DOCKETED	
Docket Number:	18-IEPR-06
Project Title:	Integrating Renewable Energy
TN #:	223869
Document Title:	Deep Decarbonization in a High Renewables Future - Implications for Renewable Integration and Electric System Flexibility
Description:	Presentation by Amber Mahone at the June 20, 2018 IEPR Workshop on Renewable Integration and Electric System Flexibility
Filer:	Stephanie Bailey
Organization:	Energy + Environmental Economics
Submitter Role:	Public
Submission Date:	6/19/2018 2:34:42 PM
Docketed Date:	6/19/2018

Energy+Environmental Economics

Deep Decarbonization in a High Renewables Future

Implications for Renewable Integration and Electric System Flexibility

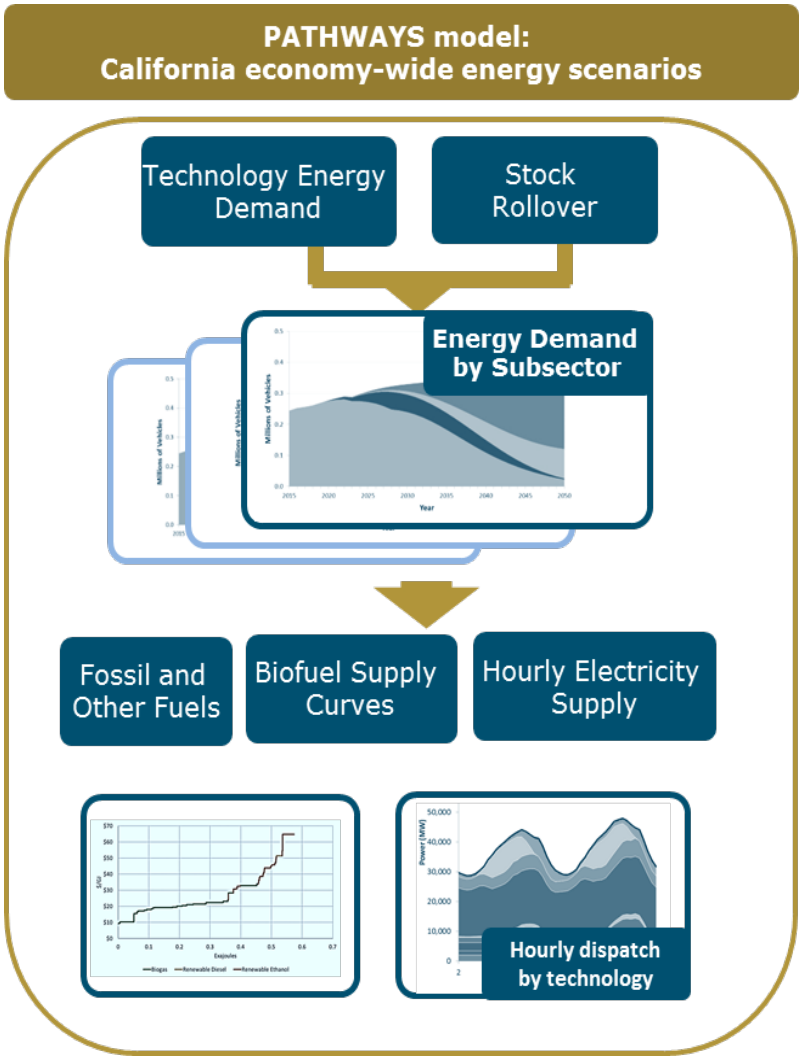
2018 CEC IEPR Workshop on Renewable Integration and Electric System Flexibility

June 20th, 2018

Amber Mahone, Zach Subin,
Doug Allen, Gerrit De Moor, Nancy Ryan, Snuller Price

Agenda

- **CEC EPIC project "Deep Decarbonization in a High Renewables Future"**
  - Published June 2018 CEC-500-2018-012
- **Implications for renewable integration and electric system flexibility**
  - Insights from the PATHWAYS and RESOLVE models



Mitigation Scenarios achieve CA's 2030 and 2050 GHG Goals

1. Reference Scenario

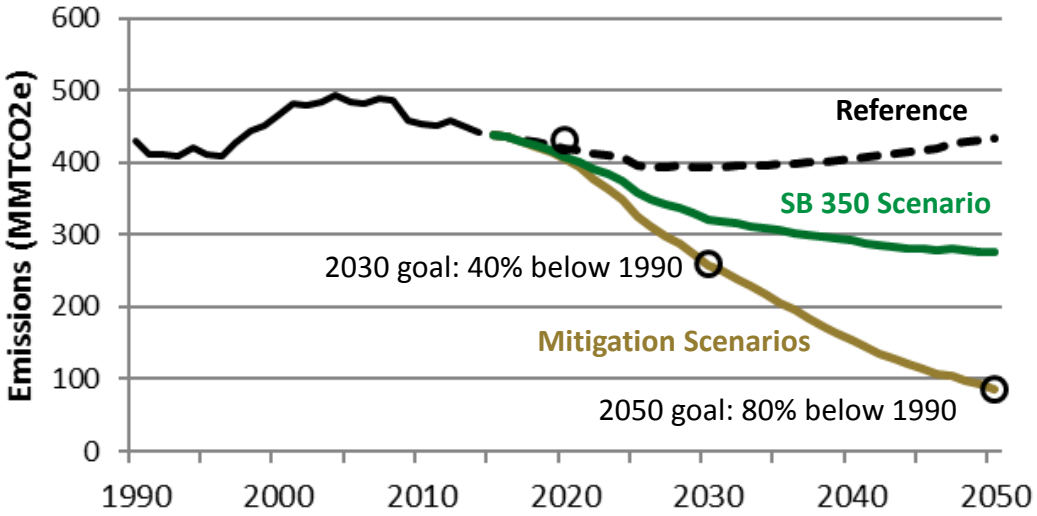
- ✓ Reflects pre-SB 350 policies (e.g. 33% RPS, historical energy efficiency goals)

2. SB 350 Scenario

- ✓ Includes SB 350 (50% RPS by 2030), mobile source strategy Cleaner Technology and Fuels, plus additional reductions in non-combustion GHGs

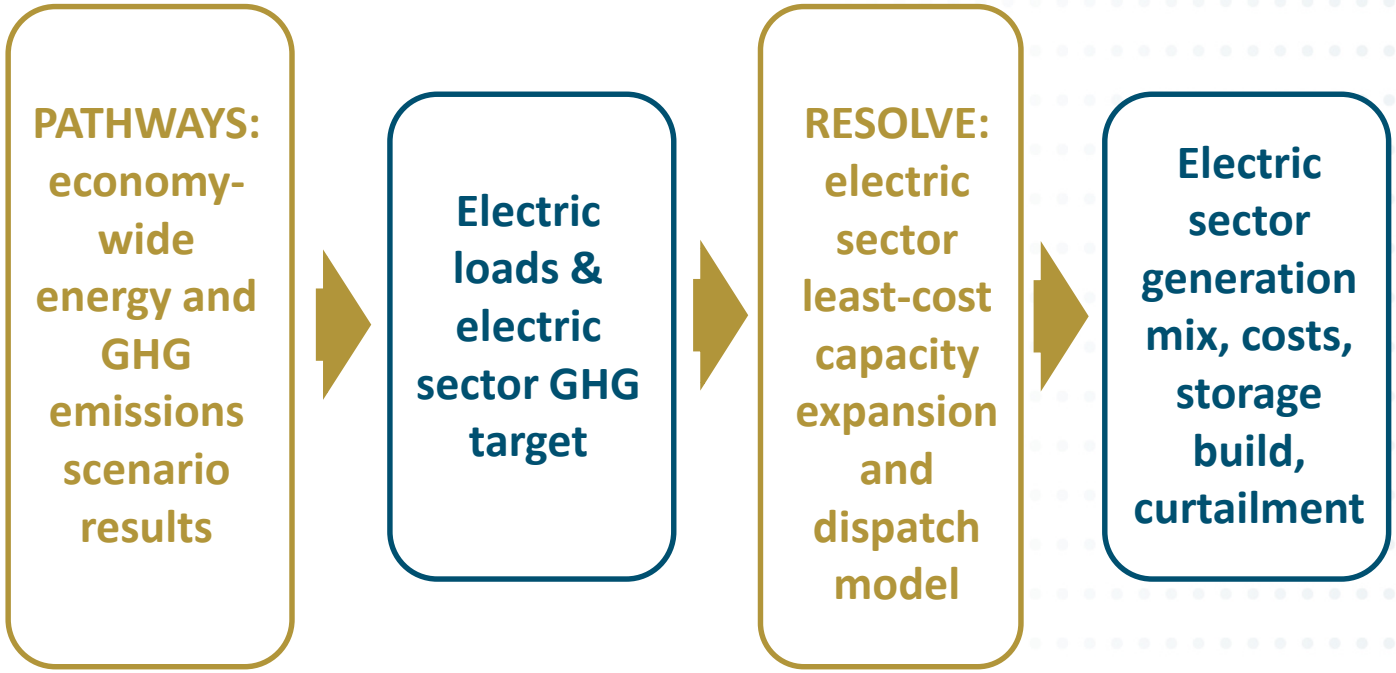
3. Mitigation Scenarios

- ✓ We evaluated 10 mitigation scenarios, all meeting 2030 and 2050 GHG goals



A Two Model Project

- **California PATHWAYS model:** Economy-wide GHG mitigation scenarios
- **RESOLVE model:** Results from the PATHWAYS high electrification scenario were used to develop least-cost electric generation portfolios, capacity build, and electric sector costs



HIGH ELECTRIFICATION SCENARIO RESULTS

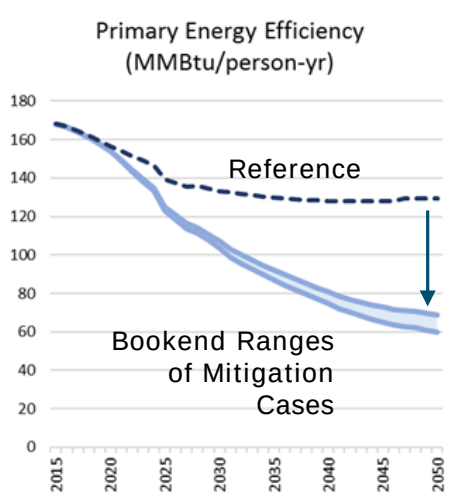
Four Pillars of GHG Reduction are Needed Across All Scenarios Evaluated

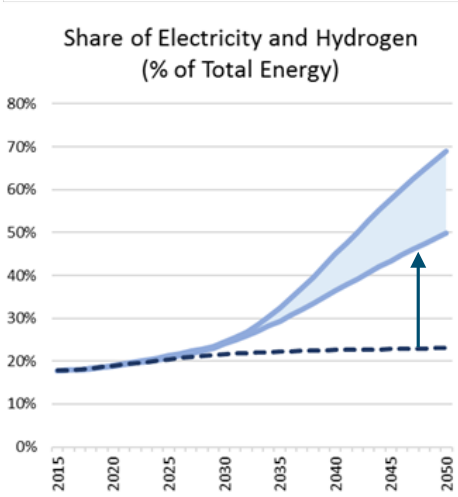
Energy efficiency & conservation

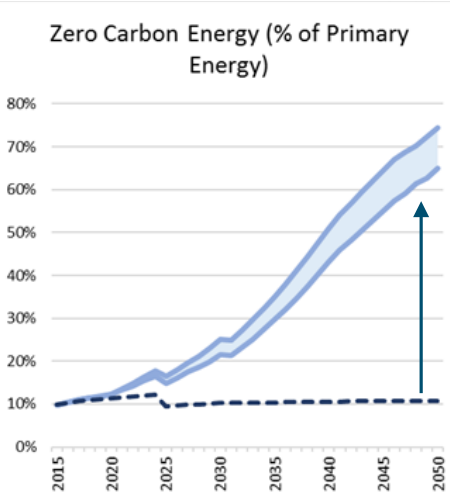
Electrification

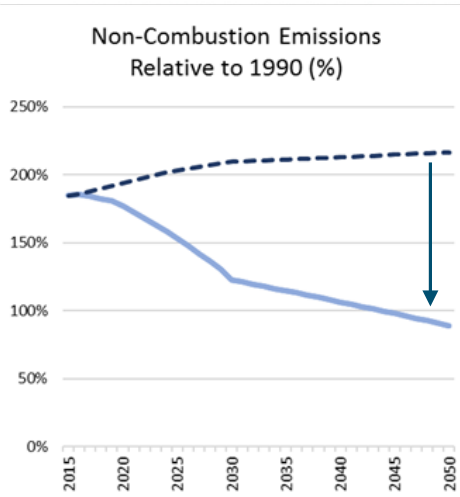
Low-Carbon Fuels

Reduce non-combustion emissions





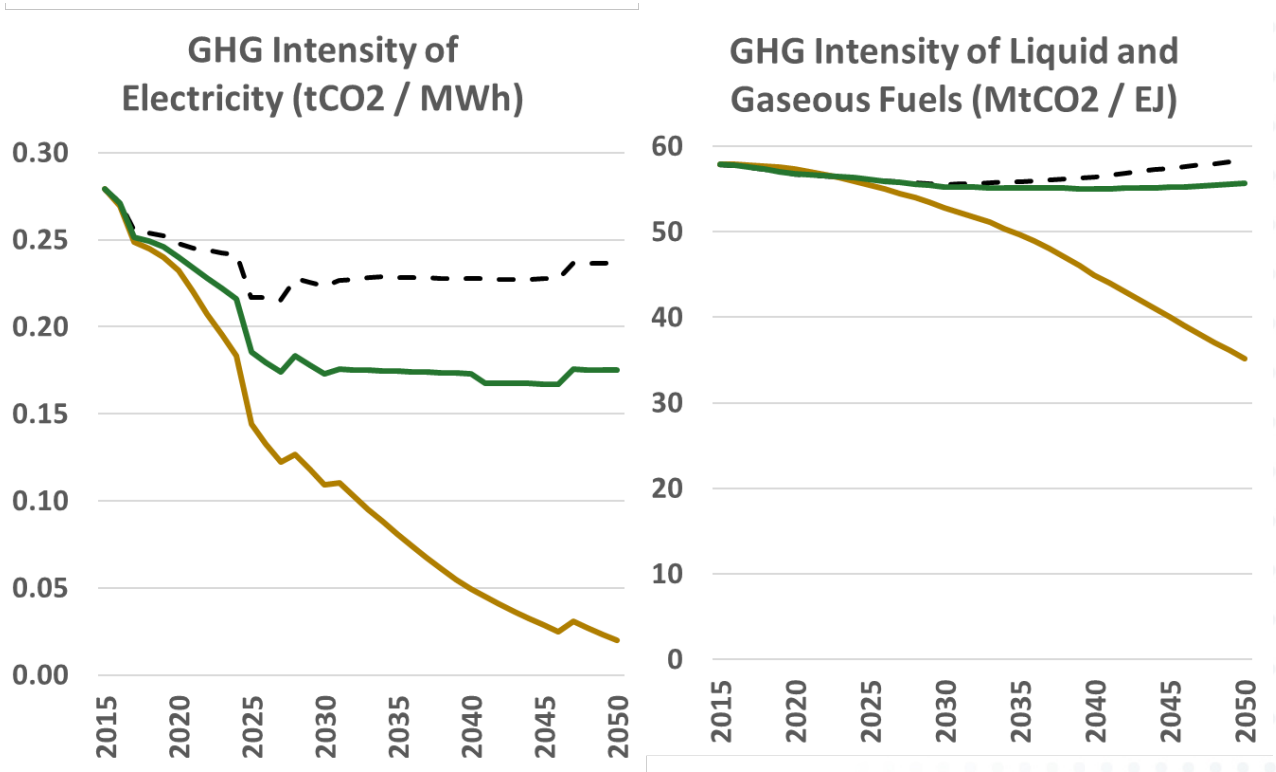




- Significant progress is needed across all four pillars, with fastest ramp-up between today and 2030

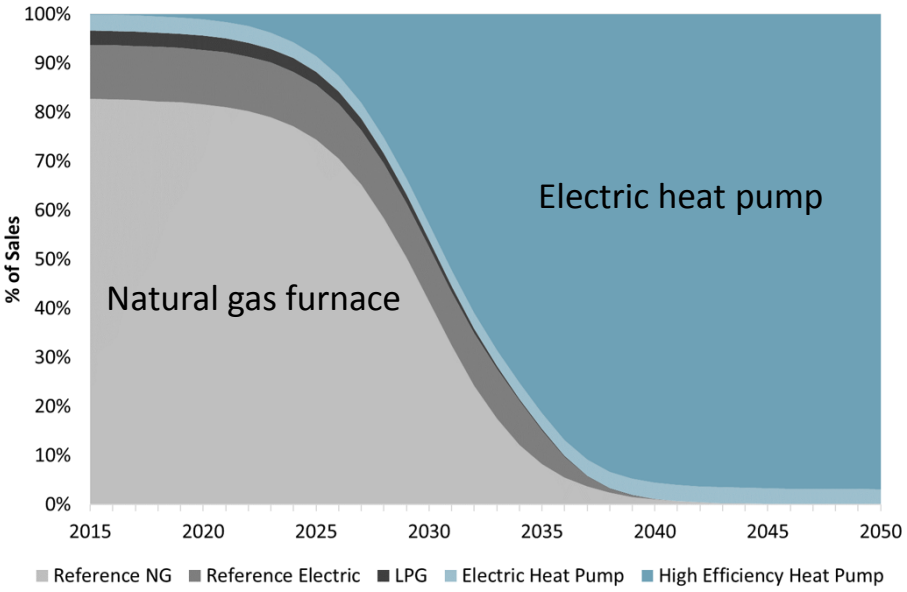
High reliance on renewables, less reliance on biofuels than prior analyses

Low-Carbon Fuels = **Renewables and hydropower** **+** **Biofuels**

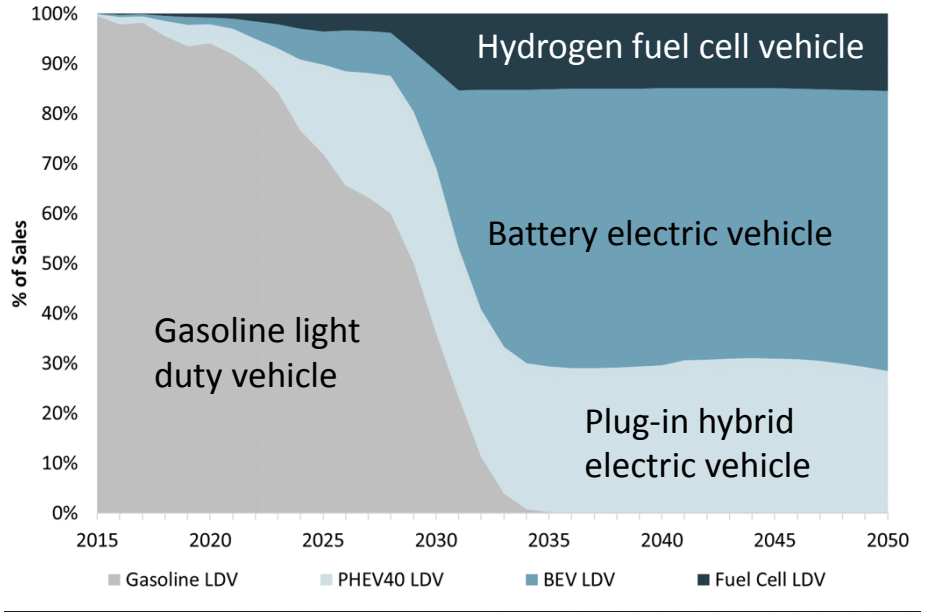


Buildings and vehicle sales shift to electric alternatives in High Electrification Scenario

Residential space heating sales (%/year)

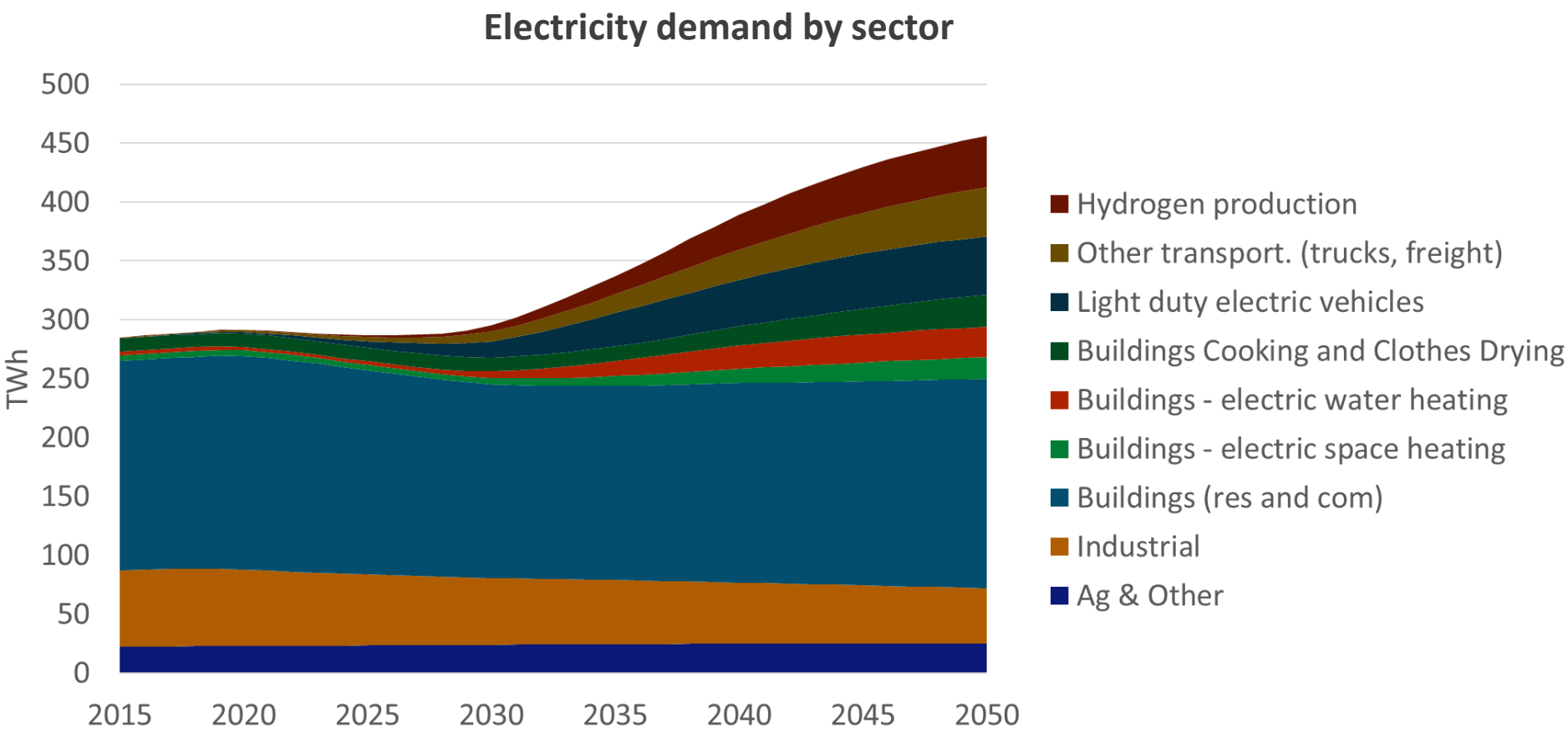


Light duty vehicle sales by type (%/year)



- **Similar trends towards electrification are seen in the High Electrification Scenario for residential water heating, HVAC and water heating in commercial buildings as well as medium duty and heavy duty trucks, and busses**

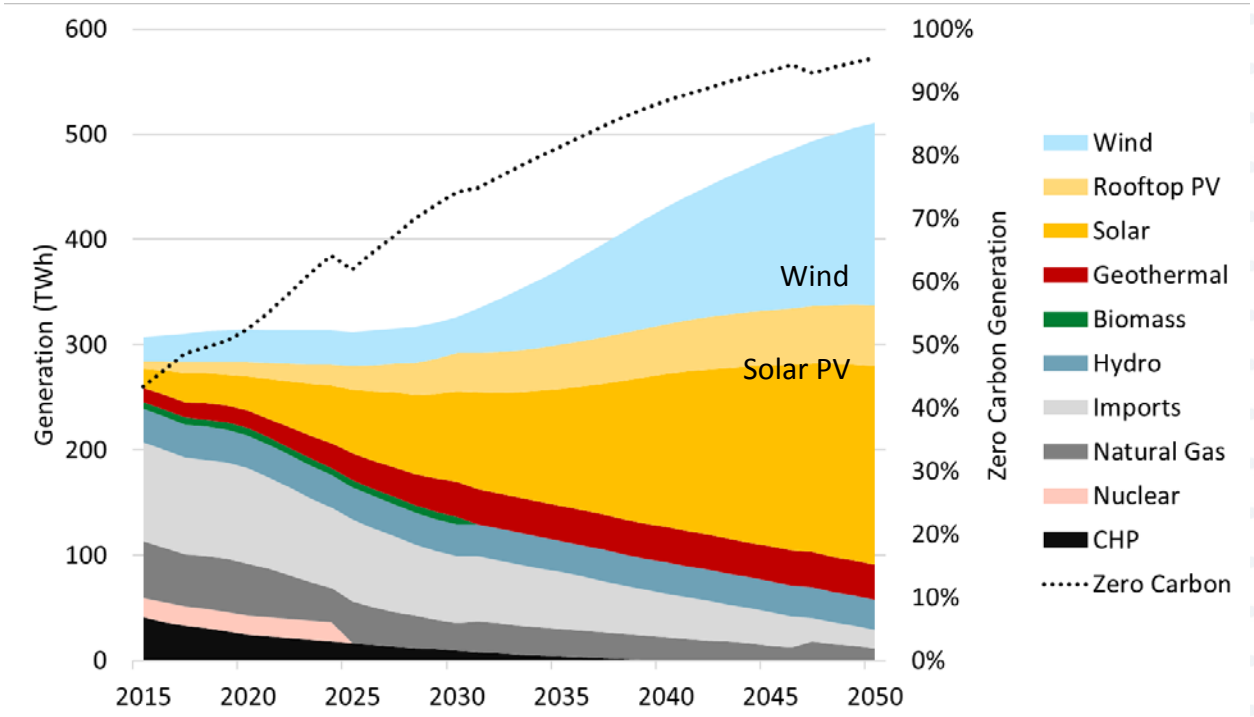
Electrification drives rapid growth in electric generation after 2030



Generation mix is increasingly renewables, diversity and flexible loads help integrate renewables

- **95% of electricity generation is renewables and hydro, 5% is gas generation in High Electrification Scenario by 2050.**
  - High Electrification Scenario 44 GW of out-of-state wind helps to balance solar PV
  - Gas capacity factors fall from ~40% today to ~5% by 2050

Electricity Generation in High Electrification Scenario



All Mitigation Scenarios assume high levels of flexible loads

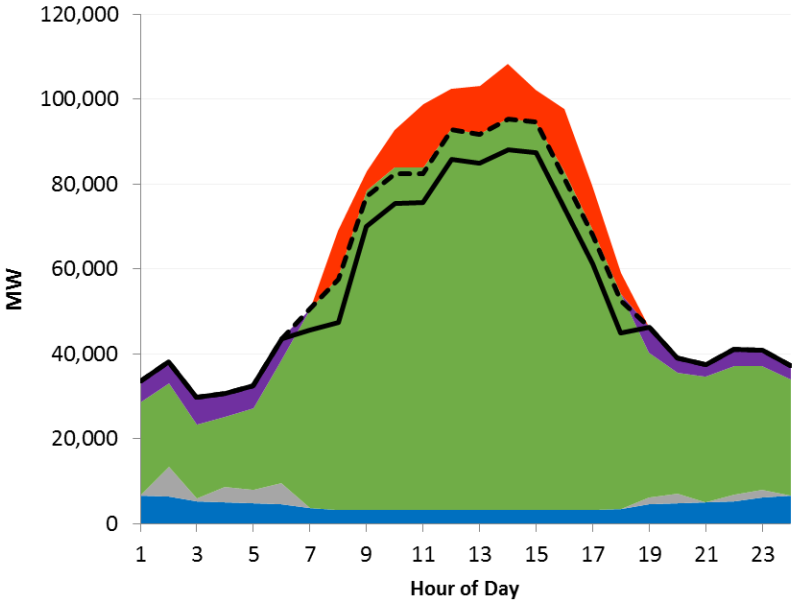
- Flexible loads ("shift DR") in PATHWAYS are modeled as a % of load by end use that can be shifted (advanced or delayed) by a specified number of hours each day based on simplified assumptions
- More precise characterization of flexible load capabilities in buildings, industry, electric trucks, buses, and other electric vehicle types is needed

	% Flexible		
Subsector – Electric End Uses	2030	2050	Hours Shift-able
Commercial Water Heating	20%	80%	3
Commercial Space Heating	20%	80%	2
Commercial Air Conditioning	20%	80%	3
Commercial Refrigeration	20%	80%	2
Residential Water Heating	20%	80%	3
Residential Space Heating	20%	80%	2
Residential Central Air Conditioning	20%	80%	3
Residential Room Air Conditioning	20%	80%	3
Residential Refrigerators	20%	80%	2
Light Duty Vehicles	50%	90%	12

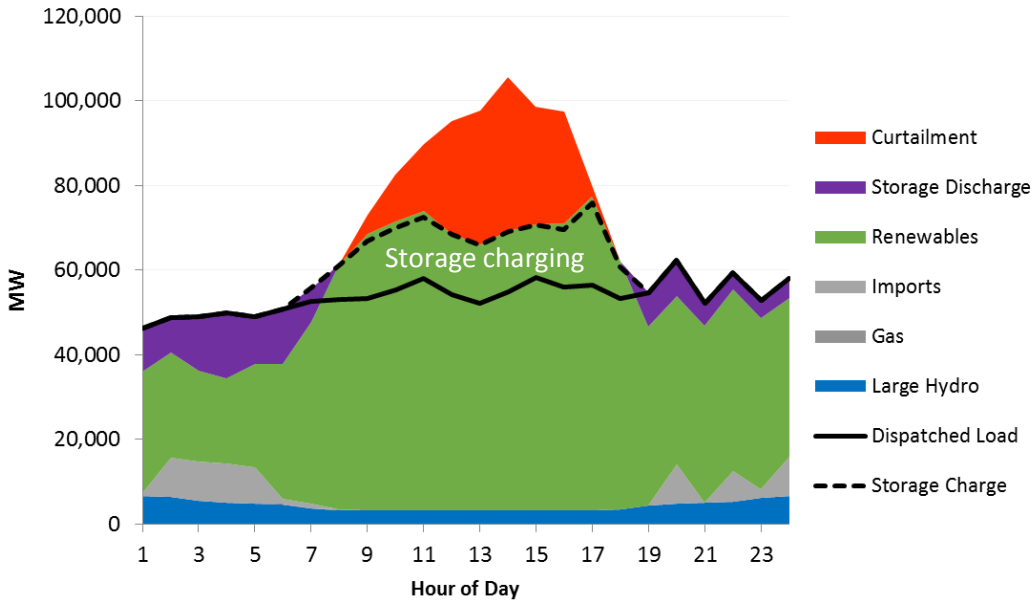
Flexible loads reduce renewable curtailment and system costs

- **High flexibility of building loads, EV charging loads, and hydrogen production loads absorb surplus renewable generation, and avoid costly need for additional storage and renewable overbuild**
  - 9% curtailment in High Electrification Scenario in 2050
  - 22% curtailment in In-state, Low Flexibility Sensitivity in 2050

Spring Day in 2050,
High Electrification Scenario



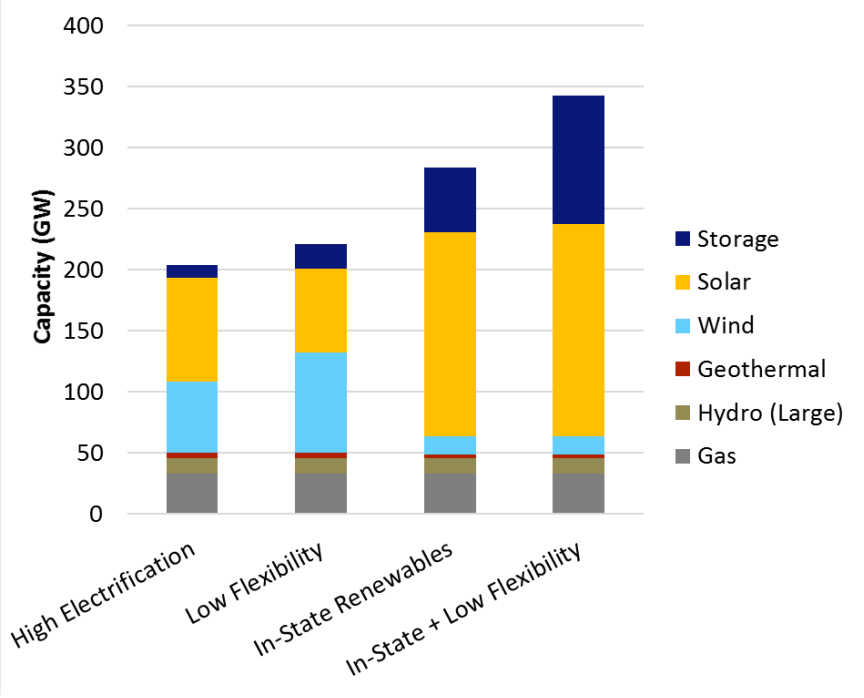
Same Spring Day in 2050,
Low Flexibility Sensitivity



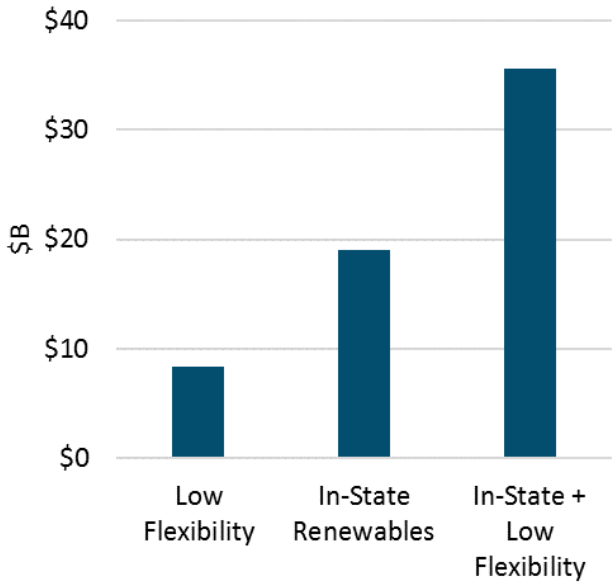
Without renewable integration solutions, 2050 electricity costs are $8 - $36B higher in 2050

2050 High Electrification Case with 95% zero-carbon electricity sector emissions (8 MMT CO2) RESOLVE model results:

2050 California Installed Nameplate Capacity (GW)

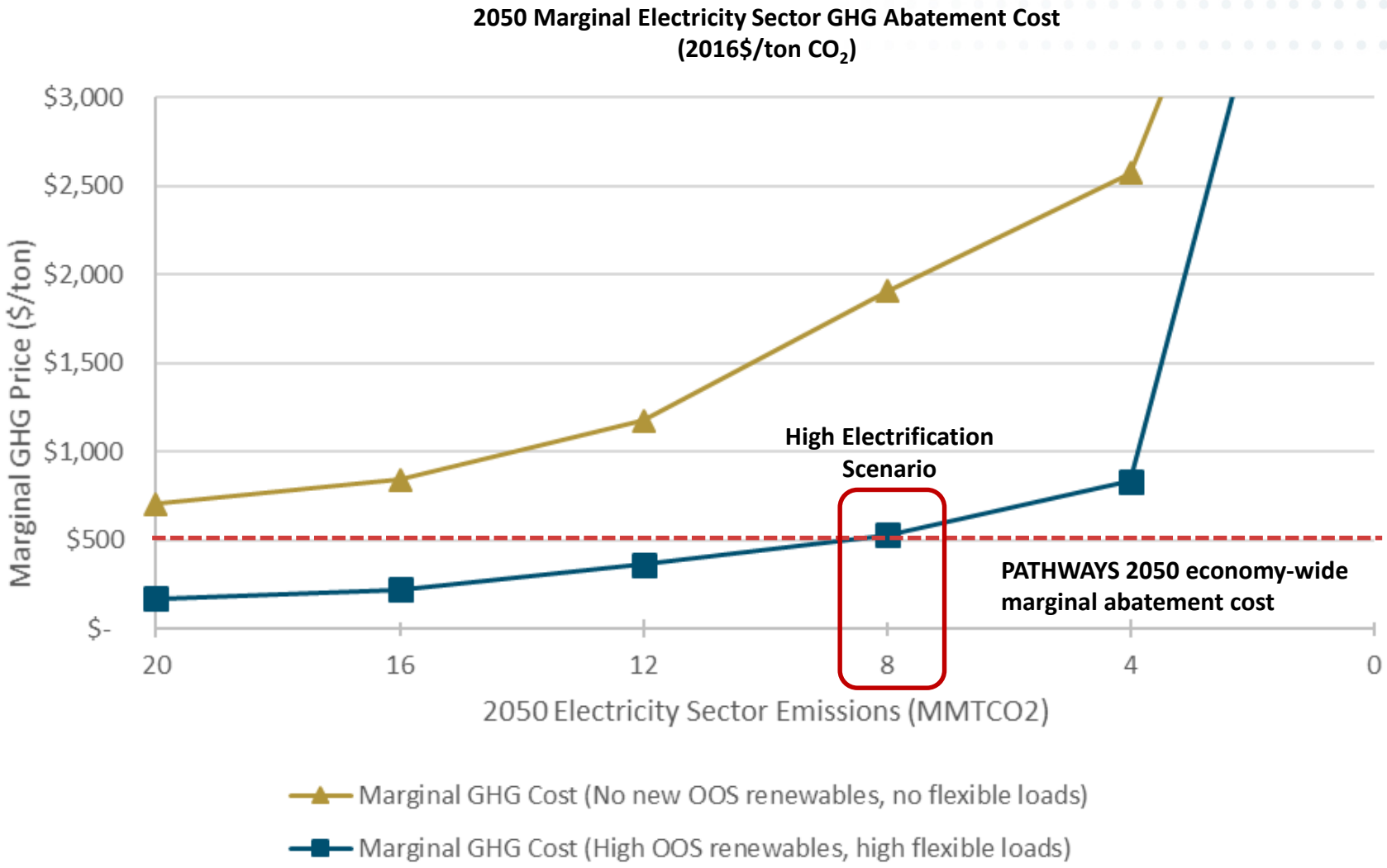


2050 Additional Cost Relative to High Electrification Scenario (2016$B in 2050)



- High Electrification includes “best case” renewable integration solutions including a diverse renewable portfolio (44 GW of OOS wind). Cost reductions in solar and storage will reduce the difference in cost between in the In-state renewables case and High Electrification scenario.
- The land area required for new utility-scale solar PV in the “In-state + Low Flexibility” scenario exceeds ~1700 square miles (~1% of state land) vs. ~600 square miles in the High Electrification Scenario

Renewable diversity & flexible loads enable lower-cost GHG reductions in electricity compared to other sector's mitigation costs



OOS = out-of-state; recent cost declines in solar and battery storage costs are not reflected here

Conclusions

- **Meeting California's climate goals could result in 40% - 90% higher electricity demands by 2050, relative to today, even with aggressive energy efficiency**
- ***85% - 95% zero-carbon electricity*** **is needed by 2050 to meet California's climate goal**
  - Achieving absolute zero carbon electricity may not be necessary, and would require technology innovation such as zero-carbon biofuels, power-to-gas, or multi-day/multi-week energy storage
  - Absent new technology breakthroughs, gas capacity can provide system reliability in a high renewables future, without compromising climate goals
- **Renewable diversity and integration solutions are needed to reduce overgeneration of renewables and lower electric system costs**
  - Flexible loads in electric vehicles, buildings, industry, and potentially hydrogen production from renewable electricity
  - Diverse renewable portfolio
  - Energy storage, with increasing need for longer-duration storage

Energy+Environmental Economics

Thank You!

Full report available here: https://www.ethree.com/wp-content/uploads/2018/06/Deep_Decarbonization_in_a_High_Renewables_Future_CEC-500-2018-012-1.pdf