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Global Energy Technology Strategy Program

Energy and Technology in a California Context

GTSP Annual Meeting

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California: A Regional Analysis Example

This talk will present long-term analysis of California buildings and renewable energy as a regional analysis case study.

The United States has a large, diverse energy system. The analysis of a specific region can:

- Provide relevant information to regional decision-makers
  - ⇒ Some regional details differ significantly
- Make use of more detailed regional information
  - ⇒ California has a substantial data collection and analysis system
- Make use of detailed studies to inform analysis
  - ⇒ A substantial body of applied work conducted under the CEC PIER program
  - ⇒ A detailed regional study of a specific topic may be more feasible than a national study in terms of data needs

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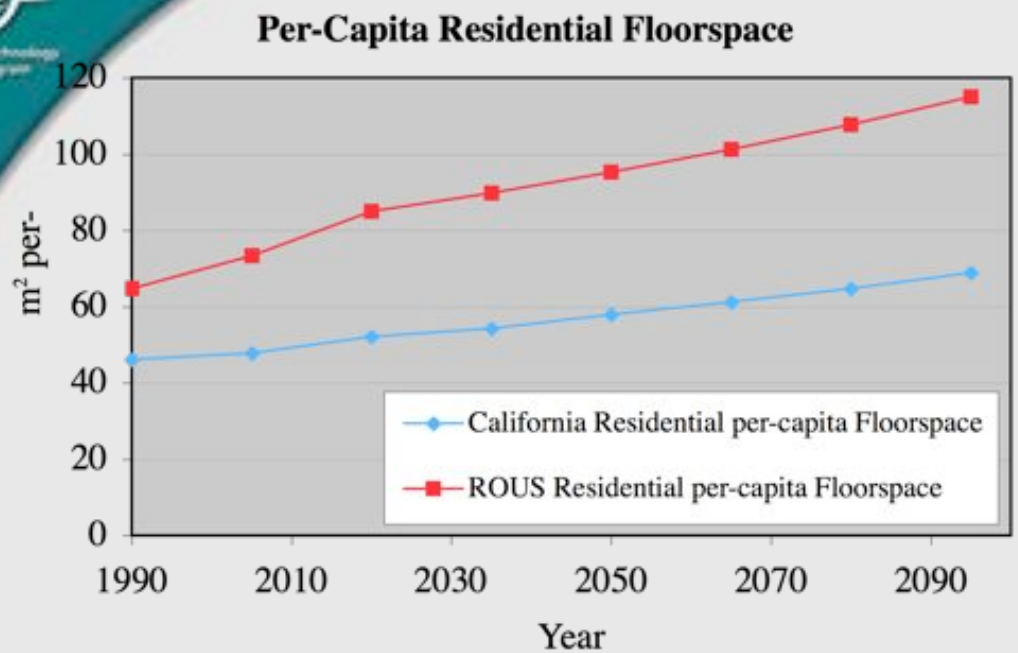
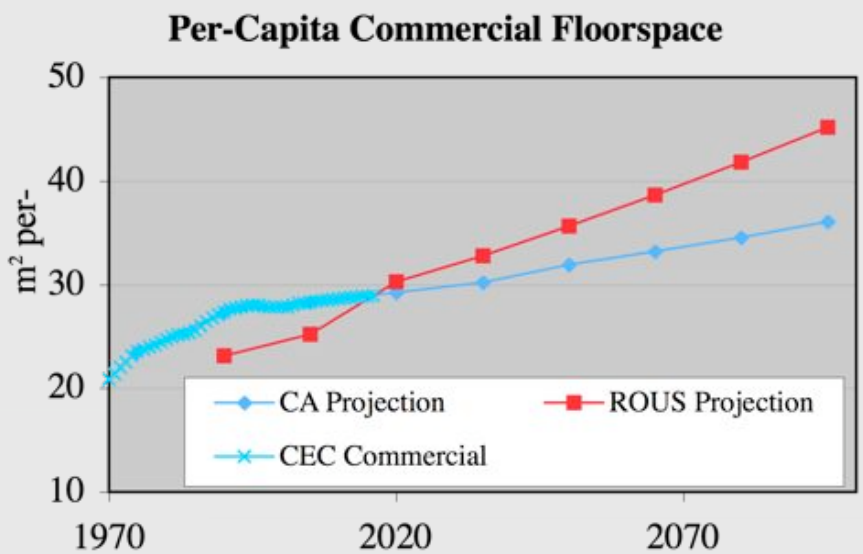
California Building Energy

Floorspace Scenarios



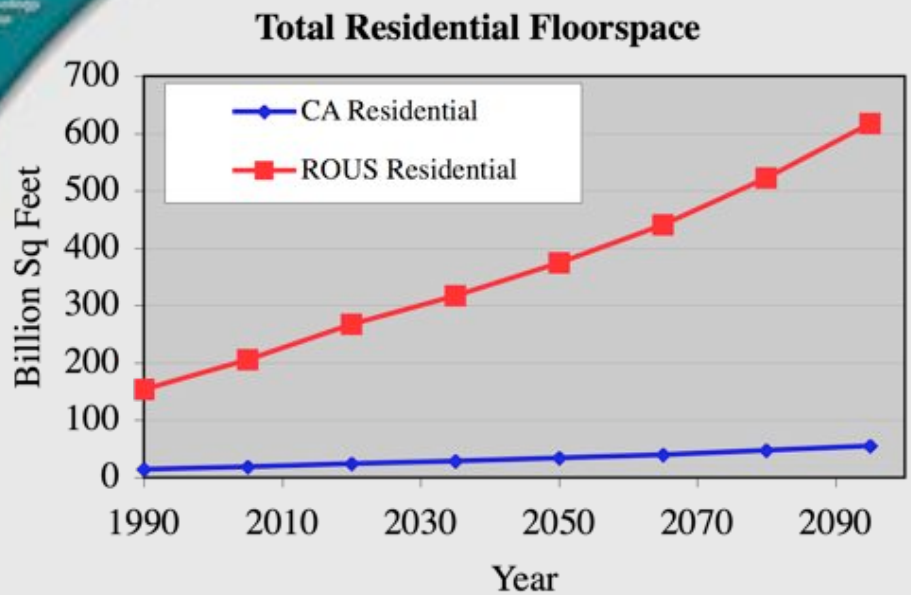


The foundation of a building scenario are floorspace assumptions.

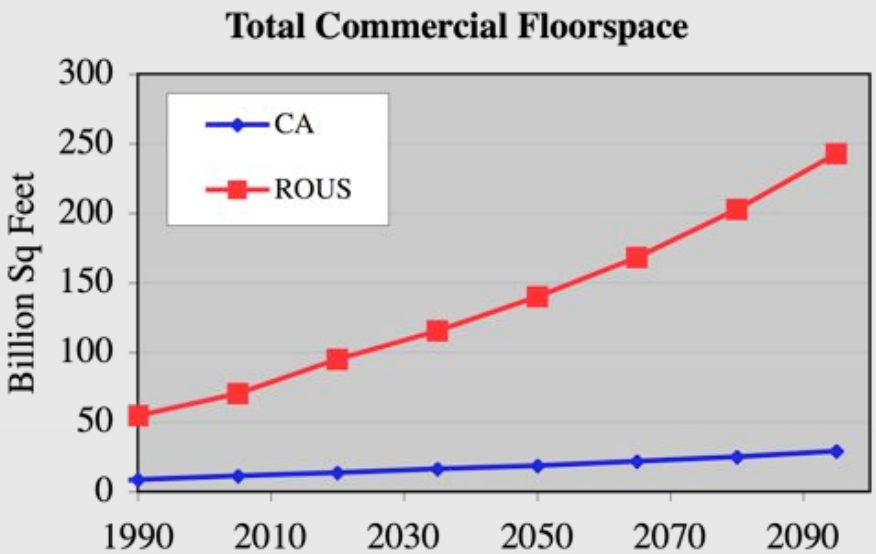
California has much smaller per-capita residential floorspace, apparently, with a slower growth rate.

While commercial building comparisons are particularly prone to uncertainty due to definitional issues, it appears that California is comparable to the rest of the US in per-capita commercial floorspace, although the growth rate may be much less.

CA Floorspace



While the per-capita growth rate of residential floor space in California is smaller than that in the rest of the United States, the growth rate for total floorspace is about the same — a factor of 3 over the next 90 years.



The growth rate of total commercial floorspace in CA is lower than that in the rest of the US in this projection.

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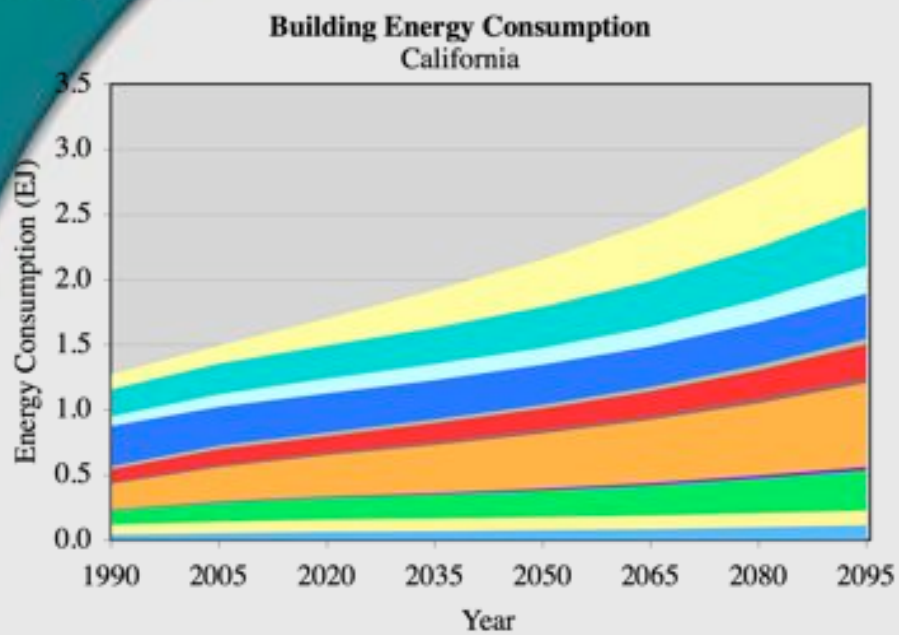
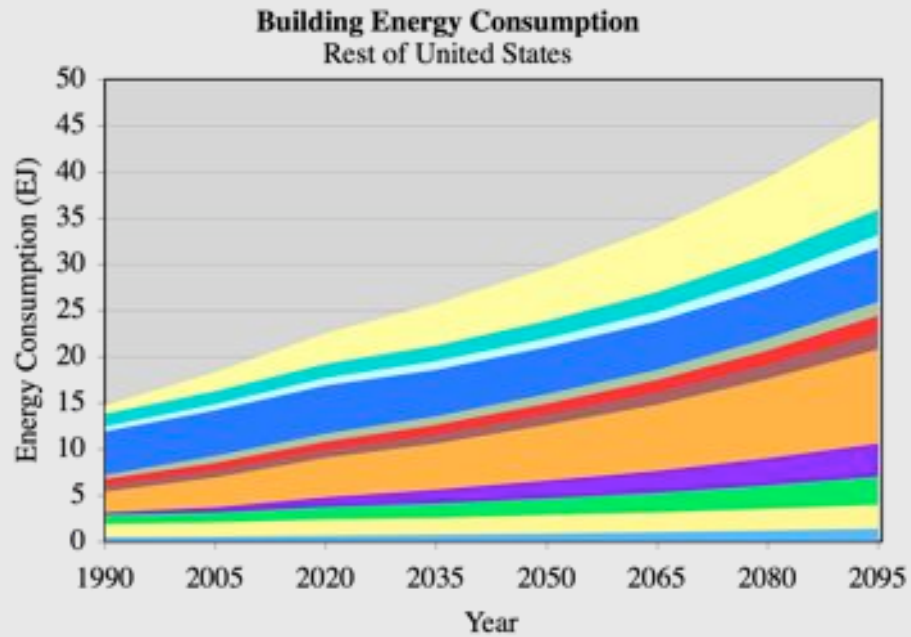
A CA version of our end-use buildings model was embedded in our global model

Building Energy





- Current energy use profile is different, but not dramatically so.
- Heating and cooling energy smaller per m^2, as expected due to difference in HDD and CDD between CA and ROUS.
  - ≈Residential cooling still half of what would be expected
- Per capita residential water heating similar
- Some significant differences in commercial sector

residential others
residential water heating
residential lighting
residential heating
residential cooling
residential appliances
commercial water heating
commercial others
commercial office equipment
commercial lighting
commercial heating
commercial cooling

"Rest" of US is not the same as CA.

Unfortunately nether are the data sources.

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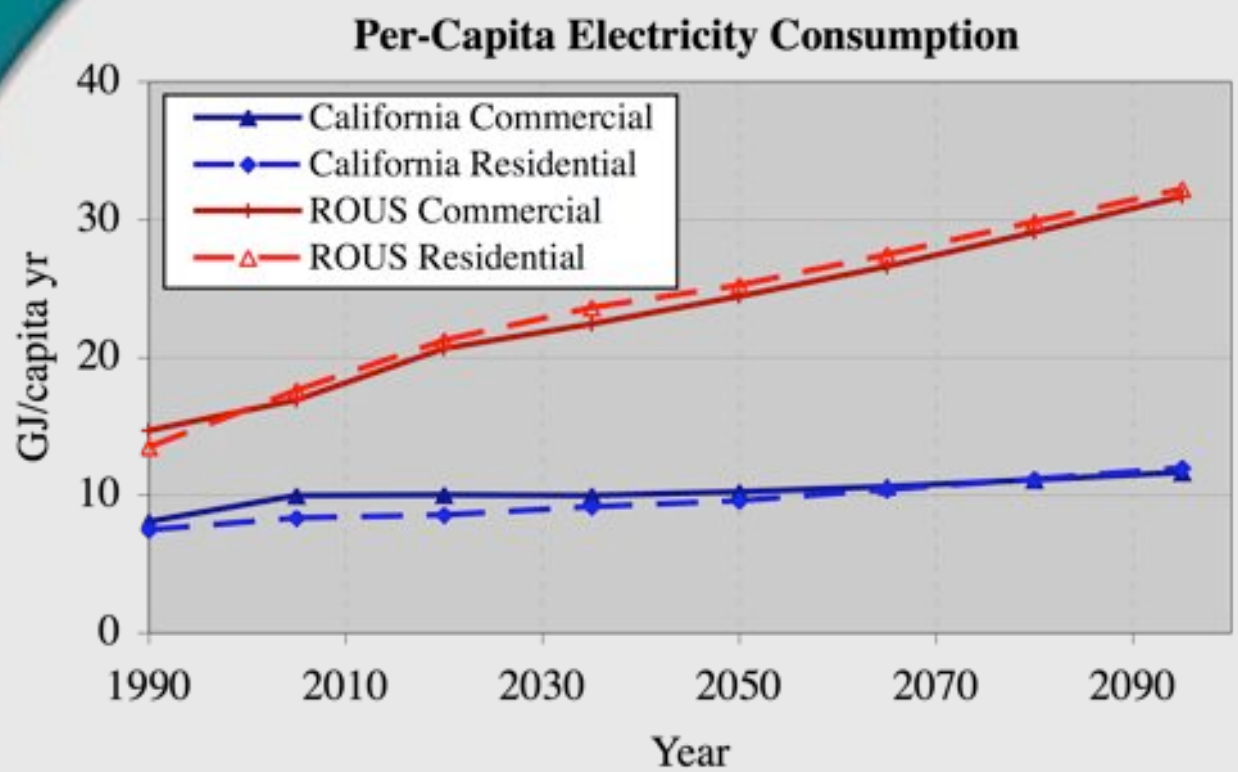
CA Energy Use



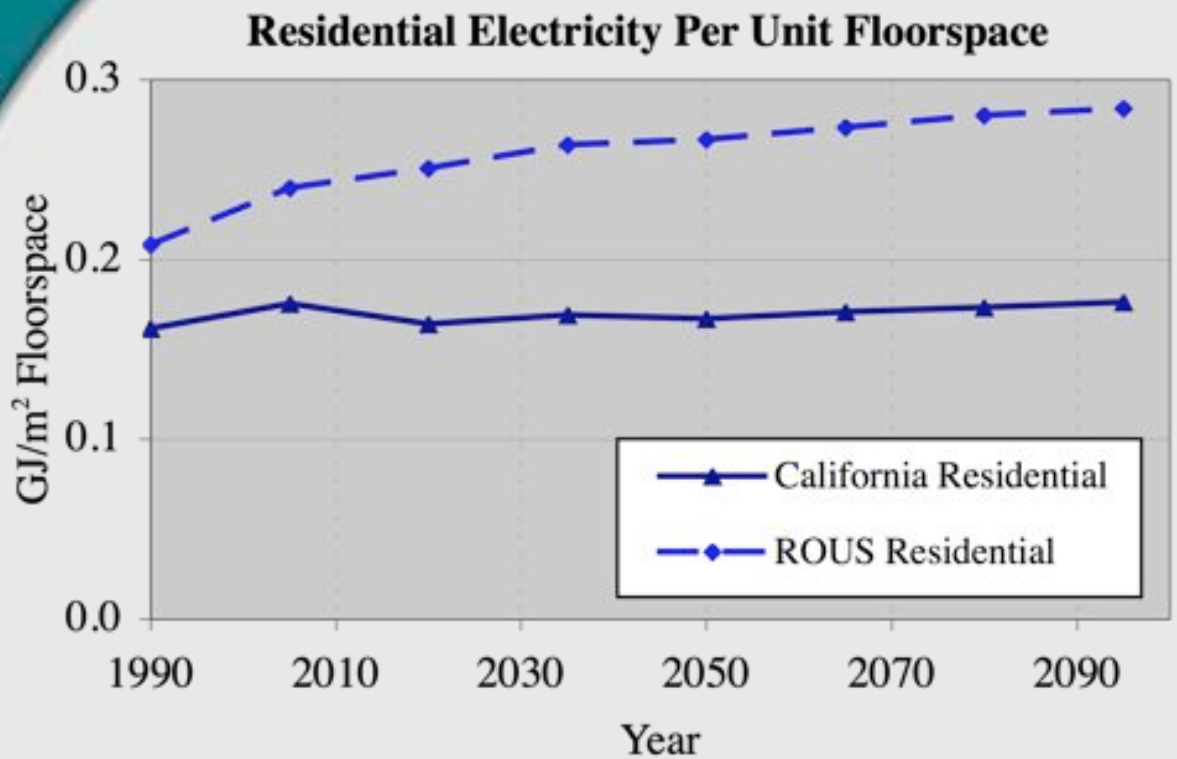
California per-capita electricity consumption increases slightly over the century.

Per-capita electricity consumption increases substantially in the rest of the U.S.

Over the next 90 years, **total electricity** demand (not per-capita) increases by a factor of 2.6 in California and 3.6 in the rest of the United States.

While California also faces the challenge of increasing electricity demand, efficiency measures reduce the magnitude of this challenge relative to the rest of the United States.

CA Energy Use



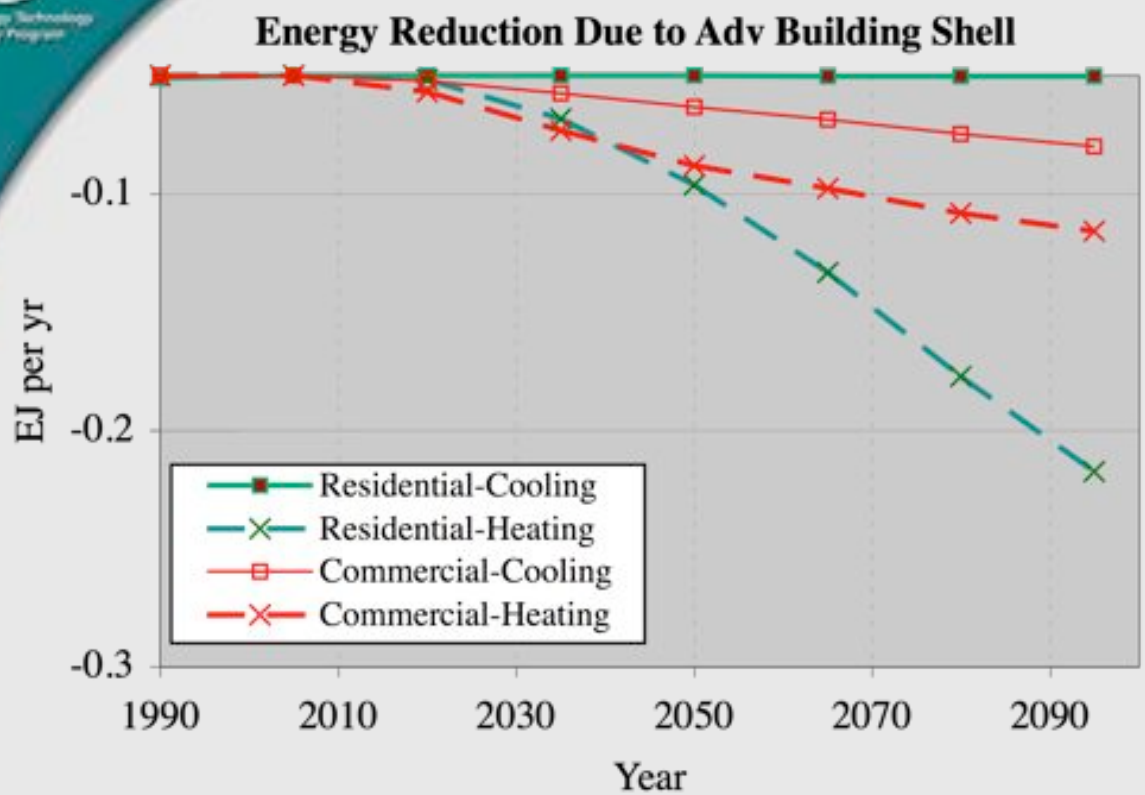
California residential energy consumption remains relatively constant per unit floorspace.

While California per-capita residential electricity consumption is half that of the United States, much of that difference is due to differences in floorspace per person.

On a per-unit floorspace basis, California has about 25% lower energy consumption as compared to the rest of the country.

Part of the difference in trend over time is due to different heating and cooling loads.

Building Shell Improvements



Building shell improvements primarily affect heating demand.

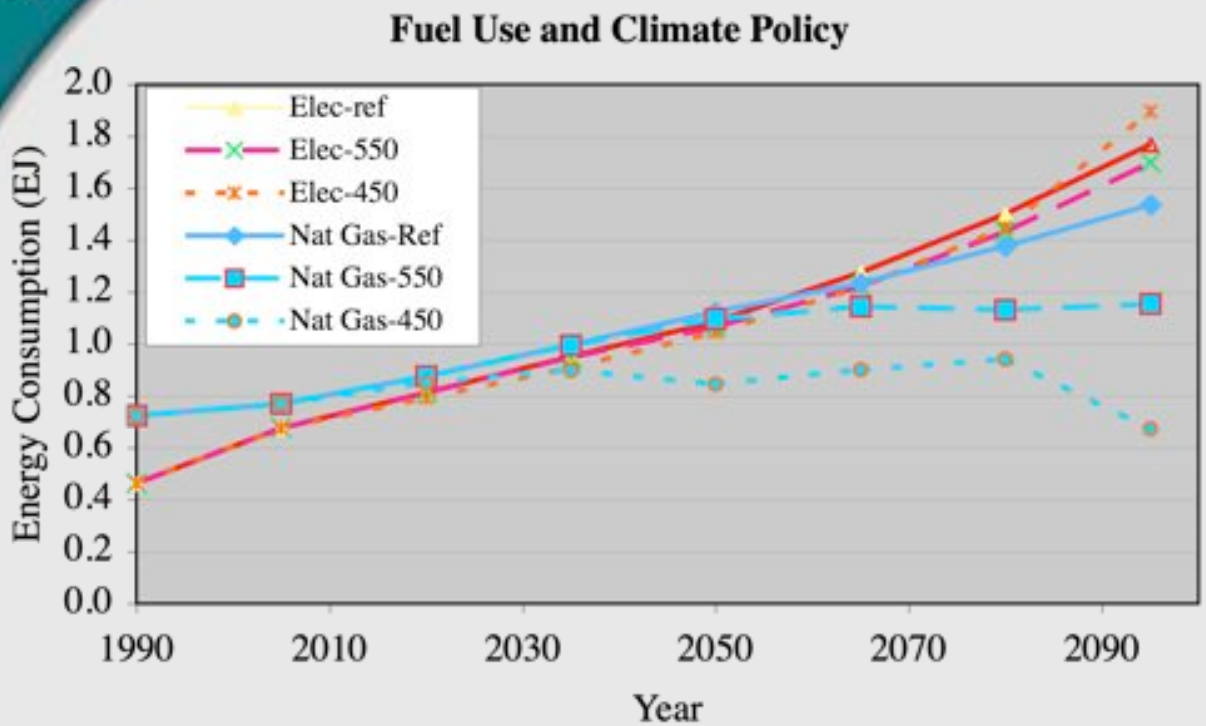
Building shell improvements are more important in the rest of the US due to higher heating demands.

Improving the thermal characteristics of building shells decreases the heat flux, but that also affects internal gains, resulting in a differential effect on heating and cooling demand.

— Shell improvements better trap the heat from internal loads, so heating demand decreases.

— The decrease in heat flux from the outside reduces cooling load, but the improved trapping of internal gains will increase cooling load.

Building Energy and Climate Policy



Electricity consumption changes are small due to counteracting forces: 1) substitution for gas (increase) and 2) decreased service demand due to higher energy prices (decrease).

From the end-use buildings perspective, the primary result of a climate policy is a lower growth rate for the consumption of natural gas.

The value of building energy efficiency in terms of a climate policy is to:

- Reduce energy consumption overall
- Reduce electricity demand (since climate policy doesn't reduce this overall)
- Facilitate switch away from natural gas

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WIND AND SOLAR ENERGY

Wind and Solar Approach

In order to better assess the potential of wind and solar technologies we have implemented a technology and resource-based representation. Each technology has two components:

- A set of resources, denominated in km^2, that are characterized by a distribution of distance to the electric transmission grid. Each resource can have any number of properties, for example:
  - Average Irradiance (Direct, total, etc.)
  - Number of cloudy days
  - Wind Speed
  - Wind speed shear
- A technology description
  - Capital Costs
  - Financing Assumptions
  - Turbine hub height, power rating, blade diameter.
  - Solar conversion efficiency, backup requirements

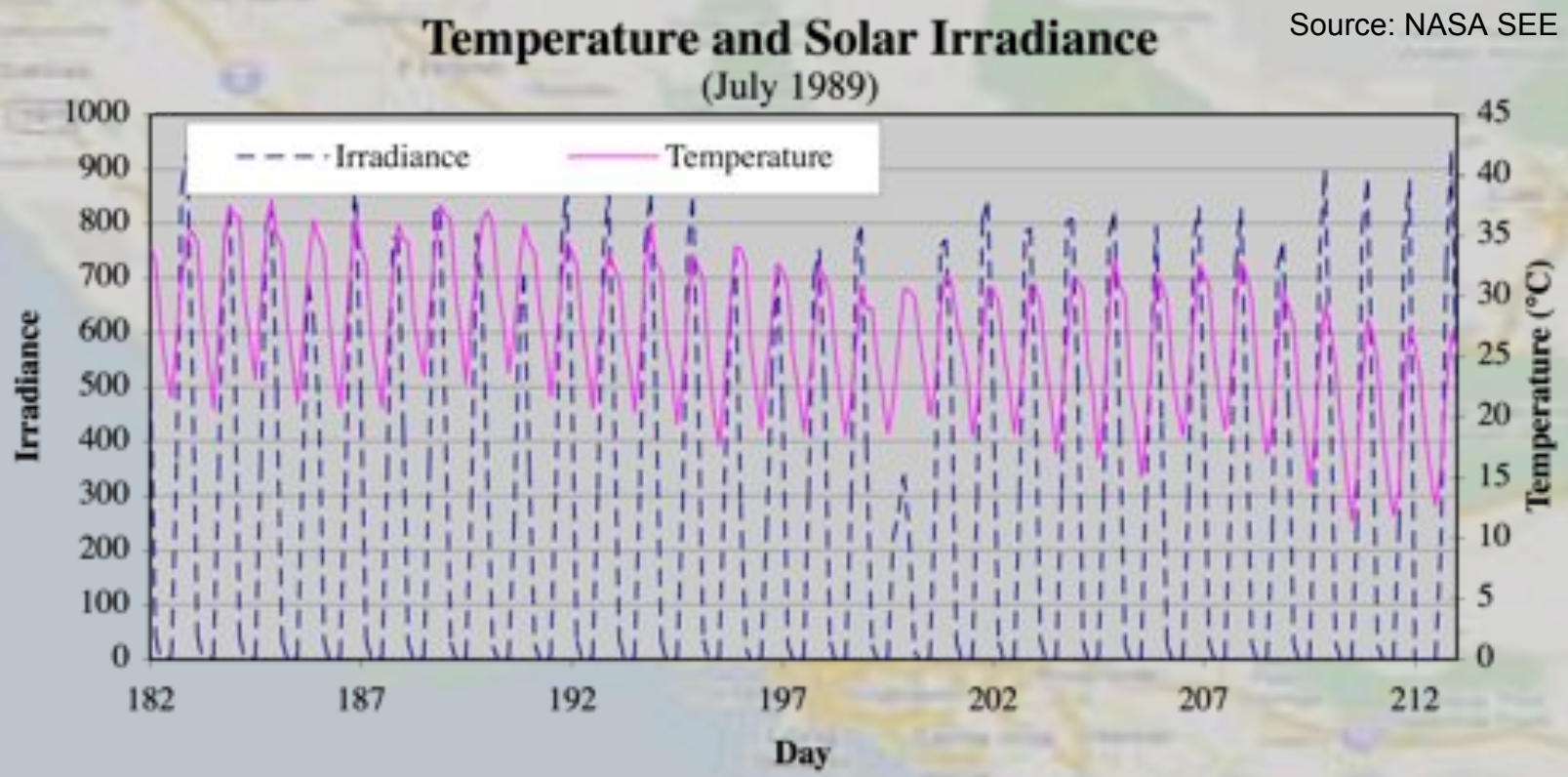
This allows us to examine the impact of different technology characteristics or resource quality, for example.

Photovoltaics

On a cost of energy basis, PV systems will become increasingly competitive. PV systems have significant advantages over CSP in terms of modularity and performance in partially cloudy regions.

Reliability at high PV penetration levels is, however, a significant issue:

Source: NASA SEE Data



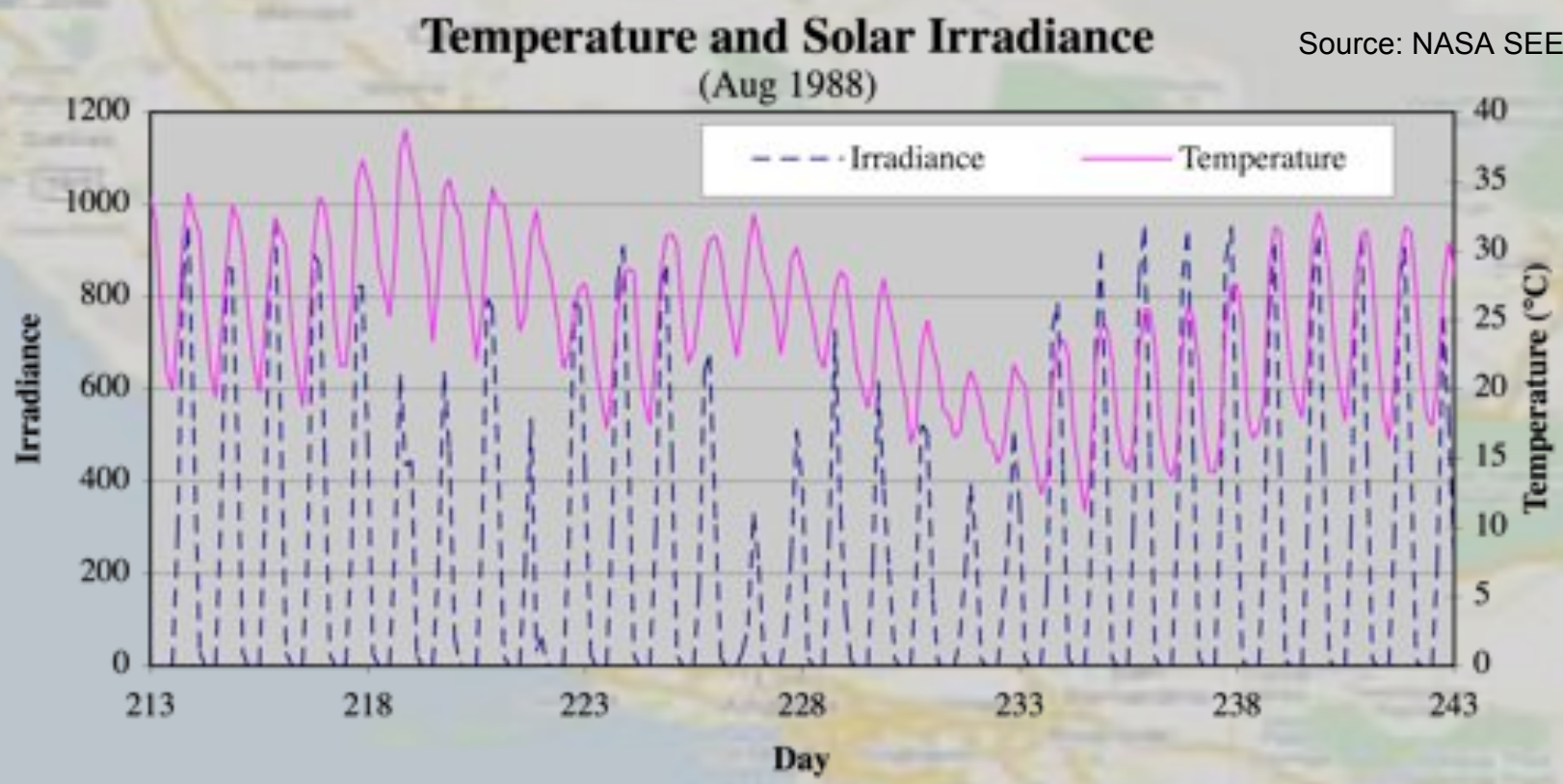
One cloudy day occasionally may be typical.

But several consecutive cloudy, but hot days, can occur.

Photovoltaics

The electric system must be able to provide service for periods when solar PV output over an entire region may be reduced by weather patterns.

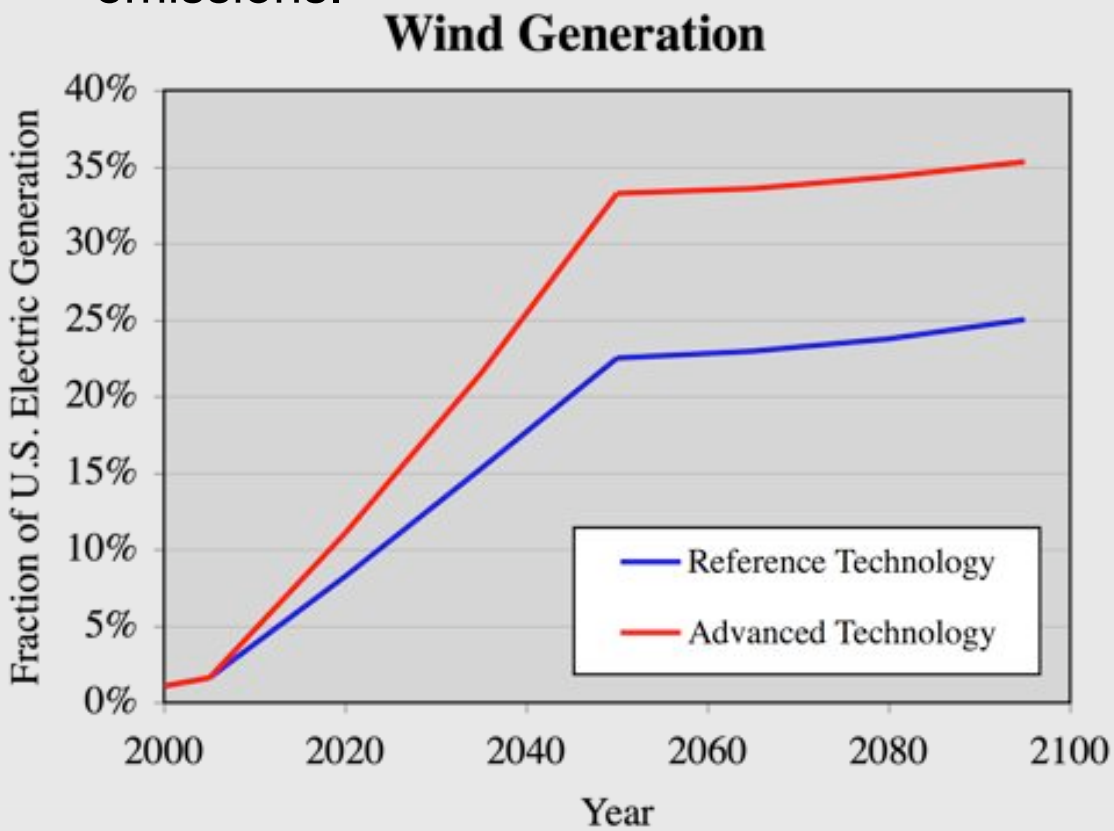
Source: NASA SEE Data



Regional details can be used to better understand an issue

Wind Power

Wind may become the largest renewable energy source. Wind is particularly important from a climate perspective as it supplies around the clock power, thus potentially displacing significant fossil emissions.



Our work and others have indicated that system reliability does not appear to be a significant constraint at moderate penetration levels.

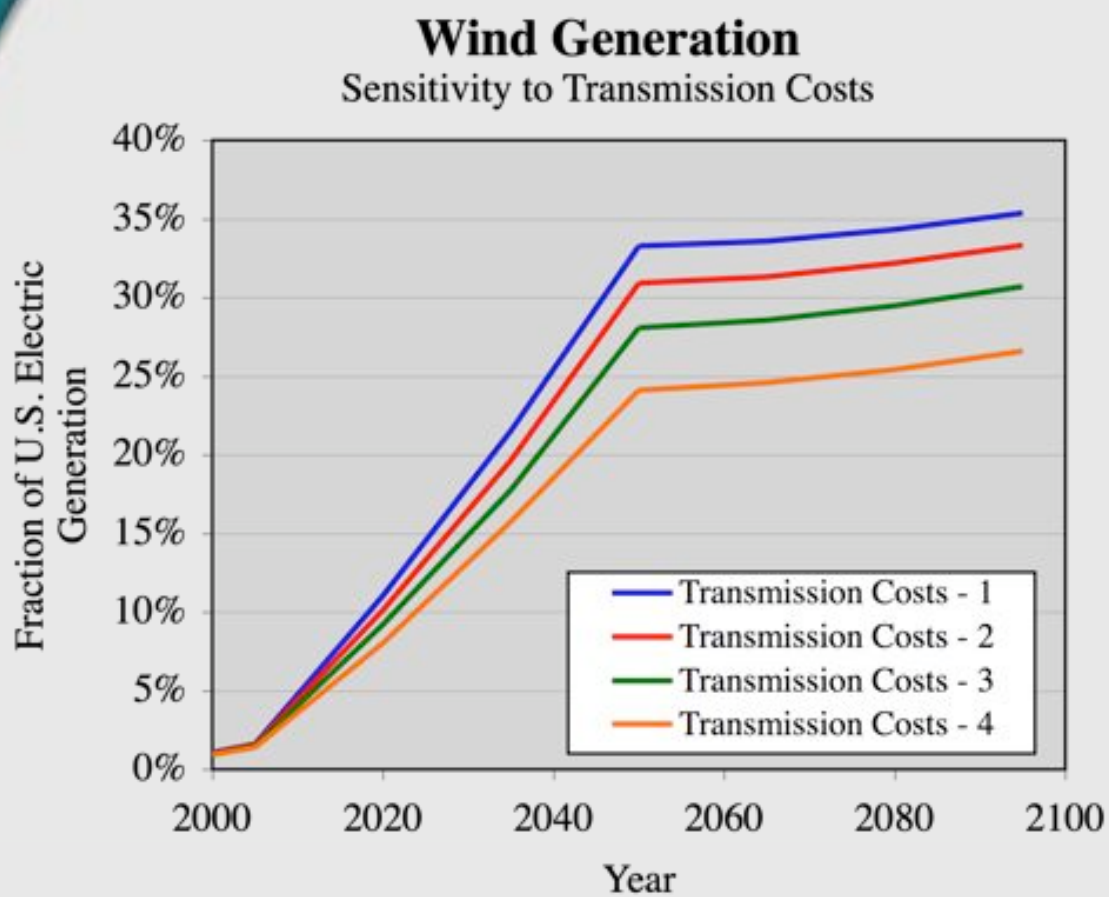
At high penetration levels loss of output due to transmission bottlenecks or mis-match with load become more significant.

This is a national aggregate calculation

The results shown here do not include energy loss and additional transmission requirements at high penetration levels, nor do they include off-shore wind.

Wind and Transmission

A large role for wind will require that wind sites be connected to the transmission grid. At higher penetration levels the grid will need to be augmented to transmit power to load centers.



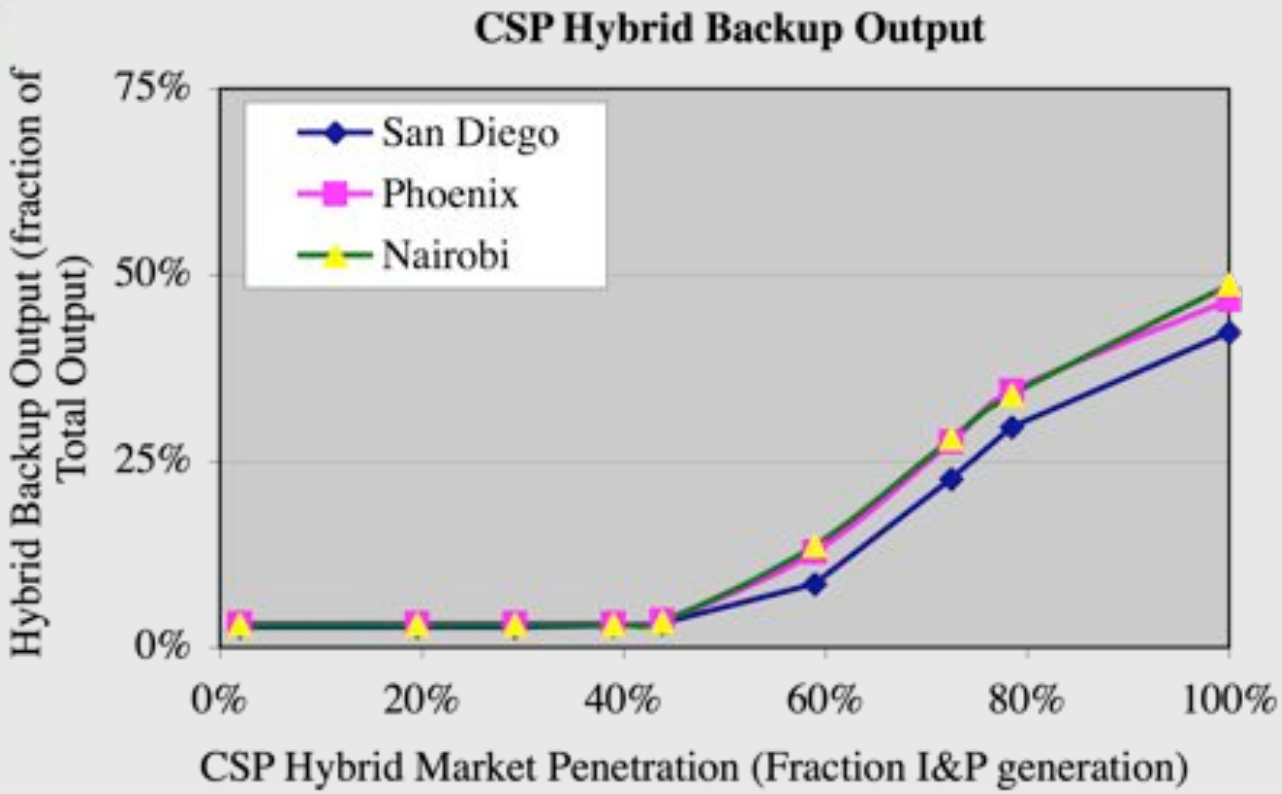
The GIS analysis underlying our calculation indicates that up to to 80 km of new transmission lines are being built to connect new wind farms to the transmission grid.

This sensitivity study indicates that the penetration of wind is dependant on the ability to build new transmission lines.

National analysis can identify a relevant issue

Concentrating Solar Power

Concentrating thermal Solar Power (CSP) systems, such as solar trough or power tower, are attractive because they can provide firm power through the use of relatively inexpensive integrated hybrid systems (usually gas fired).



The case shown here does not include integrated thermal storage,which would lower the need for backup operation.

Even so, there is sufficient I&P capacity during the day such that hybrid-backup operation is not required to meet demand for penetration levels up to 40%..

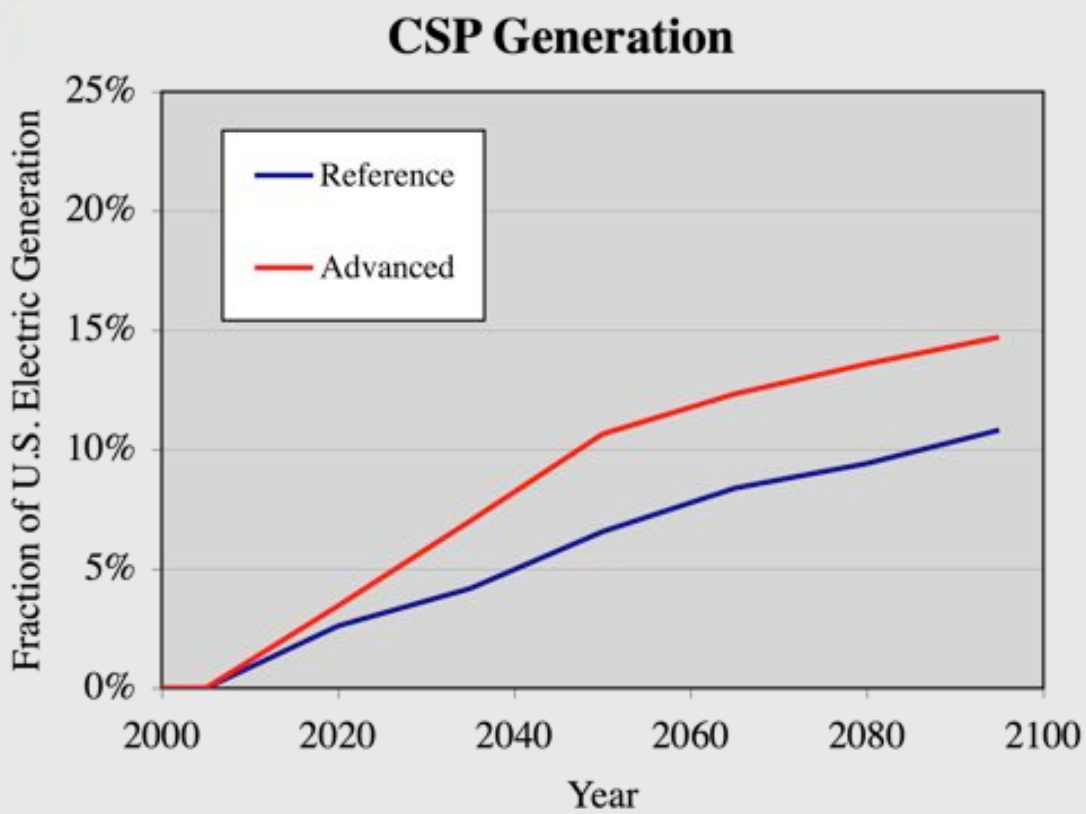
Technology performance can vary by region

For CSP total direct irradiance is the key regional parameter

Source: Zhang and Smith (2007)

Concentrating Solar Power

Using cost projections from the US DoE, we find that based on generation cost, CSP technologies could contribute a significant amount to US generation.



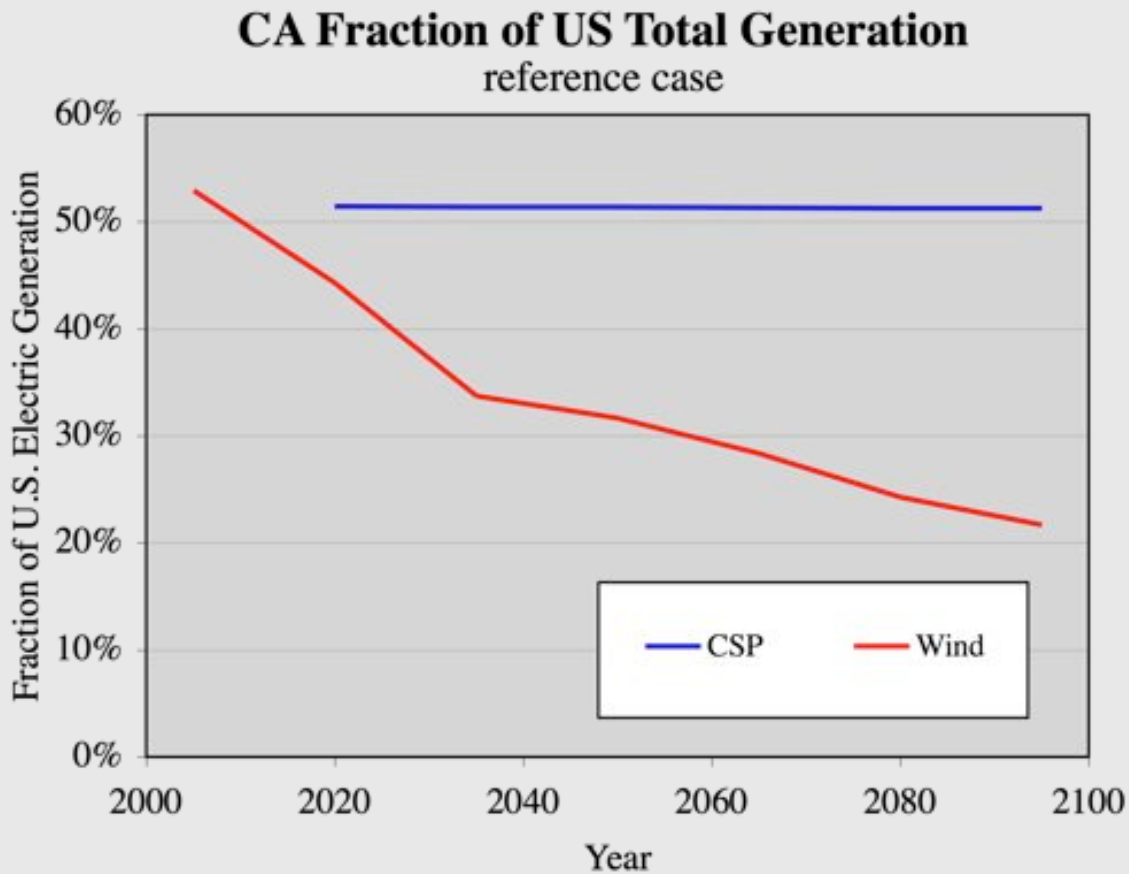
This is a national analysis, is this reasonable?

These results, however, would imply that a significant "turndown" of baseload generation would be needed in order to accommodate the higher penetration levels shown.

This does indicate, however, that **if system costs can be lowered to the extent projected,** even without integrated thermal storage CSP systems can play a significant role.

The value of thermal storage will depend on cost vs additional performance tradeoff. Sufficient thermal storage would allow CSP to displace baseload capacity.

CA Wind and Solar



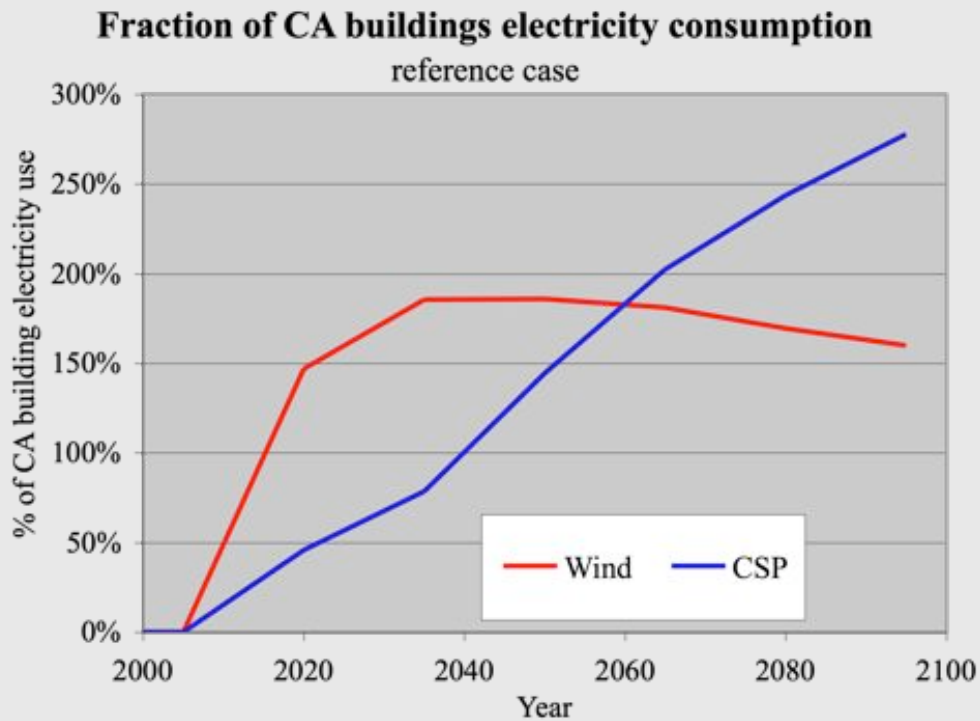
Note -- results from spatial resource data plus economic analysis. Not calibrated to 2005 actual generation by region.

California has a large share of initially competitive wind but a lower share over time as larger wind resources elsewhere in the US begin to come into development.

California has a large fraction of the high quality resource for concentrating solar technologies.

What does this imply?

CA Wind and Solar



Buildings comprise 75% of electric demands in CA (source: PIER CALEB)

Total CA wind generation is somewhat larger than demand so wind may be overestimated.

- ⇒ Plug-in hybrids could, however, significantly increase electric demand.

Without substantial thermal storage, CSP supplies only intermediate and peak energy, which is only a fraction of even building demand.

- ⇒ CSP energy is substantially overestimated by national analysis as power export opportunities are likely limited.

Summary Points

- Future energy demand trajectory in CA on a per-capita basis remains divergent from U.S., but total energy demands still grow substantially.
  - ⇒ Further comparison of CA and rest of US would likely yield useful information on the potential of energy efficiency (would require more detailed analysis of source data)
- Wind and solar energy can potentially supply a large portion of CA energy needs.
  - ⇒ But a national analysis would substantially overestimate CSP generation potential due to resource concentration. (regional limits could be placed on generation)
  - ⇒ How can CA utilize and transmit to load centers high levels of renewable energy? (regional analysis of transmission needed)
  - ⇒ PV may play an important role, but reliability must be assured. (historical information could be used to determine correspondence between load and PV supply)

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END OF SLIDES