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The Role of Electricity in Decarbonizing CA's Energy System

Insights from "Deep Decarbonization in a High Renewables Future" (CEC EPIC-14-069) & other recent E3 analyses

CEC IEPR Workshop:
Sep 24, 2019

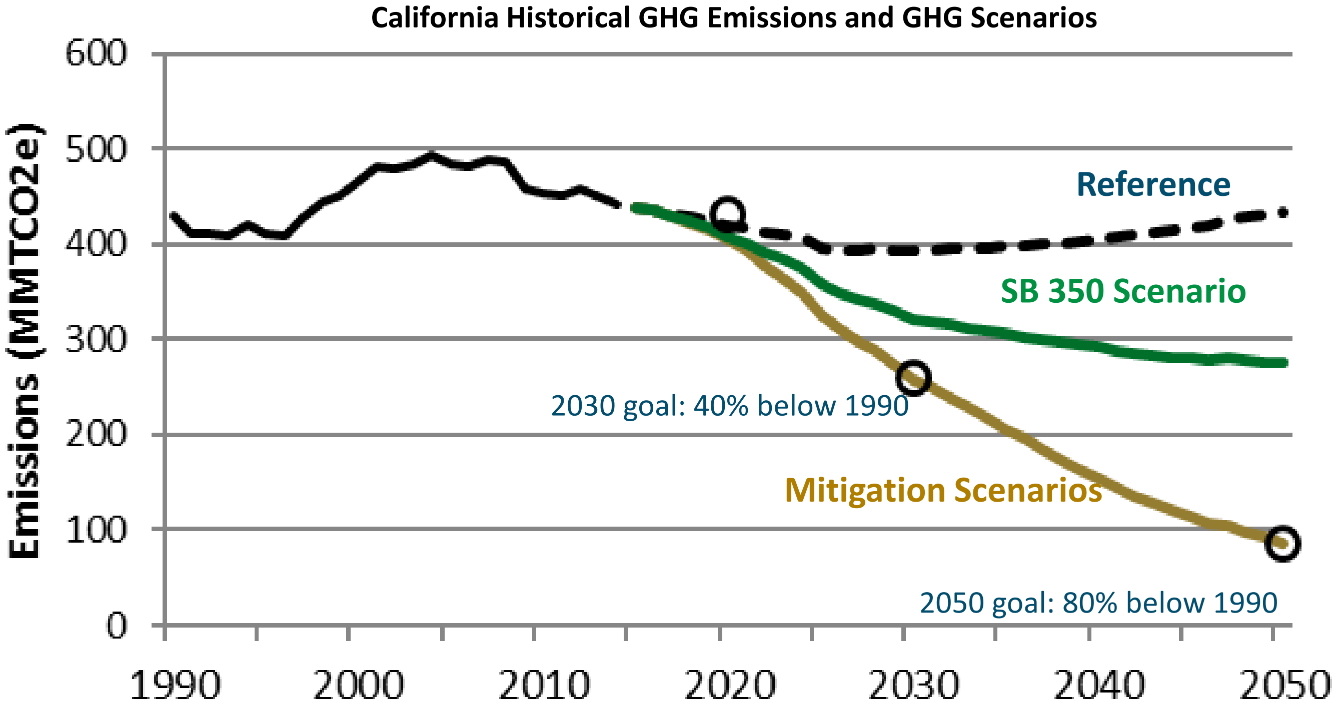
Zack Subin

Energy+Environmental Economics

Economywide Decarbonization

2018 CEC study evaluated 10 scenarios to 80% GHG reductions by 2050

- **By 2020: return GHGs to 1990 levels** (AB 32, 2006)
- **By 2030: 40% below 1990 levels** (SB 32, 2015)
- **By 2050: 80% below 1990 levels** (EO B-30-15 and EO S-3-05)
- ***By 2045: Carbon neutrality*** *(EO B-55-18)* ***not evaluated in CEC analysis***



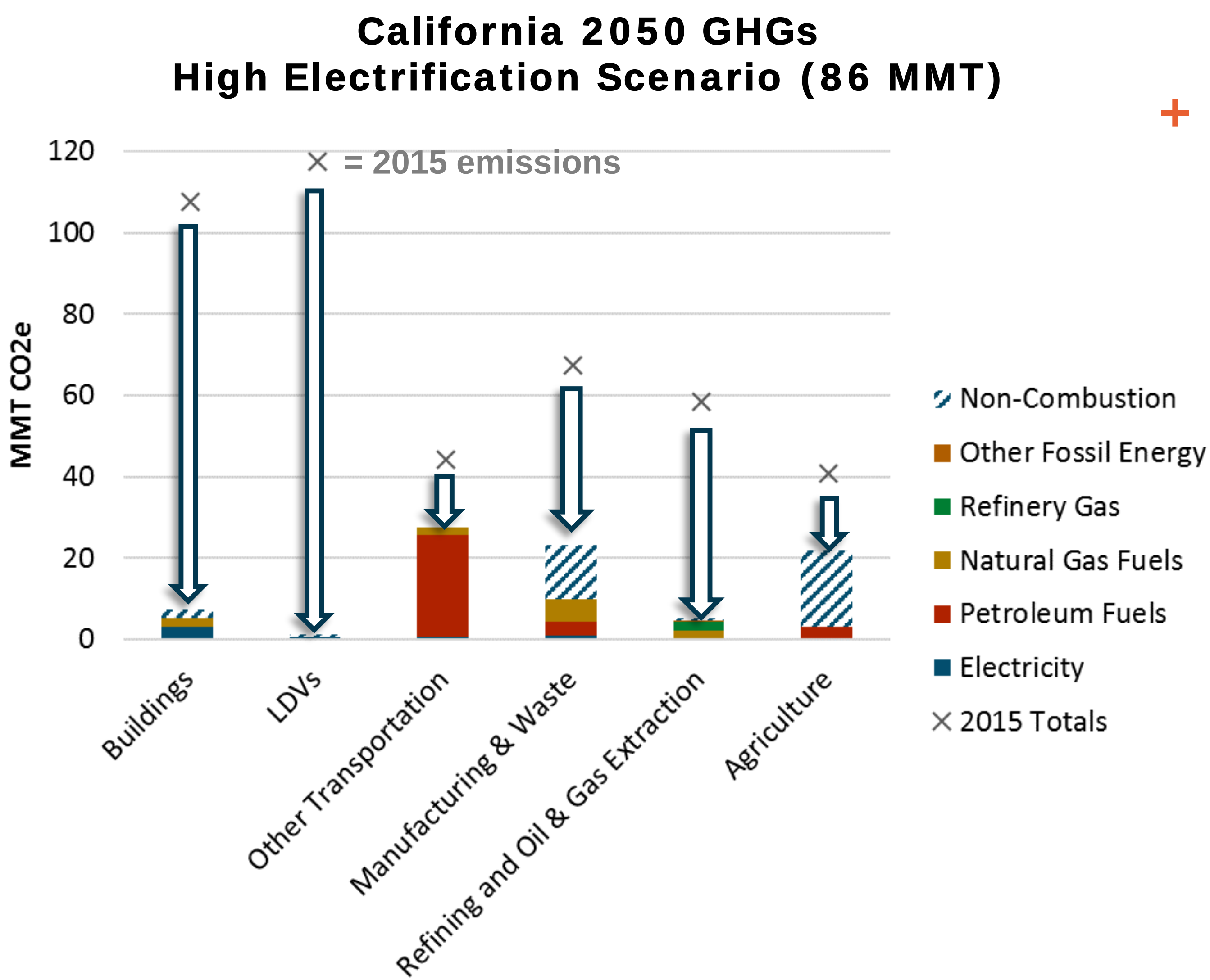
One of the 10 scenarios was the High Electrification scenario, found to be relatively low cost and low risk.

4 Pillars of Energy Decarbonization

Energy efficiency & conservation	**Electrification**	**Low carbon electricity**	**Low carbon fuels**
✓ Appliance EE ✓ Building shells ✓ Urban infill	✓ Heat pumps ✓ ZEV cars and trucks	✓ Renewables & integration ✓ Nuclear, fossil with CCS	✓ Biofuels ✓ Electrolytic fuels (H_2 and P2X)

- Purpose-grown crops considered to be an environmentally and technologically risky strategy
- High Electrification scenario utilizes CA population-weighted share of US supply of residues and wastes, while minimizing use of relatively expensive electrolytic fuels
  - More conservative approach to biomass availability leads to greater reliance on electrification and renewables

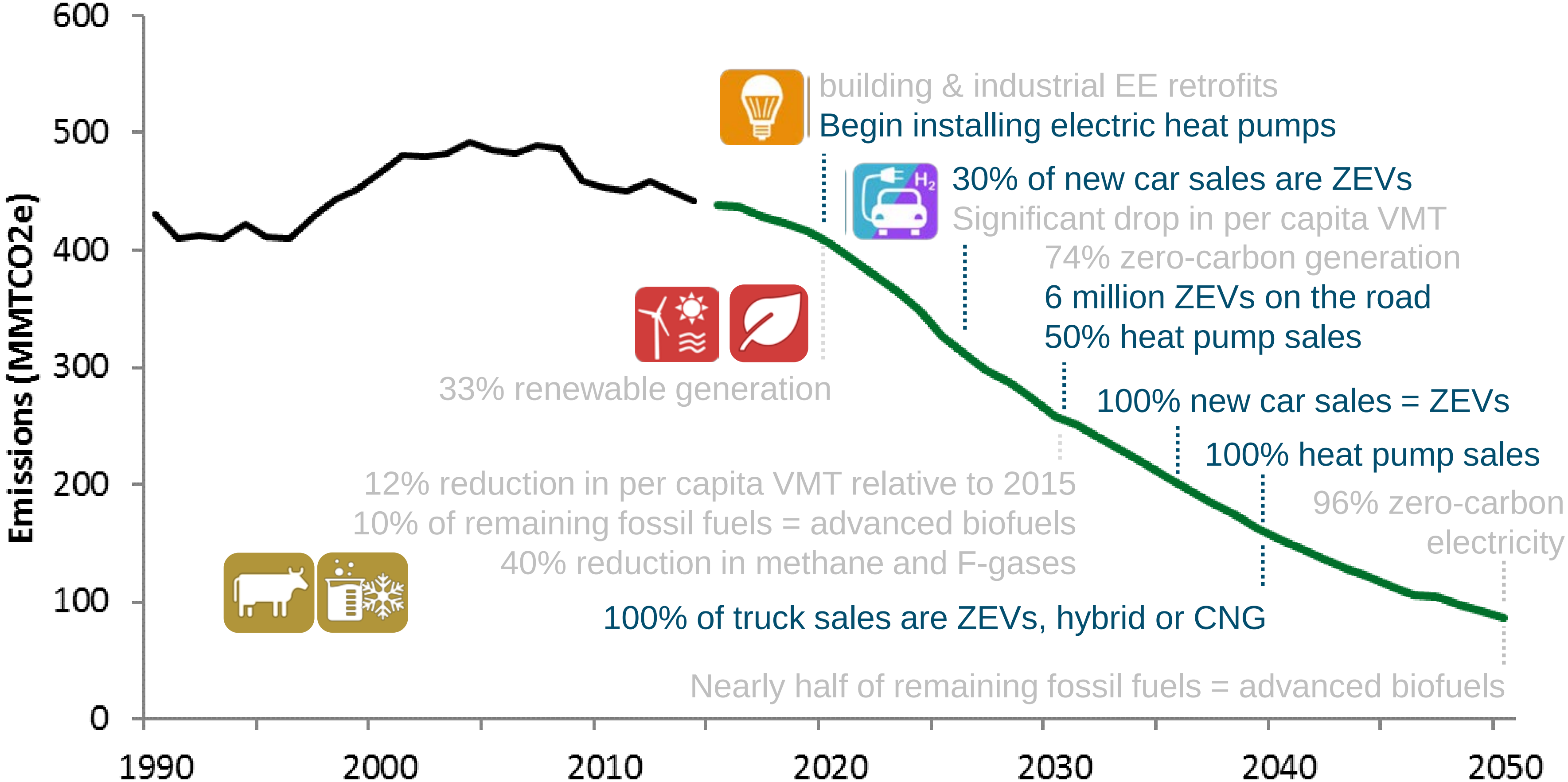
High electrification of buildings and vehicles leads the way for even more challenging sectors



- Remaining 2050 emissions are mostly from **freight** and **off-road transportation**, **industry** (combustion & non-combustion), and **waste** and **agriculture** (non-combustion)

High Electrification Scenario requires rapid acceleration of action to achieve 80 x 50

California Historical GHG Emissions and GHG Reduction Strategies in the High Electrification Scenario
(Highlighting Electrification Strategies)



+ ***Carbon neutrality in 2045 requires accelerating or adding new measures***

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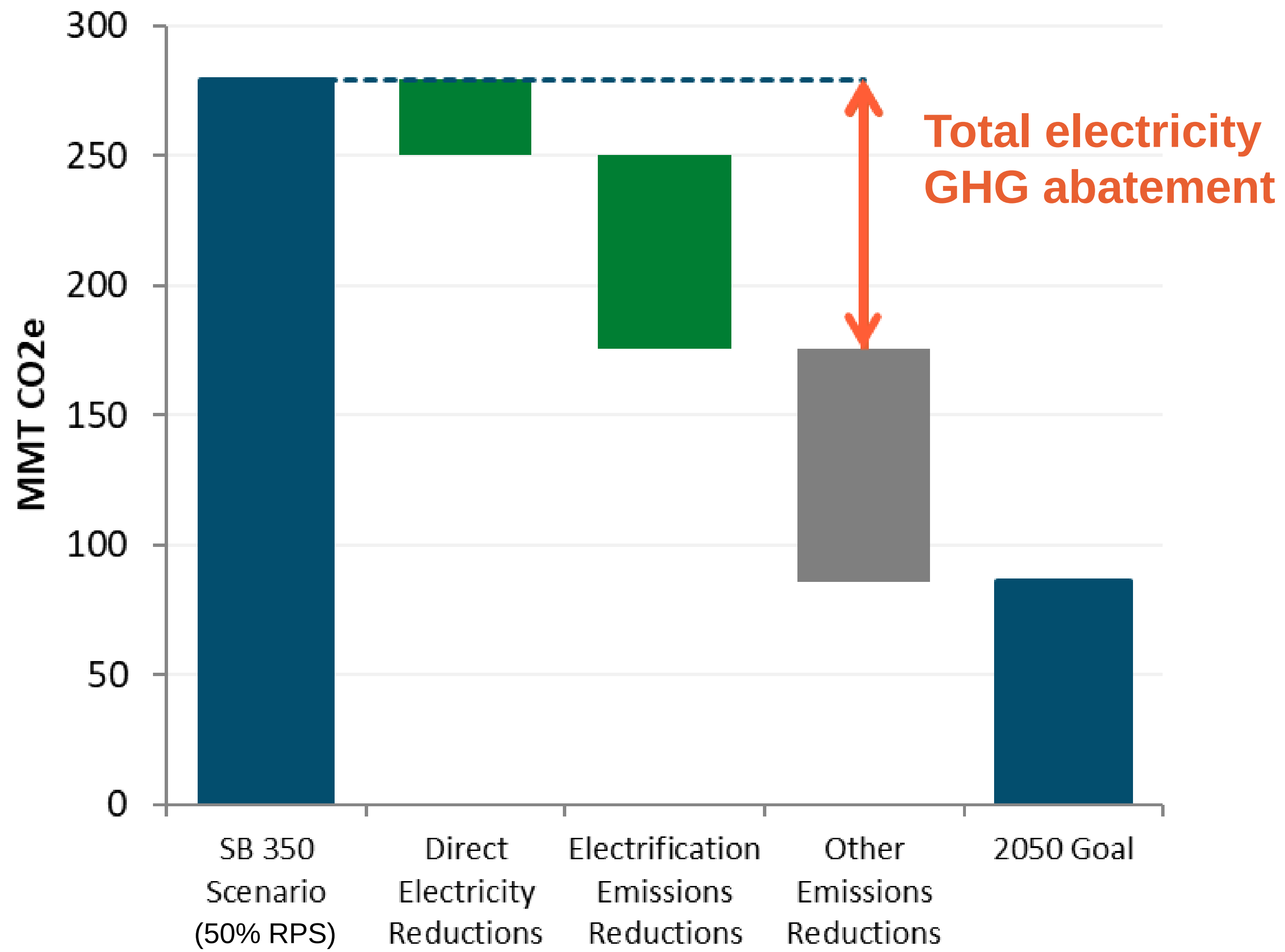
The Role of Electricity

Indirect emissions savings from electrification exceed direct electricity savings

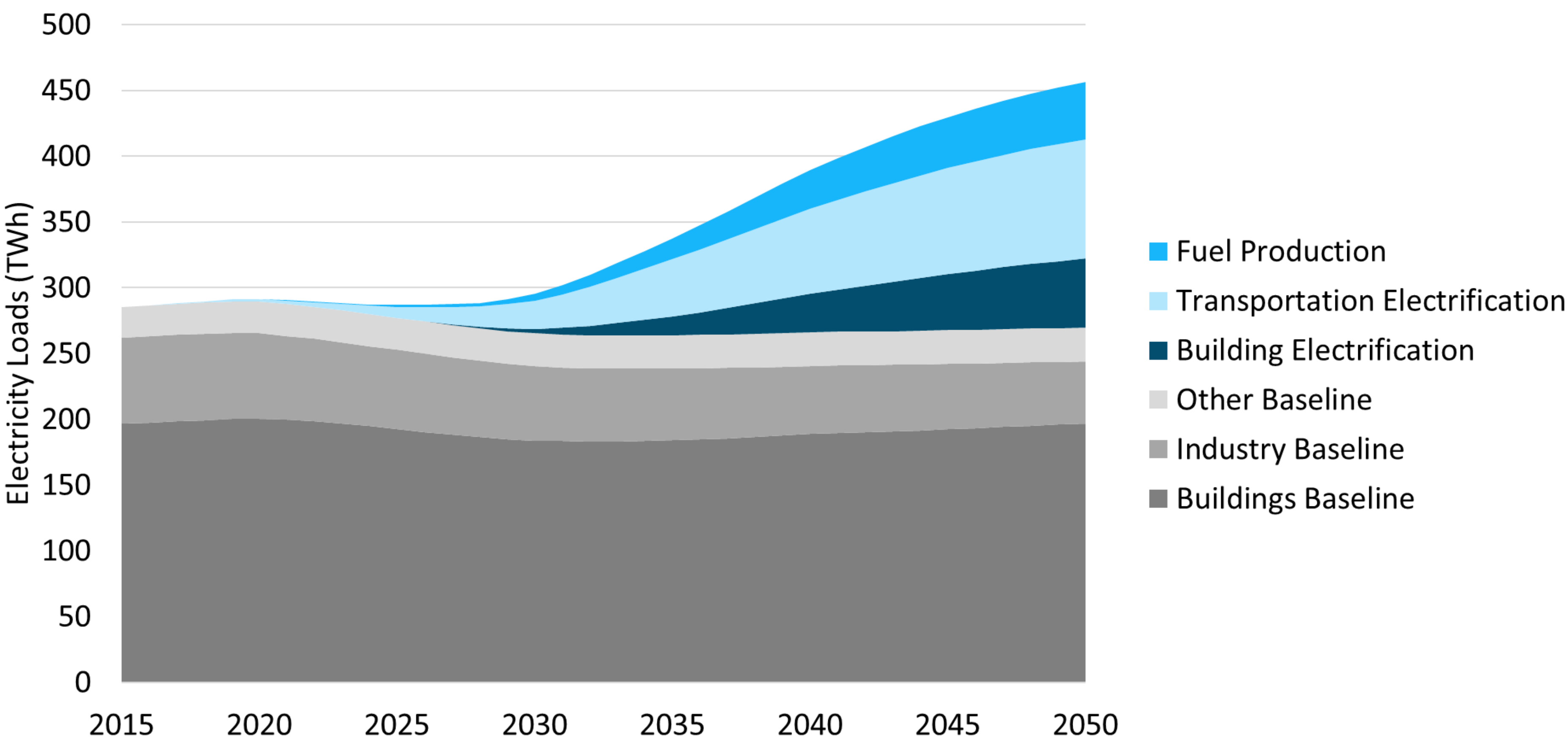
Emissions in 2050 in PATHWAYS High Electrification Scenario*



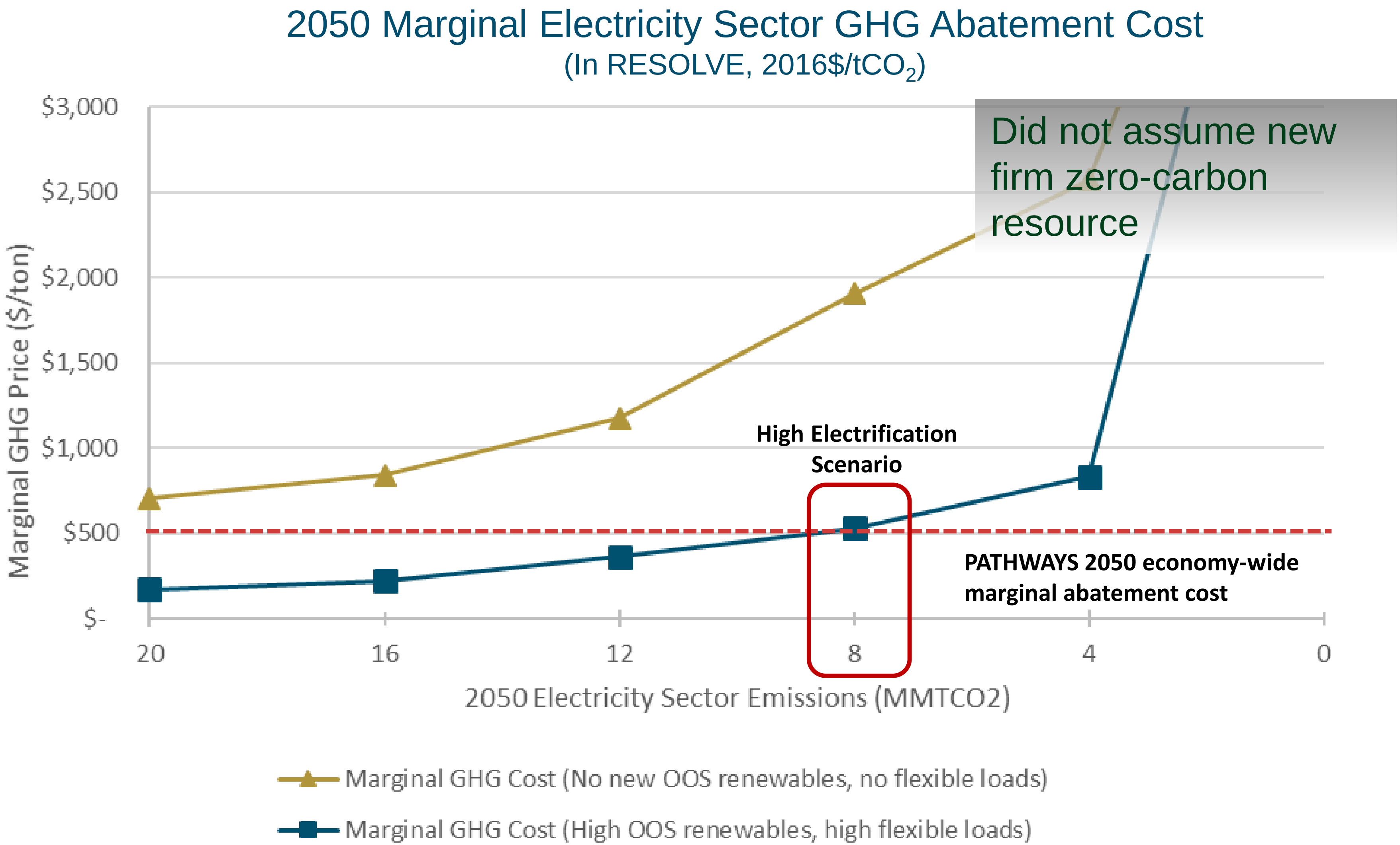
*These values are based on a sensitivity scenario similar but not identical to the 2018 published High Electrification Scenario

Electrification drives rapid growth in electric generation after 2030

Electricity demand by sector in High Electrification Scenario



Wind + solar, flexible loads, and batteries provide low cost GHG reduction, but not all the way to zero



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

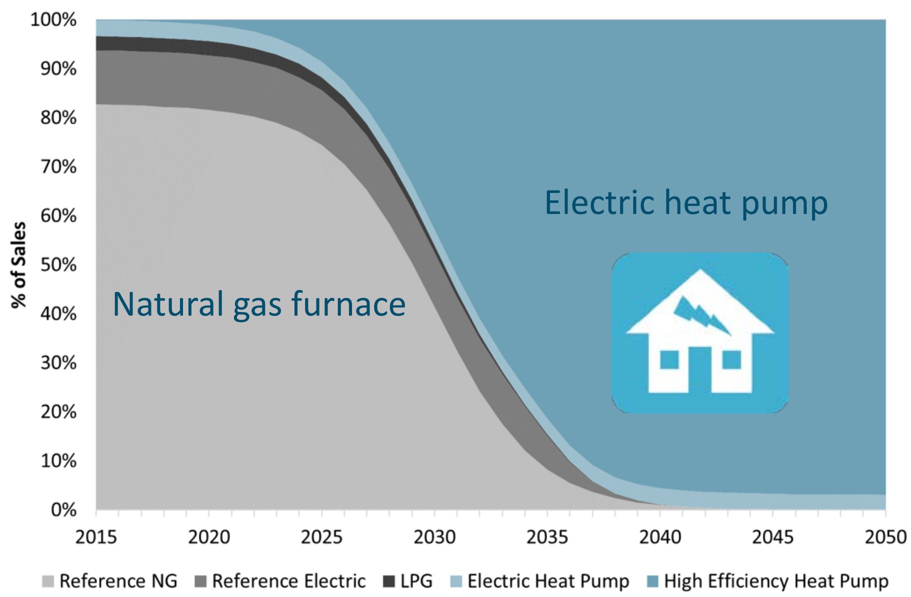
Conclusions

- **Efficiency and electrification are low-cost and low-risk pillars of energy decarbonization**
  - Limited biofuels should be targeted towards high-value uses that are difficult to electrify or substitute, supplemented by electrolytic fuels and/or CCS
    - E.g. aviation, trucking, industrial heating, and backup thermal electricity generation
- **Electricity serves as the lynchpin for decarbonizing the energy system, via electrification**
  - ~90-95% decarbonized electricity achievable by scaling up current approaches (wind + solar, flexible loads, and storage)
  - Completely decarbonizing electricity would require an additional option to provide firm capacity and long-duration energy storage
    - Biomethane, hydrogen, nuclear, CCS, or advanced storage
  - Until additional option is available, maintaining sufficient firm capacity is critical
- **<u>Because electrification is consumer-facing, CA must prioritize affordable, reliable electricity</u>**

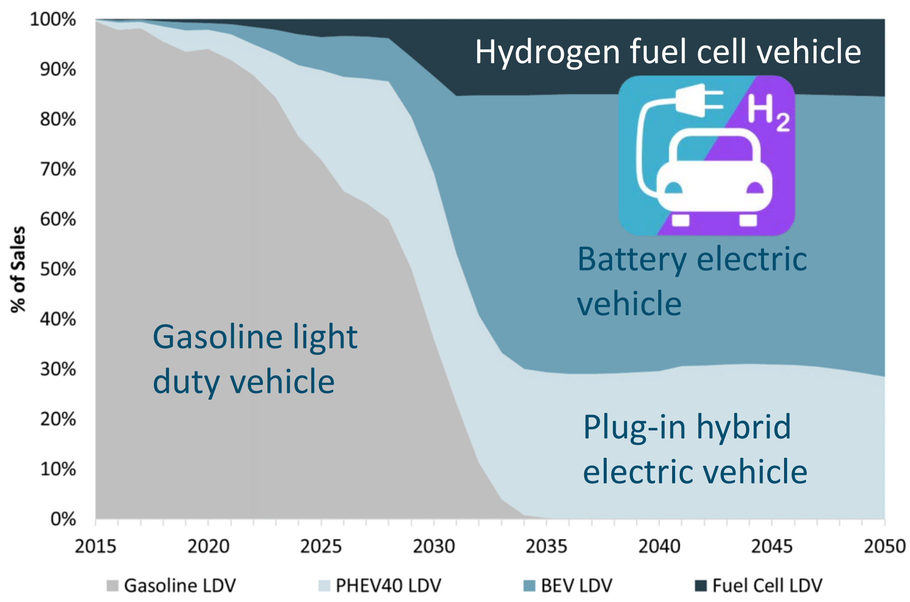
Appendix

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 and for HVAC and water heating in commercial buildings, as well as medium- and heavy-duty trucks and buses

High priority GHG mitigation strategies & key challenges to achieve '80x50'

Scale Up & Deploy	Key Challenges
Energy efficiency in buildings & industry	Consumer decisions and market failures
Renewable electricity	Implementation of integration solutions
Smart growth	Consumer decisions and legacy development
Market Transformation	**Key Challenges**
Zero-emission light-duty vehicles	Consumer decisions and cost
Advanced efficiency/ building electrification	Consumer decisions, equity of cost impacts, cost and retrofits of existing buildings
F-gas replacement	Standards needed to require alternatives
Methane capture	Small and diffuse point sources
Reach technologies	**Key Challenges**
Advanced sustainable biofuels	Cost and sustainability challenges
Zero-emissions heavy-duty trucks	Cost
Industrial electrification	Cost & technical implementation challenges
Electrolysis hydrogen production	Cost

Source: Mahone et al, (2018) "*Deep Decarbonization in a High Renewables Future*", California Energy Commission CEC-500-2018-012

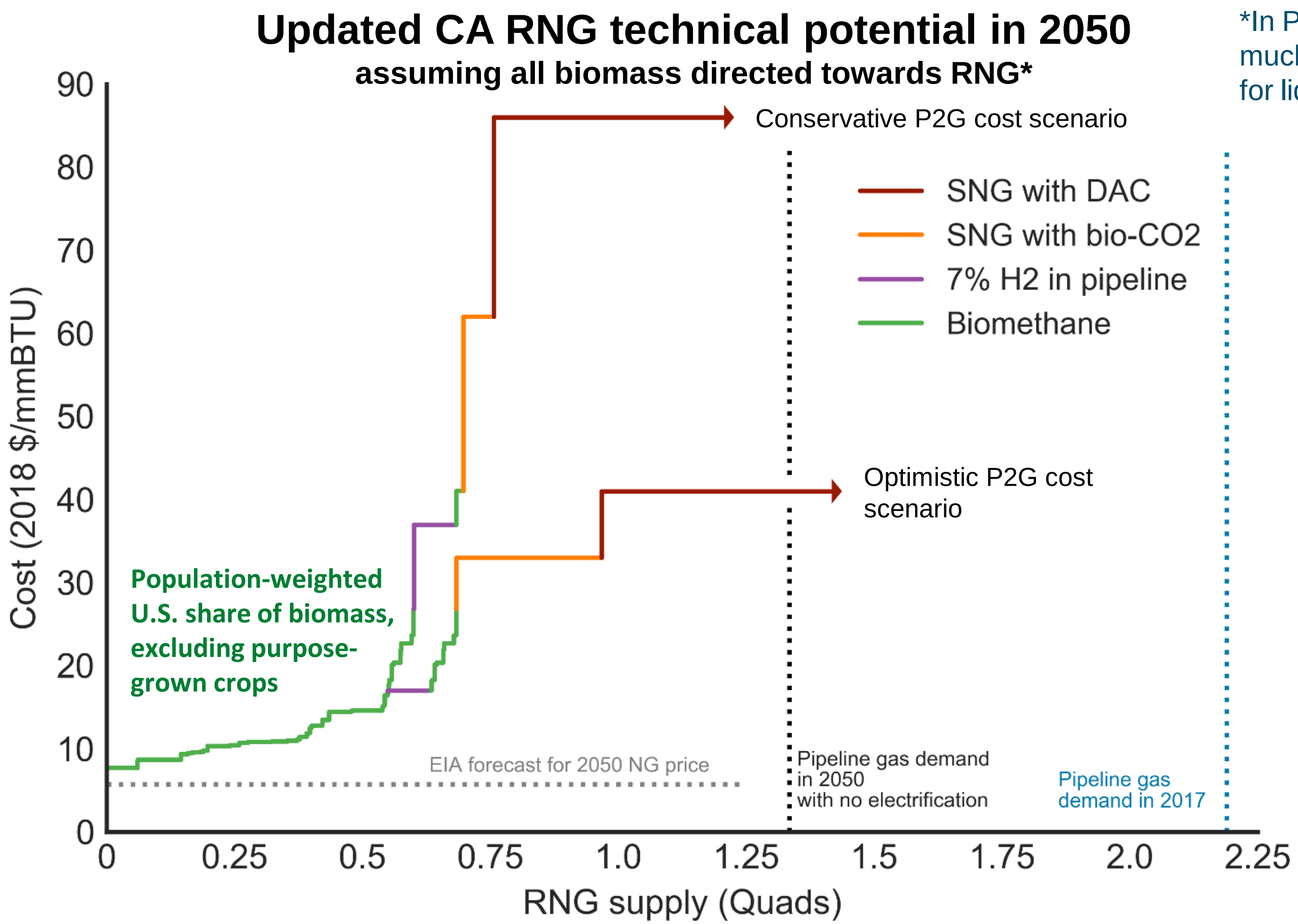
Key conclusions from 2018 study highlight role of consumer-facing measures

- ***Consumer decisions*** **are the lynchpin to meeting 2030 GHG target**
  - Investing in energy efficiency improvements in existing buildings
  - Purchasing and driving zero-emission vehicles
  - Installing electric heat pumps for HVAC and water heating
  - *Carbon pricing, incentives, and business and policy innovations* could all drive the needed *market transformation to* reduce costs, improve performance and increase choices for these key consumer-facing strategies
- ***At least 90% zero-carbon electricity*** **is needed by 2050**
  - Renewable diversity and integration solutions are needed to reduce costs
- ***At least one "reach technology"*** **that has not been commercially proven is needed to help meet the longer-term 2050 GHG goal, and to mitigate risk of other solutions falling short**
  - A "reach technology" should address difficult to electrify end-uses (e.g. heavy-duty trucking, industry)

There is insufficient low-cost RNG to fully decarbonize gas demand

+ Expensive RNG would likely be needed without electrification

- Even with aggressive technology learning and use of best-case out of state resources to produce hydrogen and SNG, RNG at scale is likely much more expensive than fossil NG

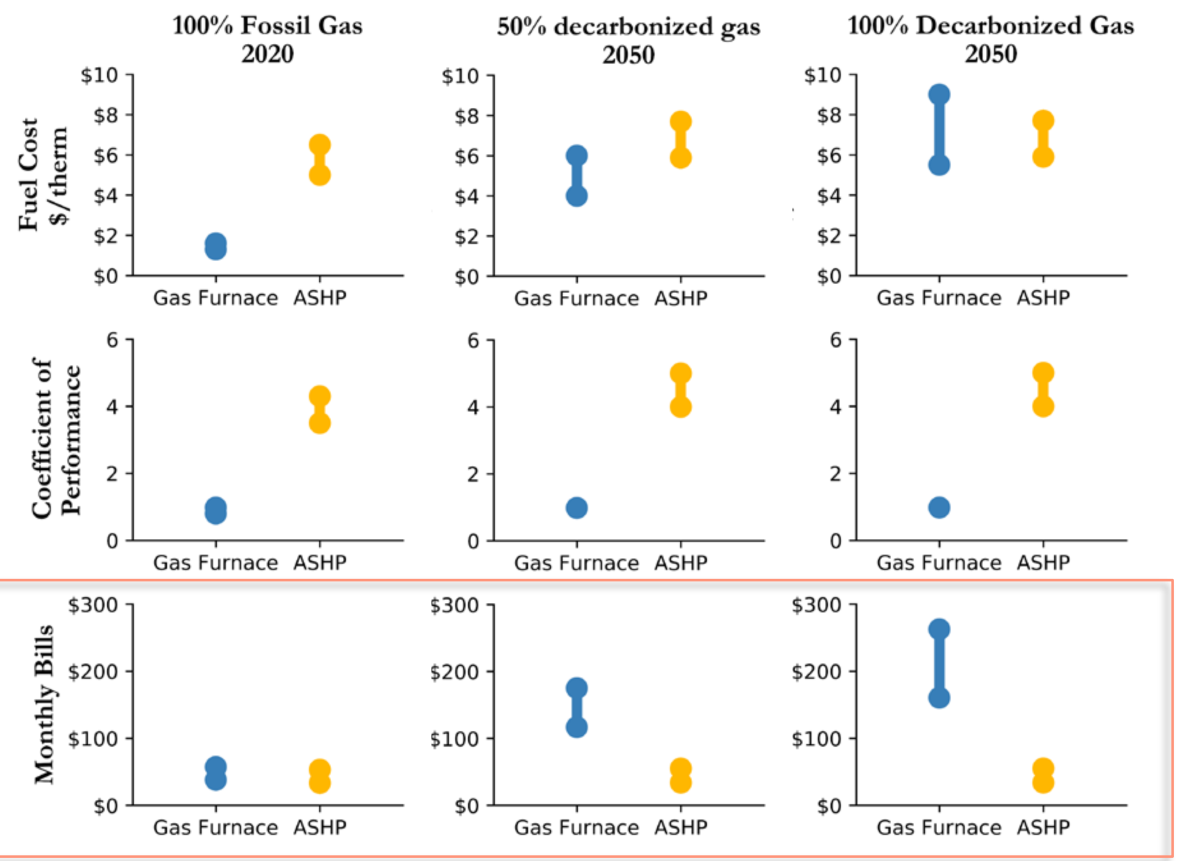


*In PATHWAYS scenarios, much of the biomass is used for liquid biofuels.

Draft findings from "Future of Natural Gas Distribution in California" (CEC PIER-16-011)

Heat pump efficiency drives much lower fuel costs when decarbonizing via electricity than RNG

Monthly bill analysis in PATHWAYS Scenarios:
Space heating costs for Northern CA single family home



Draft findings from "Future of Natural Gas Distribution in California" (CEC PIER-16-011)

+ **Delivering 1 kBTU of heat from a heat pump requires ~0.1 kWh of renewable generation; delivering 1 kBTU of heat from gas furnace with synthetic NG produced from renewables requires ~1 kWh**

Battery requirements in High Electrification Scenario dominated by EVs

- **Grid-scale storage: ~250 GWh**
- **LDV EVs: ~1200 GWh**
  - Avoiding this but still meeting the 80 x 50 goal would require at least one of these:
    - Transportation innovation and/or urbanization avoiding reliance on personally-owned cars
    - Large-scale deployment of light-duty hydrogen fuel cell vehicles (counter to current trends)
    - Unexpected breakthrough in providing ample sustainable biofuels

Assumed 50 GW of 5 hr batteries for grid-scale storage, vs. 19 million BEVs and 11 million PHEVs with an energy capacity of 50 kWh and 20 kWh, respectively. Batteries for electric trucks, buses, and other HDVs are not included.