Energy+Environmental Economics

Achieving Economy-wide Deep Greenhouse Gas Reductions

LADWP 100% Renewables/Clean Energy Study Advisory Group

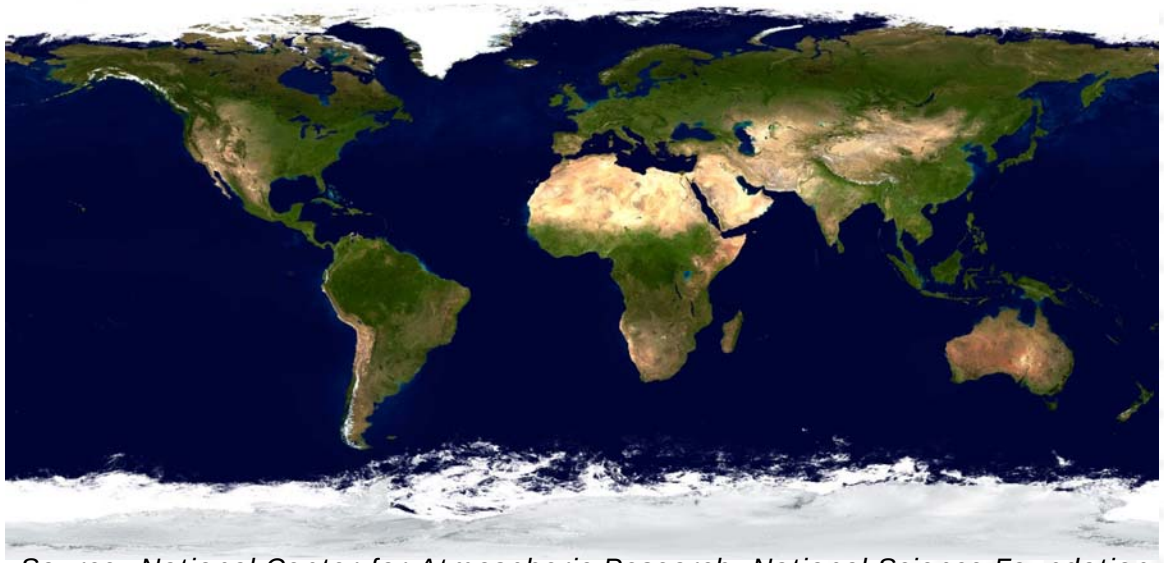
Kick-Off Meeting

Friday, June 23, 2017

Arne Olson, Partner
Nick Schlag, Senior Managing Consultant

Agenda

- About E3
- Decarbonization Modeling Background
- The California PATHWAYS Study
- Key conclusions for DWP 100% Clean Energy Study



Source: National Center for Atmospheric Research, National Science Foundation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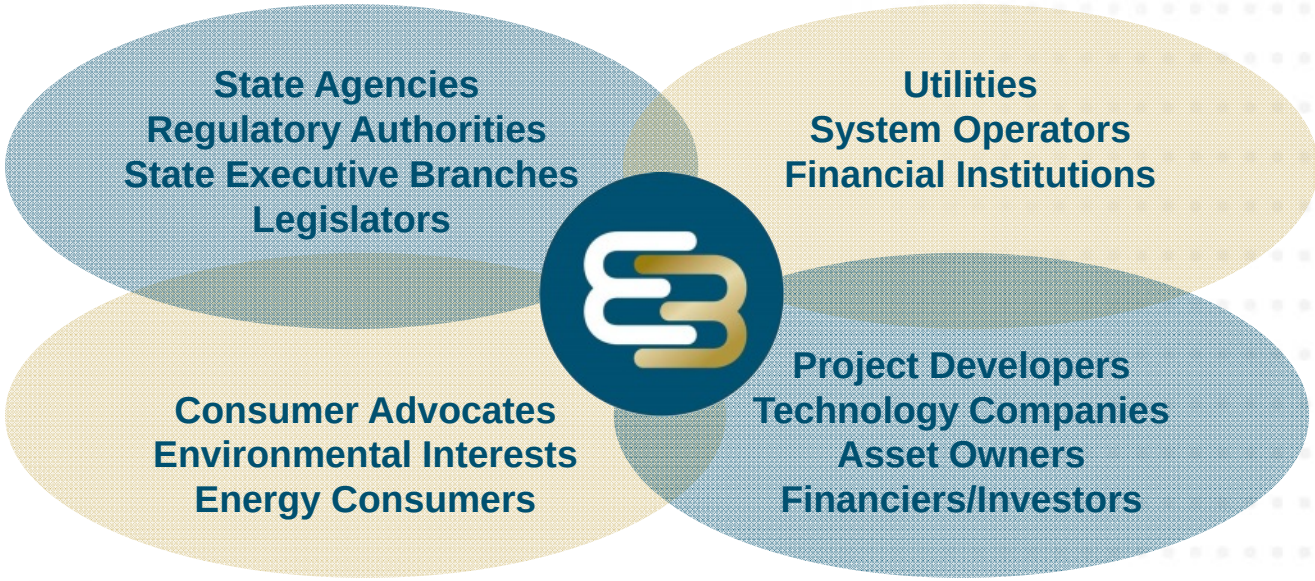
ABOUT E3

About Energy and Environmental Economics, Inc. (E3)

- Founded in 1989, E3 is an industry leading consultancy in North America with a growing international presence
- E3 operates at the nexus of energy, environment and economics
- Our team employs a unique combination of economic analysis, modeling acumen and deep institutional insight to solve complex problems for a diverse client base including critical thought leadership

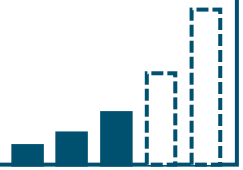


E3's PATHWAYS studies of deep decarbonization

+ **Recent projects evaluate economy-wide GHG reduction goals in 2030 and 2050 with a focus on implications in the electricity sector**

CARB Scoping Plan Support

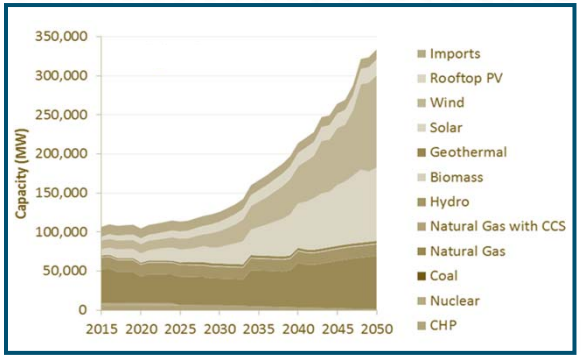
Analyzing California strategies to meet 2030 GHG targets



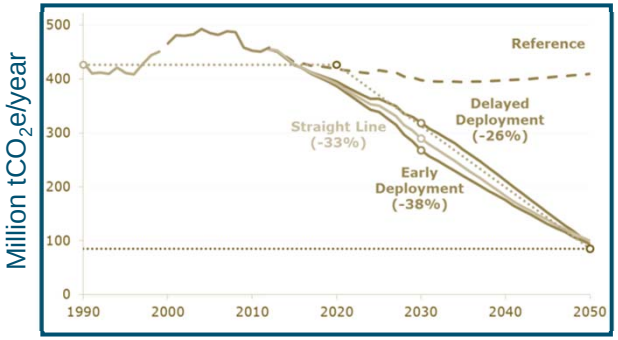
California PATHWAYS

Evaluated options to meet 80% reduction in GHGs by 2050, with a focus on 2030

Generating capacity by fuel type



Greenhouse gas emissions by scenario



Deep Decarbonization Pathways

Evaluated scenarios to meet 80% reduction in GHGs in the U.S., focus on 2050

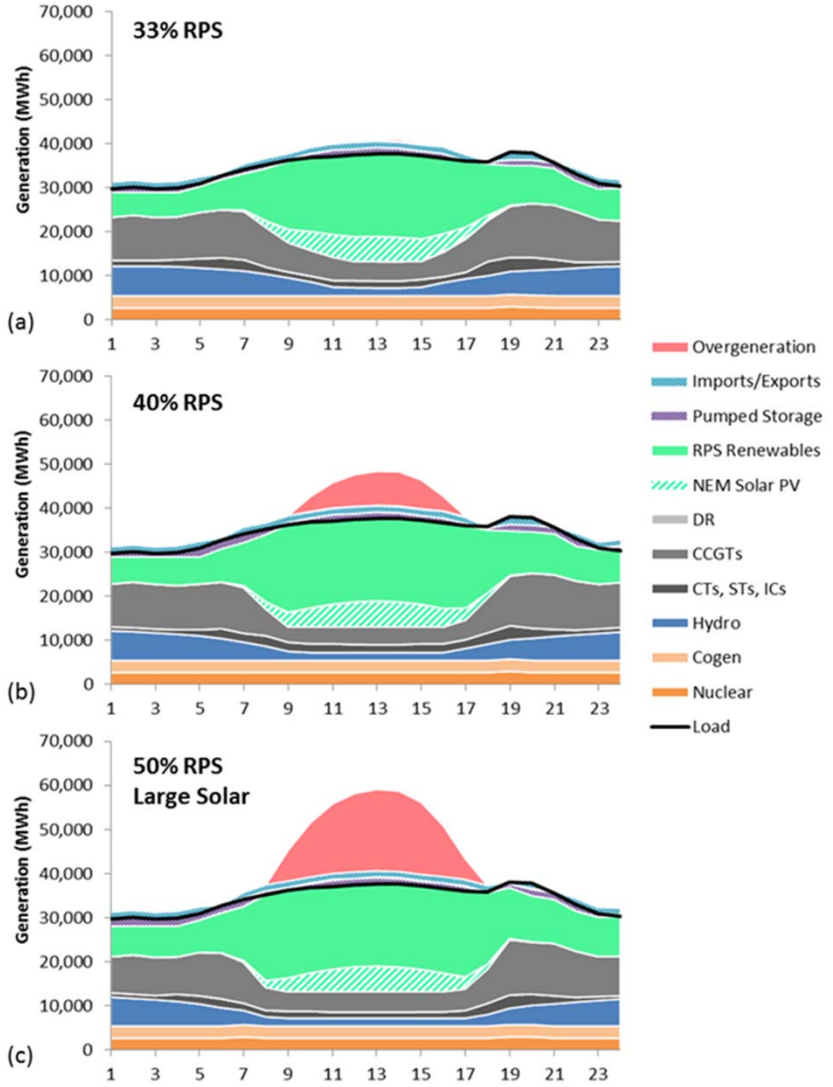
SCG Low Carbon Gas Goals

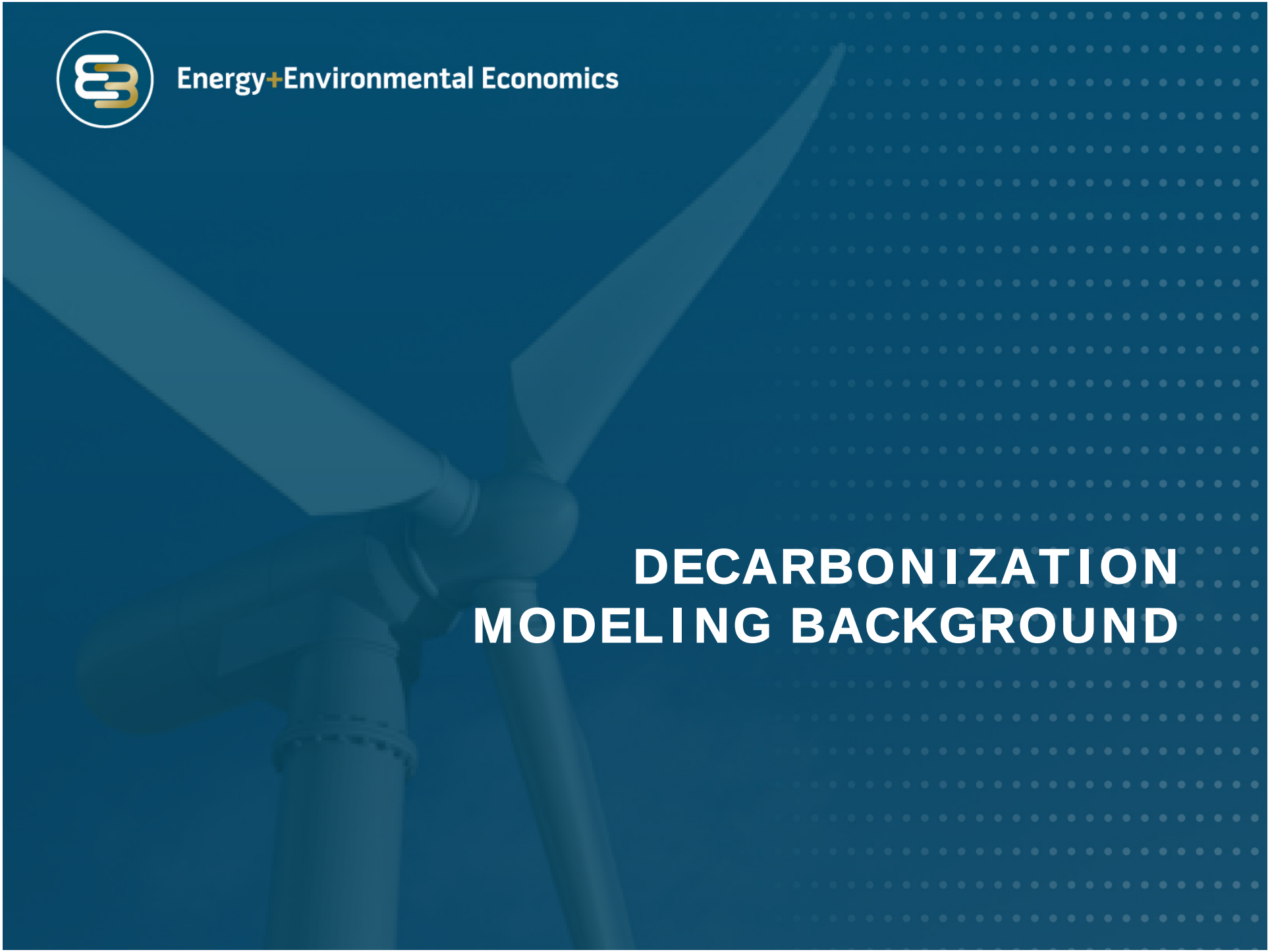
Exploring the role of natural gas, biogas and hydrogen in long-term low-carbon scenarios

E3 has completed numerous studies of high renewable penetration

+ **E3 has worked with a wide range of clients to understand the challenges of renewable integration at high penetrations:**

  - **California ISO:** ongoing support to improve modeling & inform renewable integration solutions
  - **Los Angeles Dept. of Water & Power:** ongoing support for study considering *100% RPS*
  - **Hawaiian Electric Company:** technical modeling support in filing of Preferred Energy Supply Plan to reach *100% renewables by 2045*
  - **California PUC:** ongoing support in development of Integrated Resource Planning considering renewable penetrations of up to *65% by 2030*
  - **Portland General Electric:** analysis of flexibility challenges at wind penetrations up to *50% by 2030* to support 2014 Integrated Resource Plan
  - **Western Electricity Coordinating Council:** assessment of flexibility challenges at west-wide renewable penetrations of *40% by 2026*
  - **California Utilities:** landmark 2014 study of feasibility and implications of achieving a *50% RPS by 2030* conducted for five largest California utilities





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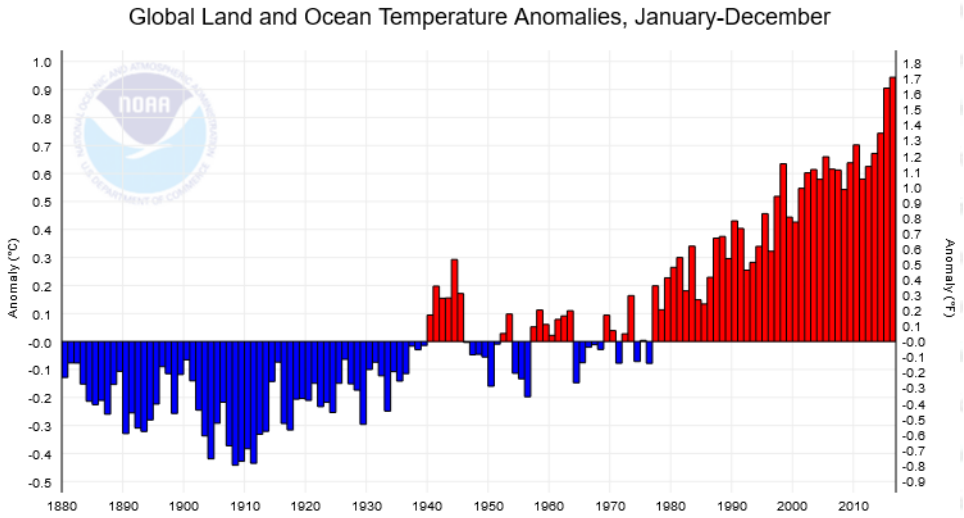
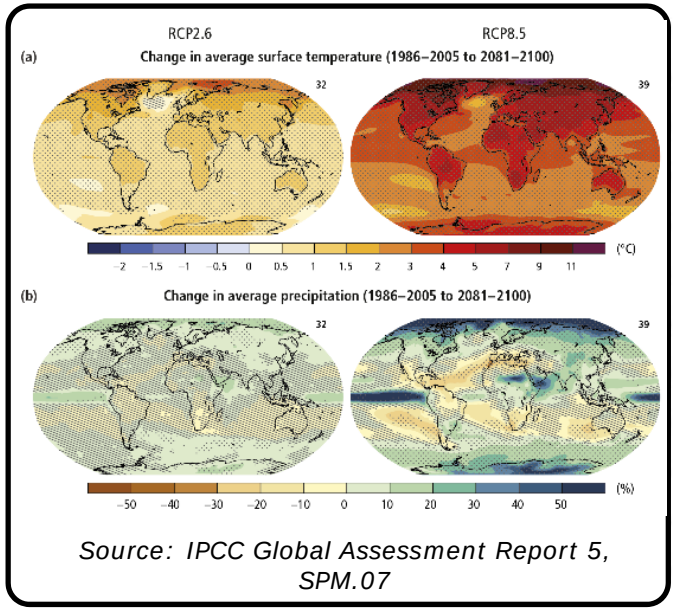
DECARBONIZATION MODELING BACKGROUND

Deep reductions in greenhouse gas emissions are called for globally

- **The 2016 Paris agreement committed industrialized nations to 80% reductions below 1990 levels by 2050**
  - Roughly consistent with IPCC/UNFCC goal of keeping global average temperature rise within 2°C to avert catastrophic climate change
- **If current trends continue, 2°C aggregate warming will be exceeded**



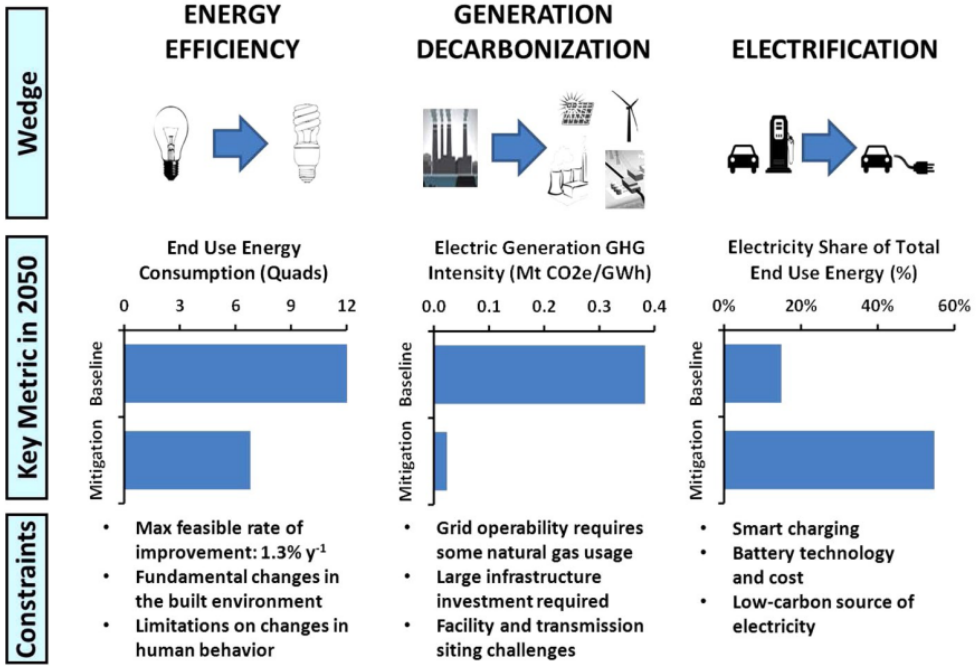
Source: NOAA, https://www.ncdc.noaa.gov/monitoring-references/faq/indicators.php Global annual average temperature measured over land and oceans. Red bars indicate temperatures above and blue bars indicate temperatures below the 1901-2000 average temperature.



Source: IPCC Global Assessment Report 5, SPM.07

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

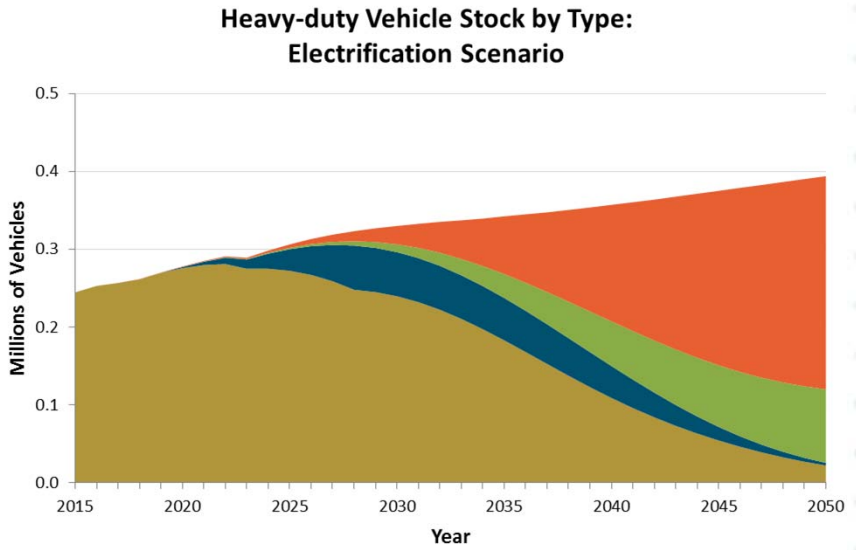
- What is the impact of the electric generation mix on the cost and feasibility of a low-carbon future in CA?
- Compared renewables, nuclear, carbon capture and storage
- Demonstrated a feasible pathway to 2050 goal with focus on electrification
- Led to development of E3 PATHWAYS Model

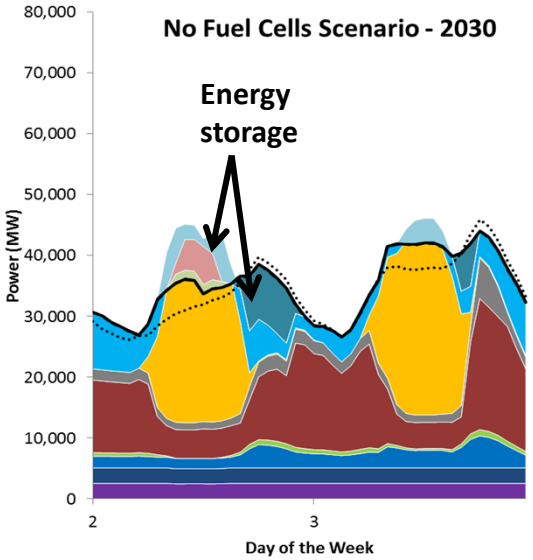


"The Technology Path to Deep Greenhouse Gas Emissions Cuts by 2050: The Pivotal Role of Electricity," Williams et al, Science (2012)

E3 PATHWAYS Model

- **Bottom-up, user-defined, scenarios test "what if" questions**
- **Economy-wide model captures interactions between sectors & path-dependencies**
- **Detailed treatment of stock rollover**
- **Hourly treatment of electric sector**
- **Tracks capital investments and fuel costs over time**

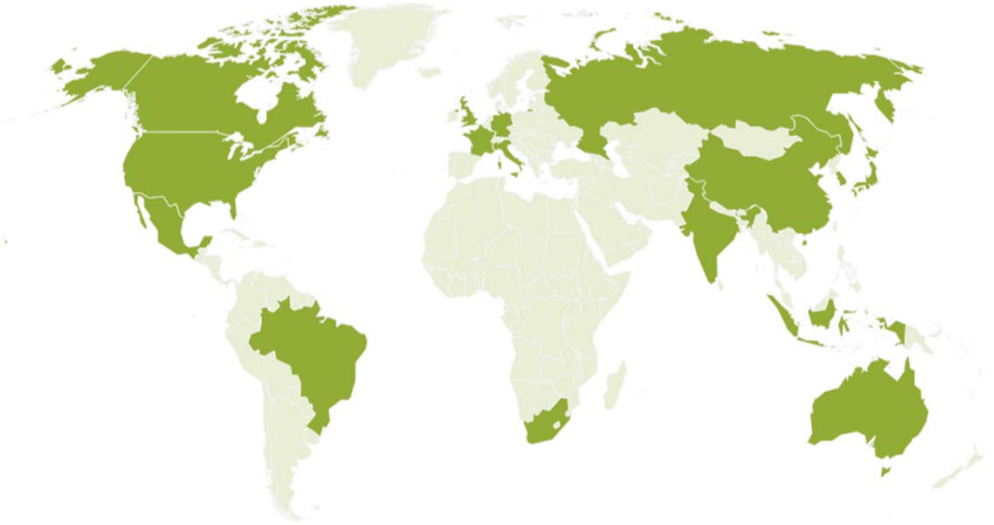




Allows for development of realistic & concrete GHG reduction roadmaps

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 using PATHWAYS model**



ECONOMY

Blueprints for Taming the Climate Crisis

JULY 8, 2014

Eduardo Porter

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

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

07/08/14 01:51 PM

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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

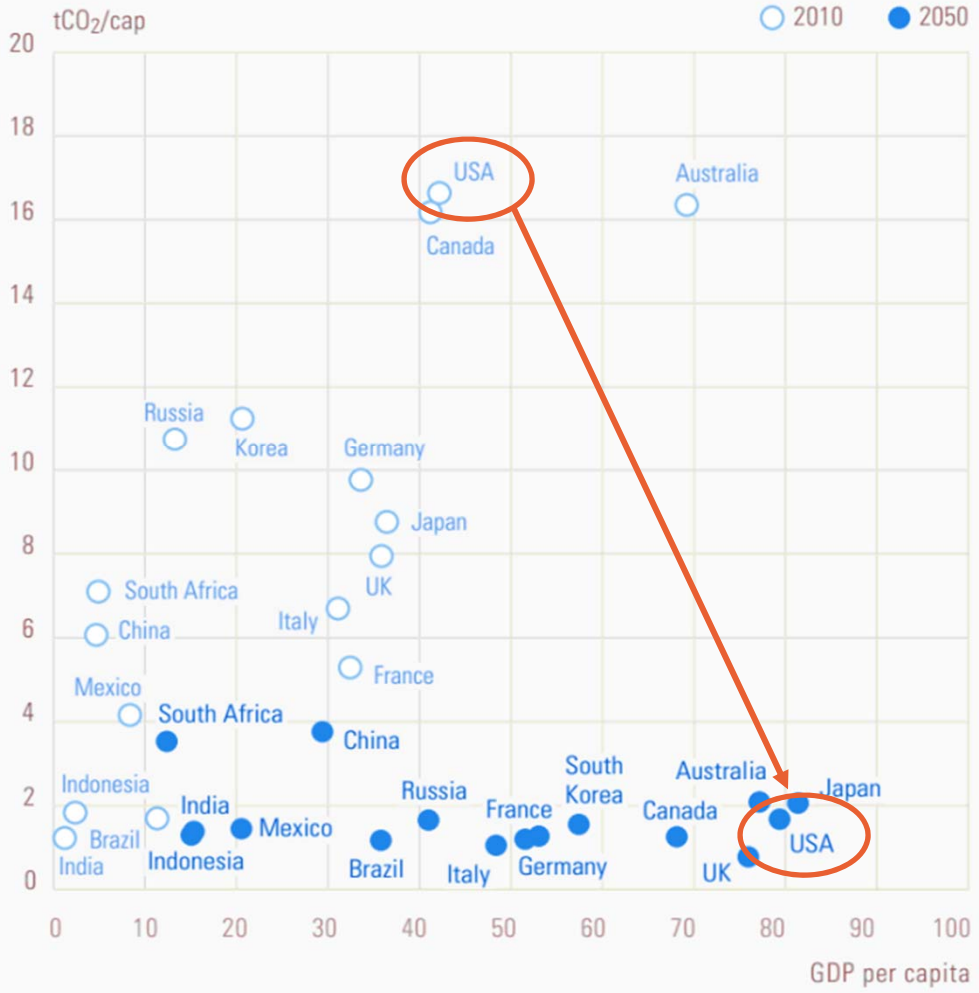
deepdecarbonization.org

IDDRI
SciencesPo.

Key finding: Decarbonization can be consistent with economy growth

- **The Deep Decarbonization Pathways Project (DDPP) study found that deep emission reductions could be achieved in all countries even as population and GDP continue to grow**

Figure 2. GDP and energy-related emissions per capita across the 16 countries

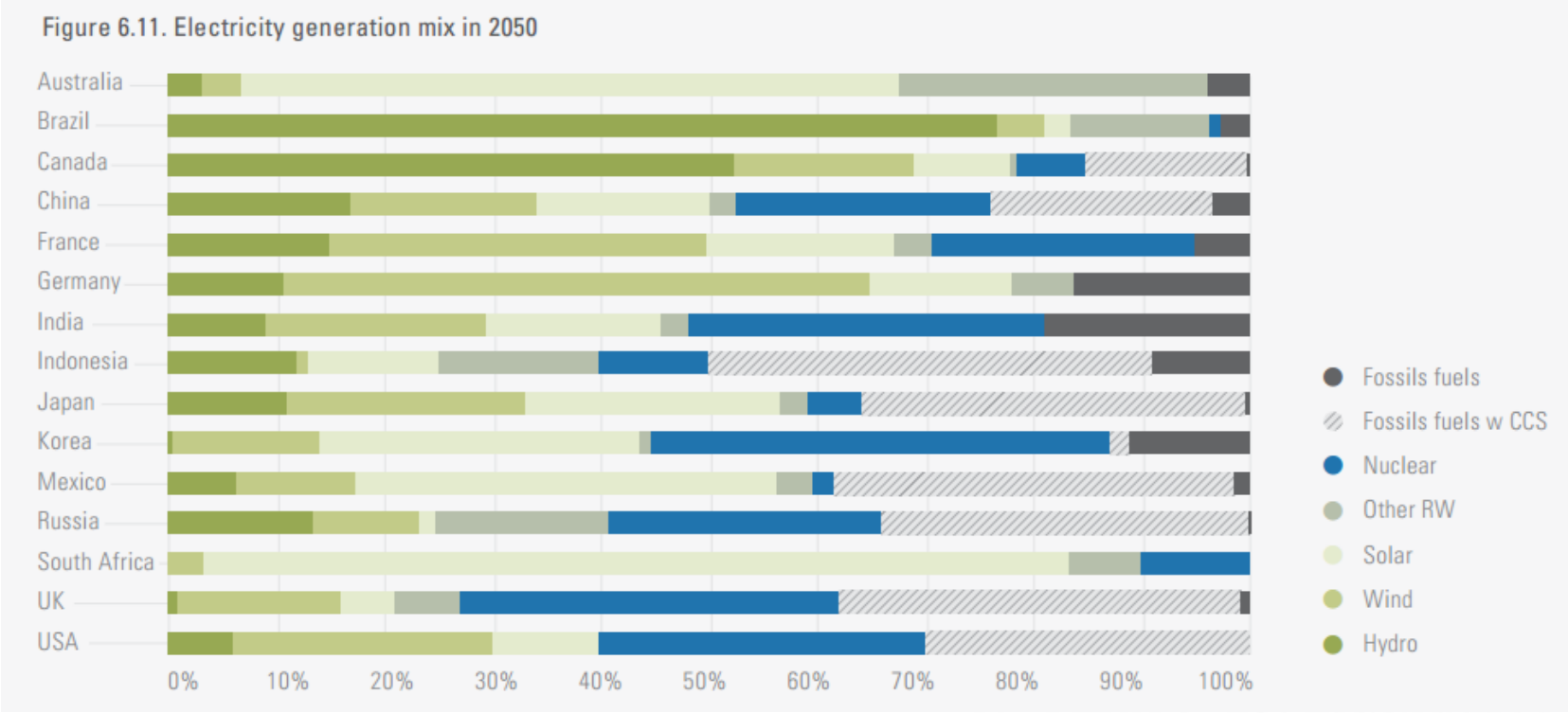


Source: Deep Decarbonization Pathways Project Synthesis Report

Different strategies to achieve low-carbon electricity

+ DDPP country teams evaluated a range of scenarios with a mix of electricity strategies

- Renewables, nuclear, fossil fuels with carbon capture and storage (CCS) all play a role in most countries
- Renewable penetration range from *40-90%* by 2050



Source: Deep Decarbonization Pathways Project Synthesis Report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CALIFORNIA
PATHWAYS STUDY

2014-2015: The California PATHWAYS Project

+ Purpose

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

+ Project sponsors

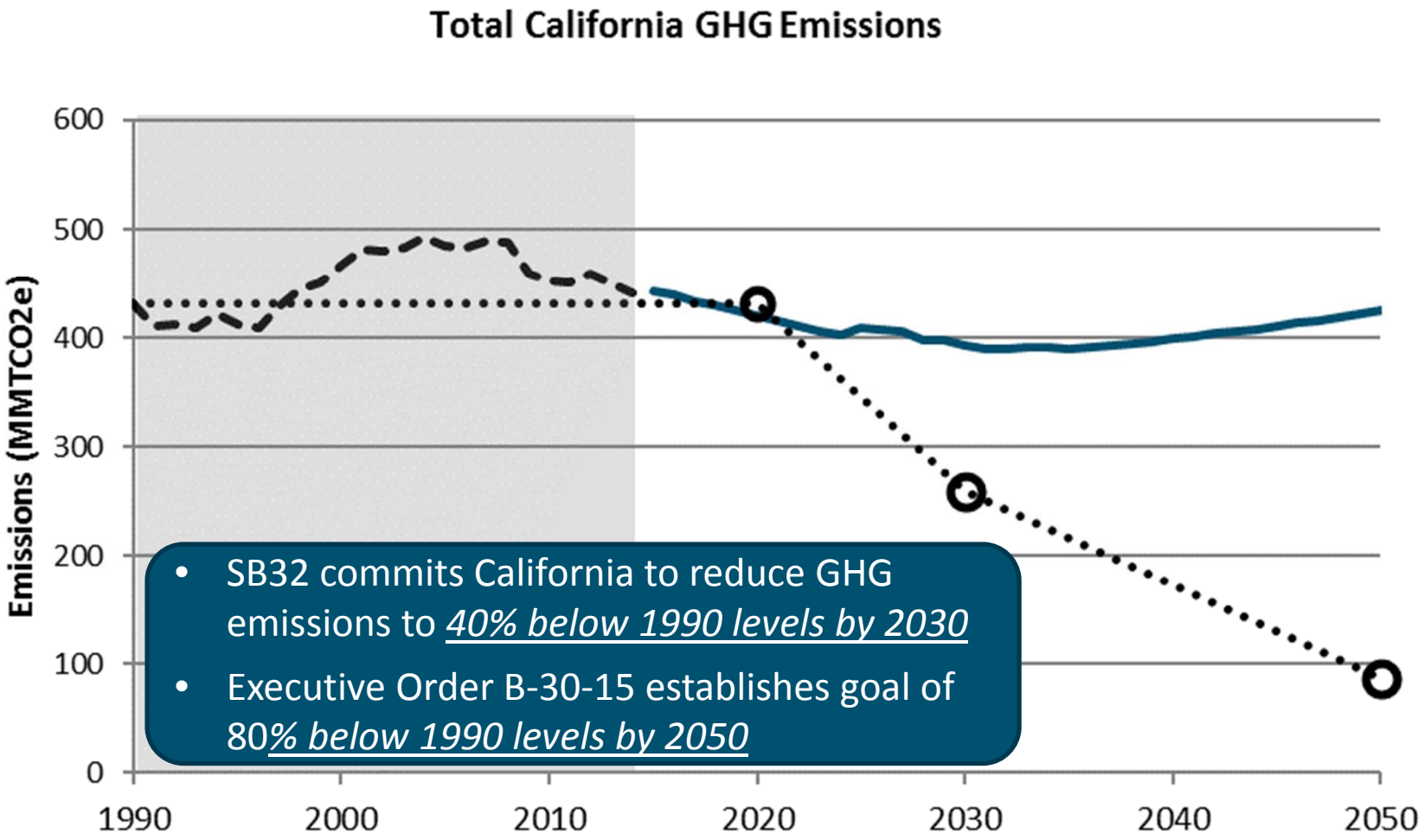
- California Air Resources Board, Energy Commission, Public Utilities Commission, Independent System Operator & the Governor's Office
- Additional funding provided by the Energy Foundation

+ Team

- Energy & Environmental Economics with support from LBNL

Study results: https://www.ethree.com/public_proceedings/summary-california-state-agencies-pathways-project-long-term-greenhouse-gas-reduction-scenarios/

California's Climate Commitments

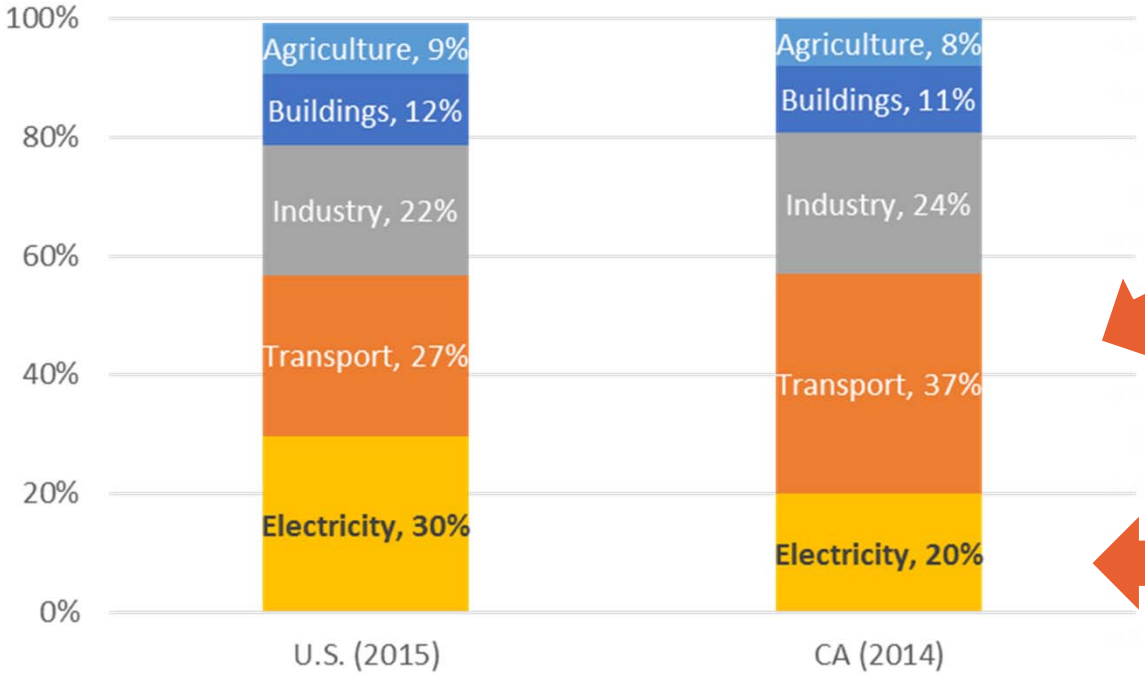


How does CA compare to the U.S.?

GHG emissions per capita

US: 16.95 MT **CA: 9.23 MT**

Share of total GHG emissions by sector
in the United States (6.2 billion tons) and California (442 million tons)



+ **California has significantly lower GHG emissions per capita**

+ **Transportation emissions are a larger share in California**

+ **Electricity emissions are a smaller share in California**

Source: Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2015 (note the GHG sinks from land use and forestry are excluded from the chart) and California GHG Inventory 2016 Edition

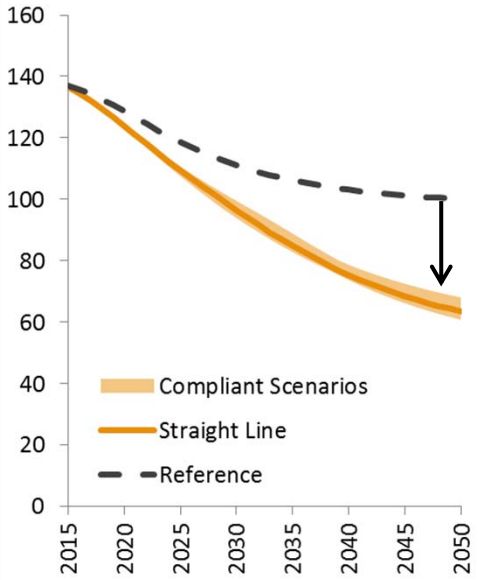
Key scenario assumptions

- Continuation of current lifestyle & growth of economic activity
- Technological conservativism, plus key emerging technologies
- Natural retirement of equipment (not early replacement)
- Biomass use is limited based on DOE estimate of sustainable supply
- Advanced biofuels are assumed to have net-zero carbon emissions
- Electricity planning and operational assumptions maintain hourly balance of electricity supply & demand

Decarbonizing CA's economy depends on four energy transitions

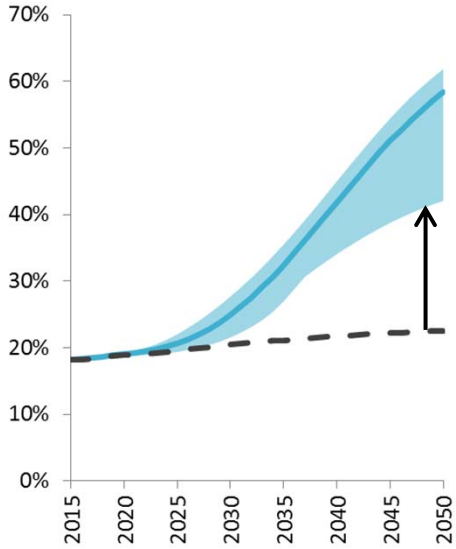
1. Efficiency and Conservation

Energy use per capita (MMBtu/person)

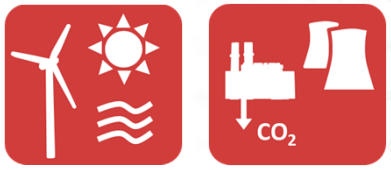


2. Fuel Switching

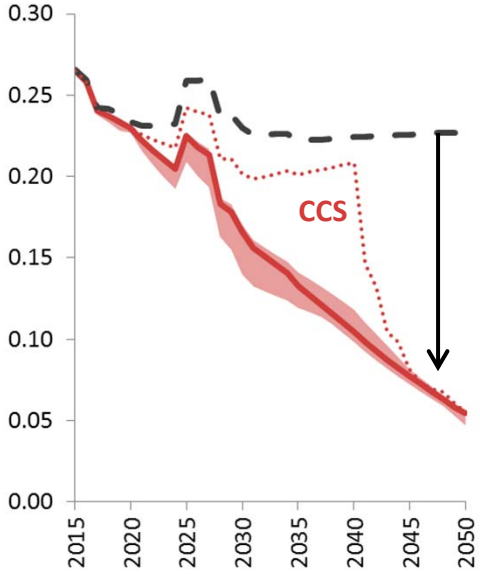
Share of electricity & H_2 in total final energy (%)



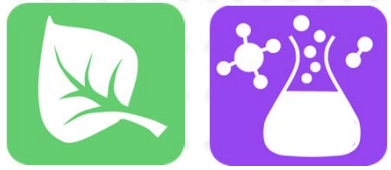
3. Decarbonize electricity



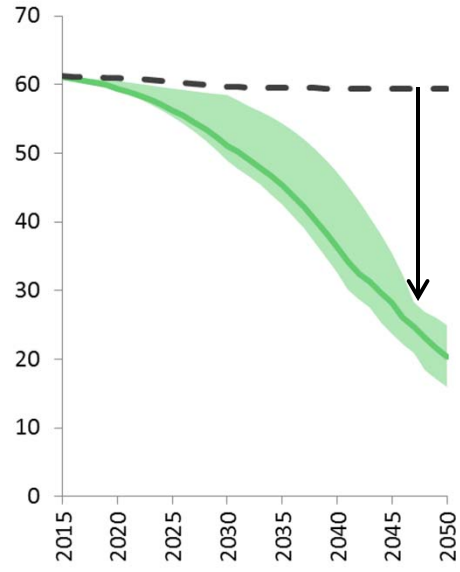
Emissions intensity (tCO2e/MWh)



4. Decarbonize fuels (liquid & gas)



Emissions intensity (tCO2/EJ)



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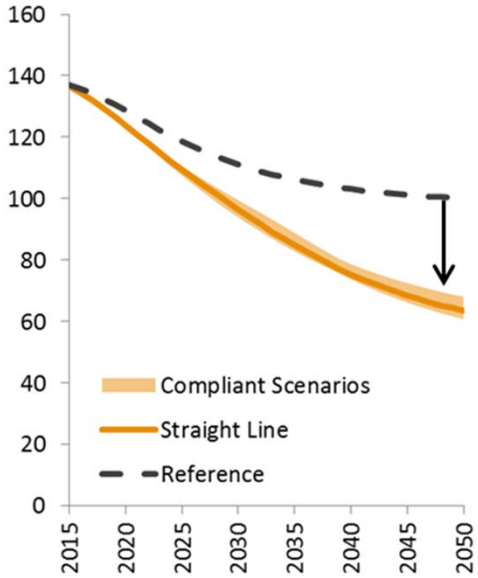
1. Doubling of current energy efficiency goals & reduced vehicle miles traveled

Energy use per capita (MMBtu/person)



+ Higher Efficiency in Buildings & Industry

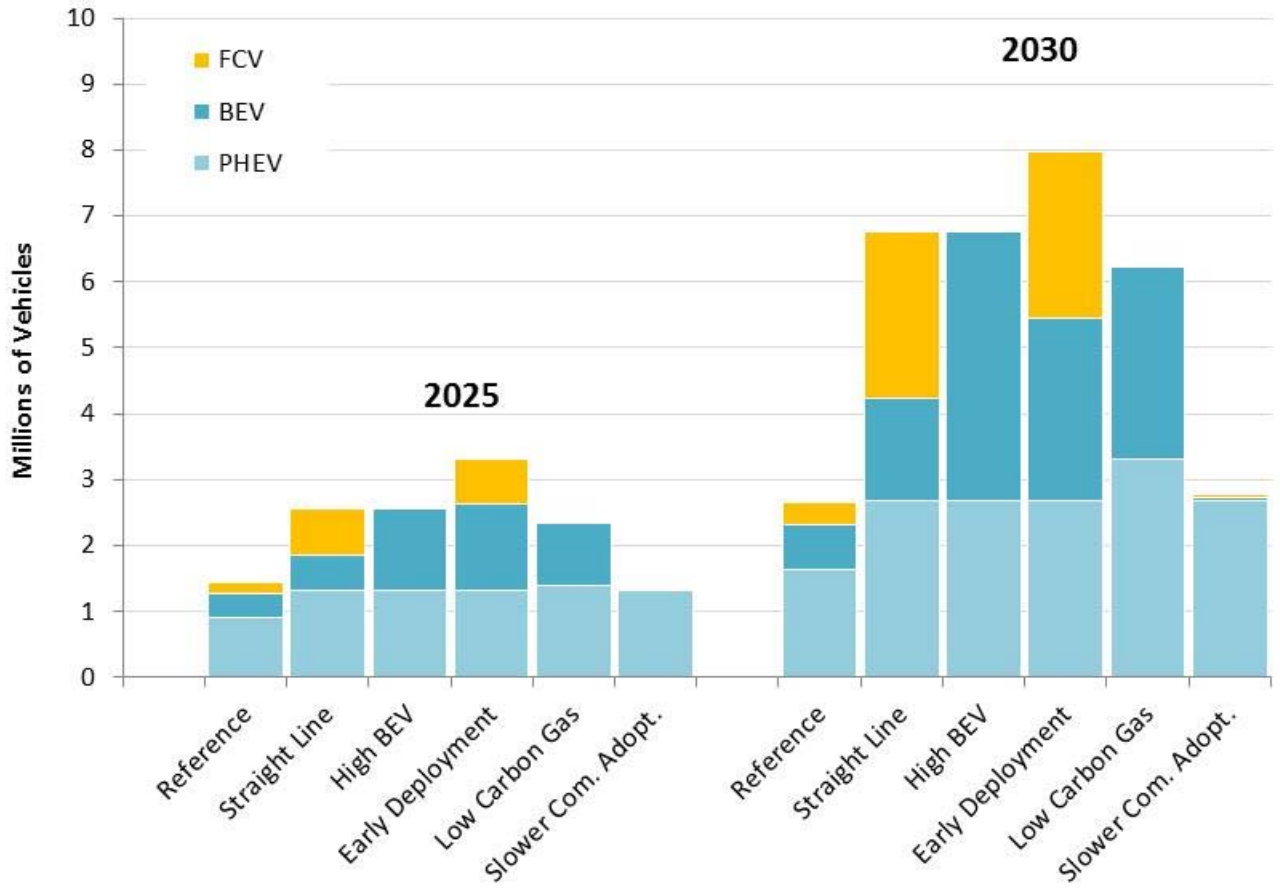
- Approximate doubling of current plans for EE savings
- Largest EE savings assumed to come from commercial LED lighting, more efficient equipment & appliances

+ Higher Efficiency of Vehicles and Reduced Demand for Transportation Services

- 8% reduction in vehicles miles traveled through smart growth policies and demographic trends by 2030
- Sustained vehicle efficiency improvements
- Petroleum refining and oil & gas extraction energy use decline proportionally with demand for liquid fossil fuels

2. Large increase in zero-emission and plug-in hybrid vehicles by 2030

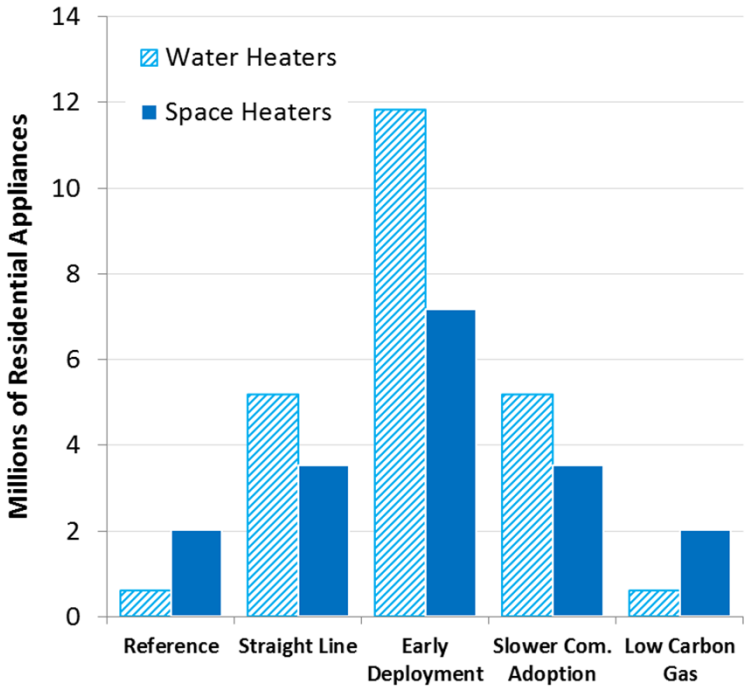
- Number of light duty fuel cell vehicles (FCV), battery electric vehicles (BEV) and plug-in hybrid electric vehicles (PHEV) on the road in CA in 2025 and 2030



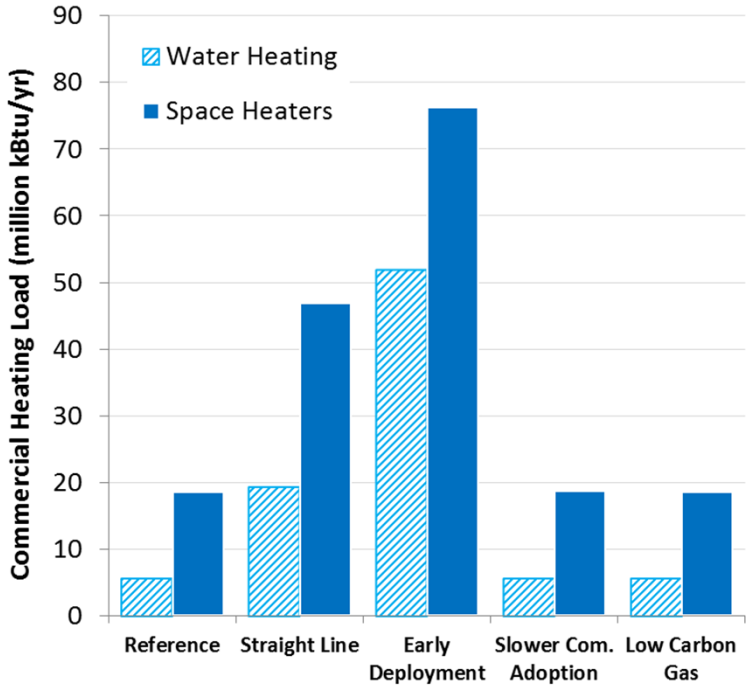
2. Increase in Building Electrification

- Transition toward electric heat pumps in buildings in Compliant Scenarios begins in 2020
- Early deployment scenario assumes *all* new building space heating and water heating in the South Coast is electric starting in 2020

Residential Electrification: 2030

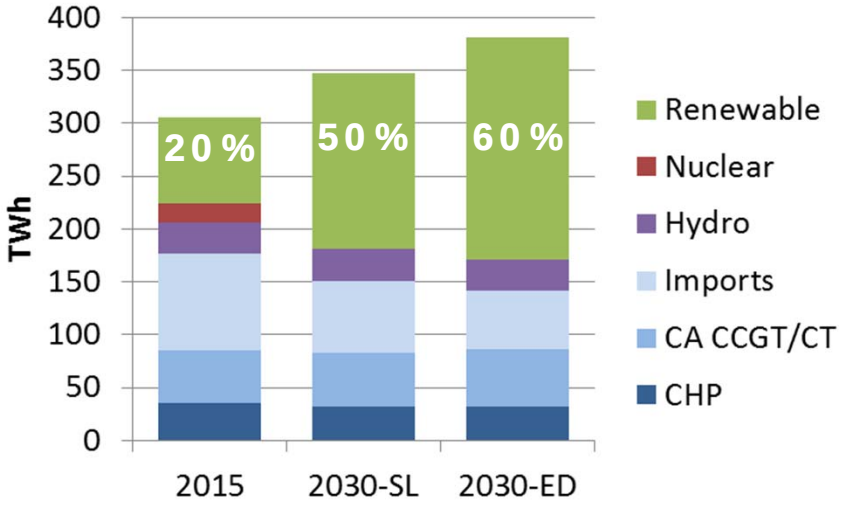


Commercial Electrification: 2030

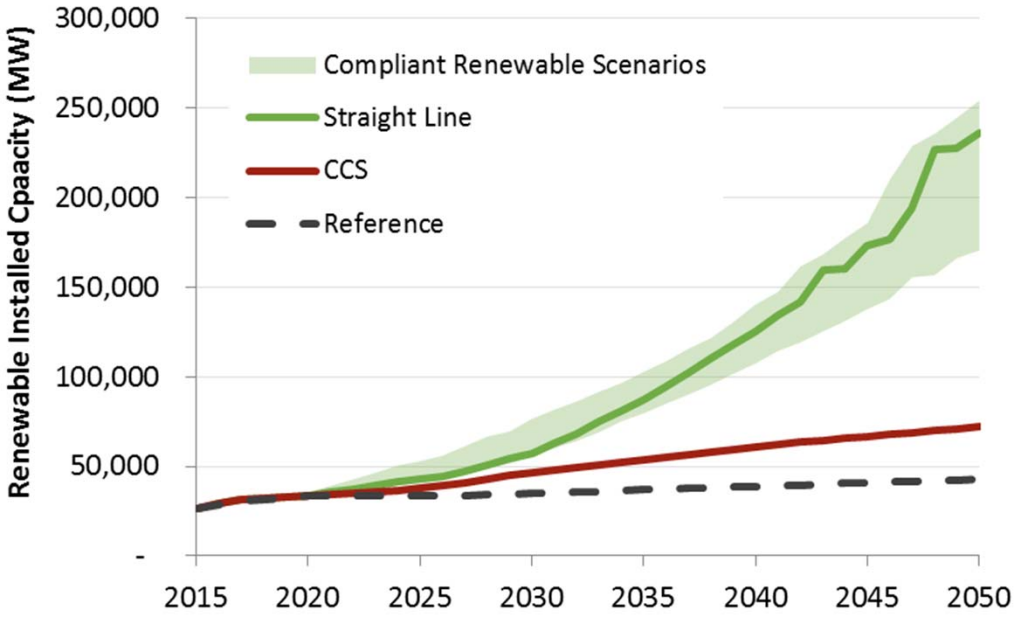


3. All scenarios rely on renewables to decarbonize electricity

- **50-60% renewables by 2030, 75-86 % by 2050**
- **Renewable needs increase dramatically post-2030**



Renewable Capacity (MW)



Note: In-state and out-of-state renewable development is assumed, including new transmission to deliver renewable resources.

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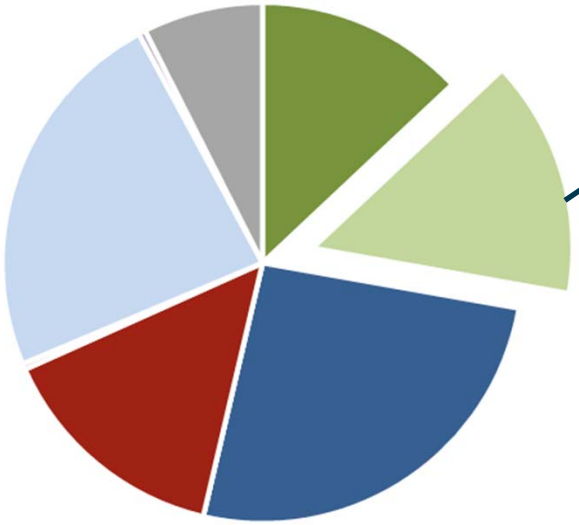
Integration solutions needed:

- Regional coordination
- Renewable diversity
- Flexible loads, especially flexible fuel production
- 4-8 hr. stationary storage
- Dispatchable hydro & thermal generation

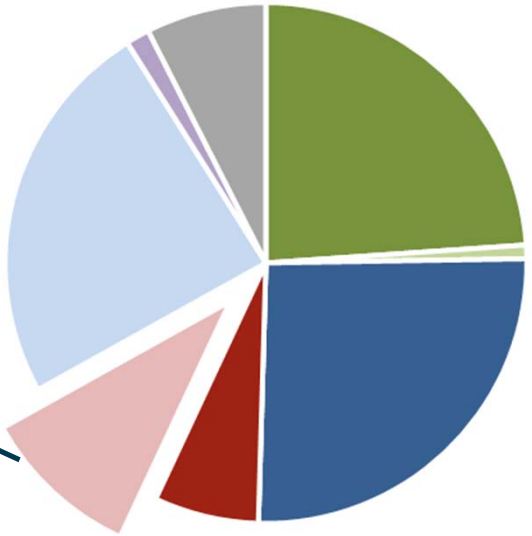
4. Sustainable biofuels used to replace <u>either</u> liquid or gaseous fuels

Share of Final Energy Demand by Fuel Type: 2030

Low Carbon Gas Scenario



Straight Line Scenario



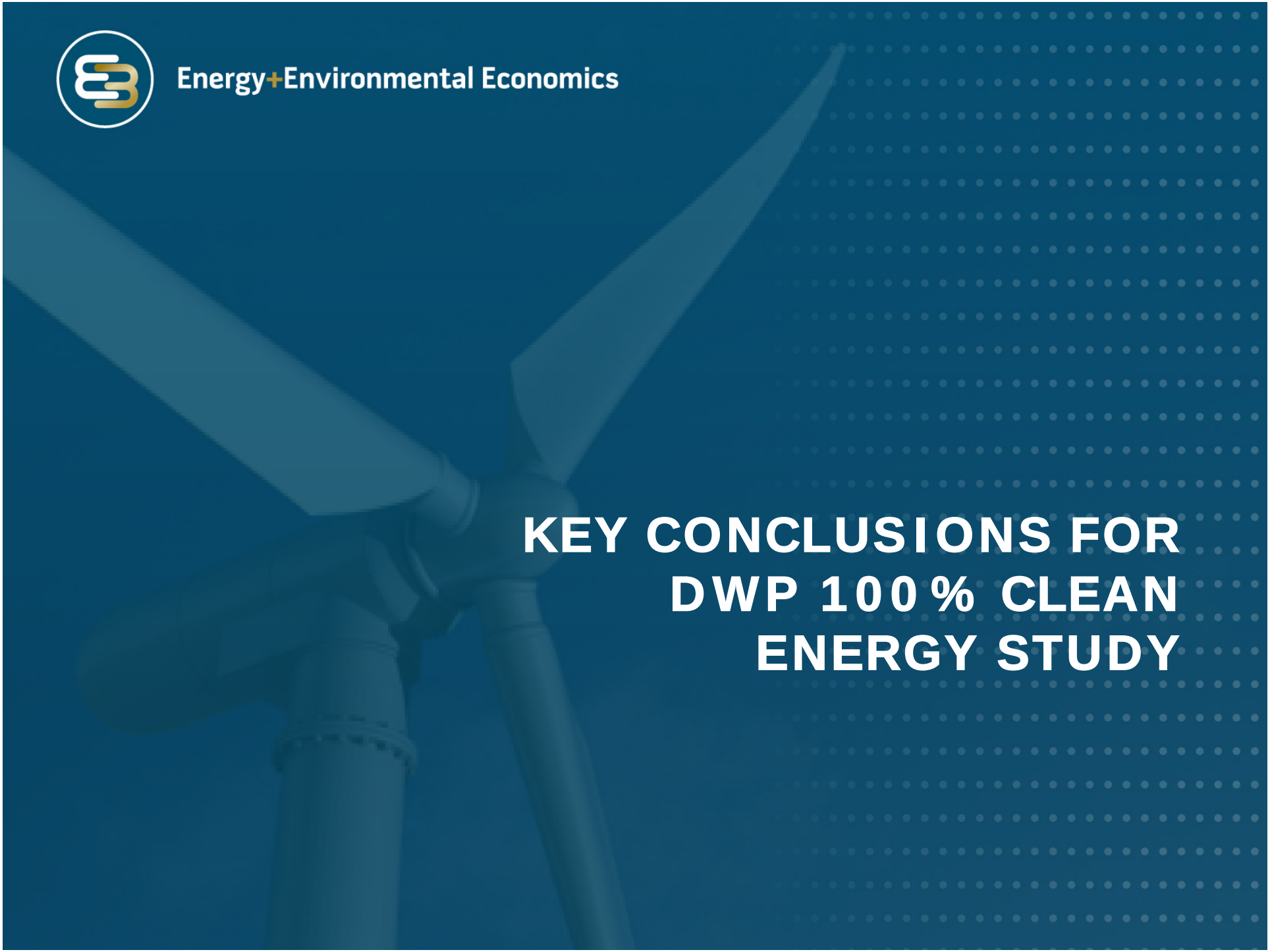
Biogas

Renewable Diesel

Biofuels used in gaseous form in buildings & industry

Biofuels used for liquid transportation fuels

Natural Gas	Biogas	Gasoline
Renewable Gasoline	Diesel	Renewable Diesel
Electricity	Hydrogen	Other Fuels



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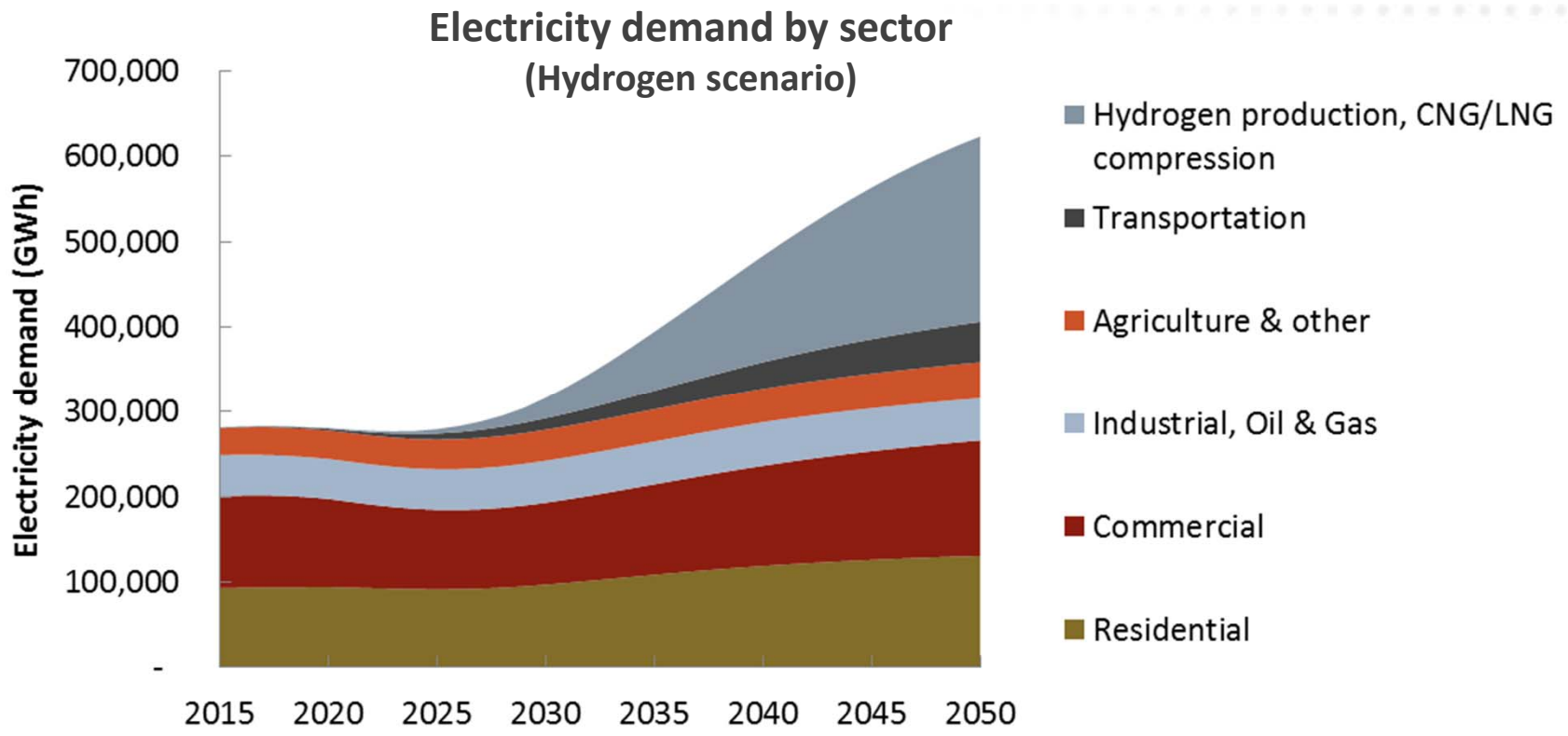
KEY CONCLUSIONS FOR DWP 100% CLEAN ENERGY STUDY

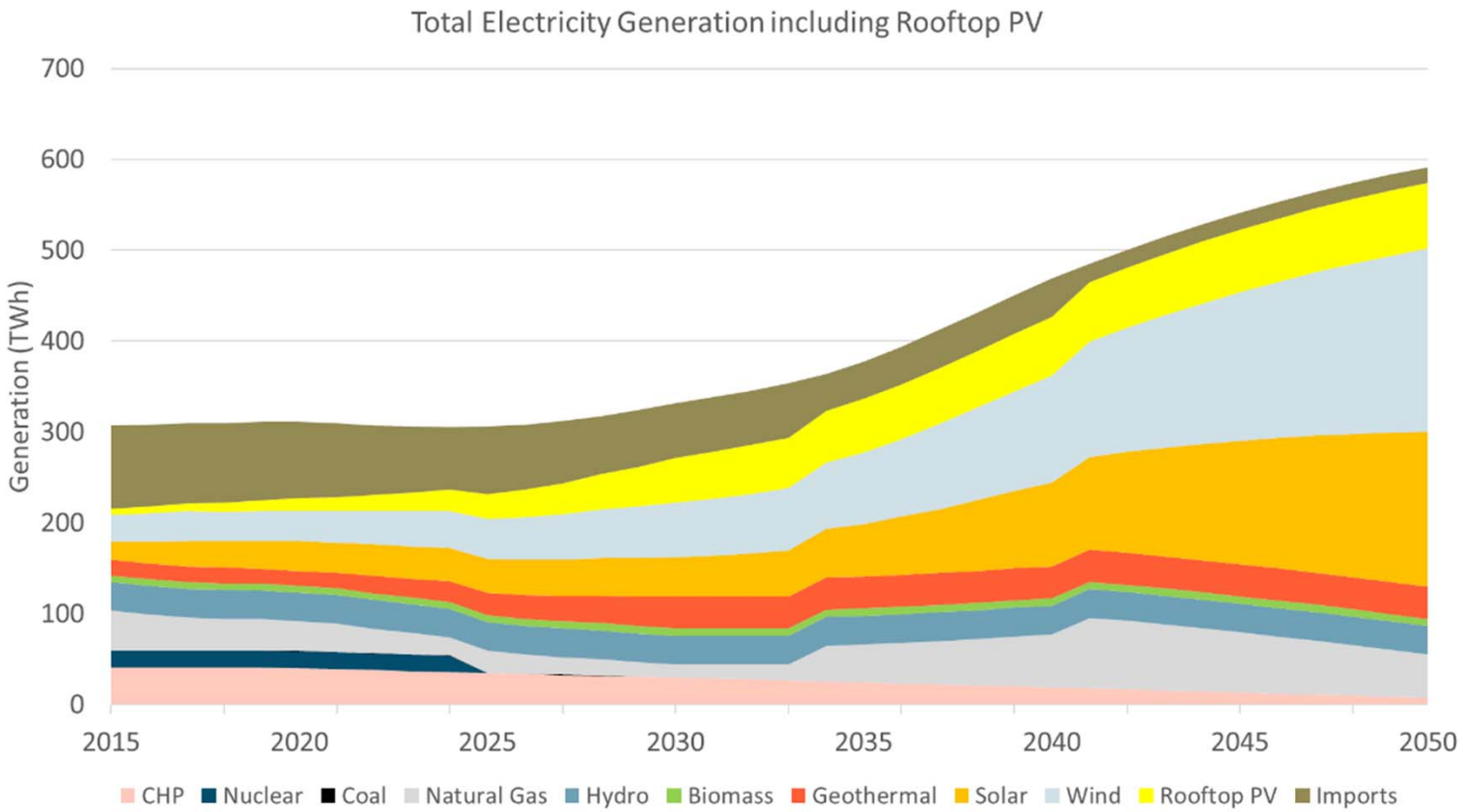
Fuel switching drives rapid growth in electric loads after 2030

- Electricity demand grows by 50-100% after 2030
- Electricity sector must contribute to decarbonization of other sectors



Renewable generation continues to increase through 2050

- **Renewables and hydro constitute 88% of electricity generation by 2050 in this scenario**
- **None of the scenarios analyzed achieves 100% renewables**



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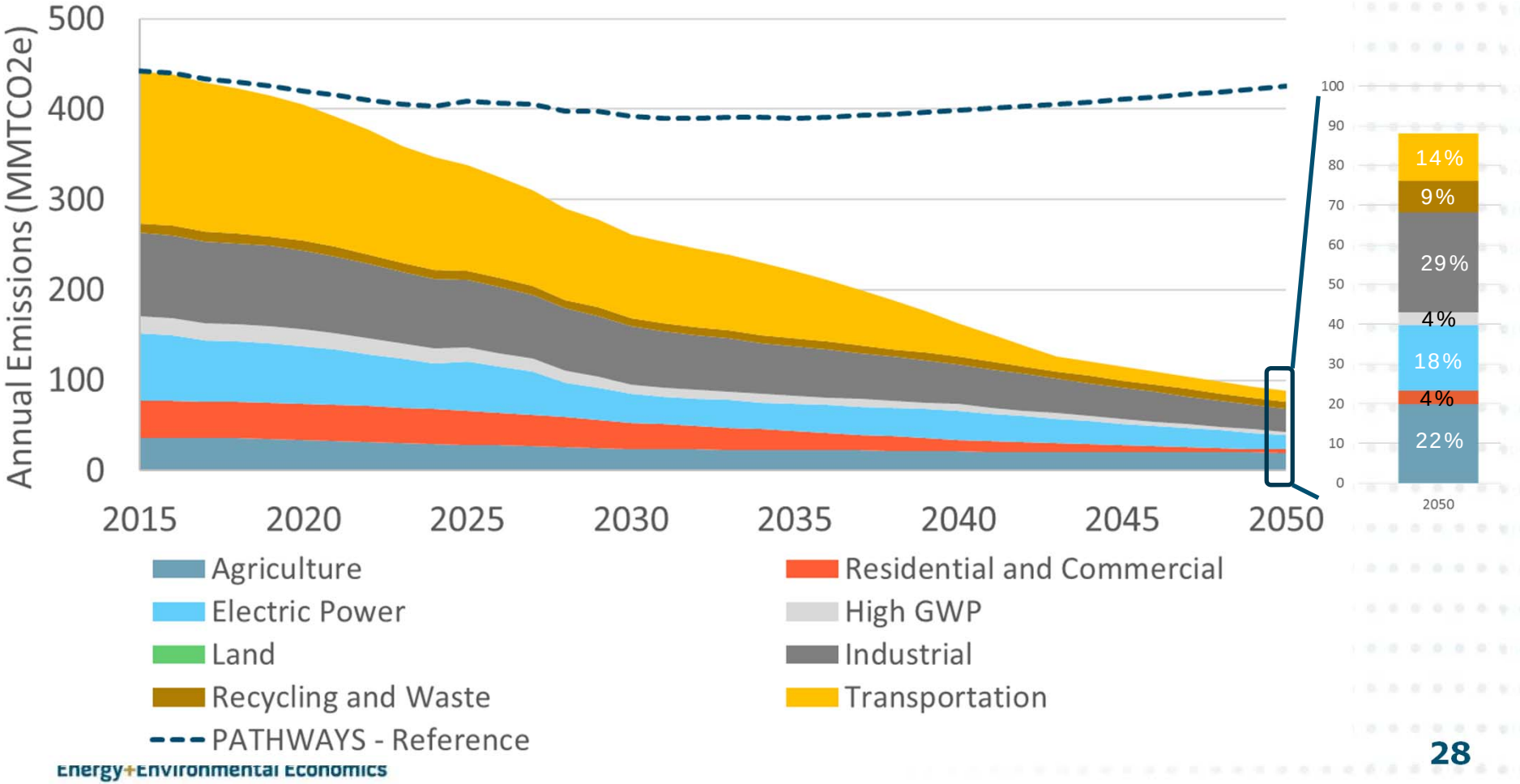
GHG Emissions reduced in all sectors of the economy

- Electric power accounts for 16 MMT in 2050, or 18% of statewide emissions
- None of the scenarios analyzed achieves 0 GHG in electric sector



Key questions for the electric sector

- **Level and shape of new electric loads for decarbonization of other sectors**
  - Electric vehicles
  - Electrification of space heating and cooling loads in buildings
  - Electrification of industry
- **Availability of additional decarbonization tools**
  - Availability and cost of renewable natural gas
  - Is there significant new demand for electricity to make hydrogen fuel?
  - Is there significant new demand to make low-carbon natural gas using power-to-gas technology?

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Thank You!

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