Cheap solar is great… but what do you do with it?

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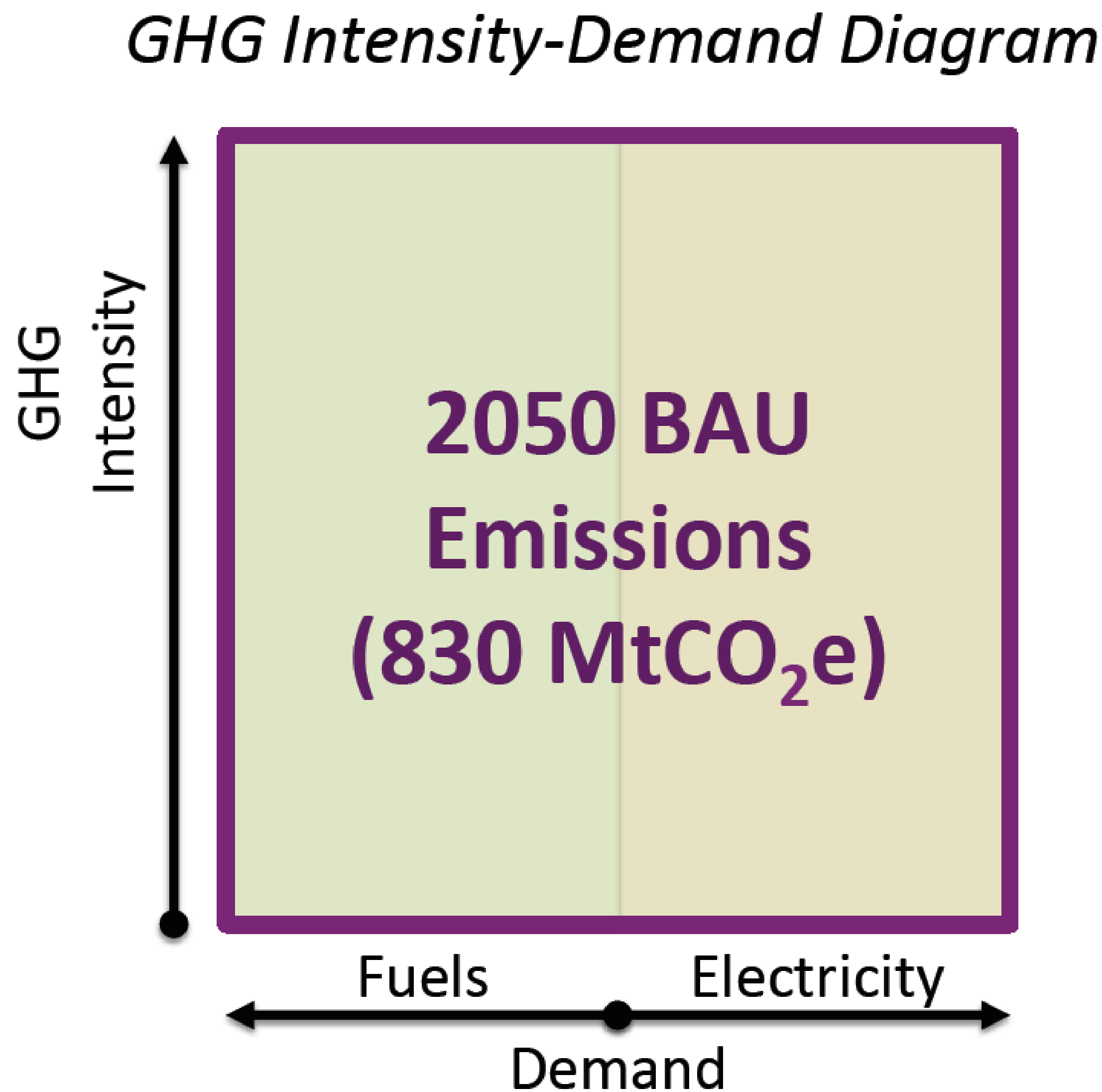
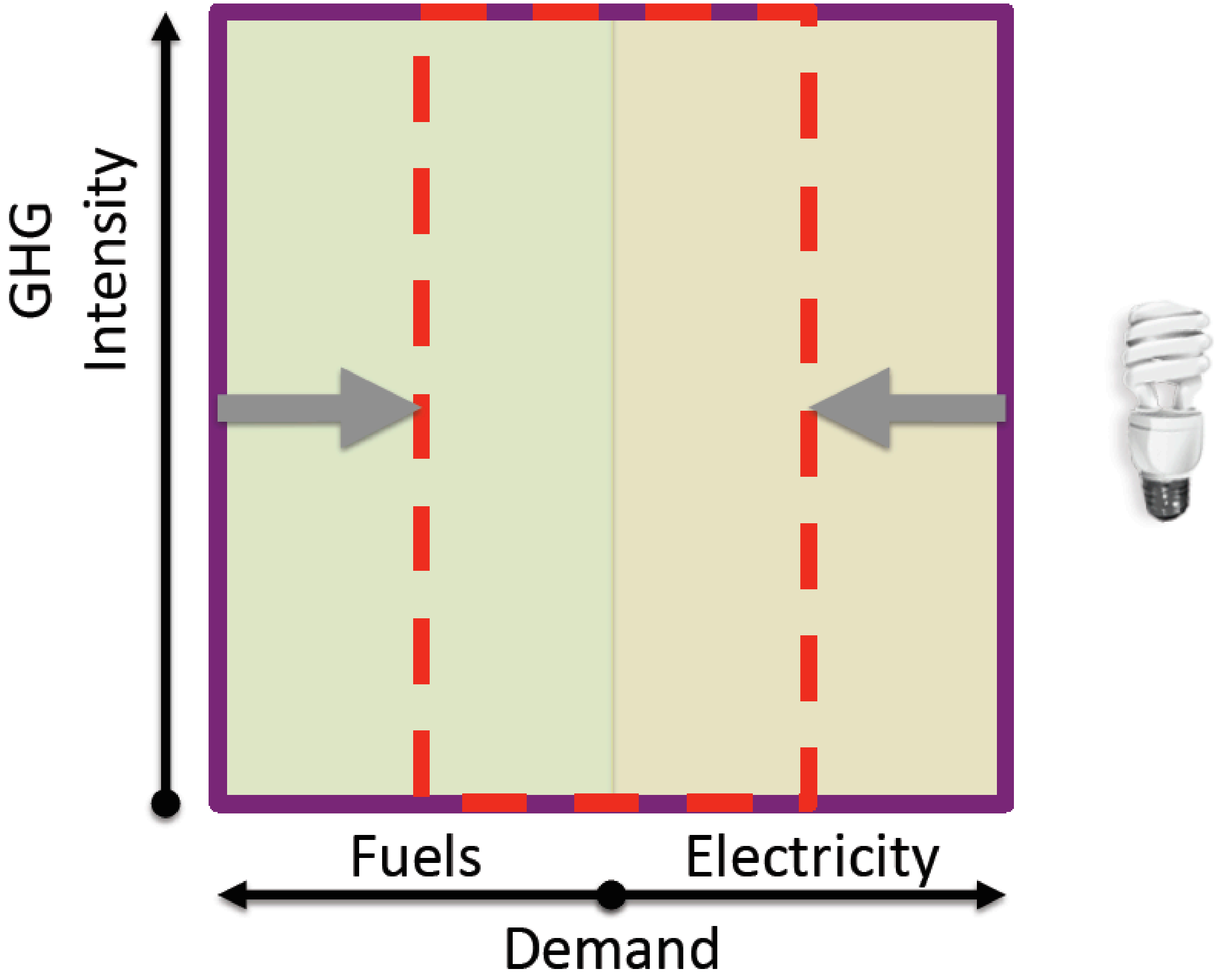
Four actions to reduce emissions



From: California's Energy Future – The View to 2050, California Council on Science and Technology, 2011

1. Efficiency



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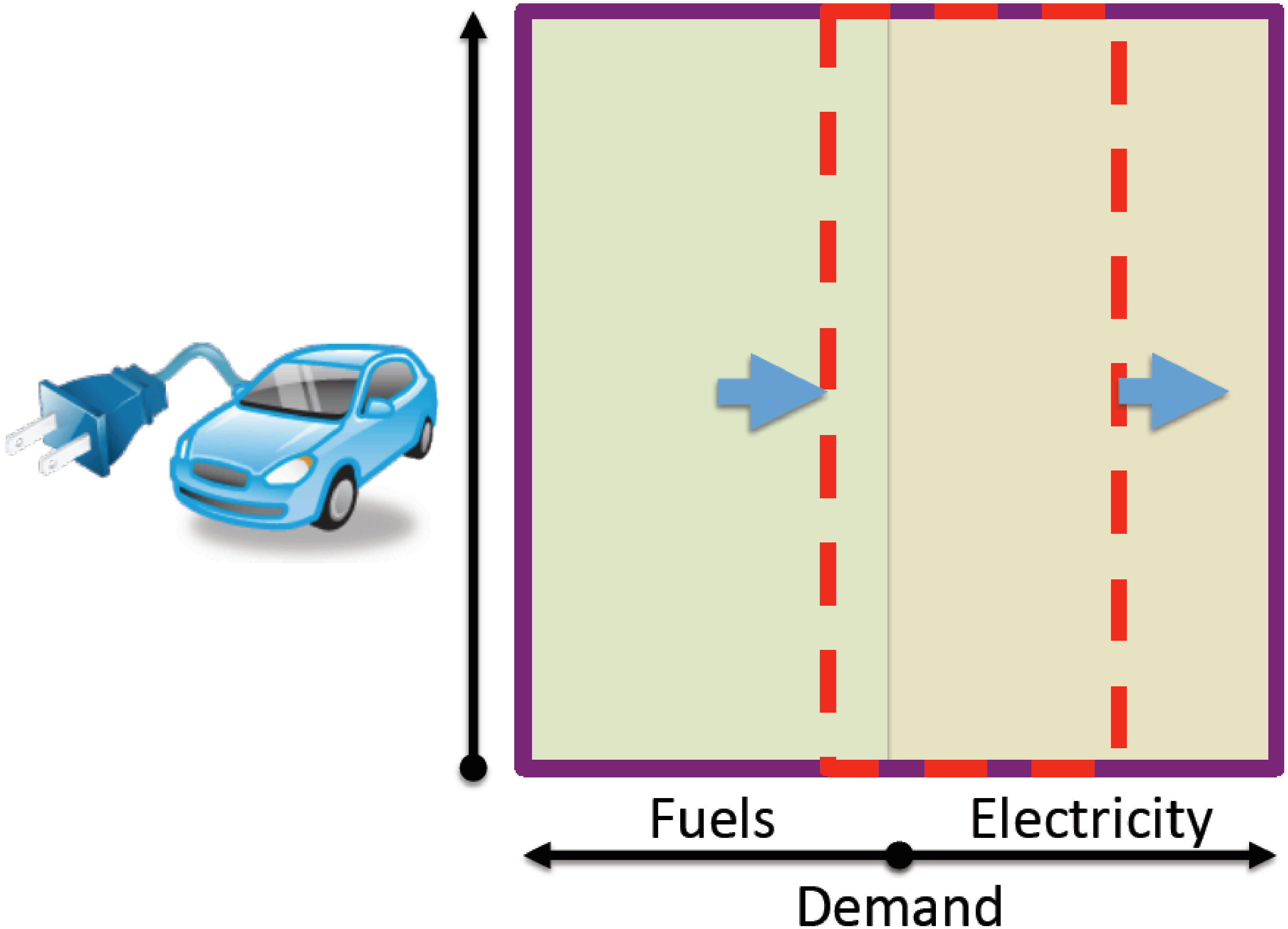
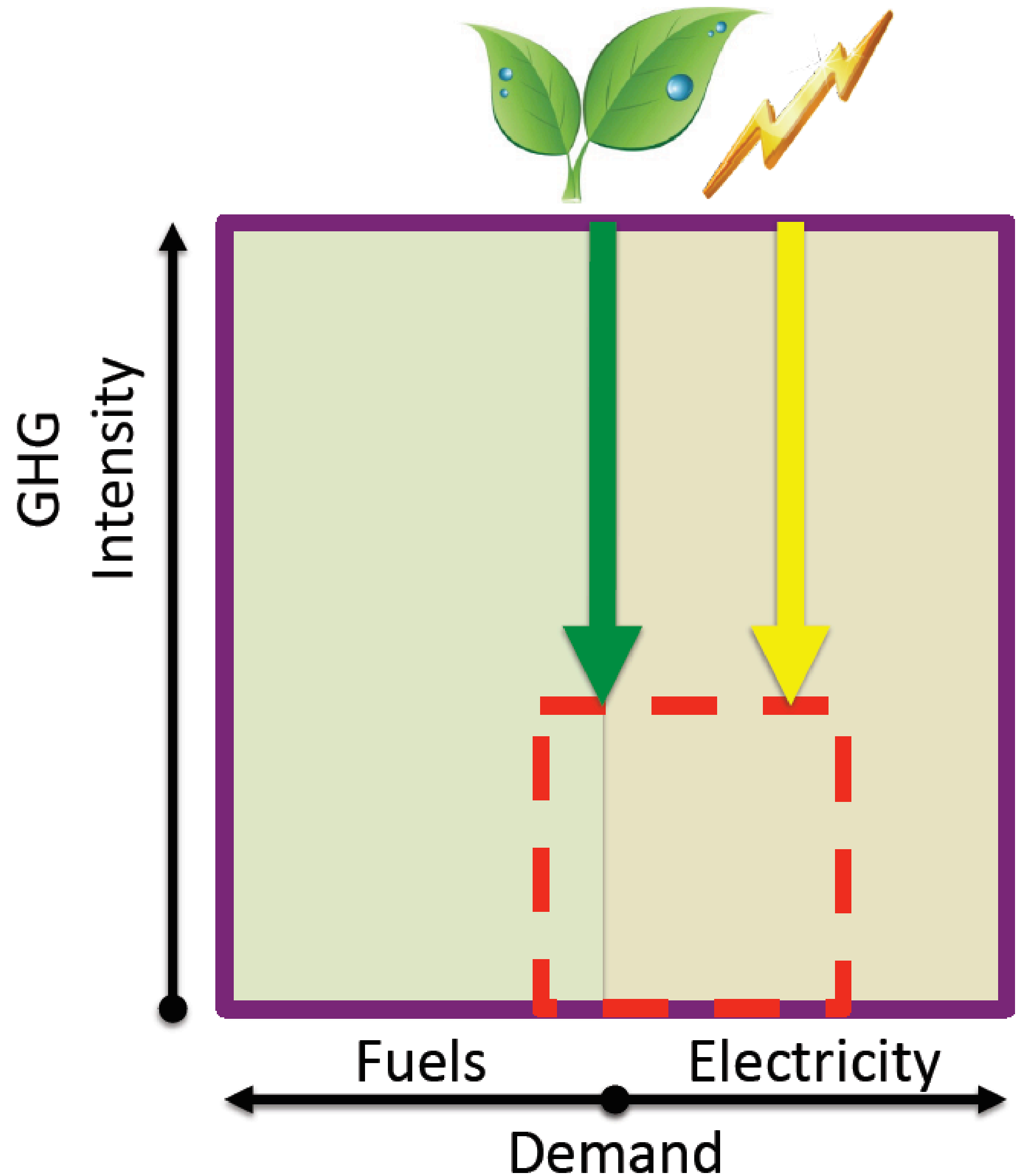
2. Electrification

- Not enough low or zero carbon fuel to go around



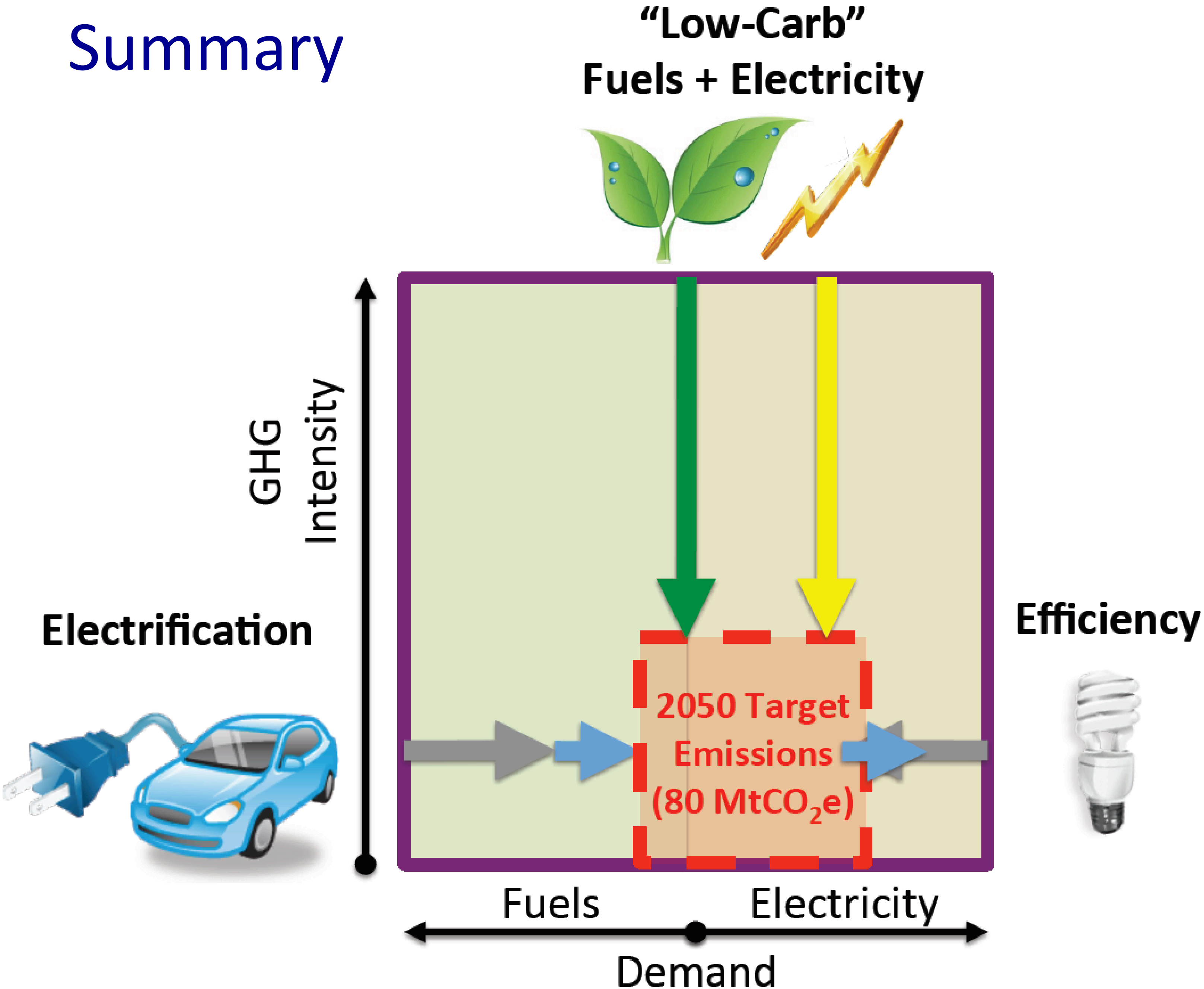
From: California's Energy Future – The View to 2050, California Council on Science and Technology, 2011

3 + 4 “Low-Carb” Biofuels + Electricity



From: California’s Energy Future – The View to 2050, California Council on Science and Technology, 2011

Summary



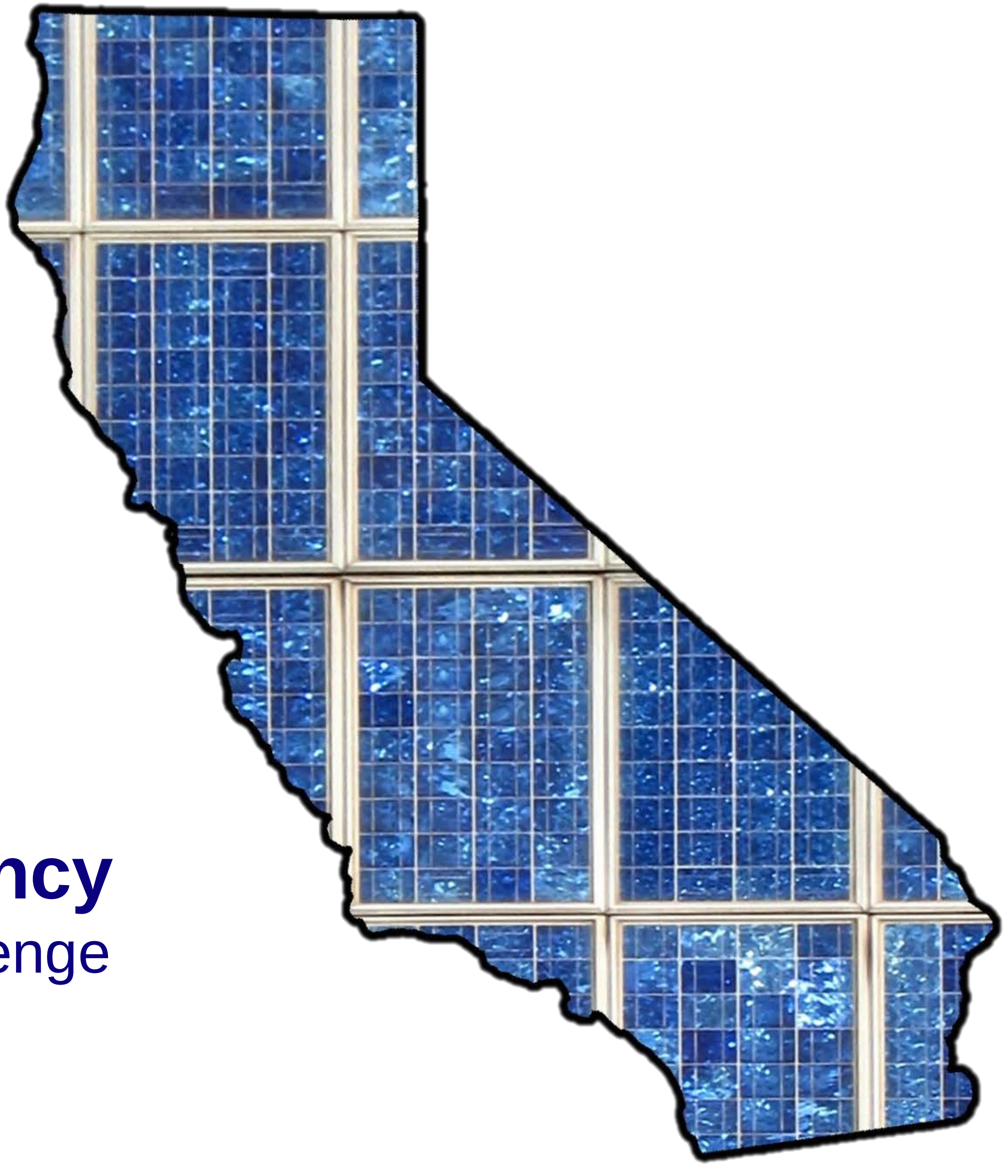
From: California's Energy Future – The View to 2050, California Council on Science and Technology, 2011

"If electricity does become the dominant component of the 2050 energy economy, the cost of decarbonized electricity becomes a paramount economic issue. […] These findings indicate that minimizing the cost of decarbonized generation should be a key policy objective" (Williams *et al*., 2012).

So we've solved everything if we have cheap solar, **right**?

Williams JH, DeBenedictis A, Ghanadan R, Mahone A, Moore J, Morrow WR III, Price S, Torn MS (2012). "The Technology Path to Deep Greenhouse Gas Emissions Cuts by 2050: The Pivotal Role of Electricity," *Science 335* 53-59

The transition to a renewable electricity system must be **smooth**



But…

renewable intermittency is a huge challenge

Image source: http://diyinsanity.blogspot.com/2011/06/solar-in-california.html

We can't control the wind or sun

One Day at 10 Second Resolution

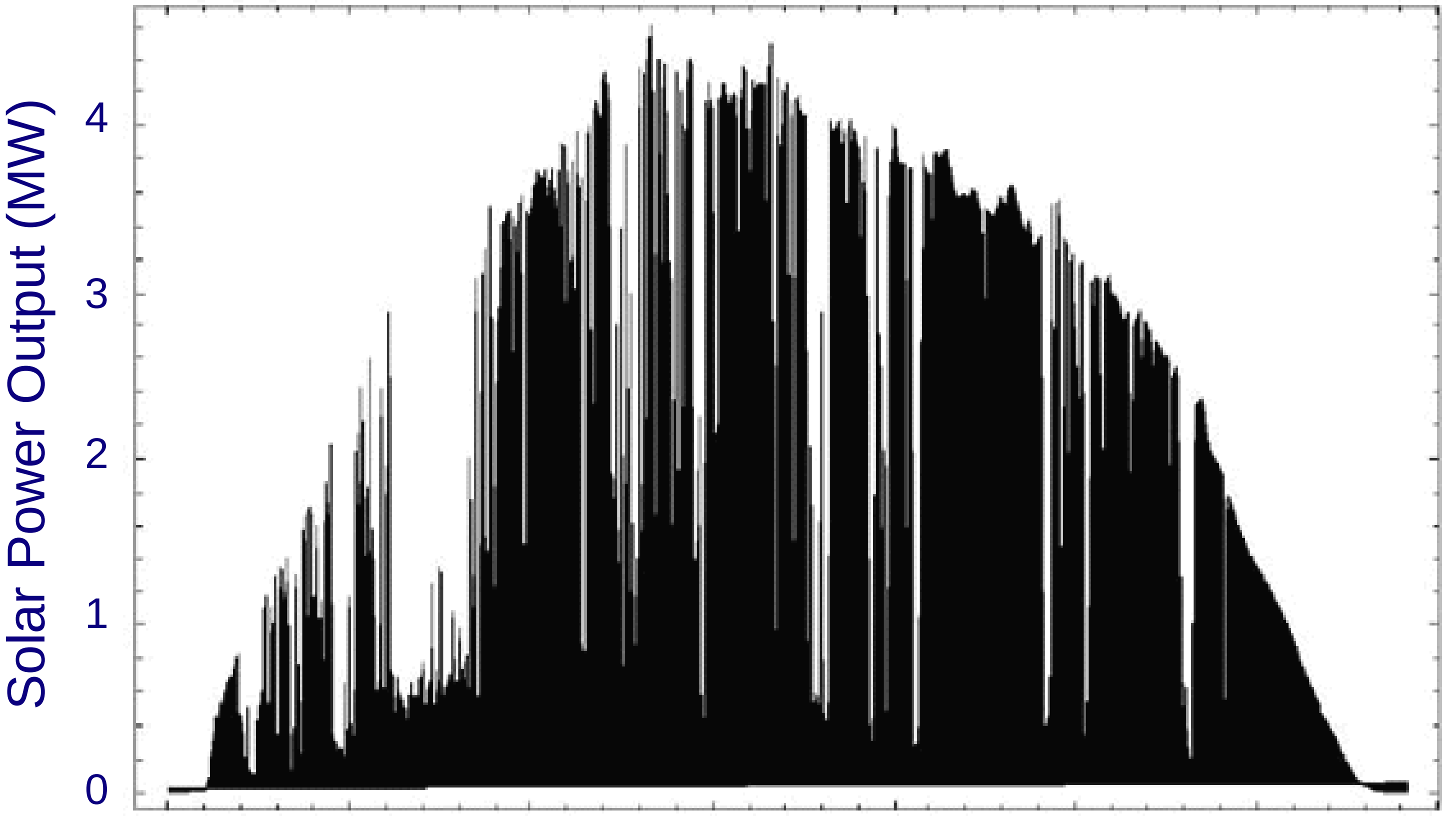
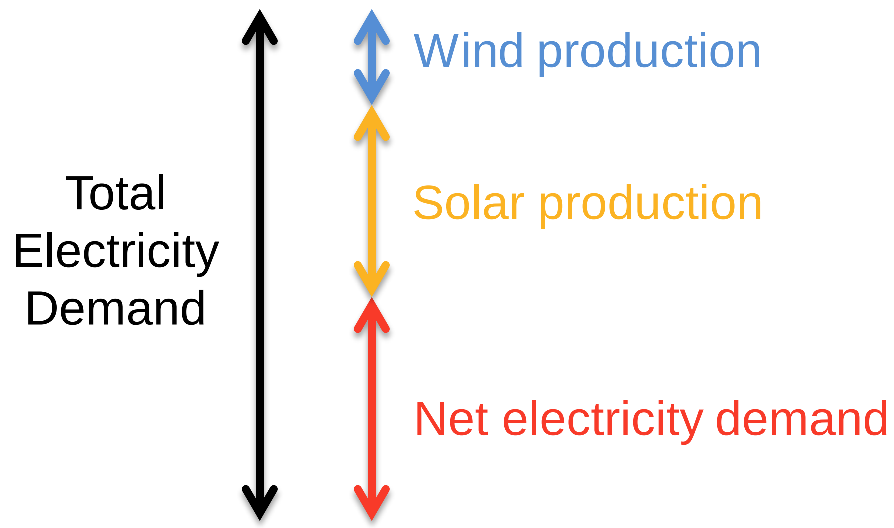


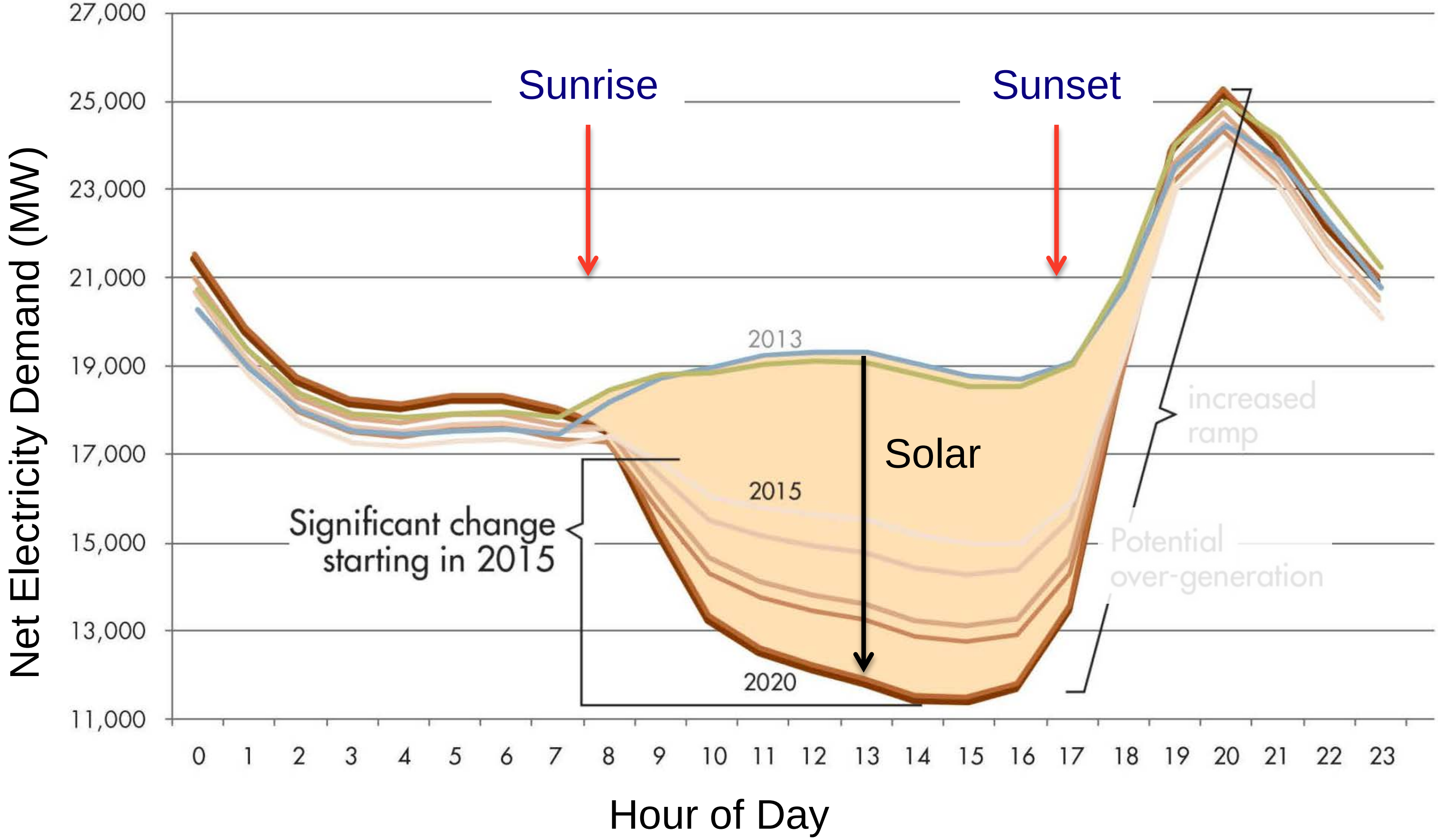
Image source: "The Spectrum of Power from Utility-Scale Wind Farms and Solar Photovoltaic Arrays", Jay Apt and Aimee Curtright, Carnegie Mellon Electricity Industry Center Working Paper CEIC-08-04

Concept: “net” electricity demand



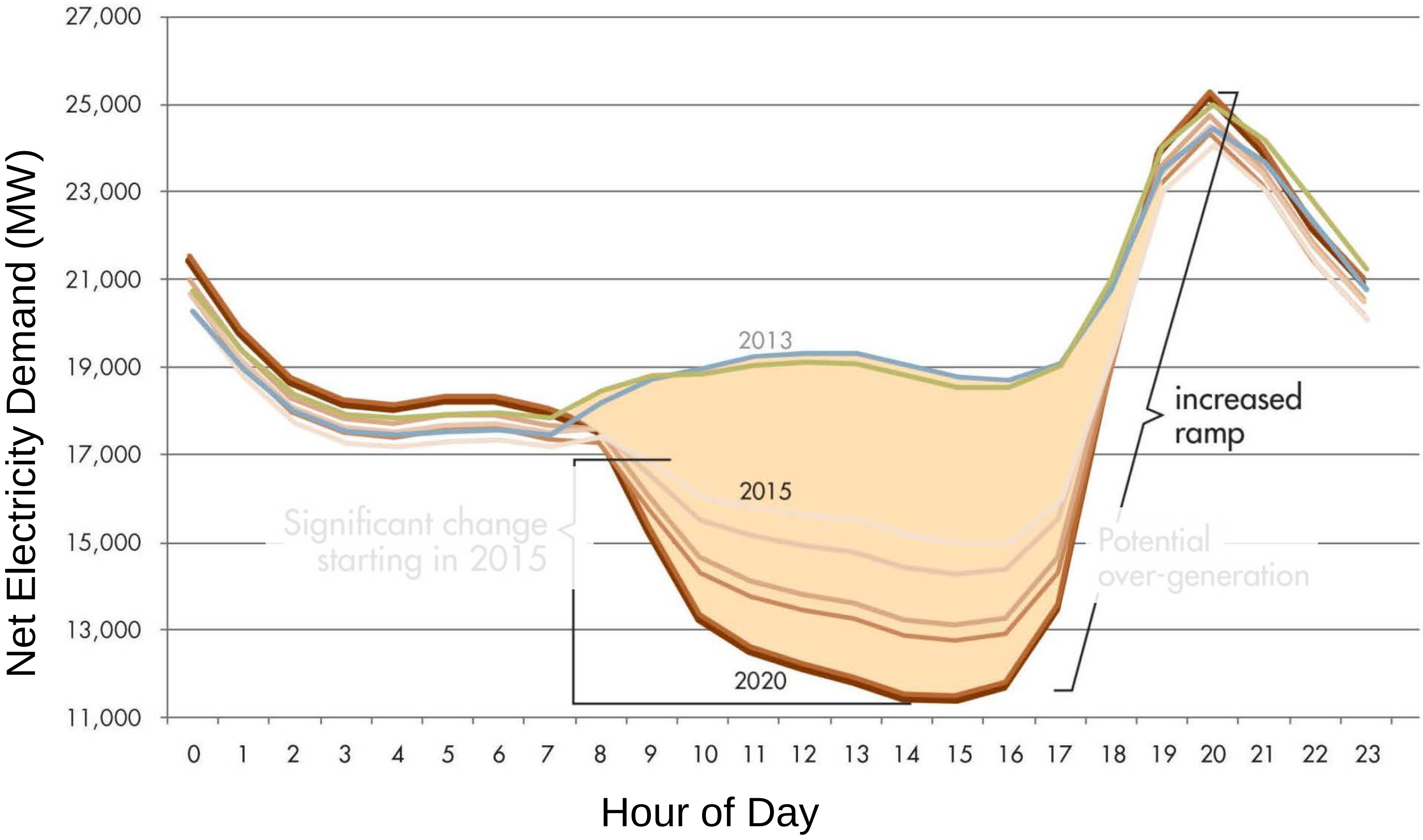
the amount of power a system operator needs to provide from sources they can control

Solar reduces daytime net electricity demand



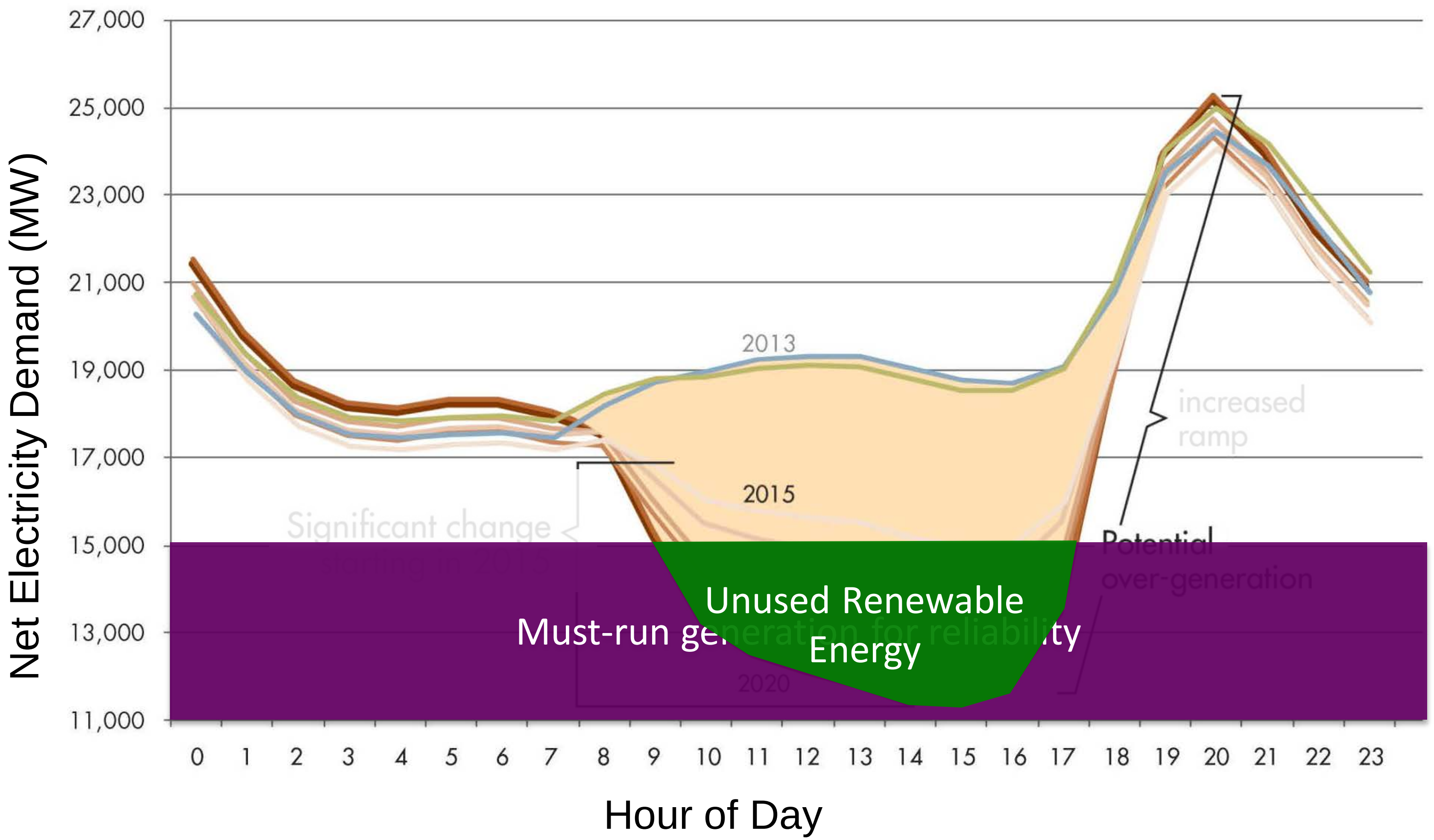
Challenge: Ramp

Ramp is difficult to follow with existing power plants

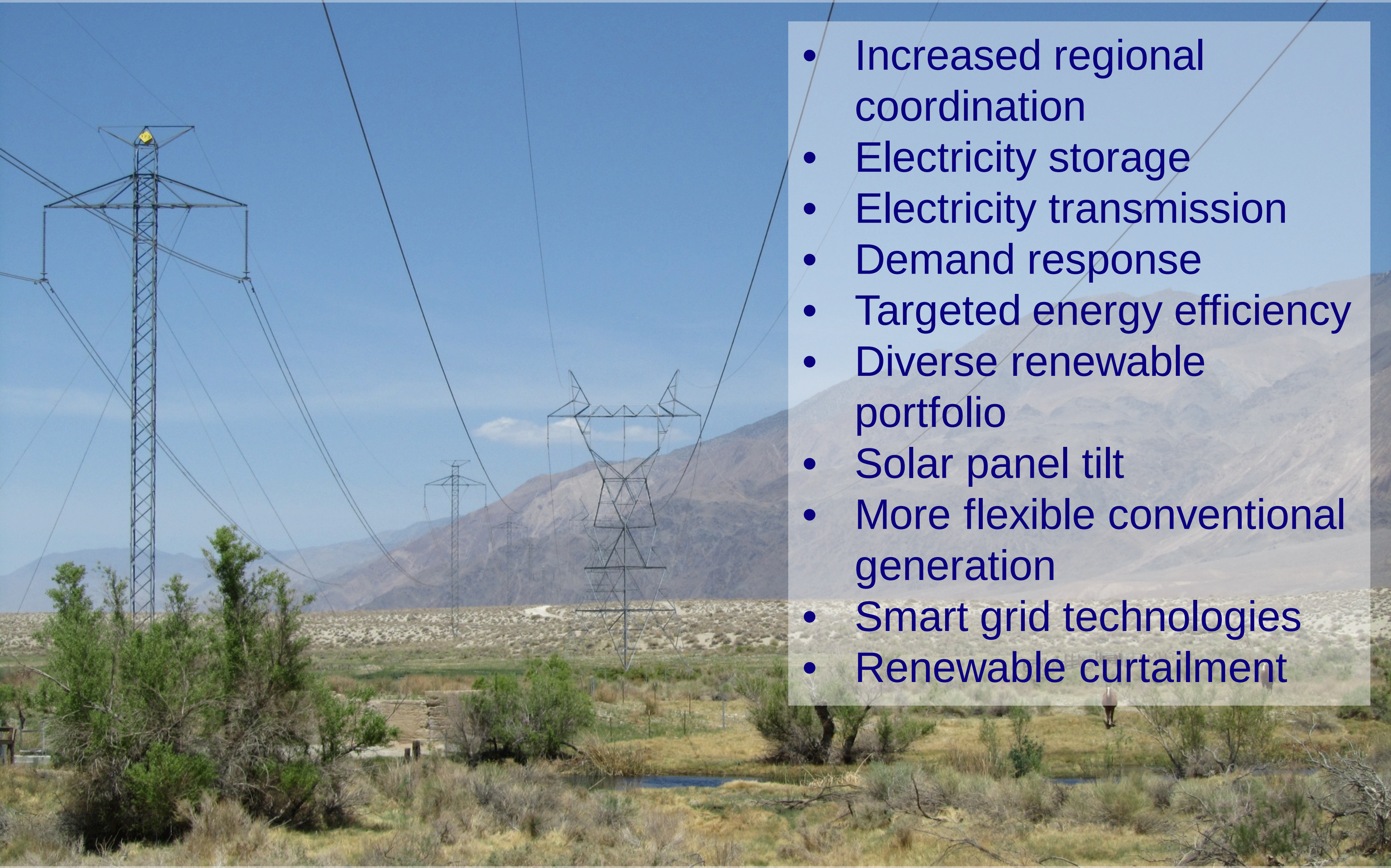


Challenge: Overgeneration

Supply and demand must be equal **every second**



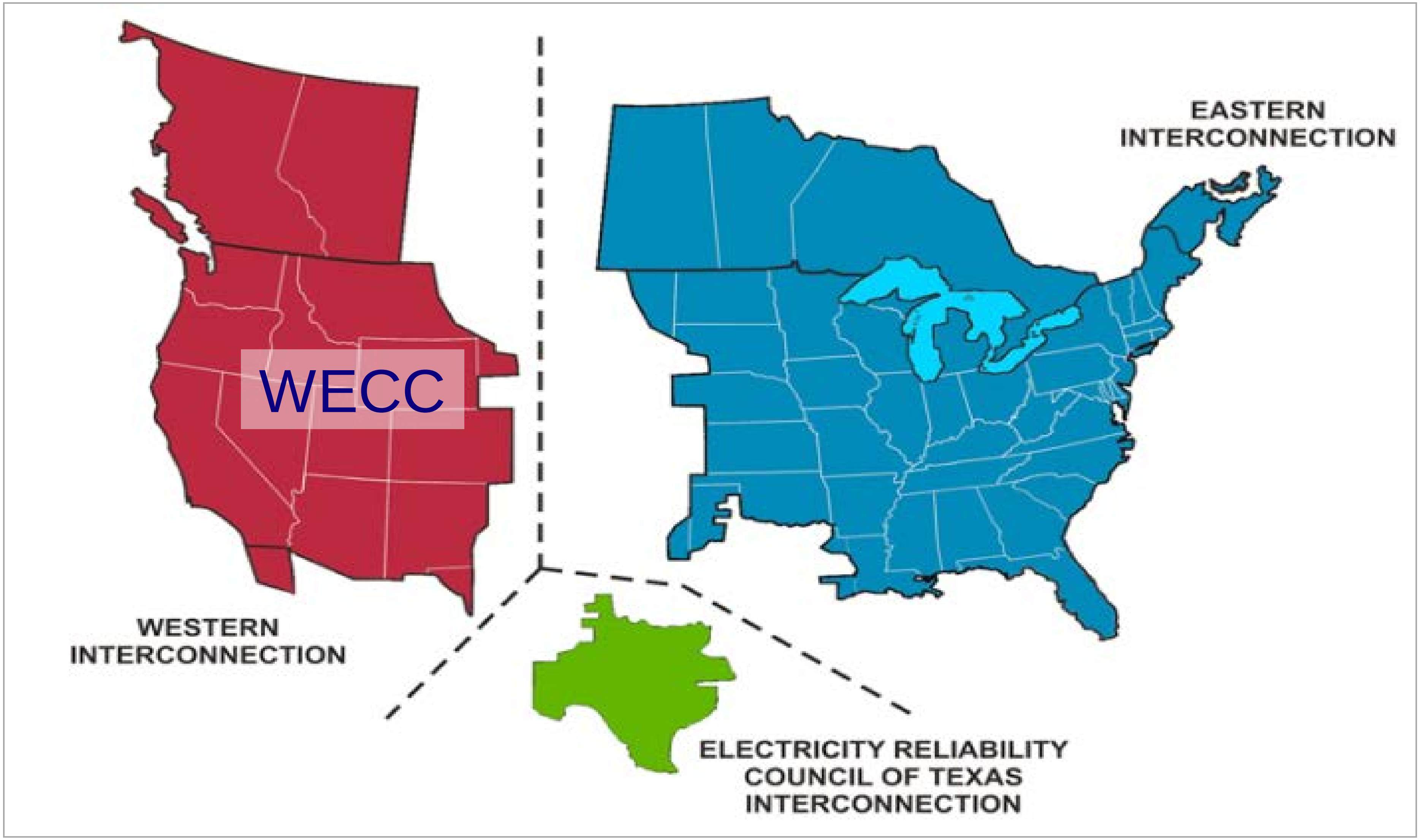
There are many possible flexibility solutions



- Increased regional coordination
- Electricity storage
- Electricity transmission
- Demand response
- Targeted energy efficiency
- Diverse renewable portfolio
- Solar panel tilt
- More flexible conventional generation
- Smart grid technologies
- Renewable curtailment

How do we choose which ones to deploy?

SWITCH-WECC:
A planning tool for the electric power system



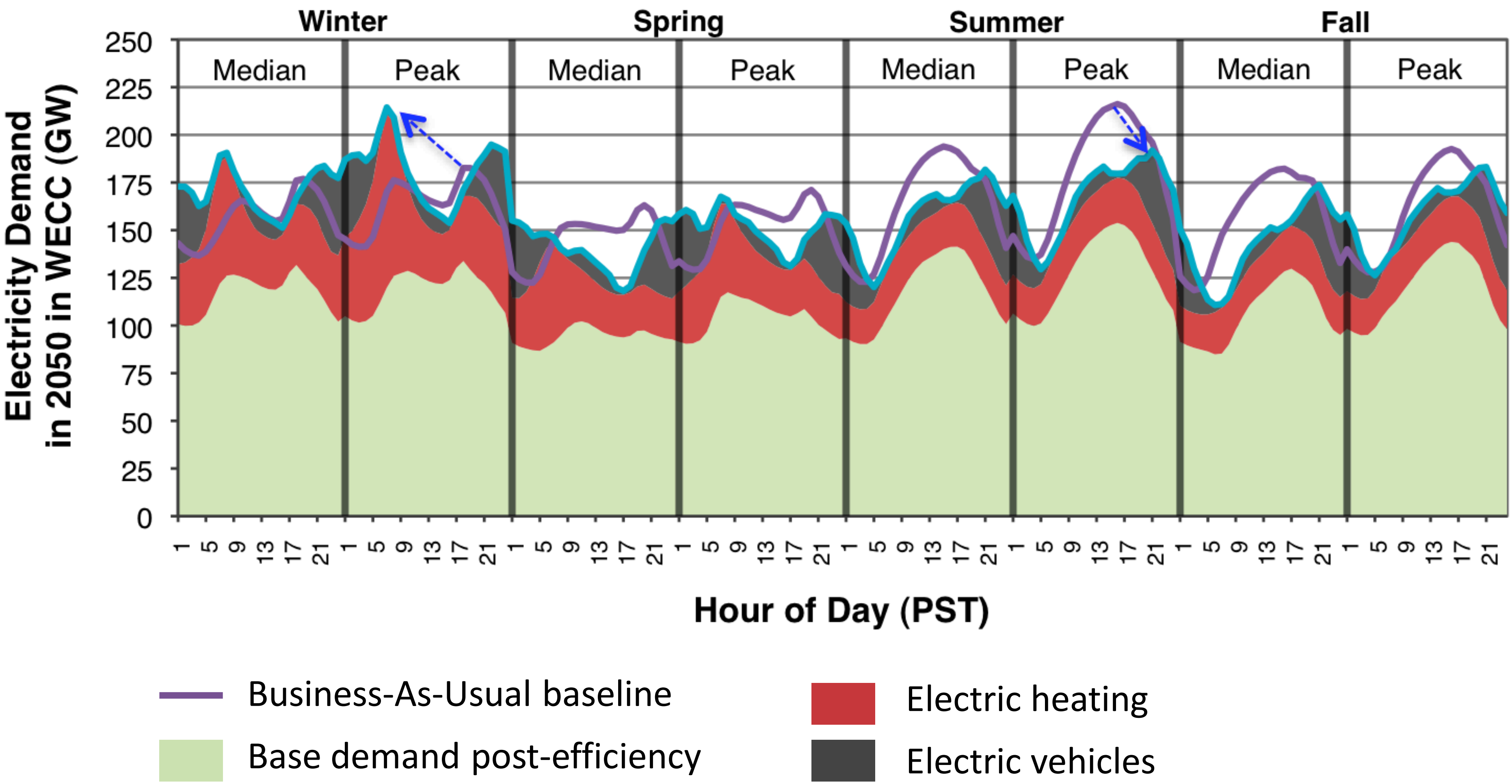
SWITCH-WECC: A planning tool for the electric power system

- Used to plan low carbon power systems
- SWITCH co-optimizes power system capacity investment and hourly dispatch
- Hourly electricity demand and renewable output profiles
  - Goal is to capture the temporal relationship between demand and renewable power
- System-wide approach is key
  - Geographic diversity reduces overall variability of demand and renewable output
  - Sharing of flexibility resources

Objective: minimize future power system cost while meeting demand, reliability, and policy constraints

Electrification could create much demand at night

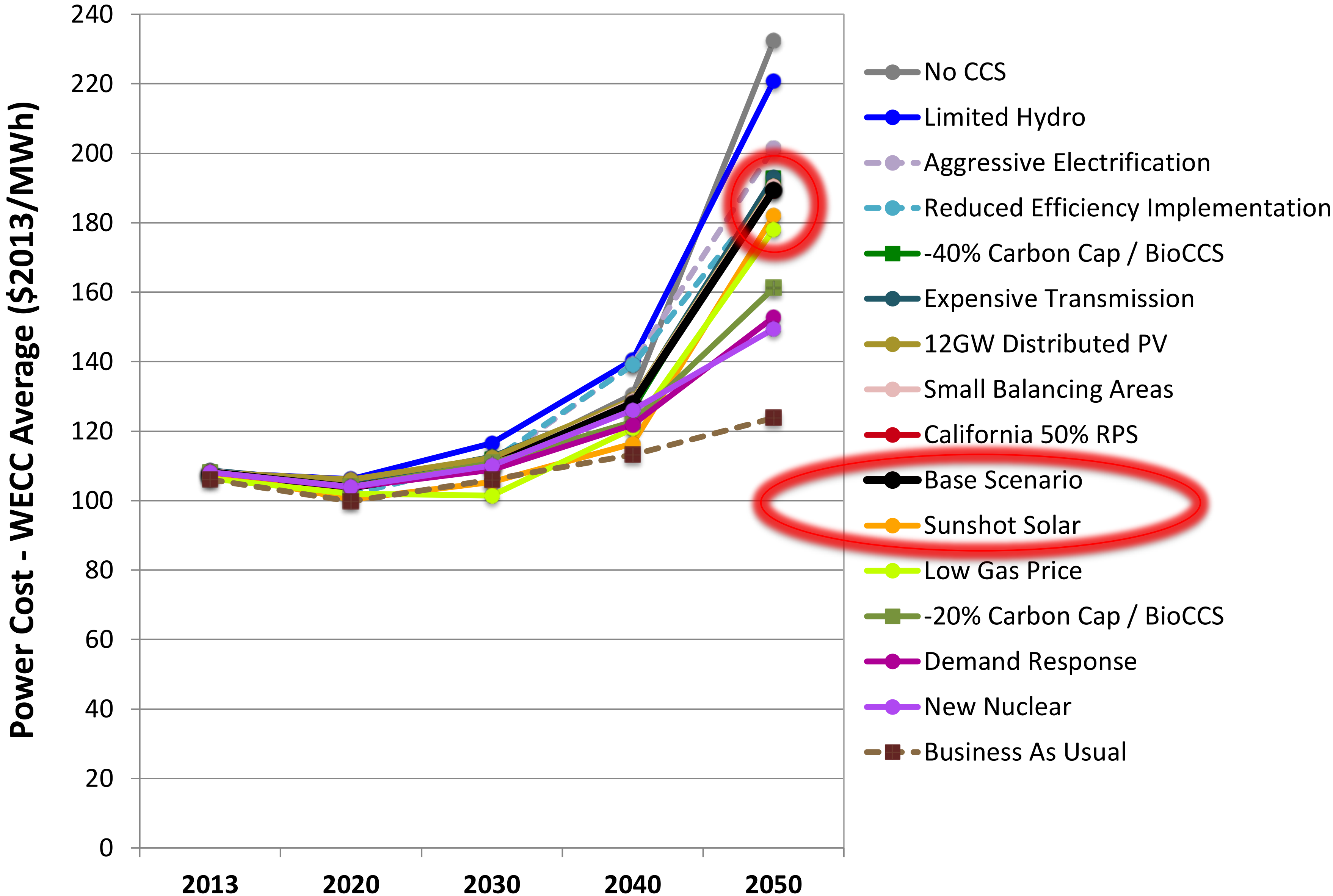
- Is this bad for solar?



Wei, M., Nelson, J., Greenblatt, J., Mileva, A., Johnston, J., Ting, M., Yang, C., Jones, C., McMahon, J., Kammen, D., 2013. Deep carbon reductions in California requires electrification and integration across economic sectors. *Environmental Research Letters* 8 (1), 014038.

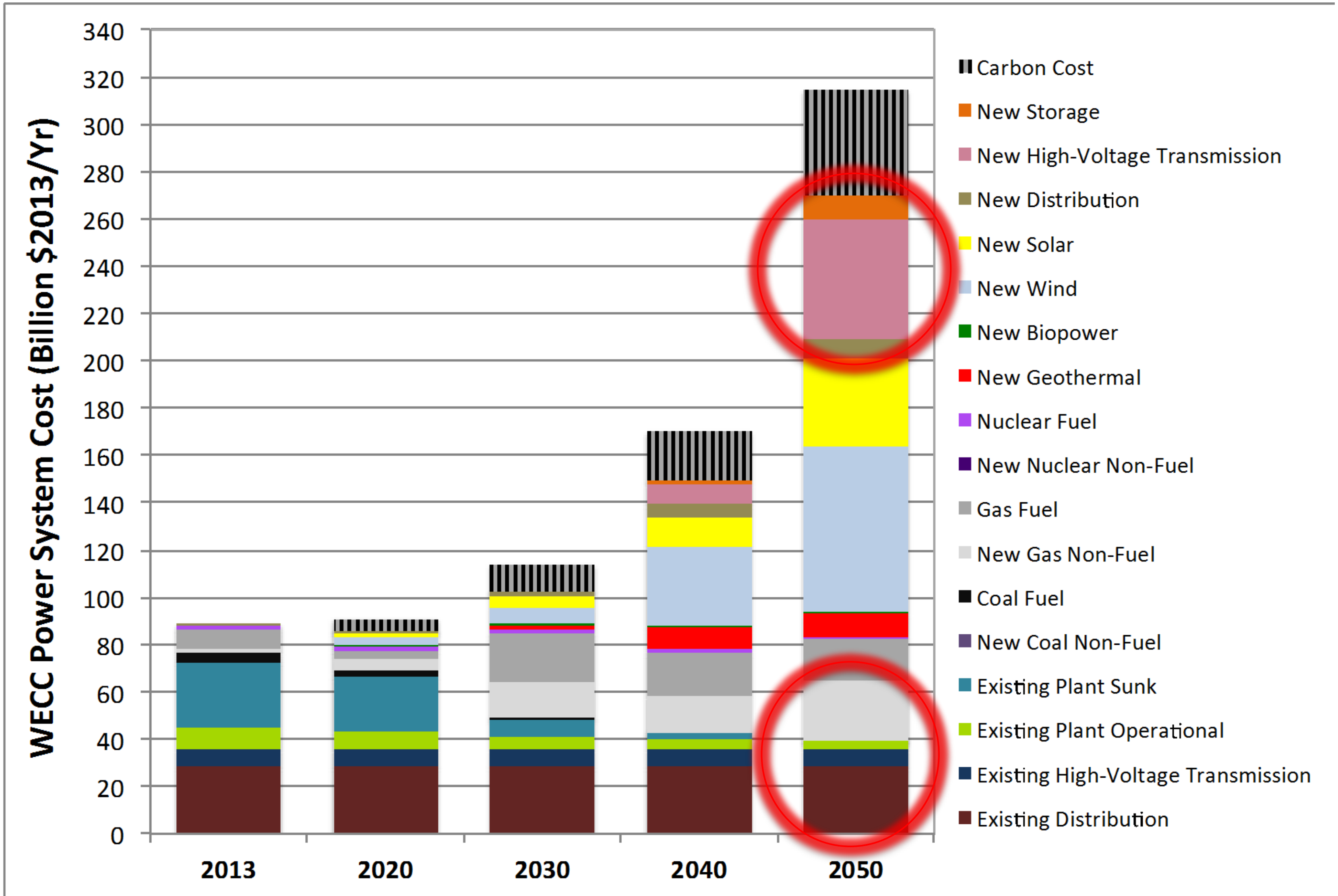
System flexibility crucial to cost containment by 2050

- Solar needs friends!

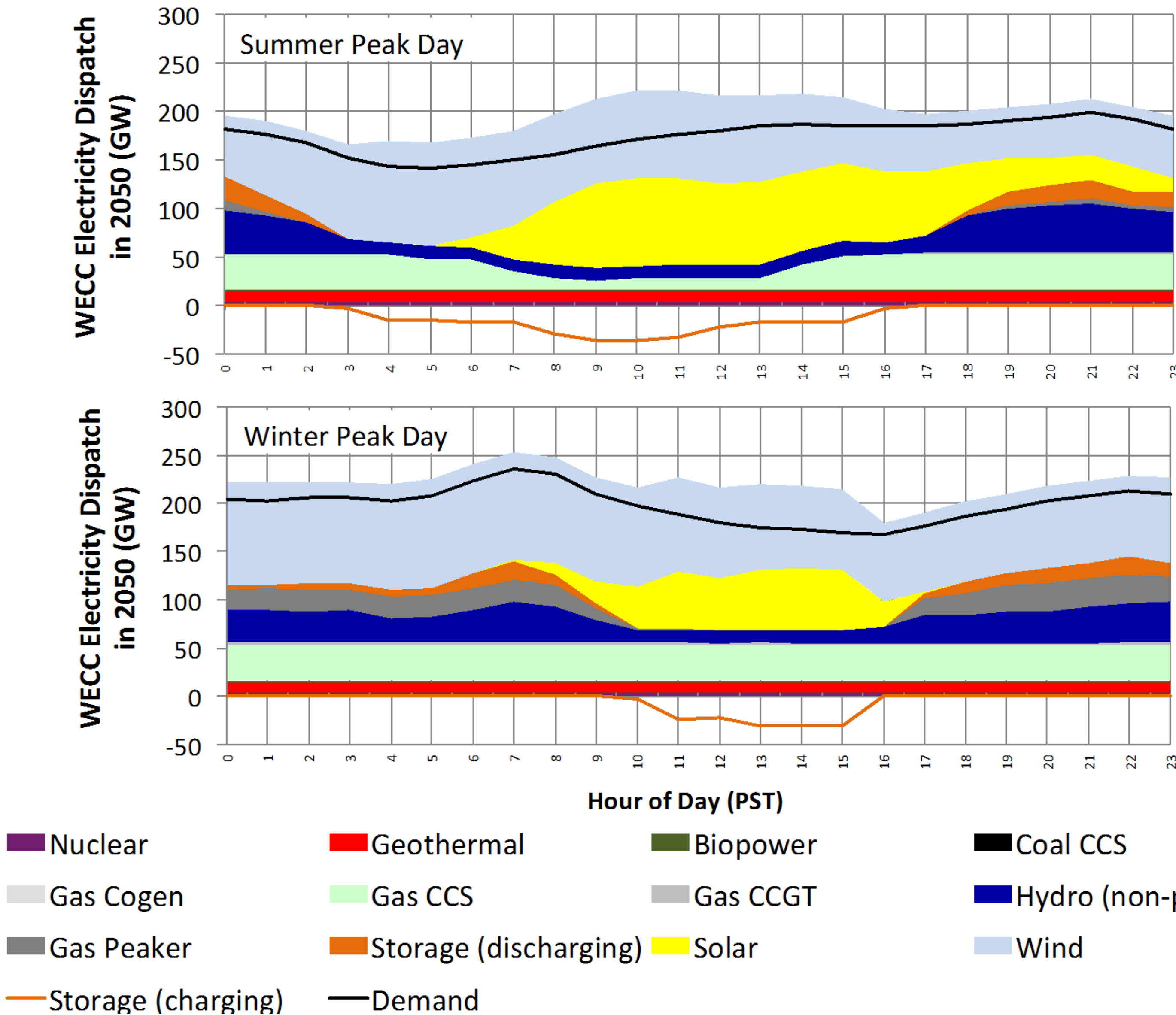


solar technology	year	reference 2010$/W	SunShot 2010$/W
central PV	*2020*	2.51	1.00
	2030	2.40	1.00
	2040	2.20	1.00
	2050	2.10	1.00
commercial PV	*2020*	3.36	1.25
	2030	3.21	1.25
	2040	2.95	1.25
	2050	2.81	1.25
residential PV	*2020*	3.78	1.50
	2030	3.61	1.50
	2040	3.31	1.50
	2050	3.16	1.50
CSP 6 h of storage[14]	*2020*	6.64	3.07
	2030	5.23	3.07
	2040	4.61	3.07
	2050	4.61	3.07
CSP no storage	*2020*	4.60	2.50
	2030	4.20	2.50
	2040	3.90	2.50
	2050	3.50	2.50

Power system cost increasingly dominated by flexibility rather than energy



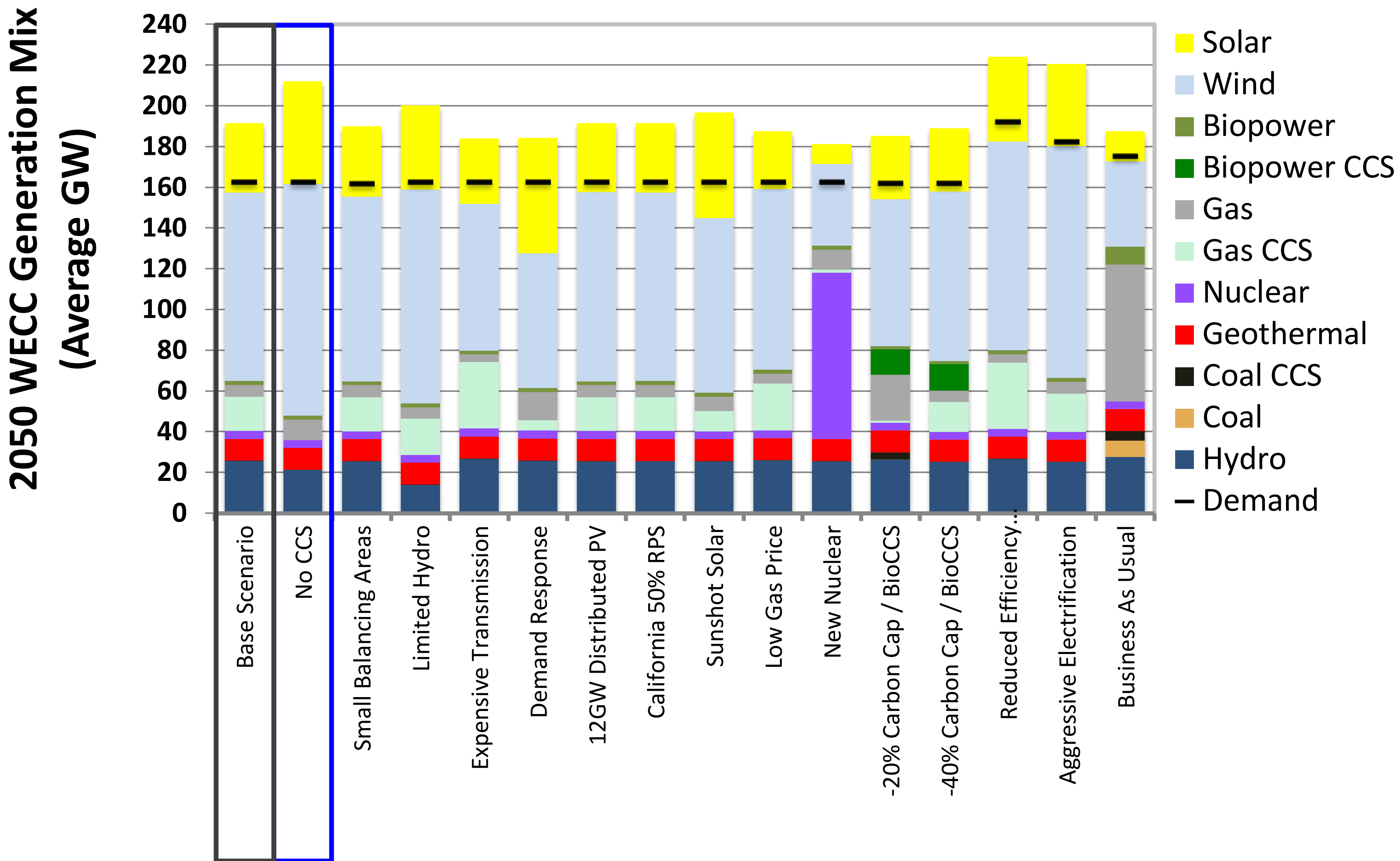
Dispatch in 2050:
Flexibility and variable renewables dominate



Storage almost exclusively moves solar to the night

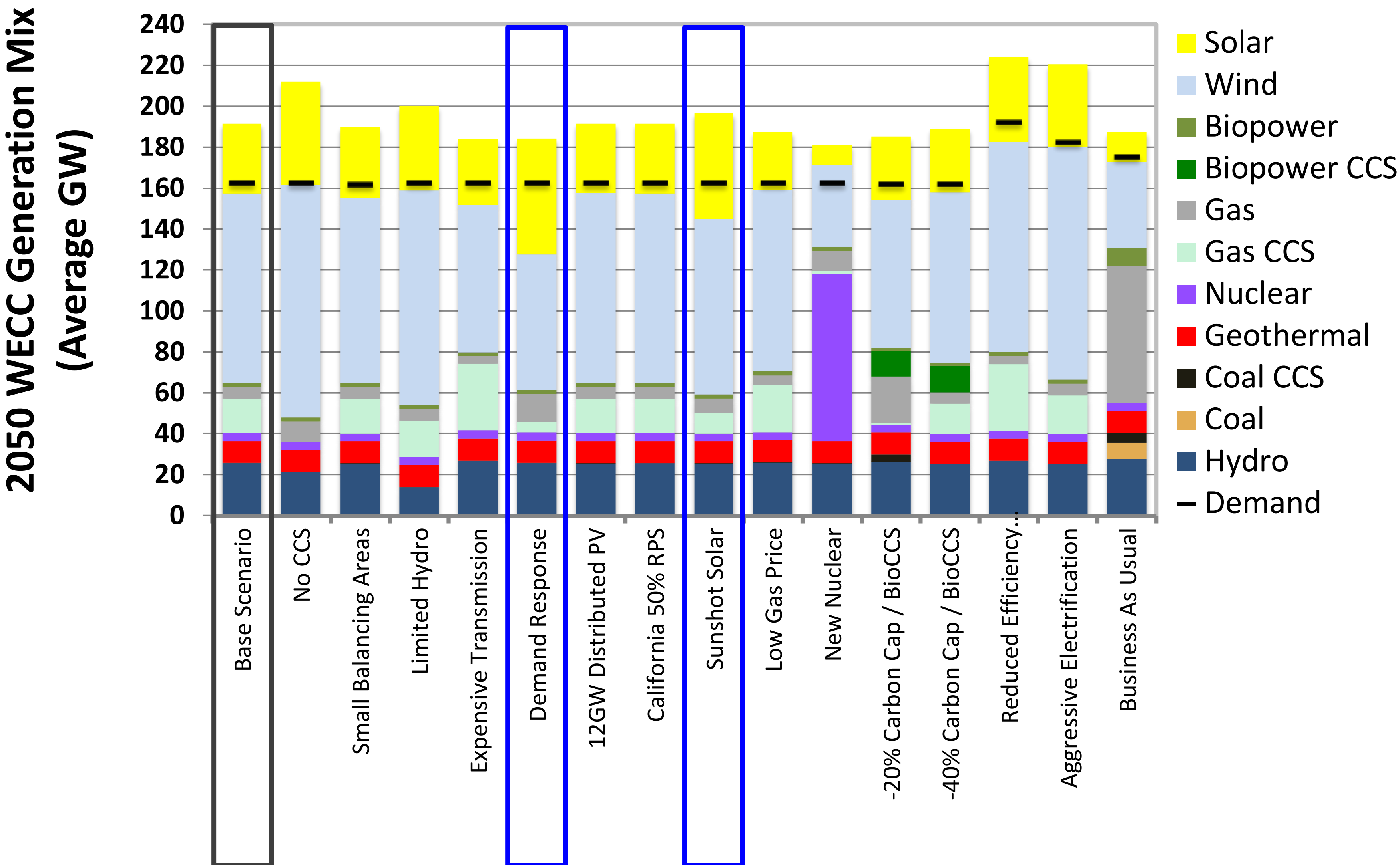
Drastic emission reductions possible without nuclear, CCS, or bioelectricity

- > 70 % of energy from wind and solar

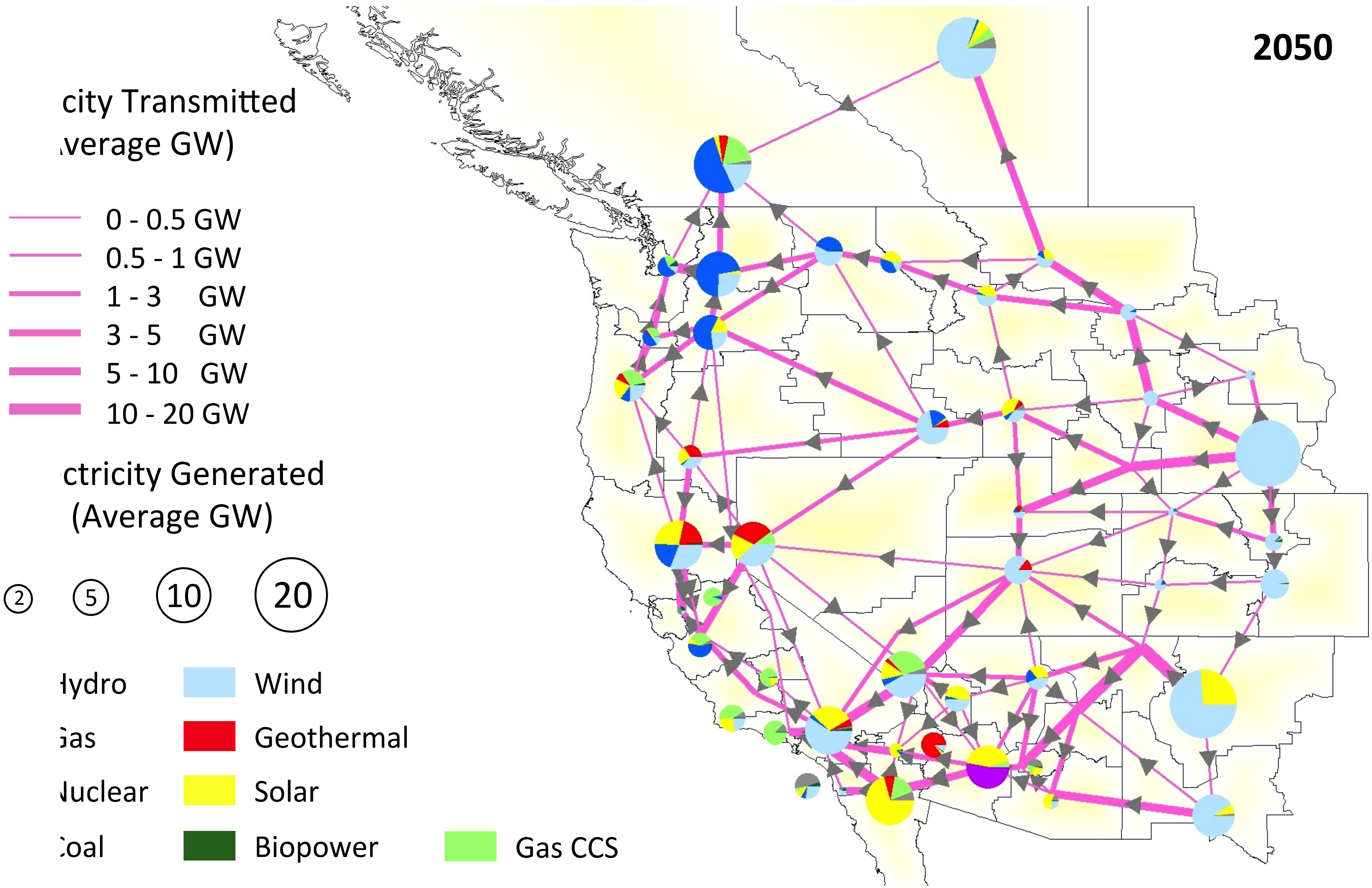


Demand response incentivizes solar… more than inexpensive solar capital costs!

- Integration costs dominate at large fractions of solar
  - Inexpensive storage (not investigated here) would likely incentivize solar



Wind in the east, solar in the south



Environmental Science & Technology

Policy Analysis

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SunShot Solar Power Reduces Costs and Uncertainty in Future Low-Carbon Electricity Systems

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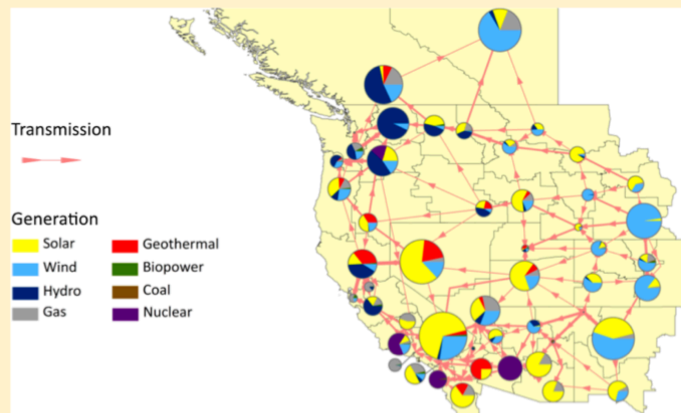
[†]Energy and Resources Group, [‡]Renewable and Appropriate Energy Laboratory, and [§]Goldman School of Public Policy, University of California Berkeley, Berkeley, California 94720-3050, United States

Supporting Information

ABSTRACT: The United States Department of Energy's SunShot Initiative has set cost-reduction targets of $1/watt for central-station solar technologies. We use SWITCH, a high-resolution electricity system planning model, to study the implications of achieving these targets for technology deployment and electricity costs in western North America, focusing on scenarios limiting carbon emissions to 80% below 1990 levels by 2050. We find that achieving the SunShot target for solar photovoltaics would allow this technology to provide more than a third of electric power in the region, displacing natural gas in the medium term and reducing the need for nuclear and carbon capture and sequestration (CCS) technologies, which face technological and cost uncertainties, by 2050. We demonstrate that a diverse portfolio of technological options can help integrate high levels of solar generation successfully and cost-effectively. The deployment of GW-scale storage plays a central role in facilitating solar deployment and the availability of flexible loads could increase the solar penetration level further. In the scenarios investigated, achieving the SunShot target can substantially mitigate the cost of implementing a carbon cap, decreasing power costs by up to 14% and saving up to $20 billion ($2010) annually by 2050 relative to scenarios with Reference solar costs.



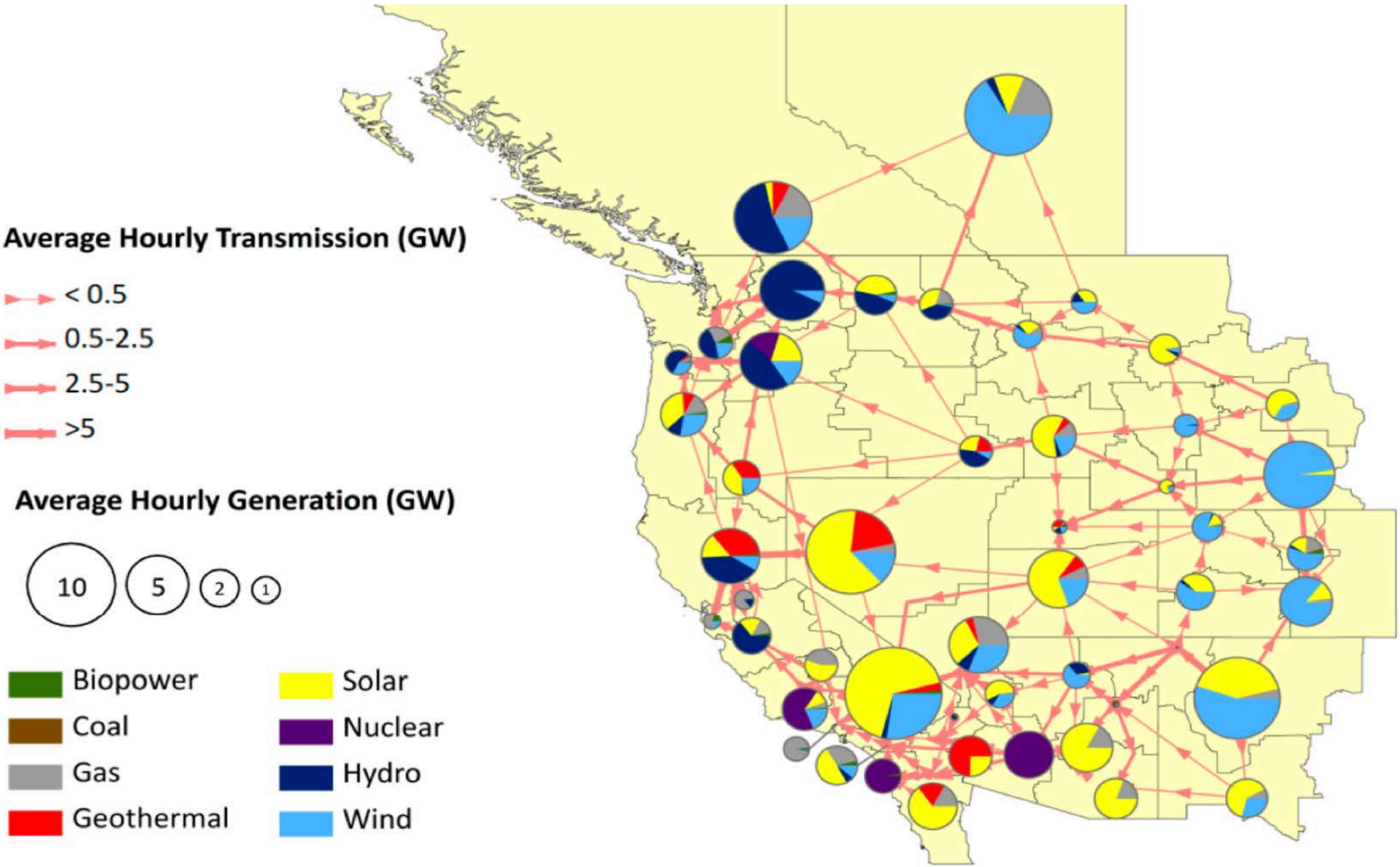
INTRODUCTION

The high cost of solar electricity technologies relative to conventional fossil fuel generation has been a barrier to their

(CO_2-e), which would limit planetary warming to 2 °C above preindustrial levels.[7] Several countries and states already have equivalent policy goals in place. The State of California has put

SunShot solar, no nuclear, no carbon capture

- Solar everywhere!



SWITCH-WECC Study team and funding

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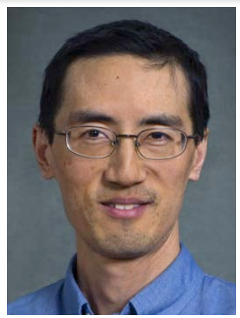

Dr. Max Wei

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IBM

Thanks!