Energy+Environmental Economics

California PATHWAYS: Long-Term Greenhouse Gas Reduction Scenarios

Connecticut Department of Energy and Environmental Protection

Exploring Climate Solutions Webinar Series

November 20th, 2015

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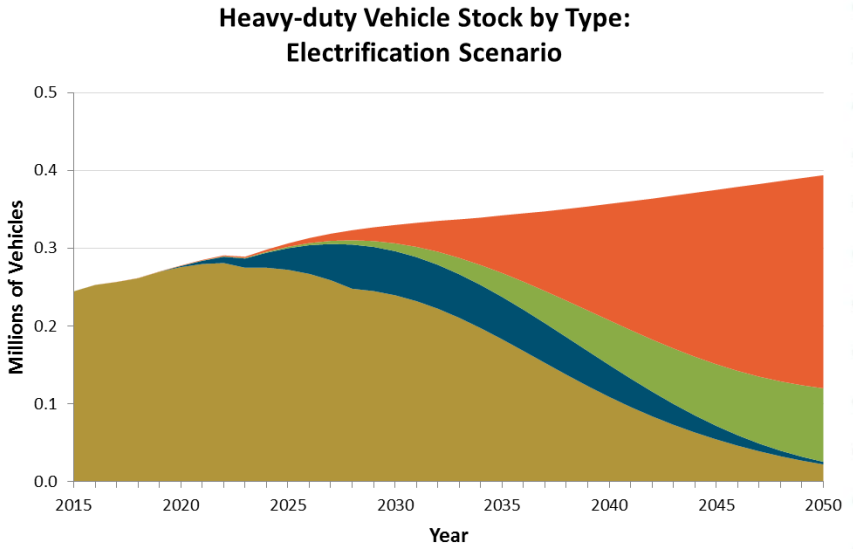
With support from Elaine Hart, Ben Haley, Jim Williams, Sam Borgeson, Nancy Ryan

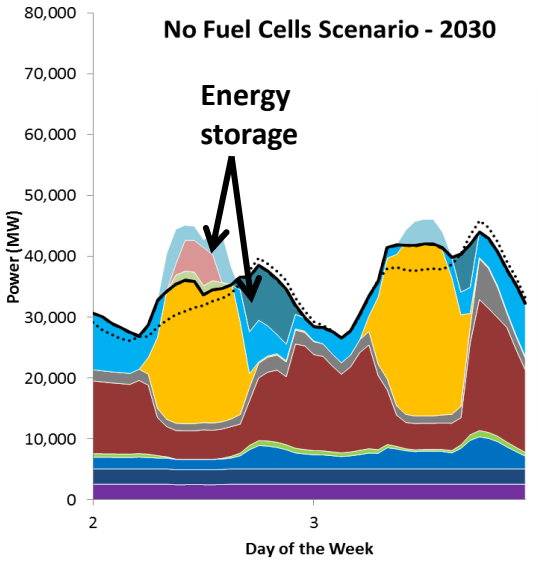
Energy + Environmental Economics (E3)

- San Francisco-based consultancy with 40 professionals focusing on electricity sector economics, regulation, planning and technical energy analysis
- Broad client base includes utilities, regulators, government agencies, power producers, technology companies, and investors
- Our experience has placed us at the nexus of planning, policy and markets

Overview: What is PATHWAYS?

- **Back-casting, not forecasting**
- **Bottom-up, user-defined, non-optimized scenarios test "what if" questions**
- **Economy-wide model captures interactions between sectors & path-dependencies**
- **Annual time steps for infrastructure-based accounting simulates realistic stock roll over**
- **Hourly treatment of electric sector**
- **Tracks capital investments and fuel costs over time**

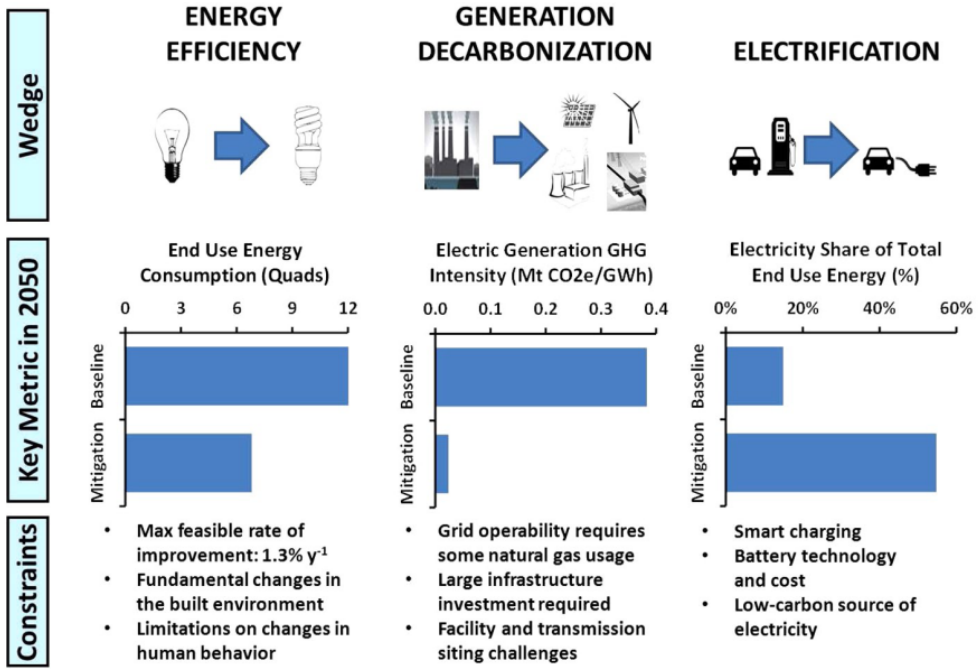




Allows for development of realistic & concrete GHG reduction roadmaps

2012 Science Paper: "The Technology Path to Deep Greenhouse Gas Emissions Cuts by 2050"

- **What is the impact of the electric generation mix on the cost and feasibility of a low-carbon future in CA?**
  - Hydrogen Energy International
- **Compared renewables, nuclear, carbon capture and storage**
- **Demonstrated a feasible pathway to 2050 goal with focus on electrification**



"The Technology Path to Deep Greenhouse Gas Emissions Cuts by 2050: The Pivotal Role of Electricity," Williams et al, Science (2012)

2014 SoCal Gas Study: Is electrification the only strategy?

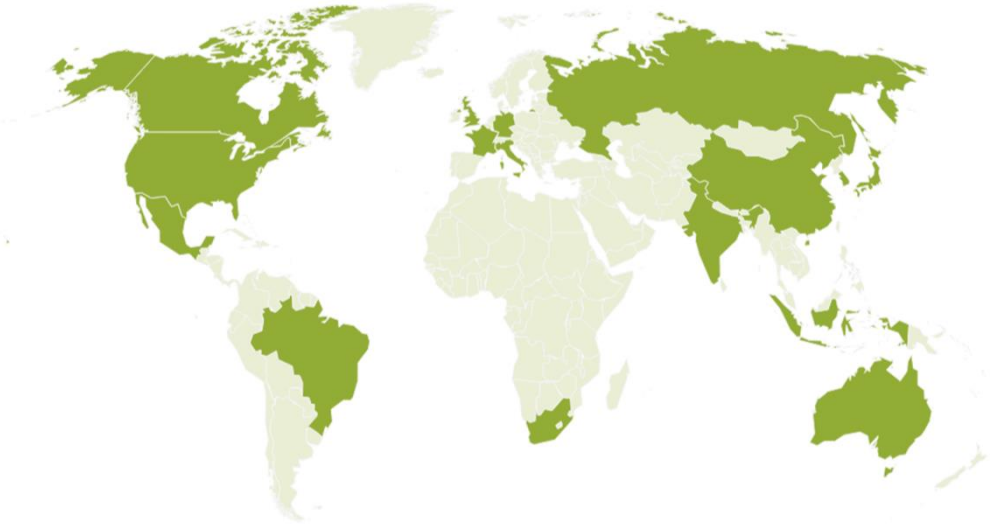
- **What is the role of natural gas and low-carbon gas in meeting California's climate goals?**
  - Southern California Gas Co.
- **Low carbon gas is:**
  - **Biogas** – from manure, landfills but also gasification of woody waste and cellulosic biomass
  - **Hydrogen** – produced from renewable electricity via electrolysis
  - **Synthetic low-carbon methane (power-to-gas)** – H_2 combined with carbon captured from the atmosphere or ocean to produce methane

Southern California Gas Company

A Sempra Energy utility®

2014: UN Deep Decarbonization Pathways Project

+ **UN Deep Decarbonization Pathways Project**
  - 17 countries, >70% of current global GHG emissions
  - Scenarios to keep global warming below 2 degrees C
+ **E3 was lead author of the U.S. country report**




ECONOMY

Blueprints for Taming the Climate Crisis

JULY 8, 2014

Here's what your future will look like if we are to have a shot at preventing devastating climate change.

Within about 15 years every new car sold in the United States will be electric. In fact, by

Eduardo Porter

UN issued with roadmap on how to avoid climate catastrophe

Report is the first of its kind to prescribe concrete actions that the biggest 15 economies must take to keep warming below 2C

UN: Avoiding climate disaster is tough but feasible

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Energy & Sustainability » Climatewire

Clean Energy to Stave Off Catastrophic Climate Change Possible by 2050, Barely

The world is not on track to keep global warming below 2 degrees Celsius but can still hold that line with tremendous effort

SUSTAINABLE DEVELOPMENT SOLUTIONS NETWORK
A GLOBAL INITIATIVE FOR THE UNITED NATIONS

deepdecarbonization.org

IDDRI
SciencesPo.

2015: The California PATHWAYS project

+ Purpose

- To evaluate the feasibility and cost of a range of greenhouse gas reduction scenarios in California (prior to development of Governor's 2030 goals)

+ Project sponsors

- California Air Resources Board, Energy Commission, Public Utilities Commission, Independent System Operator & the Governor's Office
- Additional funding provided by the Energy Foundation

+ Team

- Energy & Environmental Economics with support from LBNL

Study results: https://ethree.com/public_projects/energy_principals_study.php

California's Greenhouse Gas Reduction Goals

California Total Greenhouse Gas Emissions (MMtCO2e/yr)

600
500
400
300
200
100
0

1990 2000 2010 2020 2030 2040 2050

2020 limit: 1990 GHG level

2030 goal: 40% below 1990

California Governor Brown's 2030 Climate Agenda

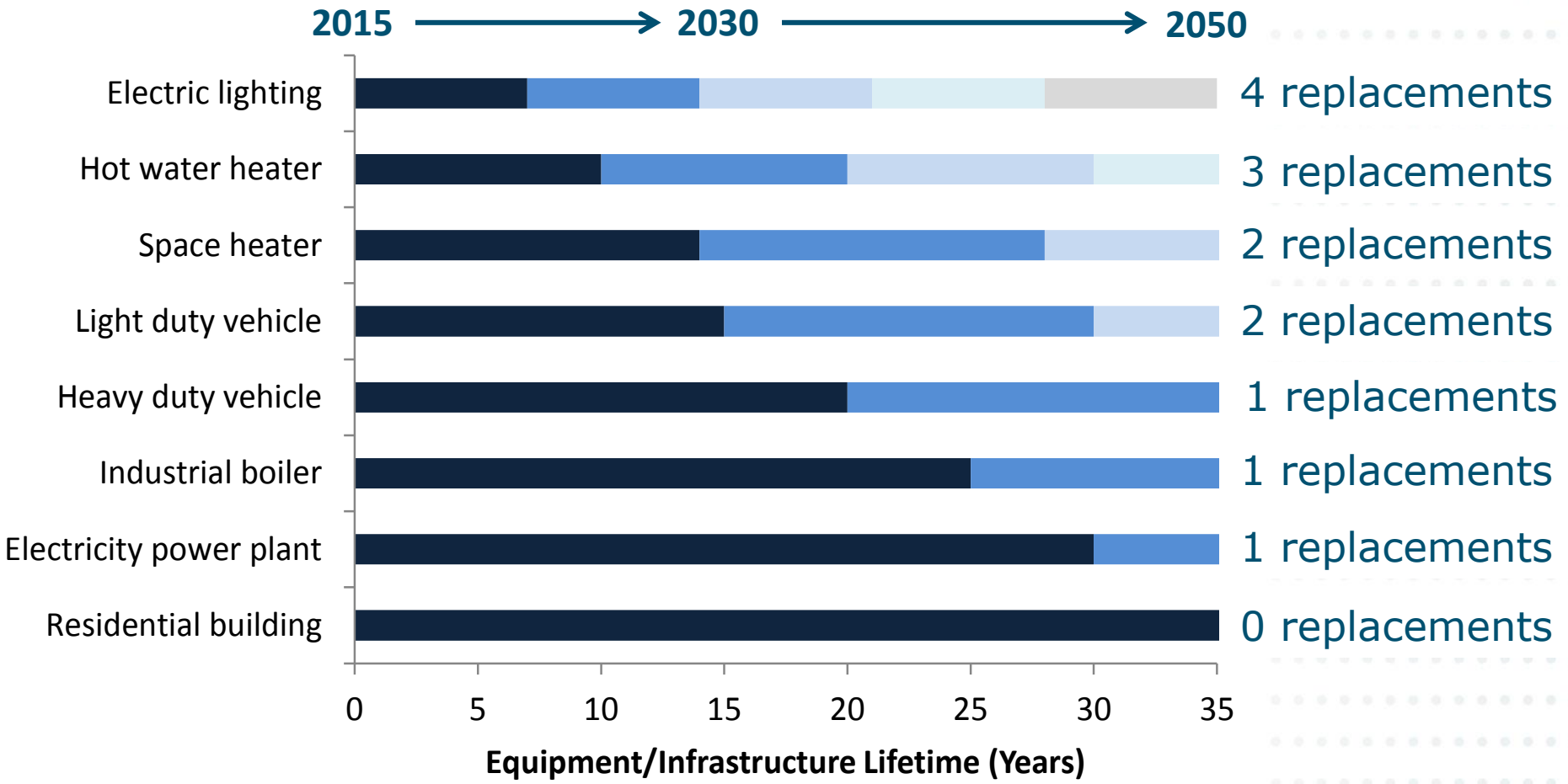
- **Reduce greenhouse gas emissions 40% below 1990 level**
- **50%** of electricity from renewables sources;
- Reduce today's petroleum use in cars and trucks by up to **50%**
- **50%** increase in savings in existing buildings **and** make heating fuels cleaner;
- Reduce methane, black carbon and other potent pollutants across industries;
- Manage farm and rangelands, forests and wetlands so they can store carbon.



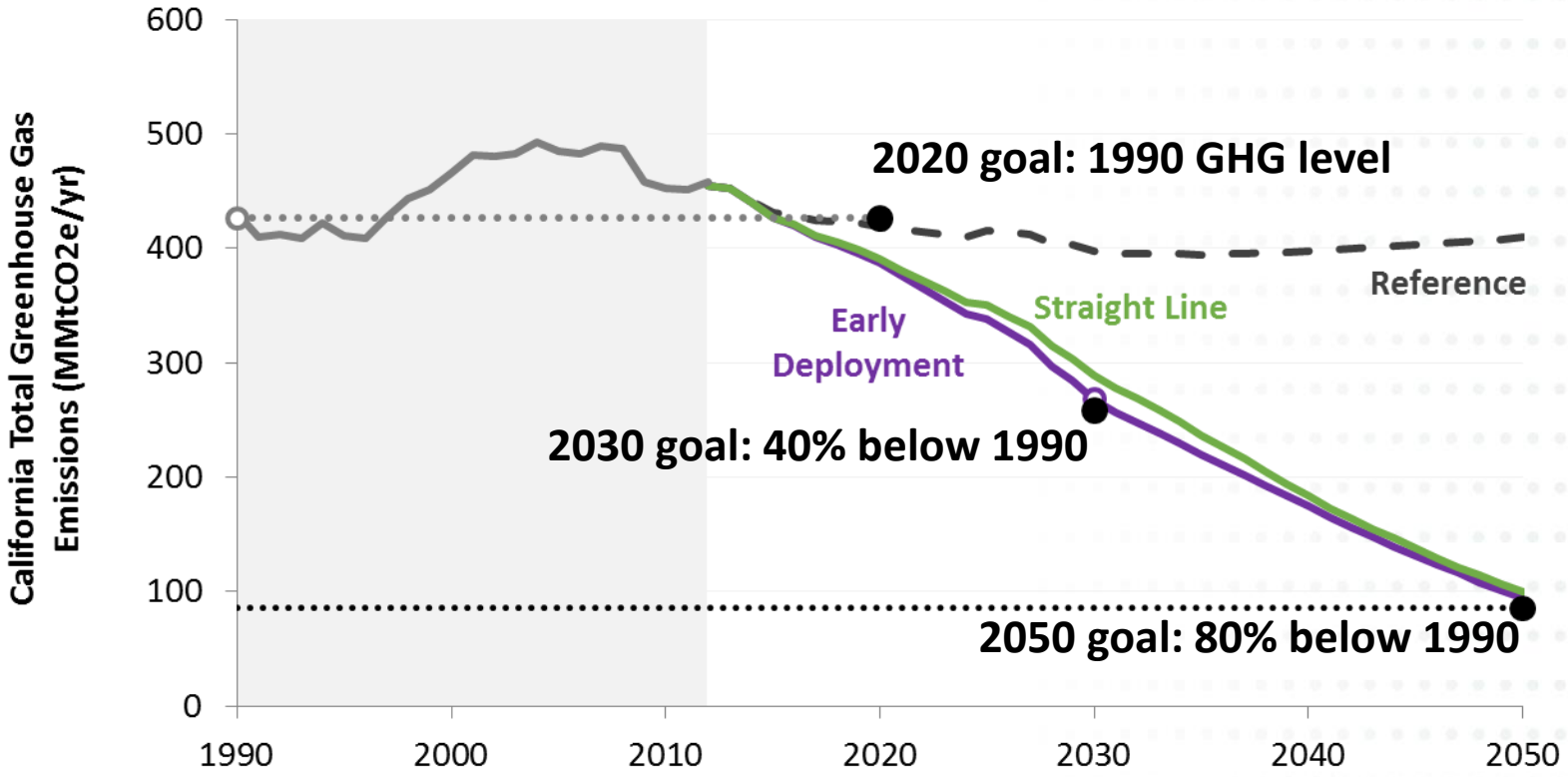


Timing for Action is Limited

- A car purchased today, is likely to replaced at most 2 times before 2050.
  A residential building constructed today, is likely to still be standing in 2050.



We modeled several scenarios that reach California's GHG goals

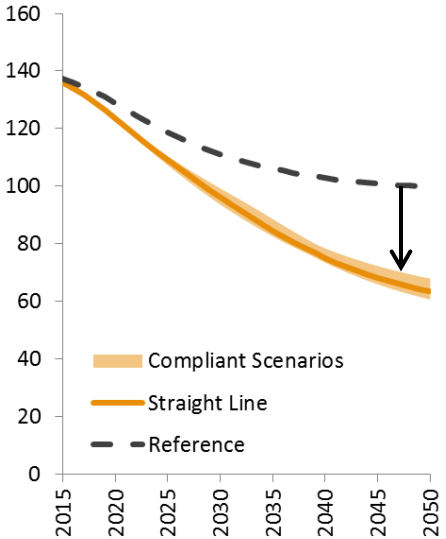


- **Current policies** (Reference scenario) are expected to achieve 2020 goal but fall short of 2030 goal
- **Aggressive policies** (Early Deployment, Straight Line scenarios) will be needed to achieve 2030 and 2050 goals

Success requires action in four areas

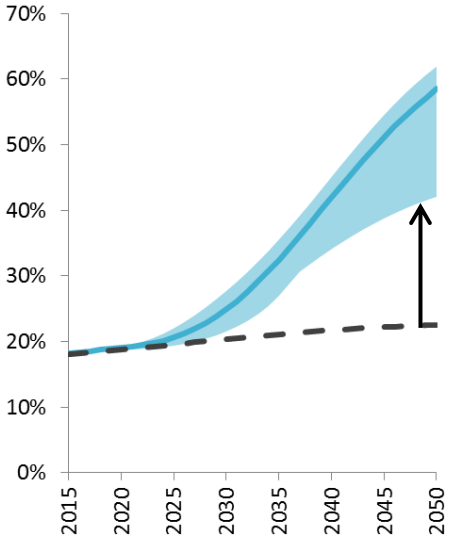
1. Efficiency and Conservation

Energy use per capita (MMBtu/person)

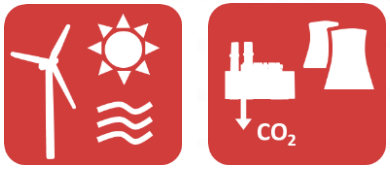


2. Fuel Switching

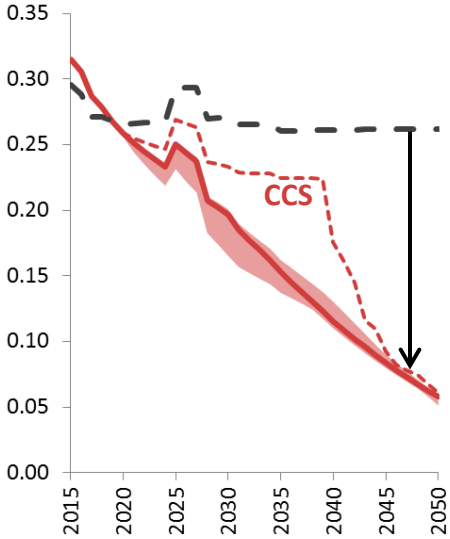
Share of electricity & H_2 in total final energy (%)



3. Decarbonize electricity

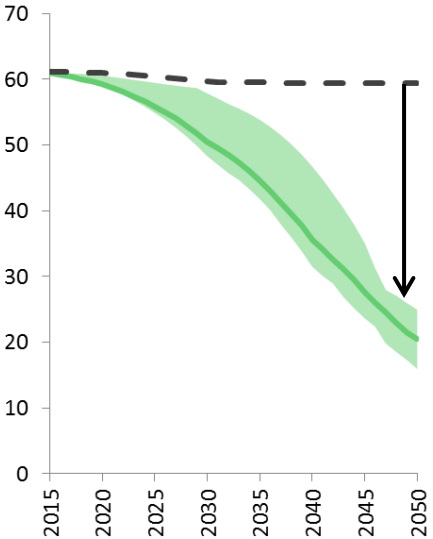


Emissions intensity (tCO2e/MWh)



4. Decarbonize fuels (liquid & gas)

Emissions intensity (tCO2/EJ)



California benchmarks for the four energy transitions

1. Efficiency and Conservation

By 2030:

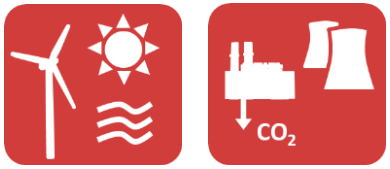
- 8% reduction in vehicle miles traveled (smart growth)
- Continued vehicle fuel economy improvements
- Approximate doubling of current building efficiency savings goals

2. Fuel Switching

By 2030:

- 6-9 million light duty zero emission vehicles
- Trucking & freight strategy, i.e. CNG, hybrid, elec.
- 10% - 40% electric space heating & 5% - 70% electric water heating, depends on use of biogas

3. Decarbonize electricity



By 2030:

- 50 – 60% renewable electricity
- Renewable integration solutions

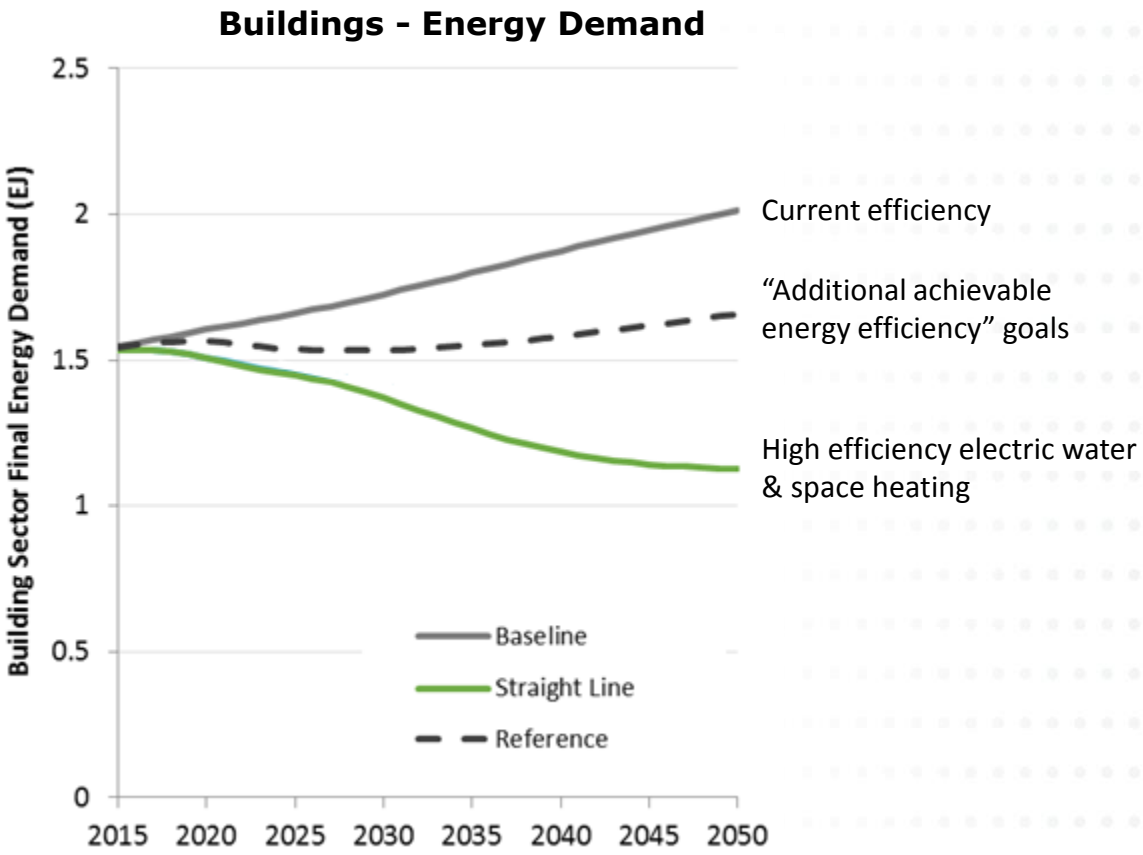
4. Decarbonize fuels (liquid & gas)

By 2030:

- 29 – 55% reduction in petroleum use in vehicles, relative to 2015
- Biofuels: Nearly all diesel use replaced with net-zero emissions biofuels, OR Nearly 50% biogas in the gas distribution pipeline

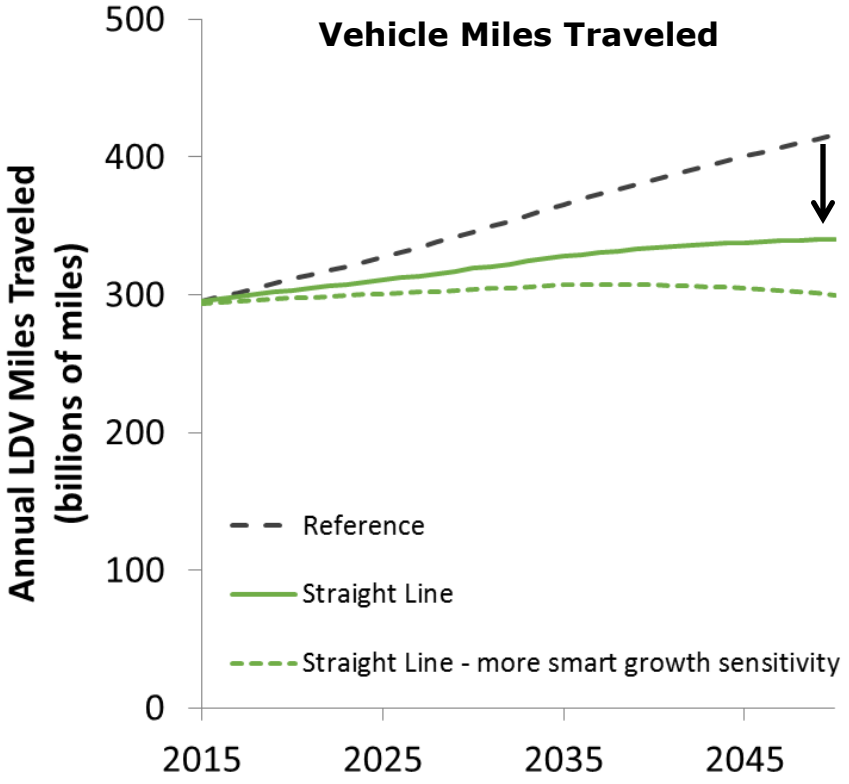
Higher energy efficiency in buildings

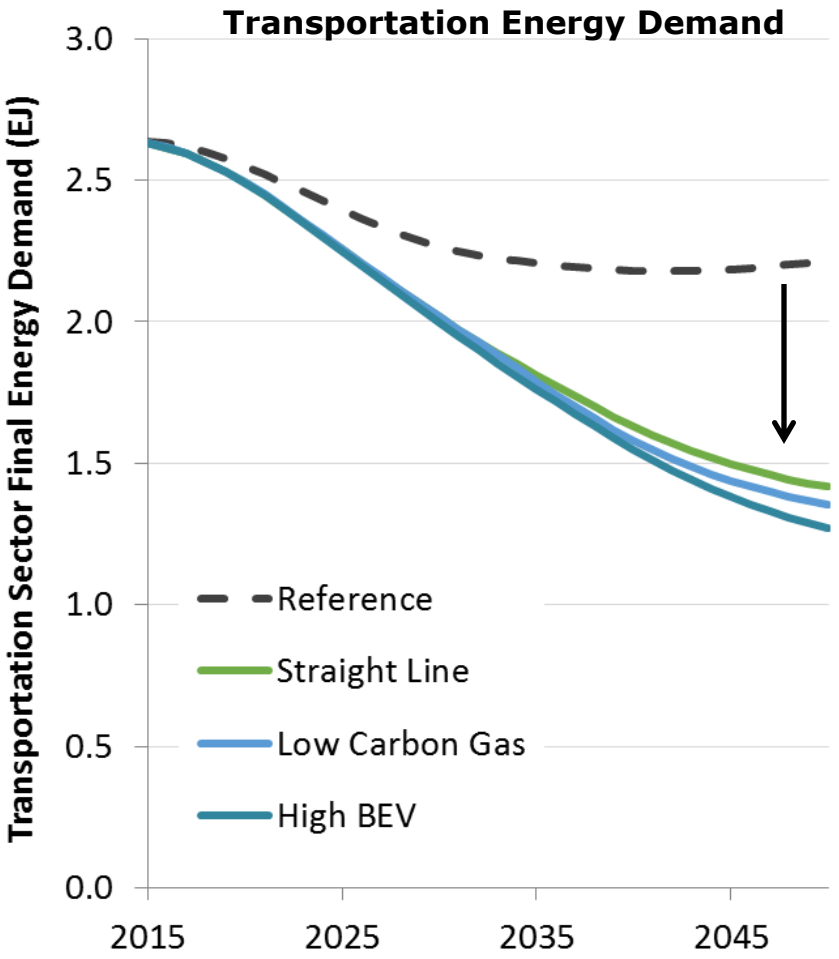
+ **Electric energy efficiency** is nearly double in the straight line scenario compared to current policy (Reference), mostly due to LED lighting and more efficient appliances



Energy Efficiency & Smart Growth in Transportation

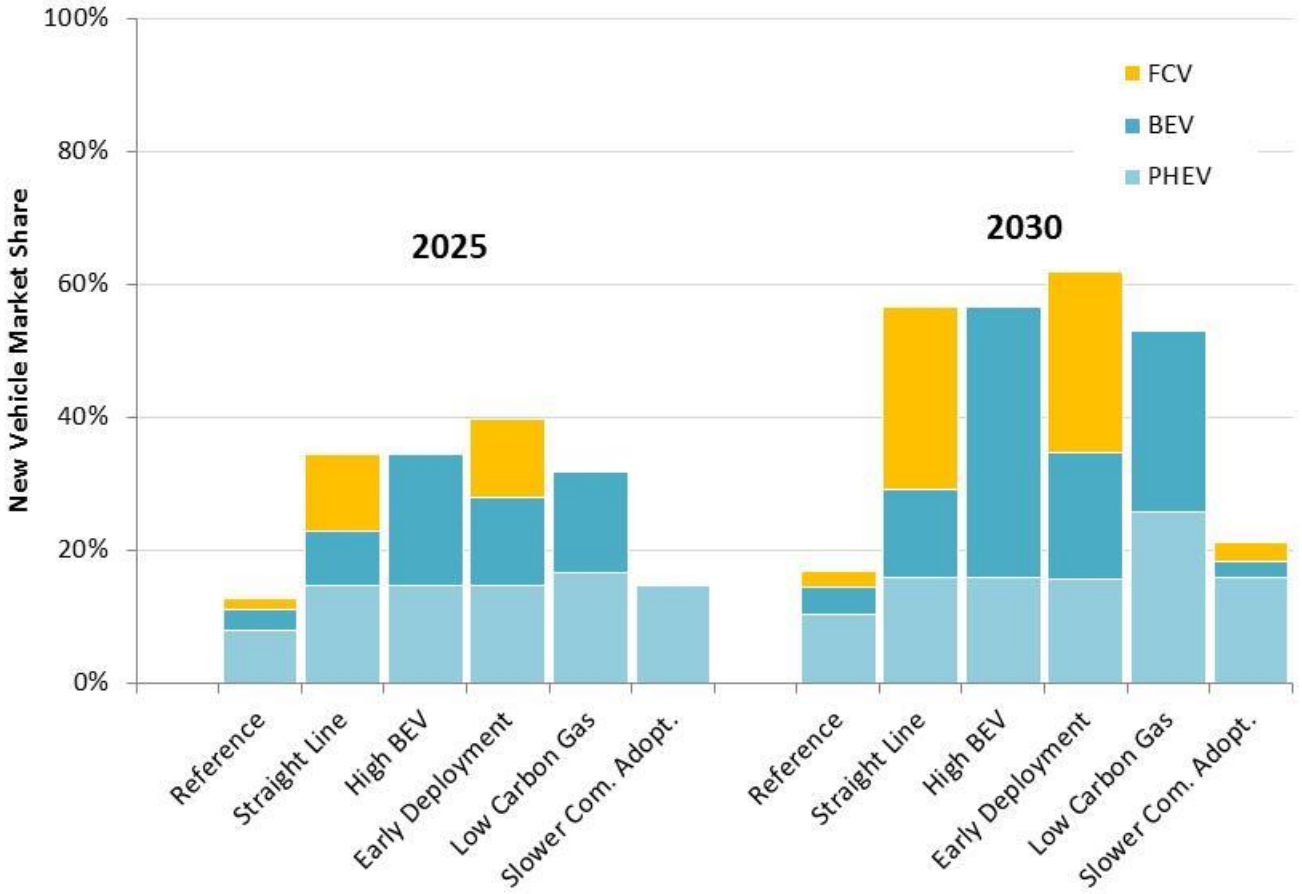
+ Significant reduction in vehicle-miles-traveled & transportation energy demand, due to improved fuel economy of electric and fuel cell vehicles





Light Duty Vehicles – ZEV & PHEV Market Share of New Sales (%) by Year

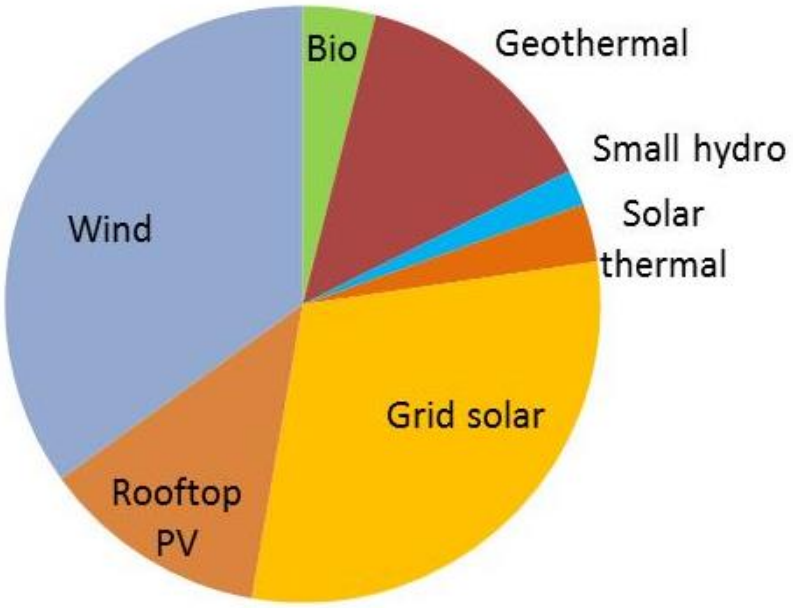
- Light duty fuel cell vehicles (FCV), battery electric vehicles (BEV) and plug-in hybrid electric vehicles (PHEV) as % of new vehicle sales in 2025 and 2030



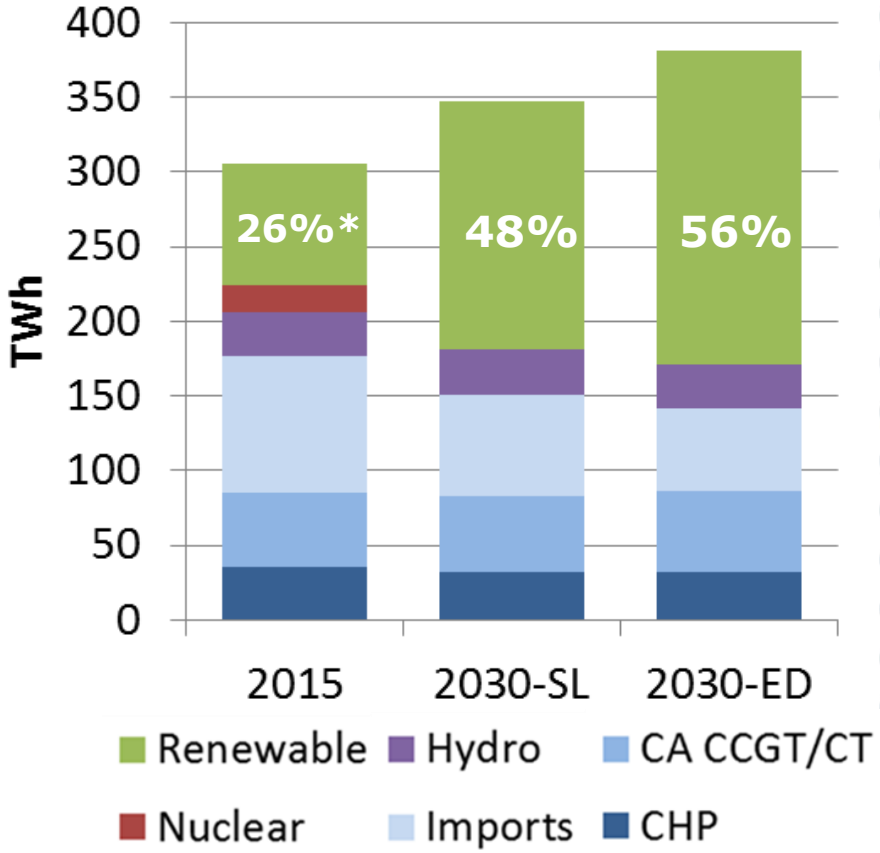
Renewables are 50-60% of annual generation by 2030

- Average grid scale renewable additions are ~2,400 MW/year (mostly solar, wind) plus total 11,800 MW rooftop PV by 2030

2030 Renewable Generation by Type (%) – Straight Line



2015 & 2030 Annual Generation

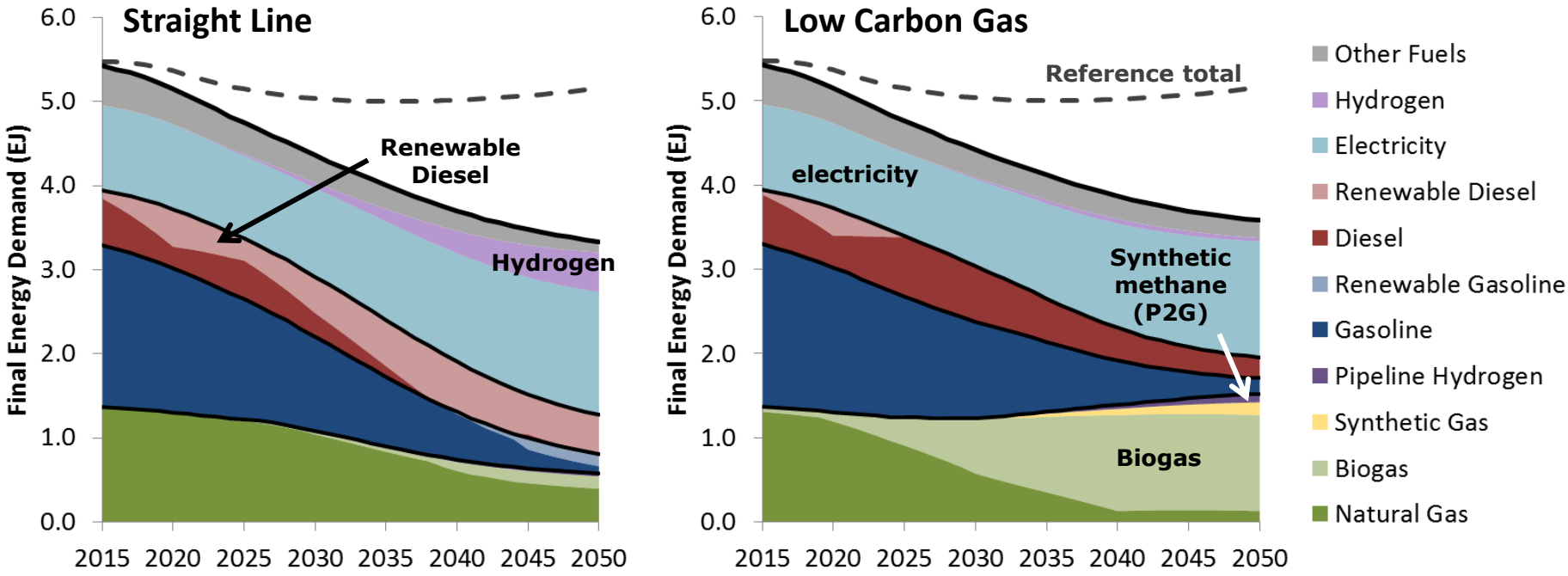


* Estimated, not actual value

Different options for use of biofuels, but sustainable supplies are limited

- **Sustainable biomass supply is limited**, insufficient supply to displace both natural gas & diesel consumption (assuming CA's share of U.S. resource)
- **If biofuel supply is limited, greater electrification and/or carbon neutral fuels produced using low-carbon electricity is needed**

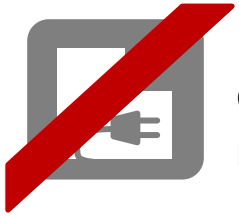
Final Energy Demand by Major Fuel Type



Two Forks in the Road

Zero Emissions Vehicles

Fuel cell vehicles, flexible grid electrolysis



No additional energy storage needed

Battery electric vehicles

Significant energy storage needs

Buildings Strategy

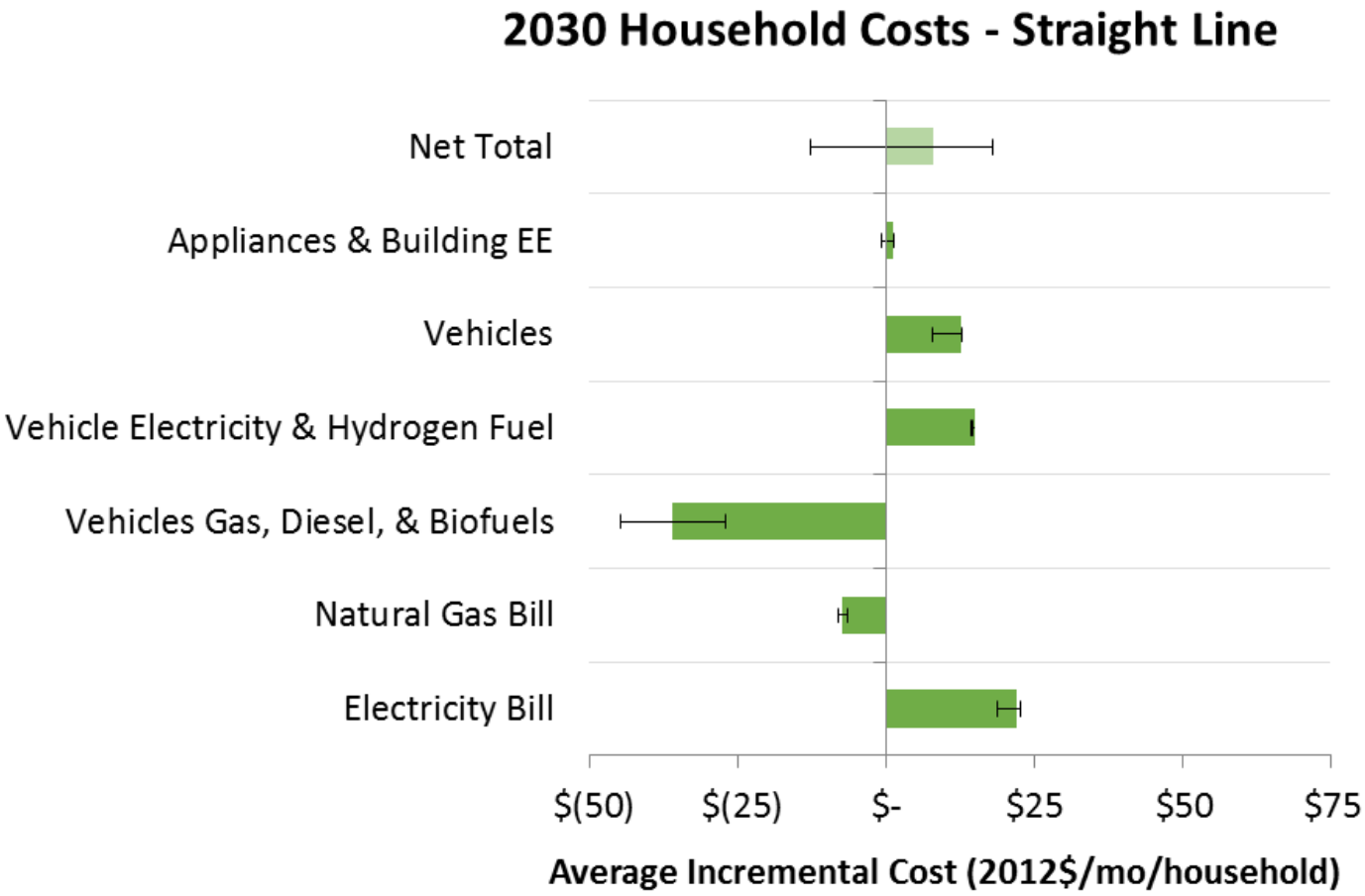
Biogas replaces natural gas in buildings

No building electrification needed

Electrification of buildings

No gas pipeline

Average Household Monthly Costs

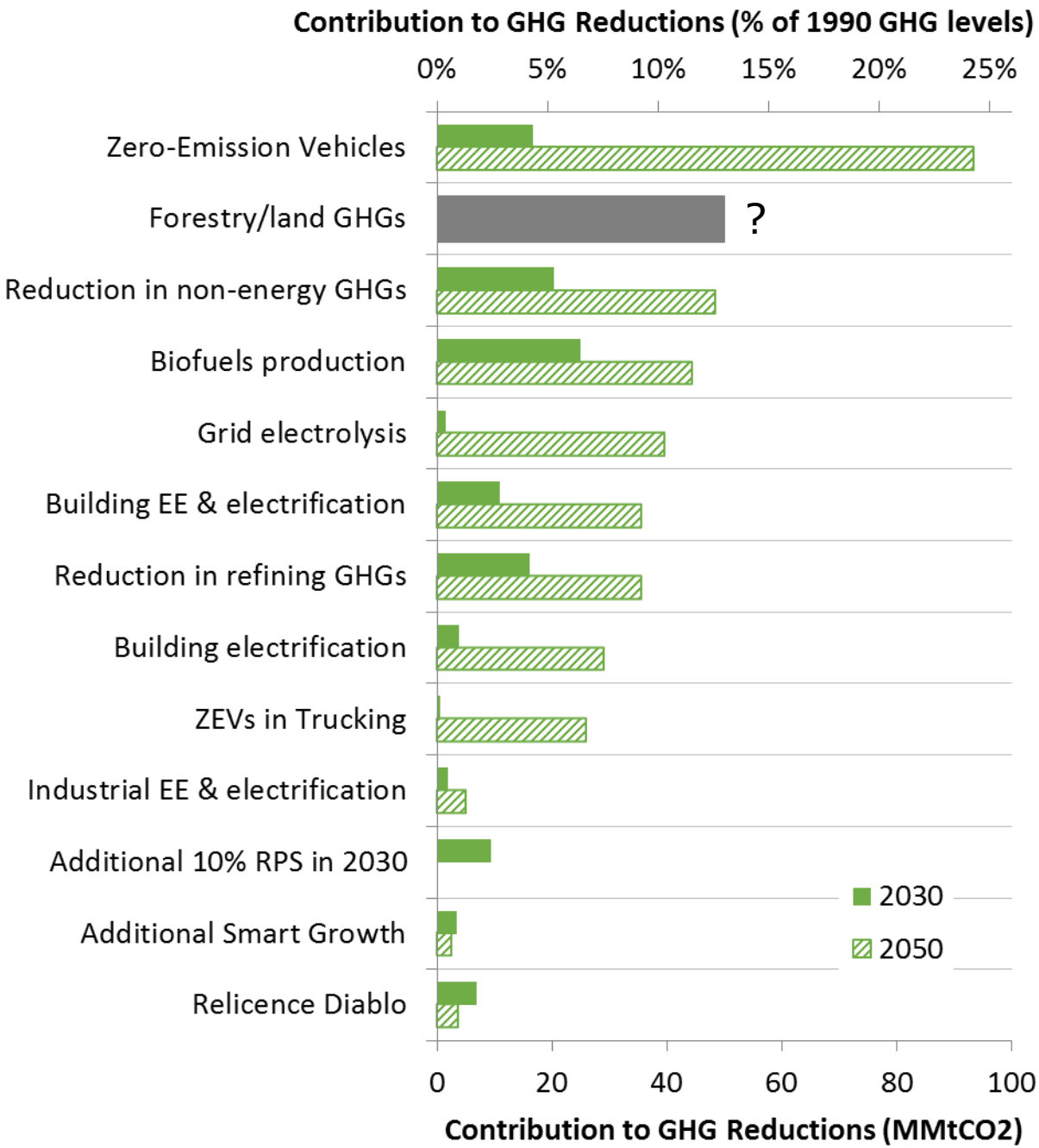


Net Total:
$8/mo/household

0.8% increase over Reference Scenario energy-related costs

($14/mo/household if assume all com. & industrial energy system costs flow through to households)

Sensitivities in 2050 show relative importance of carbon reduction strategies in long-term



Top policy objectives for California

- **Electricity decarbonization** – electricity policy must drive CA to near complete decarbonization by 2050
- **Renewable Fuel Standards** – policy must encourage development of fuels produced from electricity and should redirect biomass towards high value uses
- **Transportation** – the majority of new light duty auto sales should be electric, fuel cell, or plug-in hybrid vehicles by 2030
- **Energy efficiency and electrification** – building energy efficiency programs must unlock deeper savings and must pivot to focus on carbon rather than primary energy use
- **Be proactive on distributional cost impacts** – key to sustaining a long term policy effort

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Thank You!

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For more information:

https://ethree.com/public_projects/energy_principals_study.php

APPENDIX

Basic Energy Modeling Framework

Demand Sectors

End-Use Energy Services Demand

How many miles do Californians drive per year (2010-2050)?

Stock Rollover

How many electric vehicles are on the road?

End-Use Energy Demand

How much fuel of each type is required to meet driving demand?

Supply Sectors

Electricity Supply

What is the % of renewables on the grid?

Pipeline Supply

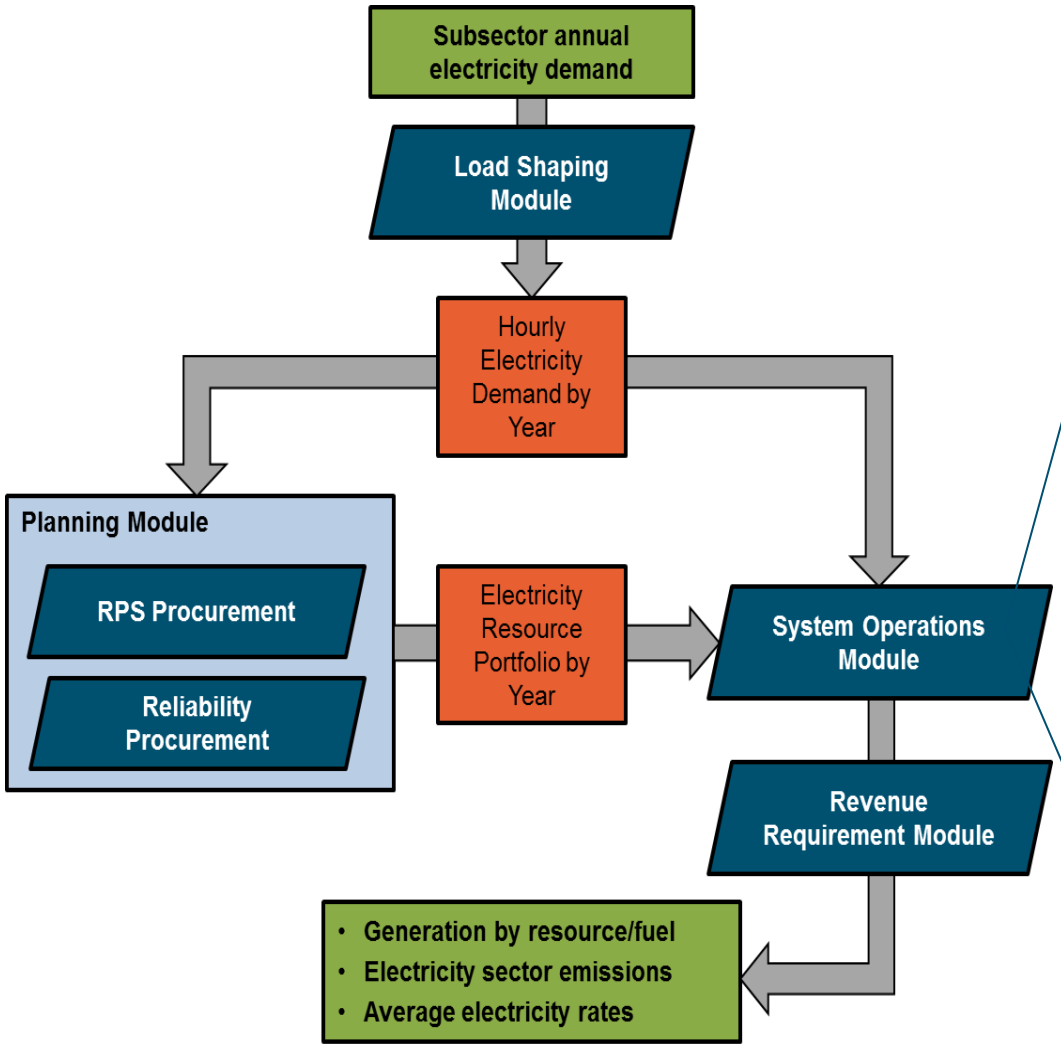
Other Fuels (Gasoline, Diesel, Hydrogen, etc.)

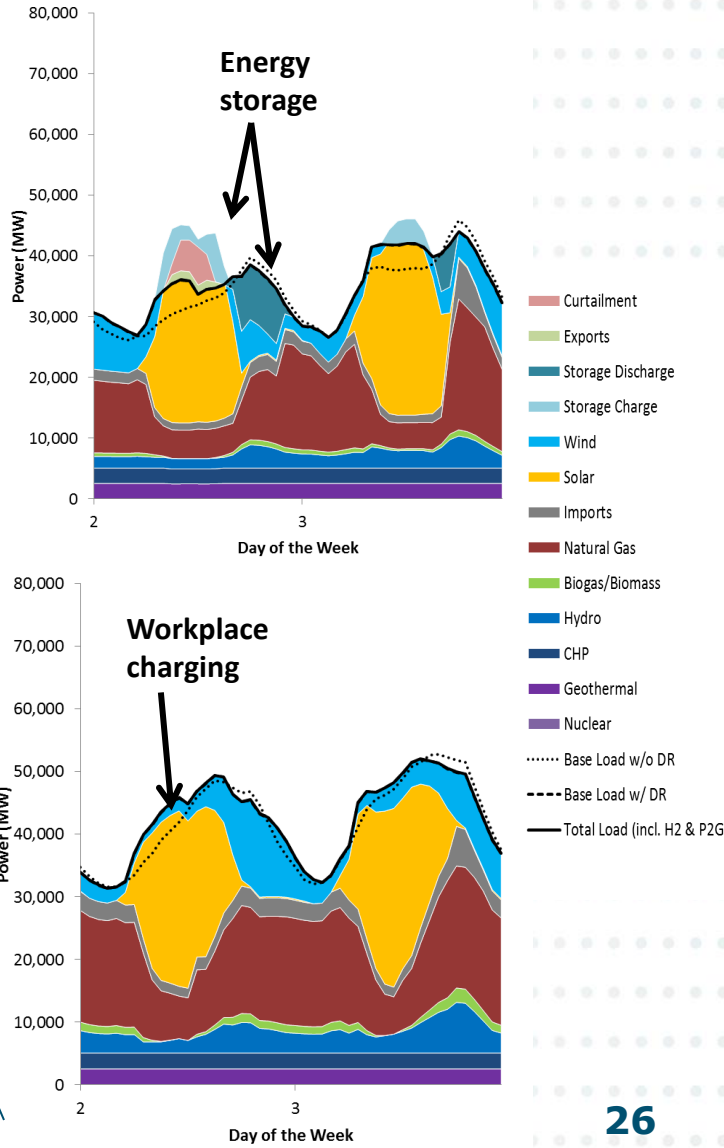
Model Outputs

How many CO_2 emissions are saved?

How much do EV's cost over the baseline internal combustion engine vehicle?

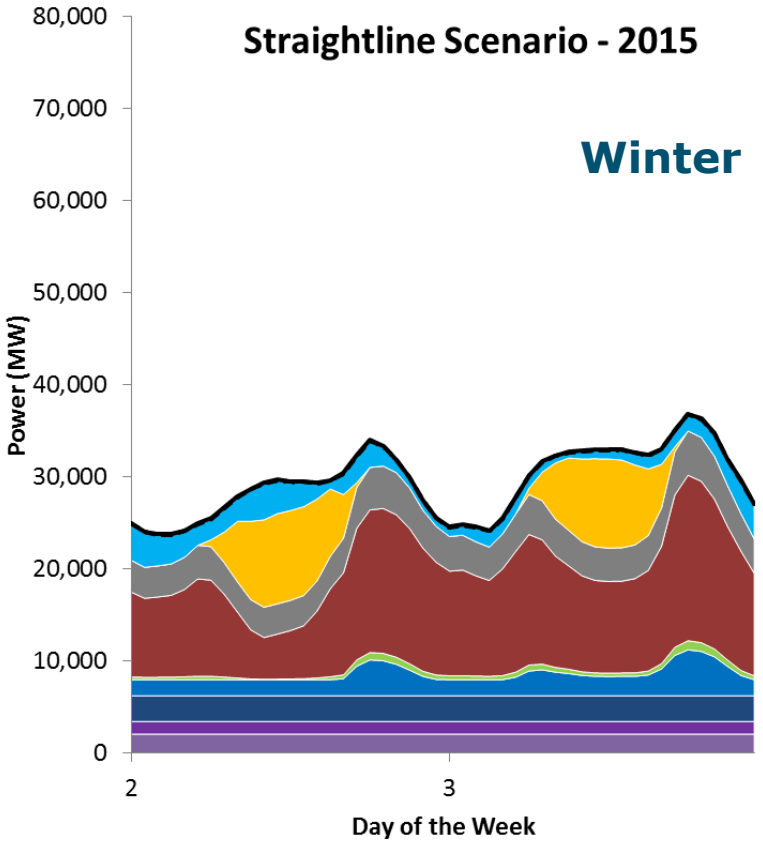
Overview of Electricity Dispatch Module in PATHWAYS

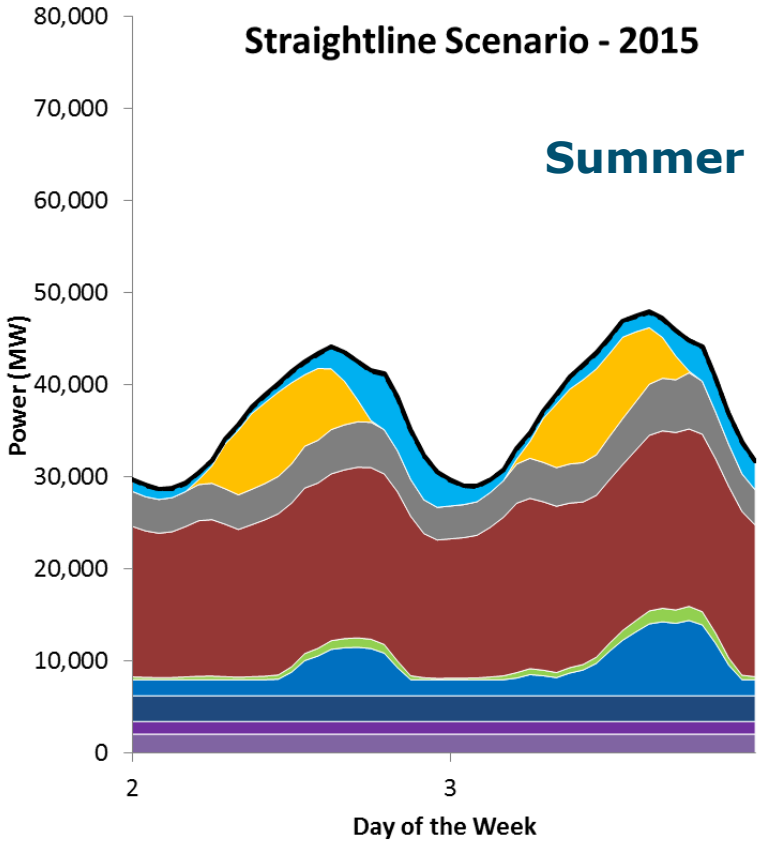


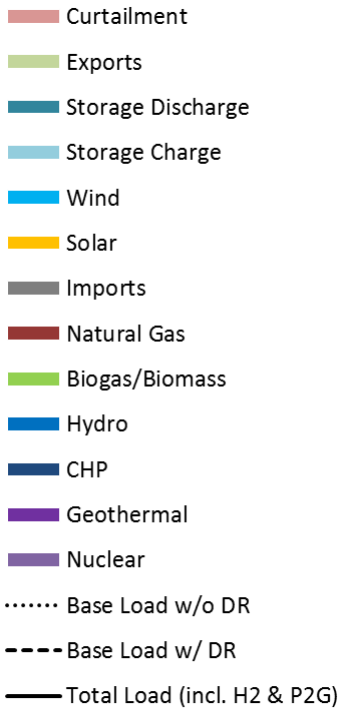


Electricity Balancing - 2015

- In near-term, renewables balanced largely by natural gas and hydro

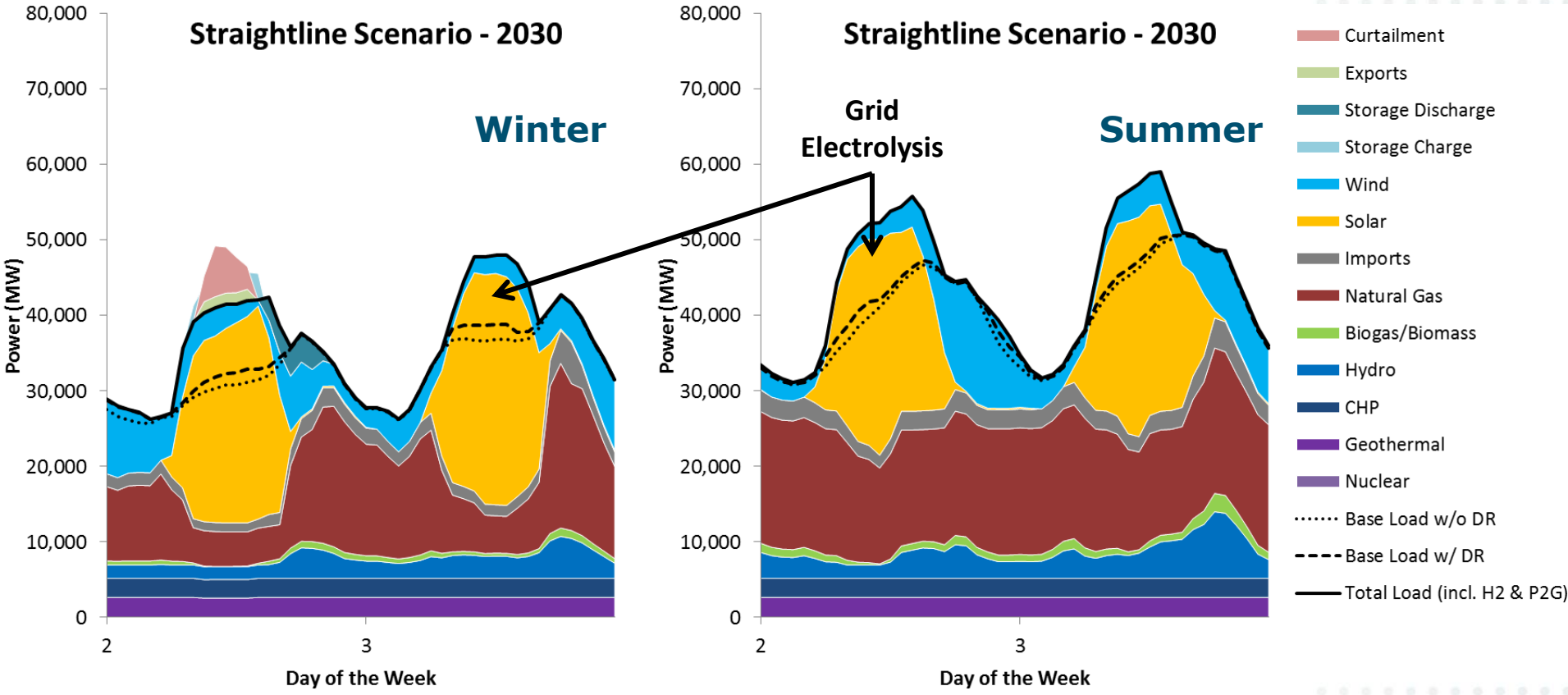






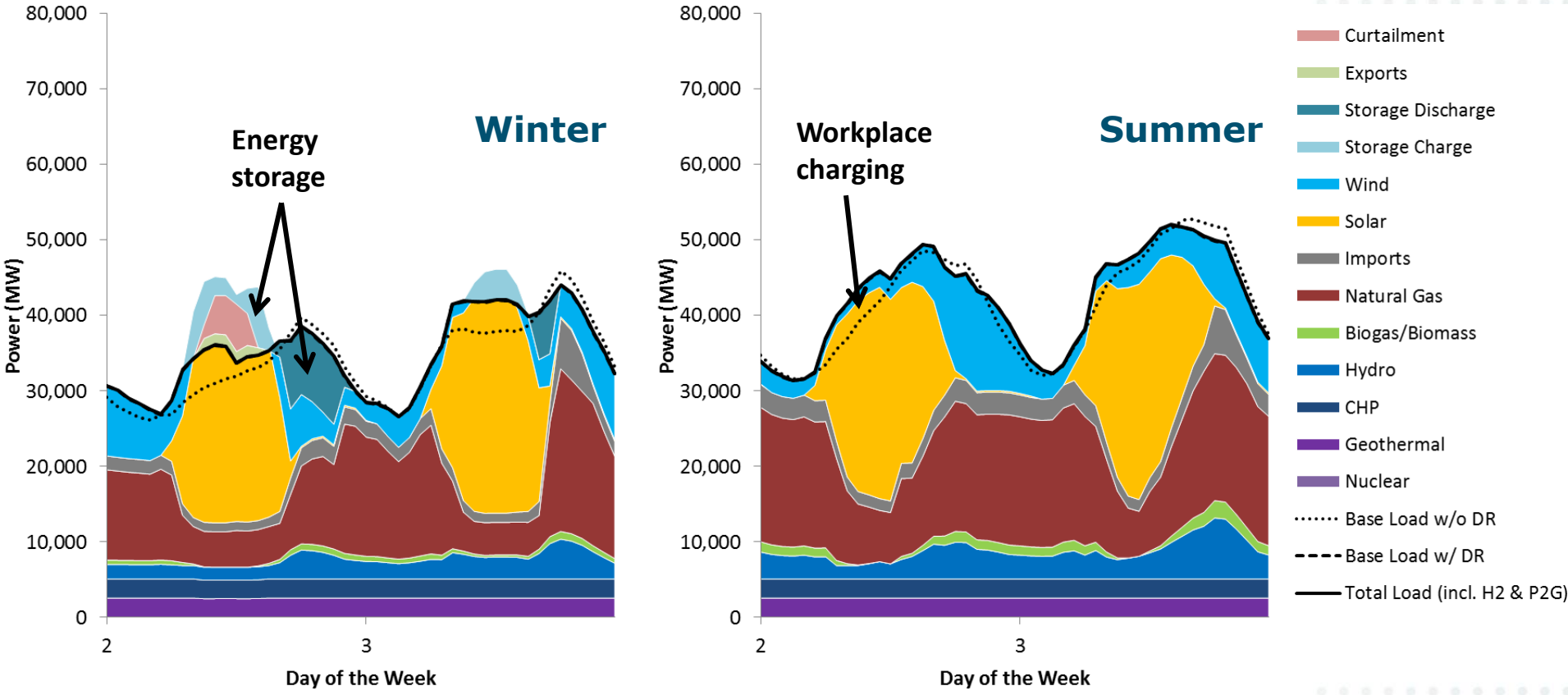
Electricity Balancing 2030 in Straight line Scenario

- **Additional renewables built for and absorbed by flexible grid electrolysis to fuel FCVs**



Electricity Balancing 2030 in High BEV Scenario

+ **Lower loads, some balancing provided by workplace charging, additional balancing required from storage**



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