What can we learn from Honda Smart Home? A zero-net energy home in California

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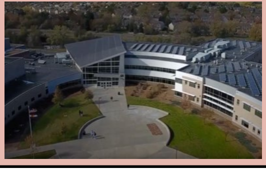
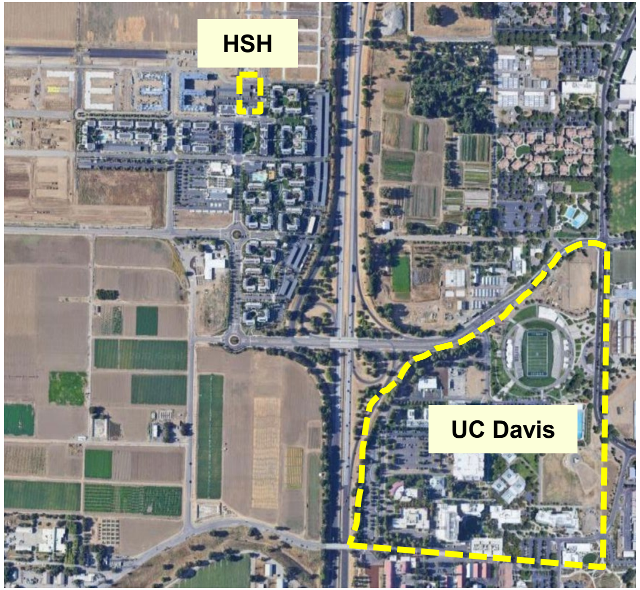
Introduction

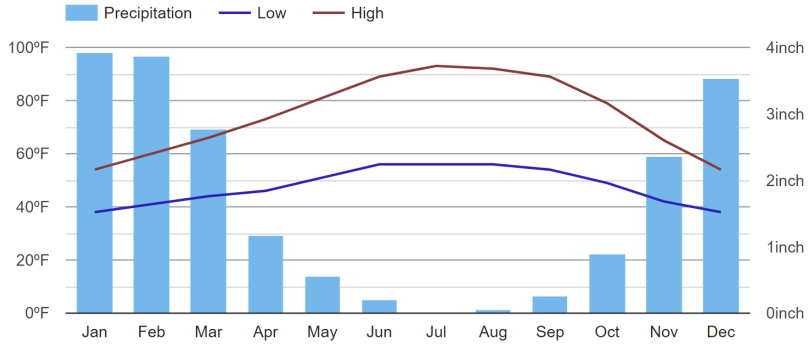
Twelve datasets delivered from the Benchmark Dataset project

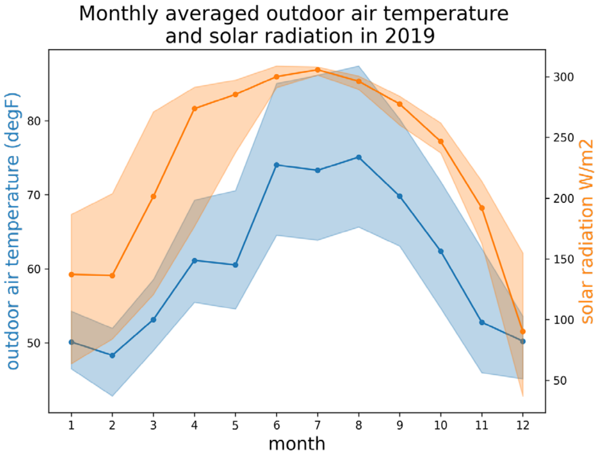
Available on Data Portal	Net-Zero Energy Residential Test Facility in Maryland * 	PNNL System Engineering Building 	Friends Center in Center City Philadelphia 	Vanderbilt Alumni Hall in Tennessee 
Curation Underway	Habitat for Humanity Net-Zero Energy Home 	A subset of Ecobee DYD * 	Honda Smart Home * 	NREL South Table Mountain Campus * 
Collection Underway	ORNL Flexible Research Platform 	PNNL Lab Homes 	Building 59 at LBNL * (+ new IAQ data points) 	Bear Creek High School in Colorado 

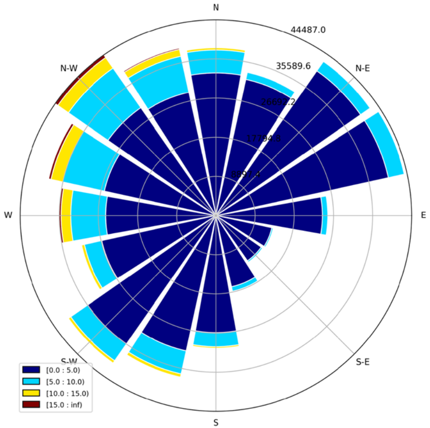
*** Completed or ongoing case study using the curated dataset**

Site 299 North Sage Street, Davis, Yolo County, CA 95616







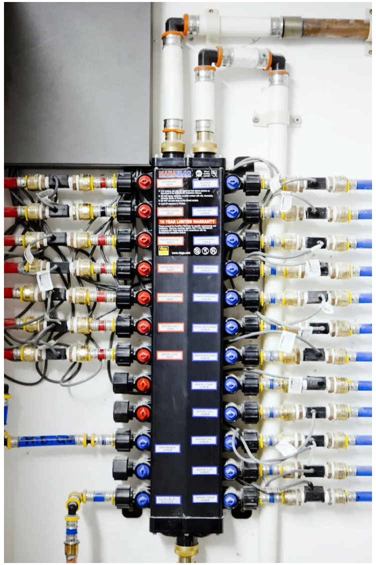


Climate 3-B hot-dry




Building info

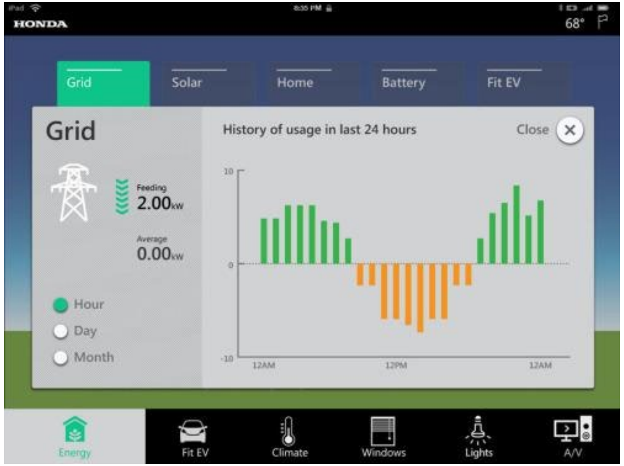
Two-story single-family residence	1,944 sf	180 m²
Detached garage	447 sf	41 m²
Visitor center	240 sf	22 m²

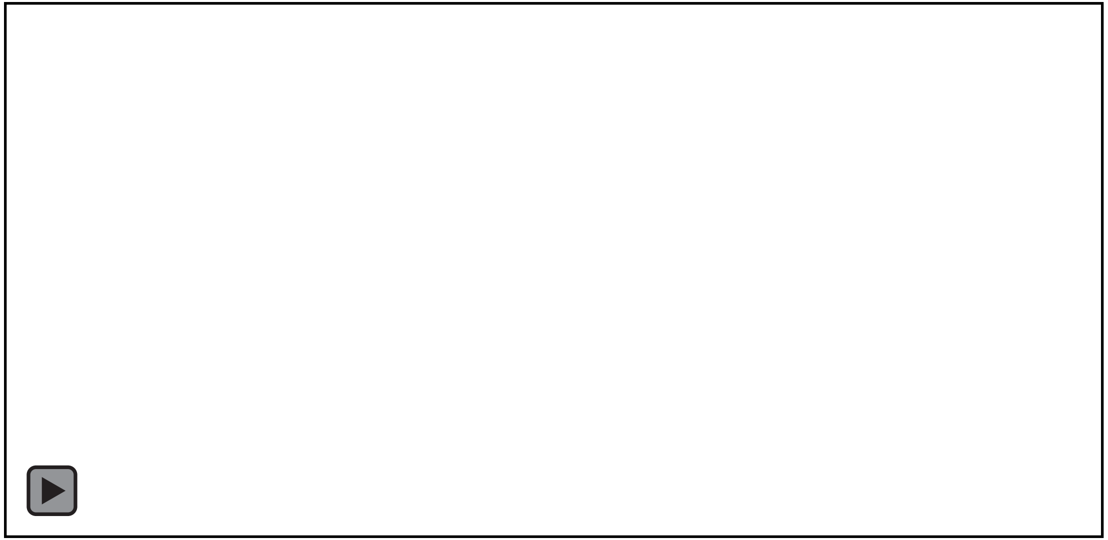


HEMS system

Data sensors for climate and energy use

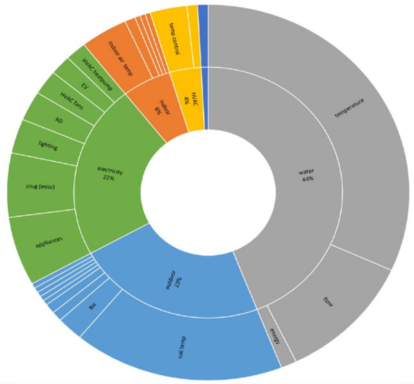
Bi-directional electric vehicle

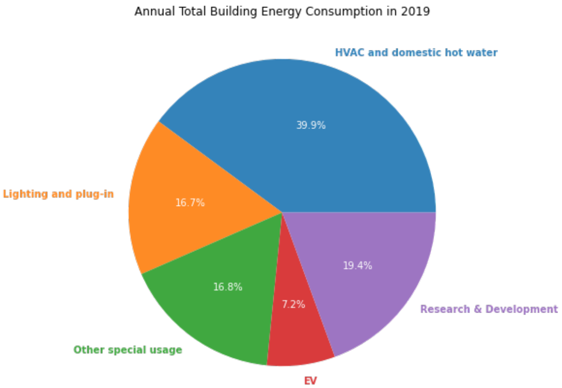


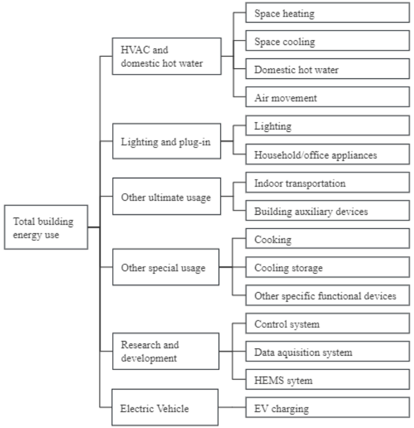


HEMS system

- Data sensors for climate and energy use
- Bi-directional electric vehicle
- Demand-response management

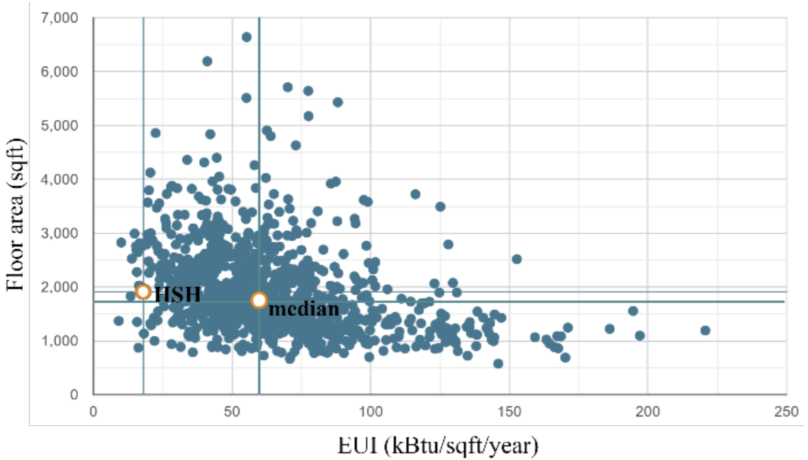






Category	Energy use (kWh)
HVAC and domestic water	4,001
Lighting and plug-in	1,673
Other special usage	1,689
EV	720
Research & Development	1948
Total	10,033 kWh

Energy Use Intensity in Climate 3B (warm-dry) in 2019



Benchmarking with other data resources from the Building Performance Database (BPD) [1]

Dataset 237 channels in minute resolution

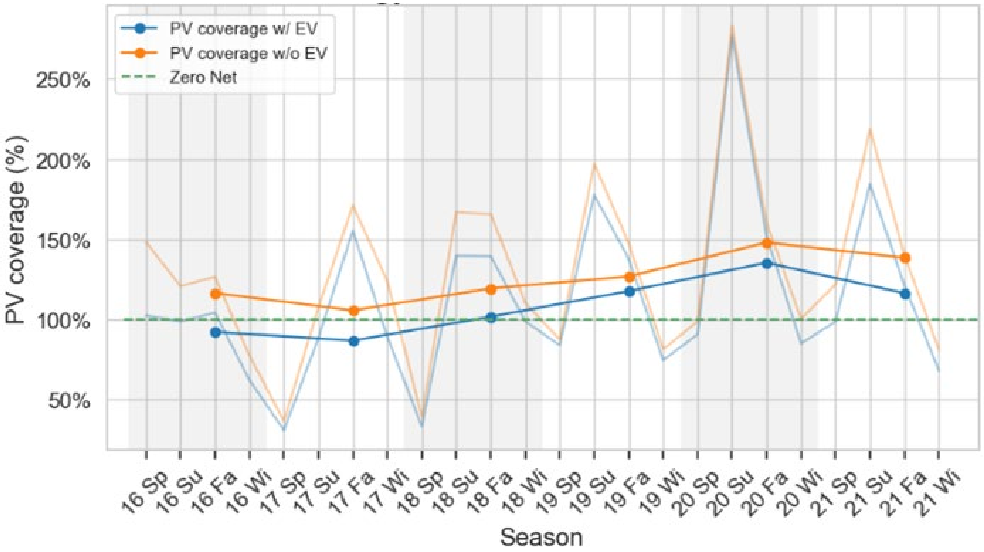
In this case study, we provide analysis and evaluation focusing on the following topics focusing on year of **2019**

- **Zero Net Energy** Evaluating the Honda Smart Home's performance in alignment with objectives set forth in the California Energy Efficiency Strategic Plan, using a multi-faceted approach.
- **Flexibility and Self-Sufficiency** Investigating the Honda Smart Home's ability to operate independently from the grid, assessed from various angles, and forecasting its future resilience potential.
- **Demand Response Operations & Grid Resilience** Evaluating how well the Honda Smart Home contributes to grid stability and its capabilities in demand response scenarios.

Zero-Net Energy

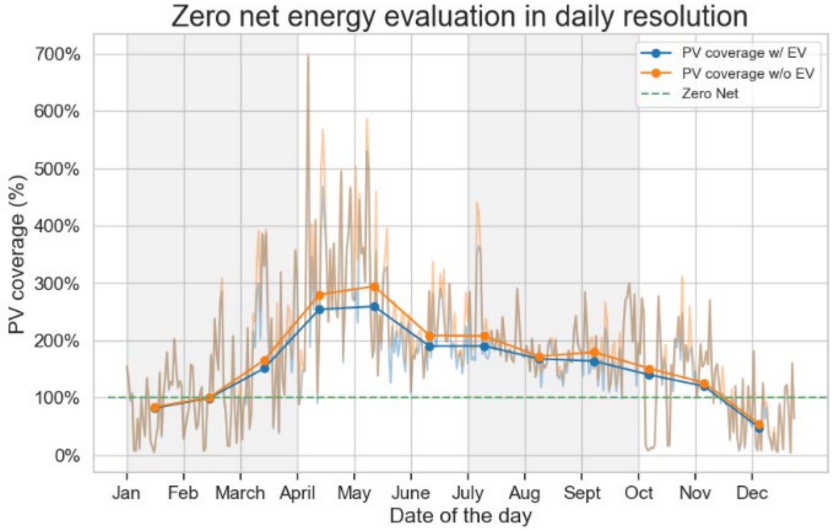
A zero net energy building is one that is optimally efficient, and over the course of a year, generates energy onsite, using clean renewable resources, in a quantity equal to or greater than the total amount of energy consumed onsite.

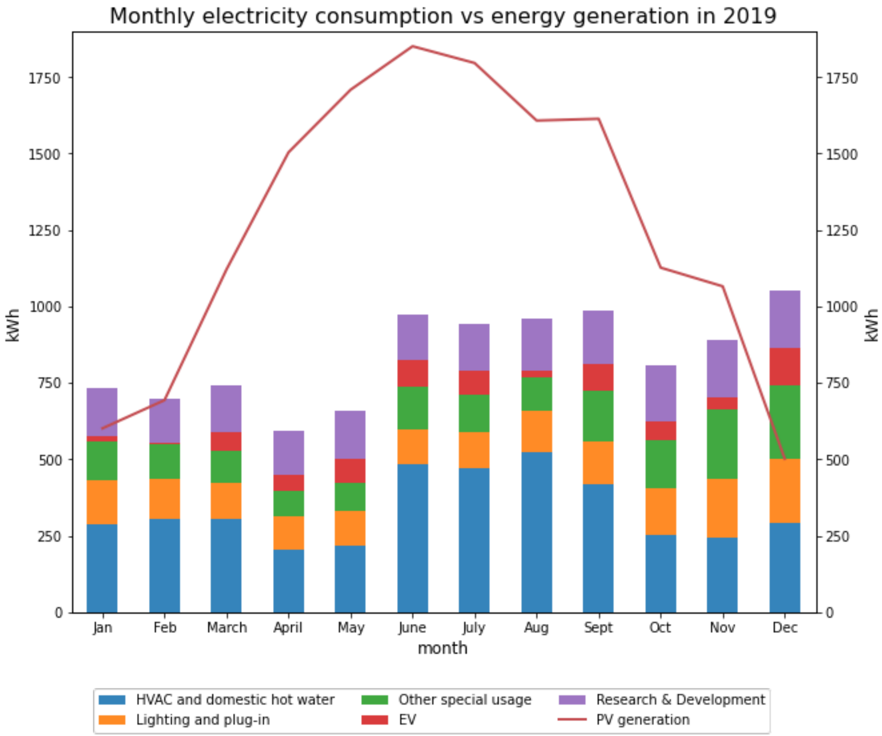
$$PV\ coverage = \frac{\sum PV\ generation}{\sum energy\ consumption}$$



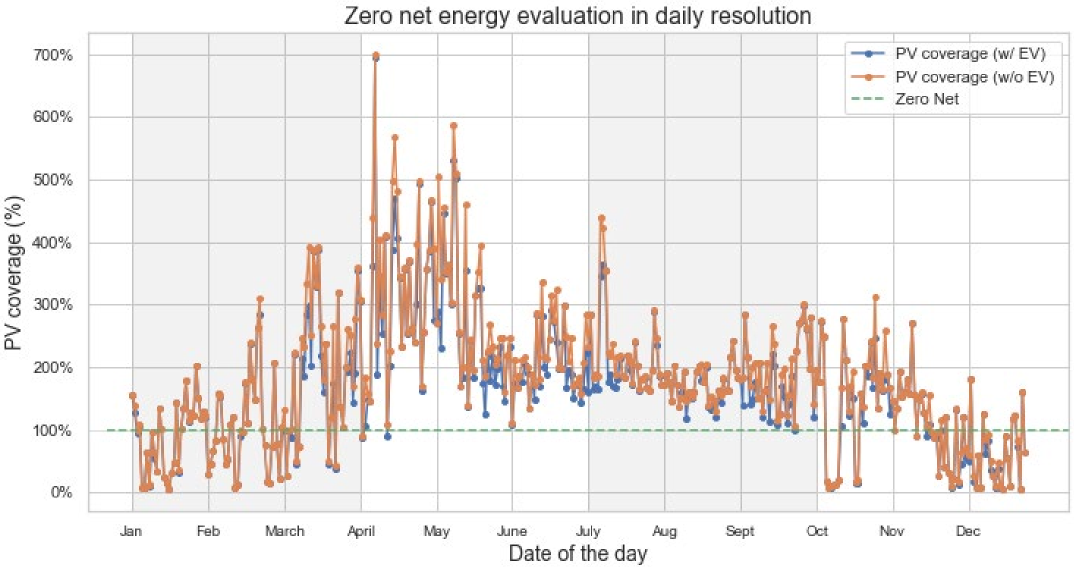
In a yearly resolution, HSH reaches ZNE goal from 2016 till present. However, if EV is considered, it reaches ZNE goal from 2018 till present.

In a seasonal resolution, HSH can meet the ZNE goal up to **three seasons** (Spring 21 – Fall 21), but HSH may fail to meet ZNE goal in spring and winter.



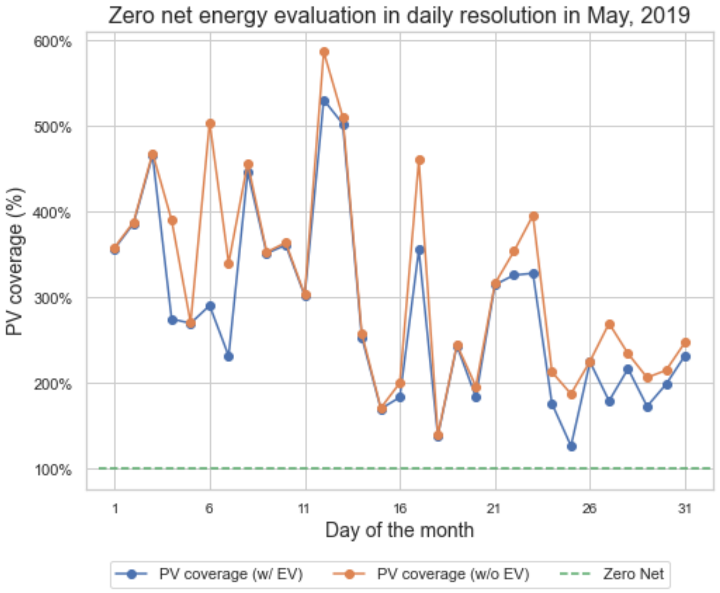


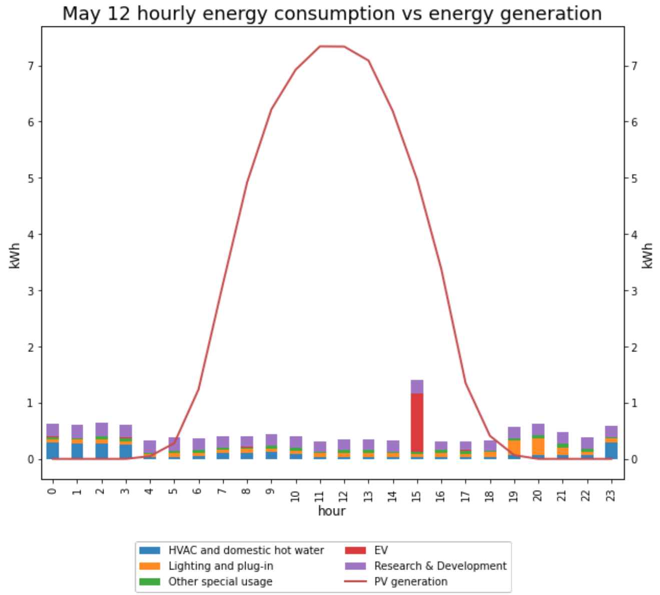
In **2019**, on a monthly basis, there were **9 month** (March to Nov.) met zero net goal, but January (-134 kWh), February (-5 kWh) and December (-552 kWh) fail to meet the ZNE goal due to the conflict between the increase of heating demand and the decrease in solar radiation. This is consistent with the seasonal trend.



Season	# days	%
Spring	55	59%
Summer	91	98%
Fall	93	100%
Winter	46	53%

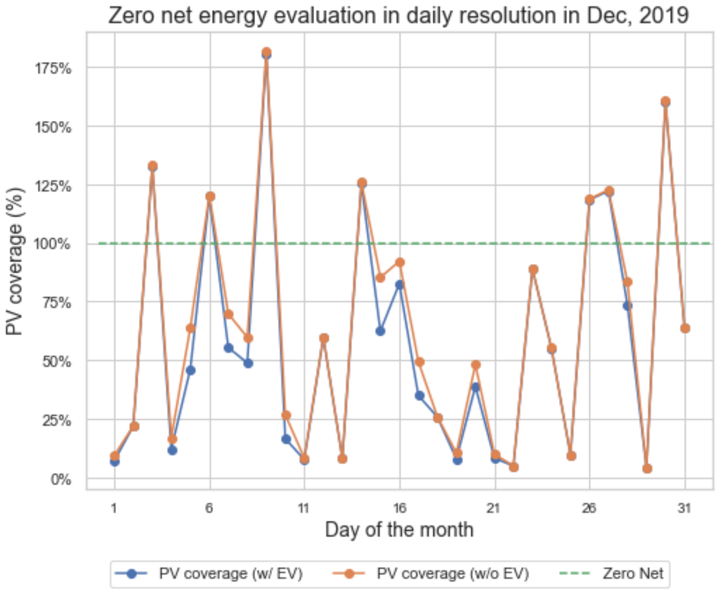
On a daily basis, there were **287 days (79%, without EV), 281 days (77%, with EV)** that reached ZNE goal.

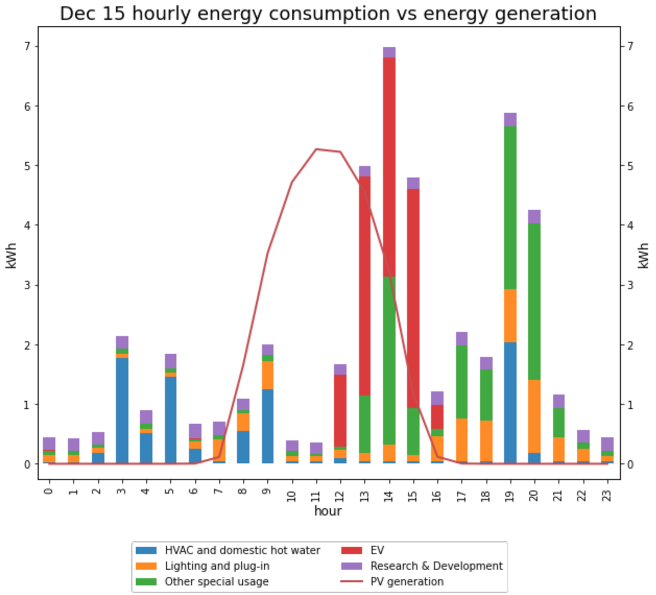




May 12	**kWh**	**%**
PV	60.84	
EV	1.10	
∑ without EV	10.38	586%
∑ with EV	11.48	530%

In summer months (e.g., May, June), the occupants tend to consume little energy, but the PV panels can generate 5 times of the energy that is required. The ZNE goal can be met daily easily.





Dec 15	kWh	%
PV	29.59	
EV	12.69	
∑ without EV	34.69	85%
∑ with EV	47.38	62%

In winter months (e.g., December, January), there are only 23% of the day (7 days) can meet ZNE goal. The discrepancies in PV coverage and energy use can be as much as 52 kWh.

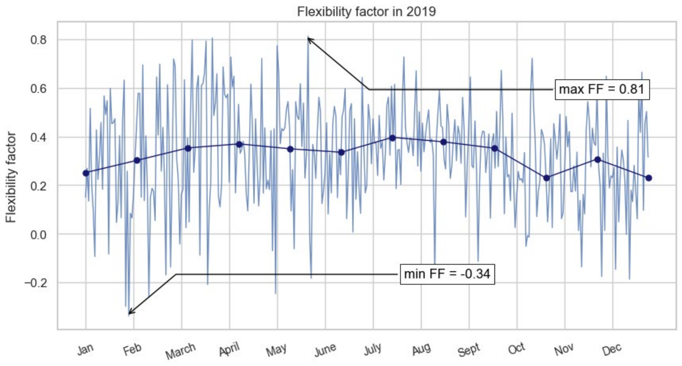
Flexibility & Self-sufficiency

Focusing on 2019, we provide analysis on popular flexibility metrics (flexibility factor, self-sufficiency, self-consumption, capacity of automated demand responses, and flexibility index) based on grid-interaction, and a detailed analysis on the influence on resiliency by introducing batteries and electric vehicles on extreme conditions.

$Flexibility\ Factor\ (FF)$ [2]

$$FF = \frac{Energy\ use_{\ LLH} - Energy\ use_{\ HLH}}{Energy\ use_{\ LLH} + Energy\ use_{\ HLH}}$$

$Yearly\ FF: 0.137$



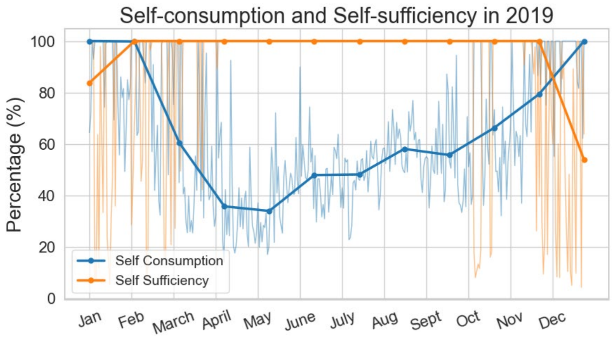
Though fluctuate a lot, 75% FF is between 0.2 to 0.4 throughout the year. Though no real-case comparative data available, some papers' simulated performance for residential building [3,4] is between -0.2 to 0.88.

$Self\text{–}consumption\ (SC)$ [5,6]

$$SC = \frac{\sum_{I=1}^{N_{t,total}} \min(P_{PV,i}, P_{elec\ load,i})\Delta t}{\sum_{I=1}^{N_{t,total}} P_{PV,i}\Delta t}$$

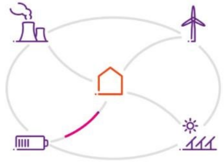
$Self\text{–}sufficiency\ (SS)$ [5,6]

$$SS = \frac{\sum_{I=1}^{N_{t,total}} \min(P_{PV,i}, P_{elec\ load,i})\Delta t}{\sum_{I=1}^{N_{t,total}} P_{elec\ load,i}\Delta t}$$



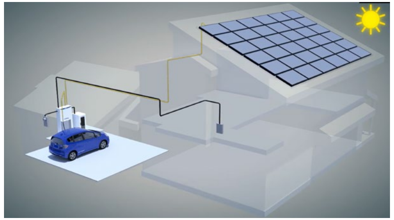
Self consumption (SC) reflects the capacity of the PV panels. In summer, the self consumption of the PV panel is around 0.5, (50% on-site PV energy is used by the household) and the surplus energy can be feed back to the grid.

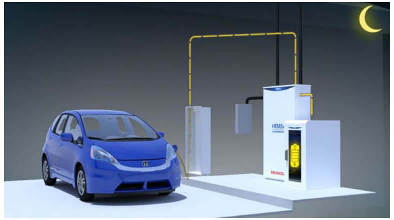
Self sufficiency (SS) reflects the electricity consumption of the household. HSH can reach 100% self-sufficiency for nearly 10 months. Drops during winter due to less solar radiation and increased heating needs.

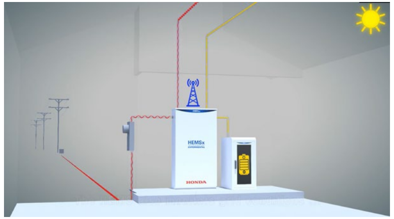


DR operation & Grid resilience

Focusing on 2019, we provide analysis on popular flexibility metrics (flexibility factor, self-sufficiency, self-consumption, capacity of automated demand responses, and flexibility index) based on grid-interaction, and a detailed analysis on the influence on resiliency by introducing batteries and electric vehicles on extreme conditions.







Demand-Response strategy

Solar Energy to DC

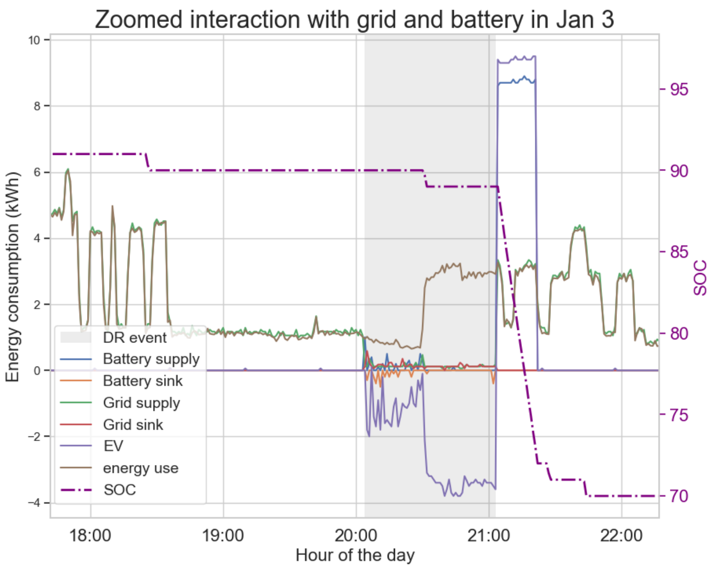
On-site solar energy is converted to Direct Current, ideal for charging the EV which also operates on DC.

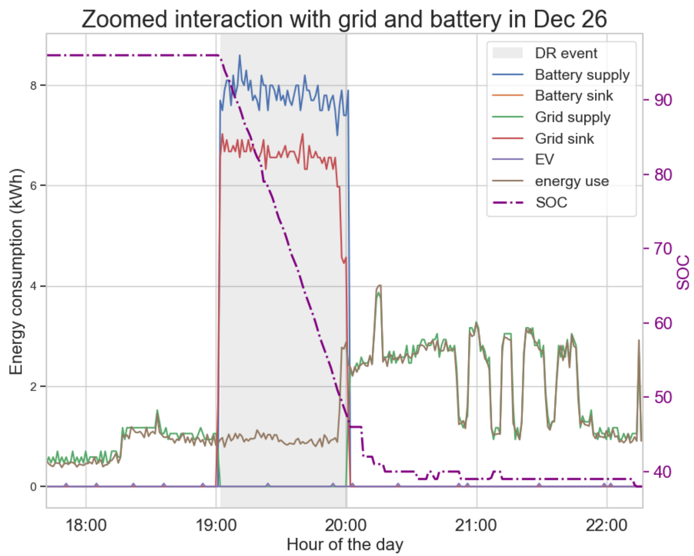
Battery Storage

Surplus energy generated when the EV is not charging is stored in the battery for later use

HEMS Strategies

- Prioritizes using grid power to meet household energy needs, minimizing power conversion losses.
- Feeds excess generated energy back into the grid during peak hour to offset energy demand.
- Efficiently charges the EV during periods when the grid has the lowest emissions.





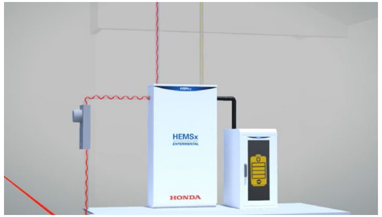
Reducing demand

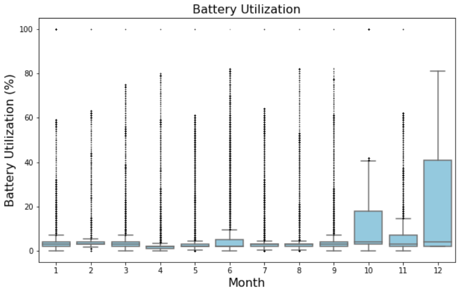
If energy use is intense, decreasing the energy use by feeding the house using battery or EV

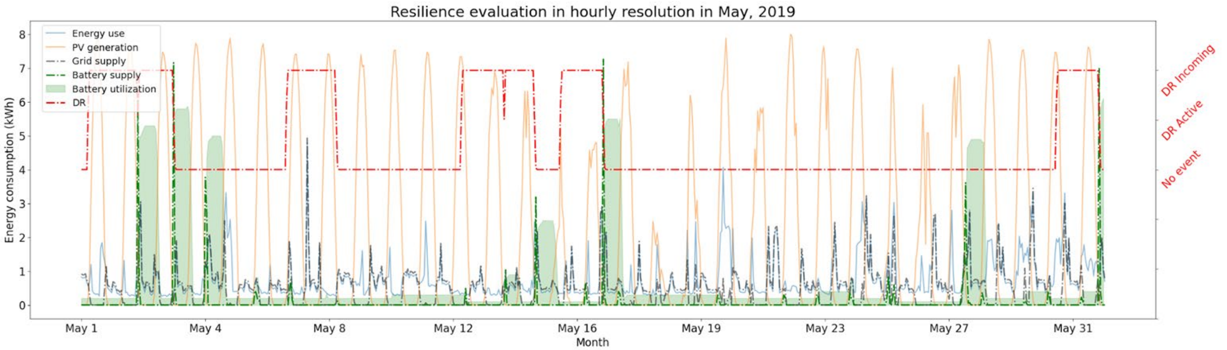
Feeding grid

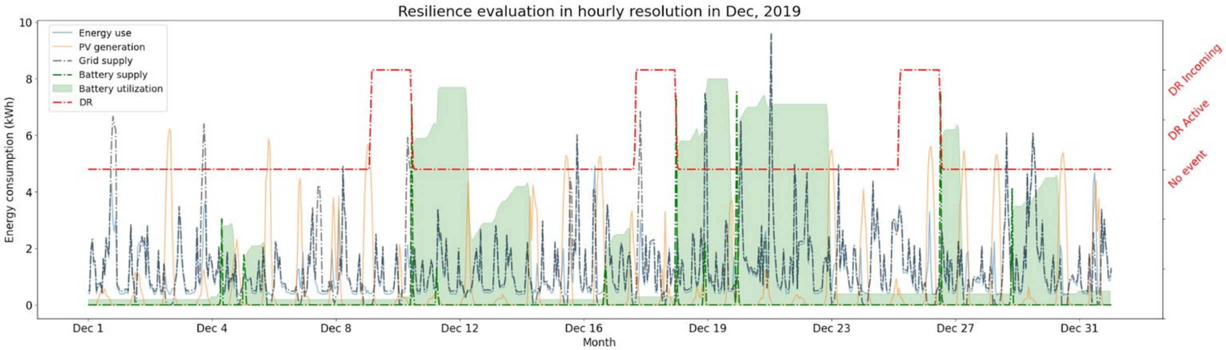
If the energy use is not intense and battery is available, use battery to feed the grid

Battery utilization & resilience



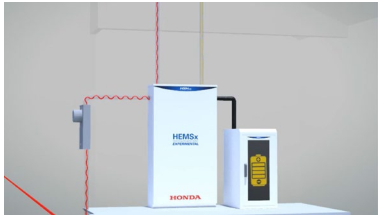


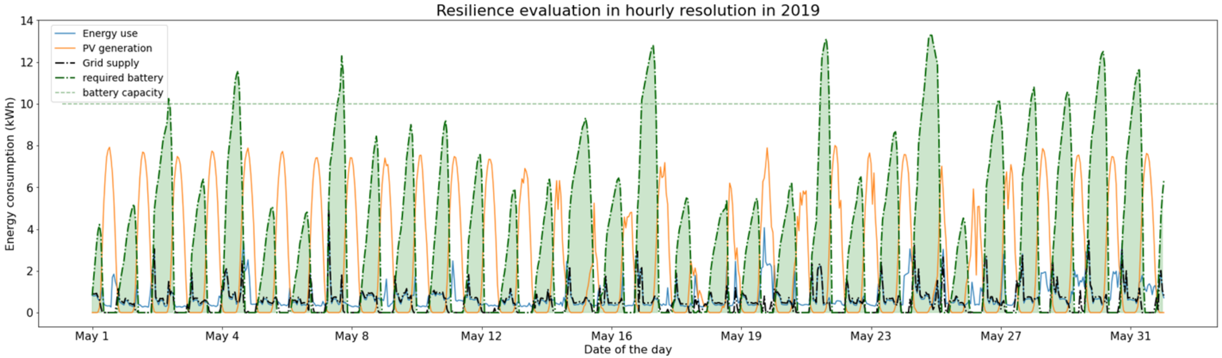


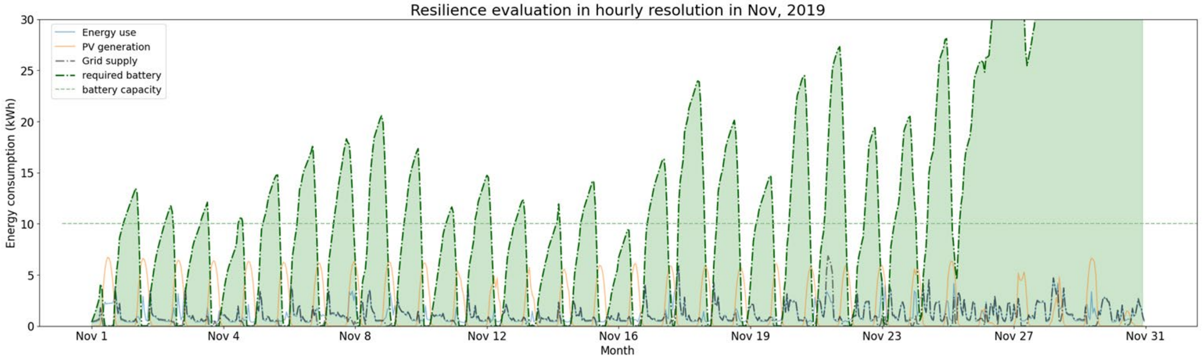


Currently the grid supply is used, and the longest time HSH is grid-independent is 10 hours in May, and 5 hours in December.

Battery utilization & resilience

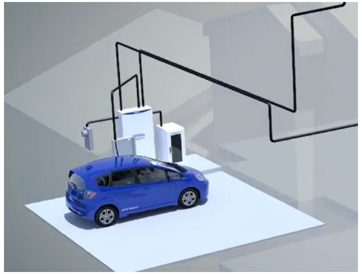


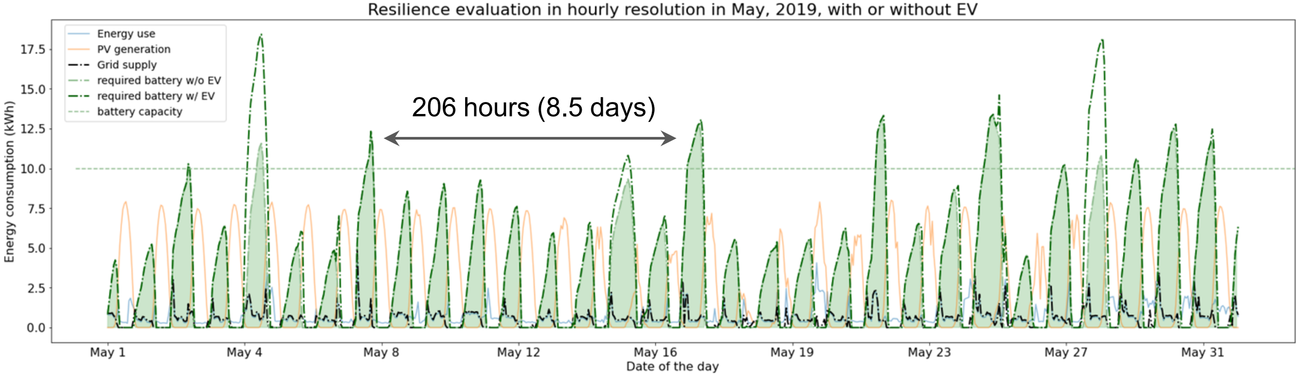


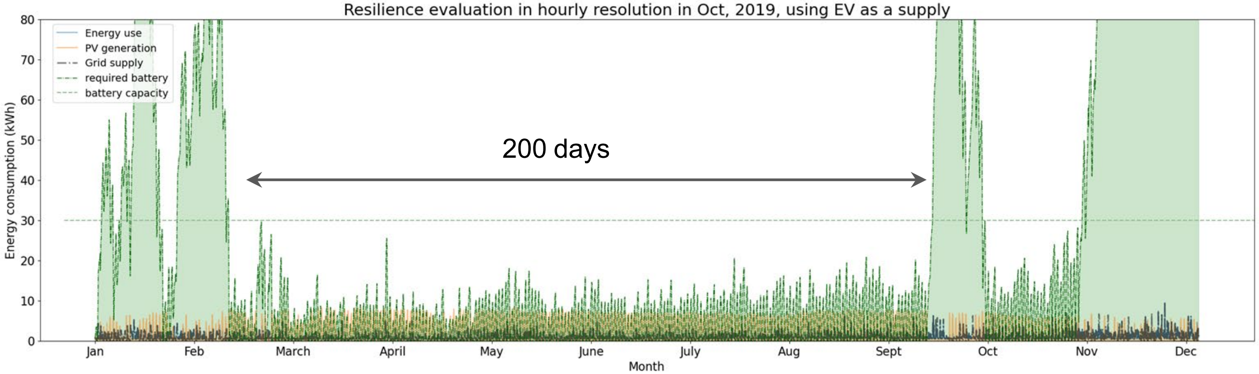


However, if we were to fully utilize battery, the grid-independency can be as long as 206 hours (8.6 days) in May. We still need grid in fall and winter months (from Oct. to April) where the solar radiation is insufficient. Fully utilize battery can have great potential on grid independency, especially in summer months.

Electric vehicle & resilience







Taking May 2019 as an example, using EV can reduce resilience from 8.6 days to 6.8 days*, not a significant percentage because the EV usage is not intense. However, the bi-directional EV with 20kWh capacity has positive potential in extreme weather condition, that if EV were fully utilized as a supply for the house, it can extend the grid-independency from 8.6 days to almost 200 days*.

* Consuming at the beginning the EV and/or battery are fully charged.

Summary

ZNE and Electric vehicle

- Consistently achieving ZNE on an annual basis, but seasonal fluctuations present challenges. High ZNE performance during summer due to abundant solar radiation, but deficits in winter.
- Substantial resilience potential during grid disruptions thanks to available battery and bi-directional EV.
- EV's prevalence in homes tend to have limited impact on ZNE performance.
- EVs can serve as emergency power storage in extreme conditions, aiding in grid independence when needed.

Resilience under Extreme Conditions

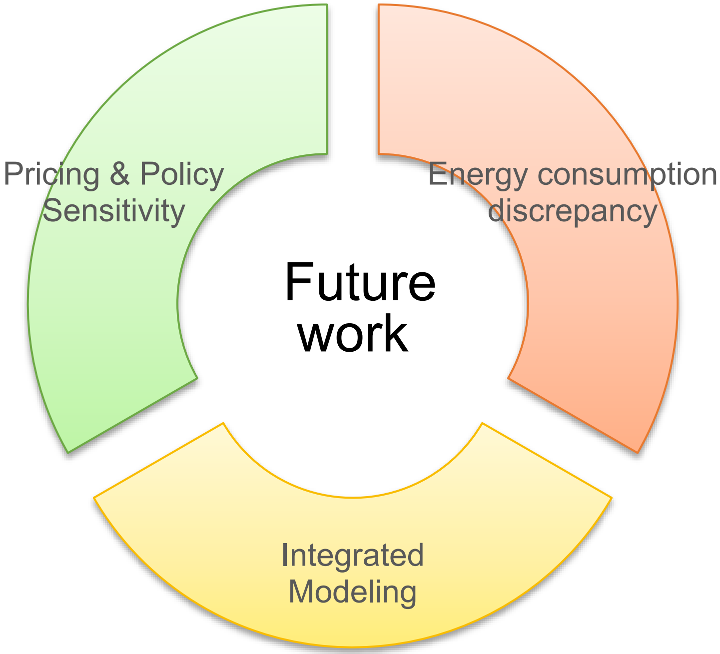
- Grid independence up to 206 hours (8.6 days) with just the battery (10 kW).
- Extends to 200 days with battery and bi-directional EV combined (30 kW).

Battery Lifespan and Environmental Implications

- V2G for Grid Balance: Parked EVs could act as buffers for the electrical grid
- Careful management and advancements in battery technology

- Examine responses to dynamic grid pricing and net metering.
- Explore ideal PV and battery sizes for economic efficiency.

- Including occupant behavior and climate impact on ZNE design strategies
- Merge building demand, on-site energy generation, and advanced control systems.



- Investigate the disparity between energy consumption and generation at daily and yearly resolutions.
- Develop strategies for optimizing end-use and distributed energy resources (DERs) to achieve maximum energy flexibility and resilience.
- Enhance demand-response effectiveness.

Questions

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