

THE GRID, AND ELECTRICITY PRICING

Electric-Grid Actors

Independent System Operator (ISO)

An organization that manages the transmission of electricity on a grid.

...And facilitates the wholesale electricity market.

California ISO (CAISO)



Independent System Operators



Regional Transmission Organizations

Electric utility

An organization that builds and maintains an electric grid.

...And manages the experience of electricity users.

An electric utility *might* also generate electricity.

Investor-owned utility (IOU)

A utility that's owned by shareholders (who get financial returns).

There are about 170 IOUs in the U.S.

IOUs serve over two thirds of U.S. utility customers.

The average number of customers served is around 650,000.



For-profit utility

Publicly-owned utility (POU)

A utility that's owned and operated by a municipal, state, or federal gov't.

There are around 2,000 POUs in the U.S.

The average number of customers served is around 12,000.

...The largest number is over 1.4 million (Puerto Rico and Los Angeles).

Cooperative utility

A utility that's owned by its members.

There are around 800 cooperatives in the U.S.

The average number of customers served is 24,000.

The utility as “natural monopoly”

Public Utilities Commission (PUC)

A government entity that regulates utilities.

They typically just regulate *investor-owned* utilities.

Public Utilities Commission

The PUC determines how much its overseen utilities are allowed to:

- 1) Invest in new infrastructure
- 2) Charge for electricity
- 3) Return to shareholders

(Often under-resourced) PUCs have a lot to regulate...



How the Grid Works

Electric grid 1.0

DIRTY POWER



Electric grid 1.0 (one-way power flow)



Generation



Transmission



Distribution

Delivery



Generation + load balancing



Grid infrastructure management,
customer relationship management, etc.

Rate basing

Electricity revenue should cover the utility's investments (in the "rate base").

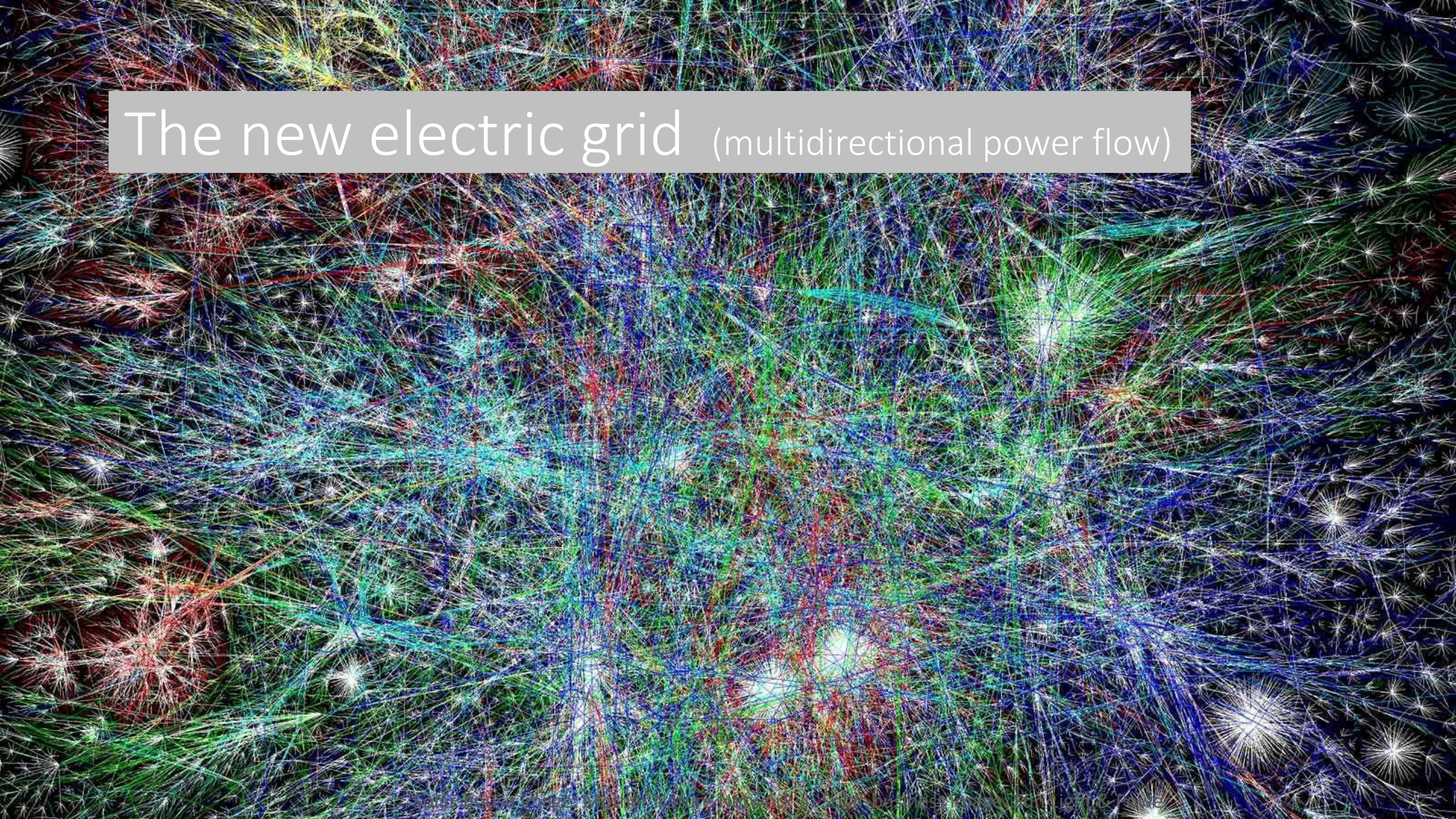
...And a reasonable return for utility shareholders.

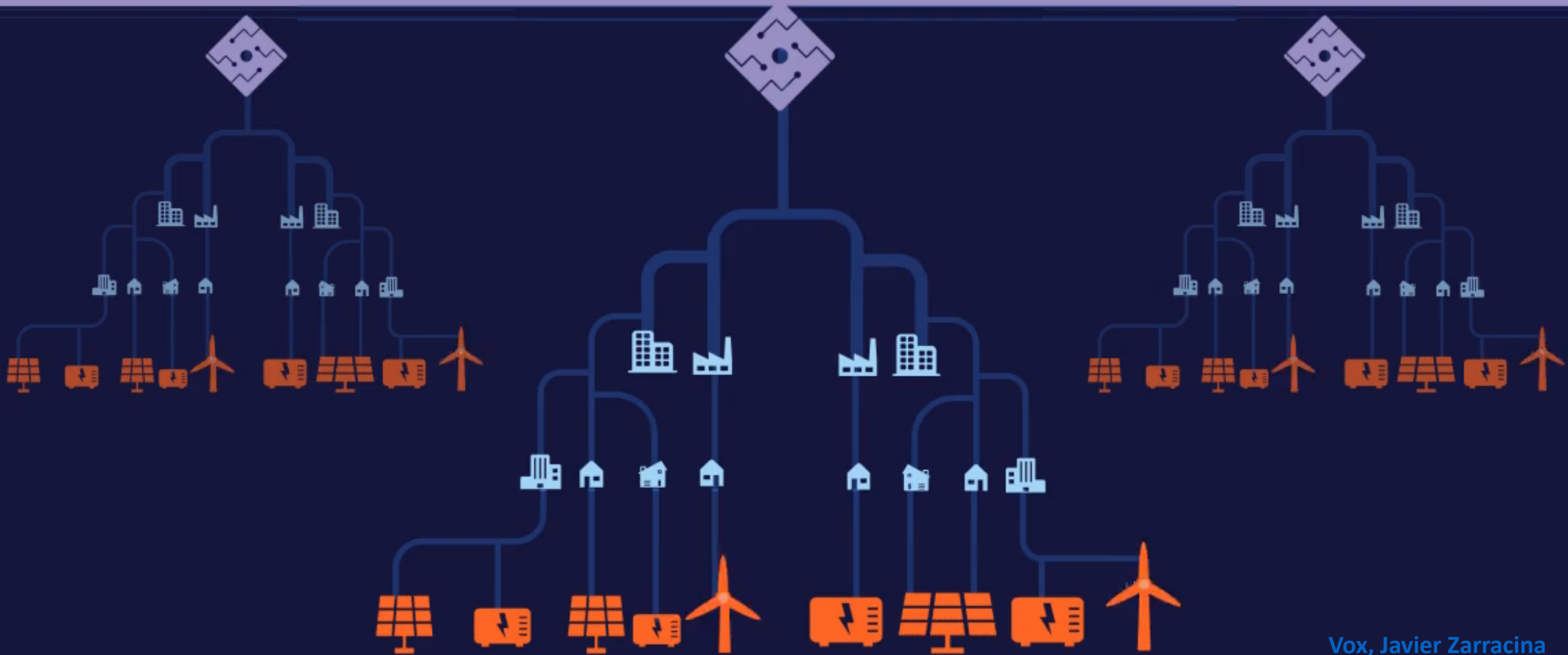


decoupling

The new electric grid (multidirectional power flow)

The new electric grid (multidirectional power flow)







Only when the utility model fundamentally changes — when utilities begin to see themselves primarily as architects and managers of high-efficiency, low-emissions, multidirectional electricity systems rather than just investors in infrastructure growth — can utilities turn in earnest to the kind of planning they need to be doing.

— David Roberts

The Electric Bill

Tariff book

A utility's collection of available rate plans, with pricing details.

Some tariff books are easy enough to understand:

Tariff Name	PDF	Title
A-1	PDF	Small General Service



Total Customer Charge Rates	
Customer Charge Single-phase (\$ per meter per day)	\$0.32854
Customer Charge Poly-phase (\$ per meter per day)	\$0.65708
Total Energy Rates (\$ per kWh)	
Summer	\$0.27251
Winter	\$0.21196

Some aren't:



Utility-customer classes

Utilities group different customer types into *classes*.



Residential



Agricultural



Industrial



All other non-residential
customer types

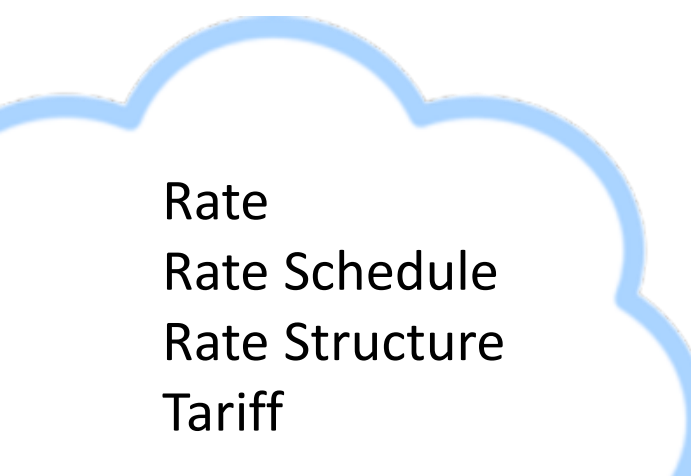
“General”

(There’s no “Commercial” class.)

Rate plan

A group of rates charged for electric service provided to a meter.

...With details on how those rates are applied.



Rate
Rate Schedule
Rate Structure
Tariff

Rate plan options

Some utilities offer more than one rate-plan option to qualifying customers.

With an SPS (Site Power System)...

Some non-residential customers could become eligible for a better rate plan.

How does the utility charge for electricity?

The customer's meter is a hint...

Analog meter



Digital meter



Price signal

The price of an item tends to influence how much of it we purchase.

And *when* we purchase it.

Is electricity an “elastic” good?

...When its price changes, do utility customers respond accordingly?

Is electricity an elastic good?

For residential and small non-residential... not for most of us.

Utility bills are confusing for many people.

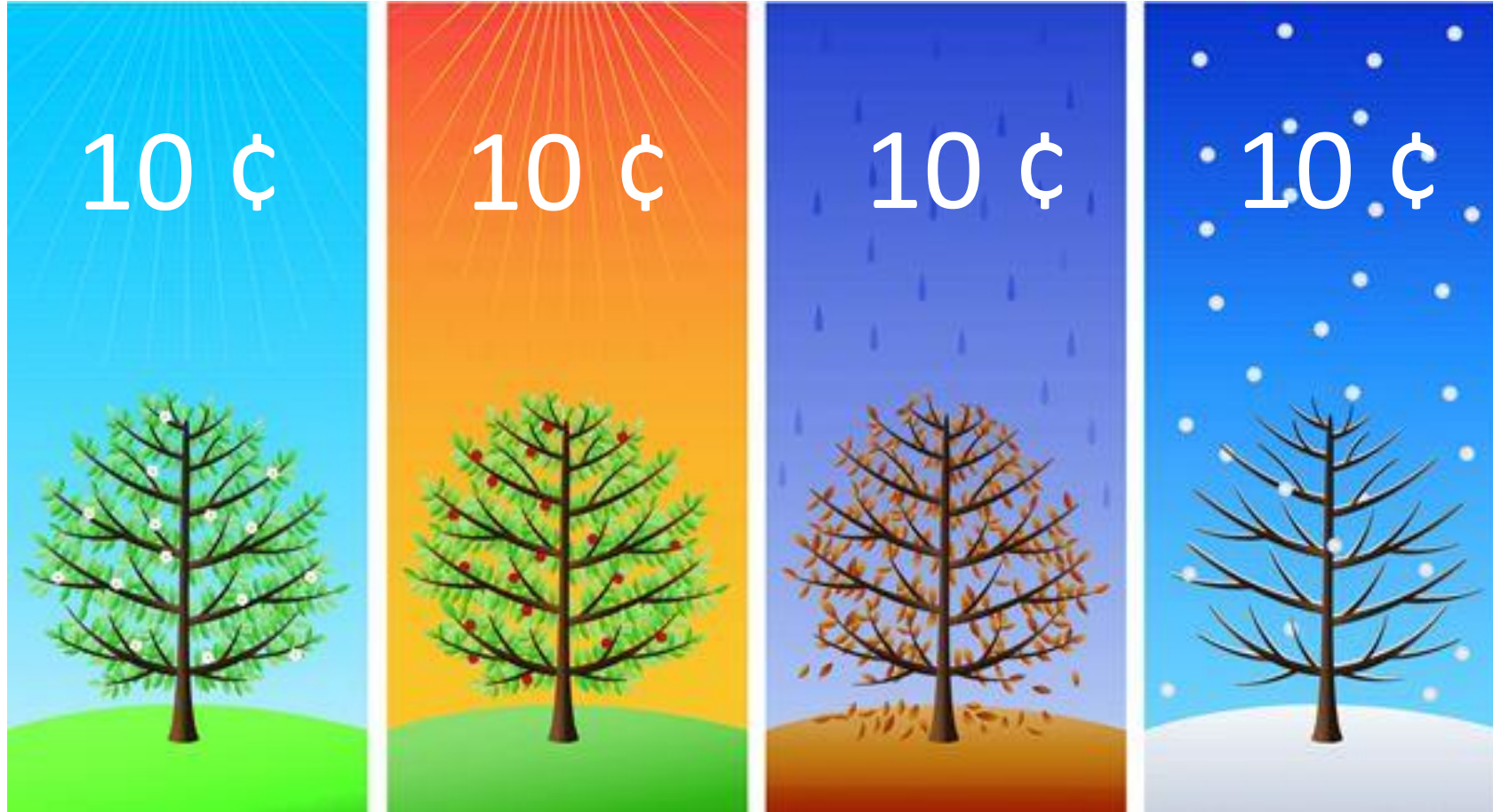
The per-unit cost of electricity is low.

Life and business is complicated enough.

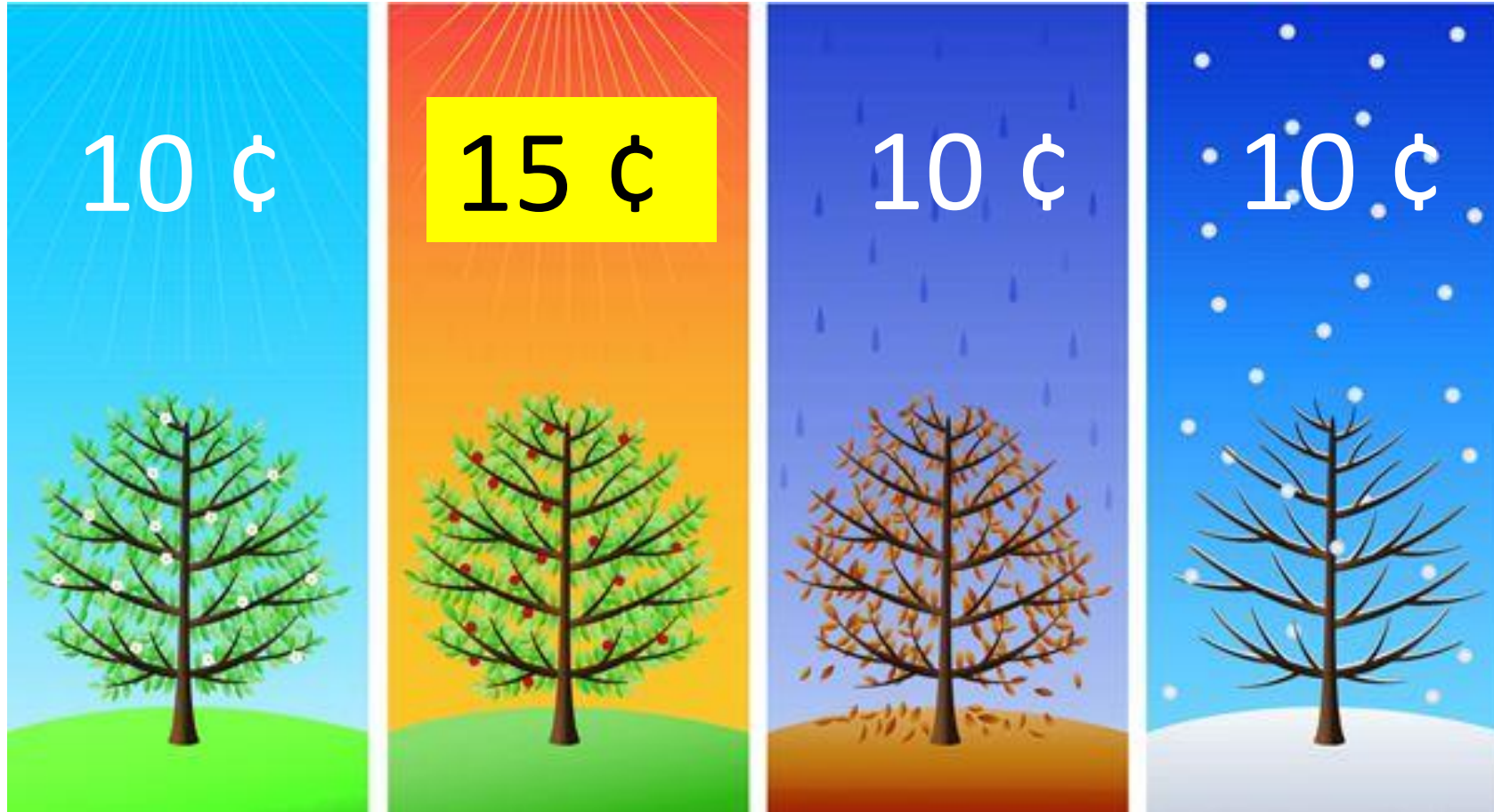
Price signals and automation

Let's respond appropriately on the backend.

Flat rate plan



Seasonal rate plan

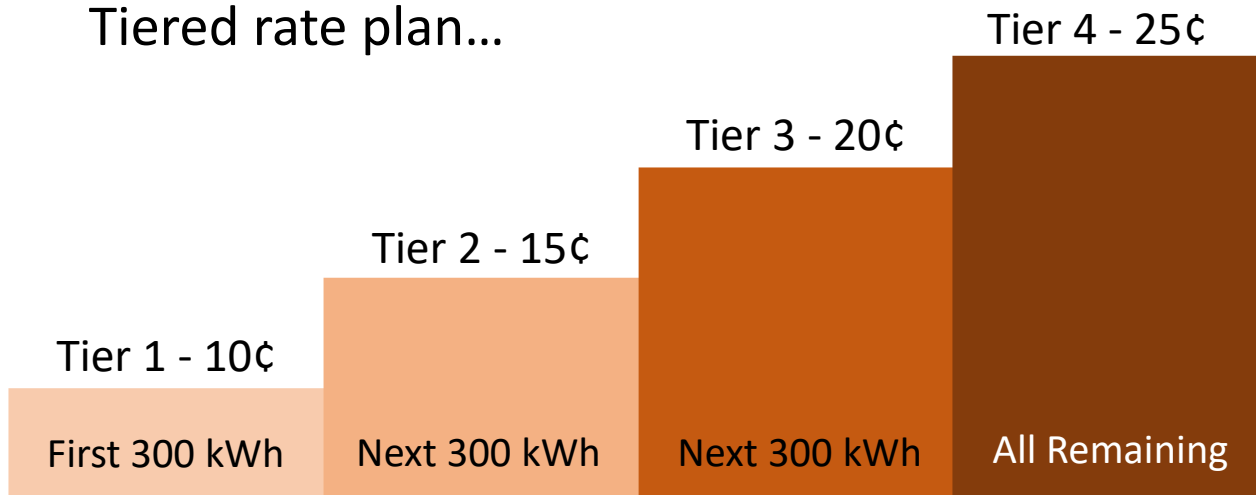


Tiered rate plan

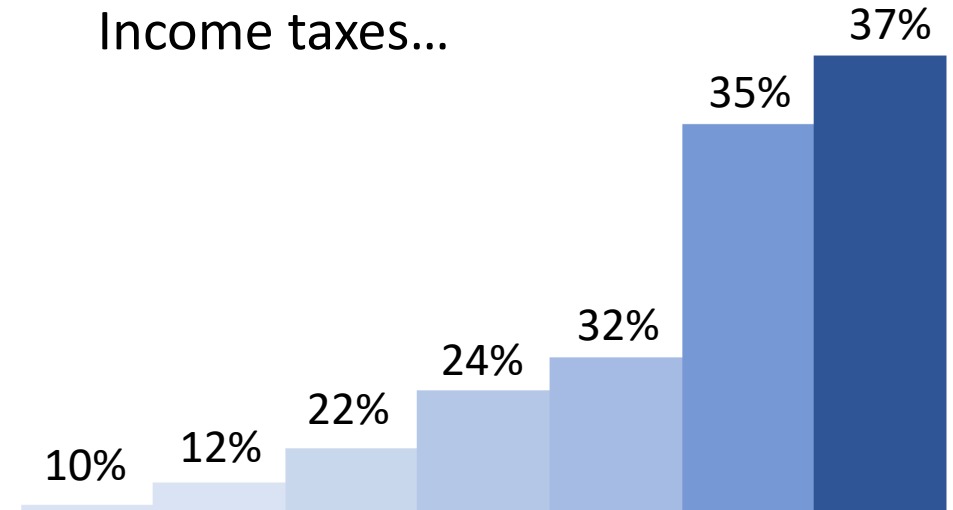


Tiered rates work like income taxes.

Tiered rate plan...



Income taxes...



Digital meter



Digital meter

Smart meter

Advanced electric billing

Advanced Metering Infrastructure (AMI)

Load stacking: residential



700 W

+

What's the total load right now?



100 W

+

=



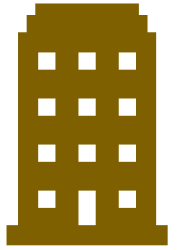
500 W

+



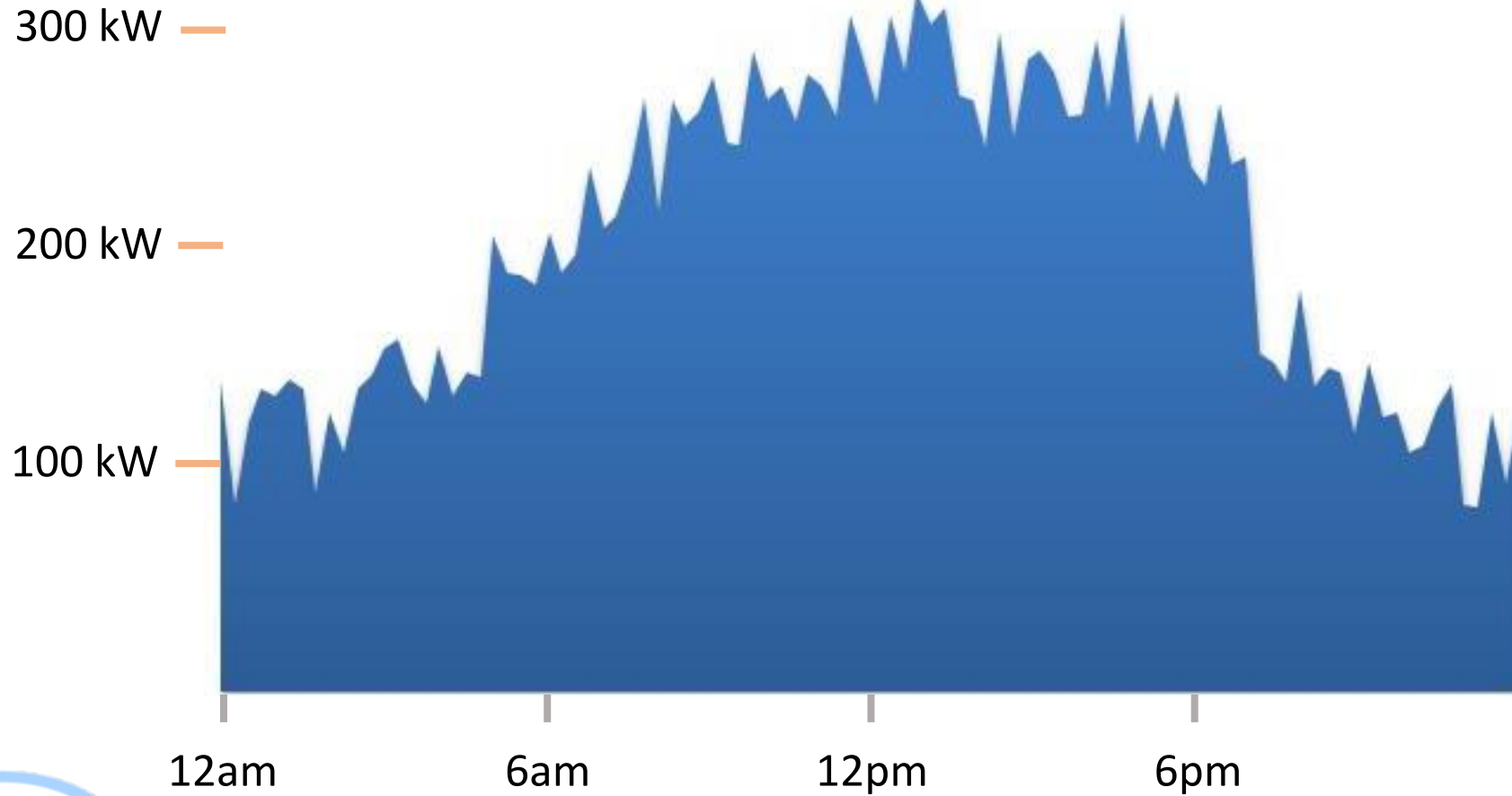
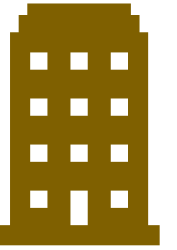
1,500 W

Load Stacking: non-residential and industrial



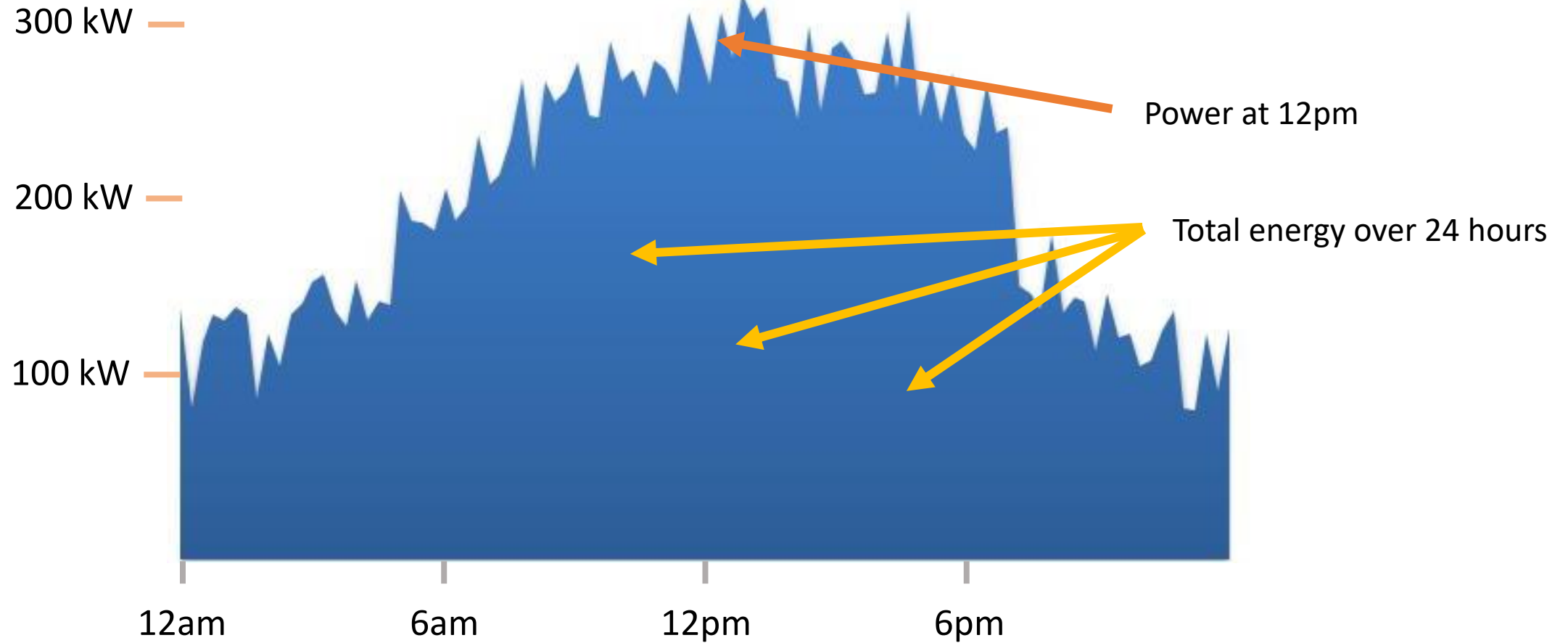
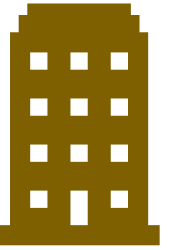
Same logic...
just add up the loads

Load profile



Load curve

Load profile



Energy interval data

Energy used in short periods of time.

Date	Start time	End time	Energy used
2021-08-12	9am	10am	7 kWh
2021-08-12	10am	11am	8 kWh
2021-08-12	11am	12pm	11 kWh
2021-08-12	12pm	1pm	10 kWh

Interval data is needed to calculate a TOU electric bill, and other more advanced billing.



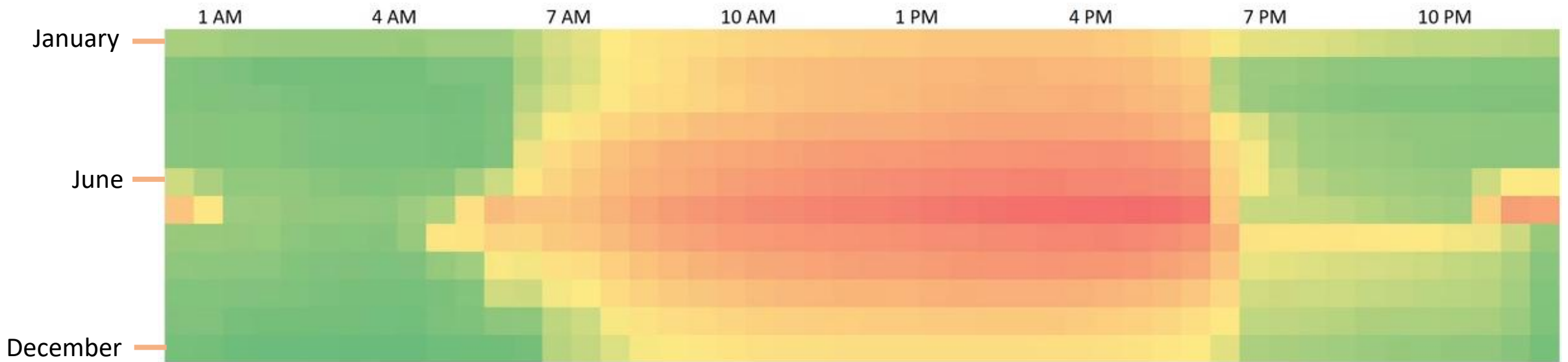
Residential
Typically per hour



Non-residential
Typically per 15 minutes

Energy interval data, visualized

Average hourly weekday energy usage, throughout the year:



Time of use

Time of use (TOU) rate plan



A rate plan with rates that change over the course of the day.

TOU can influence behavior through price signals.

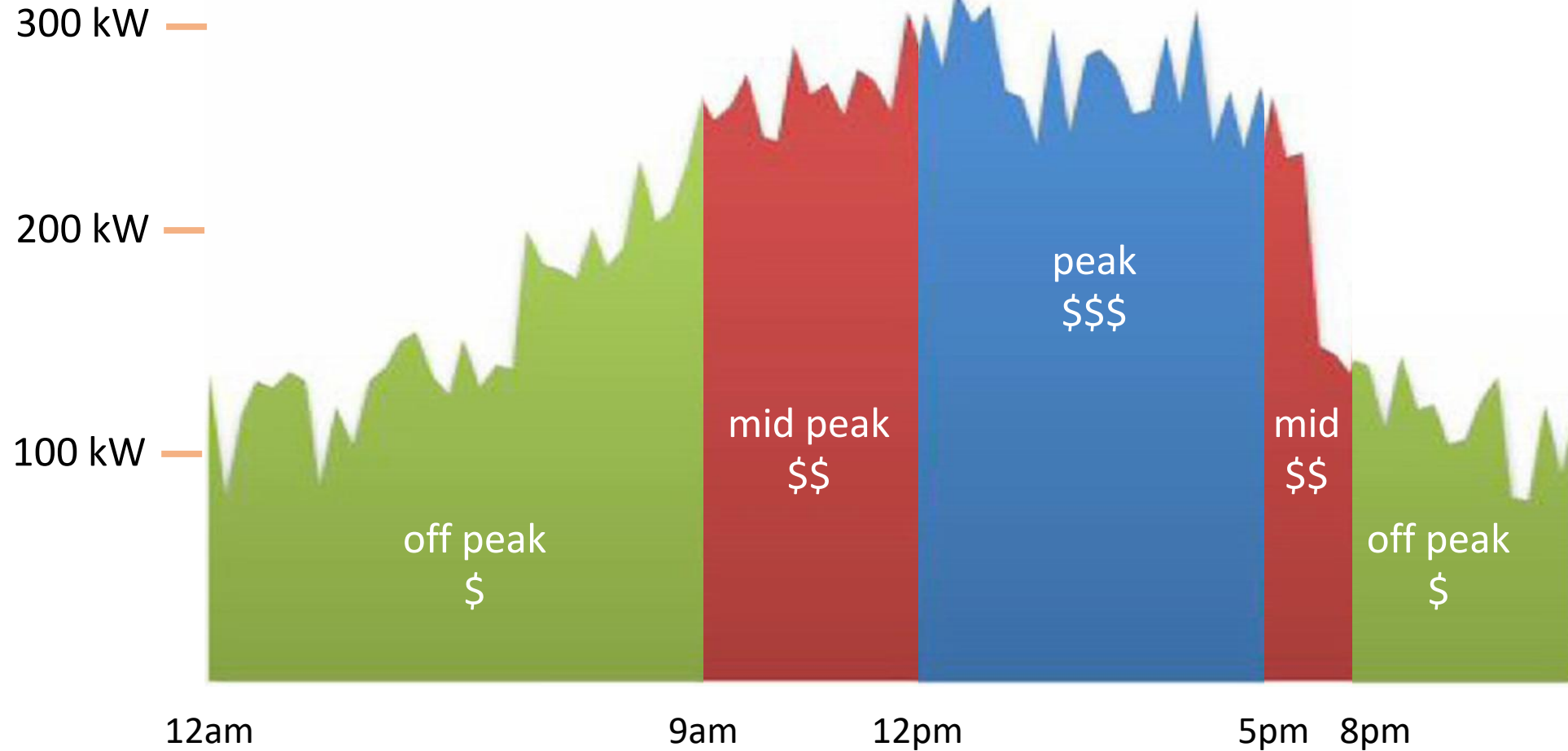
It better reflects the cost to deliver power.

There are precedents...



Time of Day
Time Varying Rate

TOU rate plan

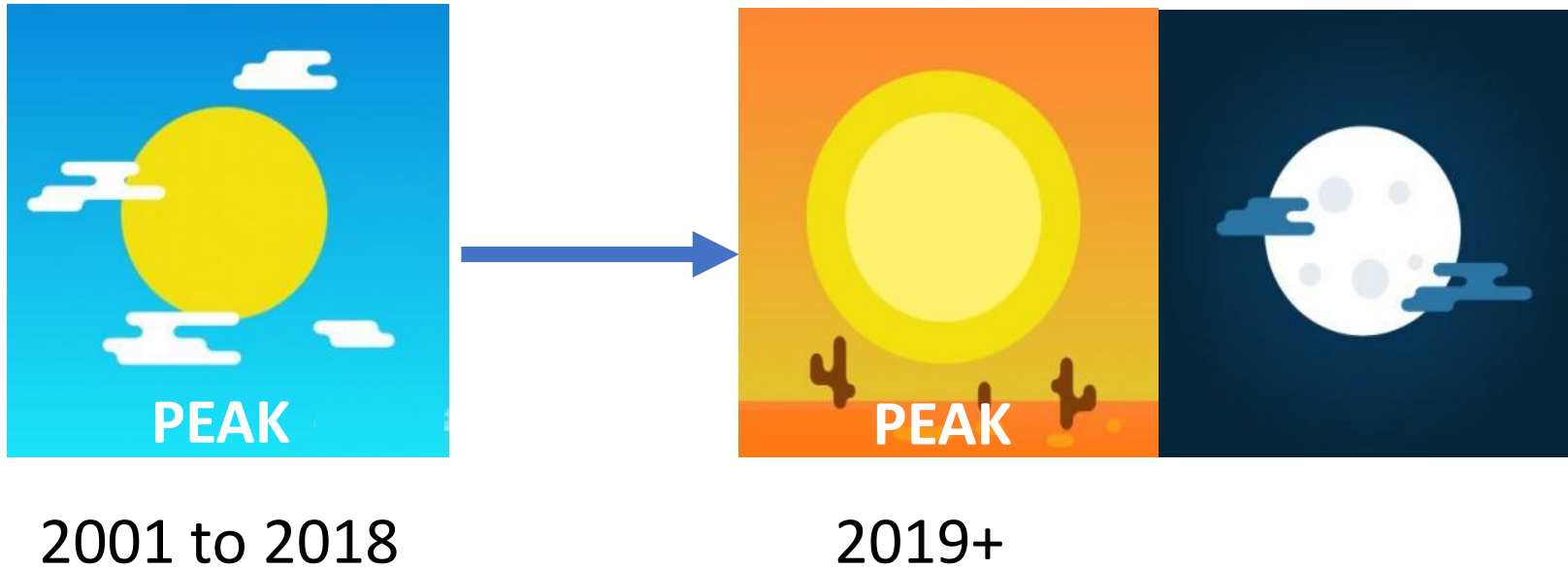


California's move to time of use

Starting in 2019, most non-TOU customers were moved over.



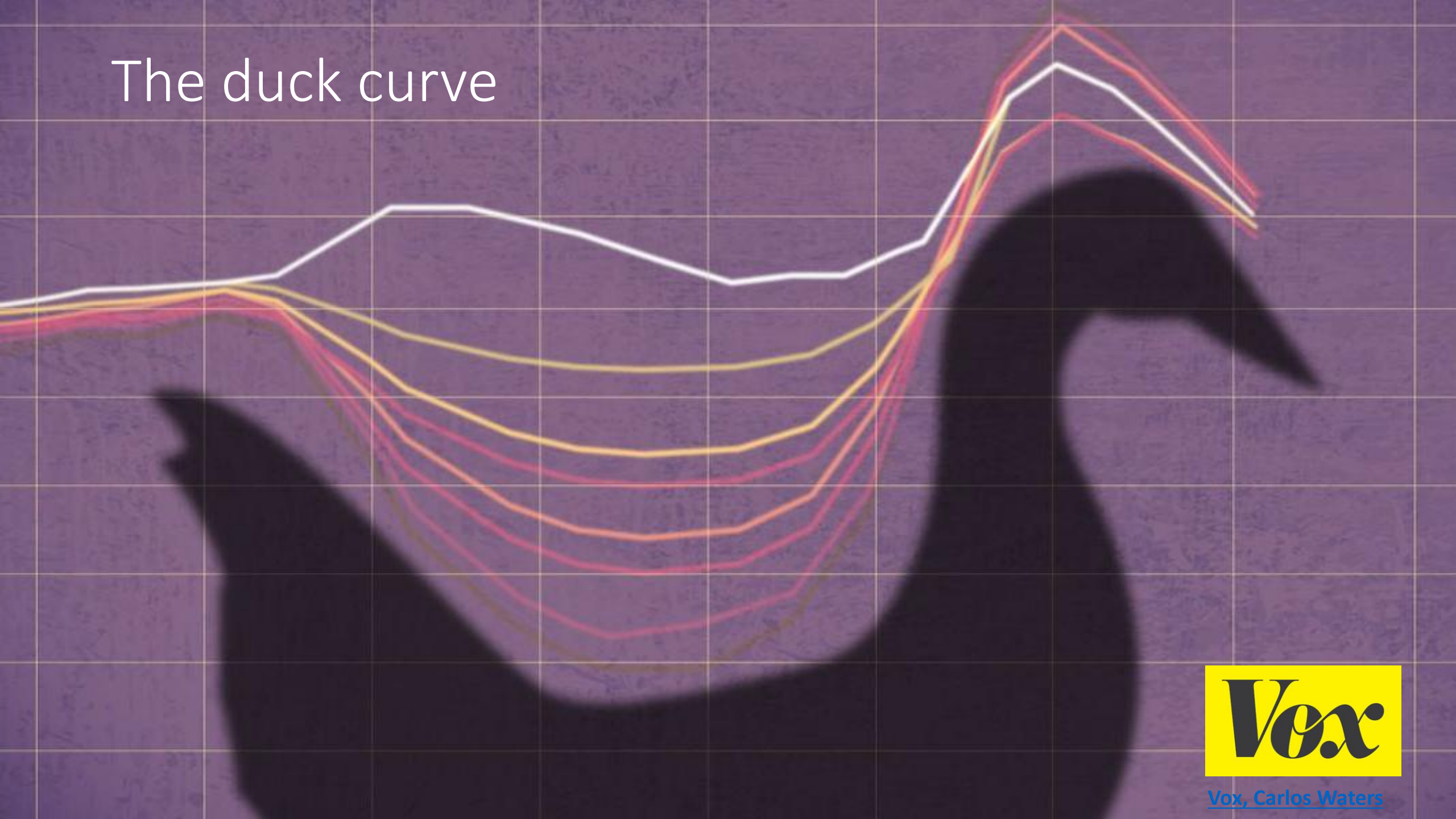
Peak-window transition to evening



Why the transition to time of use?

And why the transition from afternoon to evening peak?

The duck curve

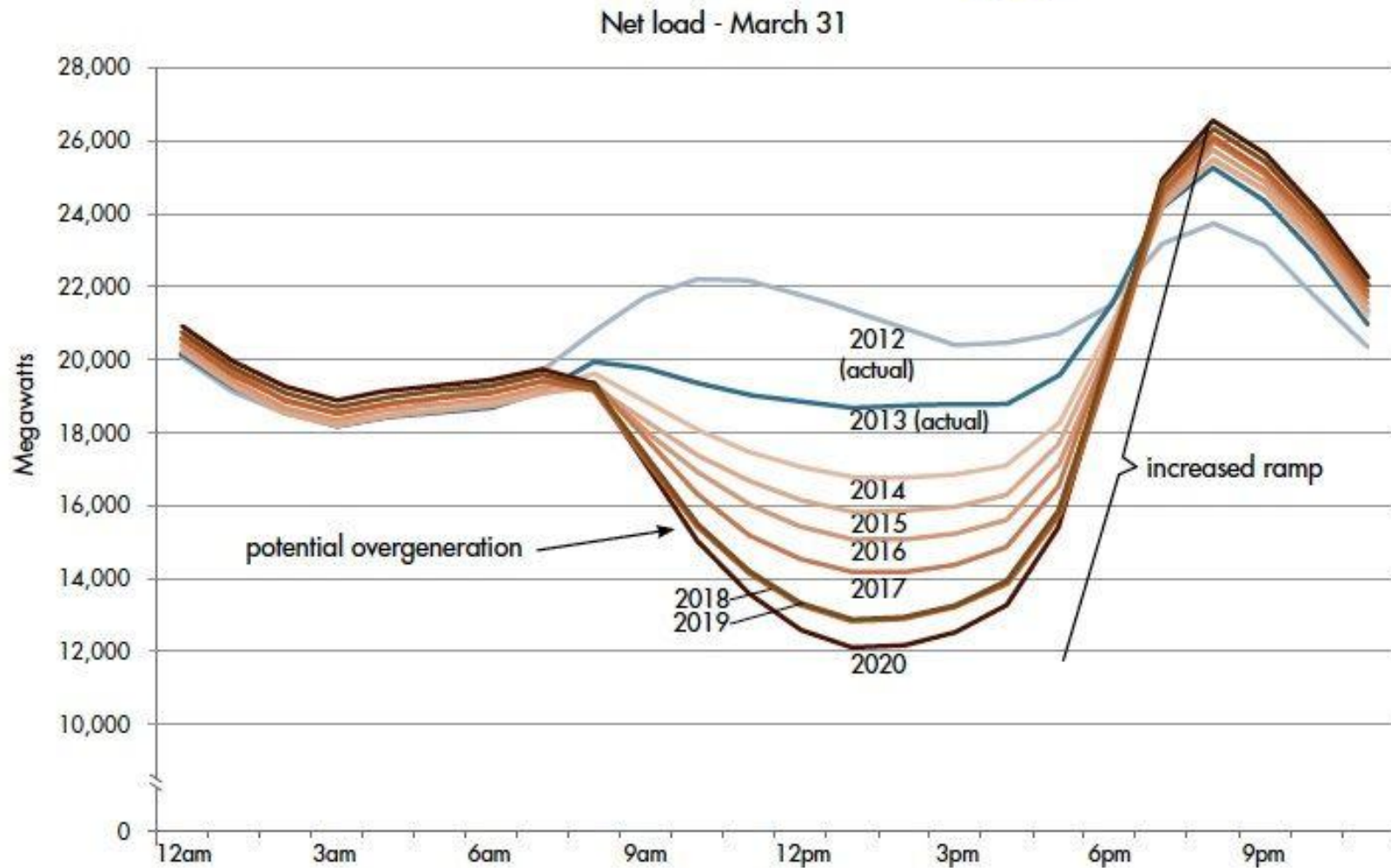


[Vox, Carlos Waters](#)

The duck curve



California ISO



The grid's load on March 31st over the years, without utility-scale solar and wind.

Let's look at California in 2019

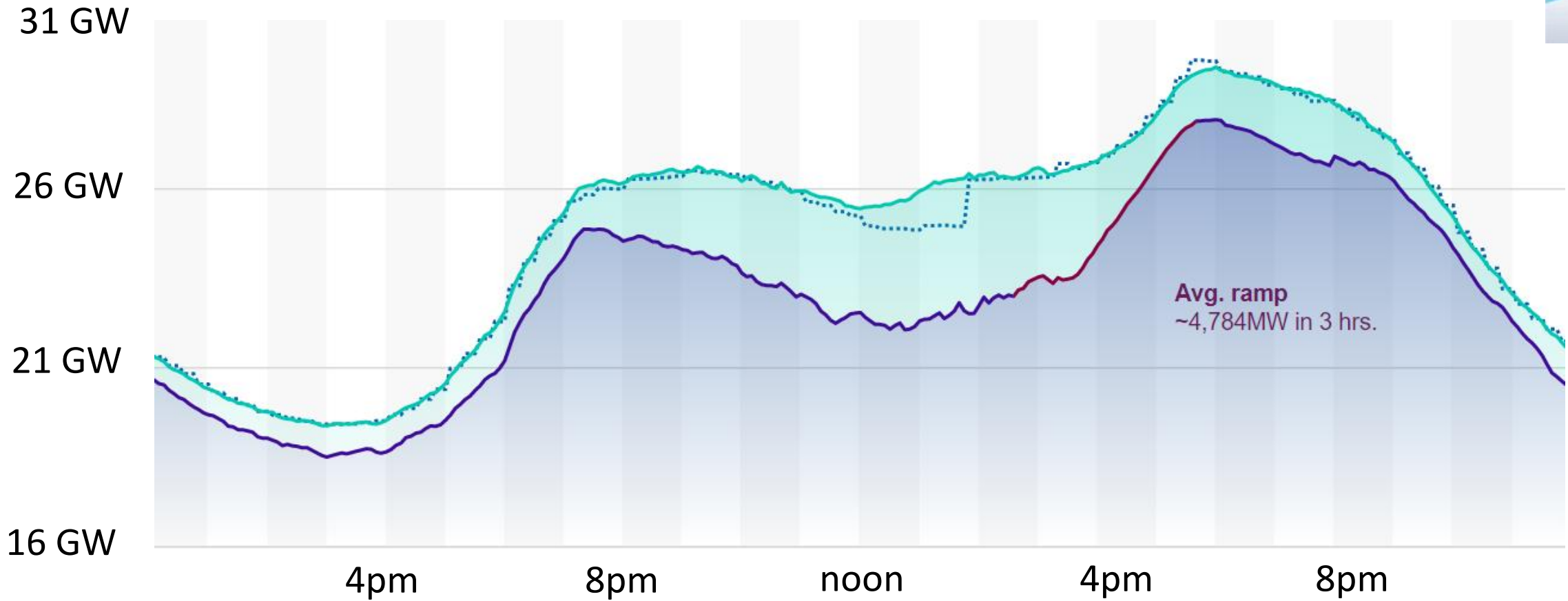
The electric grid's actual load

vs.

The grid's load if there was no utility-scale solar and wind



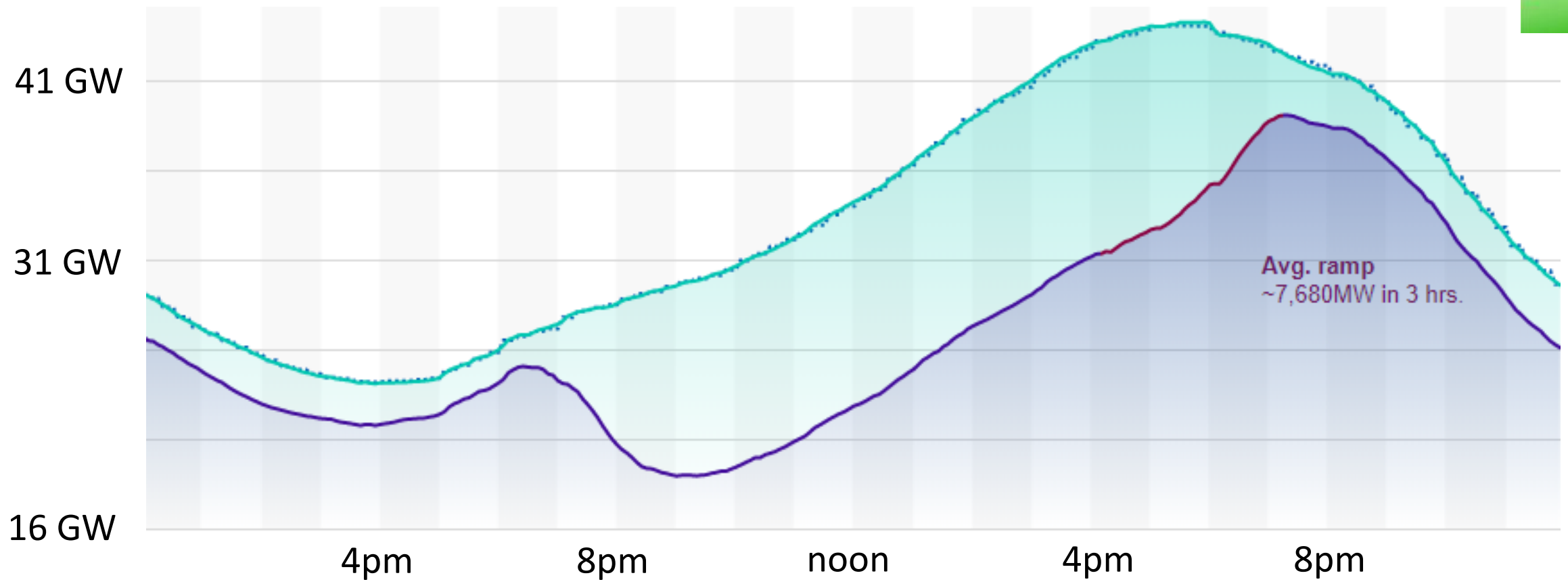
A **Winter** day in 2019 (January 15th)



● Demand ● Net demand — without utility-scale solar and wind



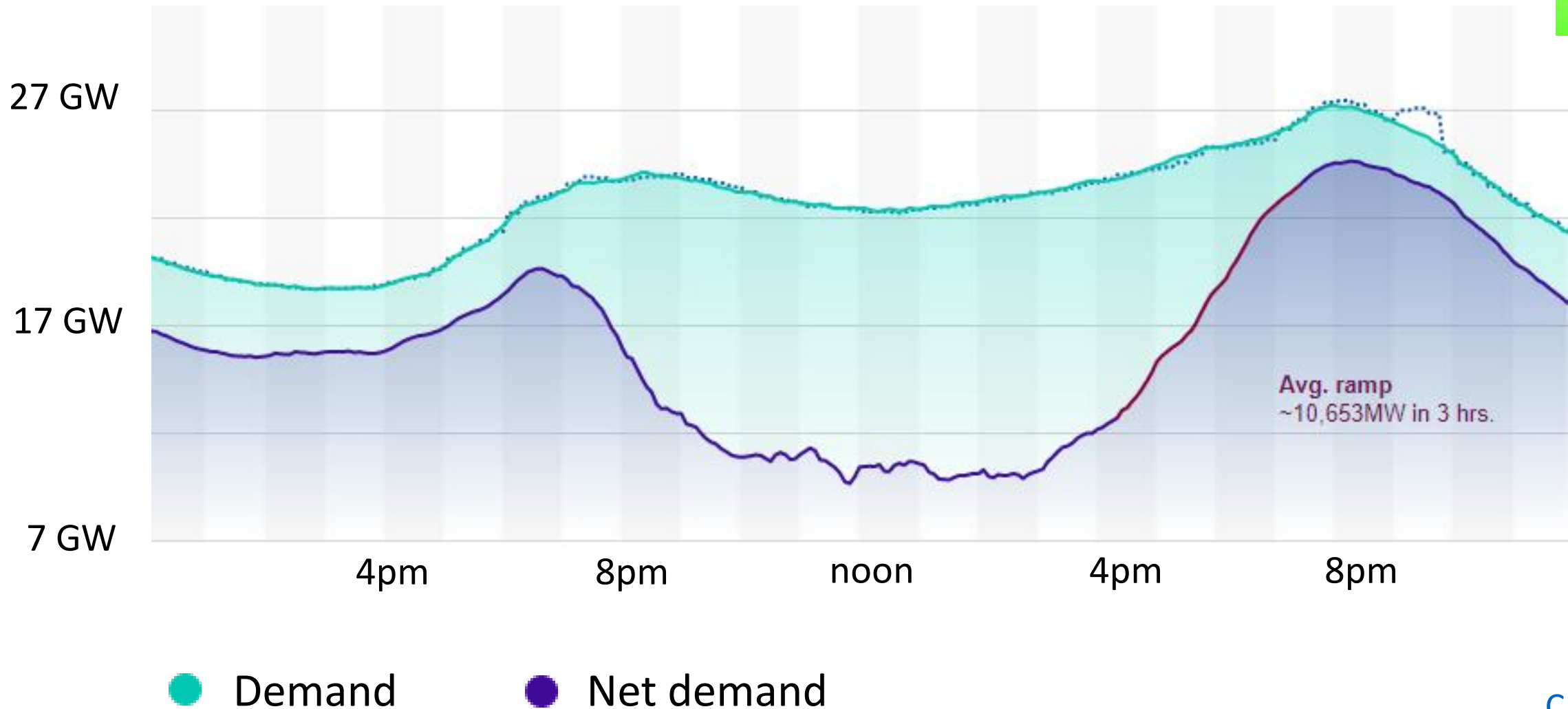
A Summer day in 2019 (August 15th)



● Demand ● Net demand

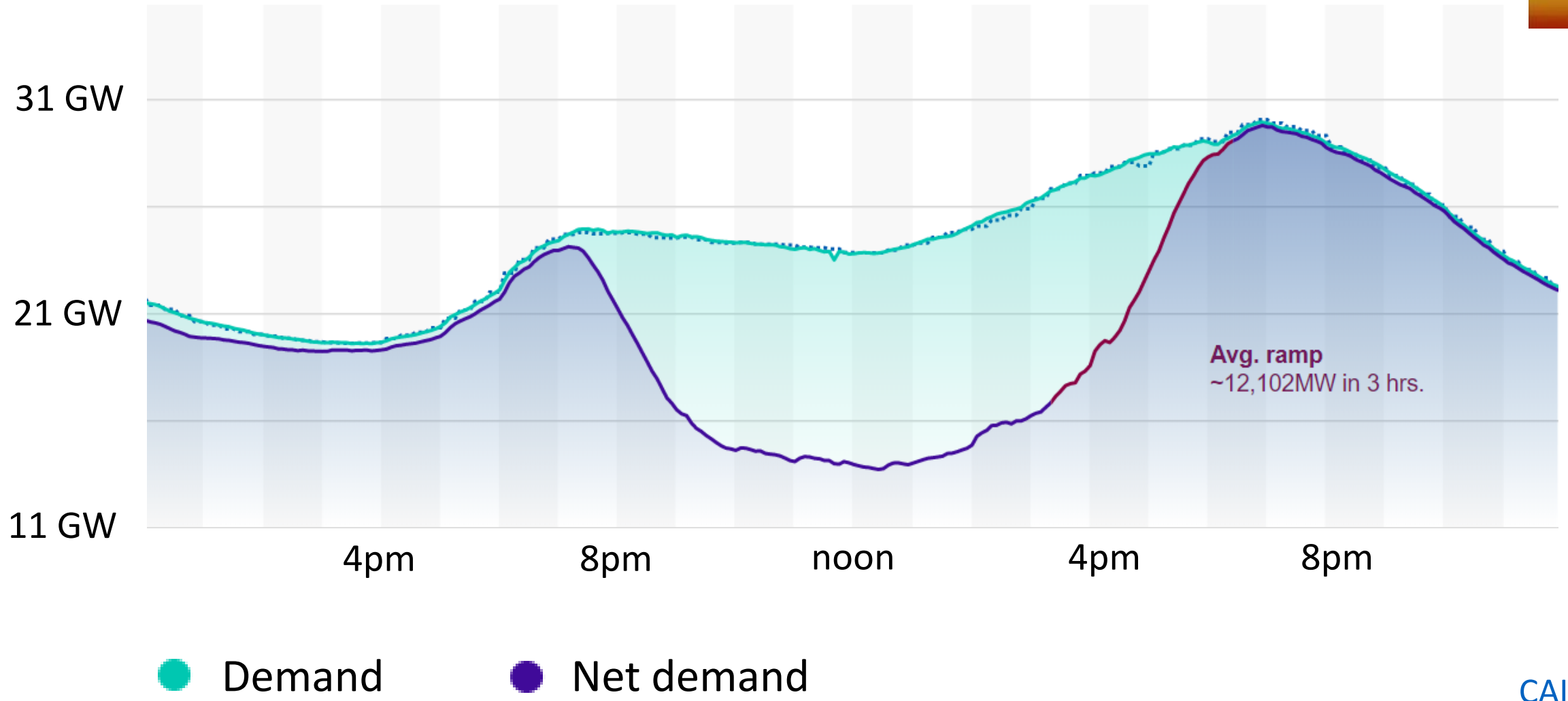


A Spring day in 2019 (April 15th)





A **Fall** day in 2019 (October 15th)



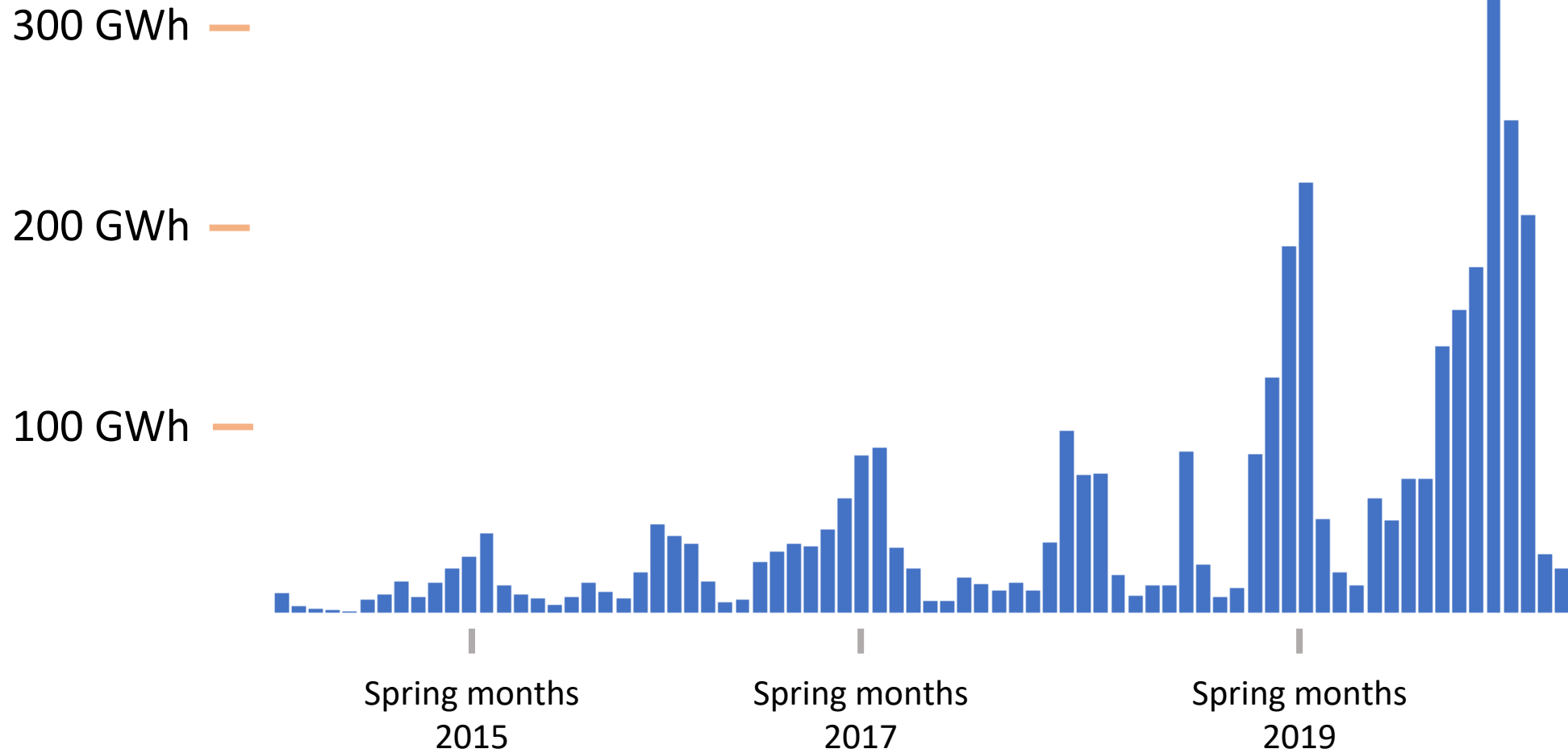
Energy curtailment

Energy curtailment

Reduction of a generation source's output, because the power isn't needed.



Utility-scale solar and wind curtailment



Data: [CAISO](#)

Utility-scale solar and wind curtailment



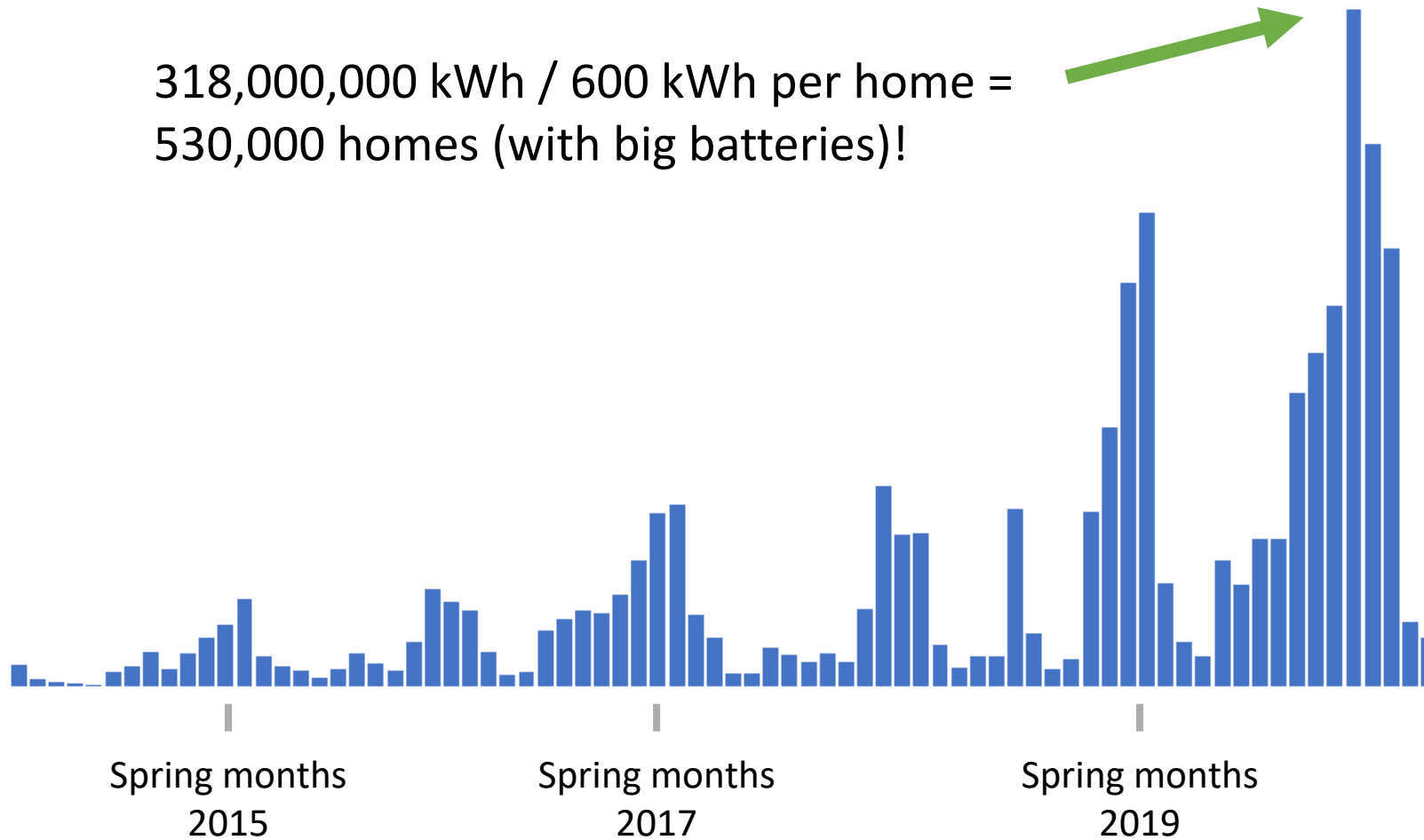
300 GWh

318,000,000 kWh / 600 kWh per home =
530,000 homes (with big batteries)!

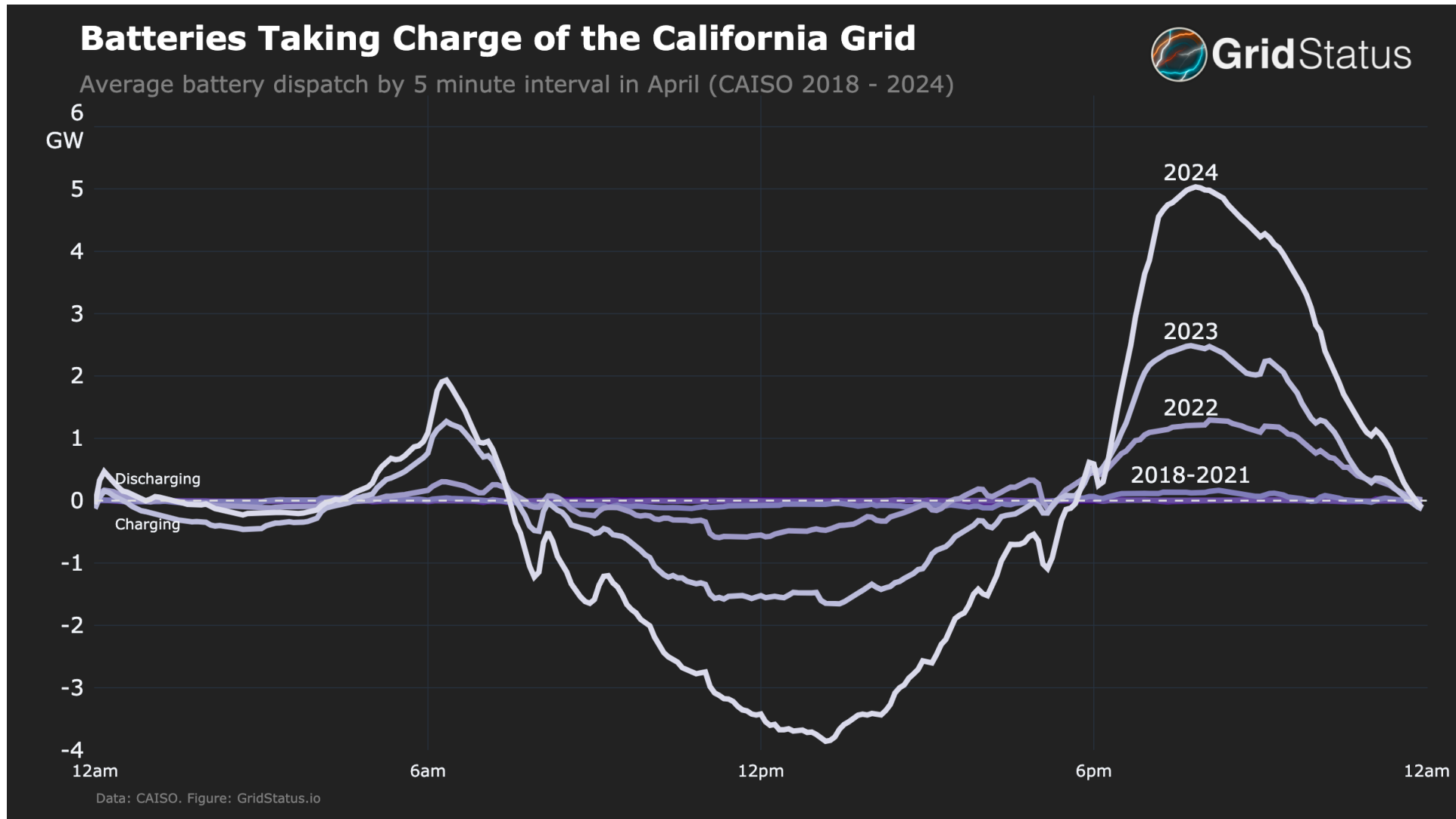


200 GWh

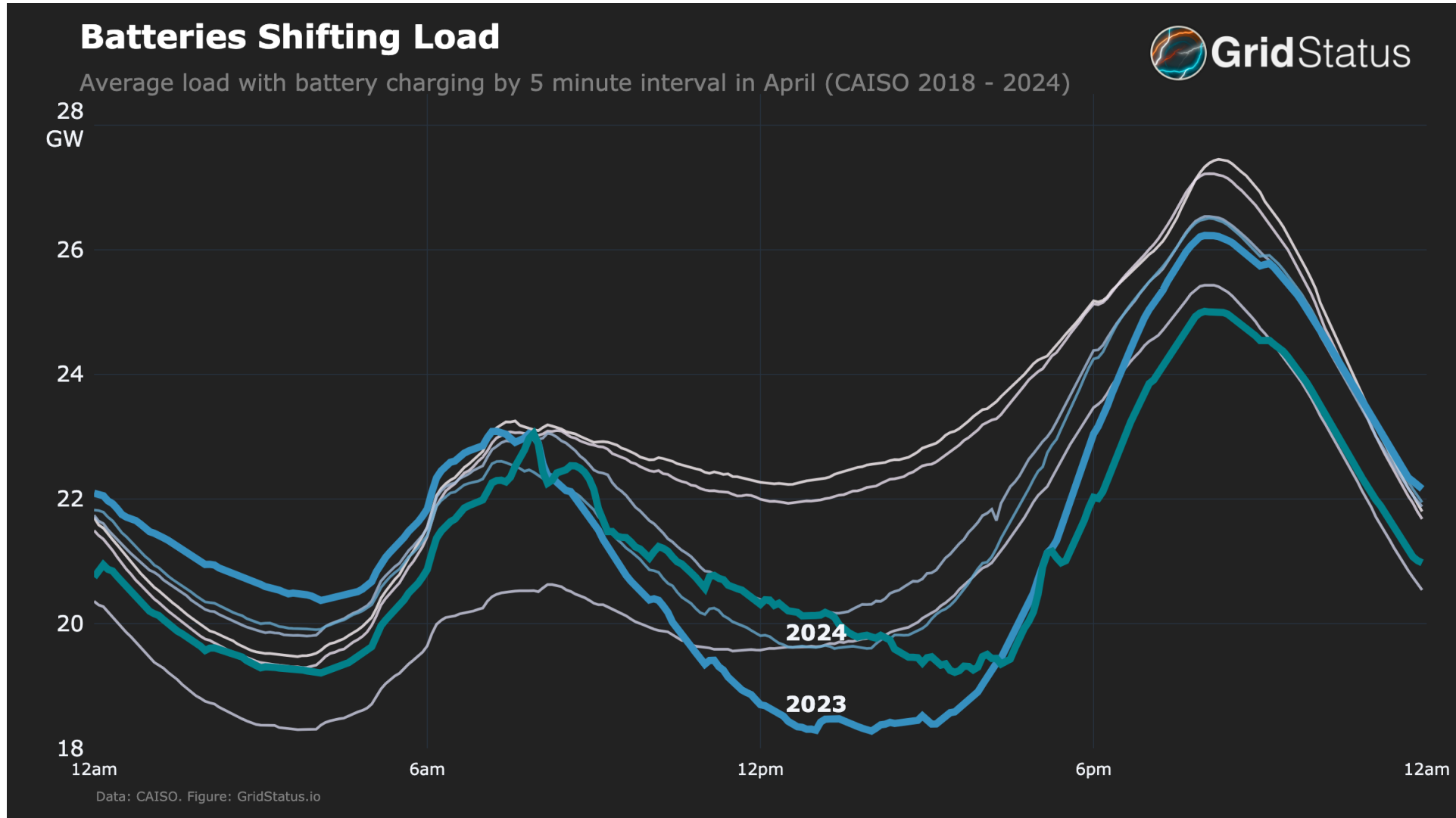
100 GWh



The duck curve and utility-scale ESS



The duck curve and utility-scale ESS



The demand charge

Fair payment for the electric grid

Consider the NASA Ames research center in Silicon Valley.

The center has arc jets that simulate atmospheric re-entry.

Largest load:

150 megawatts (MW) for 15 minutes

(equals the closest power plant's *entire peak capacity*)

Running for 15 minutes = 37,500 kWh.

Energy charge: \$4,050 total at 10.8¢ per kWh



Thermophysics facilities at Ames

Demand charge

A charge based on the maximum load measured during a billing period.

...Or the maximum load during a specific TOU window in that billing period.

The demand charge is a per-kilowatt charge.

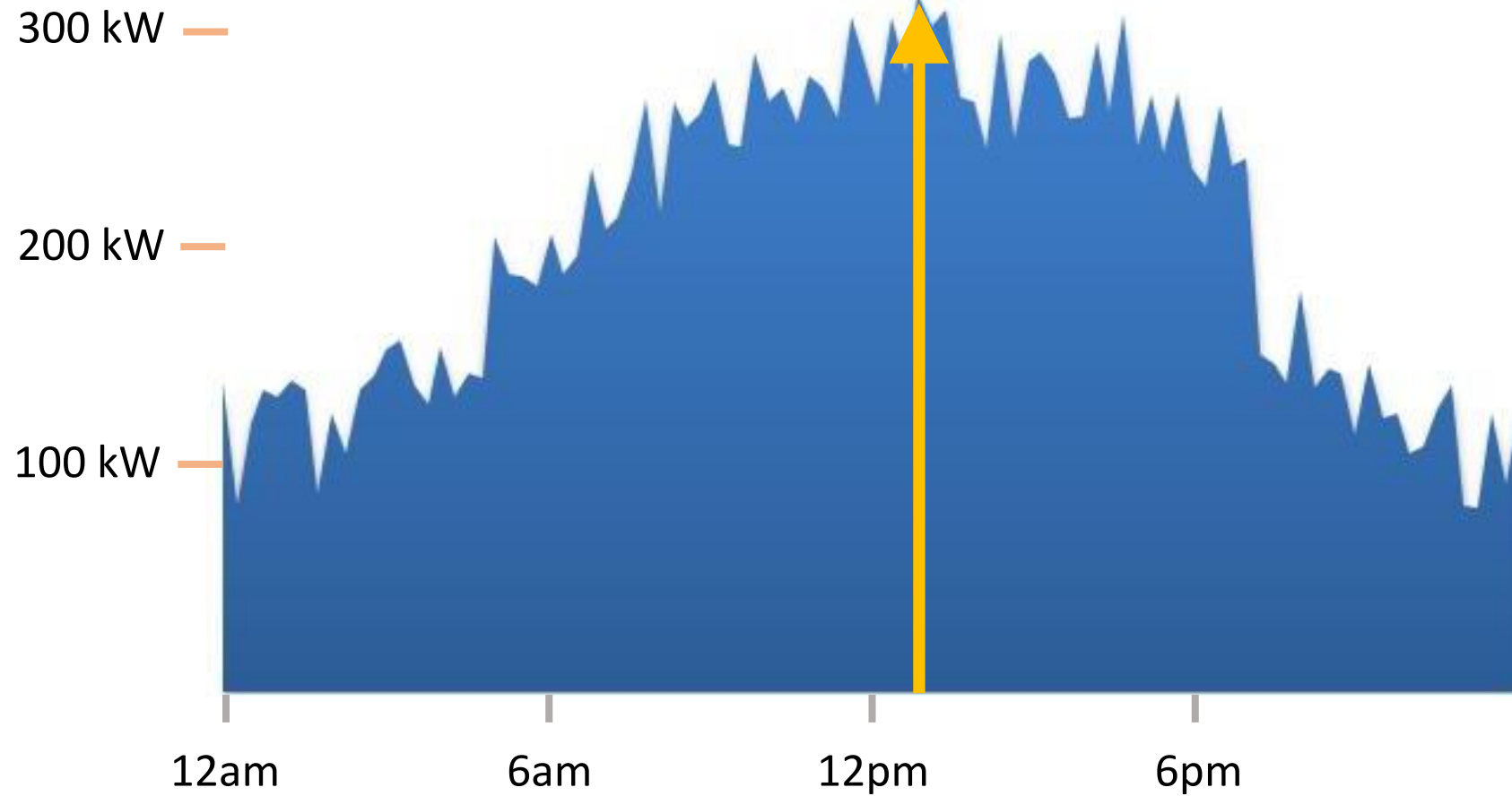
It's technically the maximum of all 15-minute load *averages* in the billing period or TOU window (or another short time interval).

Demand charge

The high-water mark.



Demand charge (\$ per kW)



Demand-charge exercise



15 kW AC unit



Billing-period demand charge?



Both on 24x7
\$10 per kW



10 kW heat pump



Billing-period demand charge?

(Assume no other loads on the electric meter)

Demand response

A utility customer reduces load in response to an ad-hoc utility request.

This is typically motivated by a strong price signal:

The energy price is discounted most of the time, in exchange for...

A very high energy price during demand-response “events.”



Motivates load reduction during events, to avoid the very high price.

Demand response

200 kW

150 kW

100 kW

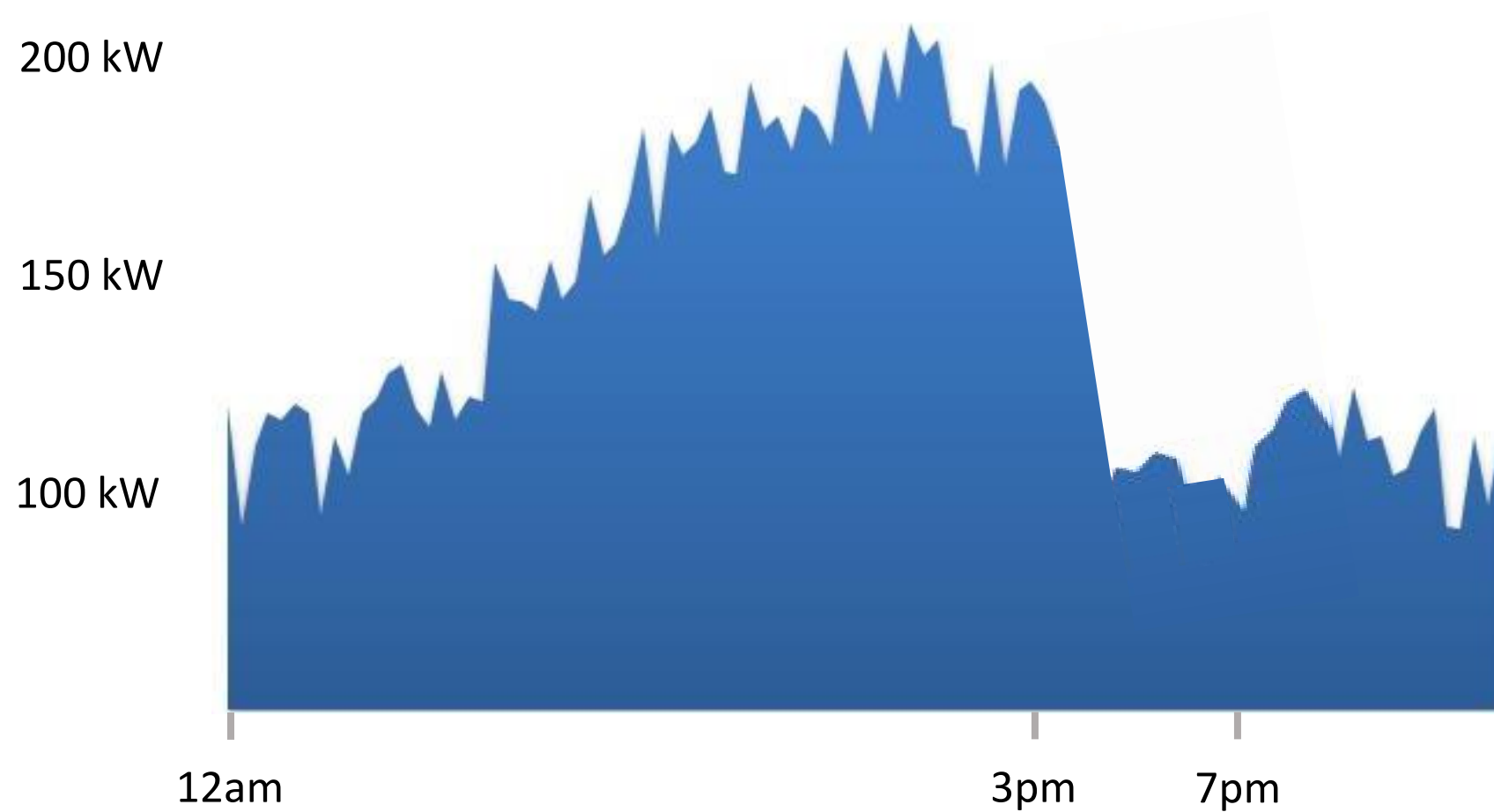
12am

3pm

7pm

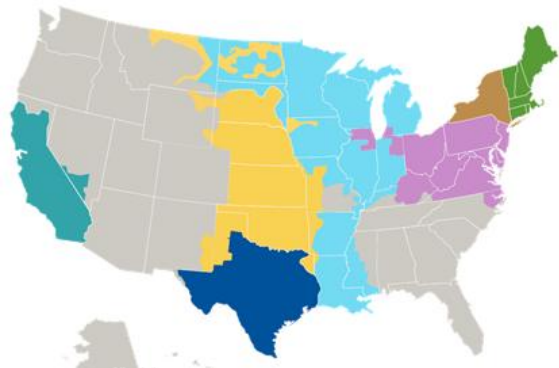
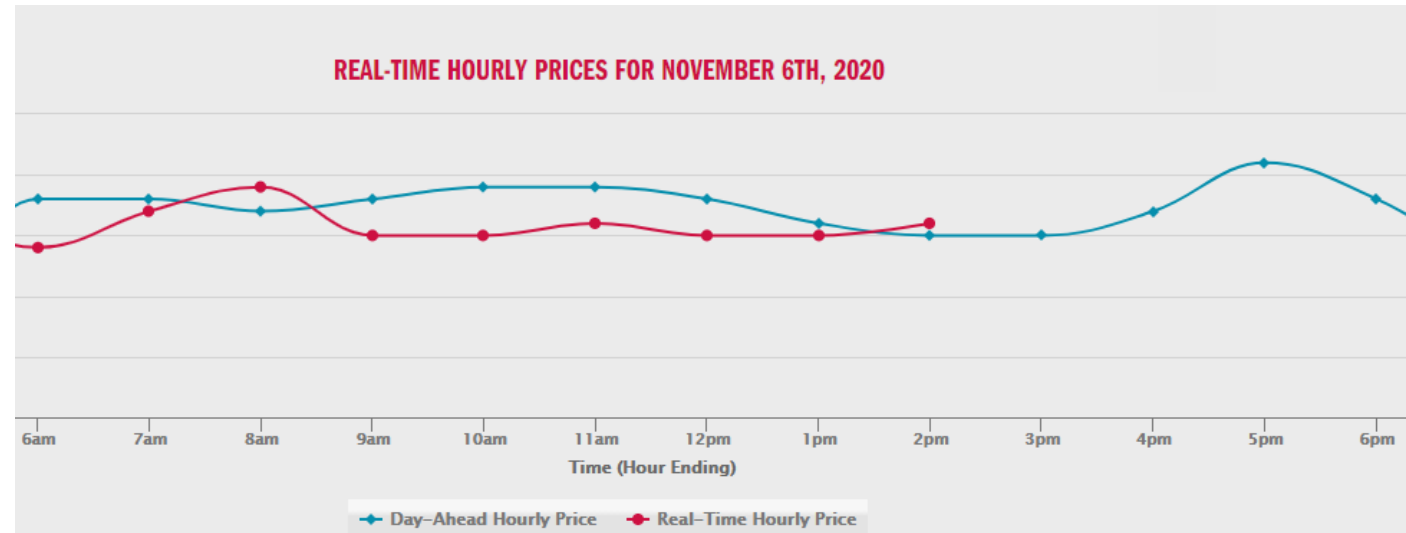


Demand response



Real-time pricing

Dynamic energy prices, that better reflect the cost to generate and deliver electricity (at any given time).



Wholesale markets

U.S. map: [EPA](#)

Real-time pricing



Manually respond to price signals
(Run around turning things off)



Automatically respond to price signals
(Let software respond in the background)

Flat utility charges

Fixed charge

A flat daily or monthly charge, required to receive electric service.



Fixed charge: \$10 per month



Fixed charge: \$10 per month

Customer charge
Service charge

Minimum charge

This charge only applies if it's above the energy charge.



Energy charge: \$120

Minimum charge: \$10

Utility bill: \$120



Energy charge: \$5

Minimum charge: \$10

Utility bill: \$10

Beware high fixed charges

New fixed charges can end a local SPS market overnight.



PV charge

A monthly fixed charge per PV kilowatt installed.

Beware high PV-customer fixed charges

A small California utility has a \$65/month charge for new PV customers.



California zero-export PV charge

The “departing load” charge.



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