-hour **WAITLIST**	$0.35/watt-hour $350/kilowatt-hour $0.25/watt-hour with ITC $250/kilowatt-hour with ITC
Equity Resiliency	Residential and Non-Residential*	*As of 9/18/2020, the Equity Resiliency budget has been expended and new submittals are no longer being accepted.
	$1.00/watt-hour $1,000/kilowatt-hour	

SGIP General Market Small Scale Residential Rebate Eligibility

- Any customer of PG&E
- Total battery storage system rated capacity size is less than or equal to 10 kilowatts (kW)
- Incentive
  - $0.25/watt-hour
  - $250/kilowatt-hour
- Waitlist for rebates

SGIP General Market Large-Scale Storage Rebate Eligibility

- Any customer of PG&E
- Total battery storage system rated capacity size is more than 10 kilowatts (kW)
- Incentive
  - $0.35/watt-hour
  - $350/kilowatt-hour
- Reduced incentive if taking the ITC Tax Credit
  - $0.25/watt-hour
  - $250/kilowatt-hour

SGIP Equity Resiliency Rebate Eligibility

As of 9/18/2020, the Equity Resiliency budget has been expended and new submittals are no longer being accepted.

You must meet one of the following criteria:

- Live in a home located in Tier 2 or Tier 3 High Fire Threat District[1] or
- Experienced two or more discrete Public Safety Power Shutoff (PSPS) events[2].

AND you must meet one of the following additional criteria:

- You are eligible or enrolled in Medical Baseline[3]
- You have notified PG&E of a potentially life-threatening illness/condition if the power shuts off
- Your home relies on electric-pump wells for water supply*
- You have received or reserved other solar-related incentives including: MASH, SASH, DAC–SASH, or SOMAH
- You are a low-income homeowner[4] or renter[5]

1 Map identifying Tier 2 or Tier 3 high-fire threat districts https://ia.cpuc.ca.gov/firemap/
2 Definition of discrete PSPS events can be found in https://www.selfgenca.com/documents/handbook/2020
3 Medical Baseline www.pge.com/medicalbaseline
4 Defined as someone living in a home subject to resale restrictions as defined in Section 2852(a)(3)(c)
5 Defined as someone living in multifamily residential building with 5+ deed restricted units AND either: (1) in a Disadvantaged Community, defined as any community in the top 25 percent most affected census tracts in the most recently release version of CalEnviroScreenOpens in new Window.Opens in new Window. OR (2) in a building with 80% of households have incomes <= 60% of the area median income

* Proposed Decision at the CPUC to add low-income requirement for those applying under the electric-pump well criteria

What to Know About SGIP

- Solar is not required but allows the batteries to be recharged during a power outage
- It is required to “cycle” – charge and discharge – your battery on a regular basis
- Things can change with the program – make sure to check the SGIP website for current budget information

How to Get Started With SGIP

Research local battery installers

Discuss SGIP with installers to confirm eligibility and what technology might be best for your facility

Work with the installer to complete the application process and install the technology

Contact your local program administrator with any questions

Property Assessed Clean Energy

- PACE is a financing mechanism that enables low-cost, long-term funding for energy efficiency, renewable energy and water conservation projects. PACE financing is repaid as an assessment on the property's regular tax bill.
- PACE can be used for residential, commercial and some non-profits.

- Financing for Wildfire Safety – Hardscaping 0-5’ from Structure, Class A Roofing, Eaves and Vents, Windows, Siding, Solar Energy Systems, Battery Backup and More
- Property-based Financing – No Income or Credit Qualifying
- Terms (10 or 20 years); 5.99% fixed interest rate; Low fees
- Paid back through the County Tax Bill system

Contact the Energy and Sustainability Division at (707) 565-6470 to learn more

Property Assessed Clean Energy

Ygrene

- Fort Bragg
- Point Arena
- Willits
- Ukiah
- Unincorporated Mendocino County

HERO

- Fort Bragg
- Point Arena
- Ukiah
- Unincorporated Mendocino County

California First by

Renew Financial

- Fort Bragg
- Point Arena
- Ukiah
- Unincorporated Mendocino County

Question and Answer

Thank you

Sonoma
Clean Power