California's Carbon Challenge: Scenarios for Achieving 80% emissions reduction in 2050

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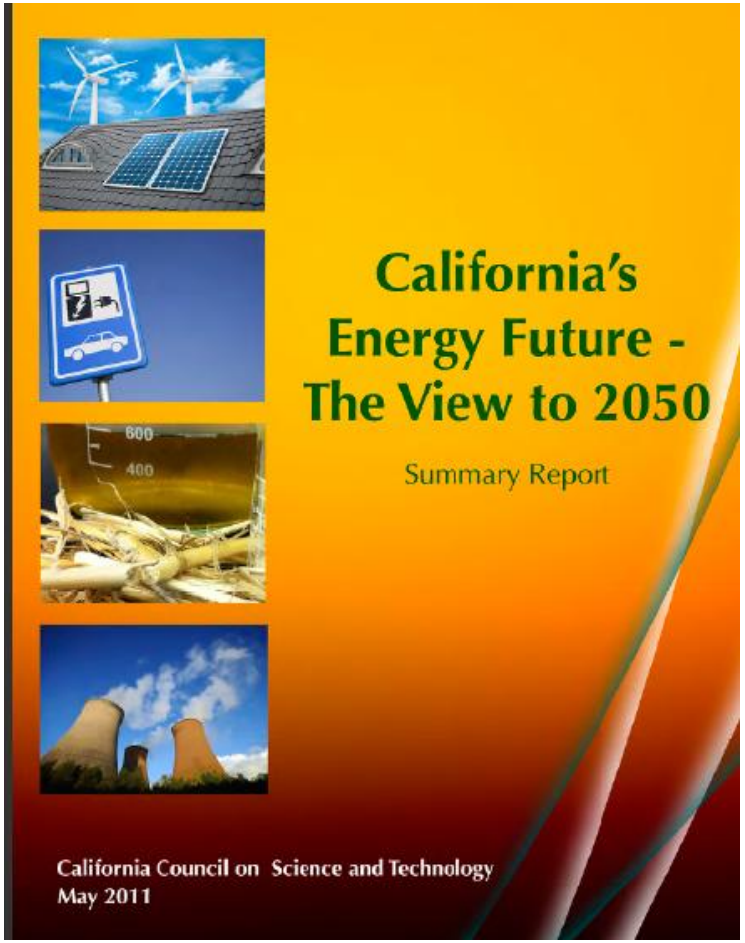
The Road to a 100% Renewable Energy System workshop
Center for Sustainable Energy and Power Systems, UC-Santa Cruz

California Energy Future Report

- Sponsored by California Council of Science and Technology and California Energy Commission
  - Released May 2011
- Closely related but distinct from this work, which has not been published yet.



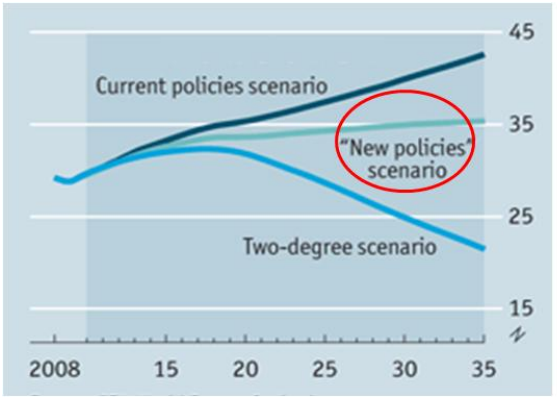
Outline

- Context
- California 2050 Modeling and Results
- Follow up areas for research

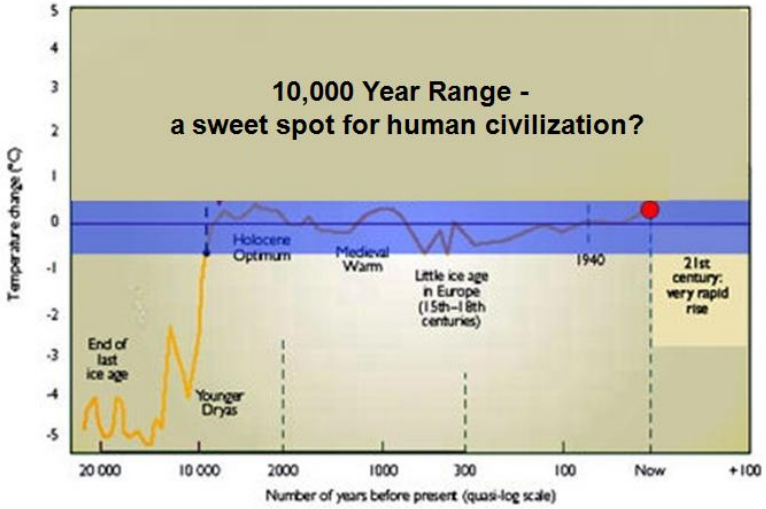
Context

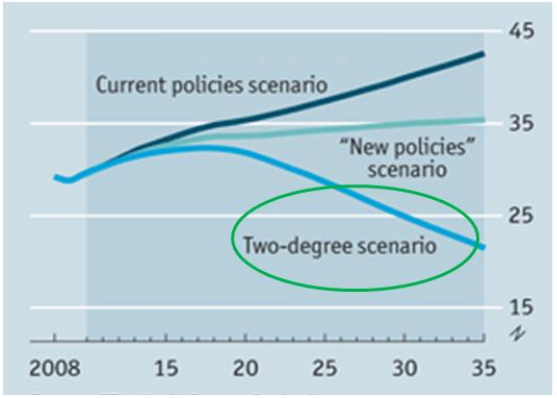
- Global warming/Climate change
- Mitigation/ Adaptation
  - **GhG reduction (AB32 for California)**
- Transitioning to “new energy economy”

Global Warming/ Climate Change



Global CO2 emissions, [Gigatons]





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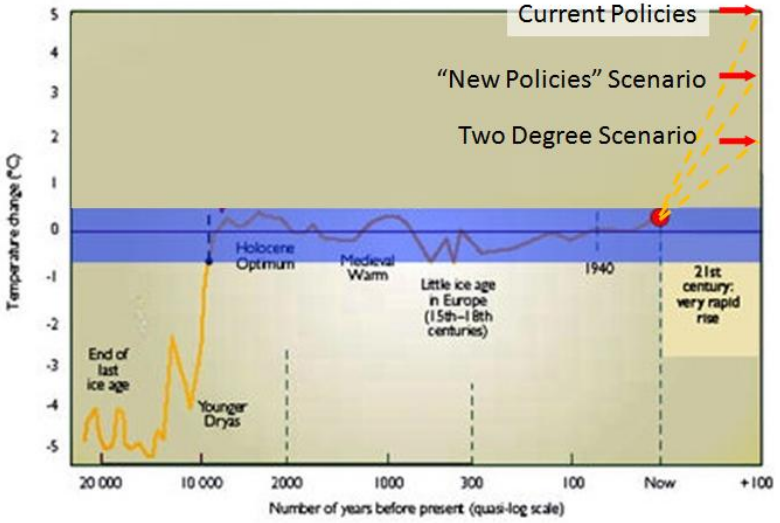
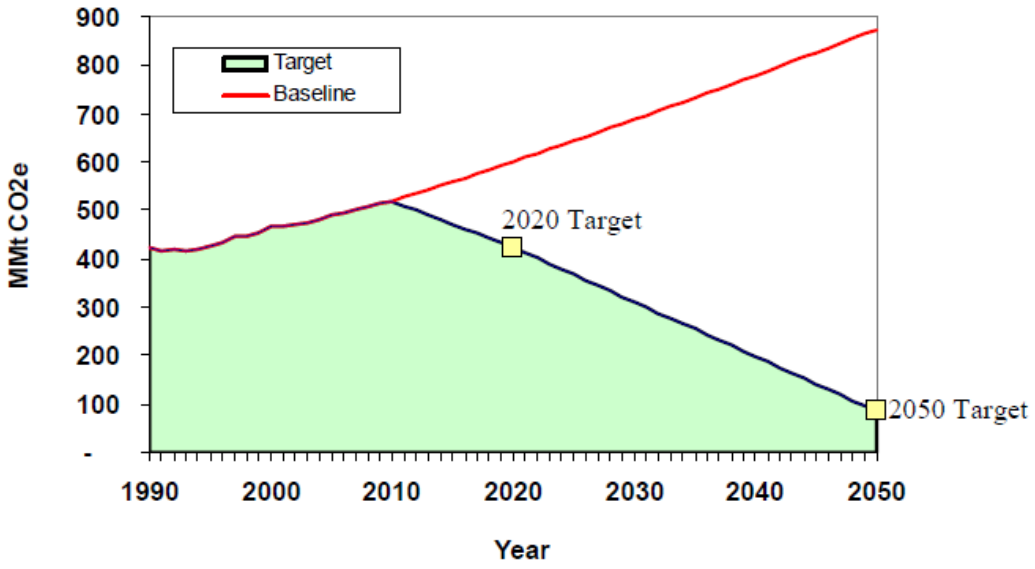


- Sea level rise
- Desertification
- Species Loss
- Greater uncertainty in climate outcomes for higher CO2 emission scenarios

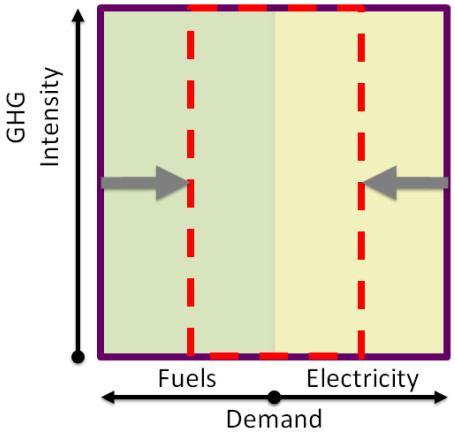
California Long Term GhG Target

- Reduce emissions to 1990 level by 2020 (AB32)
- Reduce emissions to 20% of 1990 by 2050 (Executive order)
- Detailed plans and progress for 2020 target
- **How do we meet the 2050 target?**

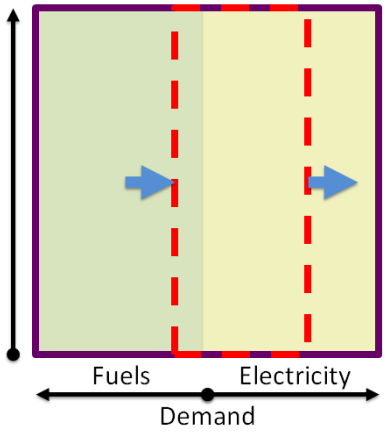


Strategy

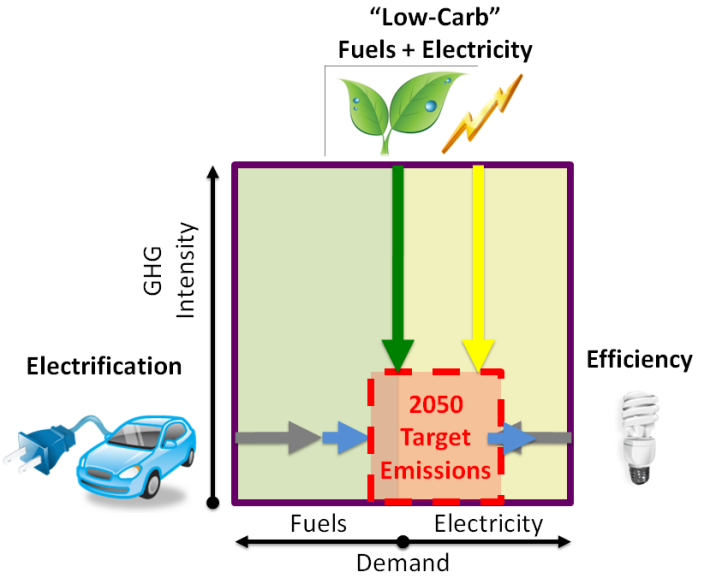
*Emissions = Energy * (Emissions/ Energy)*
*= Energy * GHG Intensity*



Energy Efficiency



Electrification



Cleaner fuels and Clean Electricity

Why Electrification? … We know how to make clean electricity but making clean fuels more difficult…

Scenarios

Base Case

- Aggressive EE (at technical potential levels)
- Clean or Low Carbon Electricity
- Electrification of vehicles and heat
- Low carbon biofuels

Base Case Variants

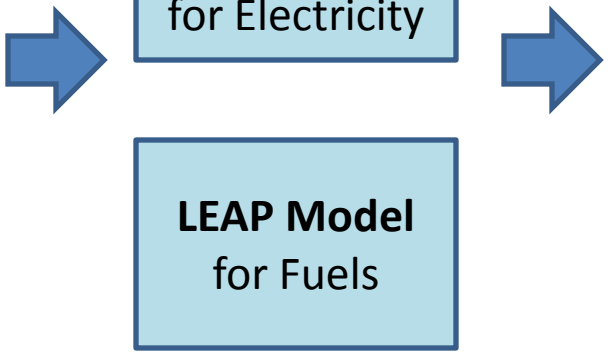
- Biofuel supply in-state and out of state
- Electricity supply sector variants
  - e.g. high/low CCS cost
- Electricity sector emissions (set by carbon cap)
- Electrification penetration
- Behavior change

Model Framework

INPUTS

- Bottom up demand aggregation
  - Building energy efficiency data (Itron)
  - Industry EE data (LBNL)
  - Transportation model (UC-Davis)
- Electrification / biofuel / behavior scenarios
- Study focuses on energy emissions

➔ Overall electricity and fuel demands



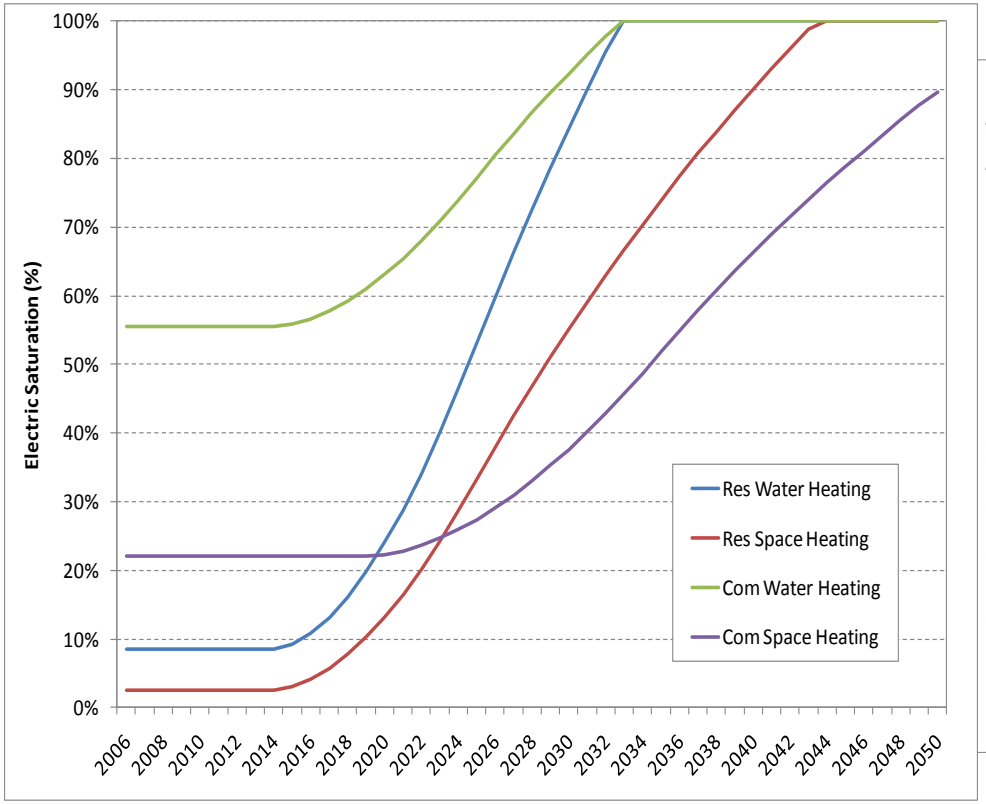
OUTPUTS

- Overall GhG emissions
- Electricity system costs
- Electricity system technologies and transmission build out

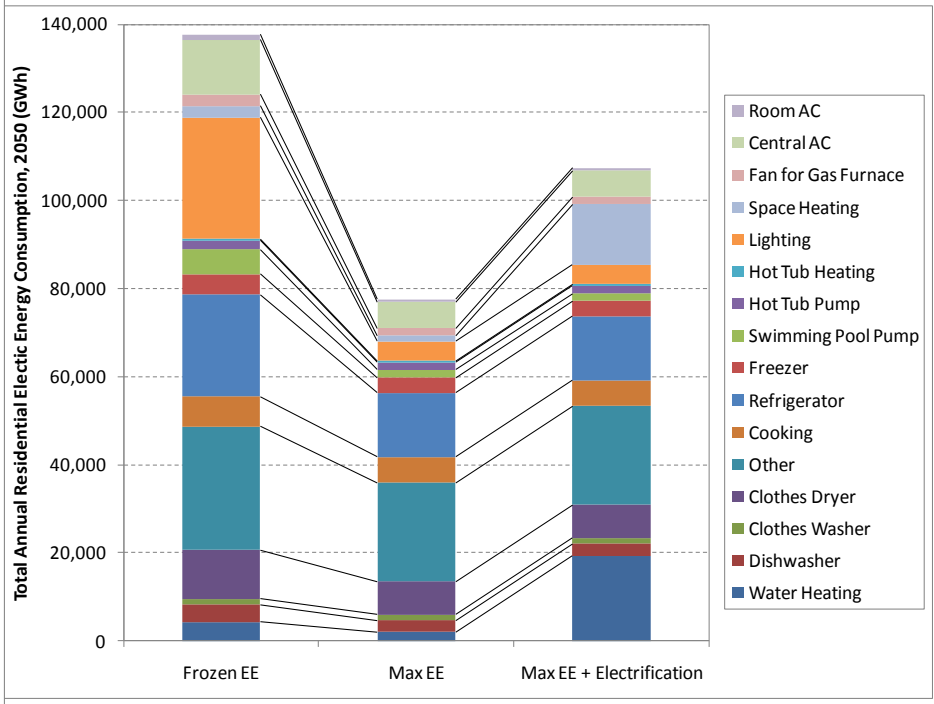
SWITCH is a cost optimization model for the electricity system

Building Efficiency and Fuel switching to 2050

Fuel Switching rates assumed

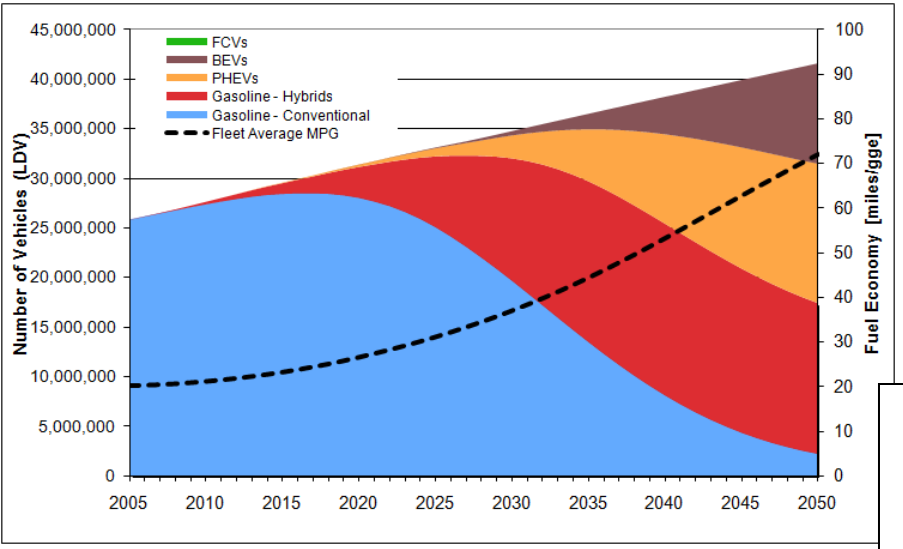


Residential End use in 2050 California



Space and water heating are electrified.

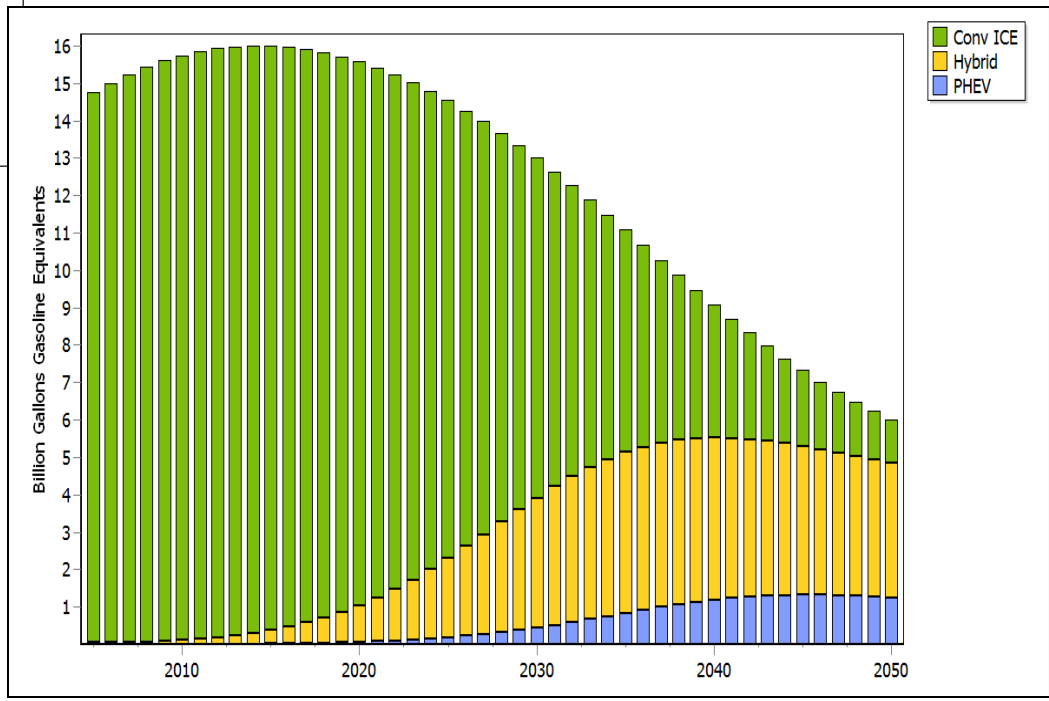
Transportation Fuel Efficiency and Electrification to 2050



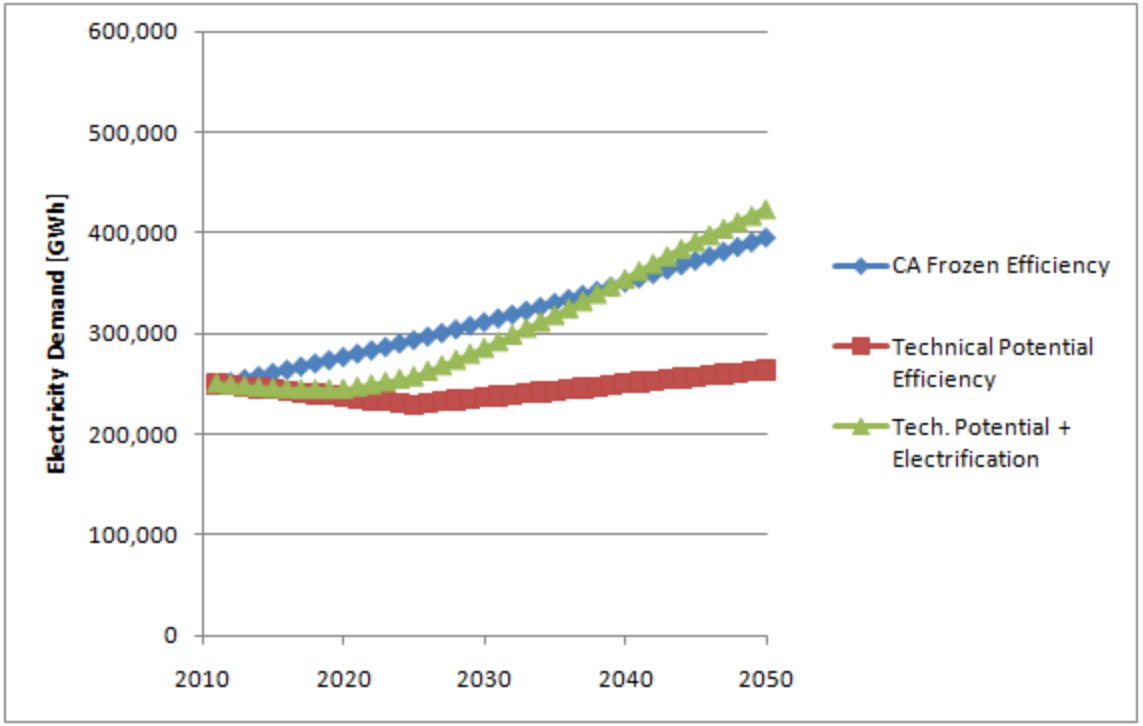
Passenger vehicle adoption curves and fleet MPG (dotted)

45% of passenger vehicle miles are electrified.

Remaining Liquid Fuel



Electricity Projections



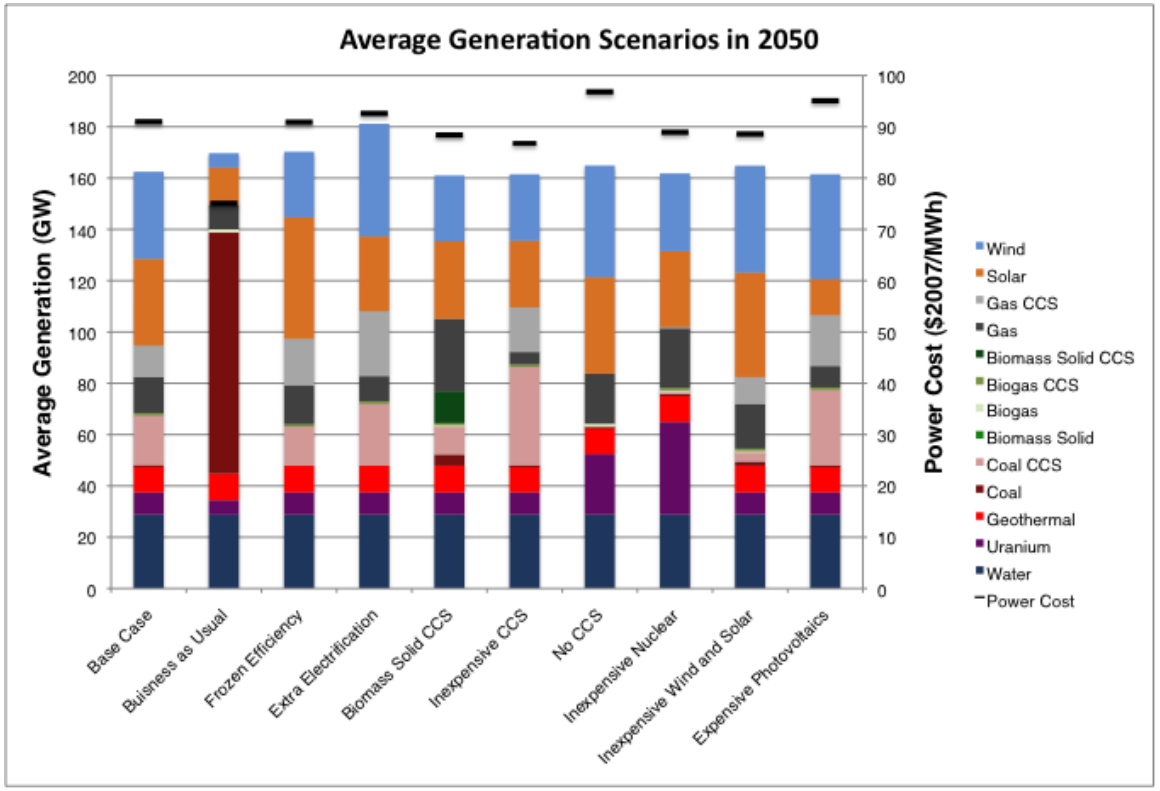
- California demand with technical potential efficiency and electrification of vehicles and heat (green curve) about 7% higher than frozen efficiency demand.

SWITCH = a loose acronym for Solar, Wind, Hydro, and Conventional generators and Transmission

- Objective: calculate the lowest total system cost, given a carbon cost or energy policy
  - WECC region
  - Carbon CAP set at 80% lower than 1990 emissions
- Meets projected hourly electricity loads
  - Projected loads / load profiles based on base case and variants.
  - Maintains 15% reserve margin for reliability
- Mixed integer linear optimization model that chooses over the course of 39 years
  - Generator and transmission investments every 4 years
  - Generator and transmission dispatch hourly
    - Peak and median day of historical months from 2004 and 2005 and winter peaking days in base case.

SWITCH Output

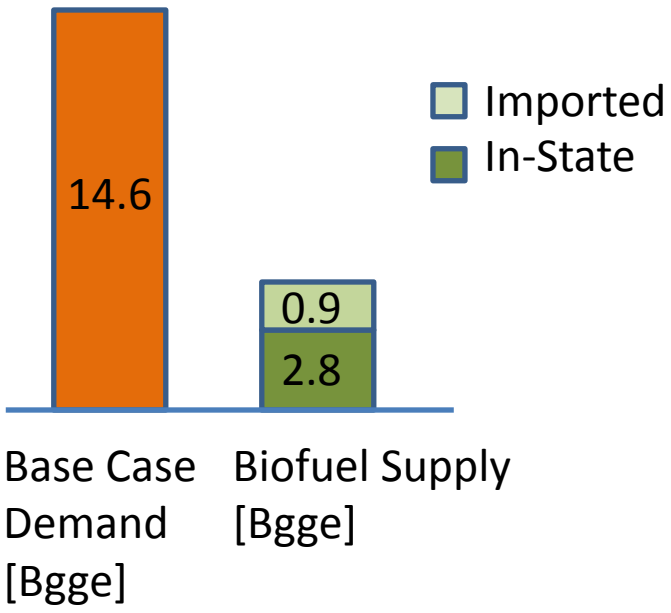
- Fairly tight band of power cost projected for various electricity supply mix scenarios



Biofuels in 2050

- Biomass supply directed to biofuel since many technologies for clean electricity
  - 35 M dry tons in state near term estimate (2.8 billion gallons gasoline equivalent)
  - 95M dry tons "technical potential" (7.5 Bgge)
- Imports limited to 25% of California total per Executive order S-06-06 (2006)

Low in-state biofuels



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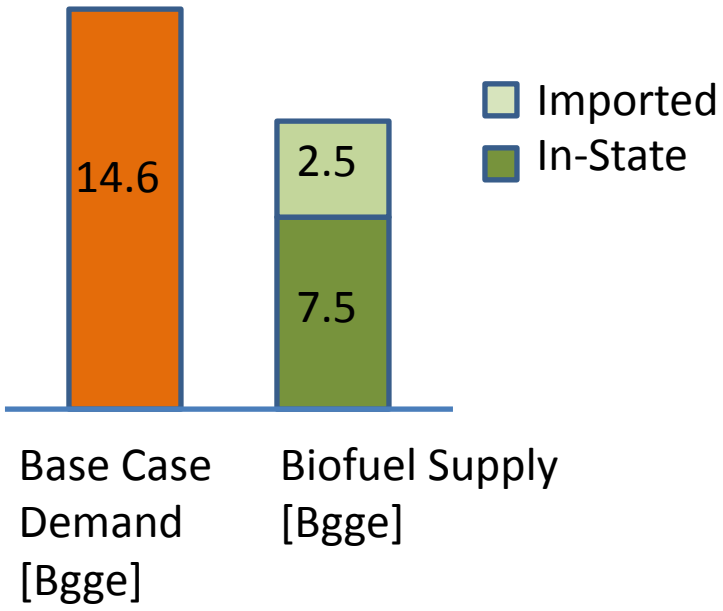
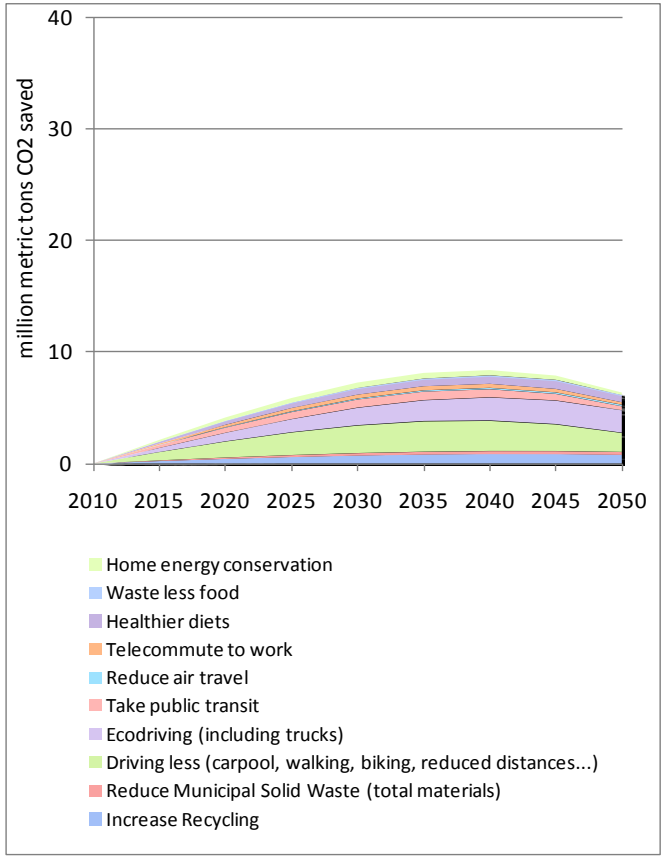


Insufficient biofuel supply to replace Base case liquid fuel demand (15 Bgge)

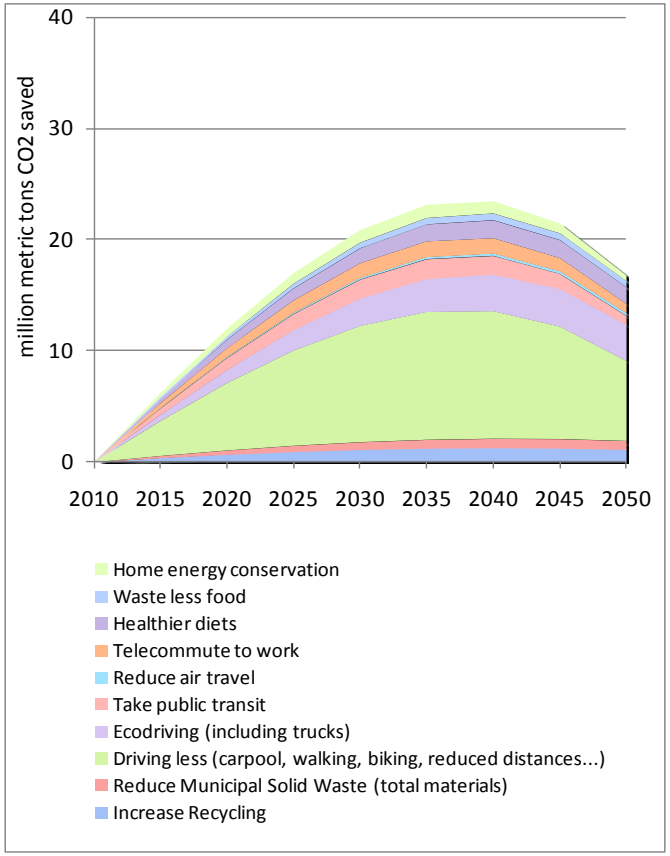
Behavior Change

- Transportation (Vehicle Mile) reduction is the largest lever.
- Recycling/reduced MSW and food/diet also contribute

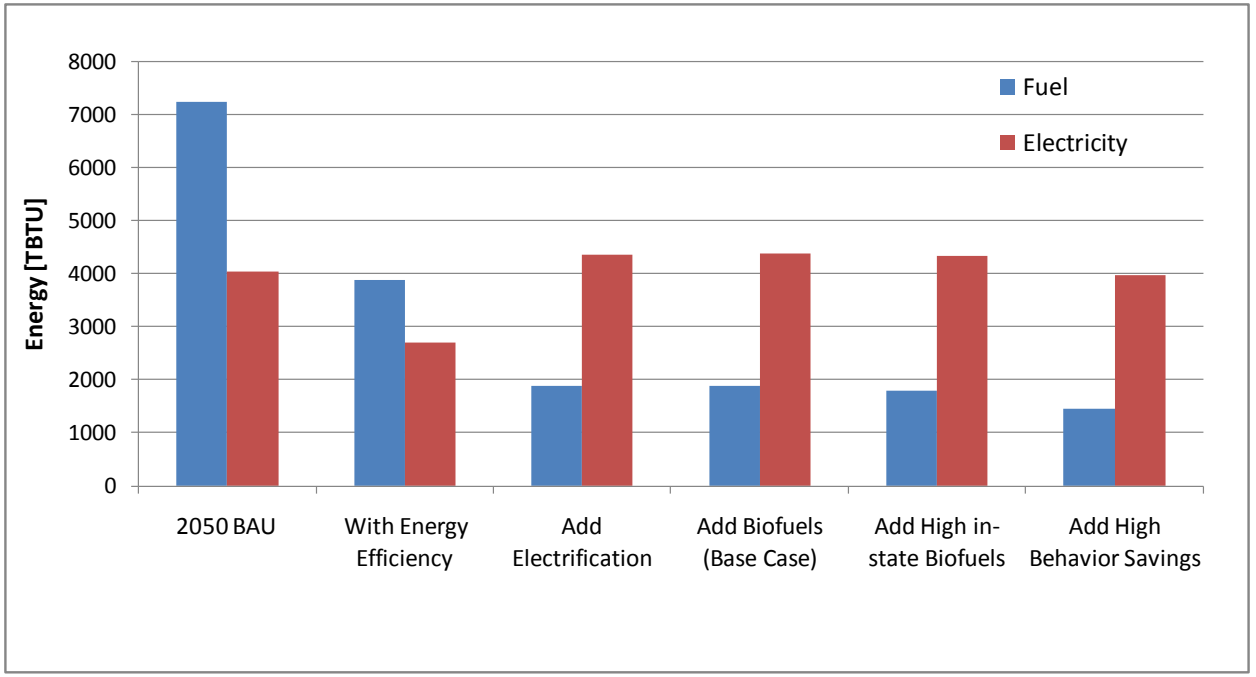
Nominal adoption : 7% GHG savings

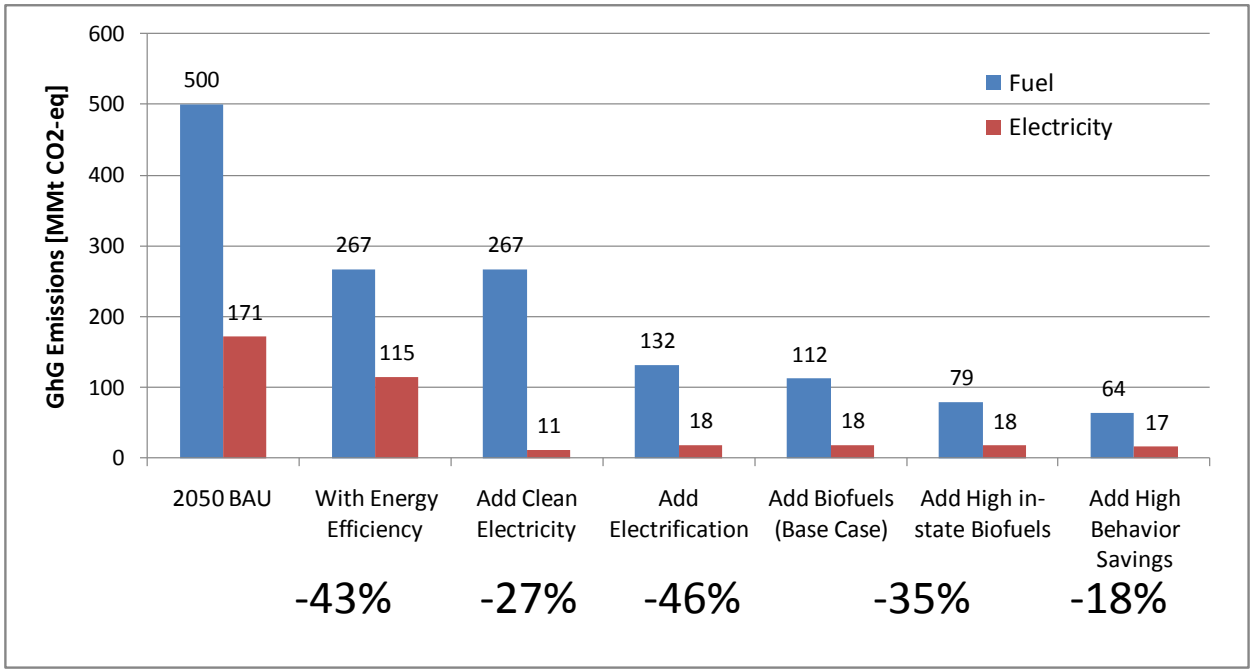


High adoption: 18% GHG savings

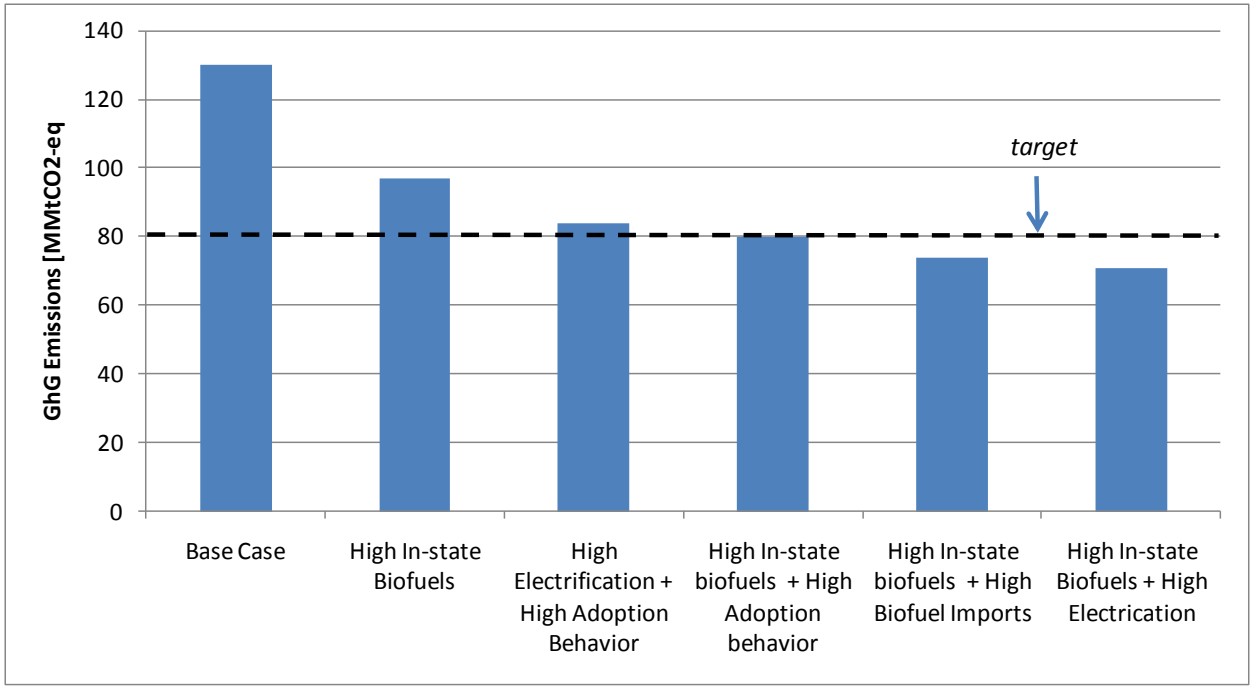


Putting it together: One pathway to meet 2050 target



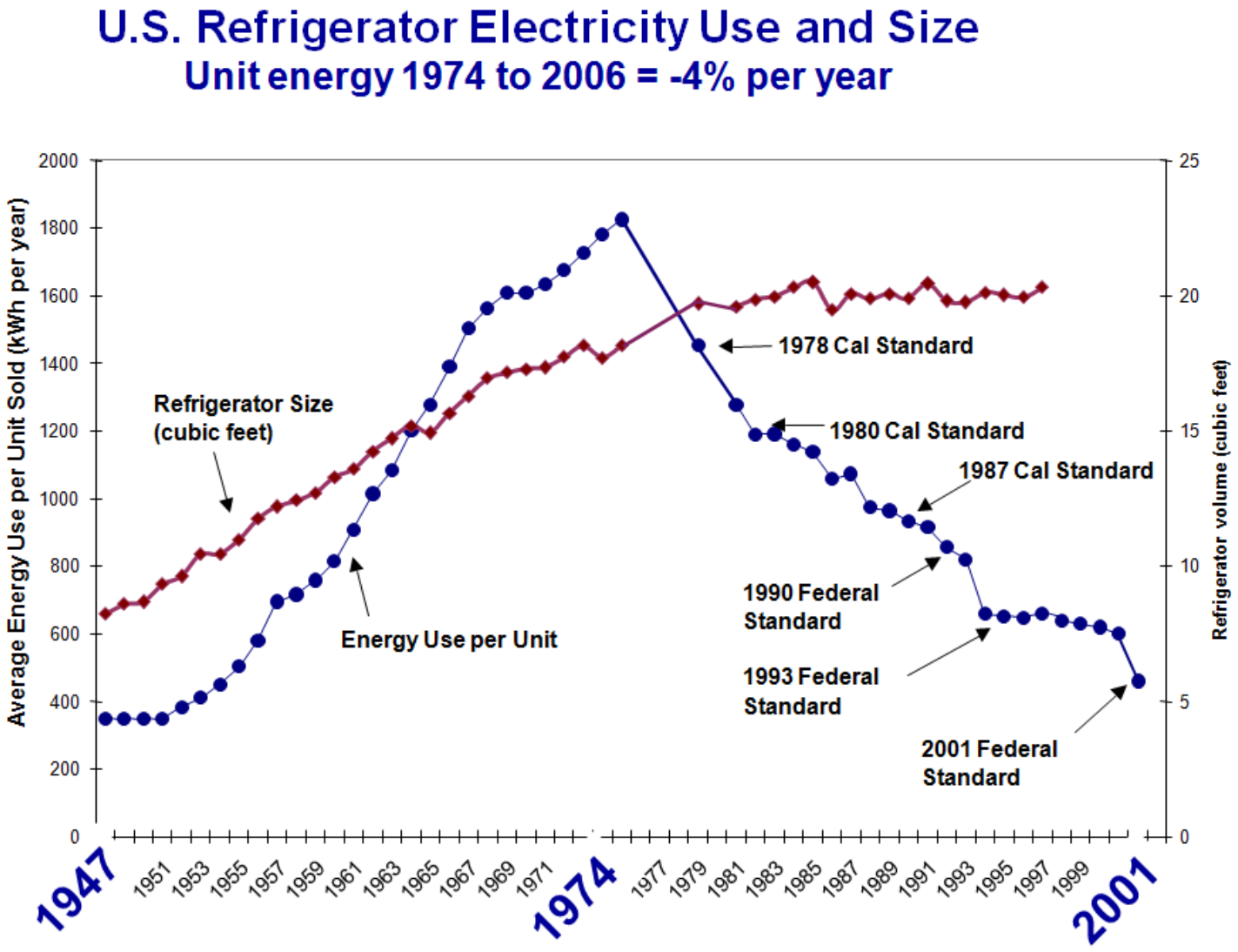


Other scenarios meeting target



High in-state biofuels are probably needed.

Affordable Energy Efficiency is a Renewable Resource



Conclusions

- The 2050 GhG target for California appears achievable, but requires significant changes in the way we use energy and in energy production.
  - Sustained technology development needed across sectors (electric vehicles, energy efficiency measures, biomass and biofuel production, renewable electricity, electric storage, …)
- Clean electricity and the development of a high in-state low-carbon biofuel supply are vital to the scenarios presented here.
- Clean electricity enables large scale electrification as a path to reduce emissions.
- From a policy standpoint, California can build upon its policy portfolio to support the long term GHG target
  - e.g. Building codes and appliance standards, EV support, RPS, utility EE programs)
  - Electrification of heat is a policy gap

Follow up work

- Integrated economic study/ optimization
- Electrification pathways for building/industry heat, electrification policy
- Power sector load balancing / demand shifting
- Optimal use of biomass resource
- Behavior change policies/ pilots
- Non-energy/High GWP sectors

Clean Energy Economy Job Studies

- M. Wei, D. Kammen. “Putting Renewables to Work” Energy Policy paper (2010)

  ➔**Extend to state and regional impacts**

Other work:

- Center for American Progress – The Economic Benefits of Investing in Clean Energy (2009)
- Lawrence Berkeley Laboratory, Charles Goldman - Energy Efficiency Service Sector Employment Report (2010)

Acknowledgements

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Thank you for your attention.

Questions?

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