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Achieving Low-Carbon Growth: from Innovation to Market Expansion

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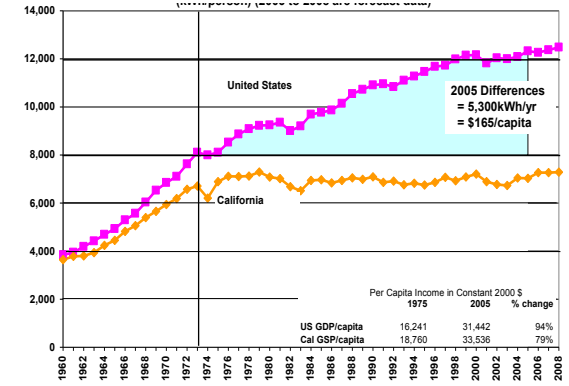
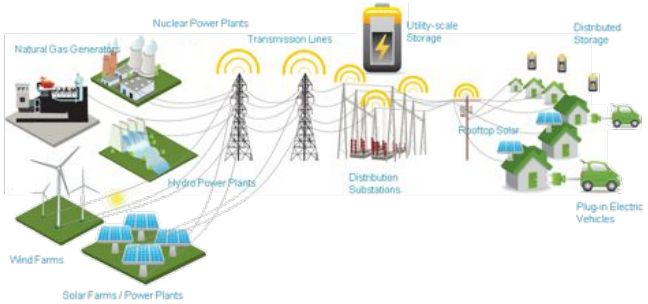
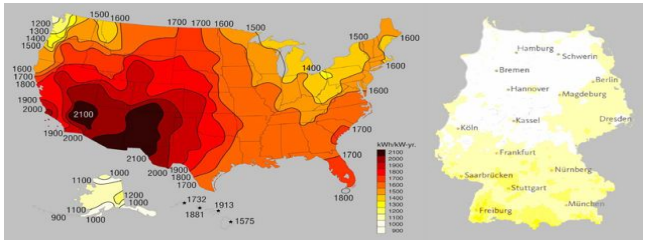


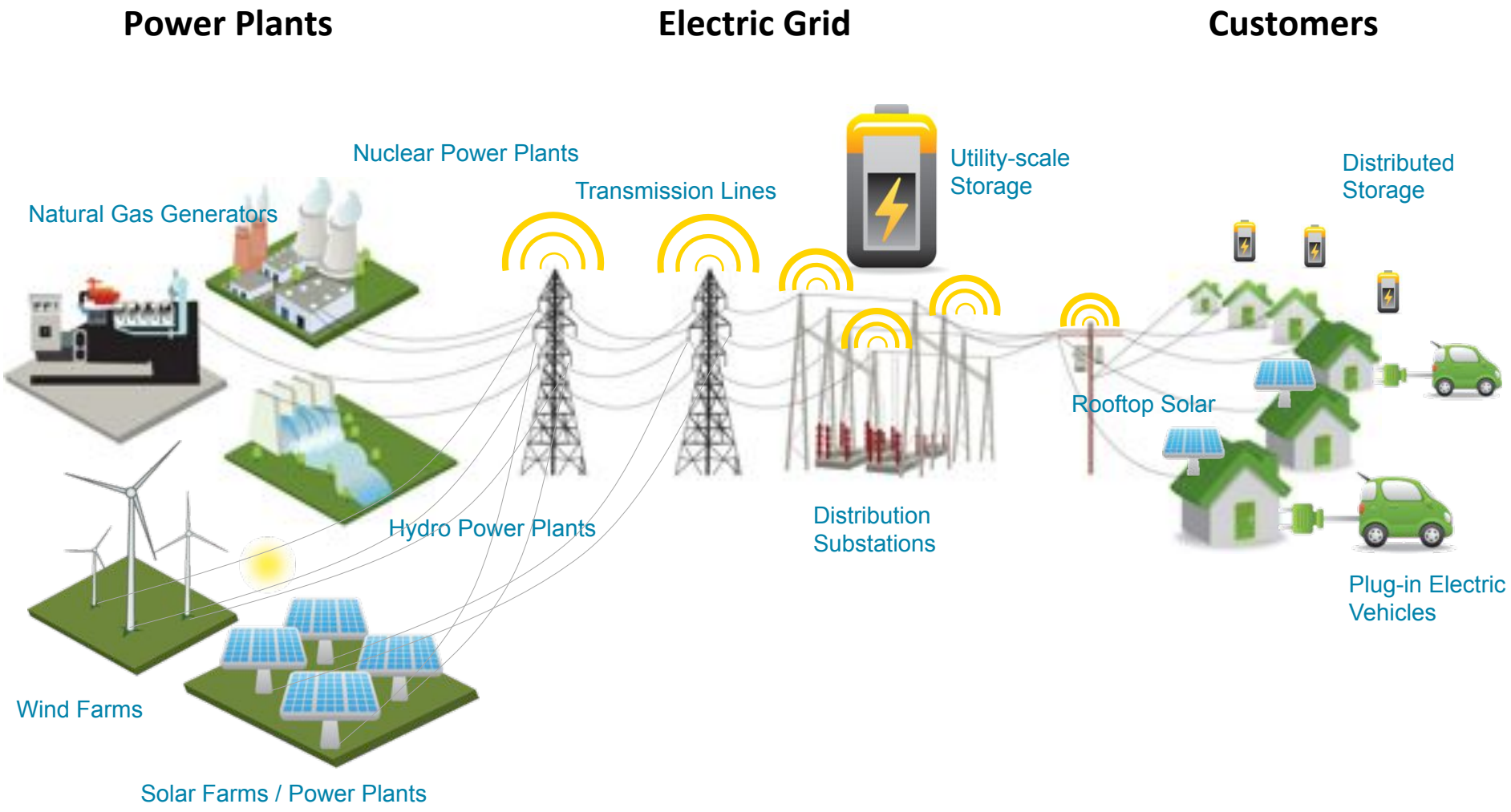




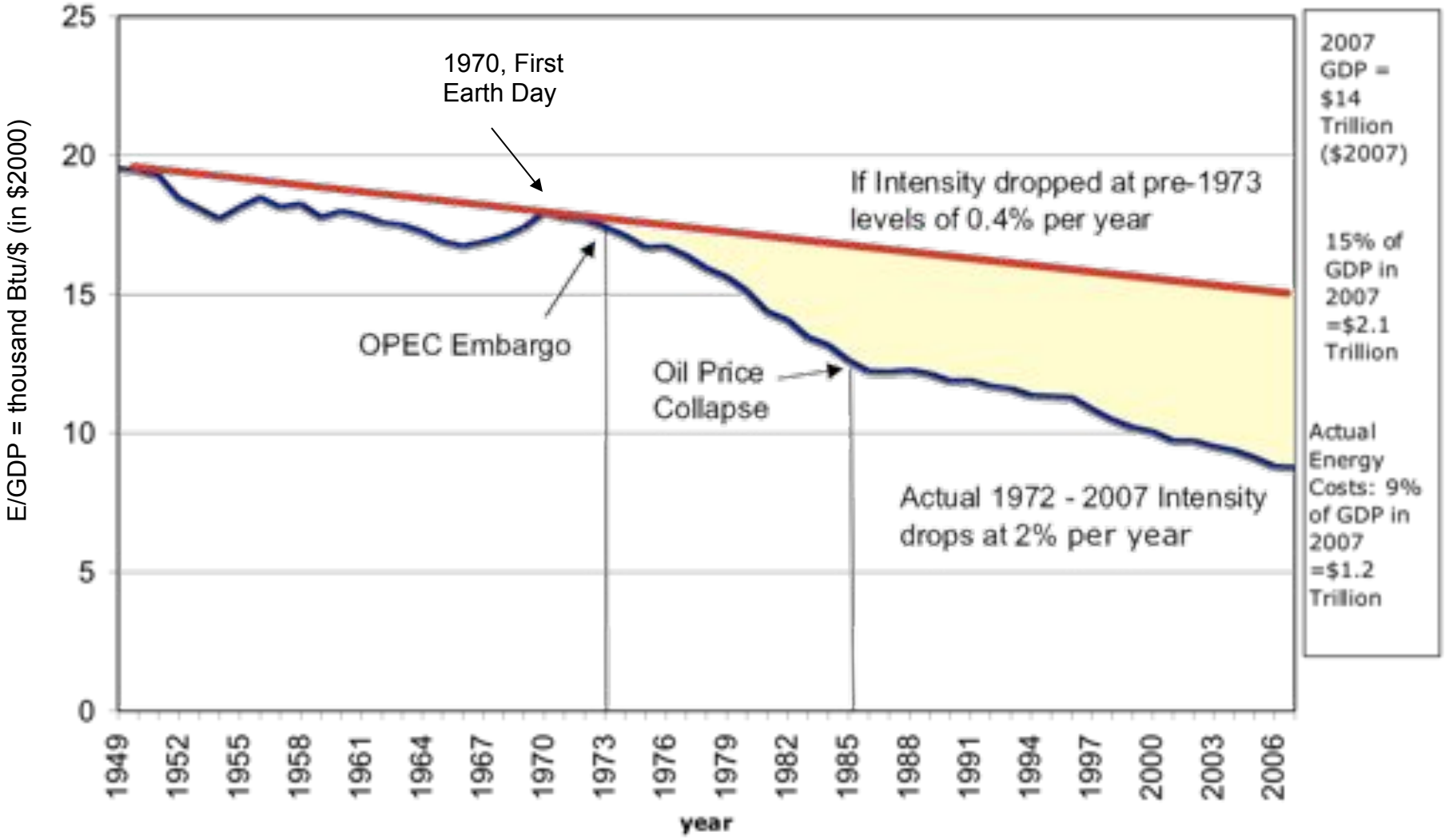
Overview of Presentation:

- Multiple renewable energy and energy efficiency tools are available; but implementation is varied in details and effectiveness
- In this talk we will examine different policy and technology tools, focusing on the US, Germany, and California to keep these ideas rooted in practice
- Smart analysis and modeling tools are needed for the smart grid
- Transportation and stationary power, once separate, and now seen increasingly as linked through energy and climate and health/air quality issues

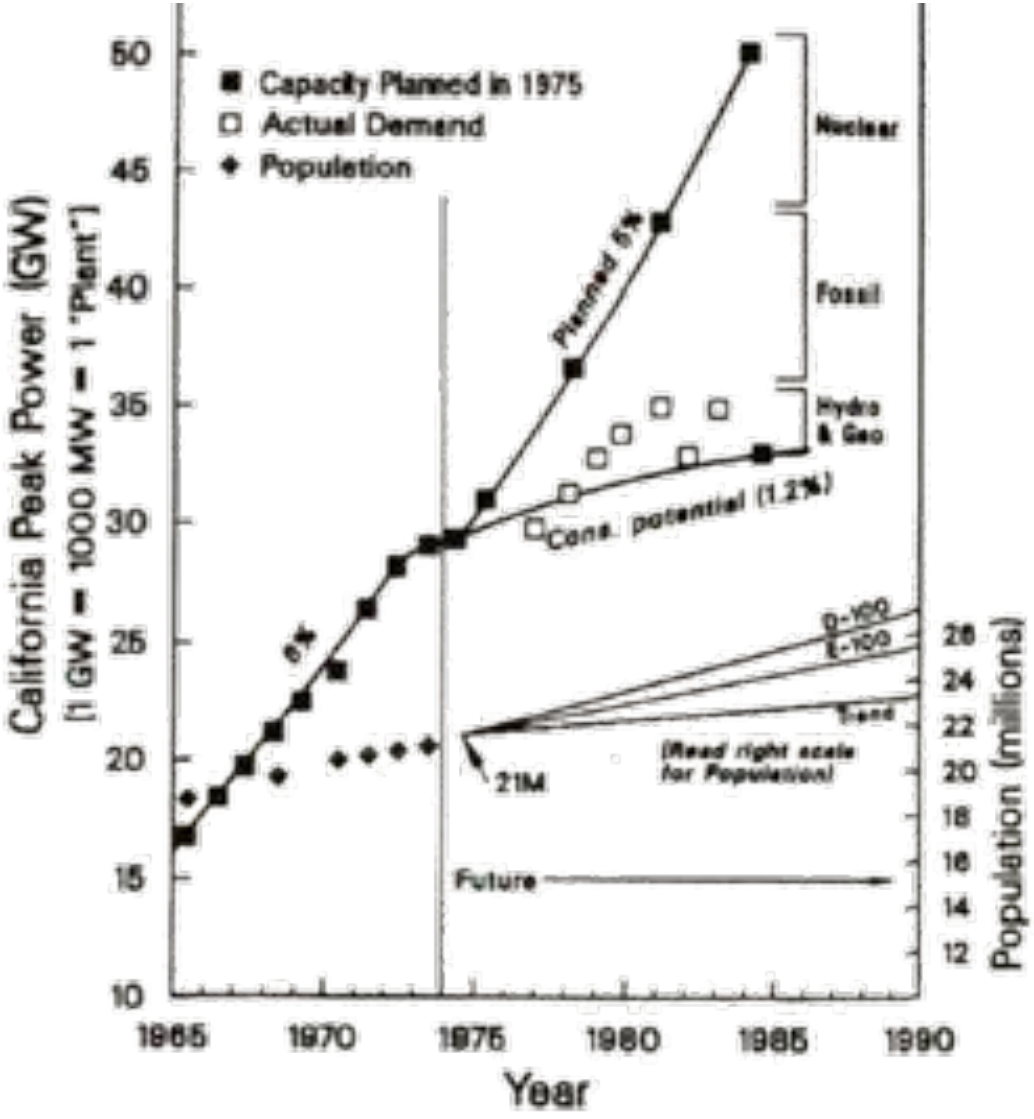
Building A Sustainable Electric System: Model and Policy Components



Energy Intensity (E/GDP) in the US 1949 - 2007

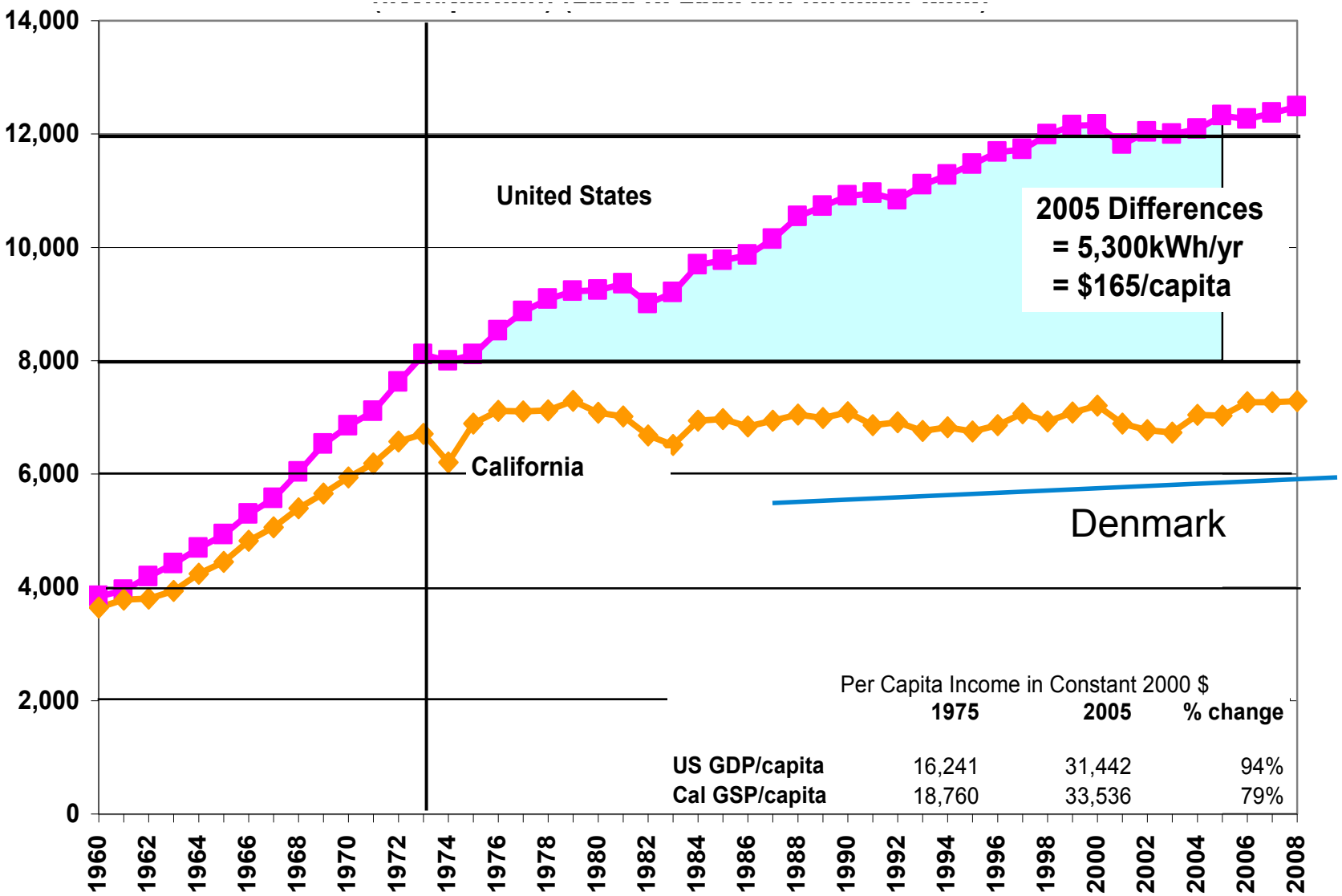


CA Peak Power: Testimony by Goldstein and Rosenfeld (Dec. 1974)



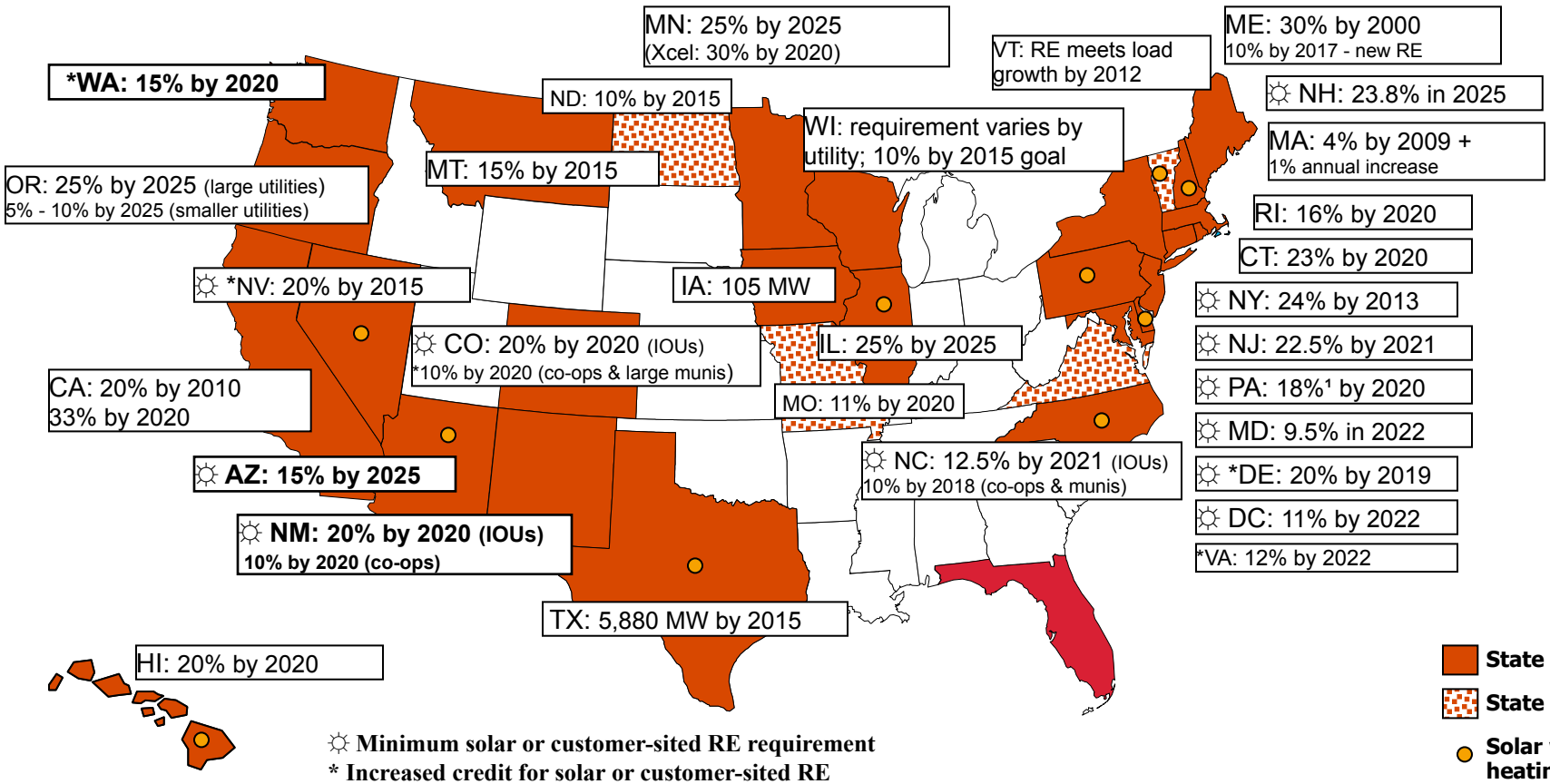
Per Capita Electricity Sales (not including self-generation)

(kWh/person) (2006 to 2008 are forecast data)



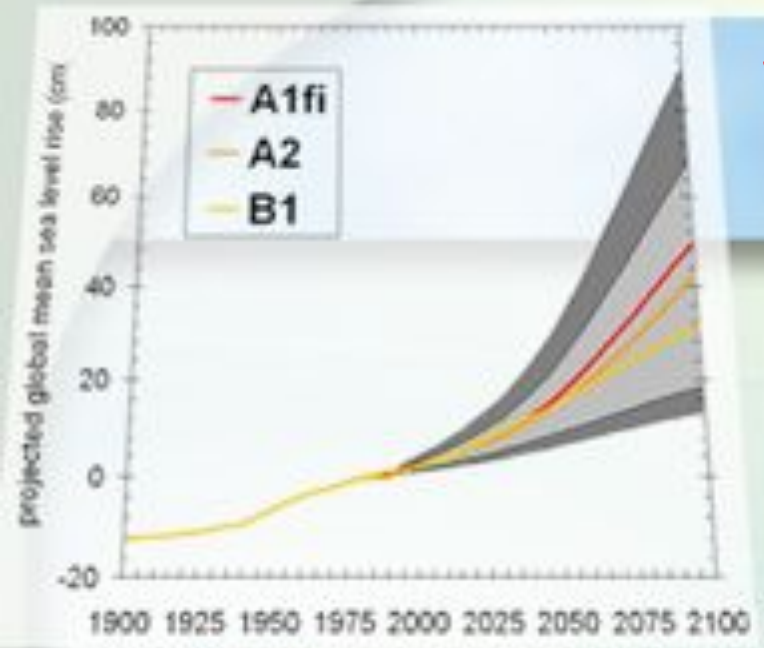
Renewable Energy Portfolio Standards

(30 states + Washington, DC)



☼ Minimum solar or customer-sited RE requirement
* Increased credit for solar or customer-sited RE
¹PA: 8% Tier I / 10% Tier II (includes non-renewables)

March 2011



Why AB 32?
Climate Impacts…

California Projected Impacts

75% loss in snow pack

1-2 foot sea level rise

70 more extreme heat days/year

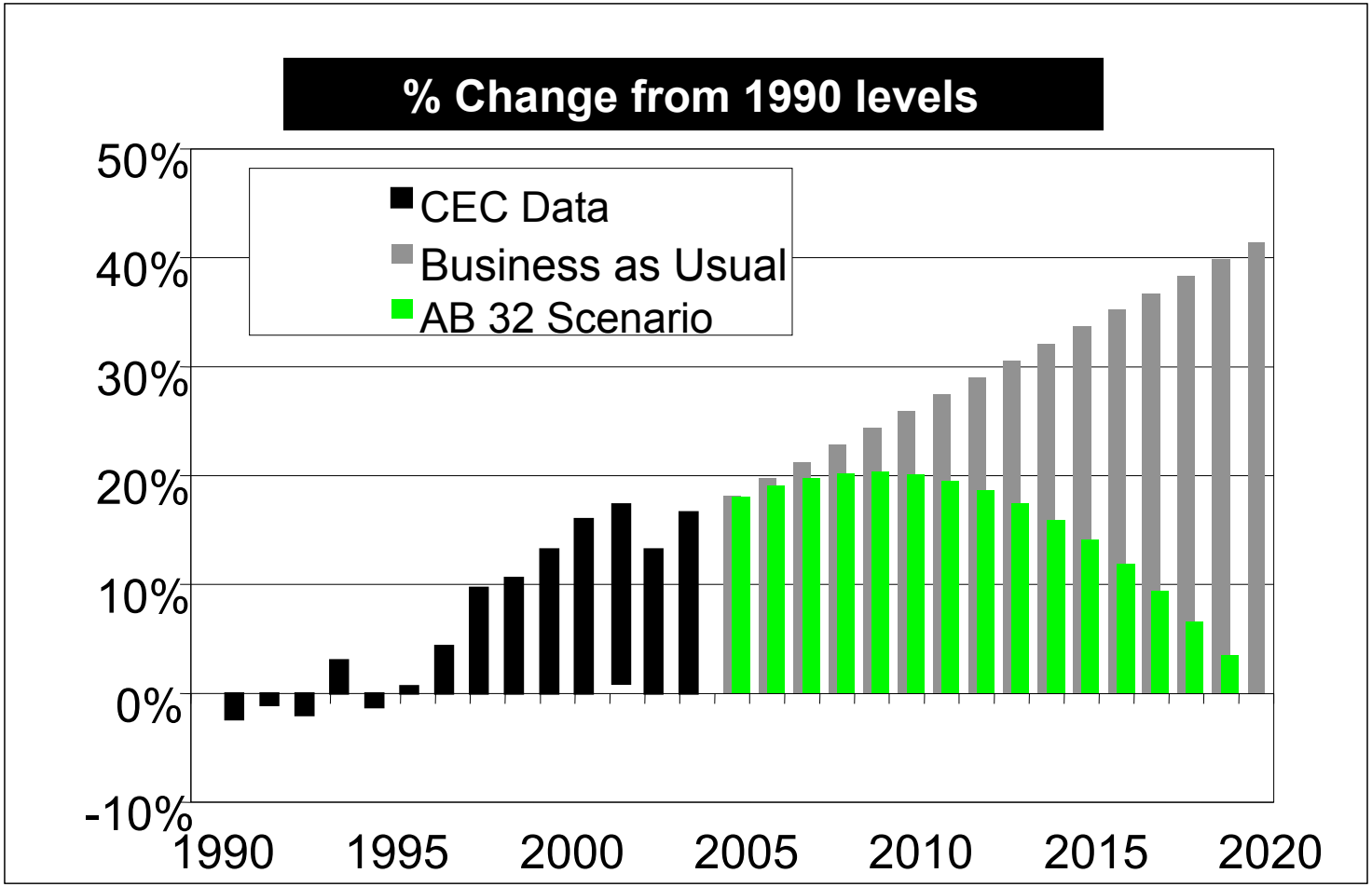
80% more ‘likely ozone’ days

55% more large forest fires

Twice the drought years

California Global Warming Solutions Act:

~25% cut in emissions by 2020



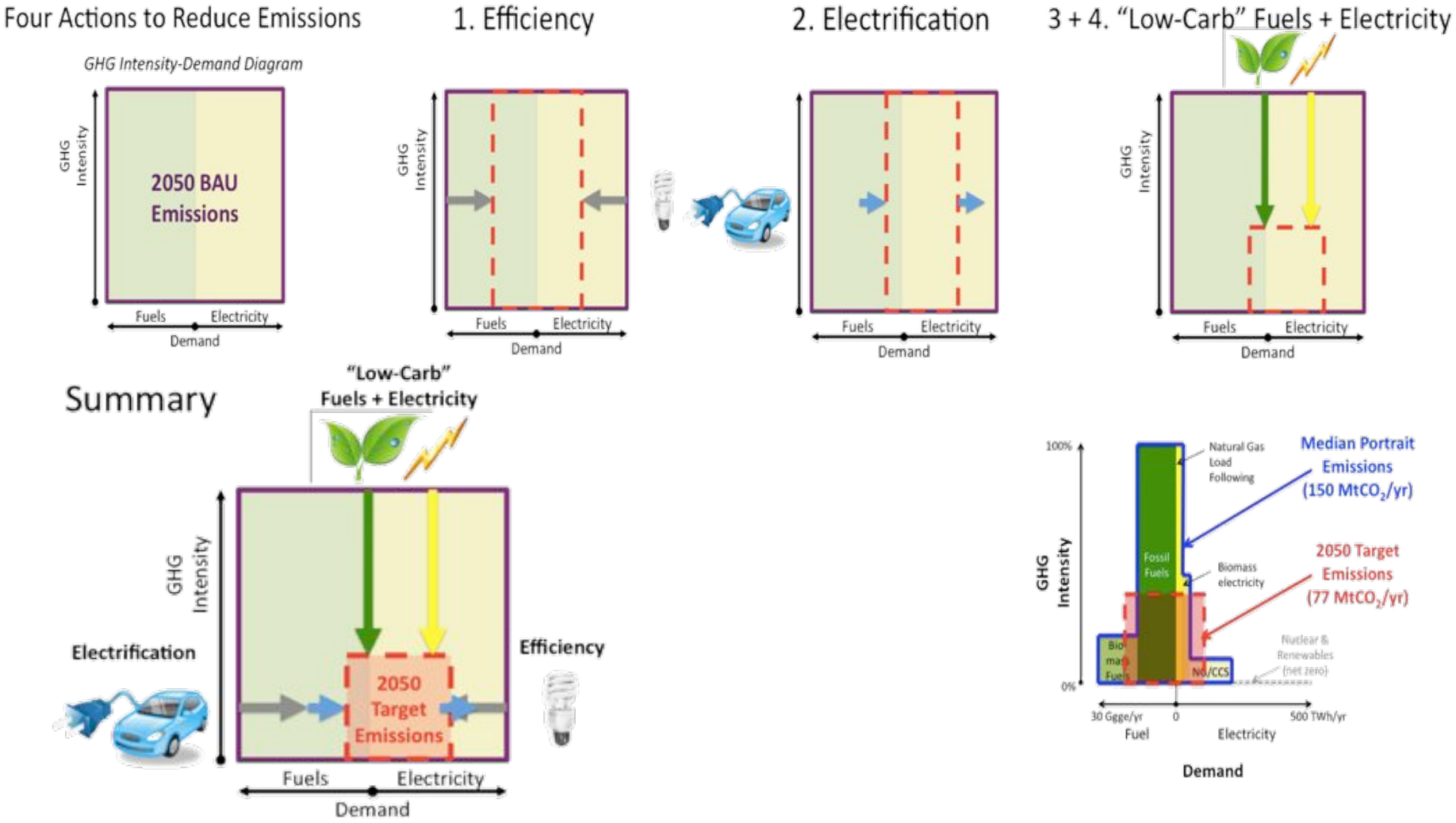
In CA:

- Carbon loading order
- ~60 GW peak, 12 new GW of DG manadate
- EV mandate

An integrated framework that uses sectoral targets and a carbon market (first auction, November 2012

California Climate Planning (2006 – 2050)

Integration across sectors



Interacting Aspects of California's Energy / Climate Policy:

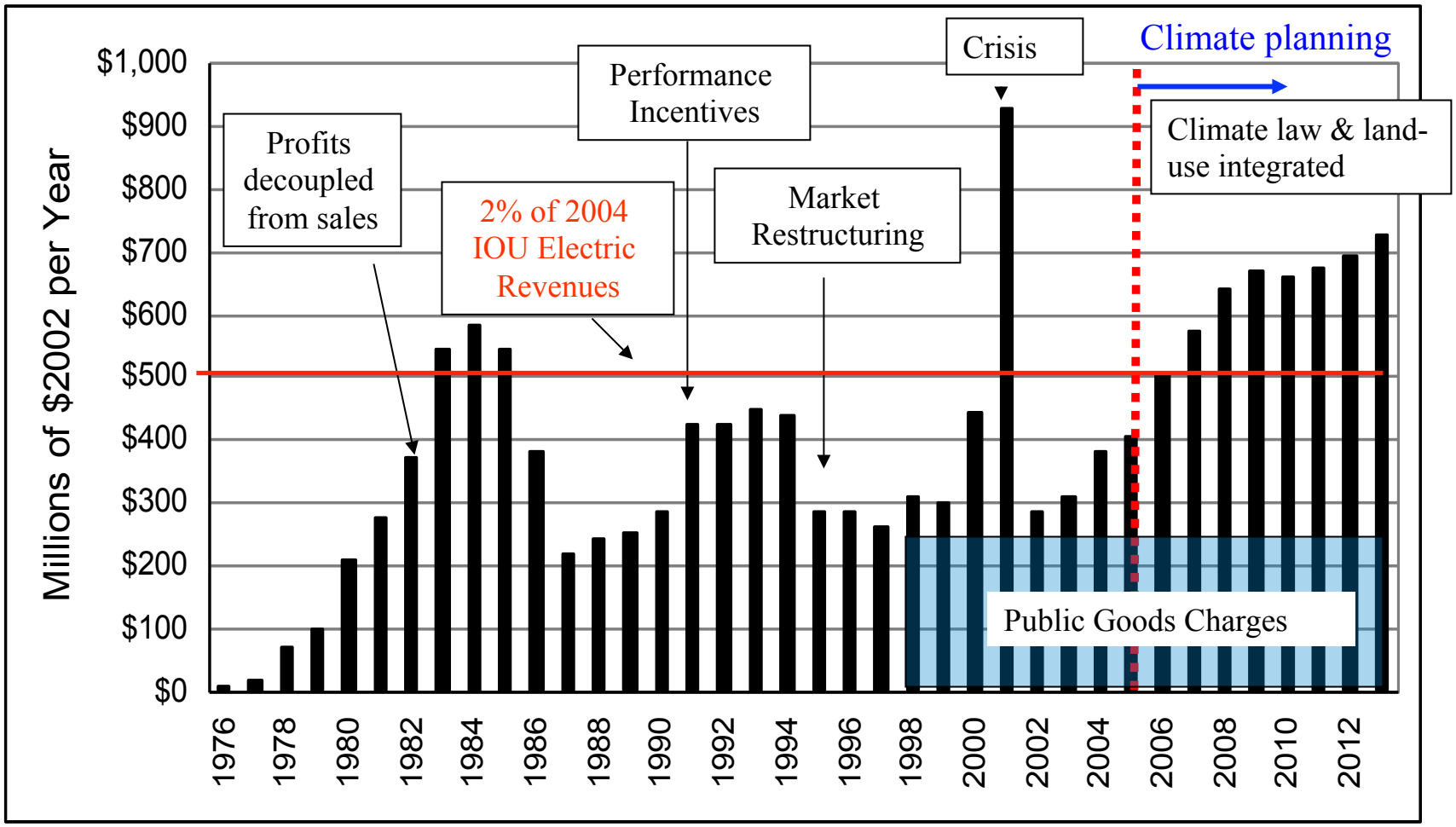
- **A history of attention and innovation in energy efficiency**:
  - Appliance standards
  - *Utility rate decoupling (the key integrative policy measure)*
- **Experiment (disastrous, but did not stop progress) with deregulation**
- **AB1493: 30% reduction in vehicle GHG emissions**
- **AB32: An integrative GHG reduction bill, reaching across the economy; return to the 1990 baseline by 2020 (~ a 25% reduction)**
- **Executive Order 7-01: A Low Carbon Field Standard**
- **An electricity 'loading order' to prioritize energy efficiency and then renewables before any fossil-fuel projects, and a CO2/kWh limit set to match natural gas power plants**
- **SB375: Land use and planning to reflect climate goals**
- **A million solar roof mandate and buy-down program (70% of US solar systems installed in California)**
- **A 12 GW Distributed Generation Mandate**
- **A million electric vehicle mandate**
- **A feed-in tariff (small systems)**
- **A 2050 goal of 80% decarbonization from 1990 levels**

Energy Efficiency Strategies

Residential New Construction

- **All new residential construction in California will be zero net energy by 2020.**

California Investor owned Utility (IOU) Investment in Energy Efficiency



Complex Power Systems: High Temporal and Spatial Resolution Modeling

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High-resolution modeling of the western North American power system demonstrates low-cost and low-carbon futures

James Nelson [a,b], Josiah Johnston [a,b], Ana Mileva [a,b], Matthias Fripp [c], Ian Hoffman [a,b,d], Autumn Petros-Good [a,b], Christian Blanco [a], Daniel M. Kammen [a,b,e,*]

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[b] *Energy and Resources Group, University of California, Berkeley, CA 94720-3050, United States*
[c] *Environmental Change Institute, Oxford University, South Parks Road, Oxford, OX1 3QY, UK*
[d] *Electricity Markets and Policy Group, Lawrence Berkeley National Laboratory, Berkeley, CA 94720, United States*
[e] *Goldman School of Public Policy, University of California, Berkeley, CA 94720-3050, United States*

http://rael.berkeley.edu/**switch**

The SWITCH-WECC Model (*Energy Policy*, 2012)

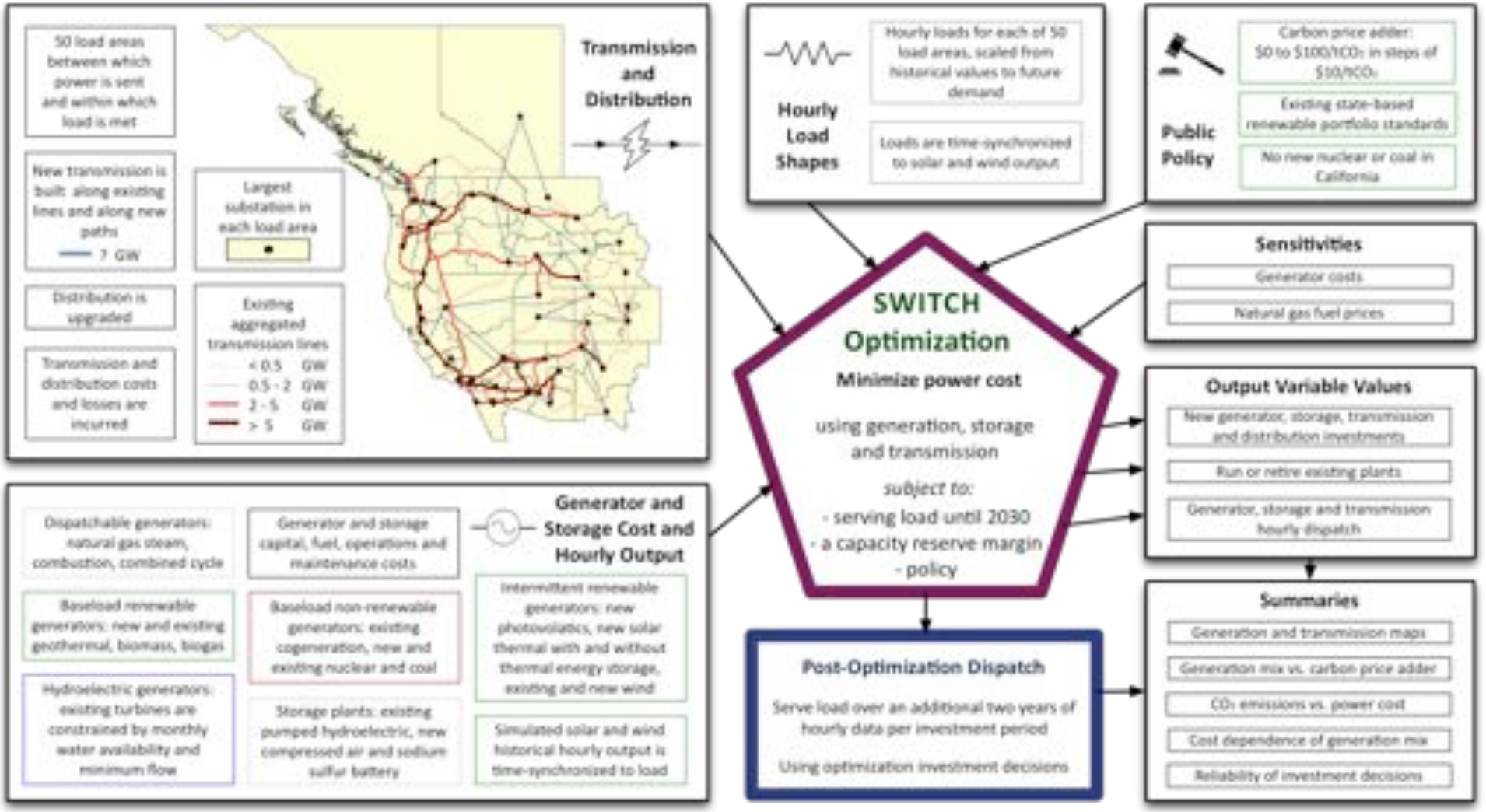
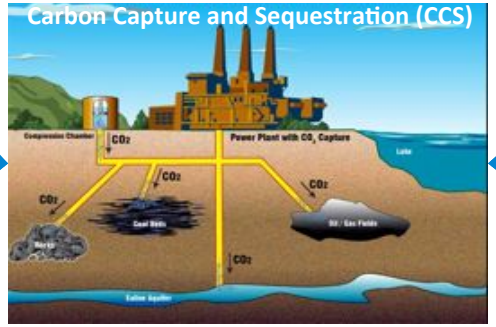


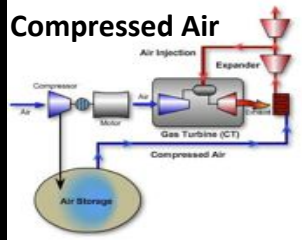
Figure 1. *Optimization and data framework of the western North American SWITCH model, WECC: Western Electricity Coordinating Council.*

New Generation & Storage Options in SWITCH



Storage

Compressed Air



Sodium Sulfur Battery

The SWITCH-WECC Model (*Energy Policy*, 2012)

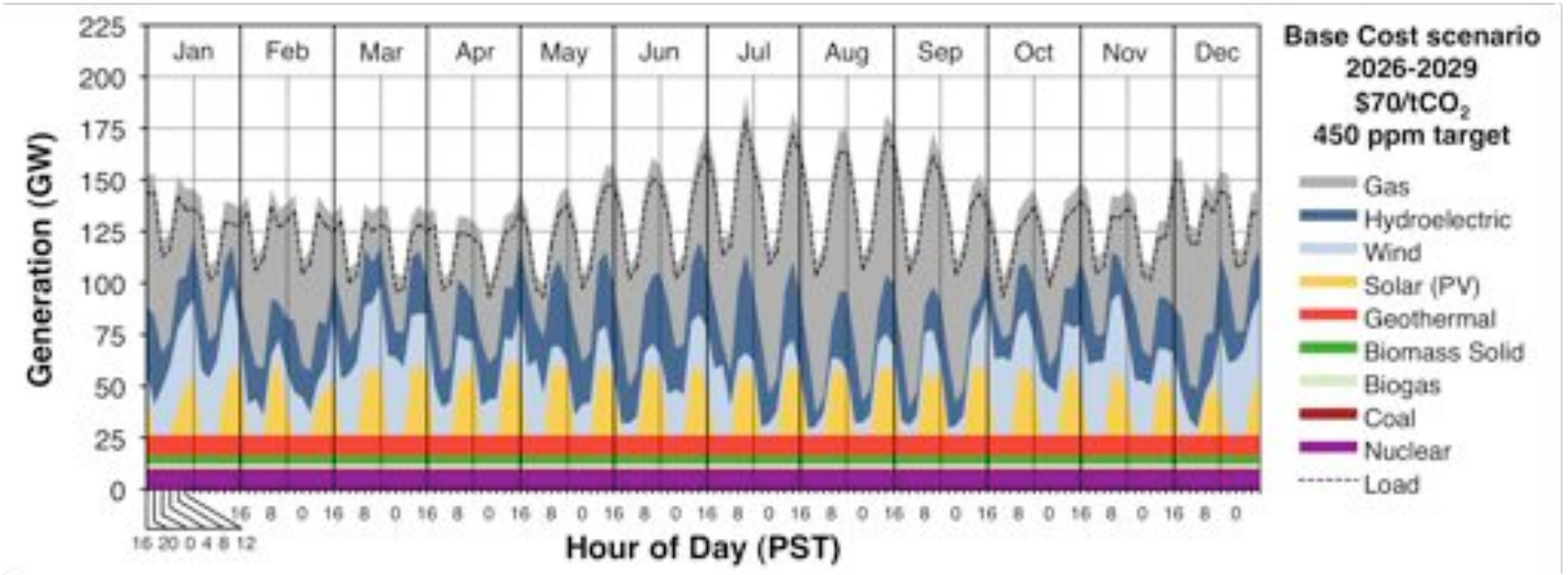
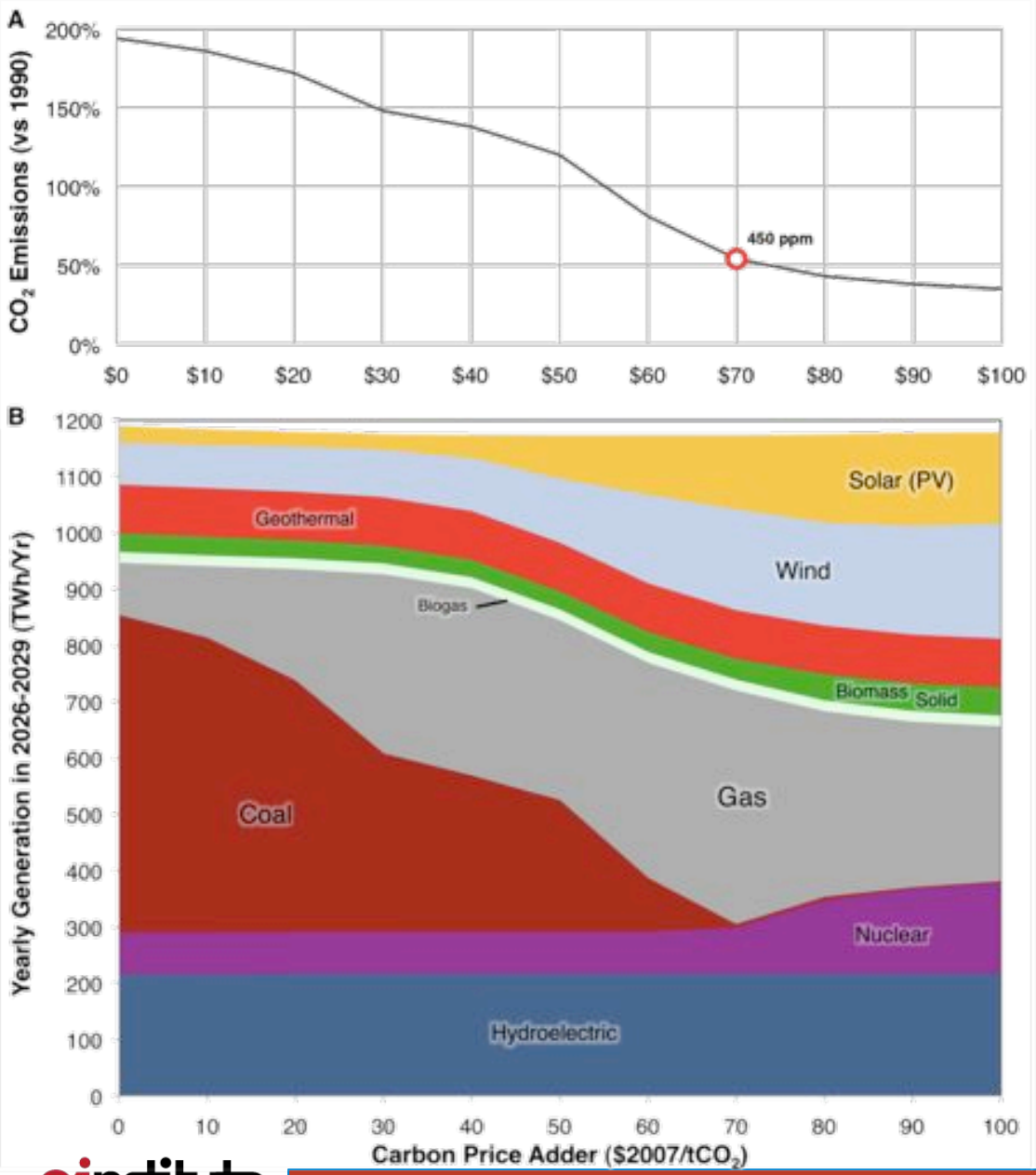


Figure 6. *Base Cost scenario hourly power system dispatch at 54% of 1990 emissions in 2026-2029. This scenario corresponds to a $70/tCO$_2$ carbon price adder. The plot depicts six hours per day, two days per month, and twelve months. Each vertical line divides different simulated days. Optimizations are offset eight hours from Pacific Standard Time (PST) and consequently start at hour 16 of each day. Total generation exceeds load due to distribution, transmission, and storage losses. Hydroelectric generation includes pumped storage when storing and releasing.*

The SWITCH-WECC Model (*Energy Policy*, 2012)

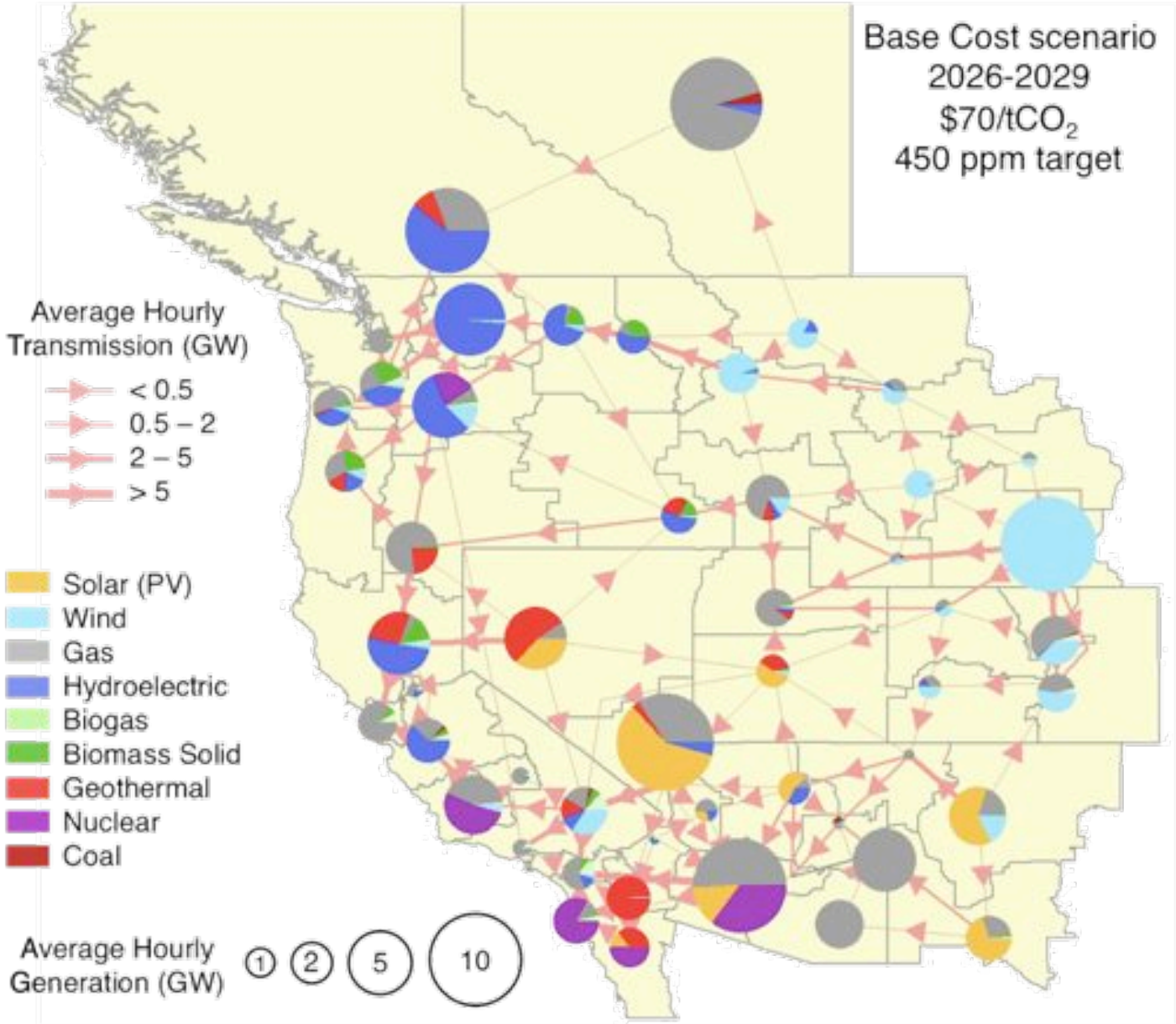


CARBON COST AND DECARBONIZATION:

Base Cost scenario CO_2 emissions relative to 1990 emission levels (A) and yearly power generation by fuel (B) in 2026-2029 as a function of carbon price adder. As shown in panel A, the climate stabilization target of 450 ppm is reached at a carbon price adder of $70/tCO_2$.

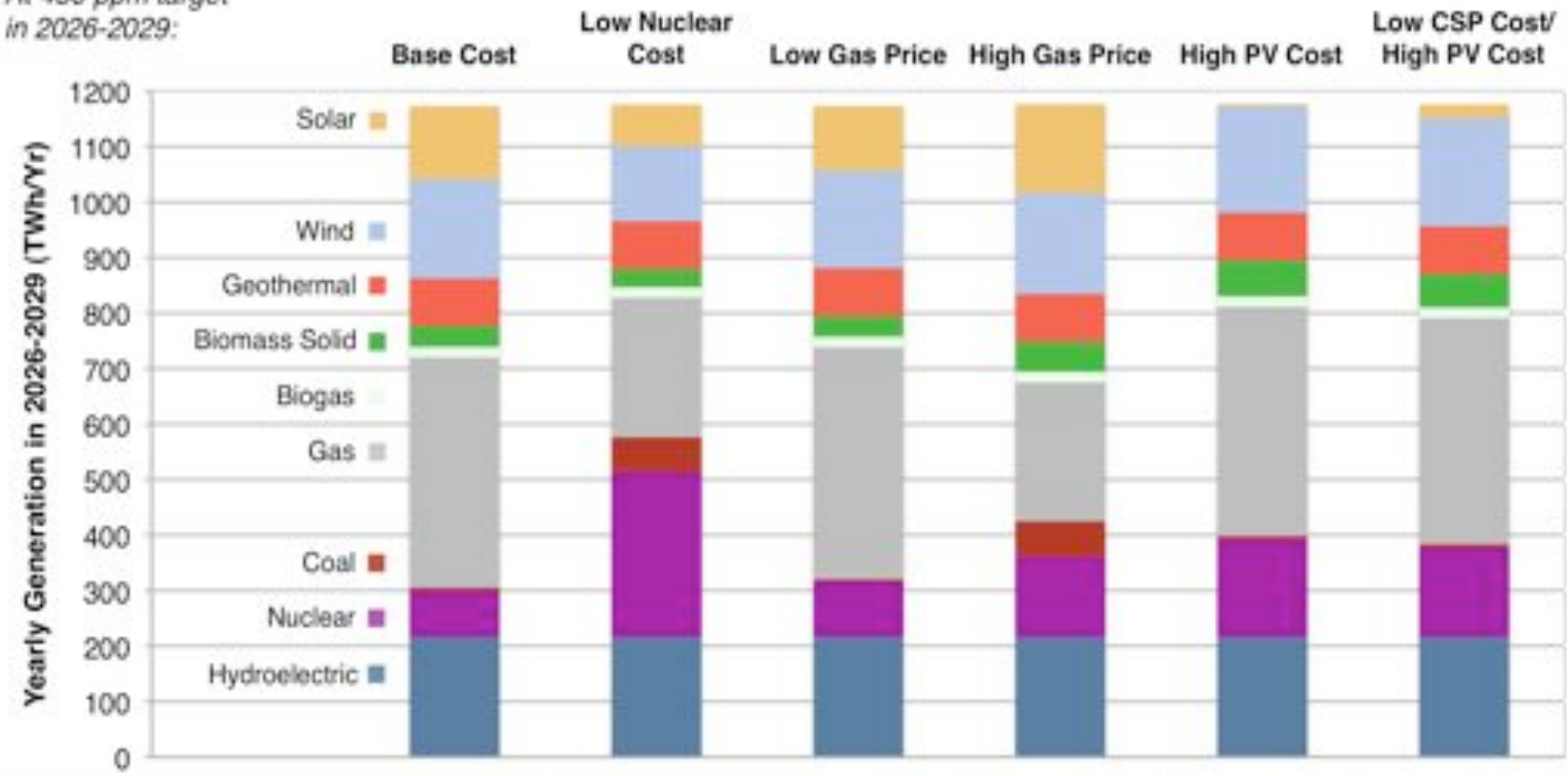
WECC: Western Electricity Coordinating Council

The SWITCH-WECC Model (*Energy Policy*, 2012)



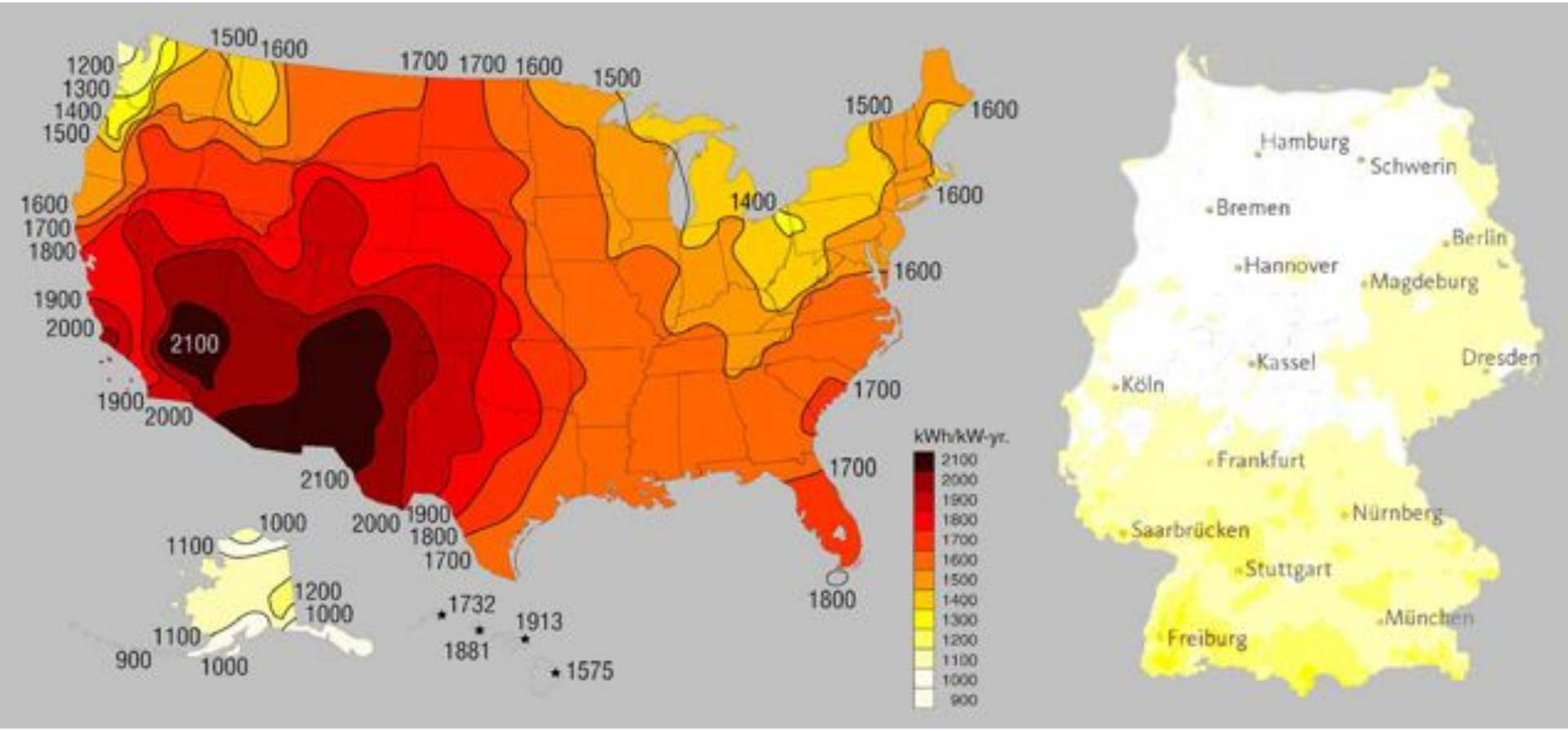
Average generation by fuel within each load area and average transmission flow between load areas in 2026-2029 at 54% of 1990 emissions for the Base Cost scenario. This scenario corresponds to a $70/ tCO_2 carbon price adder. Transmission lines are modeled along existing transmission paths, but are depicted here as straight lines for clarity. The Rocky Mountains run along the eastern edge of the map, whereas the Desert Southwest is located in the south of the map.

At 450 ppm target in 2026-2029:

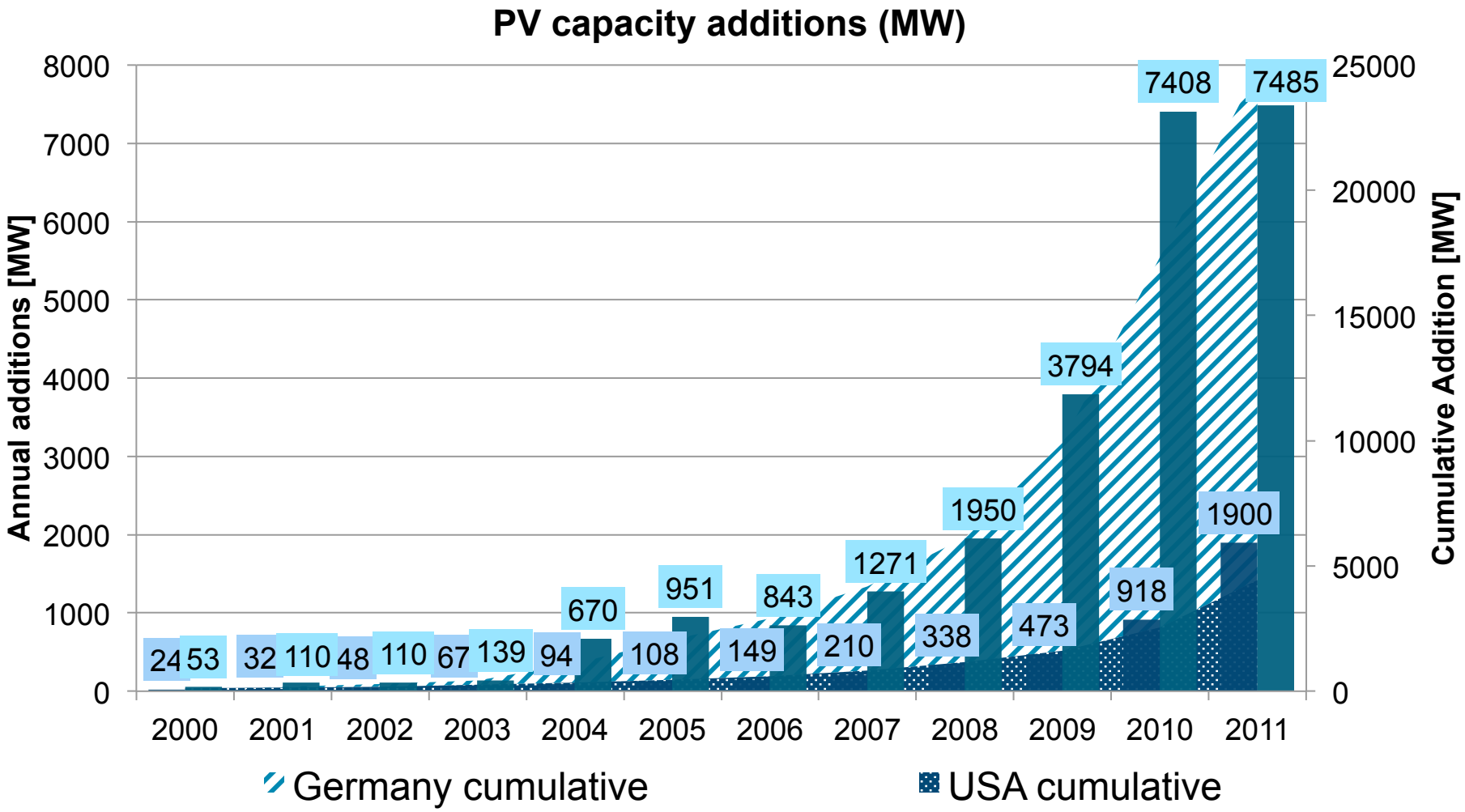


	Base Cost	Low Nuclear Cost	Low Gas Price	High Gas Price	High PV Cost	Low CSP Cost/ High PV Cost
Carbon price adder ($2007/tCO$_2$)	70	59	87	66	84	86
Power cost ($2007/MWh)	113	110	110	114	114	114
Cumulative new transmission built by 2030 (10^3 GW-km)	9.8	6.0	9.0	11.7	12.0	12.3

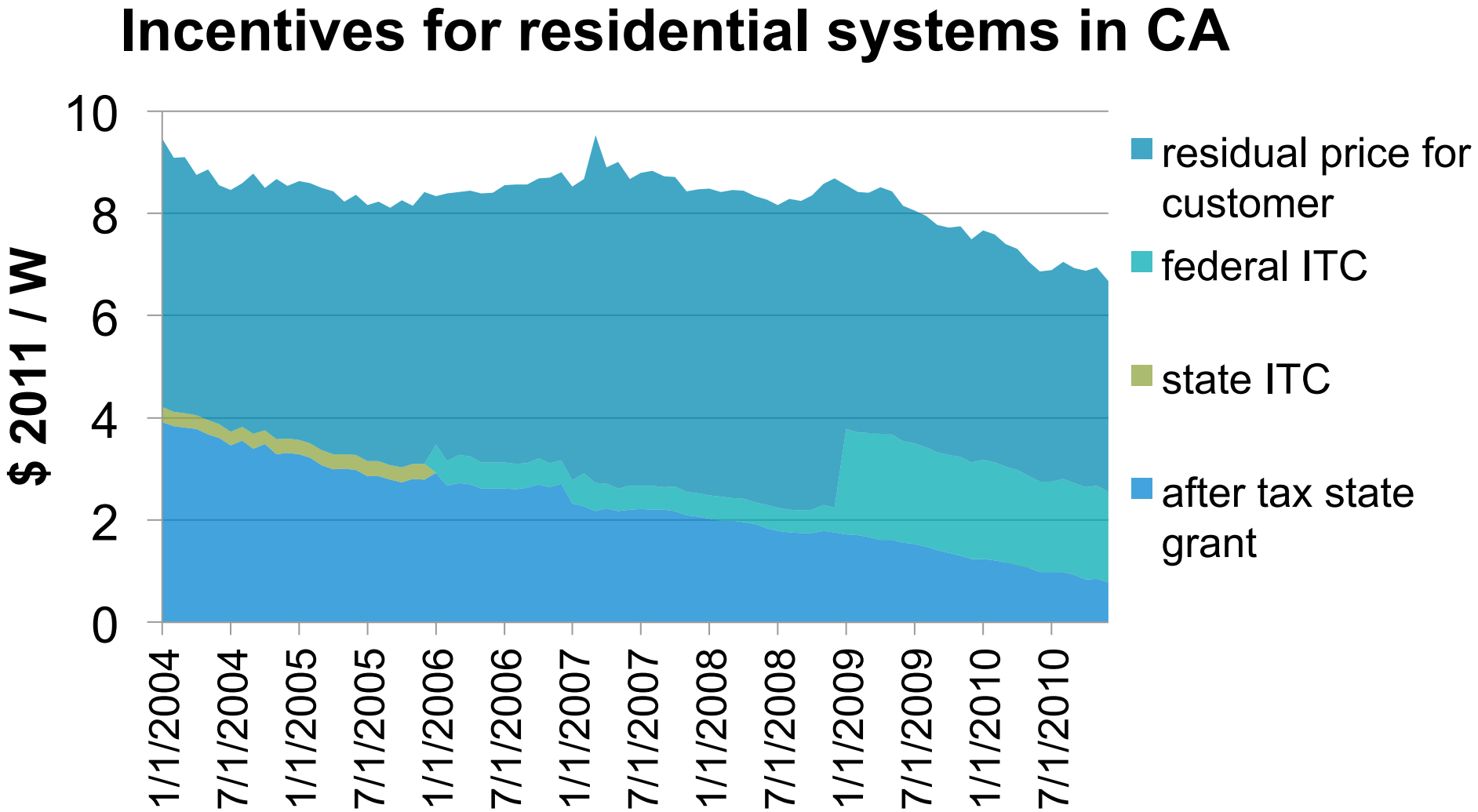
US has twice the German insolation endowment



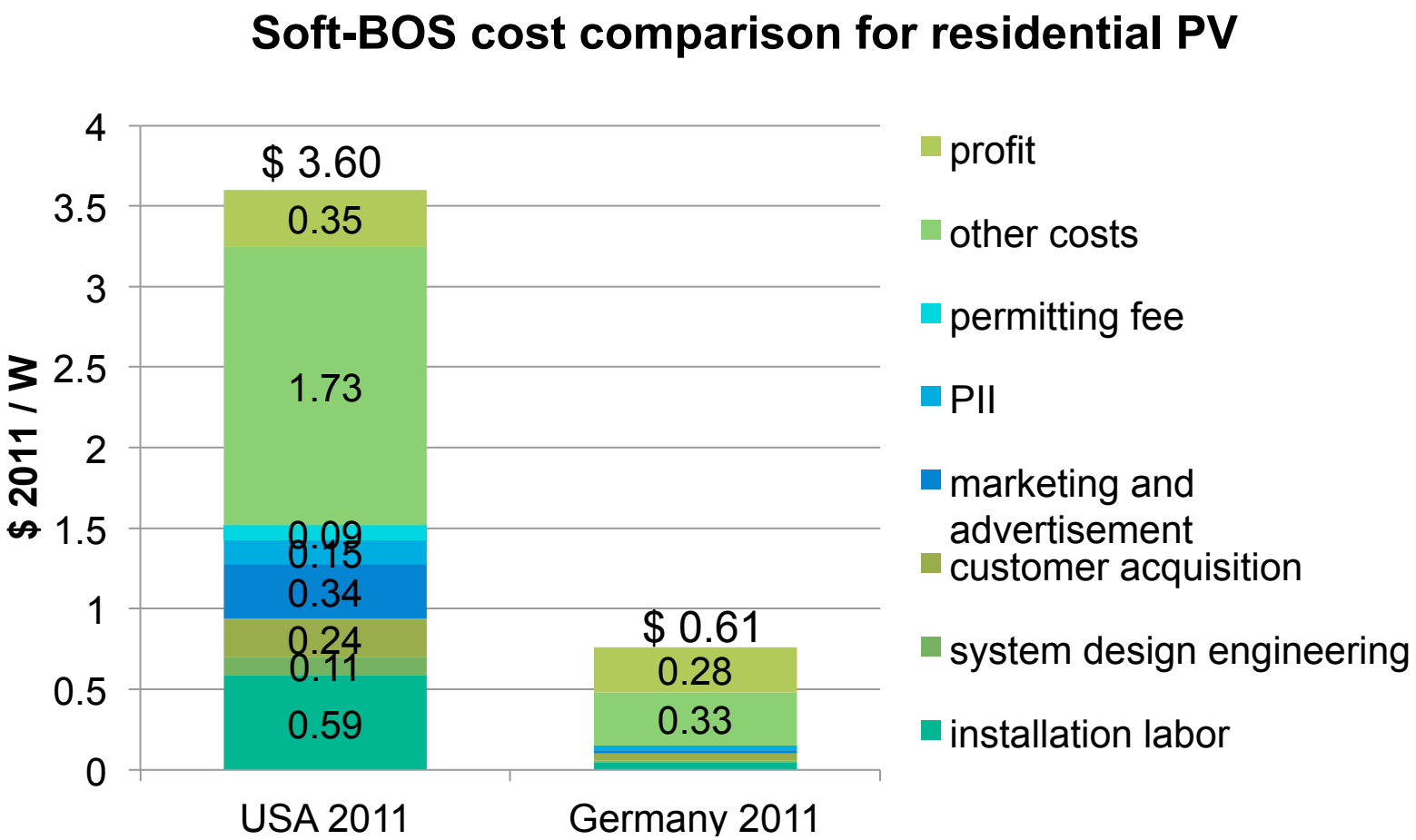
German total additions more than 5x US size, Germany's 2011 additions nearly 4x US market



70% of US solar market is CA

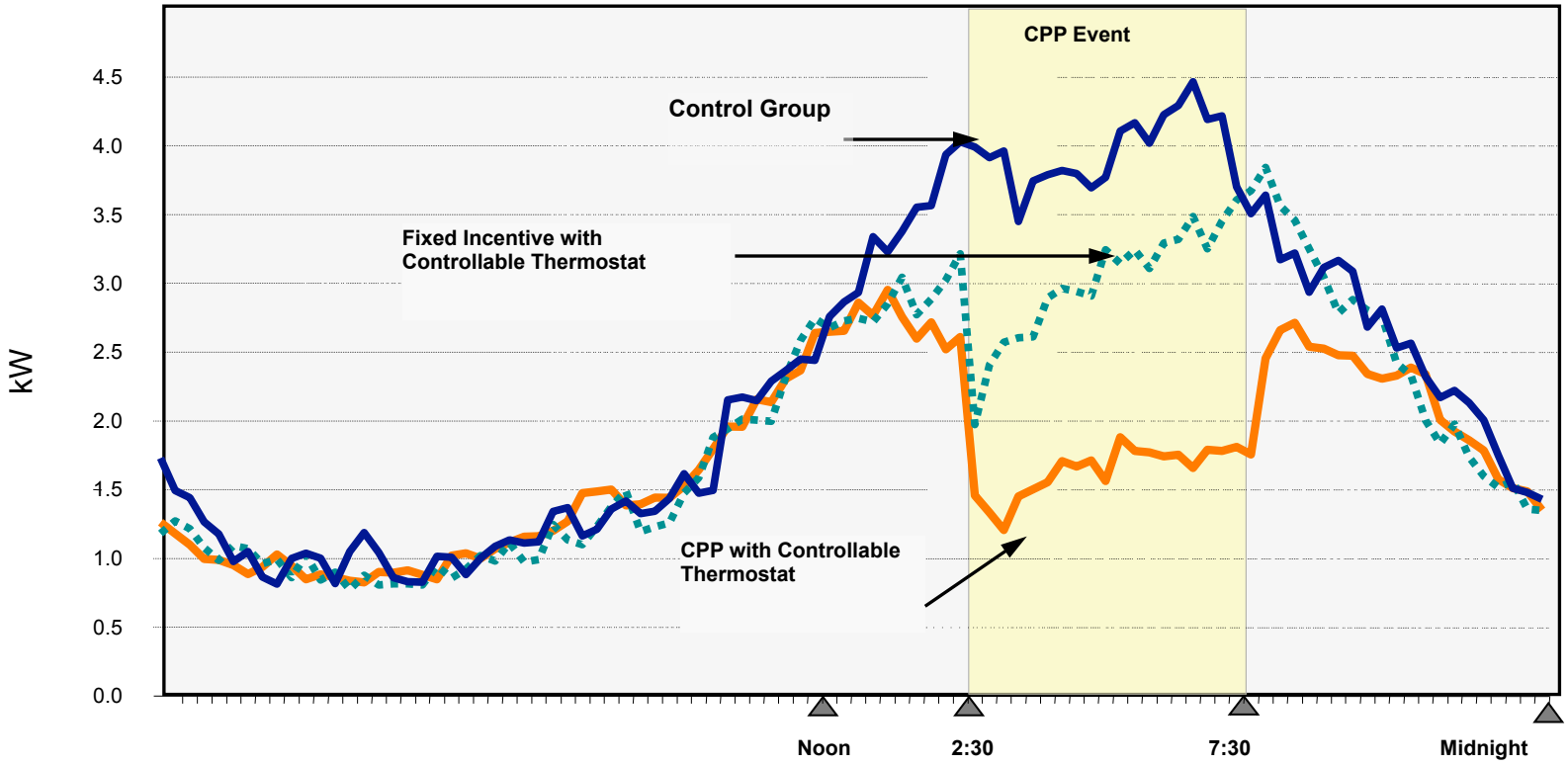


US Soft-Balance of Systems cost make up nearly all the cost difference



Critical peak pricing and the demand-side

Average Residential Response to Critical Peak Pricing



- Transportation:
- Options for reducing GHG emissions from transportation subsectors
- Provide snapshots of 80% reduction in transport emissions
- Create a spreadsheet tool for developing scenarios and calculating emissions
- Transportation Kaya identity

$$CO_{2,Transport} \equiv \left(Population\right)\left(\frac{Transport}{Person}\right)\left(\frac{Energy}{Transport}\right)\left(\frac{Carbon}{Energy}\right)$$

$$P \times T \times E \times C$$

Population
California pop.

Transport intensity
(e.g., VMT/capita)

Energy Intensity
(e.g., MJ/mile)

Carbon Intensity
(e.g. gCO_2-eq/MJ)

References:

- Nelson, J. H., Johnston, J., Mileva, A., Fripp, M., Hoffman, I., Petros-Good, A., Blanco, C., and Kammen, D. M. (2012) “High-resolution modeling of the western North American power system demonstrates low-cost and low-carbon futures”, *Energy Policy,* **43**, 436–447.

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