

Potential for Adequate Wintertime Renewable Electricity in California

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Overview

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Our big question:

What roles will storage play in decarbonizing California?

Today's smaller question:

How might generation technologies change the needed storage? (Focus on winter)

Methodology:

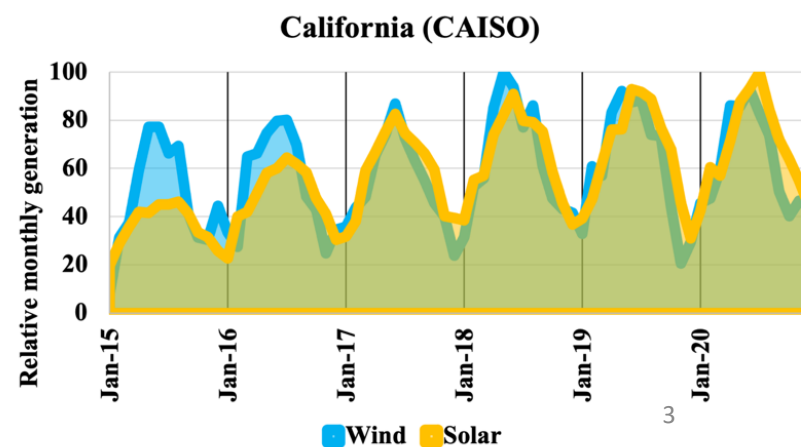
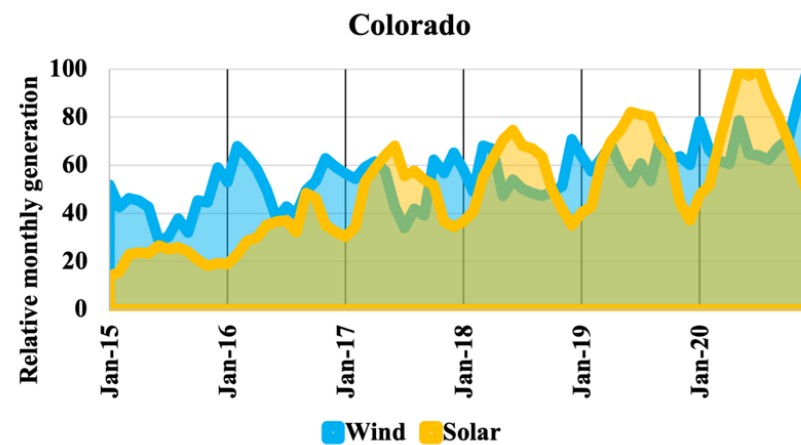
Energy balance calculations now will inform cost optimization calculations later

Key findings:

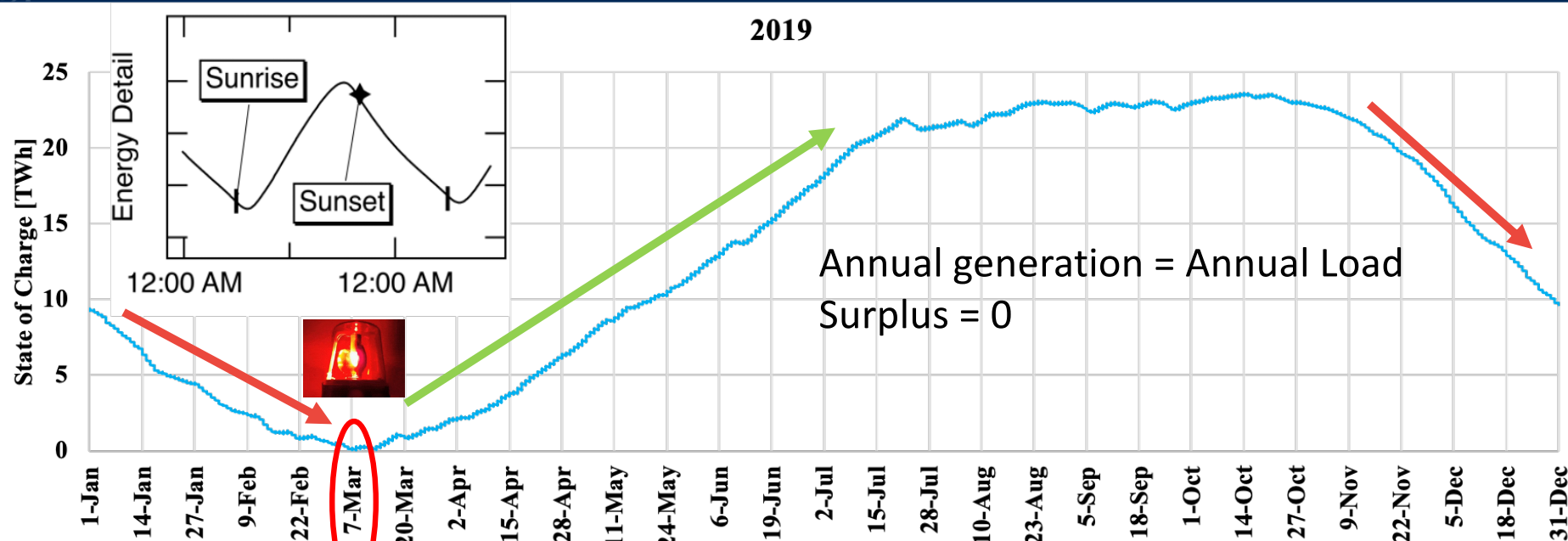
Identified two possibilities that we want to include in the cost optimization modeling

California's winter challenge

- Many places generate lots of wind electricity in the winter
1. California has poor wind resource
 2. California wind generates more electricity in summer than winter



May run low on stored energy in winter



- Storage minimum charge in January to March.
- Winter will be the challenging season.





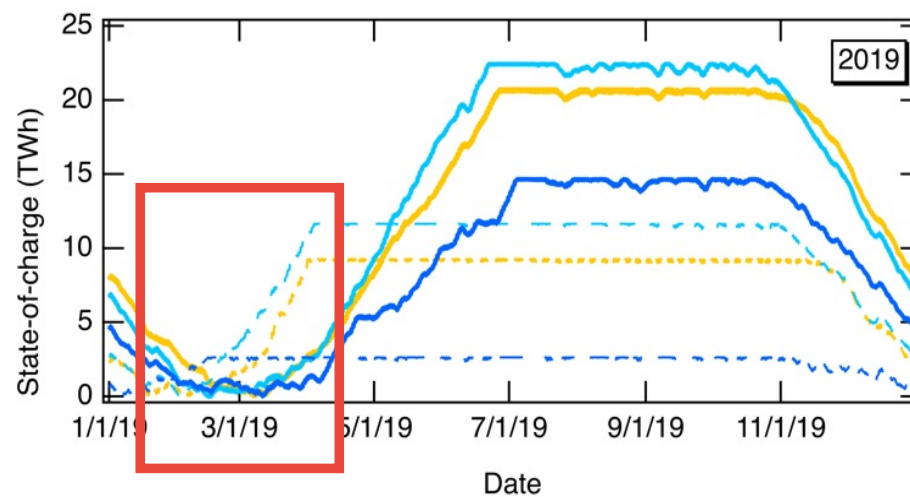
What are our generation options?

- Solar and wind are primary resources
 - Hydro is unreliable; Geothermal and Biomass are small
 - Imports are decreasing for the highest loads
 - This effect may get worse as neighbors decarbonize
- Last month we talked about:
 - Offshore wind may help
 - Geothermal or biomass are great, but small
 - All combinations of today's solar and wind result in wintertime problem

Scenarios to achieve zero-carbon grid

- All plausible scenarios conclude that winter will be the time we are most likely to run low on energy

	Ratio to load: 105%	135%
Breakdown of added power		
50% solar + 50% onshore wind		
100% Solar		
50% solar + 50% offshore wind		





Conclusion

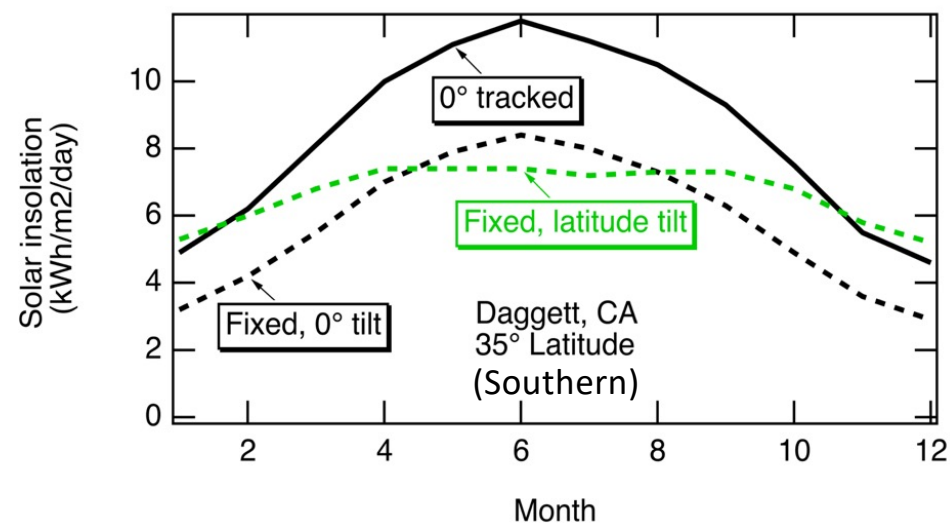
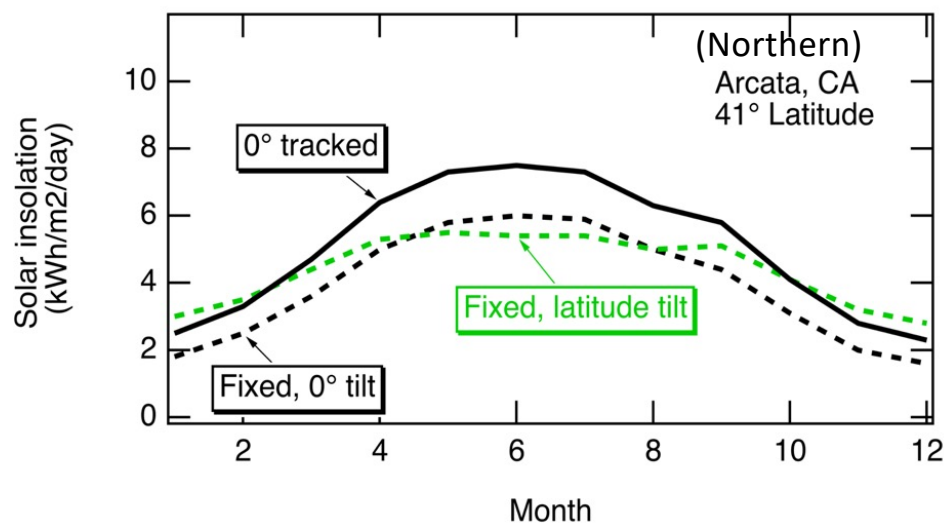
- Winter will be the challenging season for a solar-dominated grid in California.
- Imports are becoming increasingly questionable
- Next: how might we obtain more electricity in winter?
 - Solar (location and orientation)
 - Wind (where does the wind blow during the winter?)



Modeling of solar

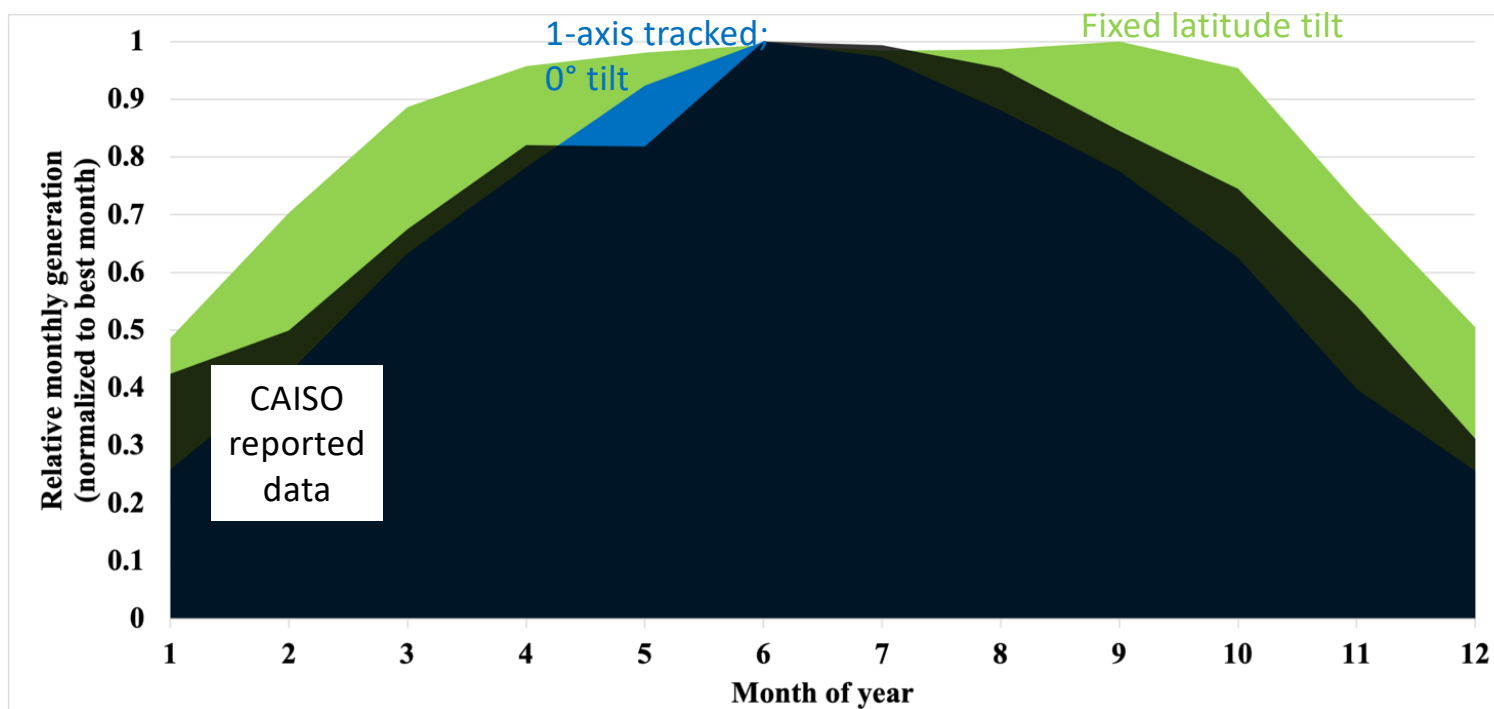
- RESOLVE 2018 RSP allowed build of 22 solar resources scattered geographically
- Generation profiles for these assumed 1-axis tracking with 0° tilt, reflecting most common configuration today
- What if we changed the orientation to latitude tilt?

Seasonal solar resource by orientation



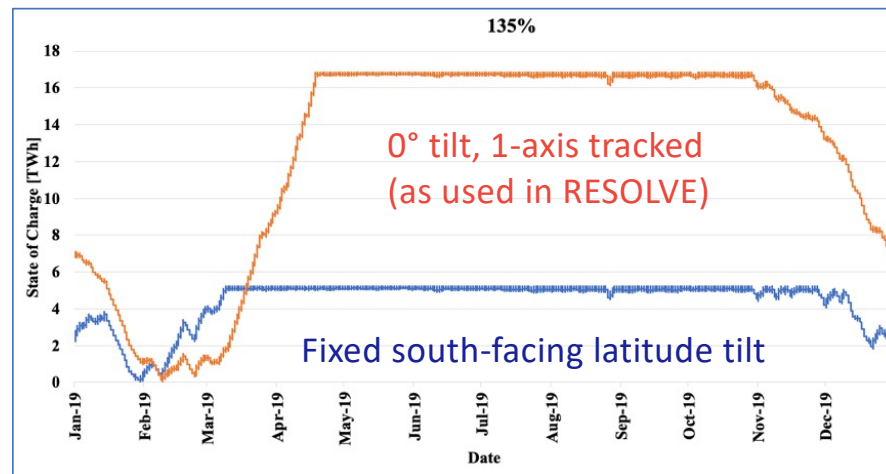
South-facing tilt is substantially better in winter

Seasonal solar generation by orientation



South-facing tilt may be substantially better than current data in winter

Solar orientation effect on seasonal storage



South-facing tilt reduces needed seasonal storage

Conclusion: should include some solar resources with different orientations

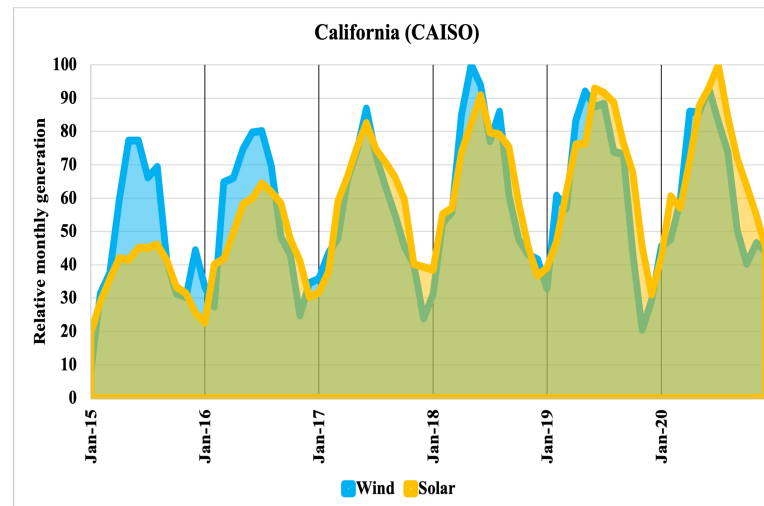
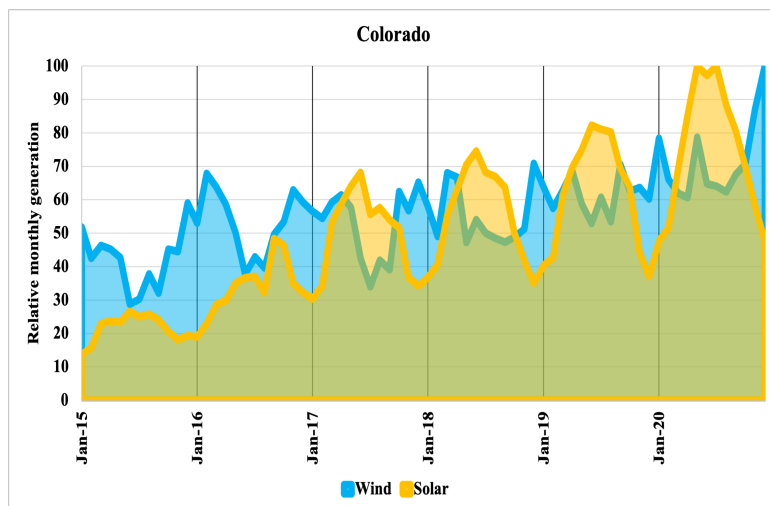
(note: diurnal storage may also be affected by orientation)

Options for wind

Zabir Mahmud will present section on wind options



Background



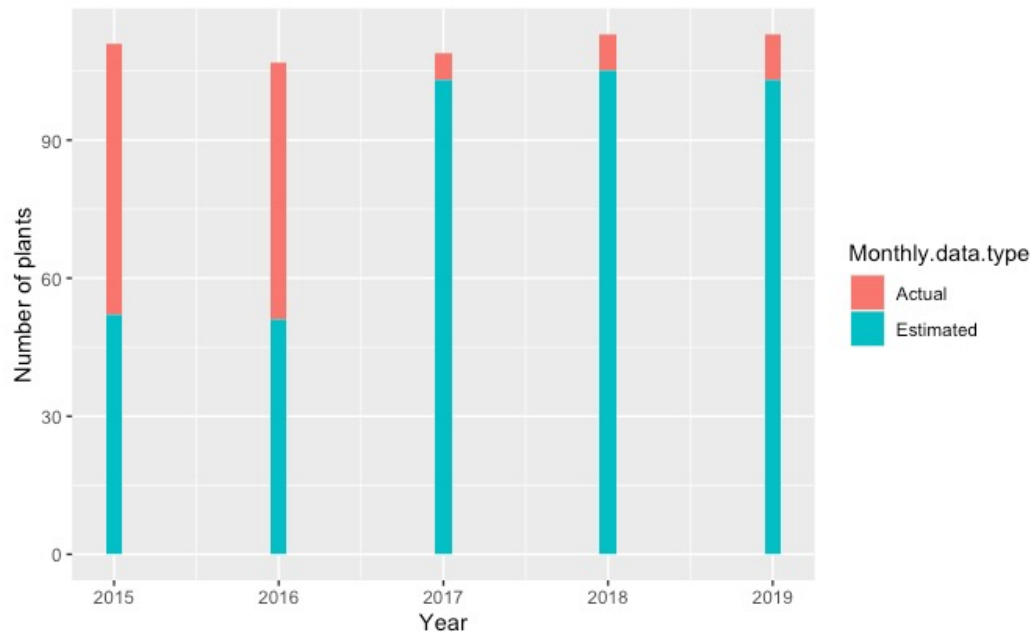
- Colorado shows complementary behavior while California does not.
- We could not follow EIA data for these calculations, instead we used CEC data.

* https://ww2.energy.ca.gov/almanac/electricity_data/web_qfer/index cms.php

* <https://www.eia.gov/electricity/data/eia860/>

* <https://www.eia.gov/electricity/data/eia923/>

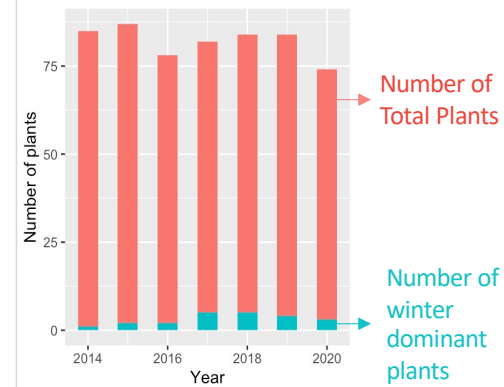
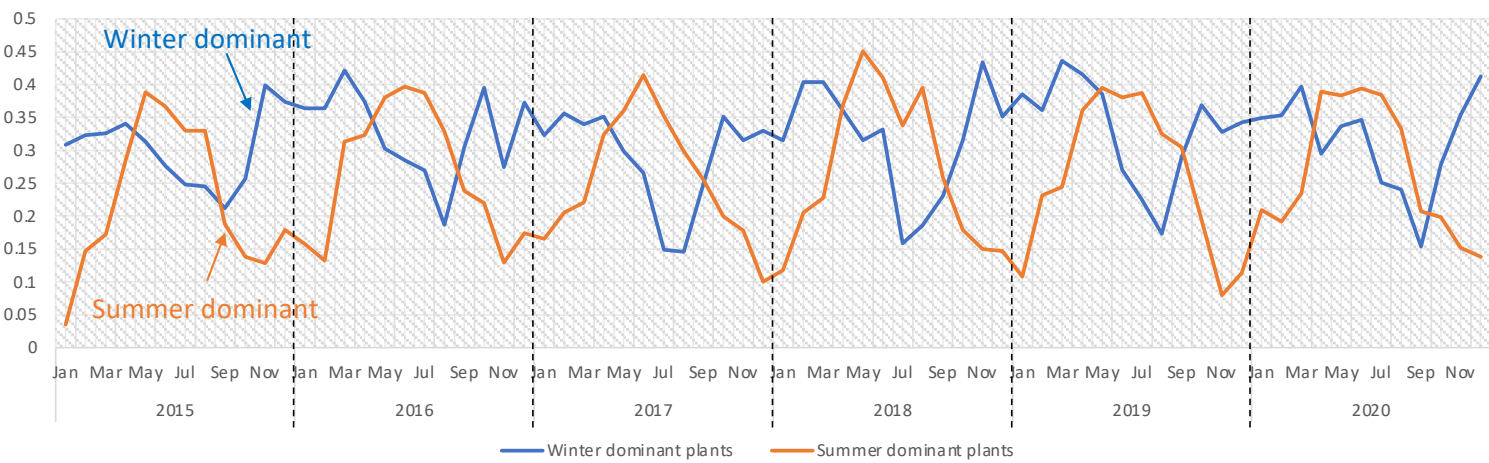
Why CAISO data instead of EIA??



- EIA 923 data accurately reflect comparable number of plants performance before 2017, majority of reports were “real” data; now > 90% are “estimated”

Existing Wind Farms Reported Data

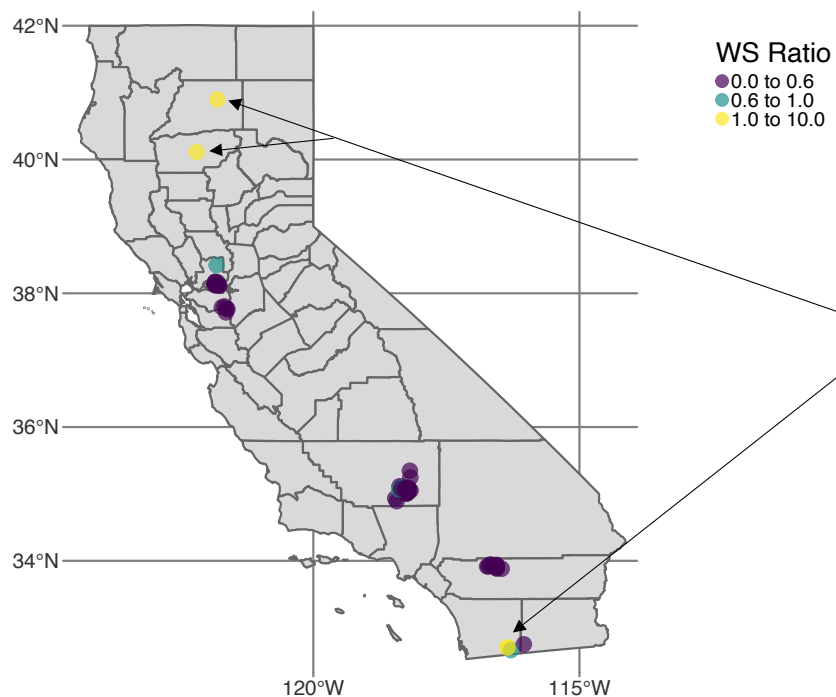
MONTHLY CAPACITY FACTOR



Some have peaks in summer, and some are peaking in winter though the number of winter dominant plants is very few

* https://ww2.energy.ca.gov/almanac/electricity_data/web_qfer/index cms.php
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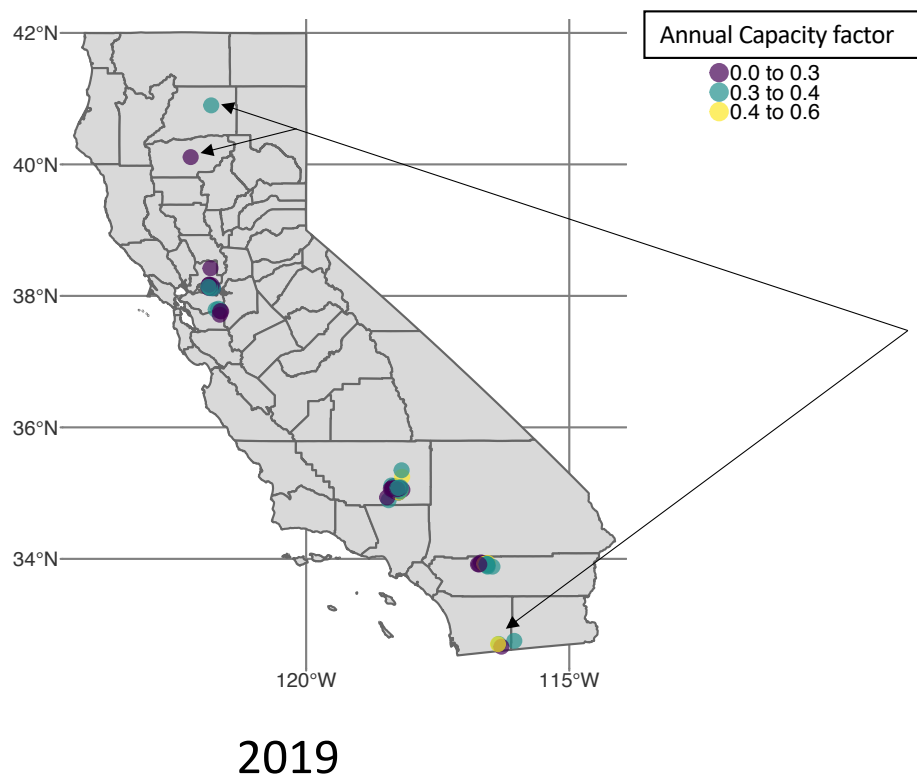
Reported W/S ratio of existing CA wind plants



2019

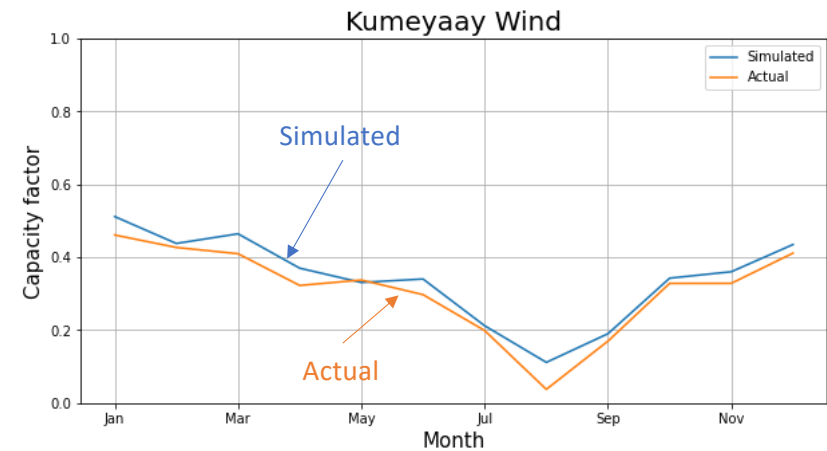
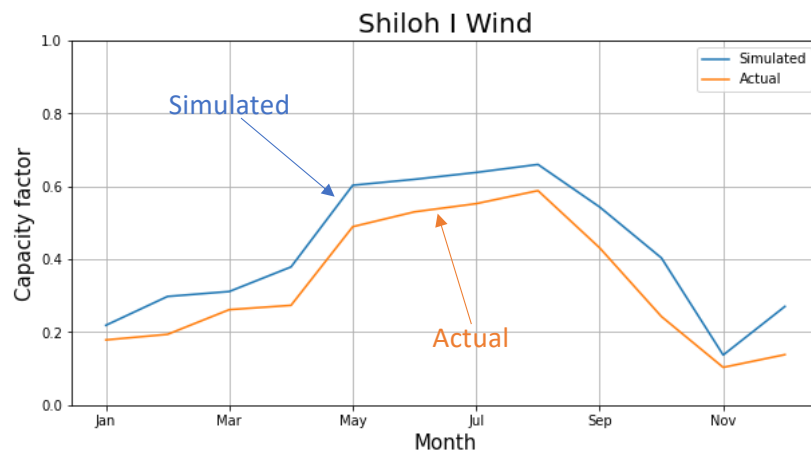
- $W/S \text{ ratio} = \frac{\text{Generation}(\text{Dec}+\text{Jan}+\text{Feb})}{\text{Generation}(\text{Jun}+\text{Jul}+\text{Aug})}$
- Existing winter-dominant wind plants tend to be found in northern California or near the border with Mexico

Reported Annual CF of existing CA wind plants



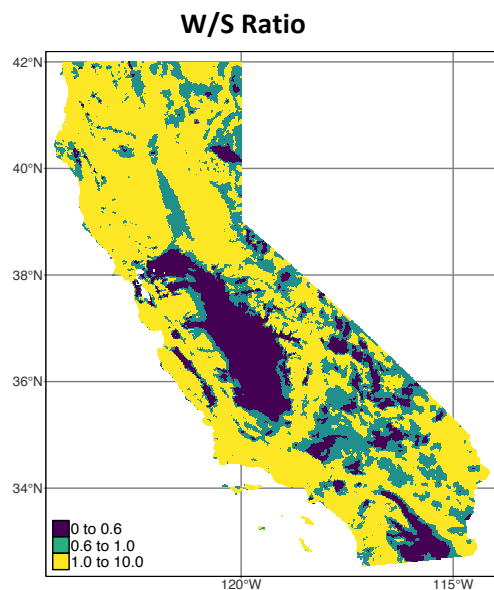
- Based on multiple years of data, the output from existing winter dominant wind is comparable to the others

Validation of the Simulation for Seasonal Effects

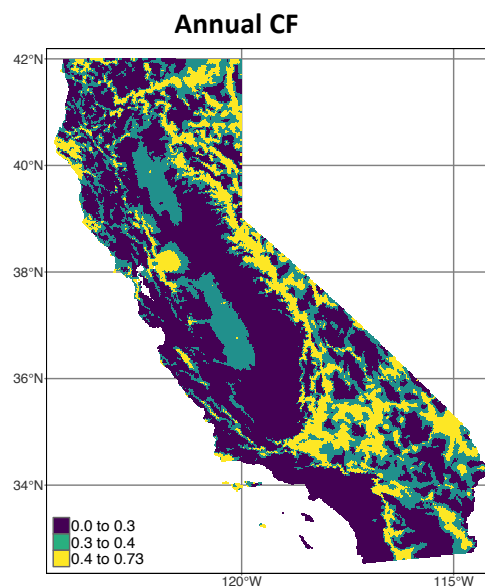


- Our simulation shape follows the actual generation profile
- For the simulation, we used NREL Wind Toolkit data

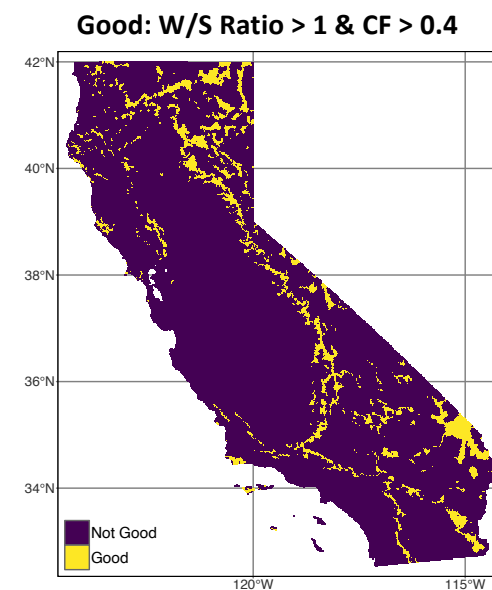
Potential Wind Sites for CA



Yellow region : winter dominant sites



Yellow region : capacity factor greater than 40%



Follow the yellow region for potential winter dominant high capacity factor wind sites



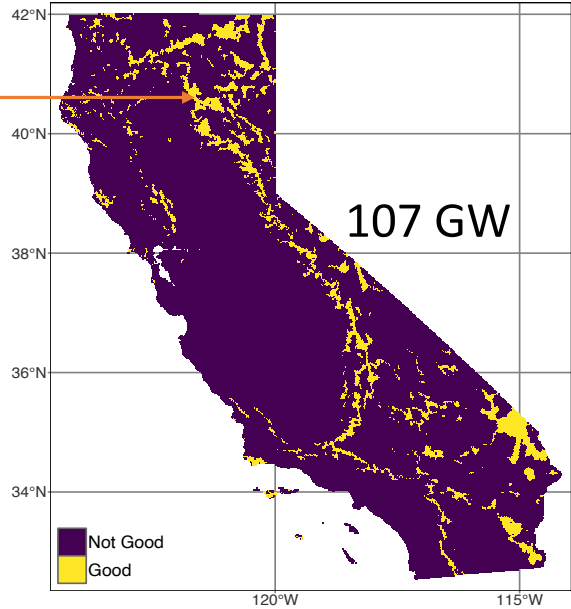
California Protected Areas Database (CPAD)

- CPAD is a GIS dataset depicting lands that are protected and it includes:
 - national/state/regional parks,
 - forests, preserves, and wildlife areas,
 - large and small urban parks,
 - land trust preserves, and
 - special district open space lands (watershed, recreation, etc.)
- We also excluded the regions where the slope is greater than 20 degree.

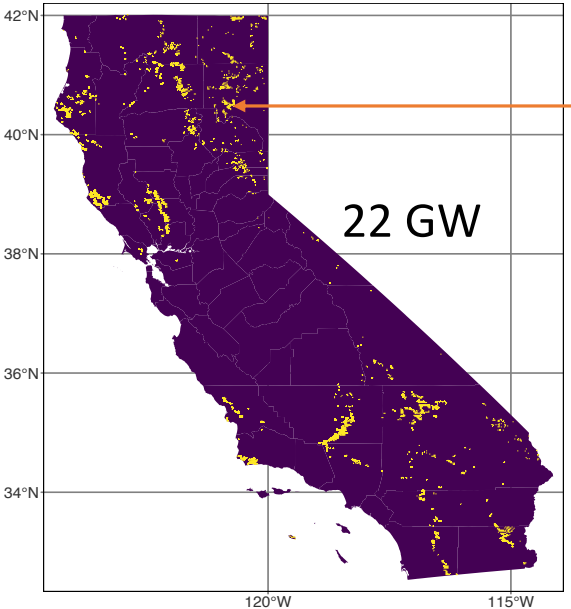


CA Wind Potential Map

Yellow regions:
Potential Wind
Sites **without**
considering
exclusion zones



Yellow regions:
Potential Wind
Sites **after**
considering
exclusion zones

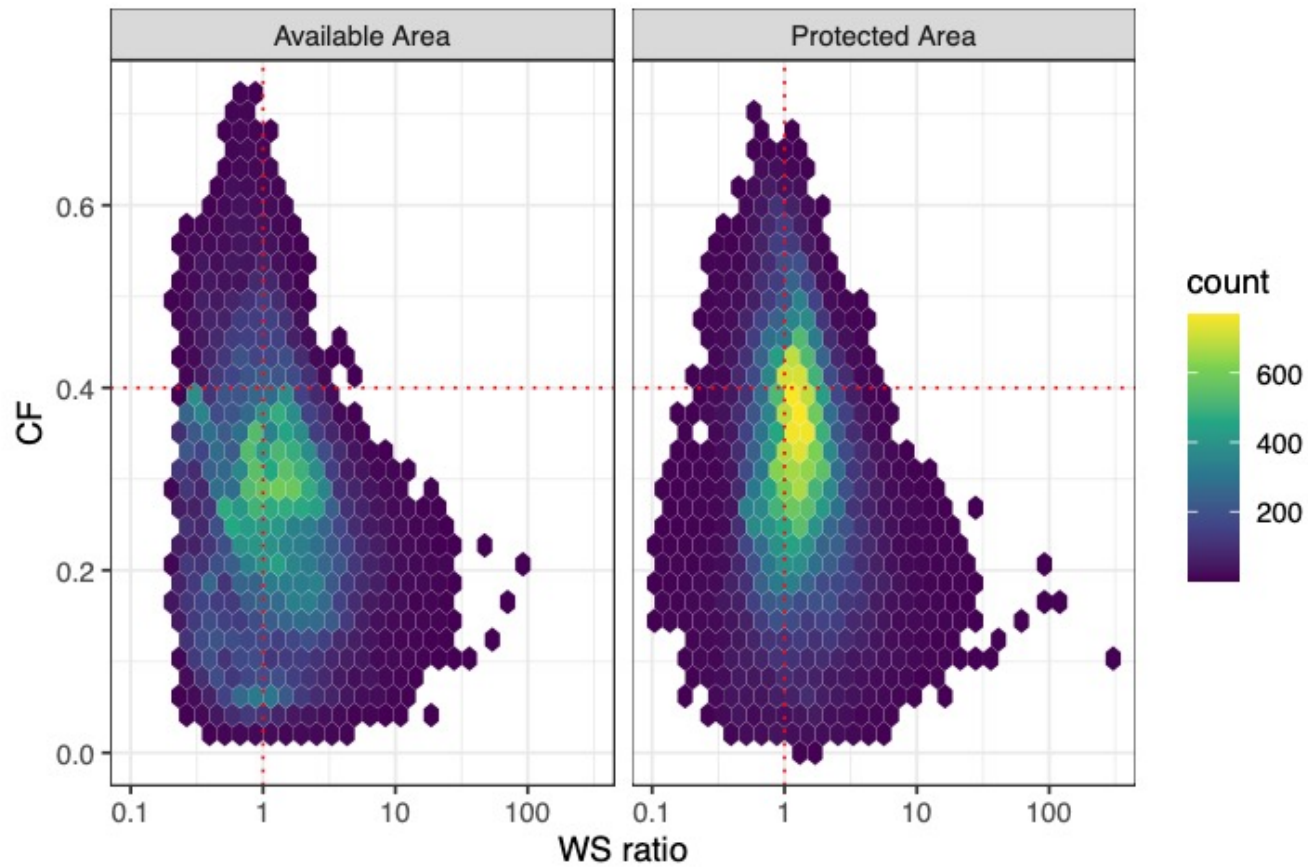




Conclusions

- Almost 60% of the state has stronger wind resources in winter than in summer
estimating around 107 GW of potential
- Exclusion of protected areas reduces the potential to 22 GW

Statistics for wind simulations in California

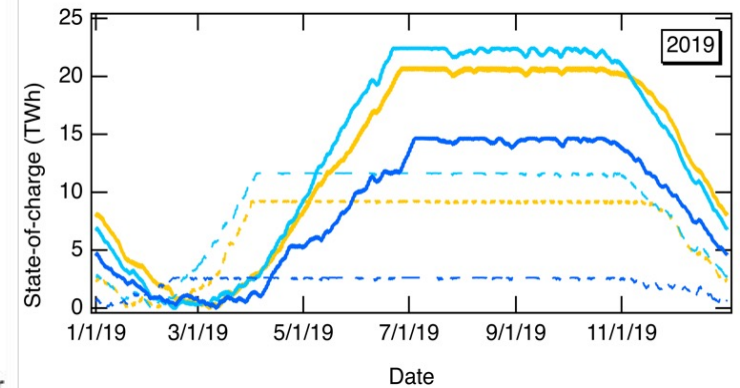
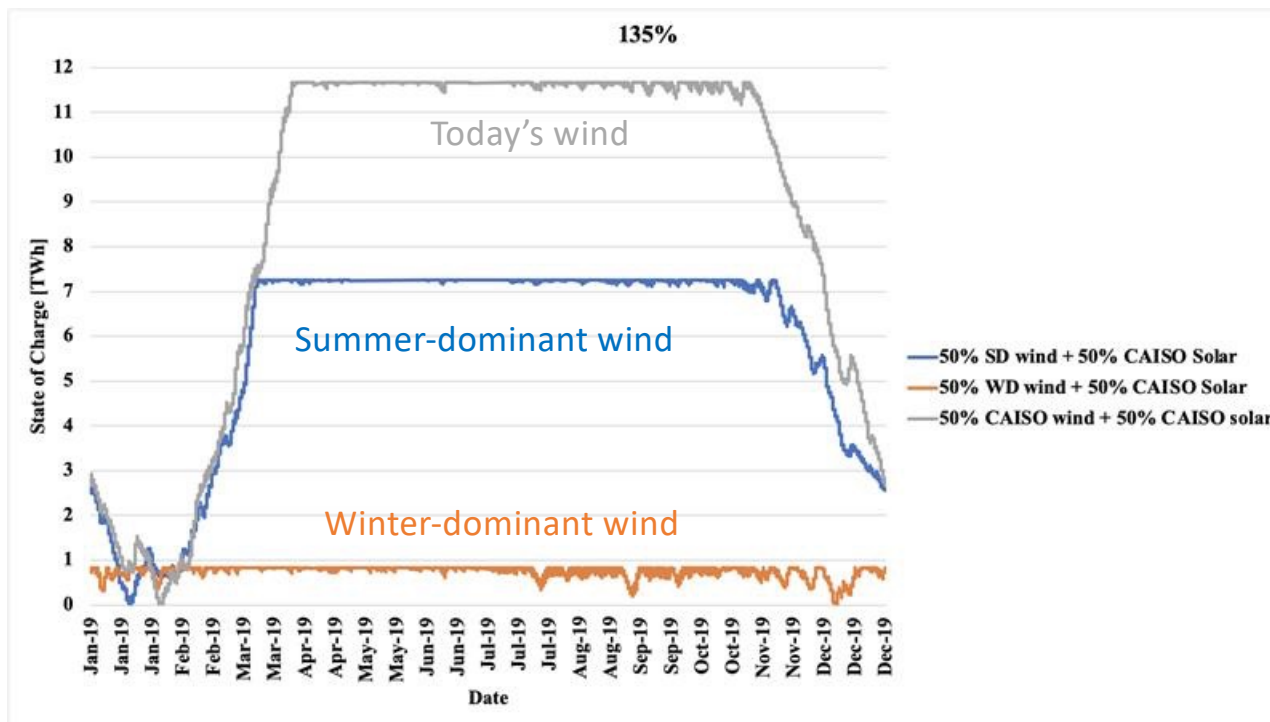




Conclusions

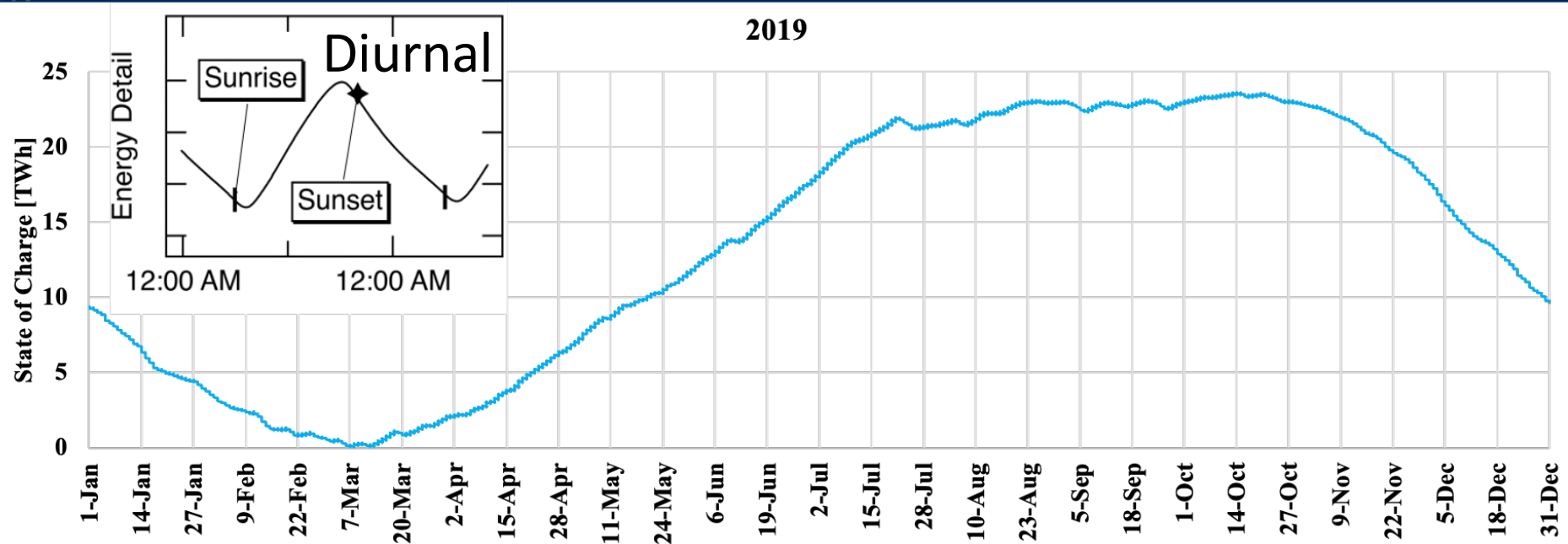
- California wind comes in multiple flavors
- What effect will the flavor of the wind have on our need for storage?

What effect would winter-dominant wind have?



Using winter dominant wind can GREATLY reduce seasonal storage needs

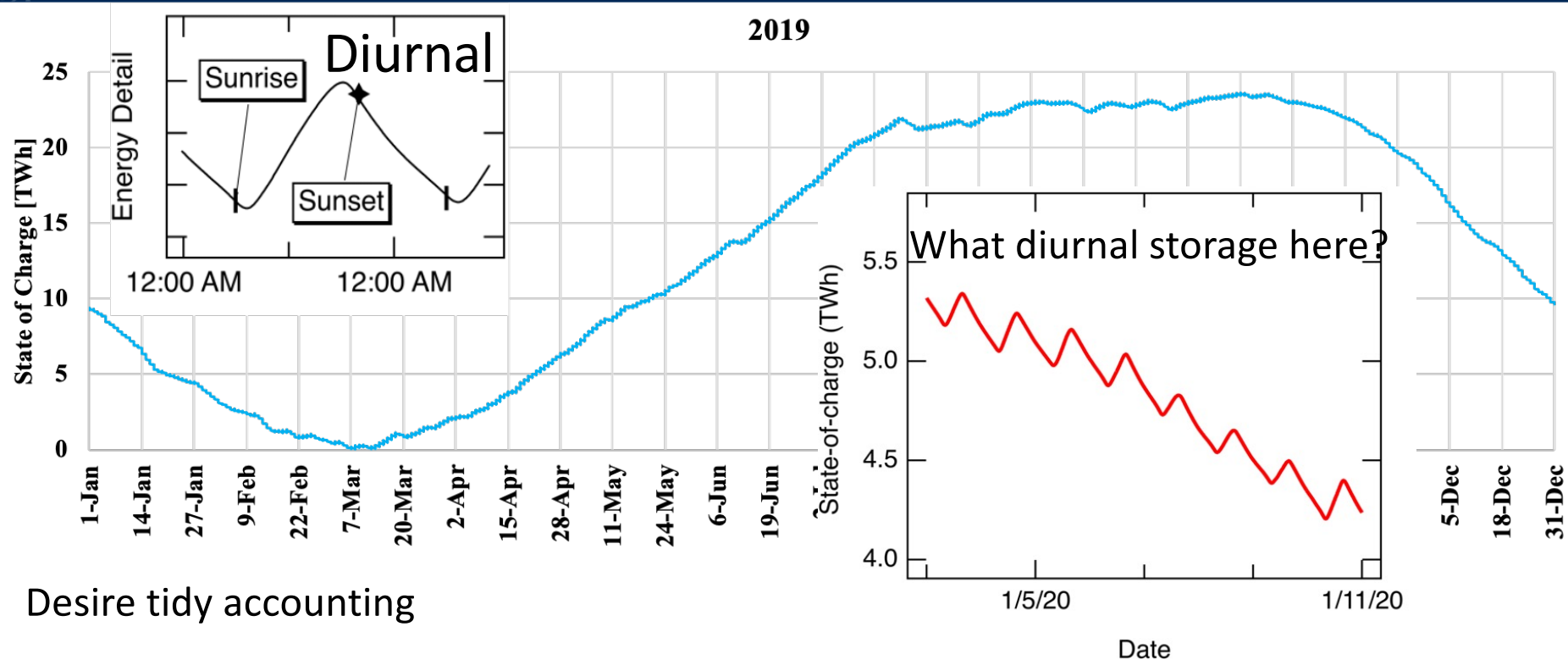
Energy-balance study of all storage types



Graph shows seasonal effects, but also shows diurnal and cross-day detail

How can we analyze the diurnal and cross day storage?

Energy-balance study of all storage types



Desire tidy accounting

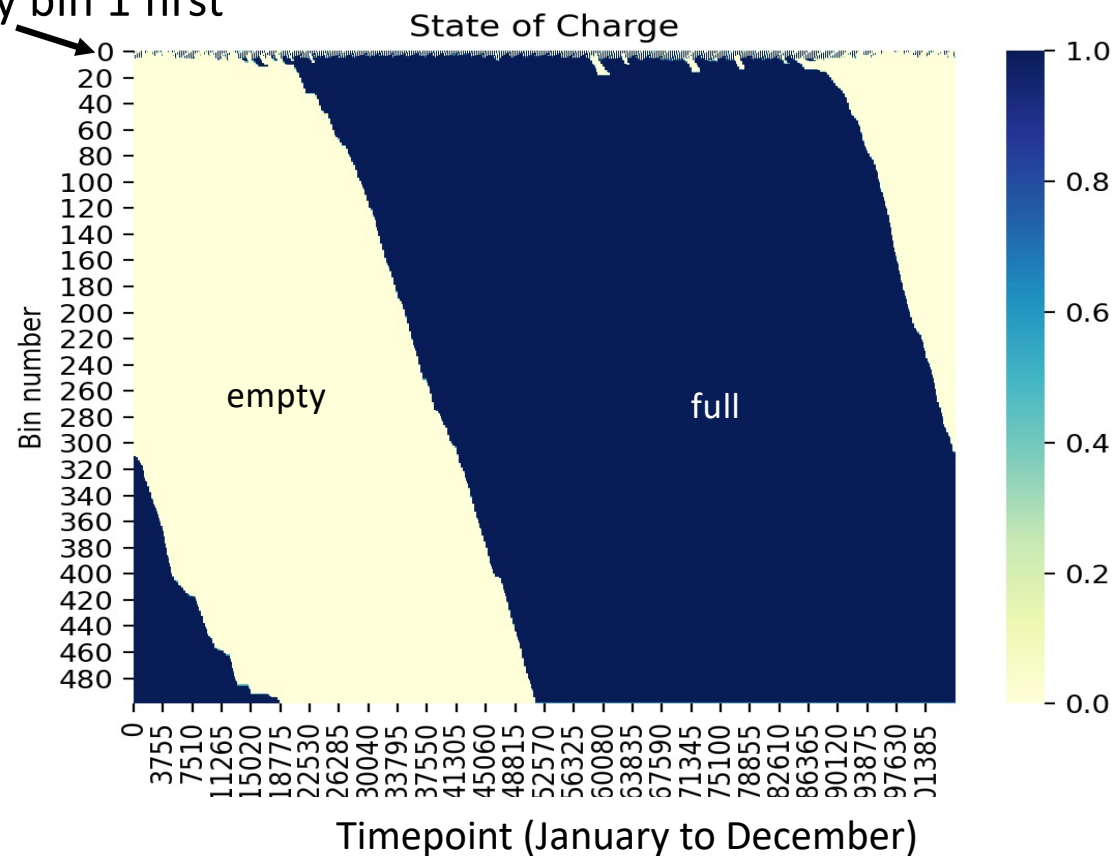
We may have some storage that is used first

Create set of storage assets with hierarchy as to the order for dis/charging

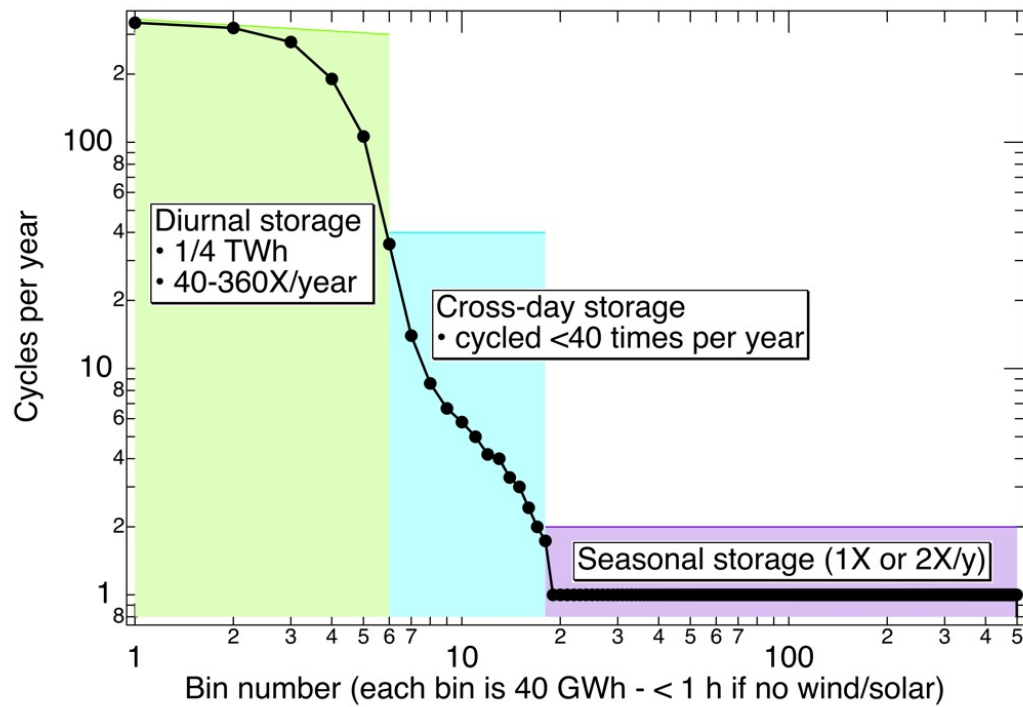
Use hierarchical storage reservoir

Always fill or empty bin 1 first

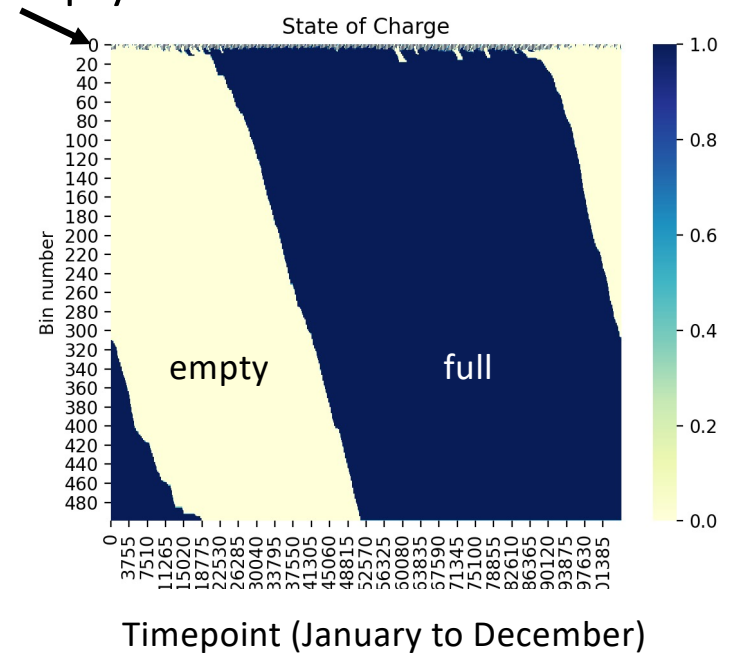
- Create as many bins as needed
- Fill and empty according to hierarchy
- Calculate statistics for each storage bin



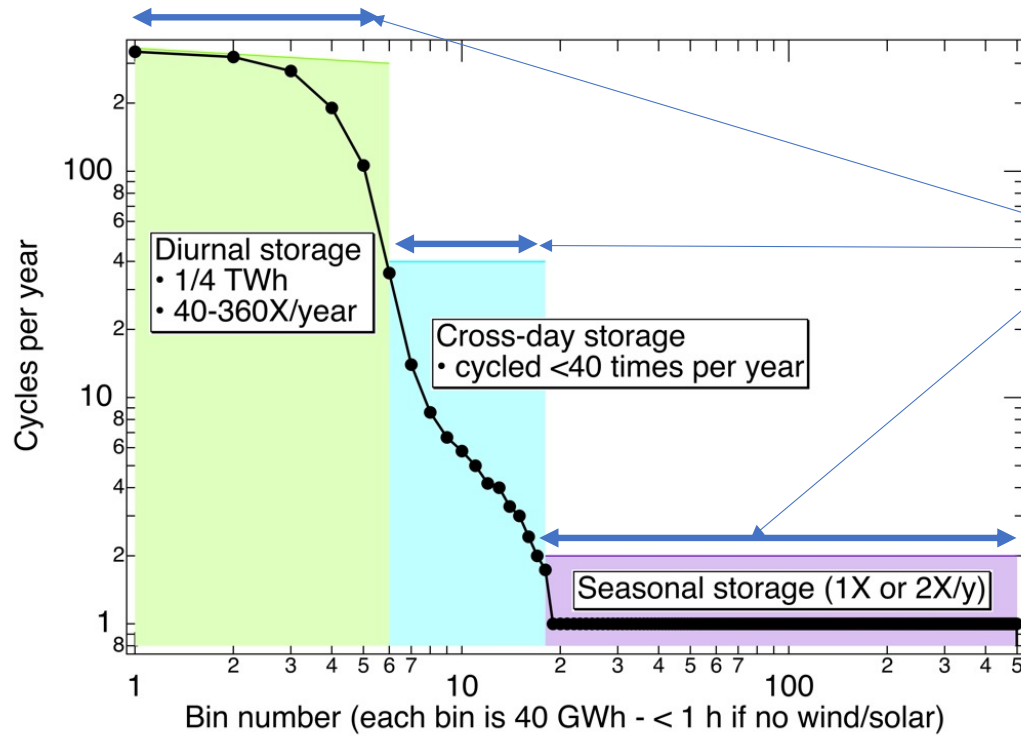
Hierarchical storage facilitates statistics



Always fill or empty bin 1 first

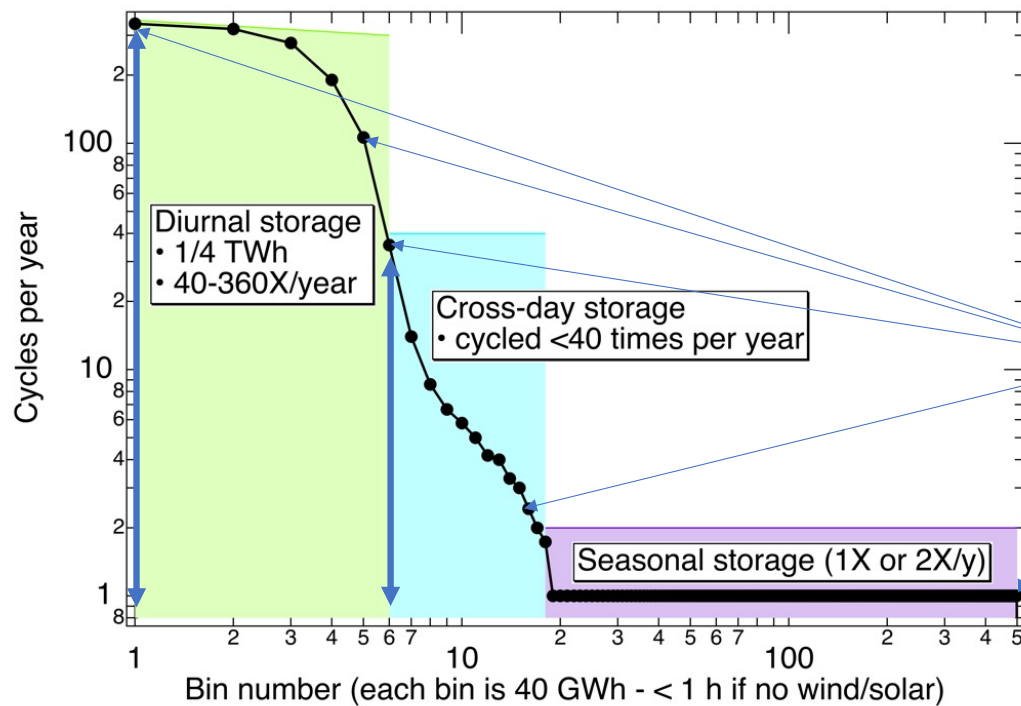


Hierarchical storage facilitates statistics



The x-axis indicates the amount (GWh) of storage to be installed (capital cost)

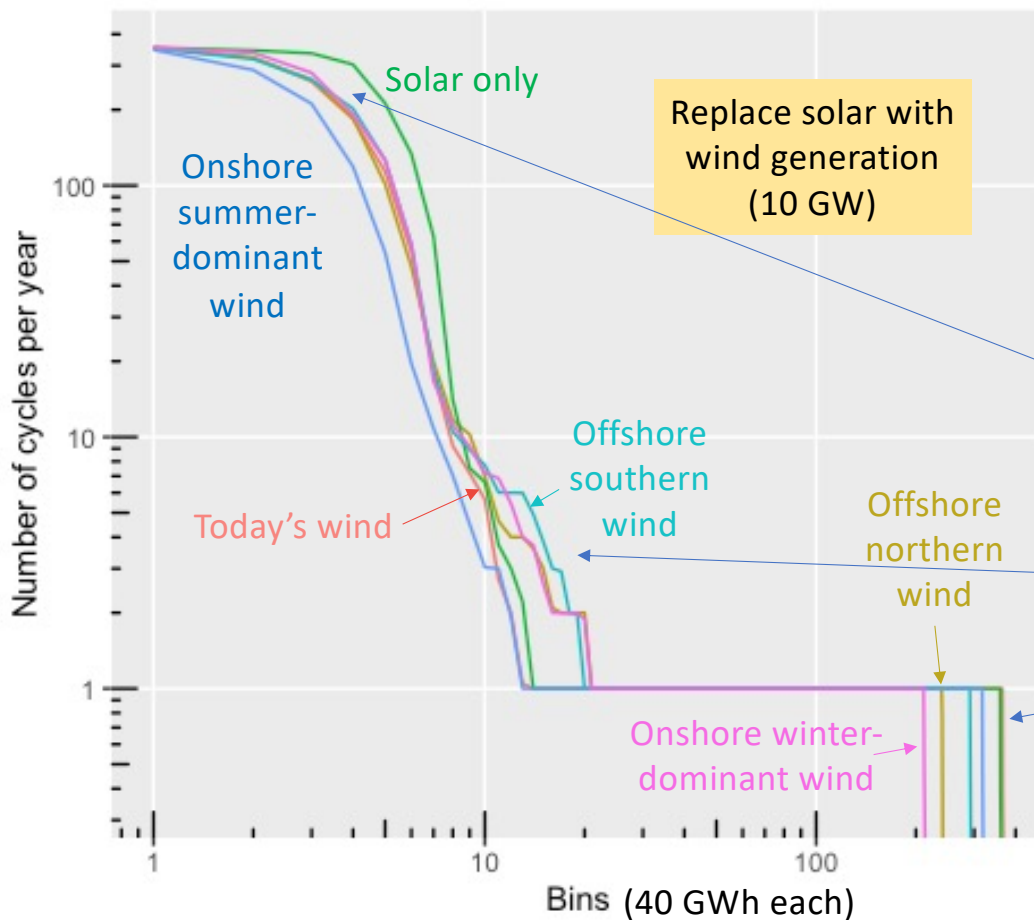
Hierarchical storage facilitates statistics



The x-axis indicates the amount (GWh) of storage to be installed (capital cost)

The y-axis indicates the number of times it is used (operating cost and income)

Effects of flavor of wind on storage requirements

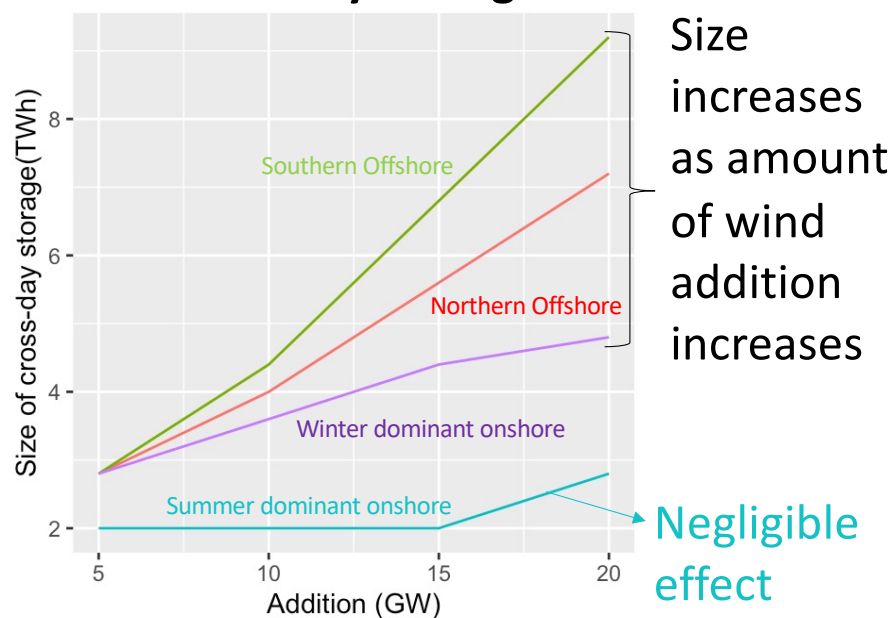


Replace today's thermal, nuclear, and imports with more solar and wind – how does the generation mix affect the needed storage?

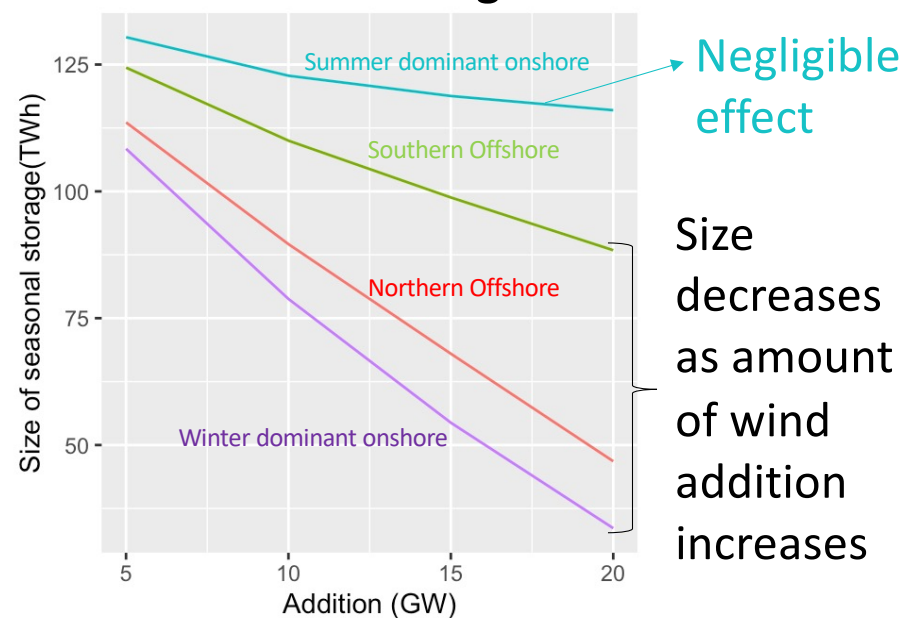
- **Diurnal storage:** solar uses most frequently; summer-dominant onshore least frequently
- **Cross-day storage:** typically need more for wind
- **Seasonal storage:** can be reduced by some wind

Flavor of wind: size of cross-day and seasonal storage

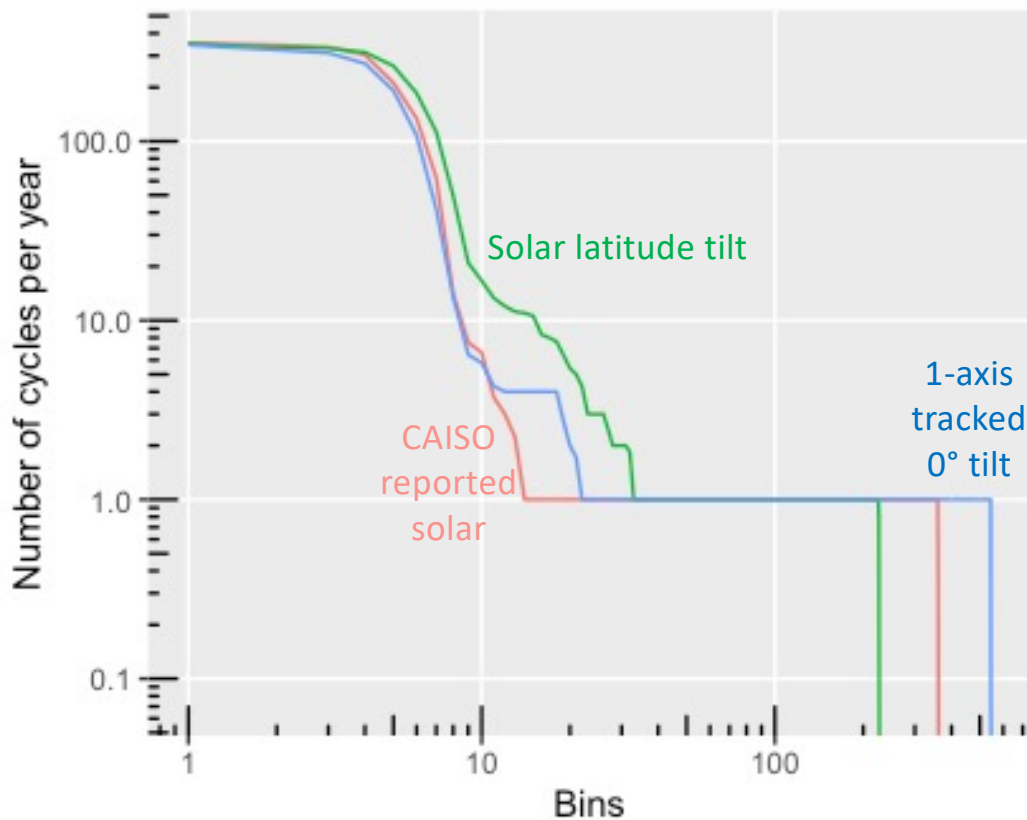
Cross-day Storage



Seasonal Storage



Effects of flavor of solar on storage requirements



Latitude tilt decreases seasonal storage need, but increases cross-day storage



Conclusions regarding generation profiles

- As we optimize cost of implementing decarbonized grid to understand the value of storage, we should consider the effects of the generation profiles
- Solar:
 - Continue to offer geographically diverse resources
 - Add south-facing tilt to affect seasonal storage
- Wind:
 - Add winter-dominant onshore wind resources
 - Add offshore wind resources
 - Retain Wyoming wind resources



THANK YOU

A large, semi-transparent watermark of the University of California Merced seal is visible on the left side of the dark blue banner. The seal features a book, a star, and the text "UNIVERSITY OF CALIFORNIA MERCED" and "HERE BE LIGHT".

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