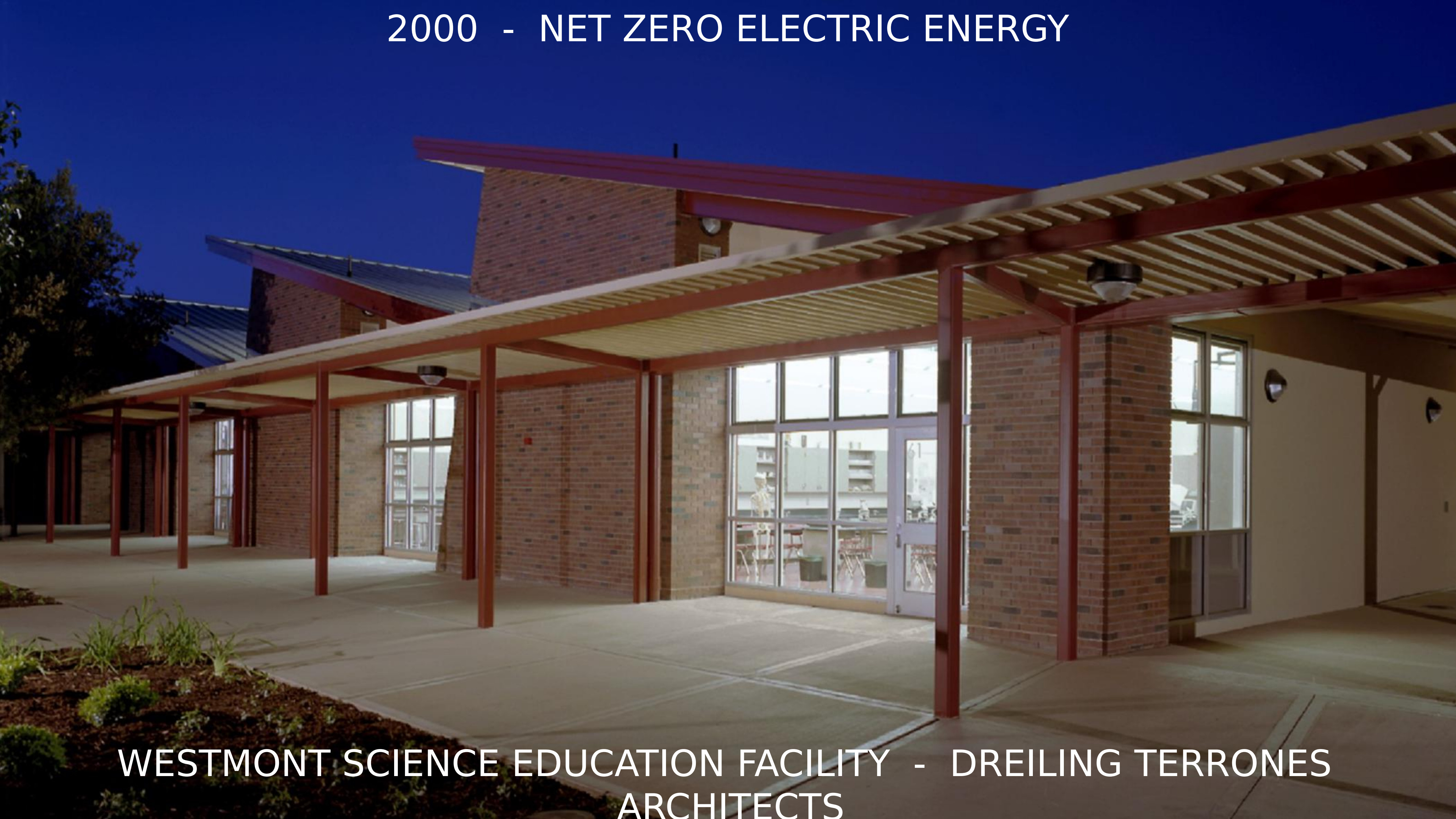
The Electrification (r)Evolution
Emerging issues in electrical engineering

Redwood Energy Zero Carbon Retreat

September 19, 2023

IDeAs Consulting

2000 - NET ZERO ELECTRIC ENERGY



WESTMONT SCIENCE EDUCATION FACILITY - DREILING TERRONES ARCHITECTS

2002 - LEED PLATINUM + BIPV

TAHOE CENTER FOR ENVIRONMENTAL SCIENCES - COLLABORATIVE DESIGN STUDIO

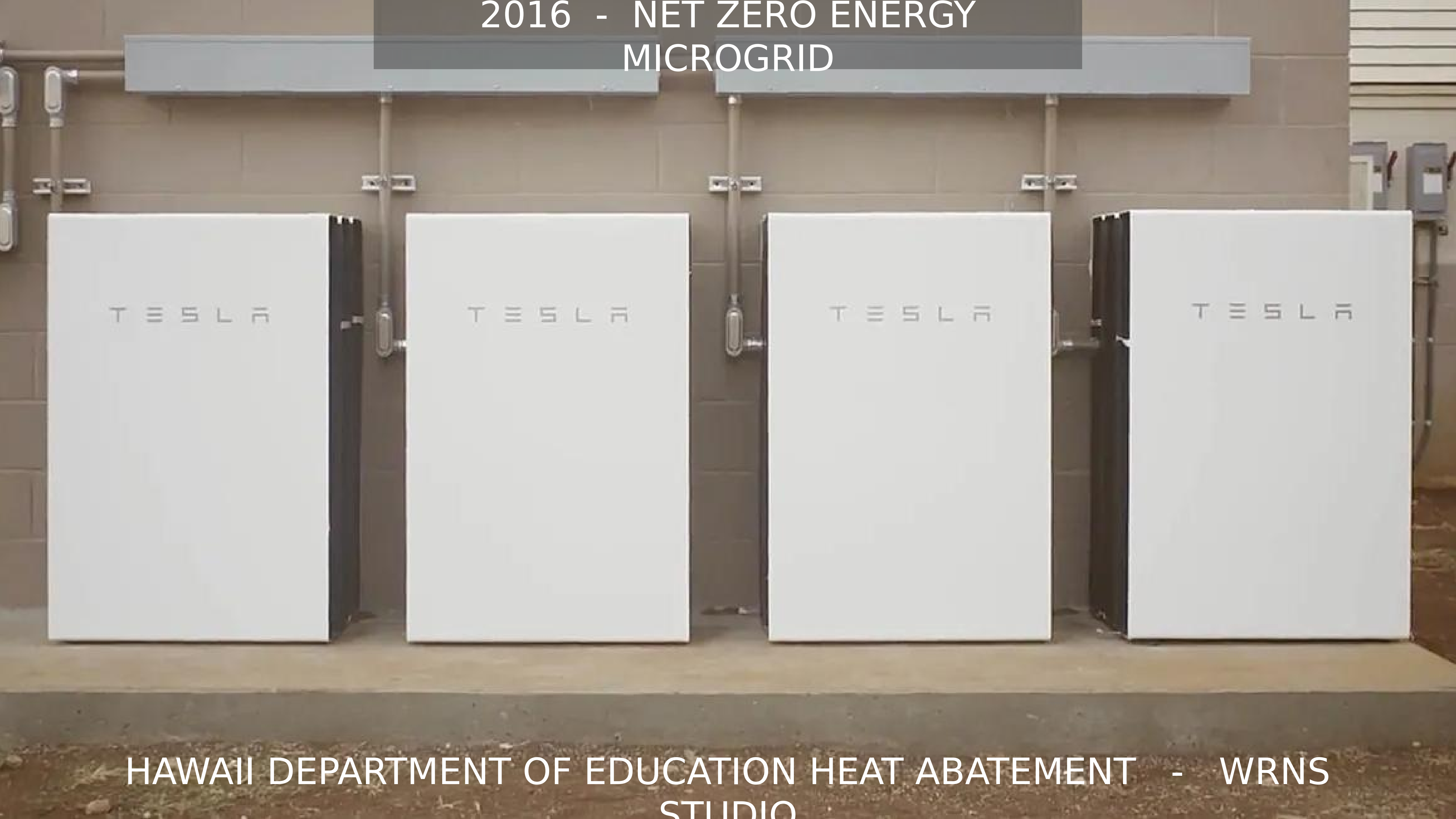
2005 - NET ZERO ENERGY

IDEAS NZE HEADQUARTERS - EHDD ARCHITECTS

2012 - FOR PROFIT NET ZERO ENERGY

415 INDIO BUILDING - RMW ARCHITECTS

2016 - NET ZERO ENERGY MICROGRID



HAWAII DEPARTMENT OF EDUCATION HEAT ABATEMENT - WRNS STUDIO

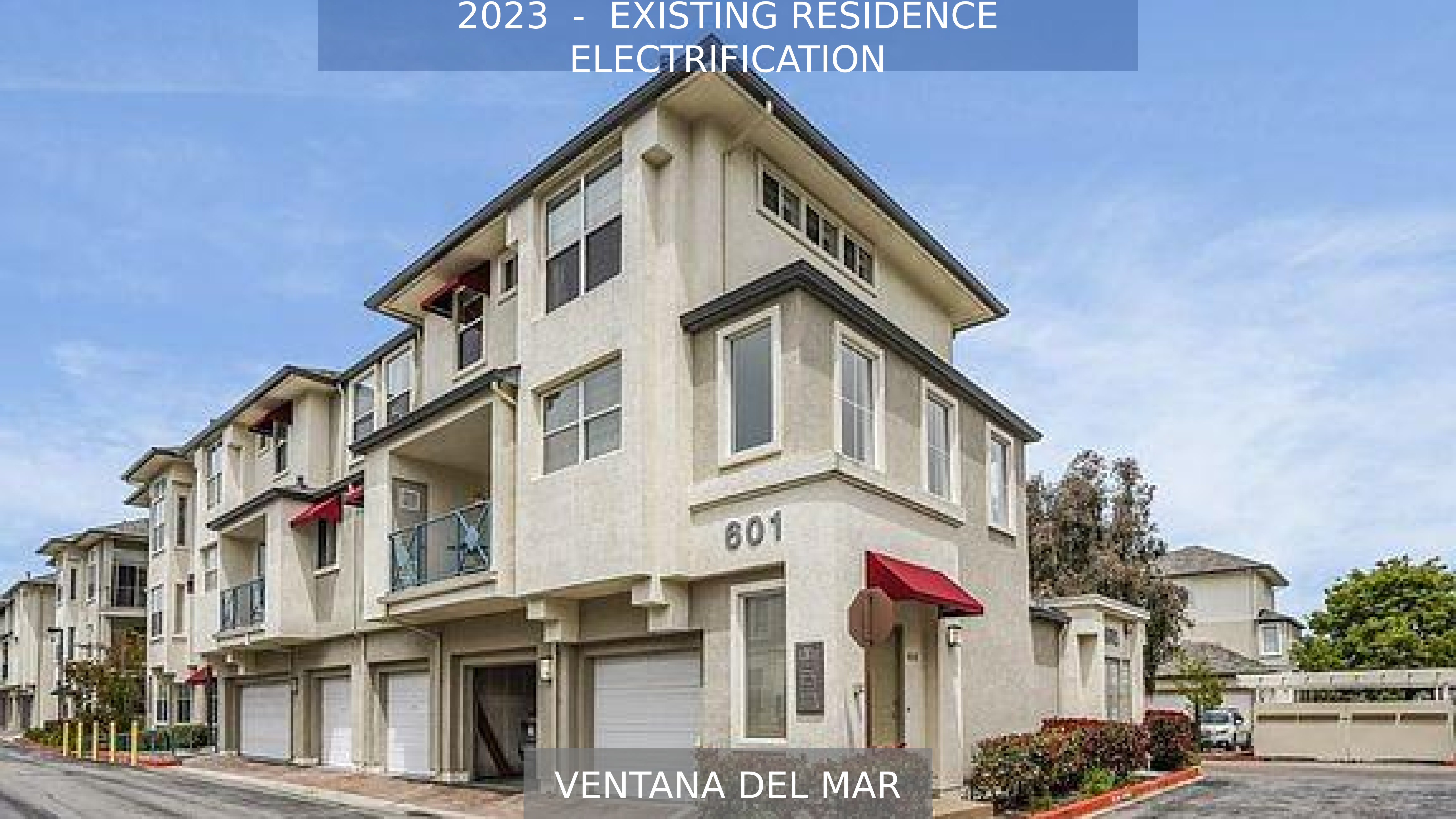
2020 - ALL ELECTRIC COMMERCIAL KITCHEN

GOOGLE BAY VIEW - BIG + HEATHERWICK

2022 - V2G SCHOOL BUS ELECTRIFICATION

TWIN RIVERS UNIFIED SCHOOL DISTRICT - BUS DEPOT

2023 - EXISTING RESIDENCE ELECTRIFICATION

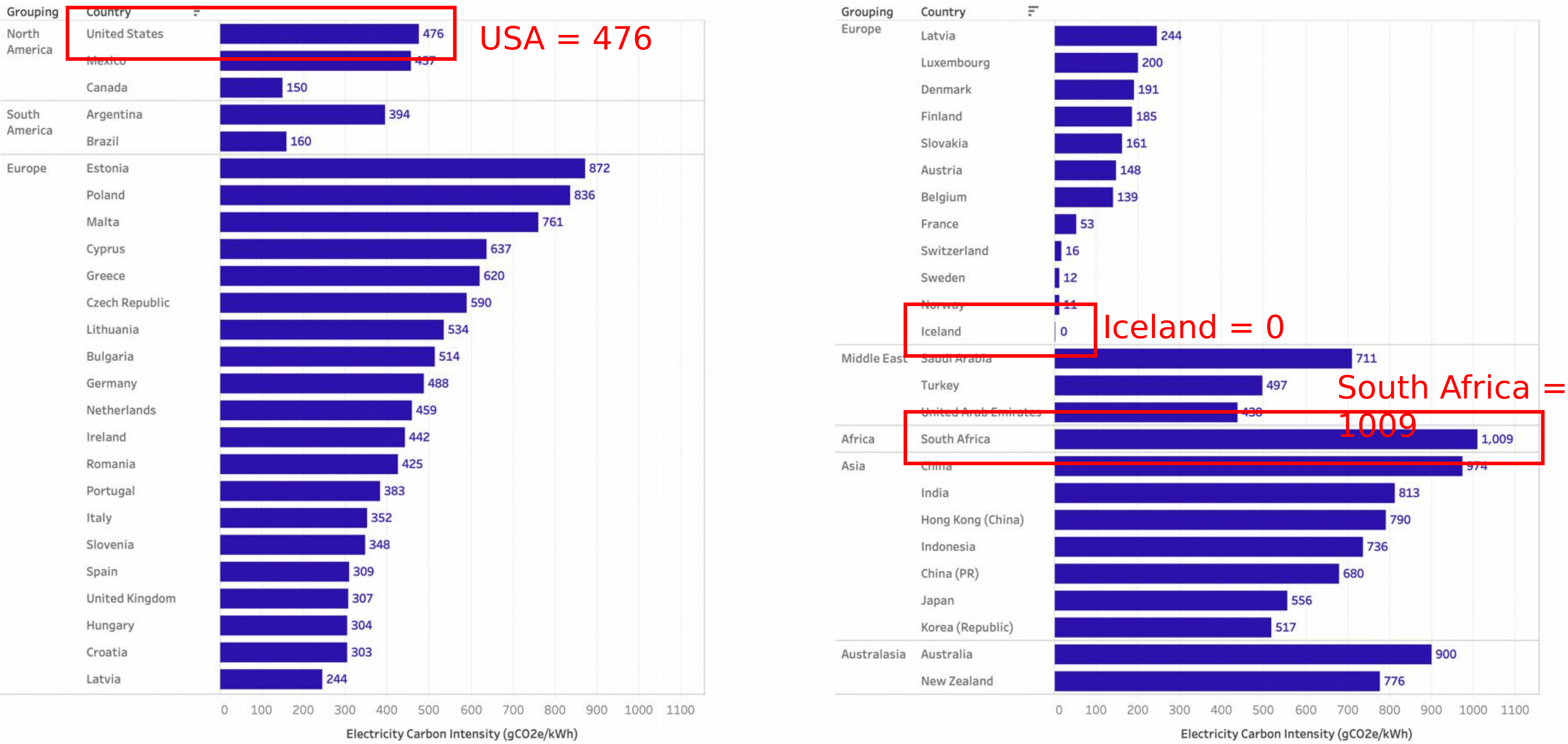


VENTANA DEL MAR

2023 - CLIMATE CHANGE HAS BECOME A DESIGN ISSUE

KEY FACTS: GRID CARBON INTENSITY - WORLD

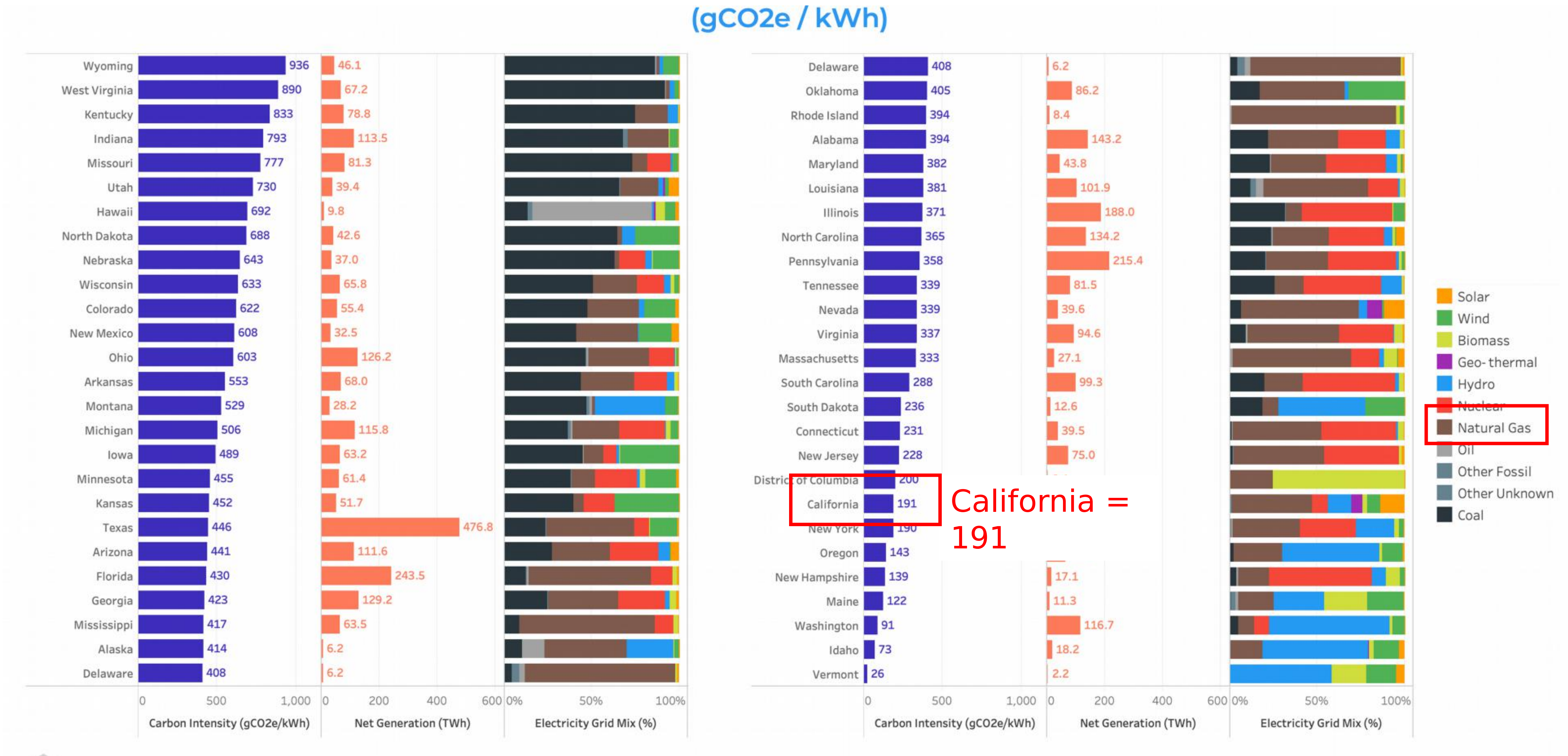
(gCO2e / kWh)



PRIOPTA

(Data Source: IGES Grid Emission Factors v10.7 - 2019, Visualization by Priopta)

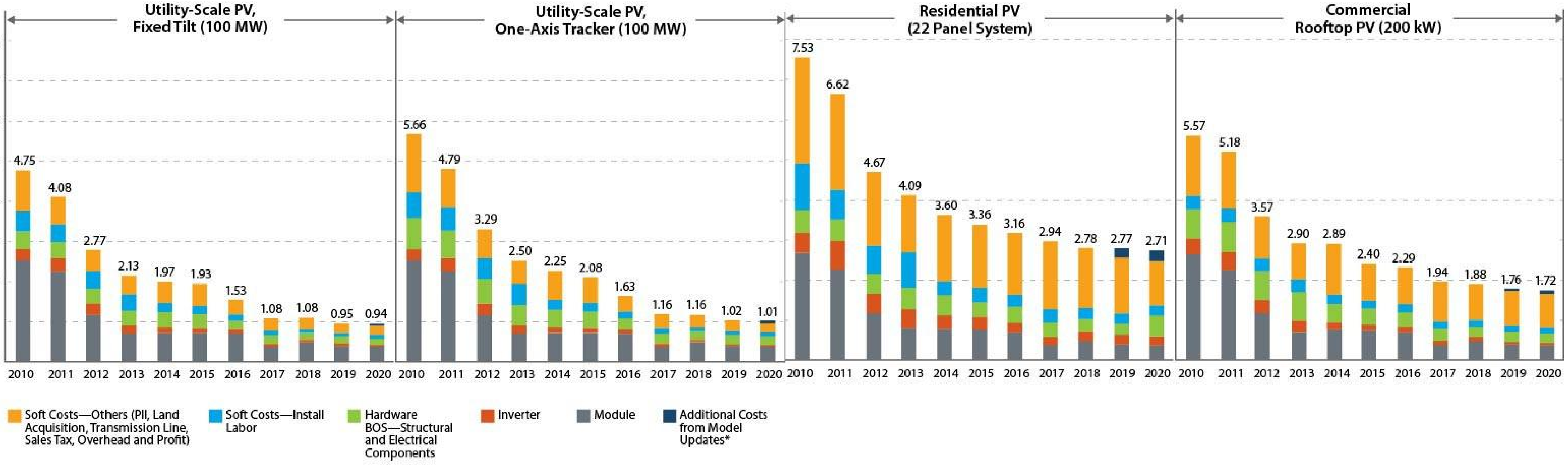
KEY FACTS: GRID CARBON INTENSITY - USA



(Data Source: EPA eGrid 2018, Visualization by Priopta)

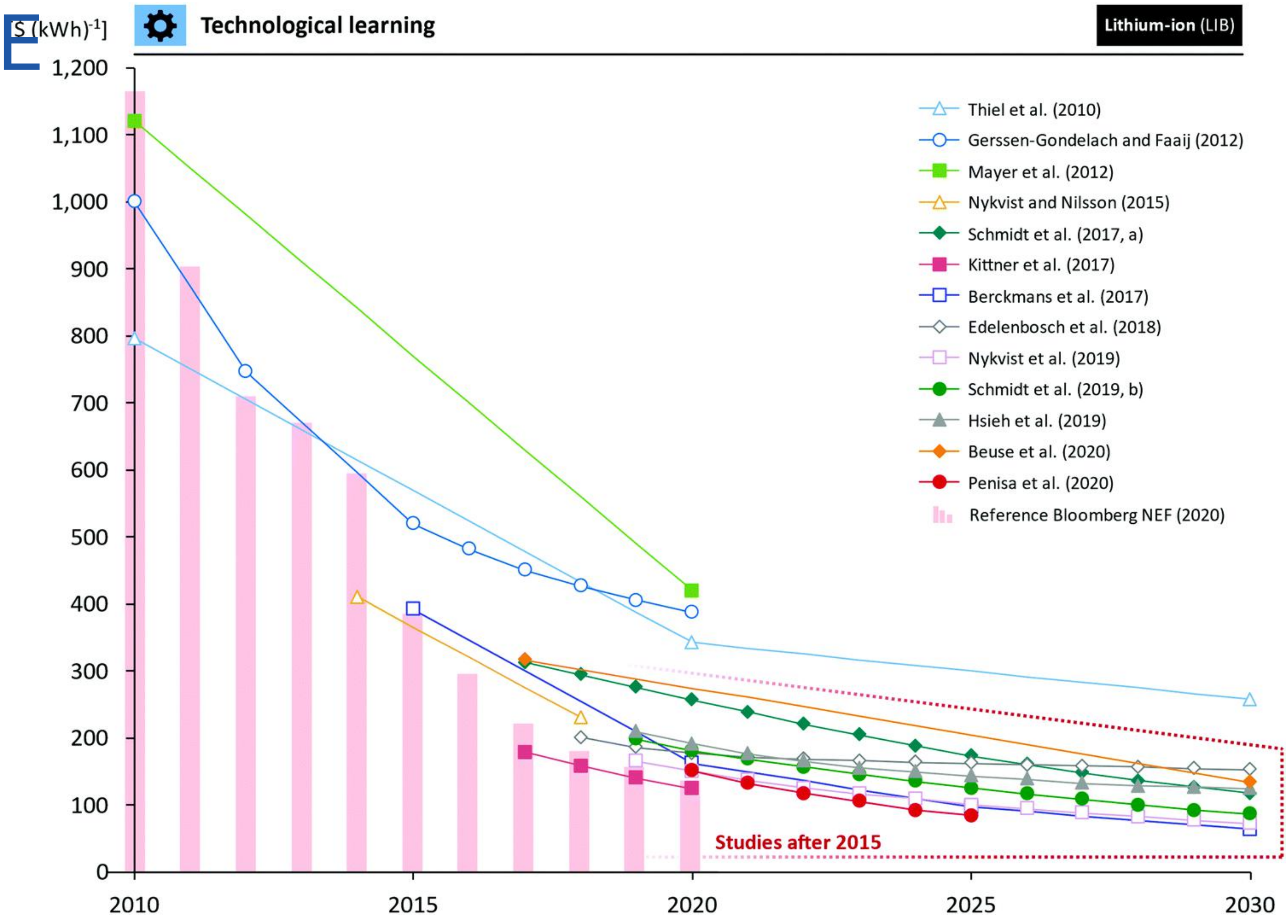
KEY FACTS: COST OF PHOTOVOLTAIC SYSTEMS

- The cost of photovoltaic systems continues to fall.
- Utility scale PV is now less than $1/watt (installed).
- Module cost fell to just over $0.20 a watt in Q3 2019.



Source: NREL

KEY FACTS: PREDICTED COST OF BATTERY STORAGE



Source: Energy and Environmental Science 2021

KEY FACTS: GRID CARBON INTENSITY - CALIFORNIA

California is rapidly moving toward all electric buildings with photovoltaics and batteries.

What are the future impacts?

SECTION 140.10 – PRESCRIPTIVE REQUIREMENTS FOR PHOTOVOLTAIC AND BATTERY STORAGE SYSTEMS

(a) **Photovoltaic requirements.** All newly constructed building types specified in Table 140.10-A, or mixed occupancy buildings where one or more of these building types constitute at least 80 percent of the floor area of the building, shall have a newly installed photovoltaic (PV) system meeting the minimum qualification requirements of Reference Joint Appendix JA11. The PV size in kW_{dc} shall be not less than the smaller of the PV system size determined by Equation 140.10-A, or the total of all available Solar Access Roof Areas (SARA) multiplied by 14 W/ft^2.

(b) **Battery storage system requirements.** All buildings that are required by Section 140.10(a) to have a PV system shall also have a battery storage system meeting the minimum qualification requirements of Reference Joint Appendix JA12. The rated energy capacity and the rated power capacity shall be not less than the values determined by Equation 140.10-B and Equation 140.10-C. Where the building includes more than one of the space types listed in Table 140.10-B, the total battery system capacity for the building shall be determined by applying Equations 140.10-B and 140.10-C to each of the listed space types and summing the capacities determined for each space type and equation.

CALIFORNIA MARGINAL CARBON EMISSIONS

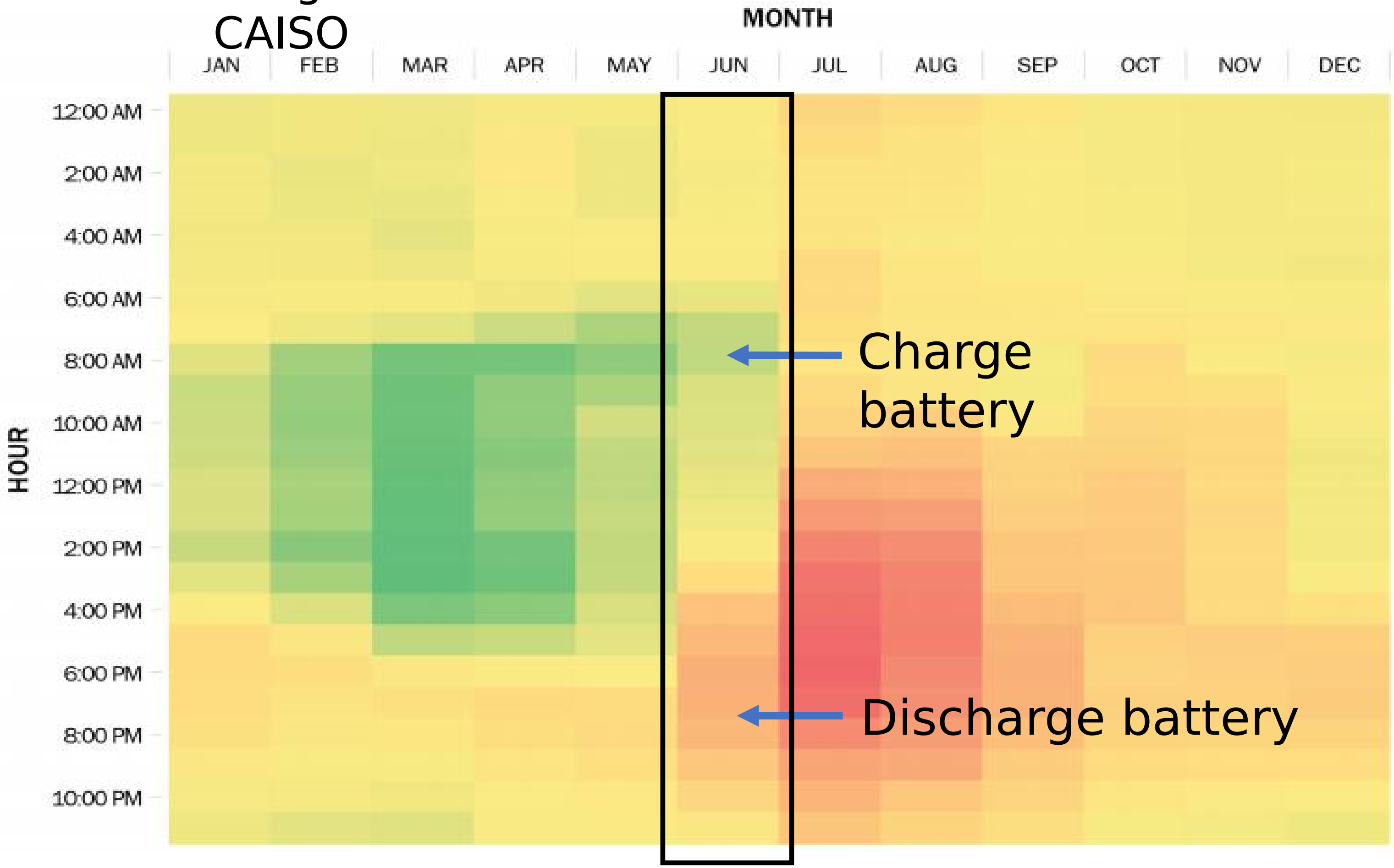
Batteries can be optimized for actual real time **marginal** carbon emissions.

Daily:

Charge battery during period of low carbon emissions: **green**

Discharge during periods of high carbon emissions: **red**

Marginal Greenhouse Gas Emissions Profile for CAISO

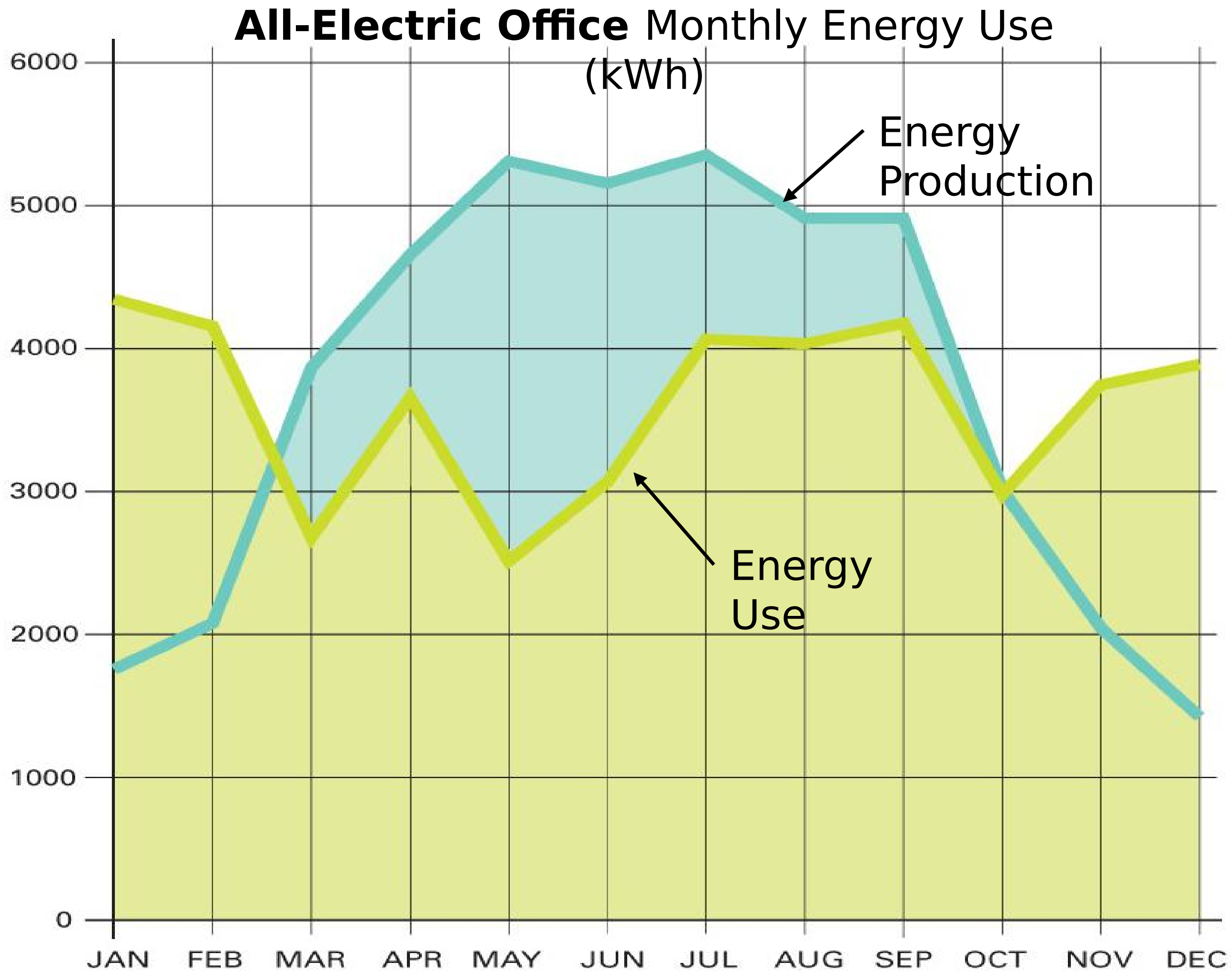


Source: WattTime: relative CO2lbs/kWh electricity Kristen DiStefano, Atelier Ten, Henry Richardson, July 2019

SEASONAL PRODUCTION VS. GRID DEMAND

Off-grid project in Pescadero

Will “electrification” and conversion to heat pump heating and heat pump water heating shift peak electrical demand from summer **toward winter?**



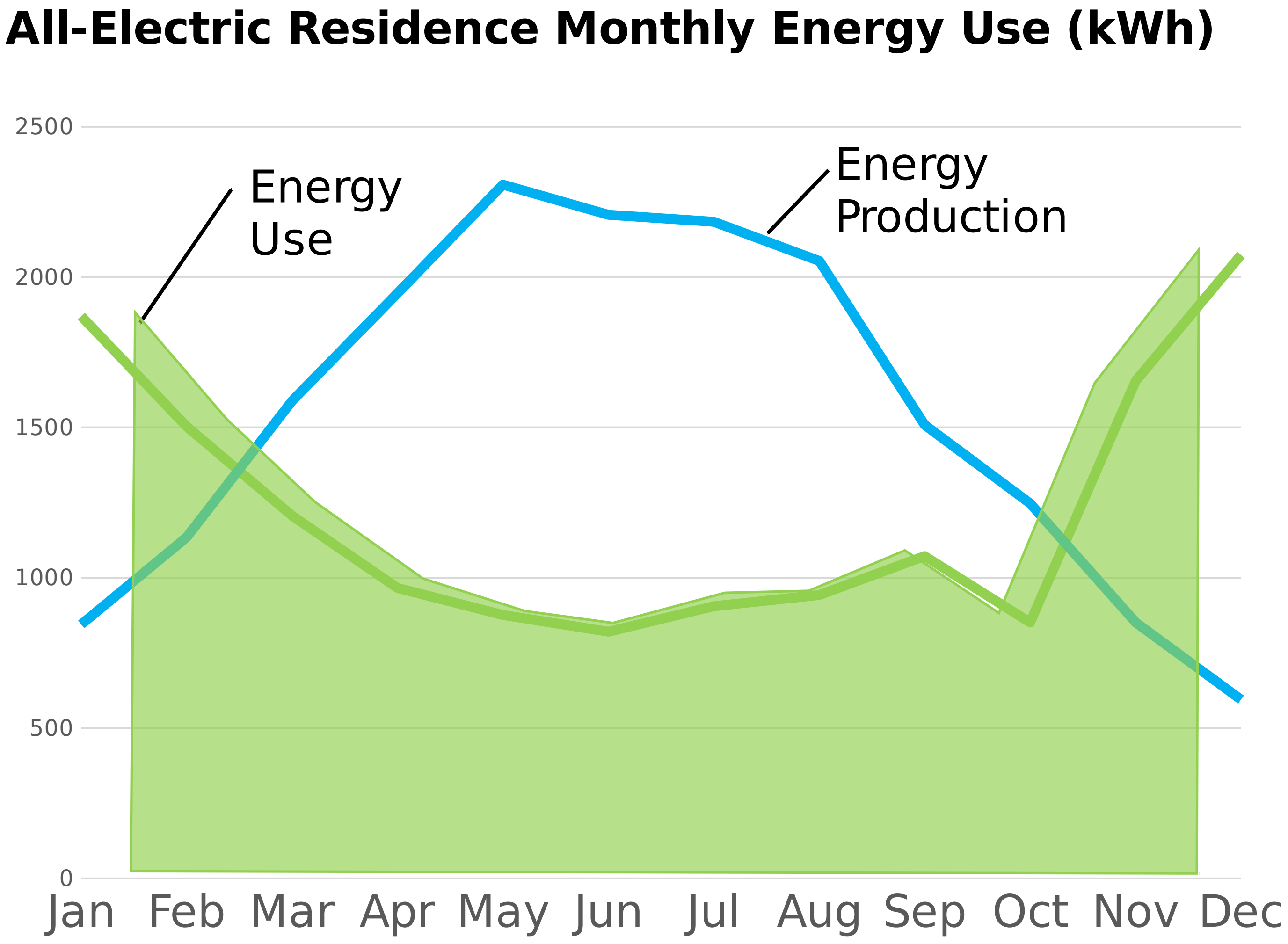
SEASONAL PRODUCTION VS. GRID DEMAND

Off-grid project in Pescadero

Will “electrification” and conversion to heat pump heating and heat pump water heating shift peak electrical demand from summer **toward winter?**

Is it possible that electric energy use will start to ***peak in winter*** *as more buildings electrify?*

If we are trying to generate 100% of energy from renewable sources, will need to **generate more energy in winter** than in summer?

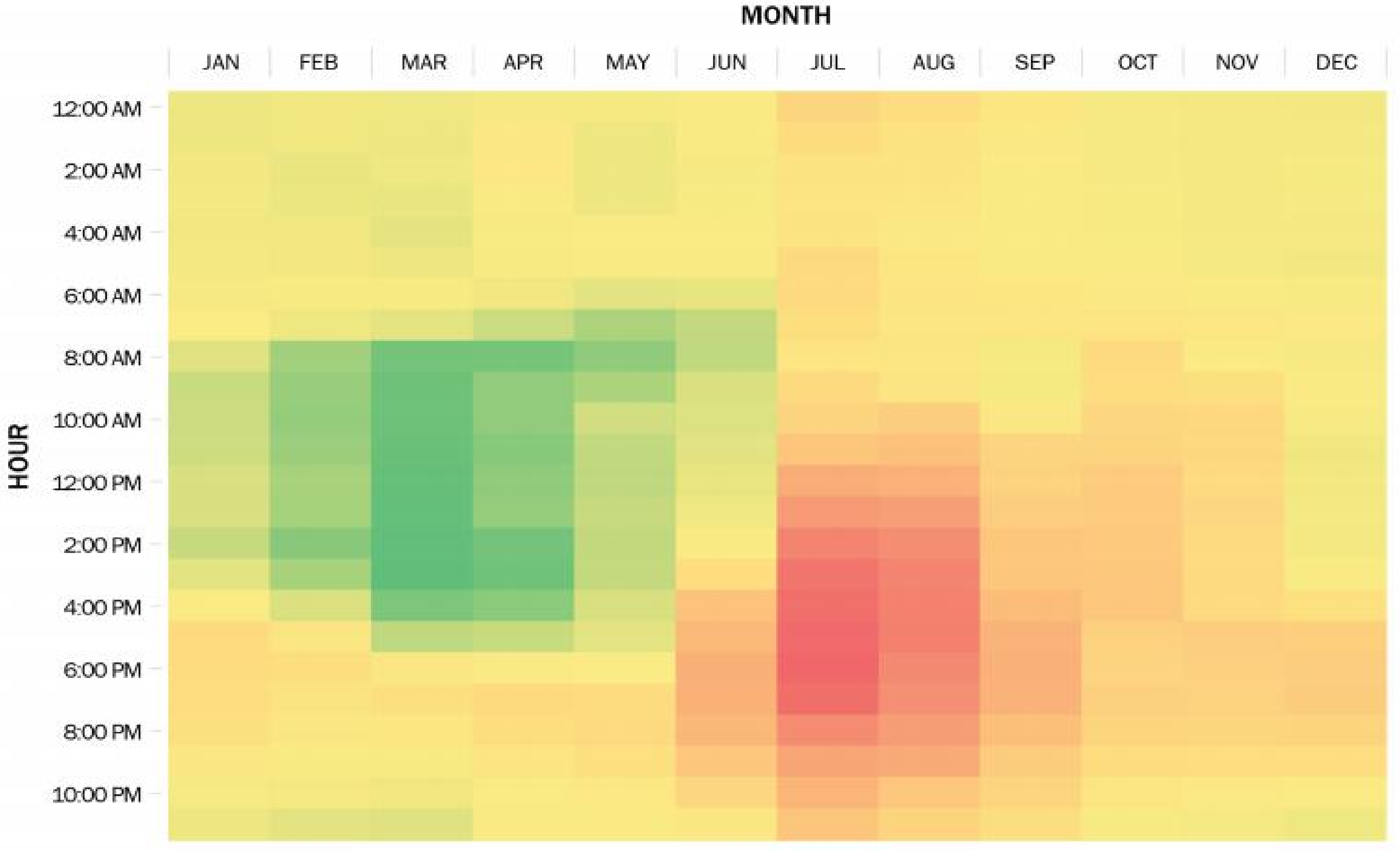


SEASONAL PRODUCTION VS. GRID DEMAND

As gas heating is replaced by electric heat pumps what will be the implication on the grid?

More electrical use in winter at night for heating.

Future Marginal Greenhouse Gas Emissions Profile



SEASONAL PRODUCTION

Depending on the tilt angle, monthly solar production changes due to seasonal changes in sun angles.

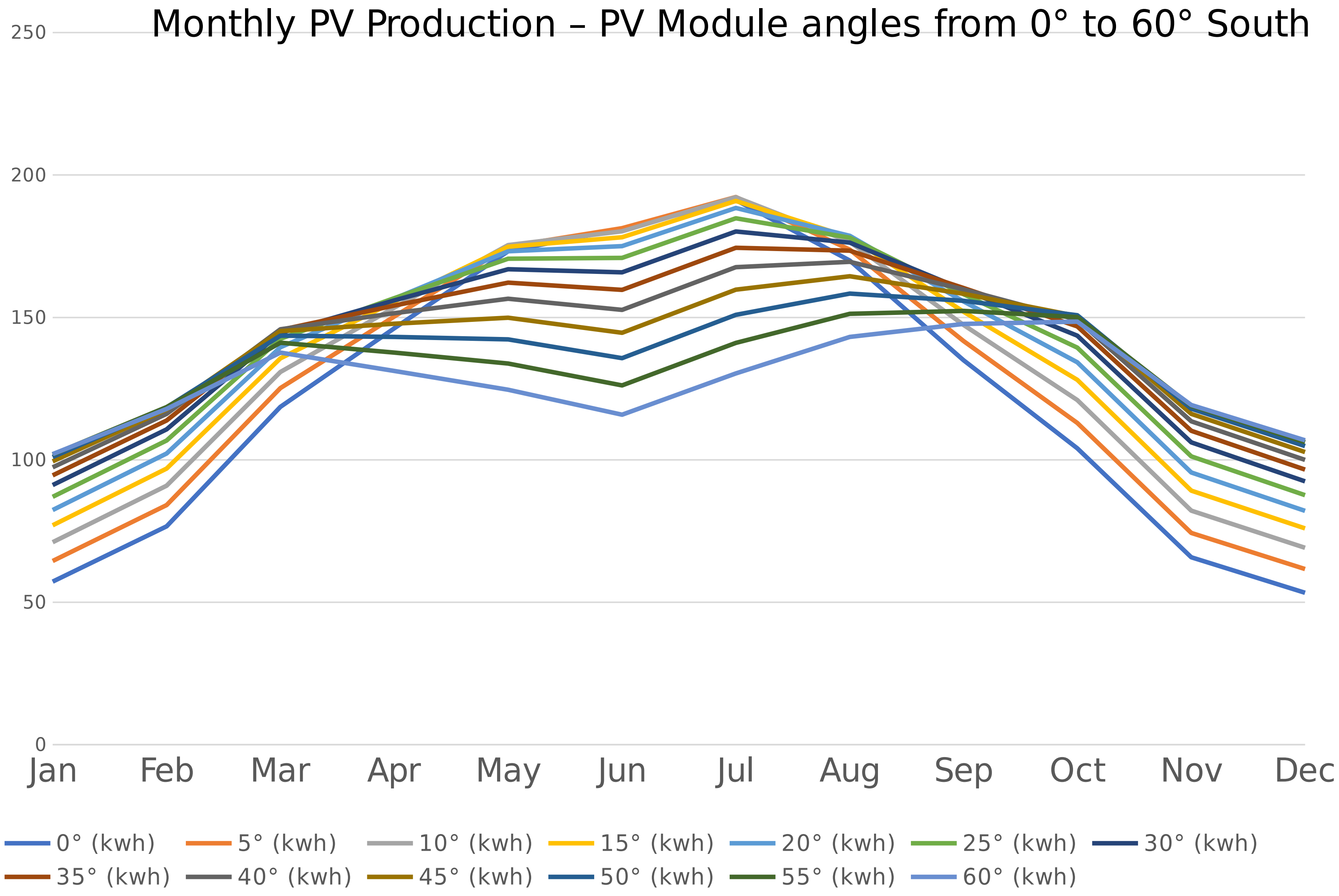
Cupertino, CA – Latitude 37.3° N
(latitude ~ tilt)

Best annual solar angel 31.4°

Best summer solar angle 13.7°

Best winter solar angle: 51.8°

https://www.solarpaneltilt.com/



SEASONAL PRODUCTION VS. GRID DEMAND

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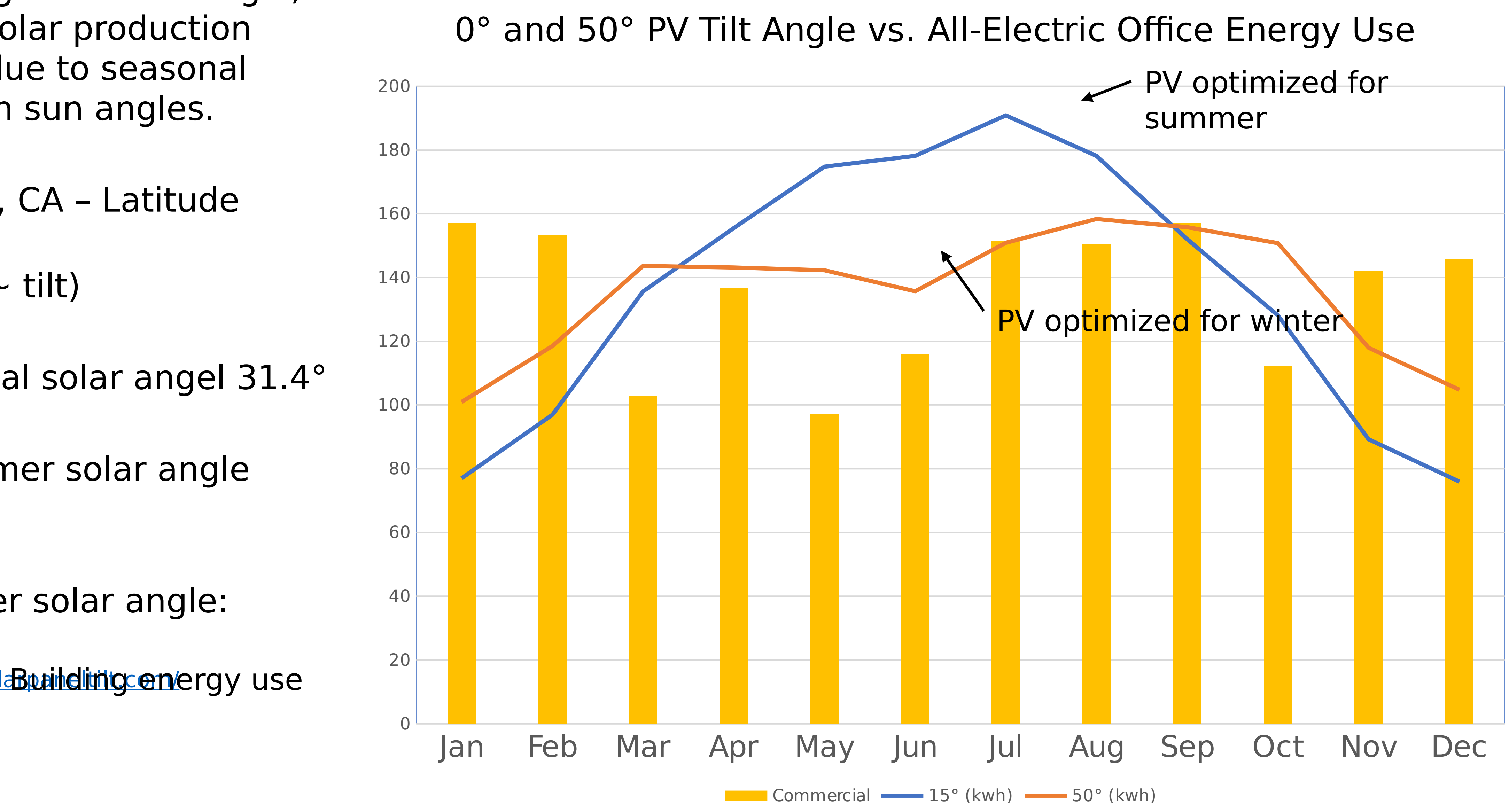


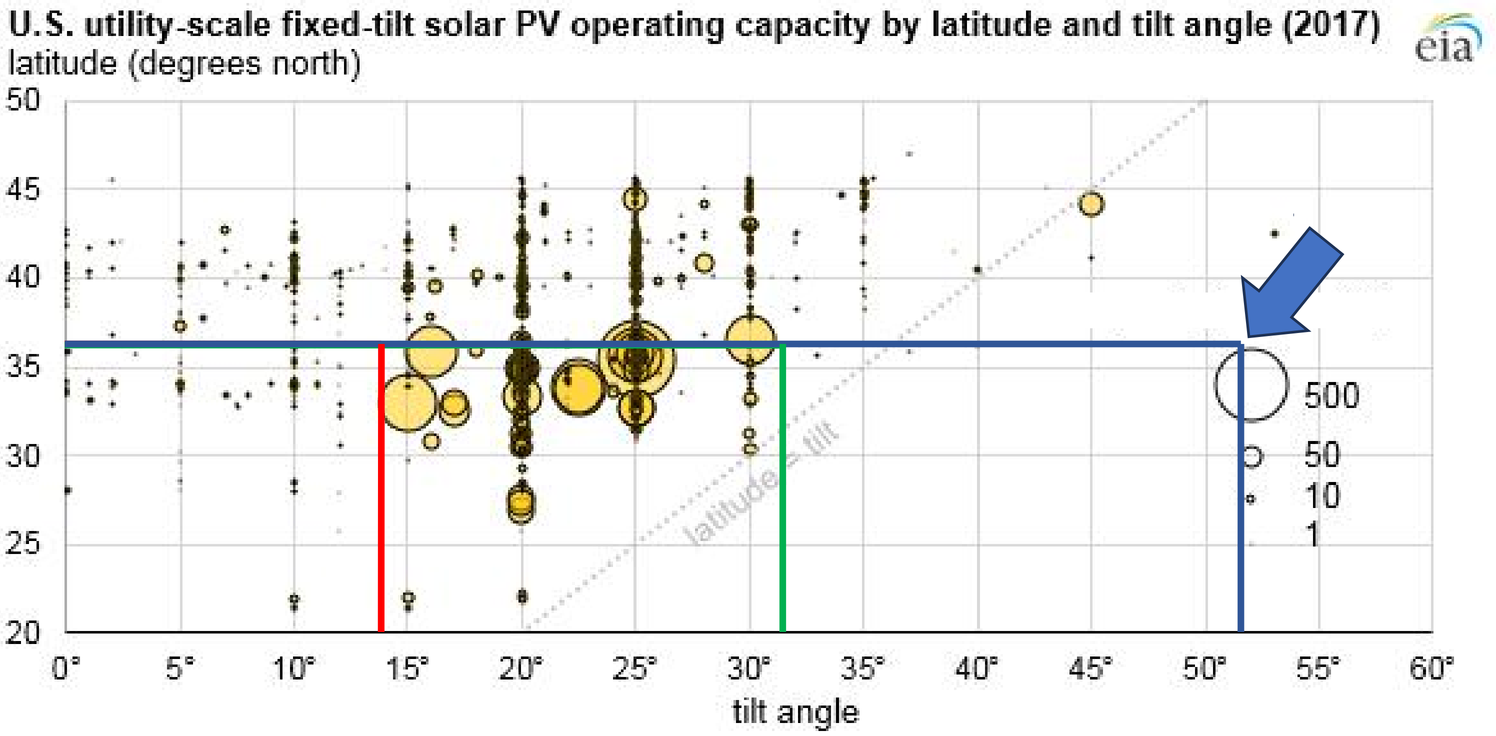
SEASONAL PRODUCTION VS. GRID DEMAND

If we are trying to generate 100% of our energy from renewable sources, we need to generate more energy in winter and less in summer.

PV optimize for summer

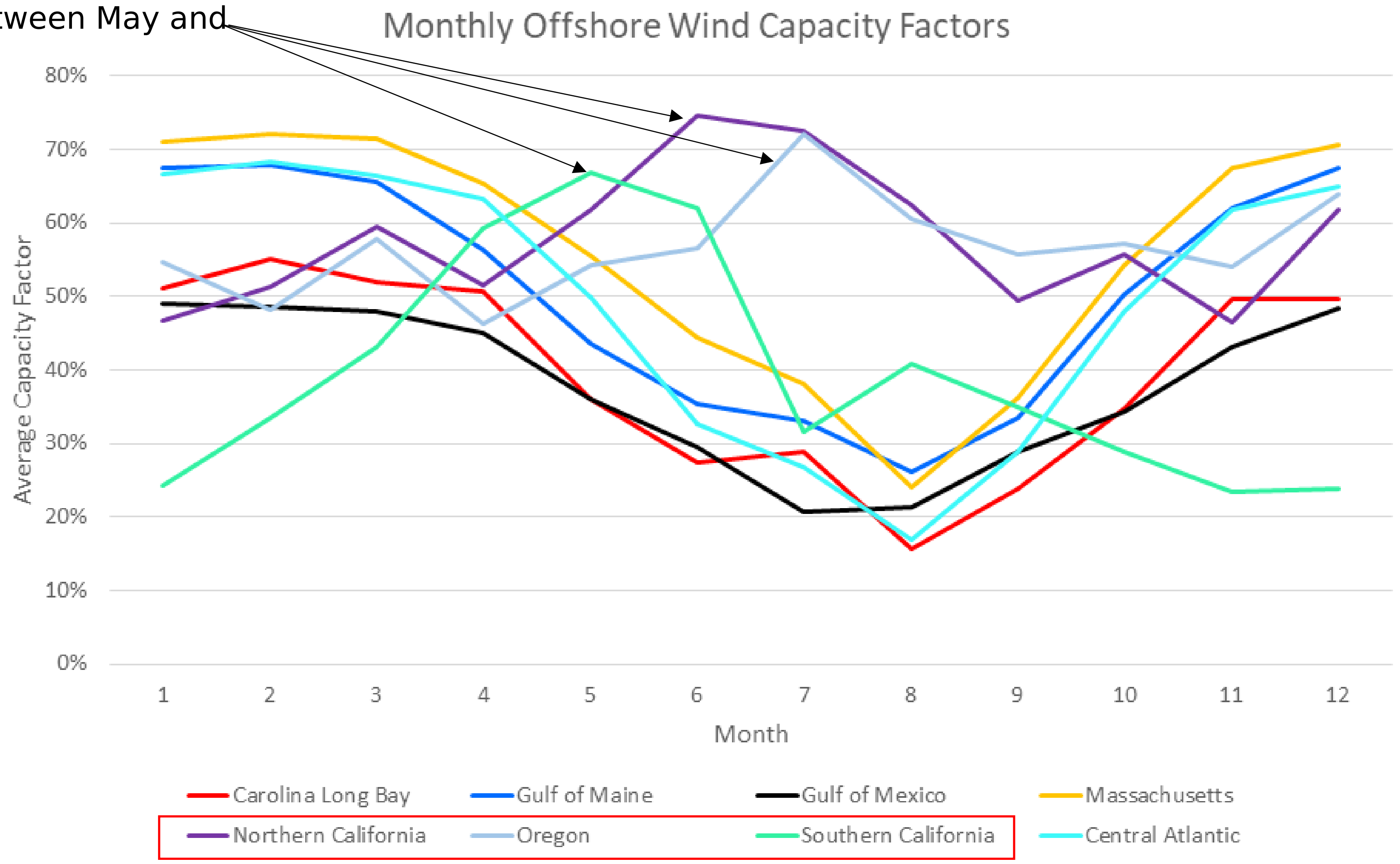
PV optimized for annual

PV optimized for winter



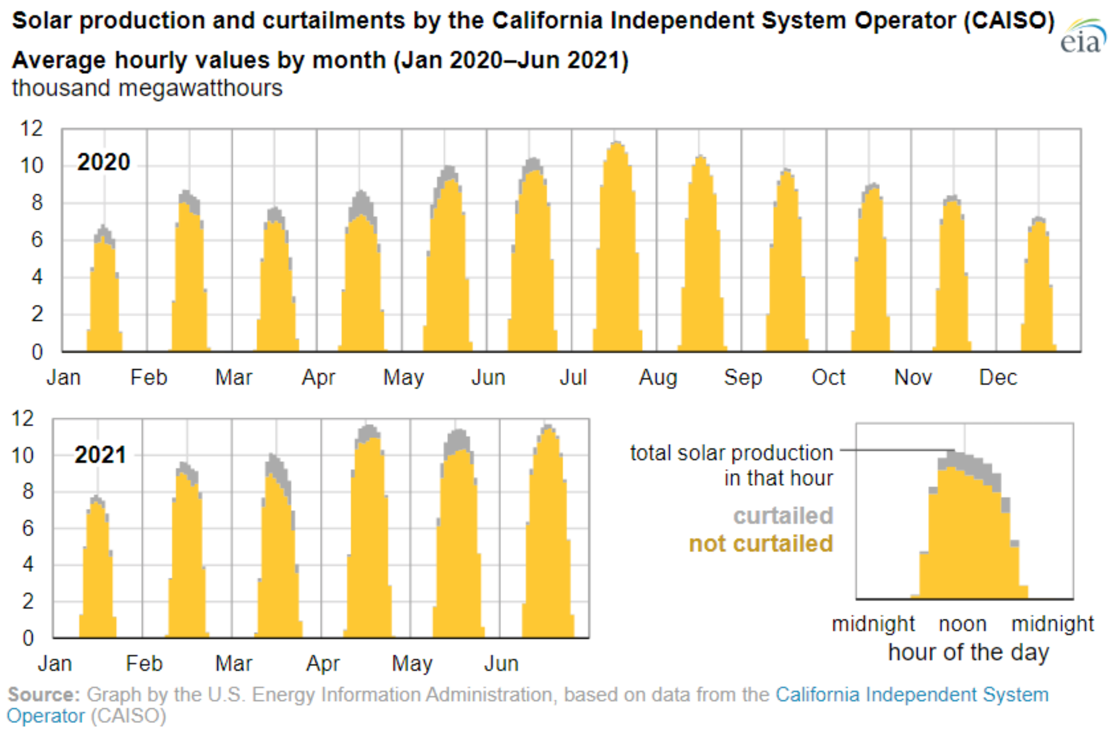
SEASONAL PRODUCTION VS. GRID DEMAND

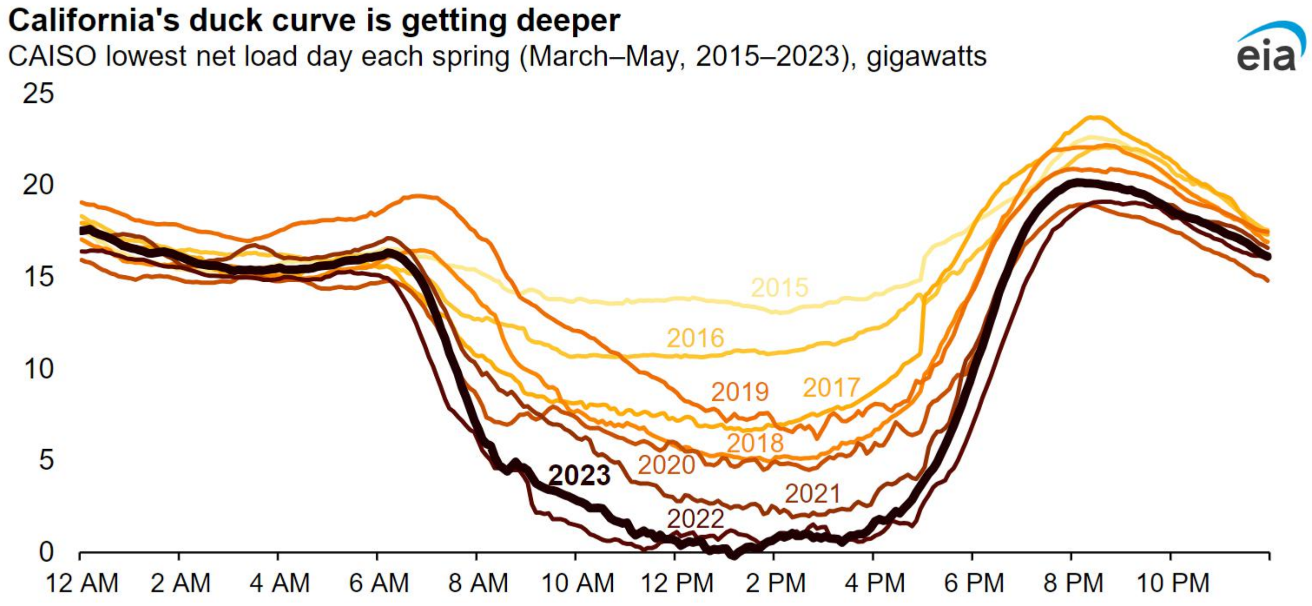
Peak wind on west coast occurs between May and July.



Note: Regional capacity factors are modeled using a Haliade-X 12 MW turbine.
Source: BTU Analytics – a FactSet Company, NREL (Data Updated May 11, 2023)

SEASONAL PRODUCTION VS. GRID DEMAND





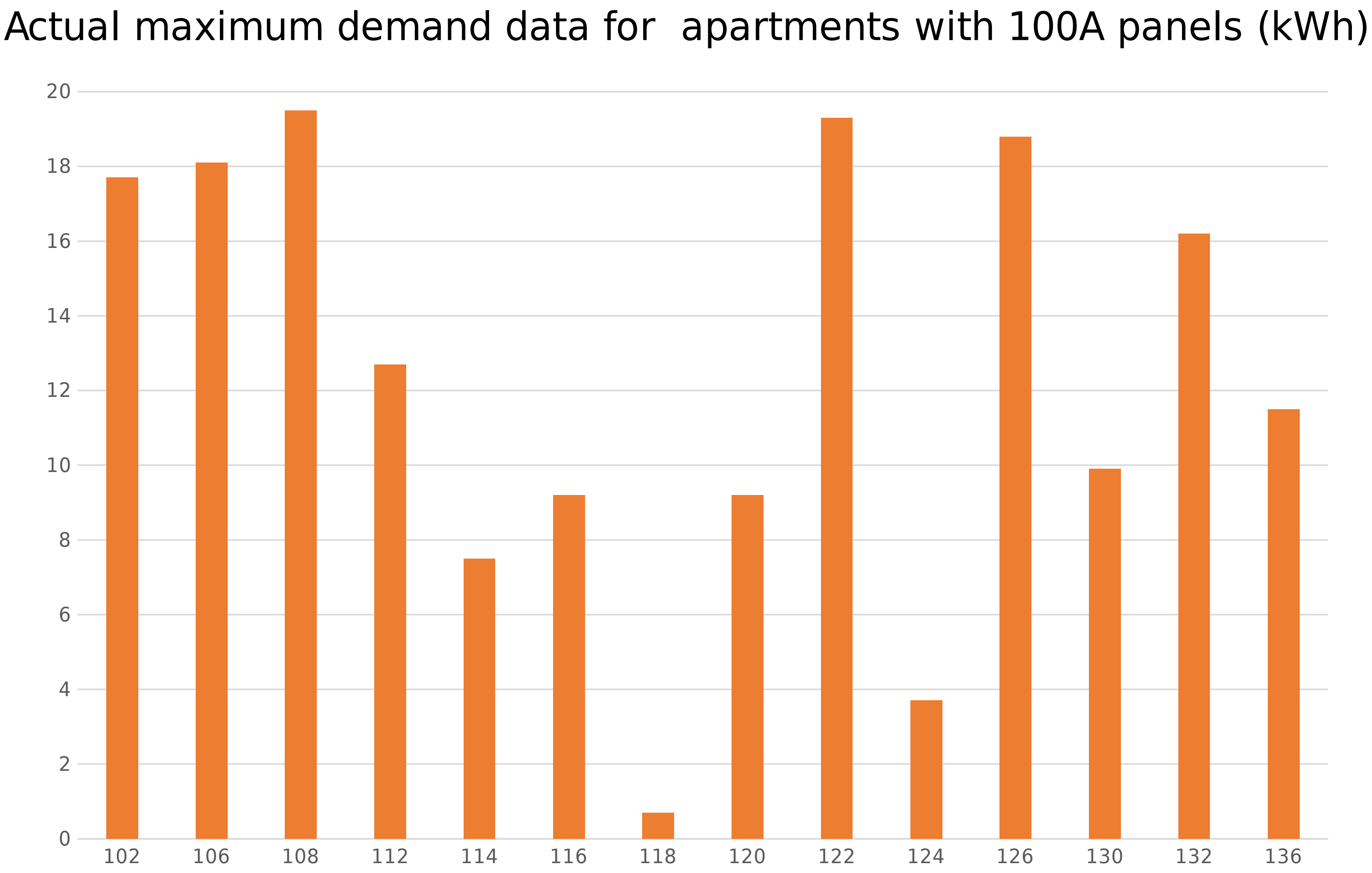
ELECTRIFYING EXISTING RESIDENCES

Maximum demand was 19.5 A for 100A, 240V, 1 phase services.

Panels loaded 20% maximum!

NEC 220.87 – allows additional 75.6 A of load to be added to the panel.

Low cost solution: add less than 75.6 A of new load.



ELECTRIFYING EXISTING RESIDENCES

If more than 75.6 A of new load: Use smart electrical panel and smart switch technology.

Smart electrical panels are programmed to automatically shut off circuits to limit total load if loads get too high.

Smart switches only allow one of two loads

Smart Electrical Panel

Smart Switch

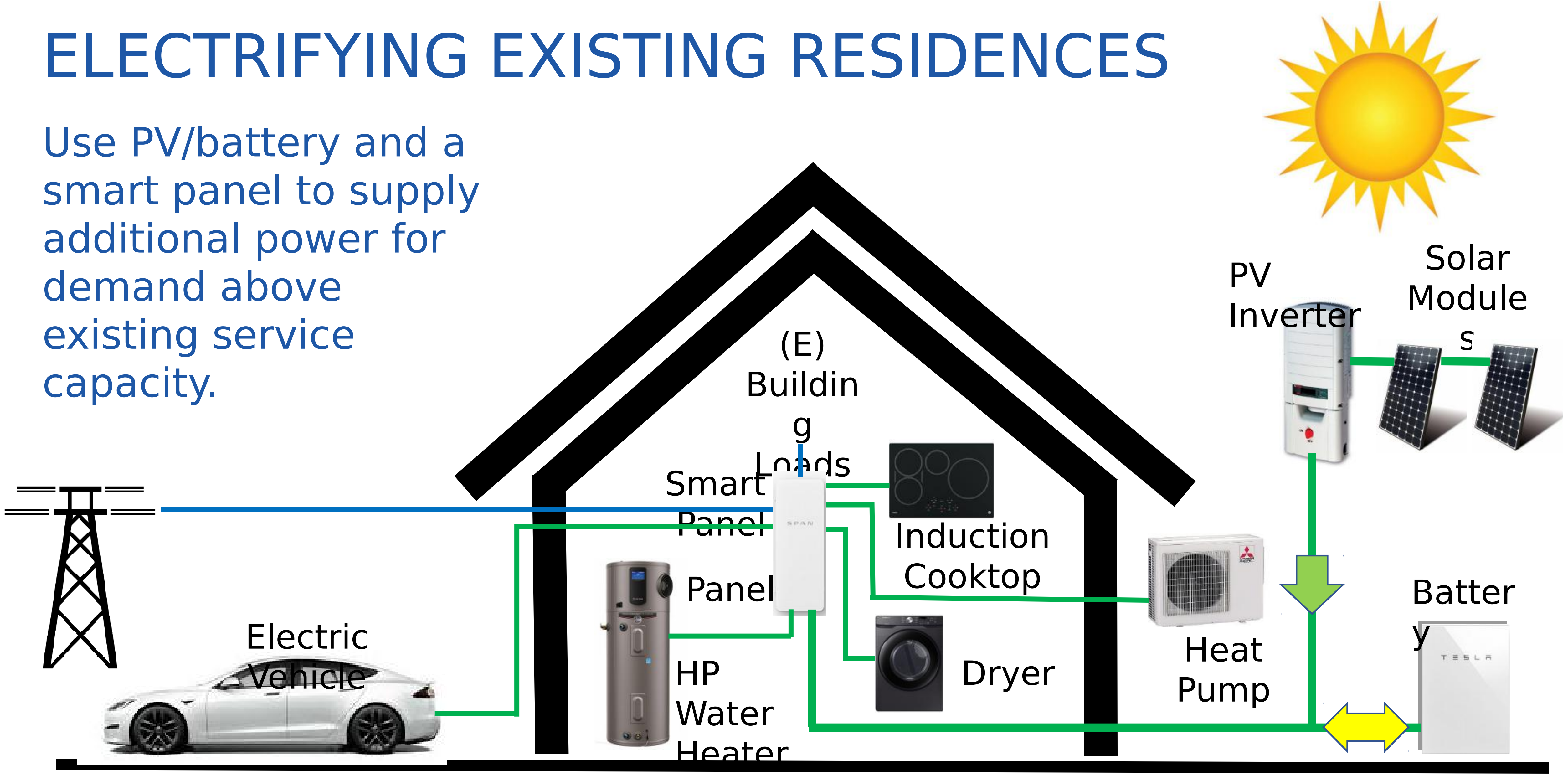
ELECTRIFYING EXISTING RESIDENCES

Smart panel plus battery can provide more power than incoming service.

The battery adds additional power if the load exceeds the service capacity.

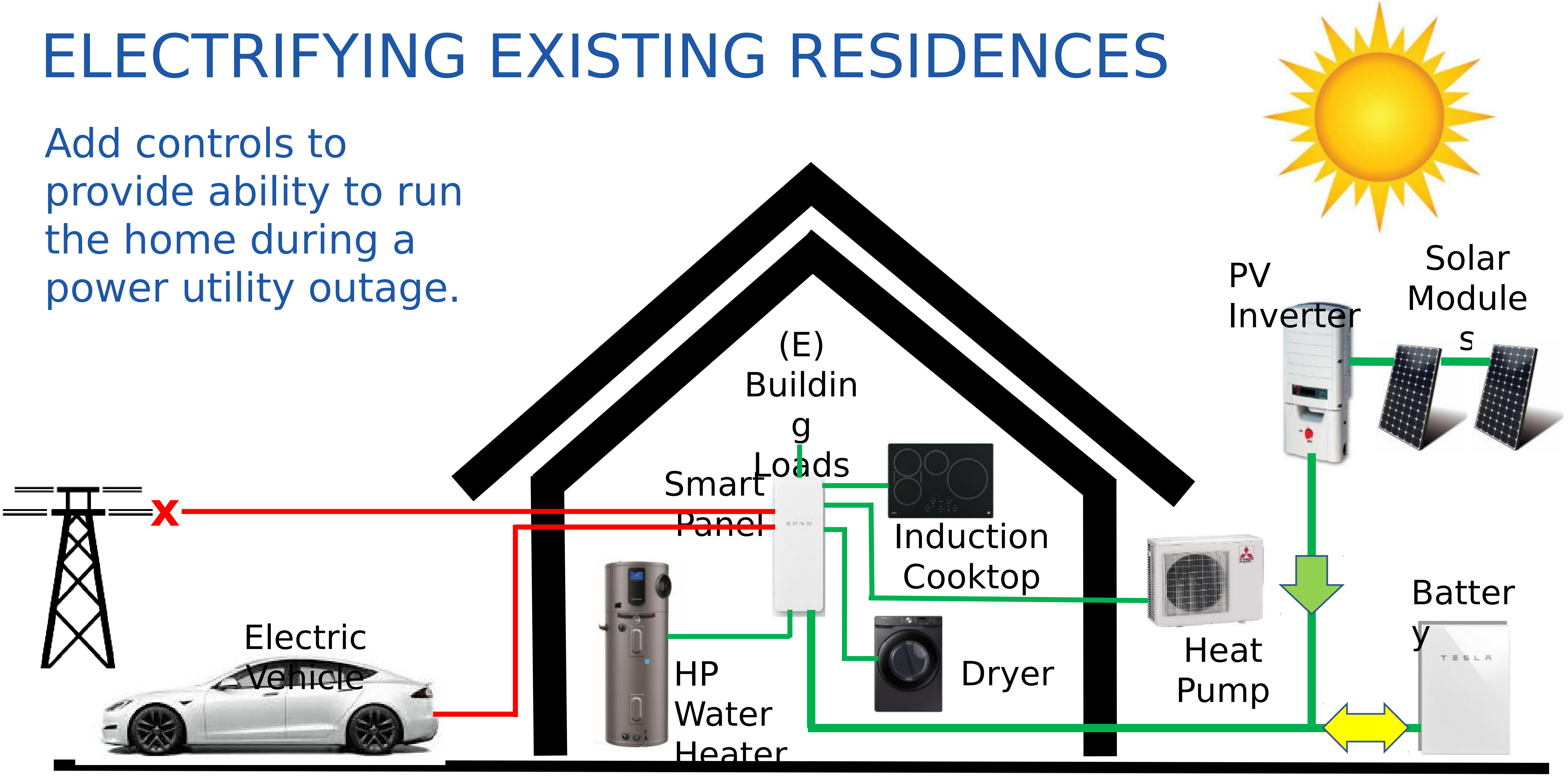
ELECTRIFYING EXISTING RESIDENCES

Use PV/battery and a smart panel to supply additional power for demand above existing service capacity.

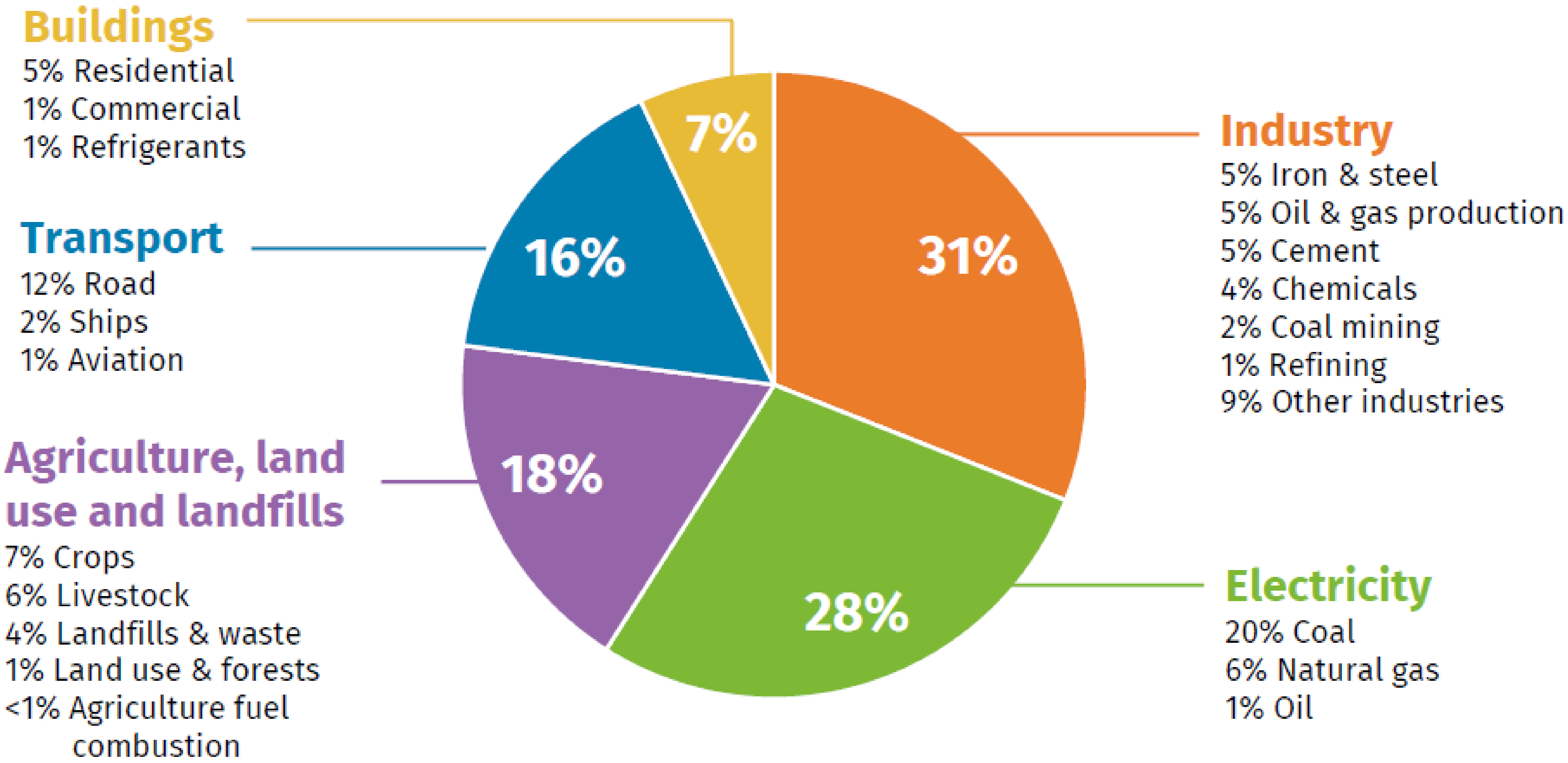


ELECTRIFYING EXISTING RESIDENCES

Add controls to provide ability to run the home during a power utility outage.



THE ELECTRIC VEHICLE REVOLUTION

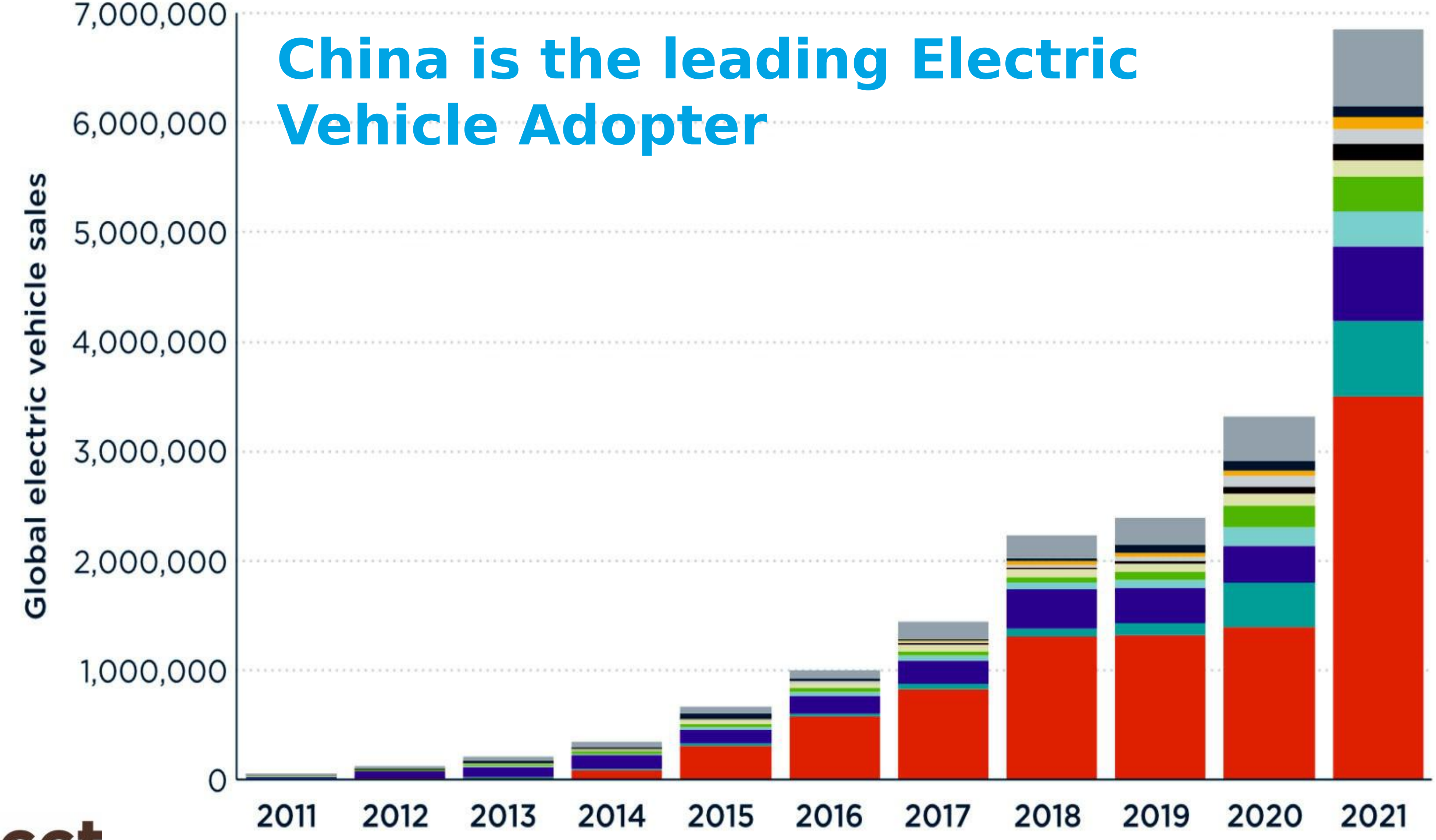


Energy Use: 2020 Global Green House Gas Emissions by Sector

Source: Rhodium Group

THE ELECTRIC VEHICLE REVOLUTION

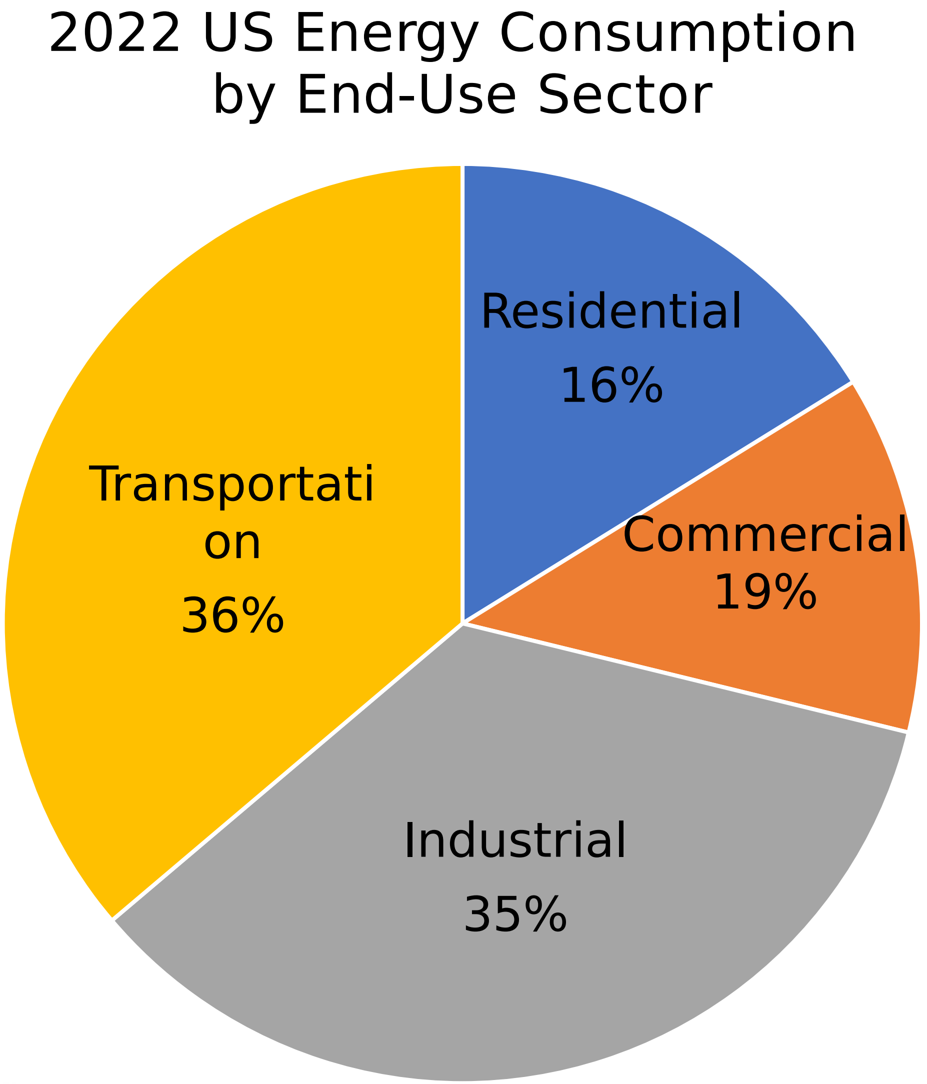
China is the leading Electric Vehicle Adopter



Source: International Council on Clean Transportation

BYD most popular EV manufacturer in China

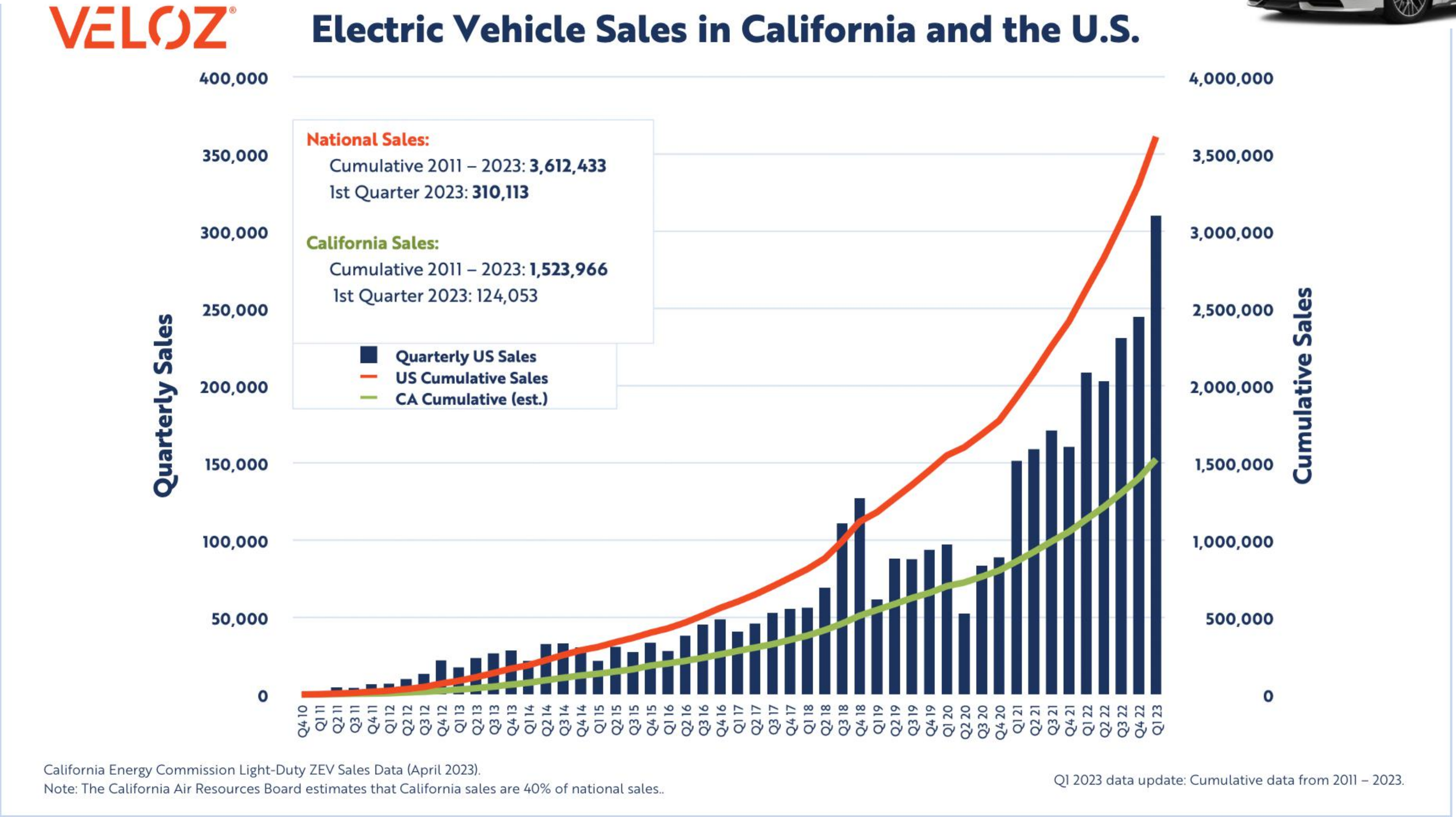
THE ELECTRIC VEHICLE REVOLUTION



Tesla Model Y – 2022 best selling EV in US

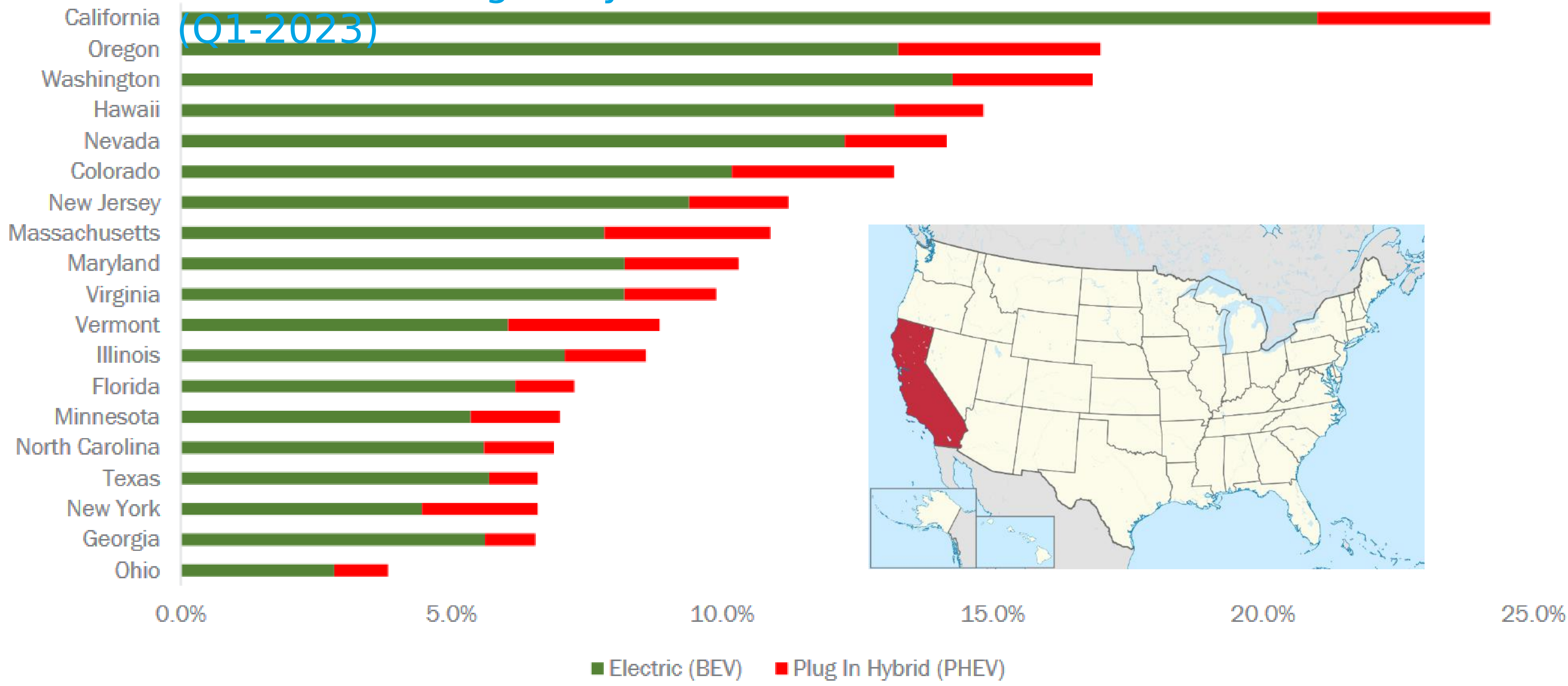
Source: Energy Information Administration

THE ELECTRIC VEHICLE REVOLUTION



THE ELECTRIC VEHICLE REVOLUTION

Electric and Plug In Hybrid Vehicle Sales (Q1-2023)



Data sourced from Experian Automotive.

THE ELECTRIC VEHICLE REVOLUTION

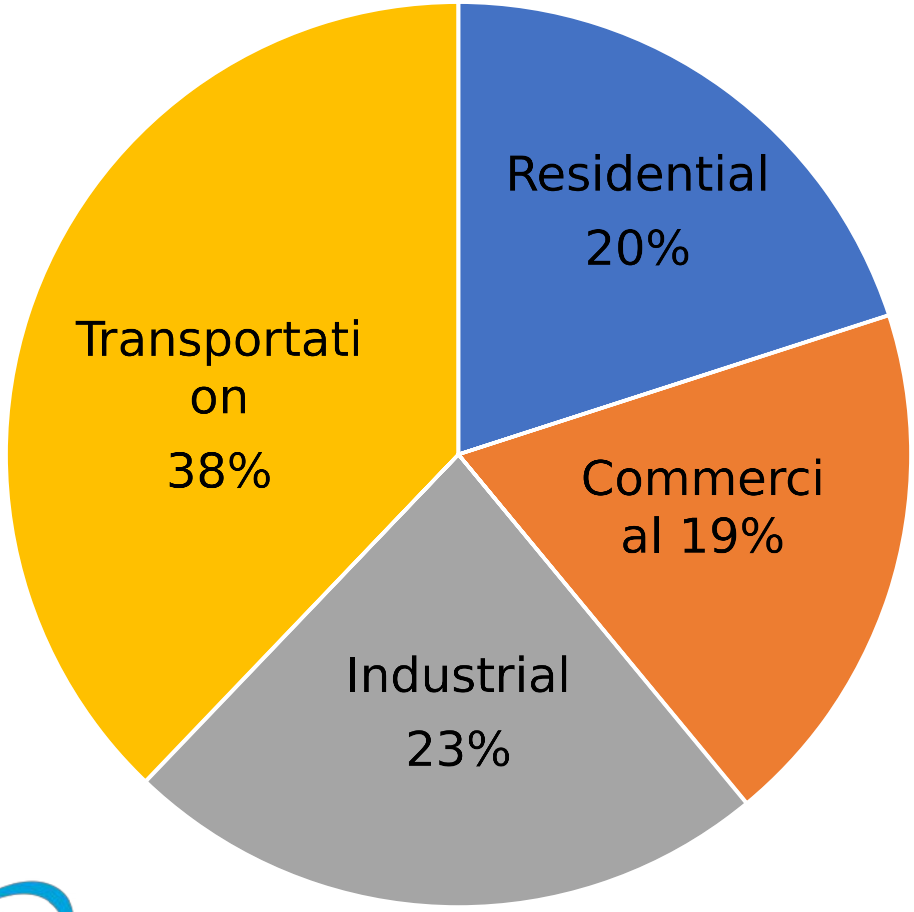
Challenges to solve:

- In California energy used for transportation is about equal to residential and commercial use combined.
    - Converting to EV’s will have a huge impact on building and grid electricity demand.

Key Trends:

- Parking garages are being outfitted to provide EV chargers for 100% of parking spaces.
- Potential parking garage charging loads can exceed the power requirements of the associated buildings.
- Employees frequently expect free charging.
- Average daily commute in California is 46.88 miles (15 kWh).

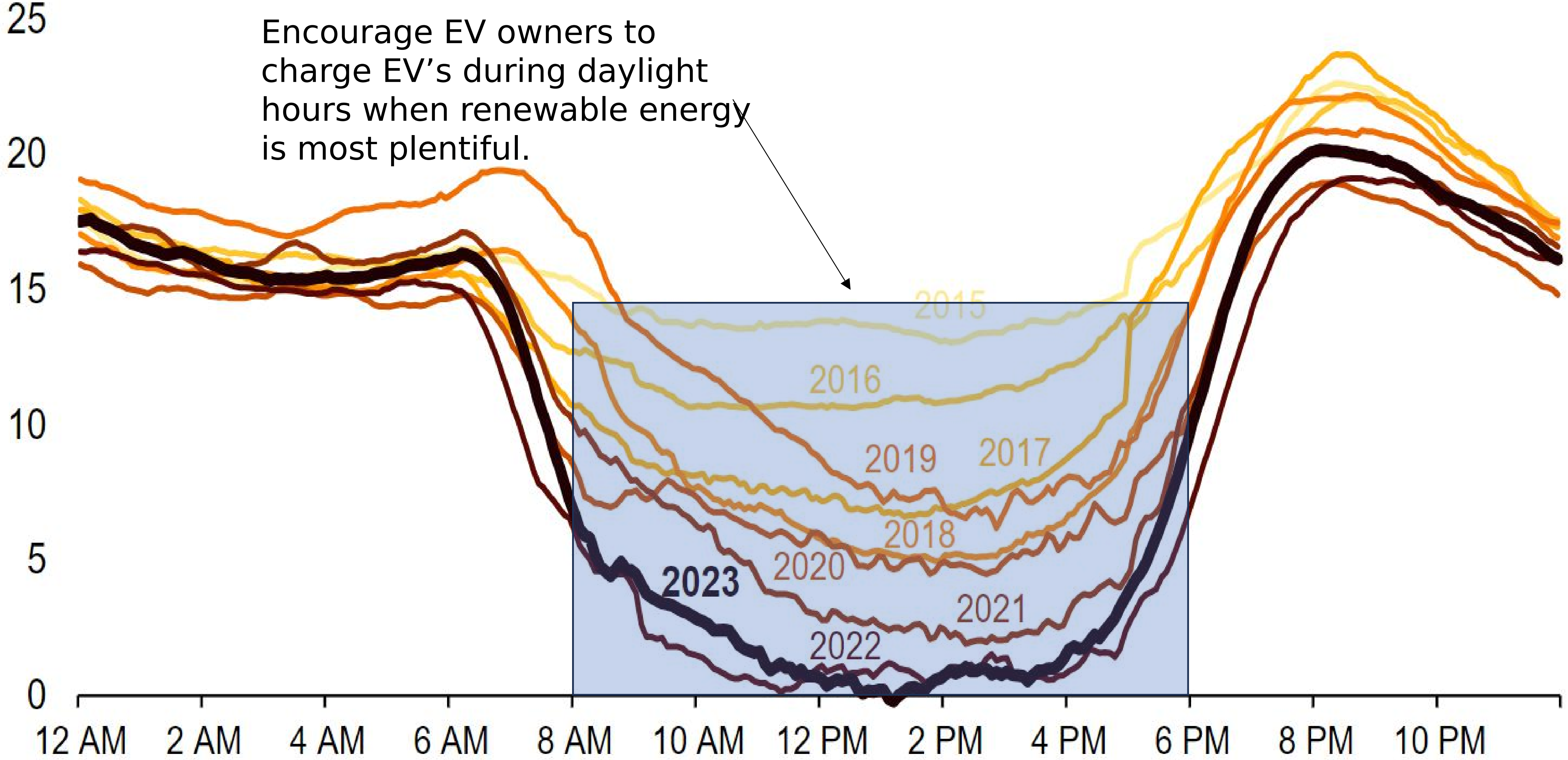
2022 California Energy Consumption by End-Use Sector



Source: Energy Information Administration

THE ELECTRIC VEHICLE REVOLUTION

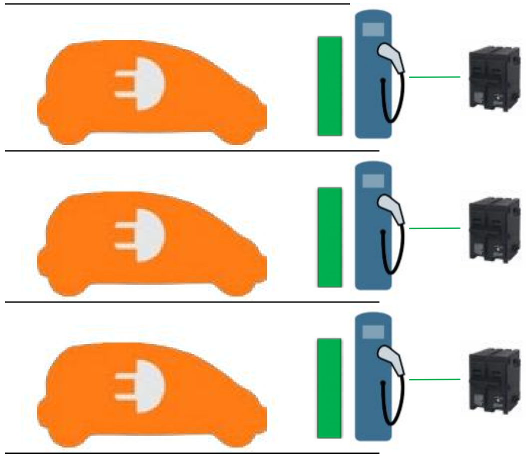
Encourage EV owners to charge EV’s during daylight hours when renewable energy is most plentiful.

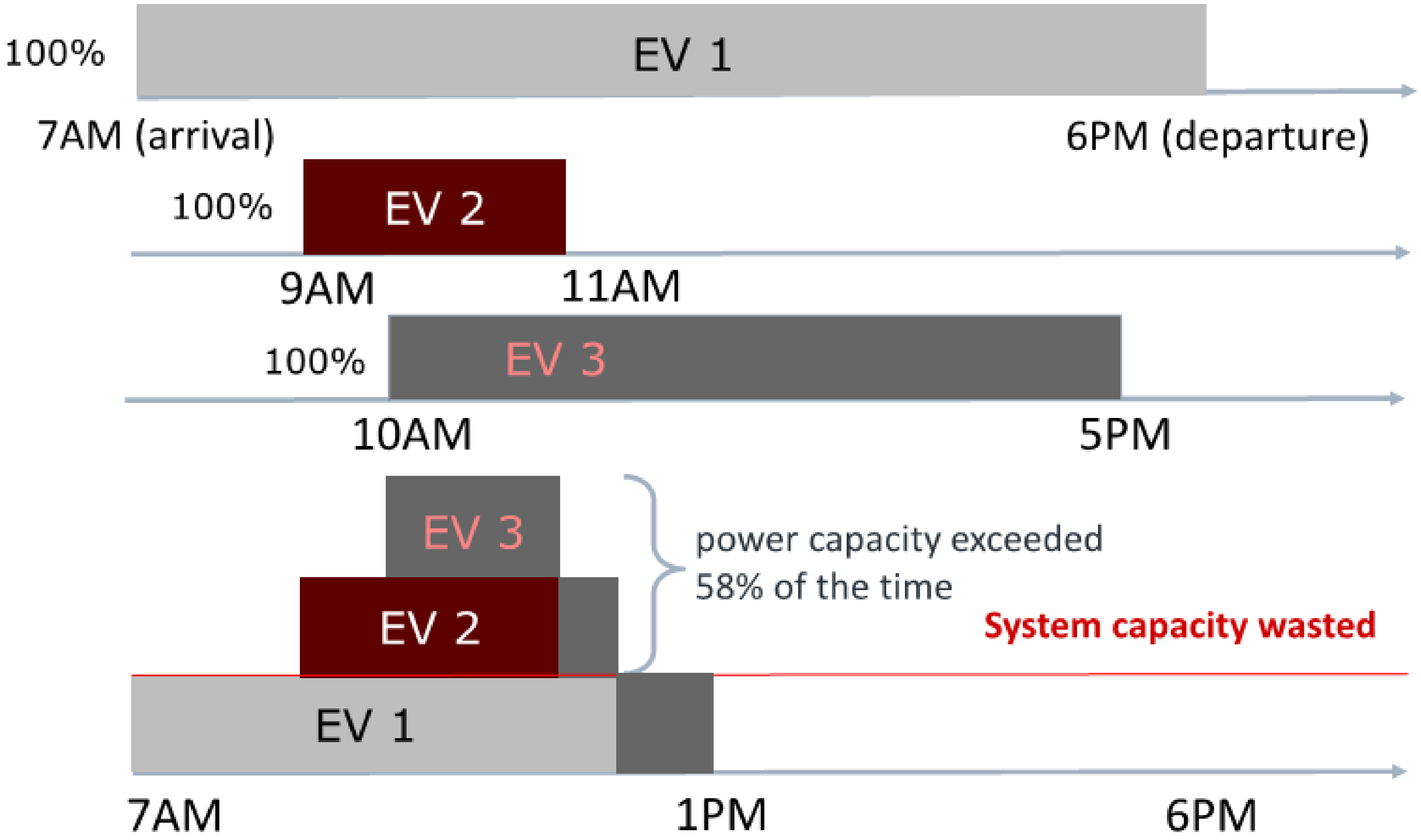


Source: Energy Information Administration

THE ELECTRIC VEHICLE REVOLUTION

Uncontrolled charging: Good for drivers, bad for owners

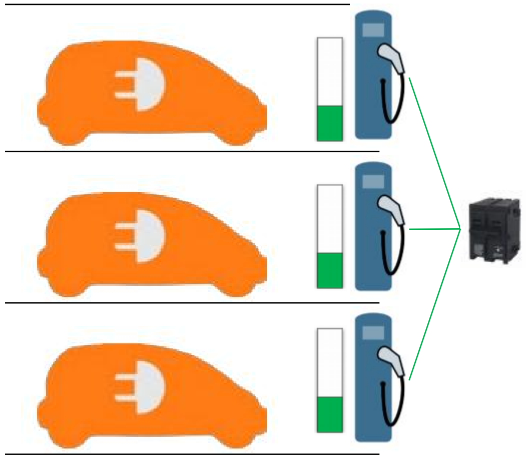


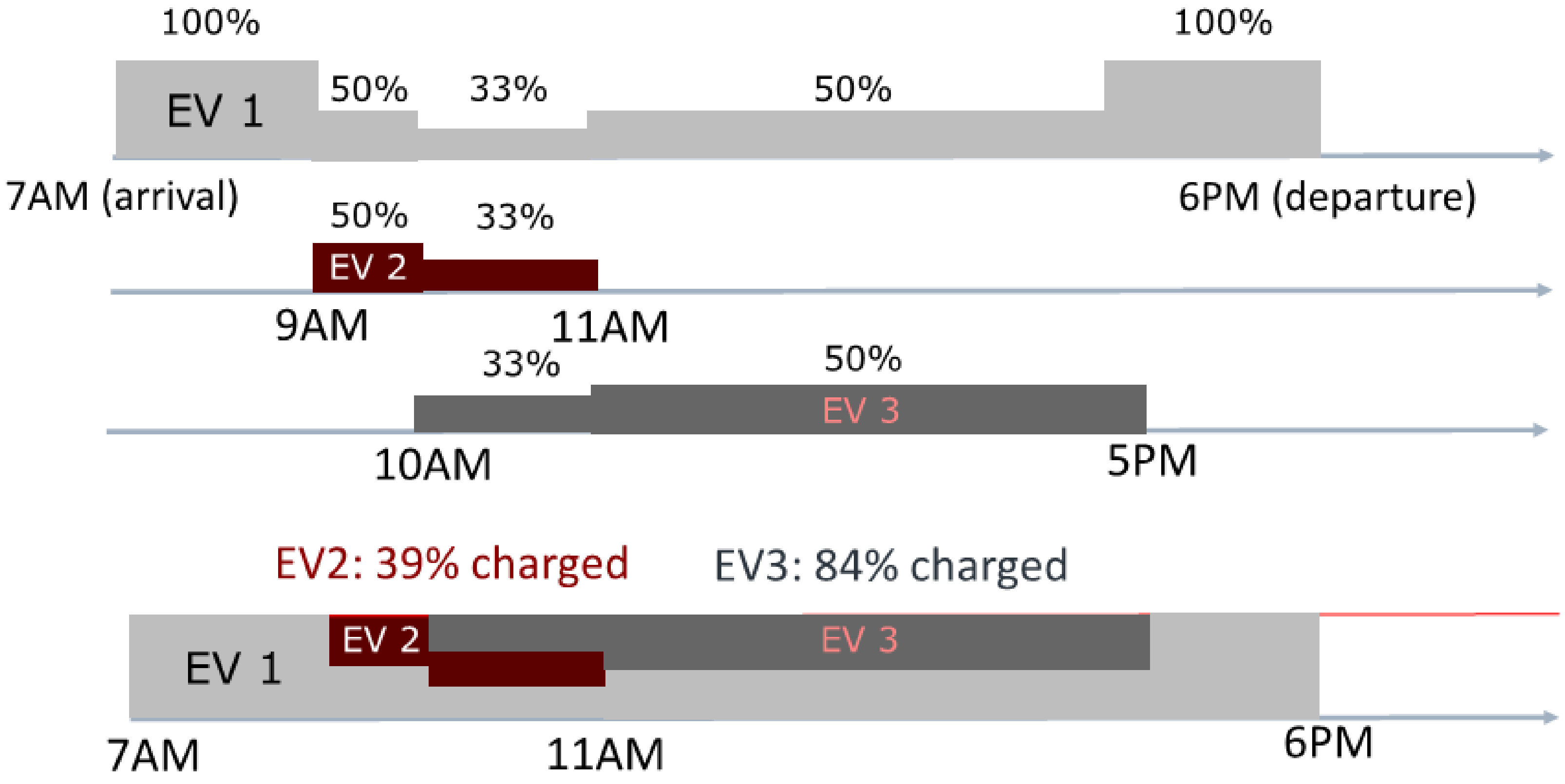


*Note: 1 charger per circuit. Charger charges at full capacity. High demand charge. System overloaded in the morning. Excess

THE ELECTRIC VEHICLE REVOLUTION

Evenly distributed charging: Good for owners. bad for drivers

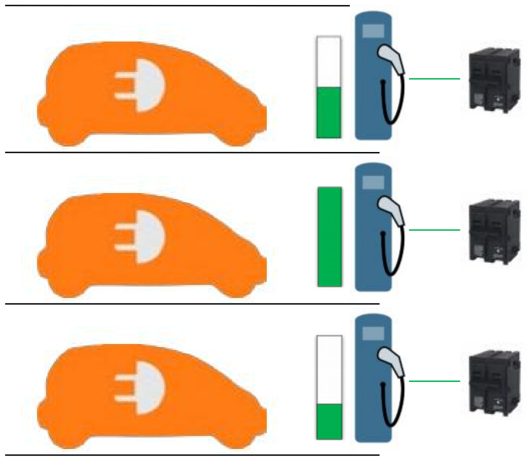


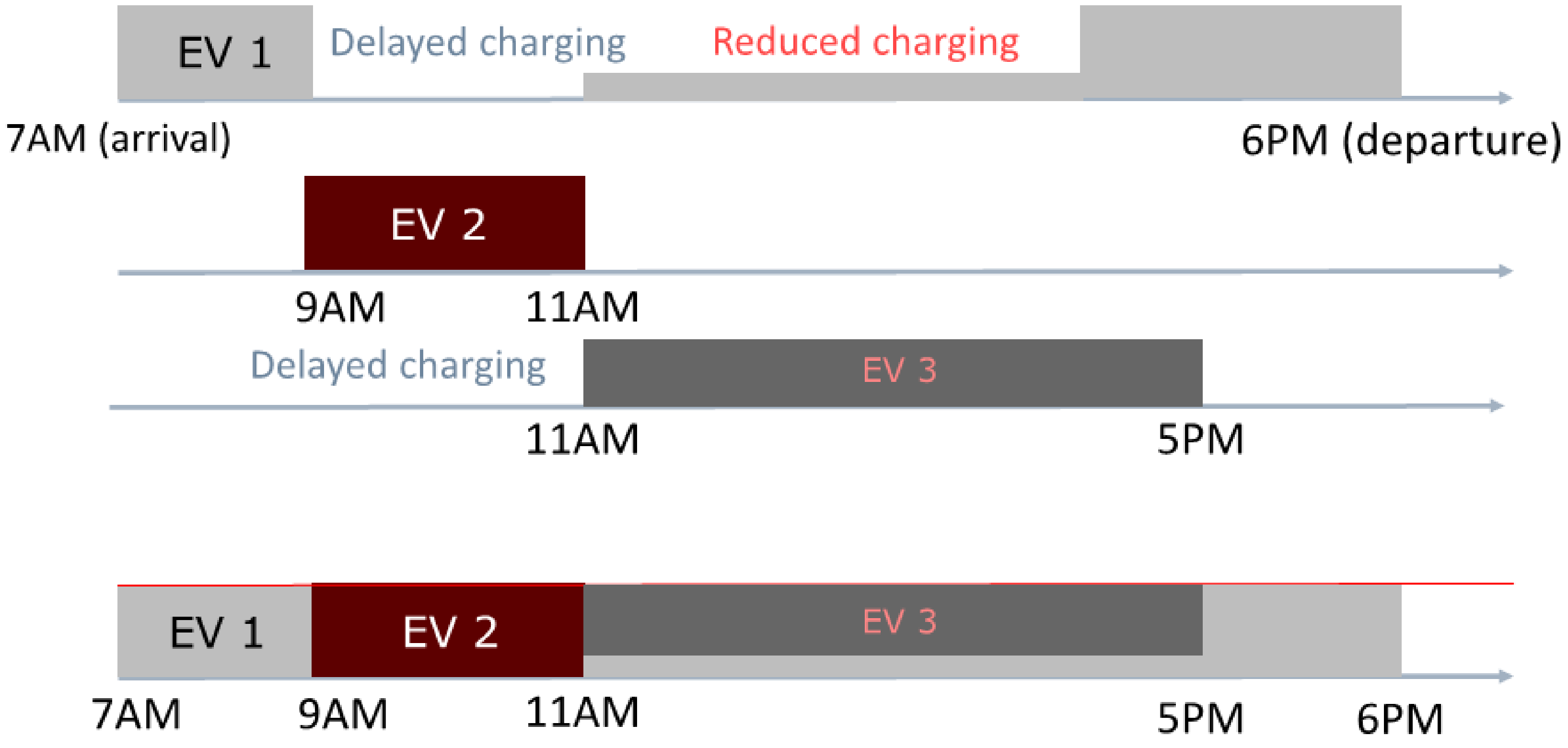


*Note: Chargers share capacity of the system equally. Some vehicles cannot be fully charged by the time the owner needs it

THE ELECTRIC VEHICLE REVOLUTION

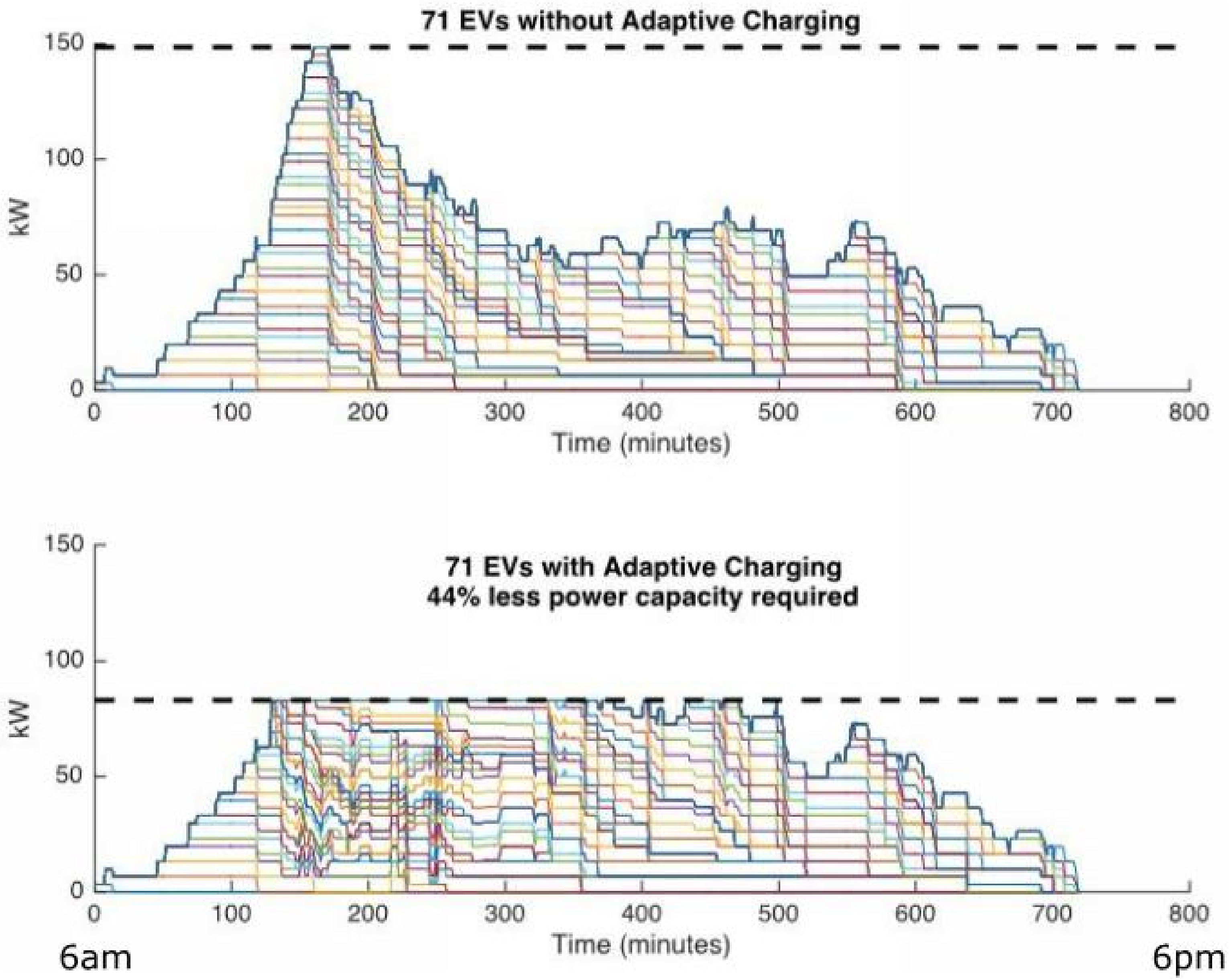
Adaptive Load Management: Good for drivers, good for owners!





*Note: 1 charger per circuit. The system strategically adjusts charging based on need for charge and departure time.

THE ELECTRIC VEHICLE REVOLUTION



POWERFLEX SYSTEMS

THE ELECTRIC VEHICLE REVOLUTION

Electric Vehicles as Microgrids

Ford F150 Lightning extended Range Battery – 9.6 kW/131 kWh

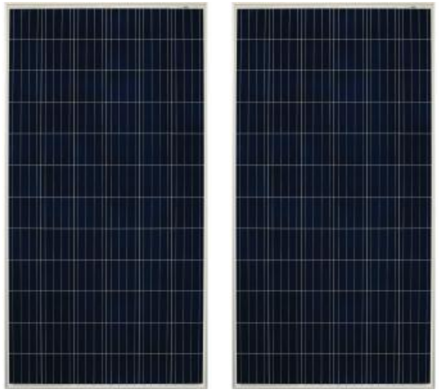
(Tesla Powerwall 3 Battery – 11.5 kW/13.5 kWh)

The Ford has almost 10 times the storage capacity as a Powerwall. More coming…

The Ford/Sunrun system can run as a microgrid in islanded mode with a PV array.

For an all-electric home that uses about 55 kWh per day, the Ford F150 Lightning should be able to run the home for over 2 days **WITHOUT PV**.

The impact on the EV battery will likely be less than driving it since the F150 Extended Range claims 320 miles of range, so the battery will likely discharge more slowly than it does when driving.



THE ELECTRIC VEHICLE REVOLUTION

Electric Vehicles as Energy Storage

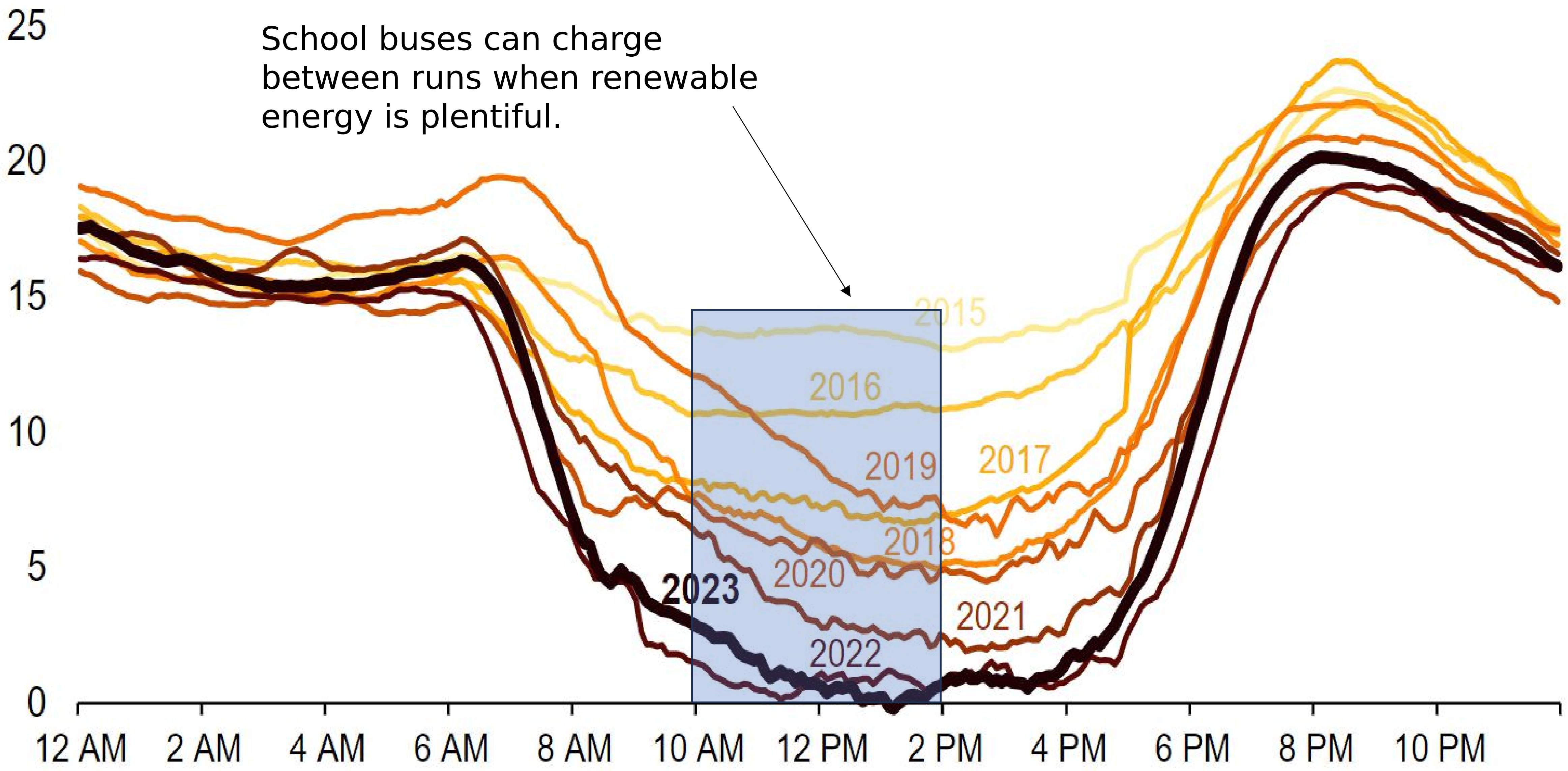
By 2024, Twin Rivers Unified School District plans to have a fleet of 82 electric buses, one of the largest in the state. These buses will represent a combined energy storage capacity of an estimated **12.7 GWh** of electricity when fully charged.

Most school buses are done running their daily routes by late afternoon.

Buses can provide spare energy back to the grid on demand.

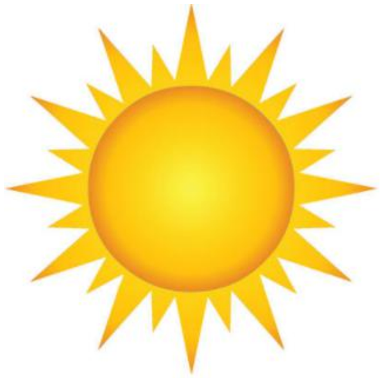
SMUD the local utility for TRUSD is collaborating to install V2G fast chargers and explore using this bus depot as an energy resource for grid support.

Leading the EV Revolution



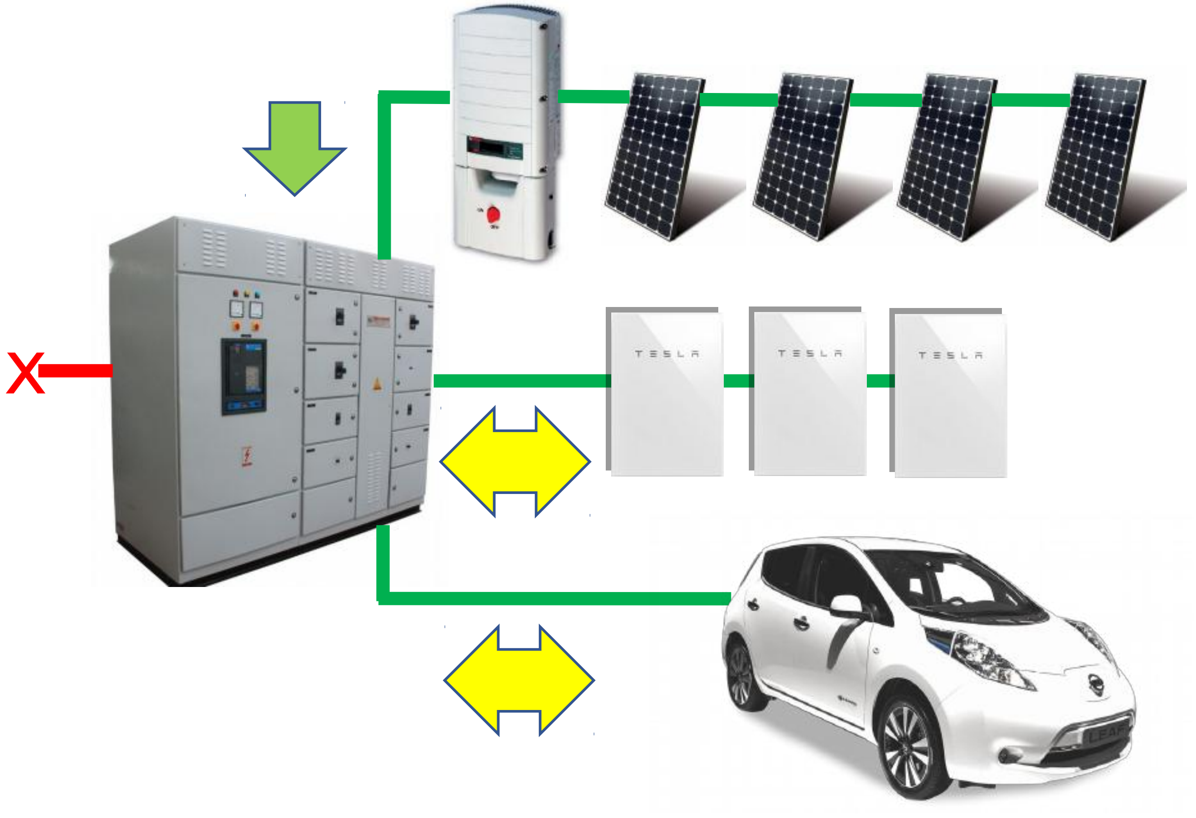
Source: Energy Information Administration

CONCLUSIONS



The combination of electrification, PV’s, EV’s and BESS is creating **new opportunities** to design **resilient buildings**.

These building will act significantly different than buildings we’ve designed in the past.



Go out and innovate!