Lessons Learned from the Residential Energy Storage Experience in Australia and the US

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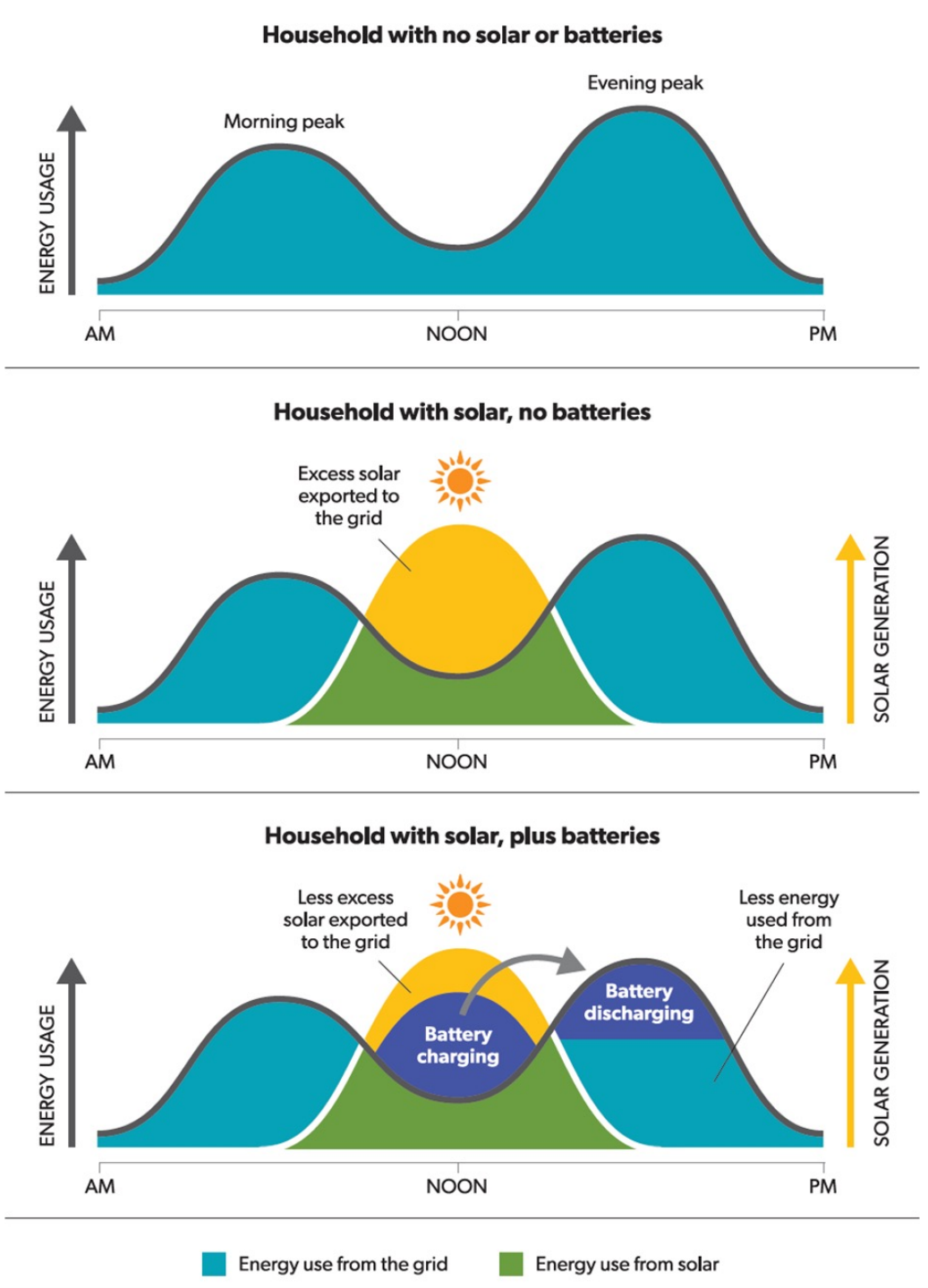
Background

- Ecos Research is a small consulting firm based in San Luis Obispo, CA and Durango, CO focused on achieving 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 and our subsequent work for EPA ENERGY STAR, PG&E, Portland General Electric, Arizona Public Service and Sonoma Clean Power on residential energy storage.

The fundamental value propositions of residential batteries

- Shave peaks and fill valleys in demand.
- Use your own solar electricity when the sun isn't shining instead of buying more expensive or less clean grid power at those times.
- Buy power when it's cheap and sell power when it's expensive.
- Keep the lights on during outages.



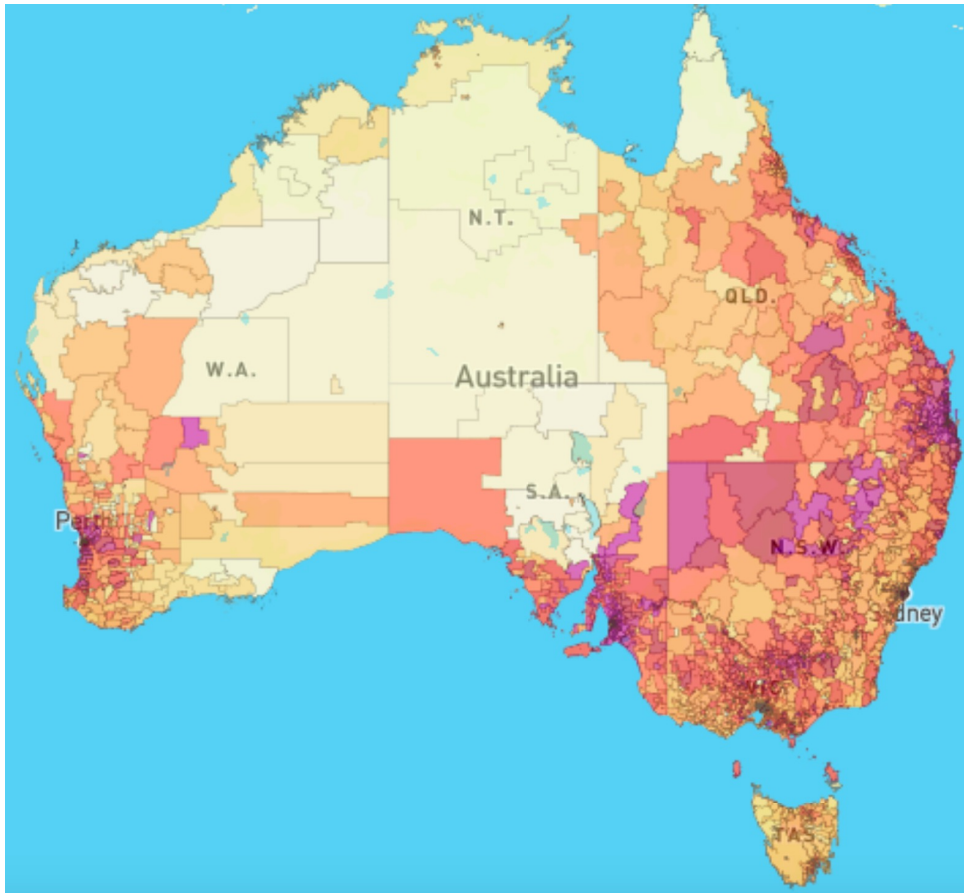
Key market drivers for residential storage systems

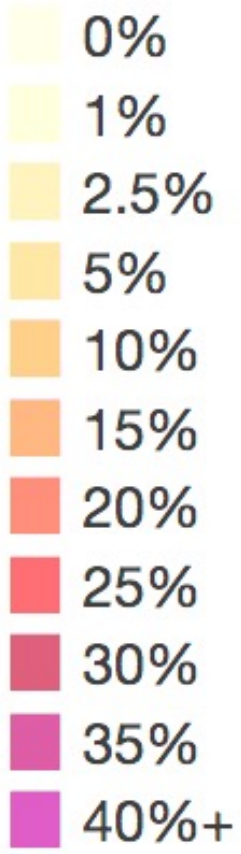
1. **Backup of whole house or critical loads** for early adopters that have the money to keep the lights on when the grid goes down. Otherwise, grid-connected solar-powered homes shut off automatically during outages to protect utility line workers. *Main driver of US market so far.*
2. **Solar self-consumption**: 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. *Main driver of Australian market.*
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. *Very rarely done profitably in the US.*
4. **Virtual power plant (VPP)**: support *utility* grid by consuming or providing power when and where needed to balance loads. *Pilots underway in Australia and the US, but still rare.*

Comparing the US and Australia

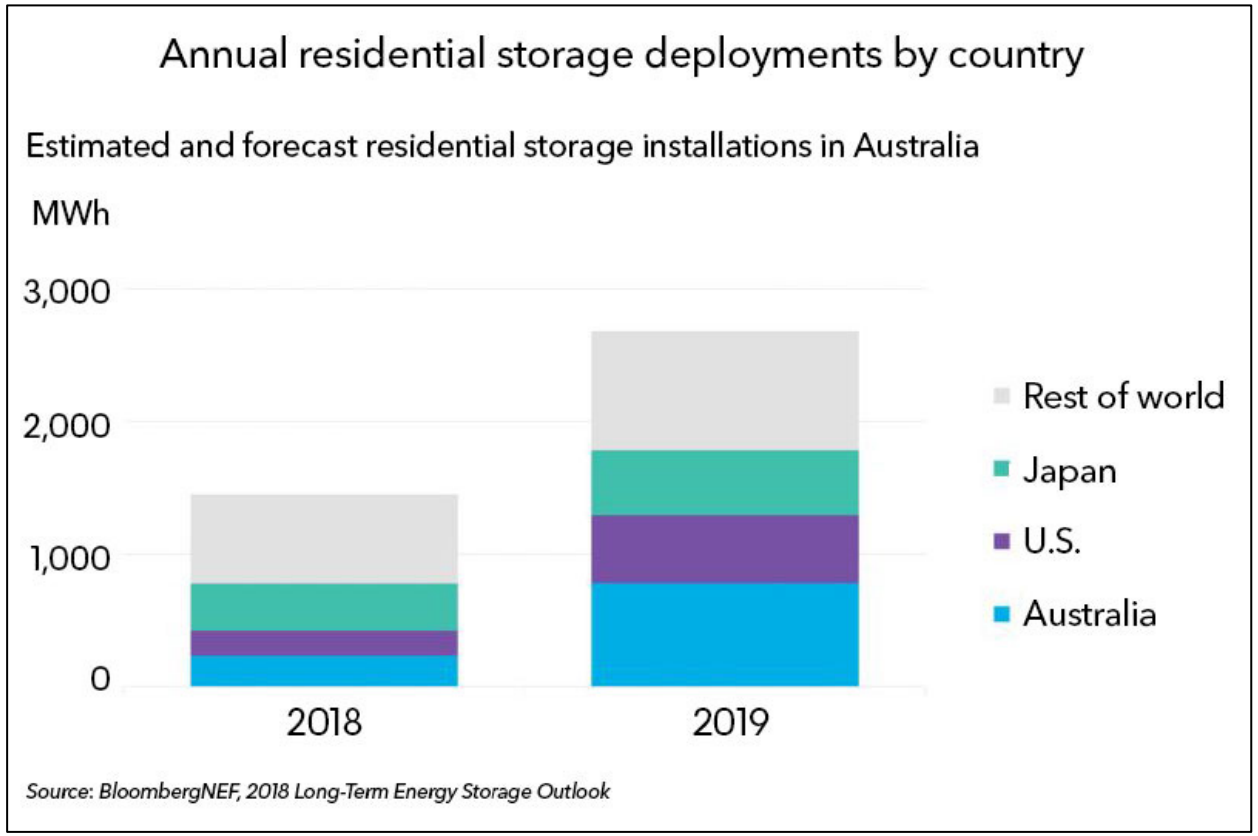
- US population is about 13 times that of Australia within similar land areas.
- Both countries have roughly 2-2.5 million residential rooftop PV systems installed. Equates to <2% of US homes and >20% of Australia homes.
- Typical US installed costs for home PV: $2.70/W. Australia installed costs: $0.70/W due to more mature market and simpler permitting.
- Most US homes pay flat electricity rates averaging $0.13/kWh. Australians more commonly choose TOU rates, but those on flat rates pay an average of $0.30/kWh (ranges from about $0.20 to $0.45/kWh).

Australia is a post card from the future for the US, much as Hawaii is for California. Very high solar and battery penetration.

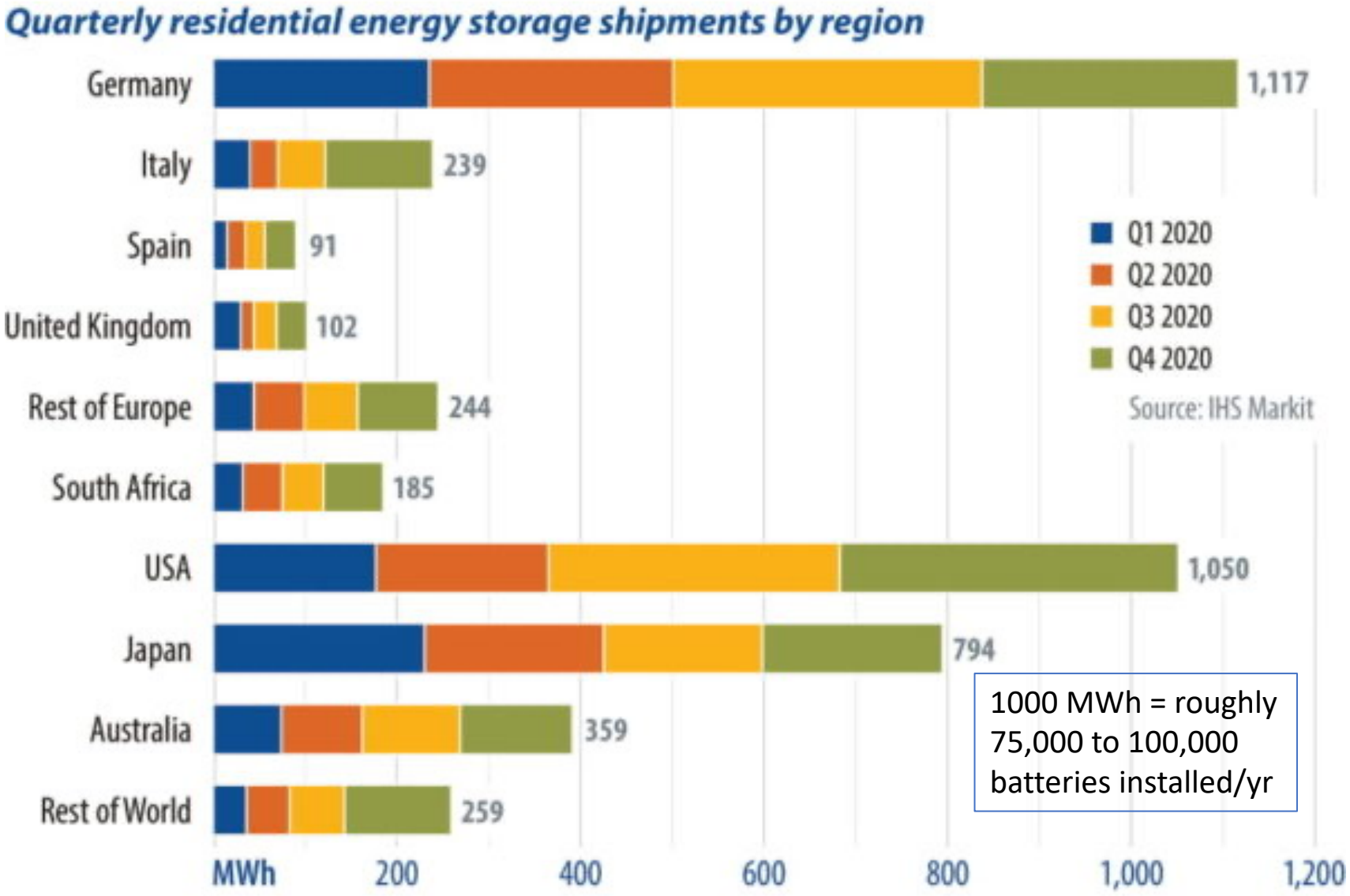




Percentage of homes with rooftop PV by post code



Which countries installed the most home batteries in 2020?



Germany still largest market, but US may soon pass it up.

Those countries still have more battery systems on a per capita basis than the US does.

Electricity price differences at various times of day and grid susceptibility to outages still play a bigger role in driving battery markets than sheer population size or the quality of the local solar resource.

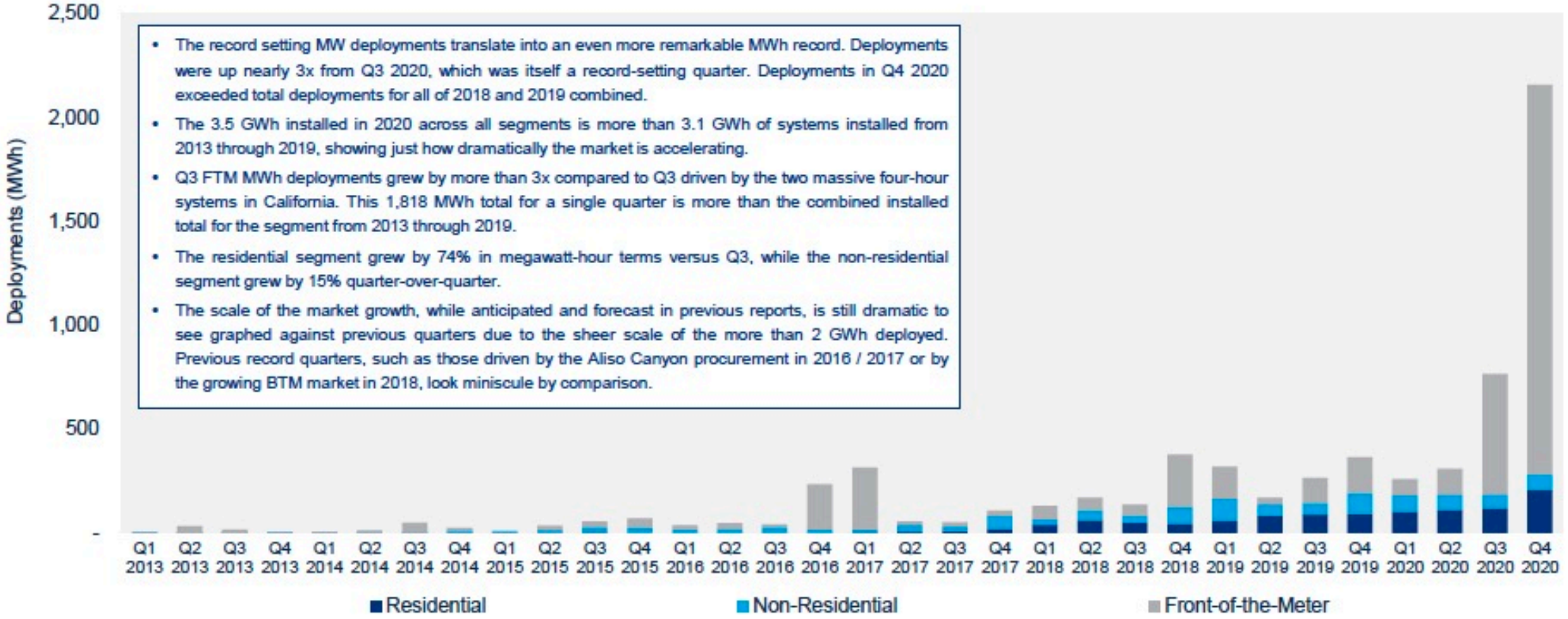
www.pv-magazine.com/2021/04/13/strong-growth-ahead-for-battery-storage/

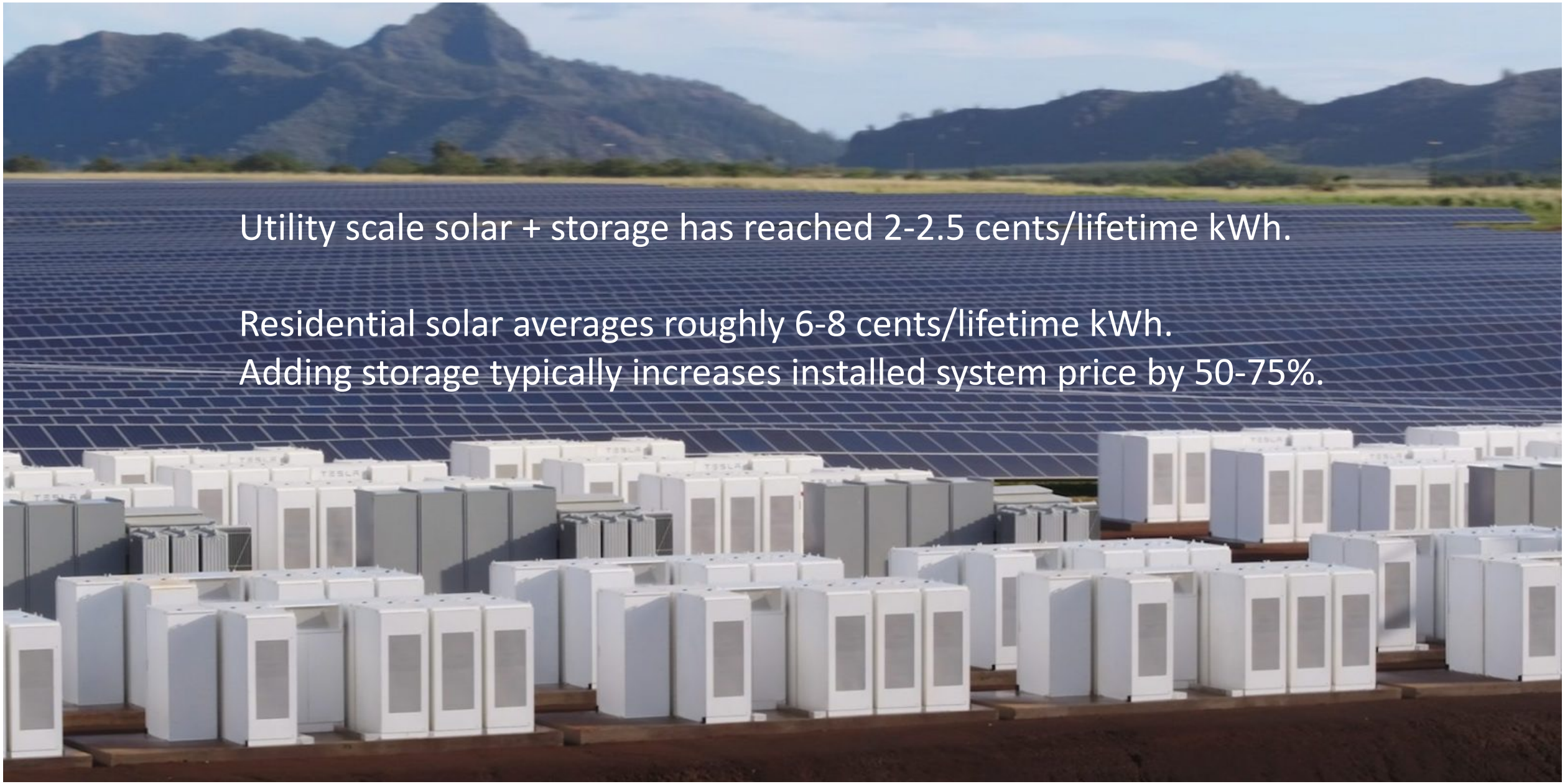
Residential system installations rose 74% from Q3 to Q4 2020. Utility scale storage is dominant.

U.S. market deployed 2,156 MWh in Q4 2020

Quarterly MWh deployment totals dwarf the scale of previous quarters, revealing exponential growth

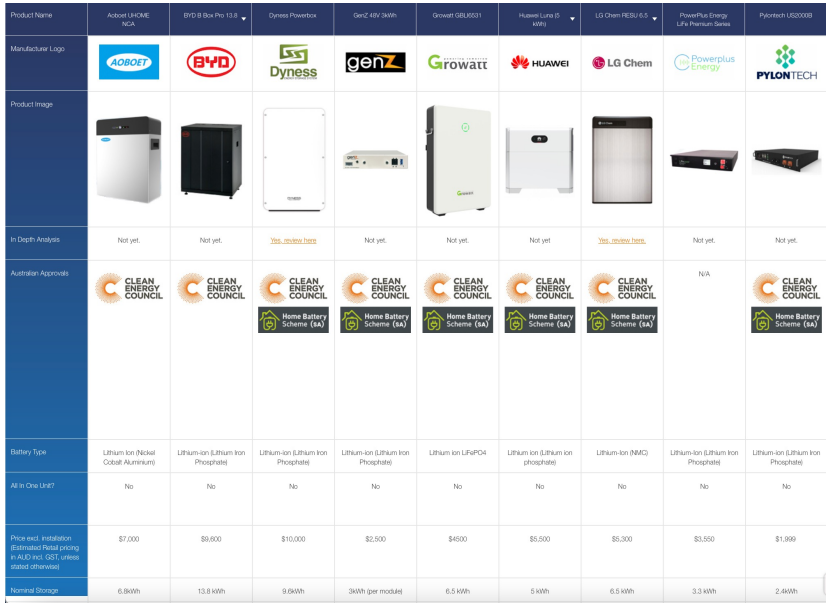
- The record setting MW deployments translate into an even more remarkable MWh record. Deployments were up nearly 3x from Q3 2020, which was itself a record-setting quarter. Deployments in Q4 2020 exceeded total deployments for all of 2018 and 2019 combined.
- The 3.5 GWh installed in 2020 across all segments is more than 3.1 GWh of systems installed from 2013 through 2019, showing just how dramatically the market is accelerating.
- Q3 FTM MWh deployments grew by more than 3x compared to Q3 driven by the two massive four-hour systems in California. This 1,818 MWh total for a single quarter is more than the combined installed total for the segment from 2013 through 2019.
- The residential segment grew by 74% in megawatt-hour terms versus Q3, while the non-residential segment grew by 15% quarter-over-quarter.
- The scale of the market growth, while anticipated and forecast in previous reports, is still dramatic to see graphed against previous quarters due to the sheer scale of the more than 2 GWh deployed. Previous record quarters, such as those driven by the Aliso Canyon procurement in 2016 / 2017 or by the growing BTM market in 2018, look miniscule by comparison.




Utility scale solar + storage has reached 2-2.5 cents/lifetime kWh.
Residential solar averages roughly 6-8 cents/lifetime kWh.
Adding storage typically increases installed system price by 50-75%.

Residential Battery Market Status

- At present, in the more mature Australian marketplace, hundreds of competing home energy storage systems are for sale from at least 31 distinct manufacturers.
- Great list of available battery models and their specs: www.solarquotes.com.au/battery-storage/comparison-table/
- Fewer models are presently available in the US market, 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.



Australian battery testing

- 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
- 11 of the batteries it has tested either experienced problems in setup or operation or both
- Impacts on capacity, efficiency, and performance over time can be significant

Australian accelerated testing across a range of temperatures shows how a fully sealed battery pack can degrade fast

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.

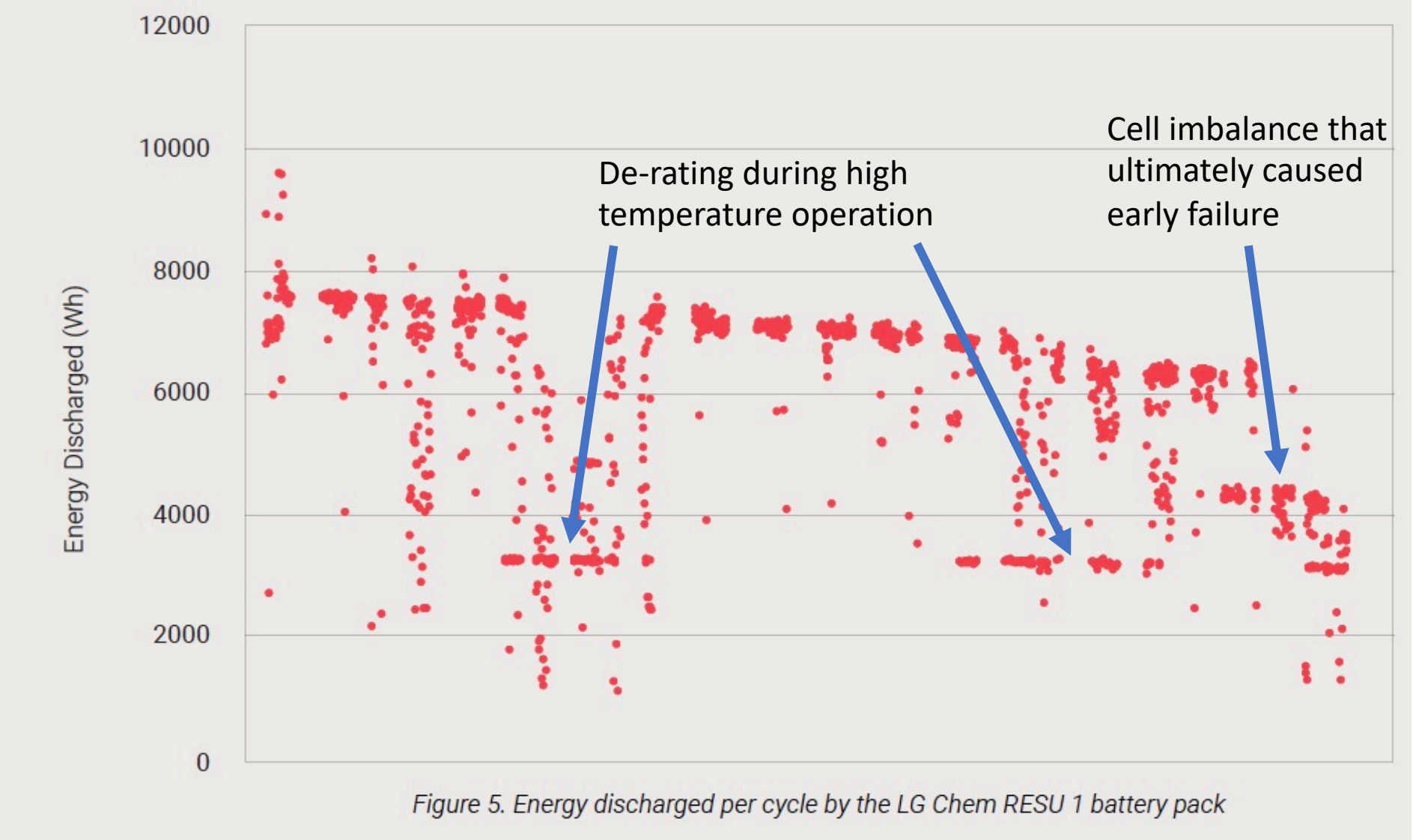
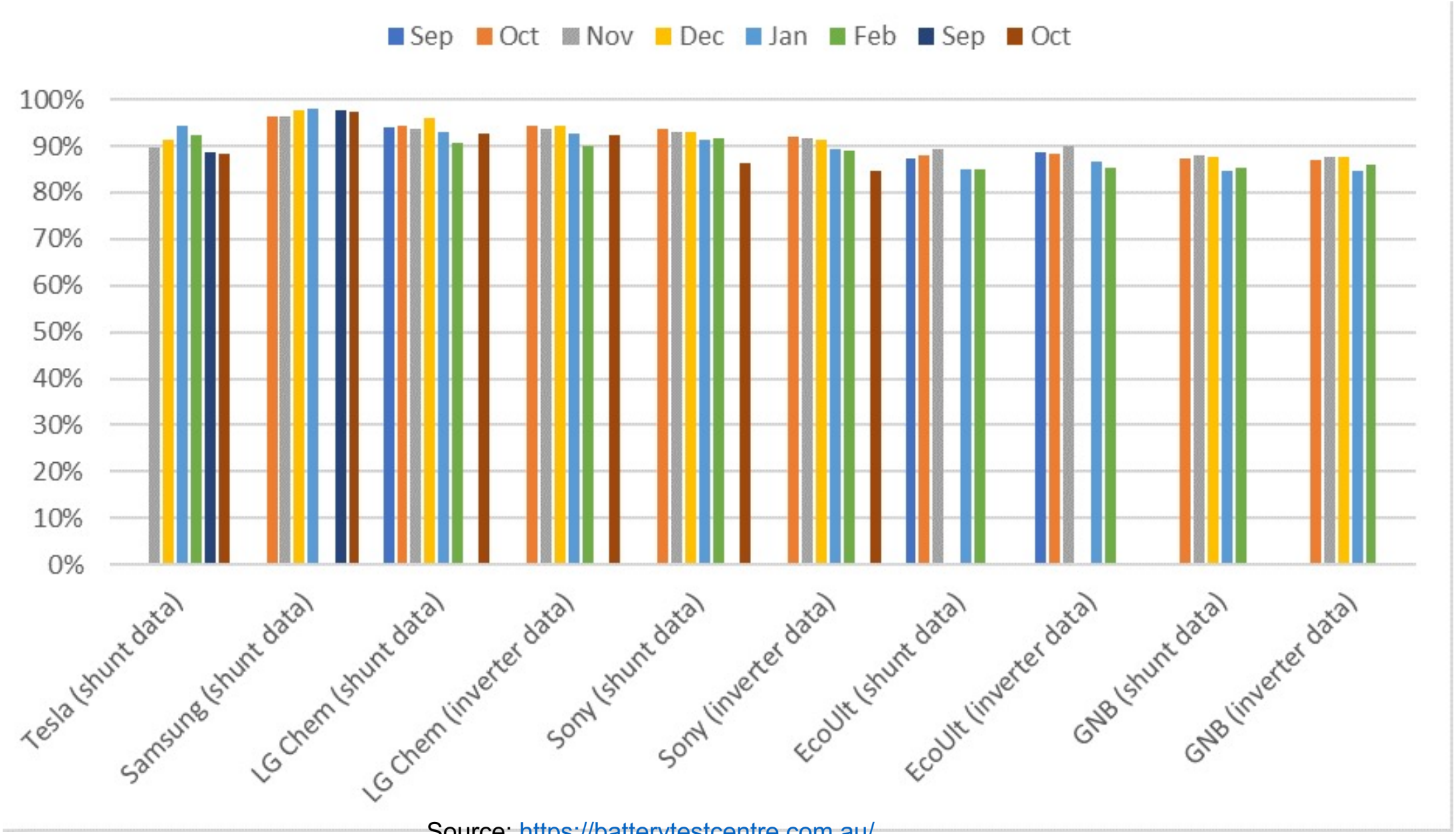


Figure 5. Energy discharged per cycle by the LG Chem RESU 1 battery pack

Round trip efficiencies often decline gradually with use. The best batteries have about half of the losses of the worst.



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

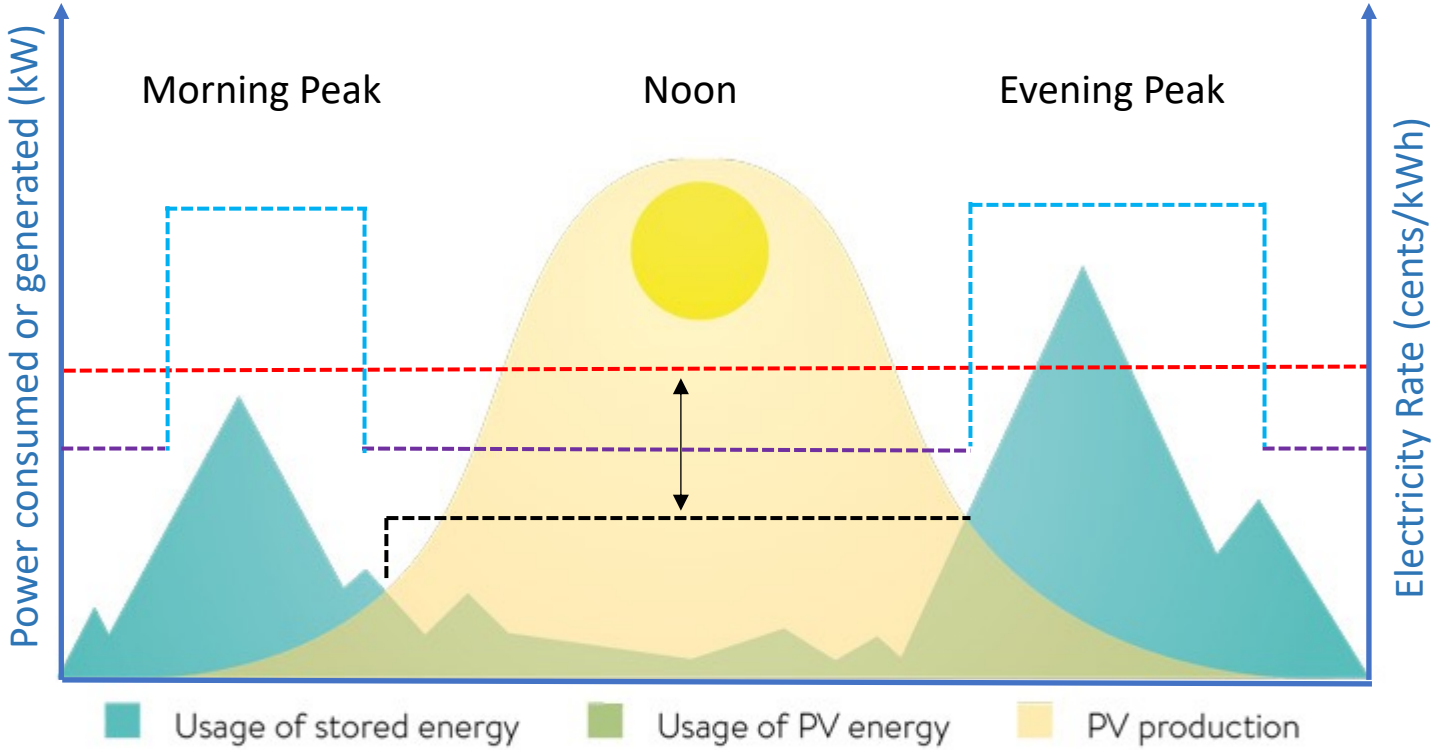
Why not encourage storage in all homes?

- Round trip energy conversion losses can be 15% or more, and the paired inverters have high standby losses, **so adding batteries increases a home's total electricity use and usually lengthens the payback period of a PV system.**
- 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.
- Performance, longevity, safety, and warranty coverage differ dramatically among available products, which greatly affects whether they will be cost-effective to purchase. And not all manufacturers report their products' performance in the same way, so it's difficult to compare product spec sheets fairly to each other.

How much energy could be saved by promoting more energy efficient residential batteries instead of typical ones ?

Criteria	Inefficient Battery and Inverter	Efficient Battery and Inverter	Savings
Average size	10 kWh	10 kWh	
Depth of discharge	90%	90%	
Roundtrip AC-AC efficiency	83%	88%	
Charge and discharge losses with one round trip cycle per day	673 kWh/yr	448 kWh/yr	225 kWh/yr
Inverter standby power	30 W	7 W	134 kWh/yr
Annual total energy consumption	848 kWh/yr	489 kWh/yr	359 kWh/yr
Annual operating cost at $0.125/kWh	$106	$61	$45

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.

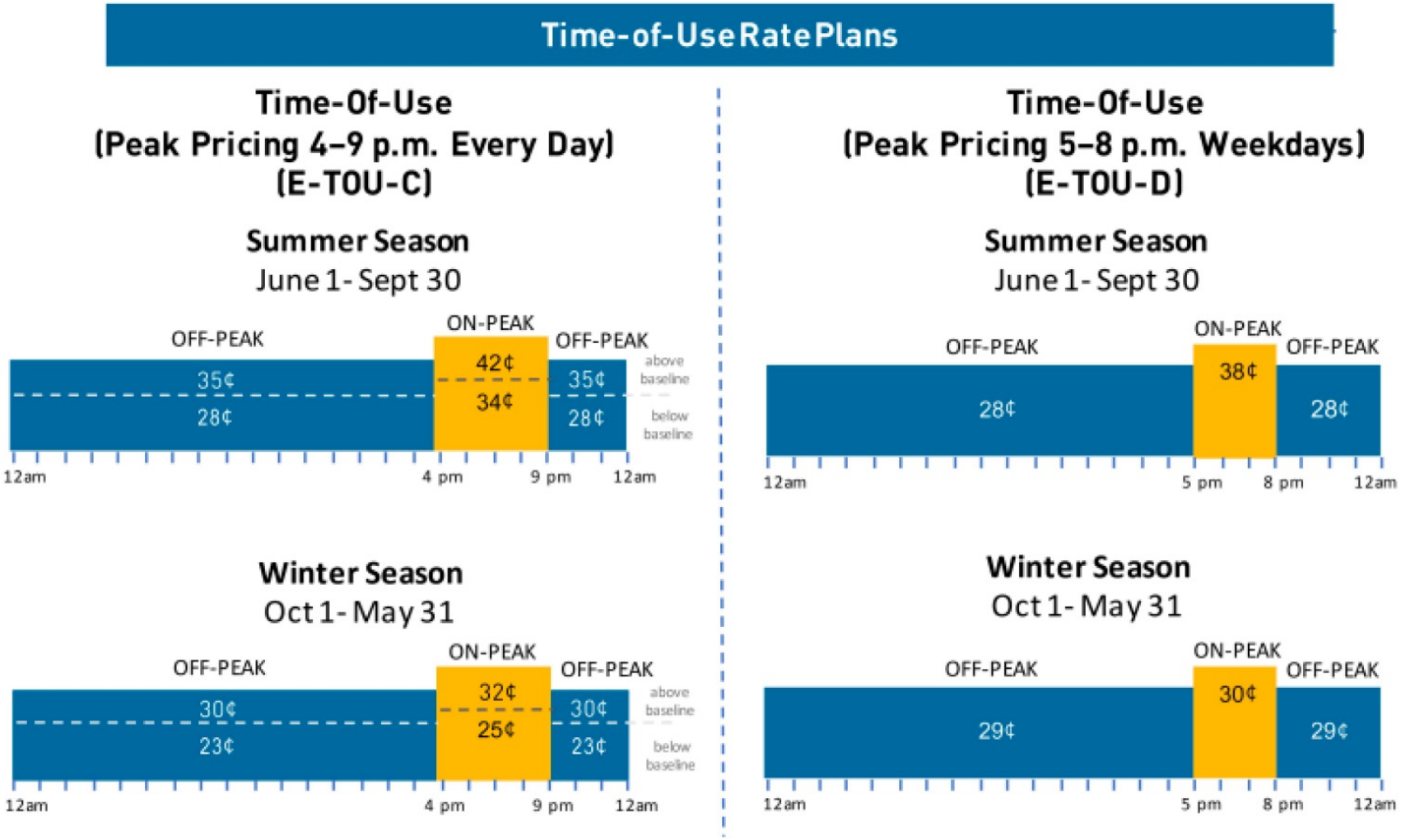
Midday: highest energy production, low energy needs.

Evening: low energy production, high energy needs.

Time of Use (TOU) rates from PG&E apply automatically if you have solar

Some people are buying batteries hoping to make money on the difference between peak and off peak electric rates.

With PG&E's TOU rates, the price differences between peak and off peak times are 1 to 10 cents/kWh, so batteries are typically not financially attractive with those rate plans.



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

PG&E's EV rates are the most promising for shifting power between different times of day: 32 to 42 cents/kWh price difference differences between peak and off-peak rates

EV 2A rate (cheaper peak but more expensive off-peak)

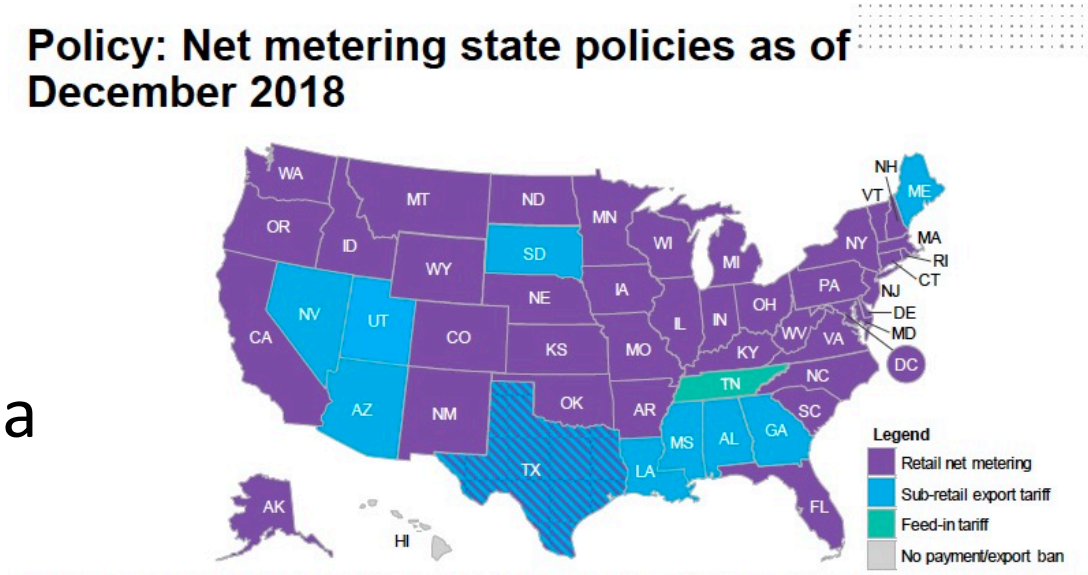
EV B rate (bigger price differences between peak and off-peak, but only separately metered EV consumption is eligible)

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

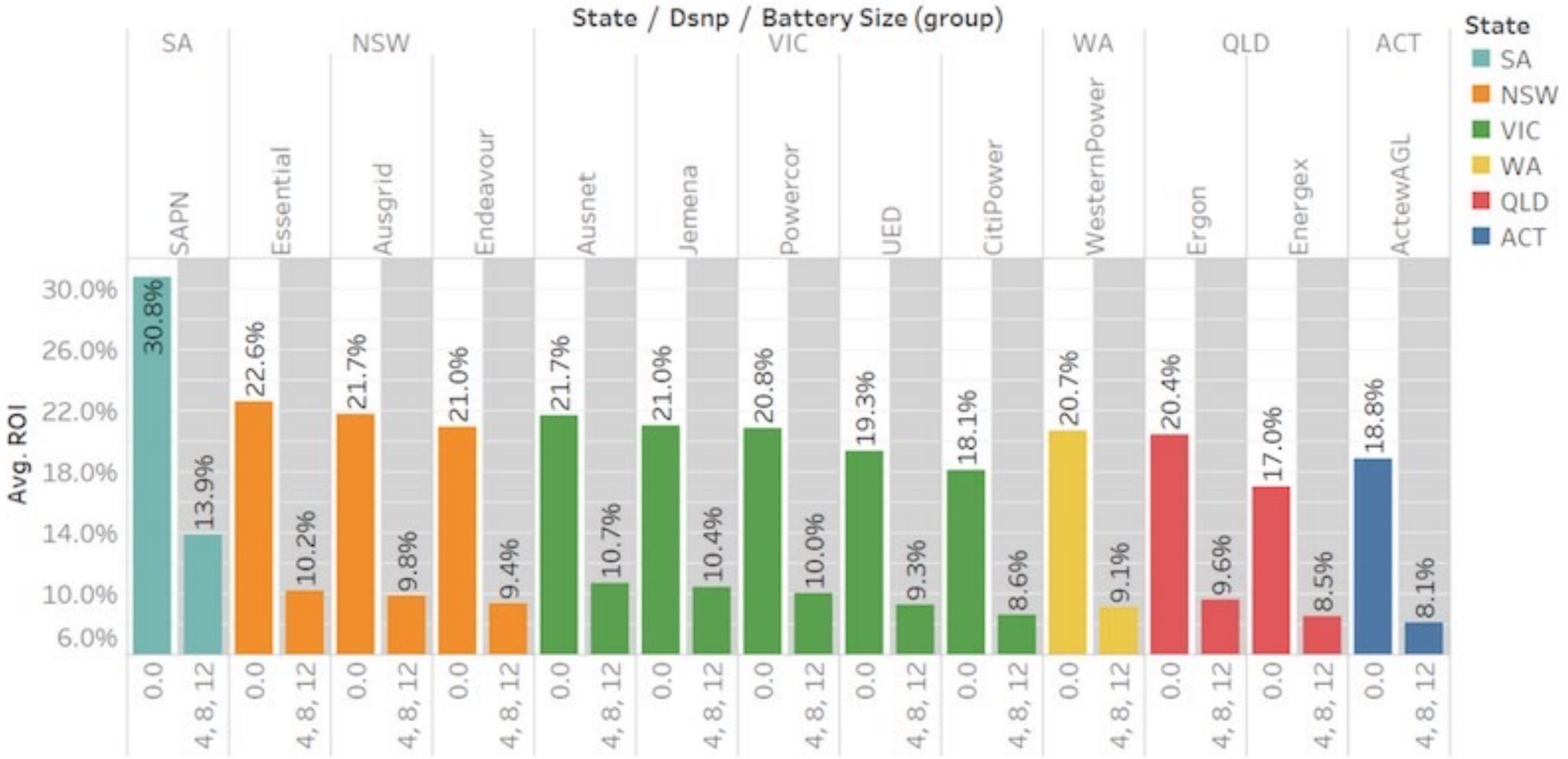
TOU rates make a big difference in battery viability

- Residential TOU rates widely employed in Australia with peak to off-peak price differences of 20-30 cents/kWh. Greatly improves home battery economics and encourages west-facing PV. Surplus solar power sold to grid midday at low prices. Morning and evening peak purchases from the grid occur at high prices.

- TOU rates less common in US and typically with peak to off-peak price differences of 5-15 cents/kWh. 1:1 retail net metering can flood grid with south-facing PV power midday, leading to low spot prices and then a big ramp in grid-supplied power at evening peak. Still only about 20% of homes have some west-facing PV.



Solar and battery economics vary sharply by Australian state, but adding batteries consistently cuts ROI in half or more

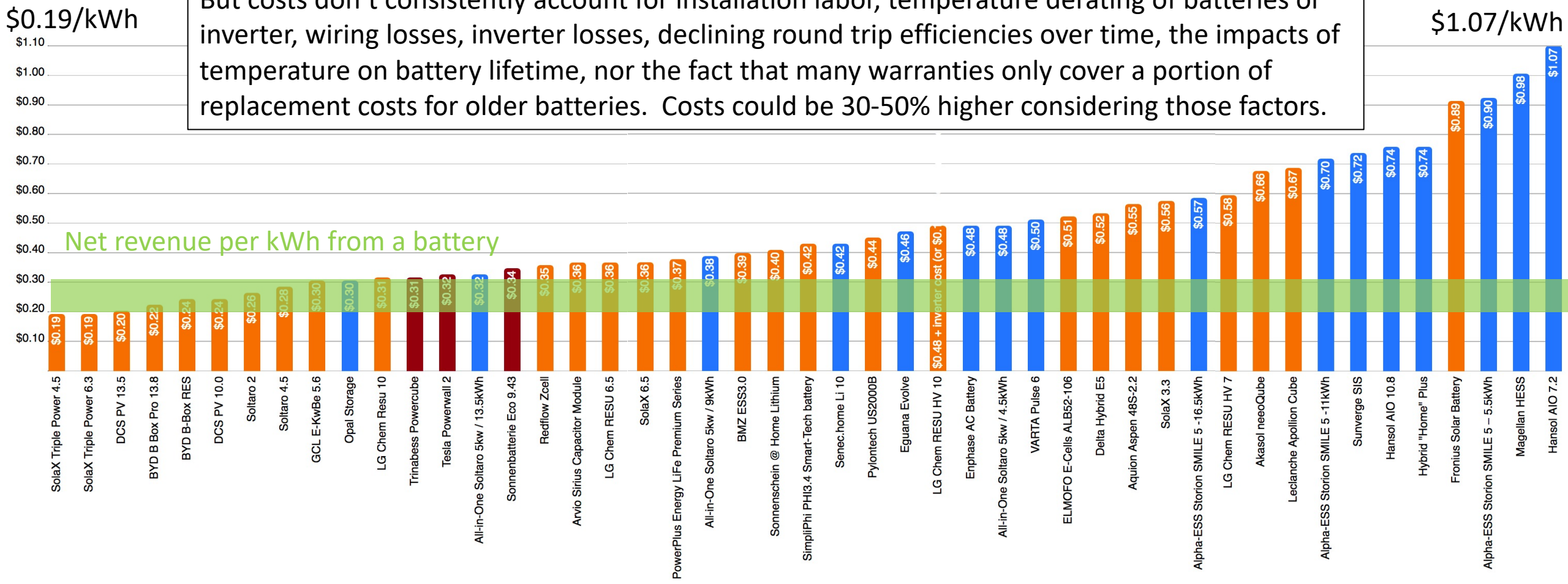


The search for a comprehensive cost-effectiveness metric

- SolarQuotes.com proposes upfront cost per lifetime warranted kWh.
- Example 1:
  - Suppose battery A costs $10,000
  - It has a nominal capacity of 10 kWh
  - It's warranted for 5,000 cycles
  - $10,000 / (10 kWh/cycle * 5000 cycles) = **$0.20/lifetime warranted kWh**
- Example 2
  - Supposed battery B also costs $10,000
  - It has a nominal capacity of 10 kWh
  - It's warranted for 7 years, assuming 1 cycle/day for solar self consumption
  - $10,000 / (10 kWh/cycle * 1 cycle/day * 365 days/year * 7 years) = **$0.39/lifetime warranted kWh**
- If the batteries only allow 90% depth of discharge, *actual* capacity is 10% lower than nominal, so upfront cost/lifetime kWh is 11% higher.
- If the batteries are warranted to be delivering at least 60% of their actual new capacity at end of life, their actual *lifetime average* capacity is about 80% of nominal, so upfront cost/lifetime kWh is 25% higher.

SolarQuotes.com estimates a difference of more than 5 to 1 in battery system cost per lifetime warranted kWh for different available models

But costs don't consistently account for installation labor, temperature derating of batteries or inverter, wiring losses, inverter losses, declining round trip efficiencies over time, the impacts of temperature on battery lifetime, nor the fact that many warranties only cover a portion of replacement costs for older batteries. Costs could be 30-50% higher considering those factors.



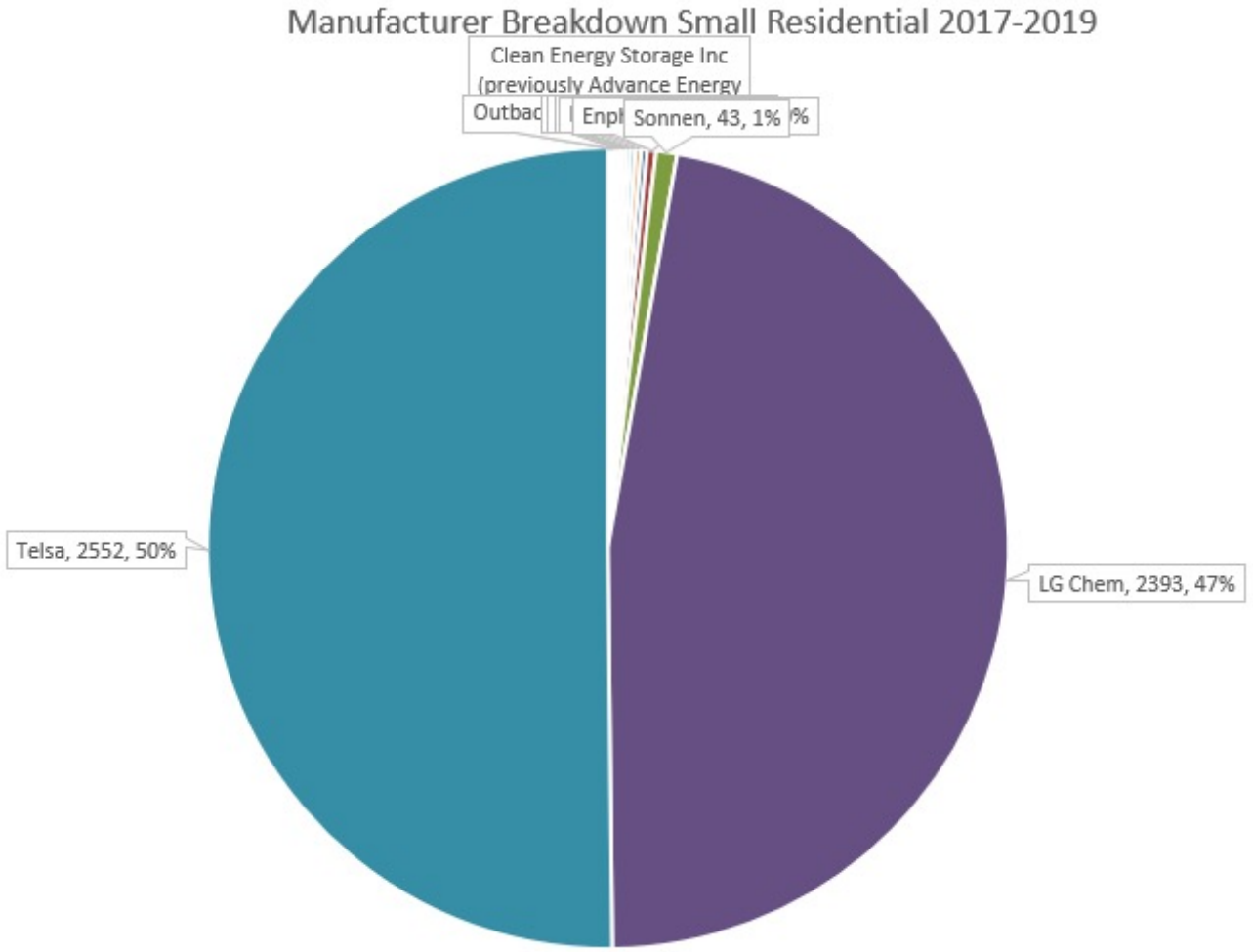
State incentives and the federal tax credit can help bring down these costs by 30-50%

= Just battery (requires extra expense on battery inverter and solar inverter)
= Battery + battery inverter (Extra cost required for solar inverter)
= All In One unit

Self Generation Incentive Program (SGIP) considerations

- SGIP is funding from the state of California's Public Utility Commission of more than $1 billion through 2024 to encourage energy storage systems.
- Most people would be eligible for the general incentive amount of $250/kWh of battery energy storage capacity.
- Some people with lower incomes or frequent outages or well pumps would be eligible for much higher incentives of $850 (Equity) or $1,000/kWh (Equity Resilliency). Unfortunately, demand for those has overwhelmed the available funds, and eligible PG&E participants went on a wait-list after December 2020.

Two battery makers dominated California's early home rebates

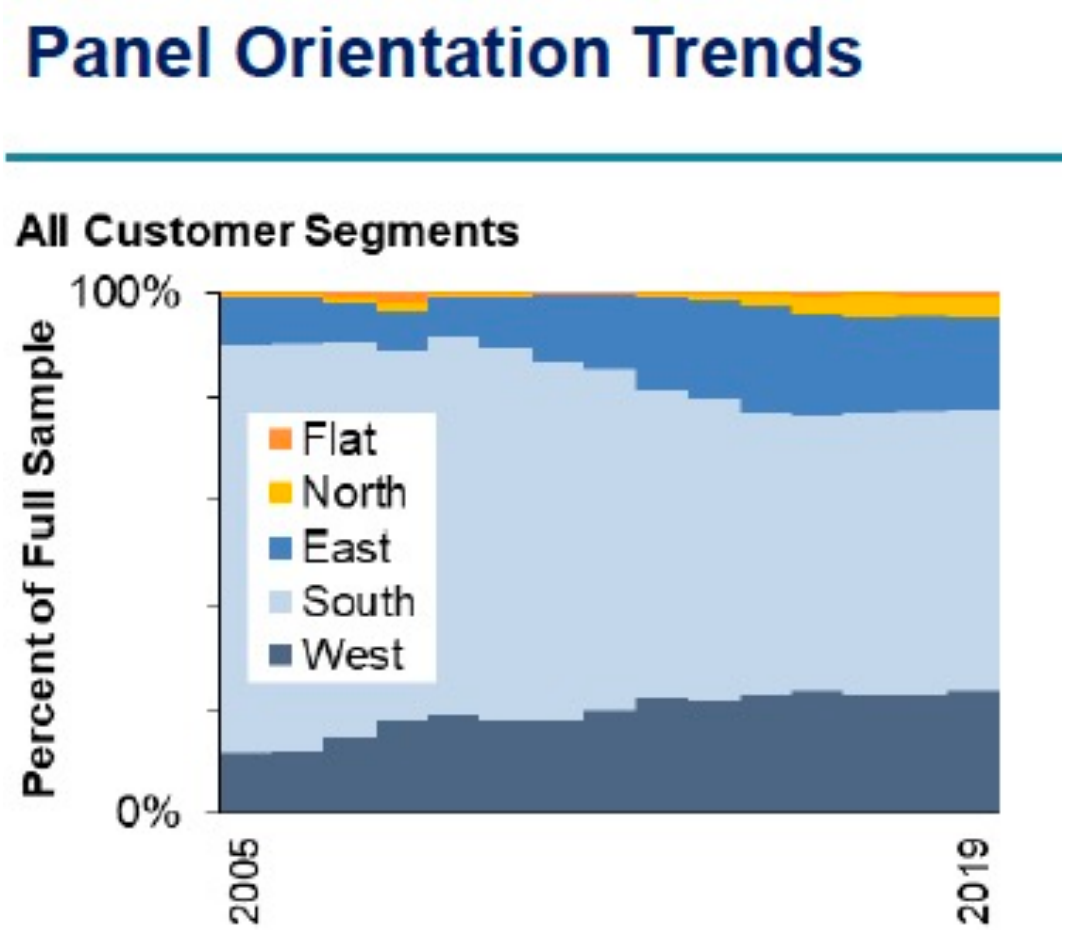


Manufacturer	Count
BMZ	1
Clean Energy Storage Inc (previously Advance Energy Storage)	1
Concorde	1
Discovery	1
LG Solar	1
NEOVOLTA	1
Solaredge	1
US Battery	1
LG Electronics	2
Outback Power Systems	2
JLM	3
Enerdel	4
Simpliphi	6
Sunverge	6
Tabuchi	7
Pika Energy	8
Adara Power	10
Energport Inc	12
Mercedes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

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

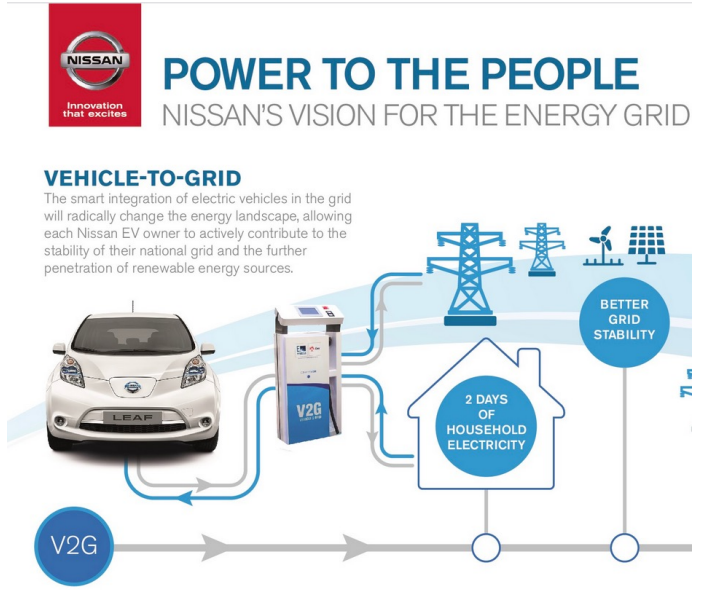
CA policies have room for improvement

- Beneficial that Title 24 requires PV on new homes, but ironic that it can be up to 25% smaller if installed with a battery system. PV system needs to be bigger to cover the roundtrip losses in the batteries.
- It's nice that the SGIP incentives are so generous, but that's a costly way to buy storage without enough quality control.
- Also should be even more west-facing PV to reduce the need for storage to cover the first couple hours of the evening peak.



V2G: bidirectional power flow capability increasingly available in EVs and chargers

- EV batteries typically have 5 to 15x the capacity of home batteries and support greater peak power flows too.
- Hardware capability for bidirectional power flow has existed in EVs for awhile; software now being increasingly enabled.
- V2G chargers now available from Nuvve, Ossiaco, Wallbox Quasar, and others.
- Can be an ideal arrangement if you work from home. If your EV is away from the house during the day when the sun is shining, this option makes less sense for you.
- But it may make increasing sense for employers to provide it under solar canopies in the parking lot, trading free charging to its employees' EVs for the ability to use their batteries bidirectionally to minimize demand charges during the day.

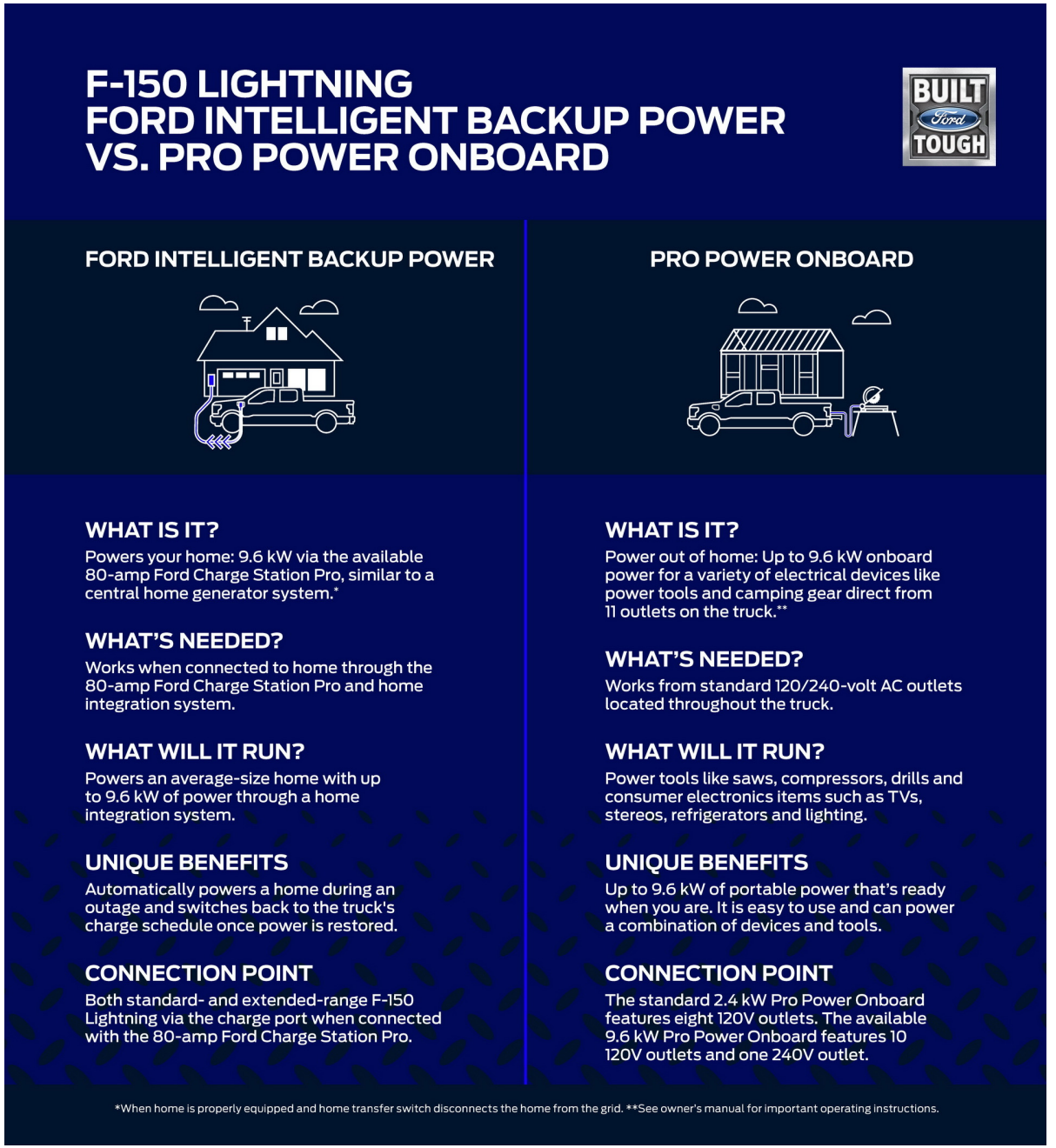


V2G-capable vehicles

- Latest generation Nissan Leaf EV models (CHAdeMO charge port)
- Latest generation Mitsubishi Outlander PHEV models (CHAdeMO charge port)
- Lucid Air (released in 2nd half of 2021)
- Rivian R1T truck and R1S SUV (released in Sept 2021)
- A wide variety of Volkswagen models starting in 2022
- Hyundai Ioniq 5 and Kia EV6 in 2022
- Ford Lightning pickup with installation support from SunRun and smart panels from Span in 2022

Tesla's insistence that the feature doesn't make sense increasingly feels like the perspective of a company that wants to sell more stationary battery systems.

Sources: https://newmotion.com/en/knowledge-center/news-and-updates/the-future-of-ev-charging-with-v-2-x-technology and www.greencarreports.com/news/1131835_mass-market-vw-evs-will-have-bidirectional-charging-starting-in-2022 and www.carscoops.com/2021/05/how-the-new-ford-f-150-lightning-can-help-you-keep-the-lights-of-your-house-always-on/#lg=1&slide=28



Conclusions

- Residential energy storage systems are tremendously promising, but don't automatically save money, pay for themselves, or reduce greenhouse gas emissions.
- Australia teaches us there are big differences between the best and worst-designed battery systems, and more systematic testing and labeling are needed in the US to help consumers buy the best products.
- It's worth promoting the most efficient systems with well-designed incentives that ensure charging and discharging occur 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, but the economics improve every year you wait.
- Breakthroughs coming in the next 1-4 years with V2G and solid state batteries should yield dramatically better performance and economics than today's home battery systems.

Thank you!

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