

California PATHWAYS: A Tool to Examine Long-Term Greenhouse Gas Reduction Scenarios

California Air Resources Board Scoping Plan

08/17/2021



Energy+Environmental Economics

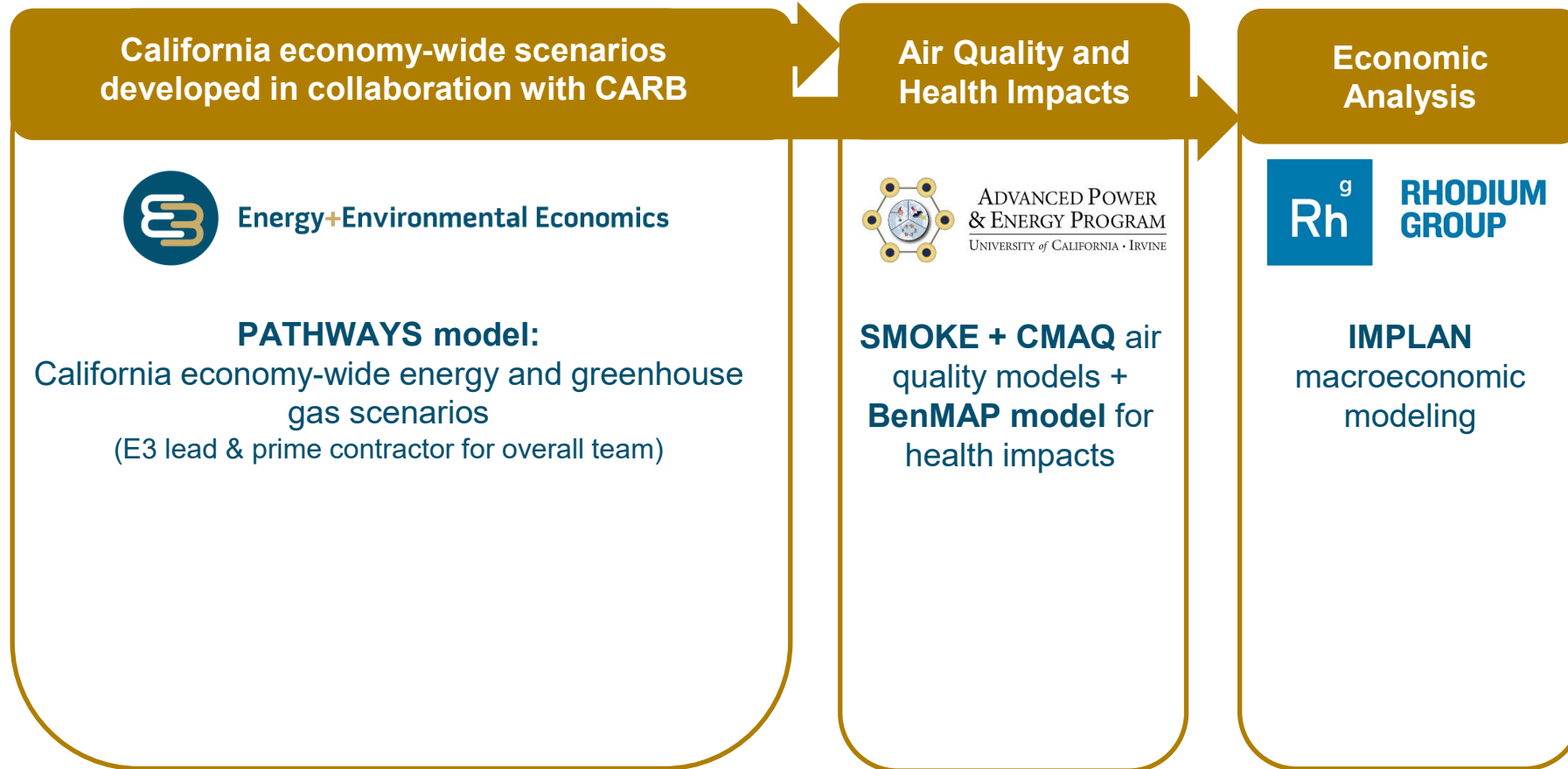
Jessie Knapstein, Managing Consultant



- + Scoping Plan 2022
- + The California PATHWAYS model
- + Inputs & Outputs

Scoping Plan 2022





About the California PATHWAYS Model

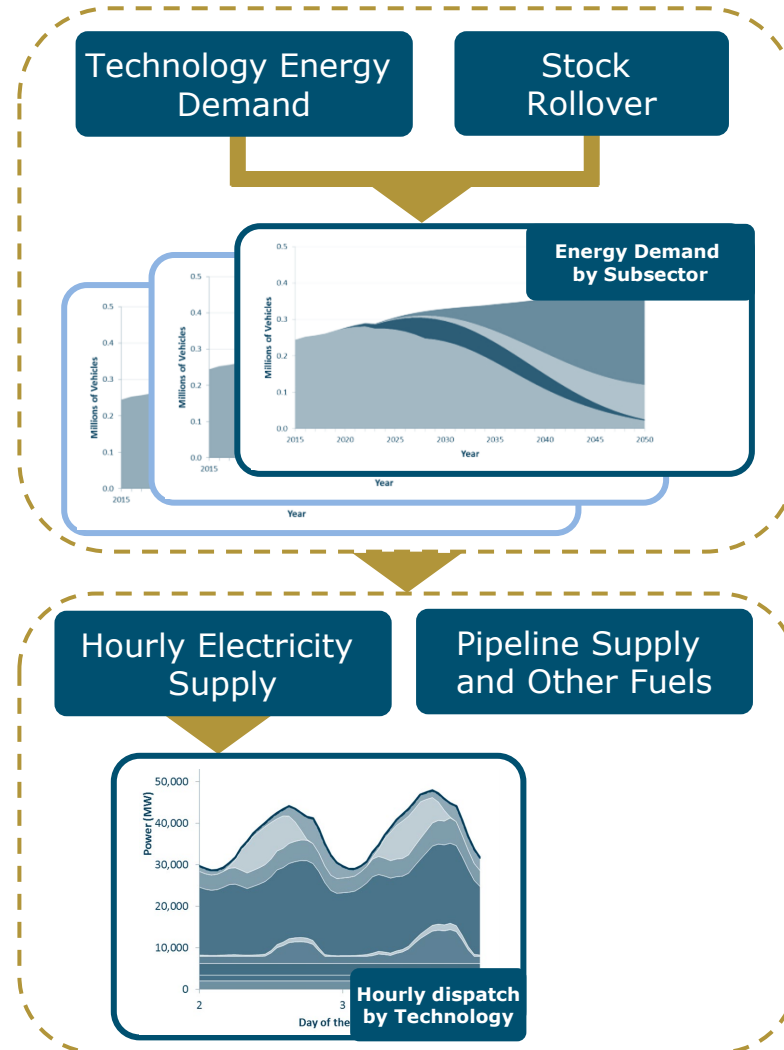


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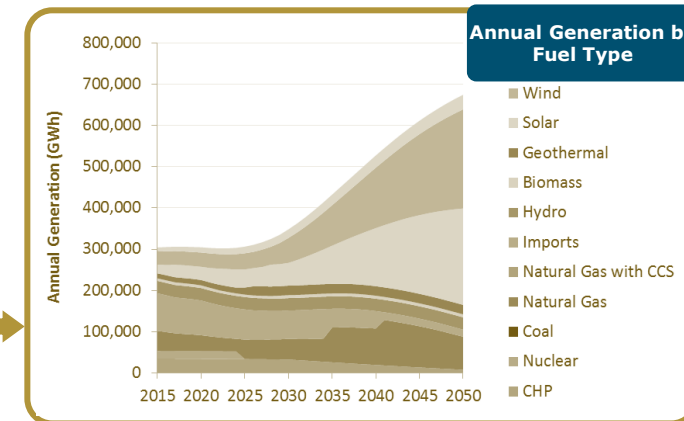
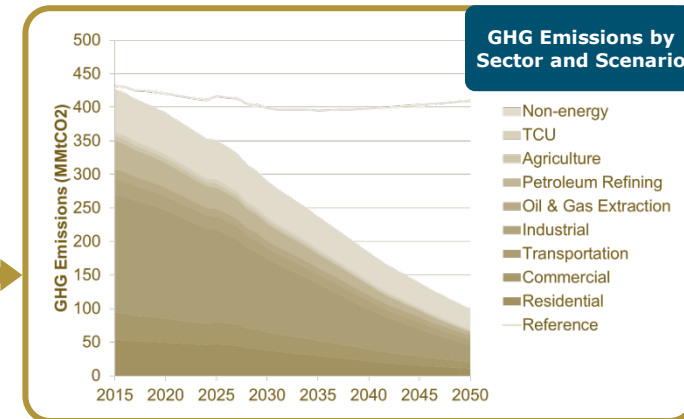


What is PATHWAYS?

- + PATHWAYS is a transparent and in-depth approach to economy-wide emissions accounting
- + 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



Sample Outputs:





What is PATHWAYS?

PATHWAYS does:

- + Compare user-defined policy and market adoption scenarios

Included in model:

- + Physical accounting of energy flows within all sectors of the economy
- + Cost accounting, including energy infrastructure and fuel costs
- + GHG accounting

PATHWAYS does not:

- + Optimize for lowest cost solutions

Not included in model:

- + Structural/macroeconomic impacts
- + Societal cost impacts (avoided damages)
- + Criteria pollutants
- + Geographic granularity
- + Policy design modeling

Data Inputs and Outputs





All Inputs and Outputs Tracked by: Sector, Subsector, Technology, and Fuel

Residential		Commercial	Transportation	Industrial	Agriculture
16 subsectors, including: <ul style="list-style-type: none"> • Water Heating • Air Conditioning • Cooking 		9 subsectors, including: <ul style="list-style-type: none"> • Refrigeration • Ventilation • Office Equipment 	9 modes of transport, including: <ul style="list-style-type: none"> • Cars, Trucks, Buses • Passenger Rail • Aviation 	7 subsectors, including: <ul style="list-style-type: none"> • Conventional boiler use • Machine drive • Process heating 	7 subsectors, including: <ul style="list-style-type: none"> • Lighting • Motors • Refrigeration
Petroleum refining		Oil & gas extraction	Water Demand	Non-Energy GHGs	Forestry & LUC
<ul style="list-style-type: none"> • Sector-Level Energy Demand Only 		<ul style="list-style-type: none"> • Sector-Level Energy Demand Only 	<ul style="list-style-type: none"> • Energy use from procurement, treatment, conveyance and wastewater-treatment of water 	<ul style="list-style-type: none"> • Sector-Level GHGs Only, with reduction measures by GHG type consistent with CARB inventory categories 	<ul style="list-style-type: none"> • Not currently explicitly modeled
Electricity		CHP	Pipeline Gas	Liquid fuels	Other fossil fuels
<ul style="list-style-type: none"> • Uranium • Hydro • Coal • Geothermal • Wind • Solar PV • Solar thermal 	<ul style="list-style-type: none"> • Natural Gas • Biomass • Biogas • Specified imports • Unspecified imports • CCS 	<ul style="list-style-type: none"> • Waste heat 	<ul style="list-style-type: none"> • Natural Gas • Hydrogen • Power to Gas • Biogas 	<ul style="list-style-type: none"> • Diesel • Gasoline • Biodiesel • Bio-gasoline • Hydrogen • Kerosene-Jet Fuel 	<ul style="list-style-type: none"> • Coke • Refinery and Process Gas • Fuel Oil • Kerosene • LPG



Model Inputs and Outputs

Raw Data Inputs (Constants)

Technology Costs, Average Number of People per Household, Population...



Scenario Input Assumptions

Percent of annual clean energy, Sales of zero-emission vehicles, Phase down of refinery operations, Electric appliance sales...



Calculated Outputs

Greenhouse gas emissions, Energy demand, Energy supply, Technology Stocks & Sales, & Cost

Examples of Model Inputs & Outputs

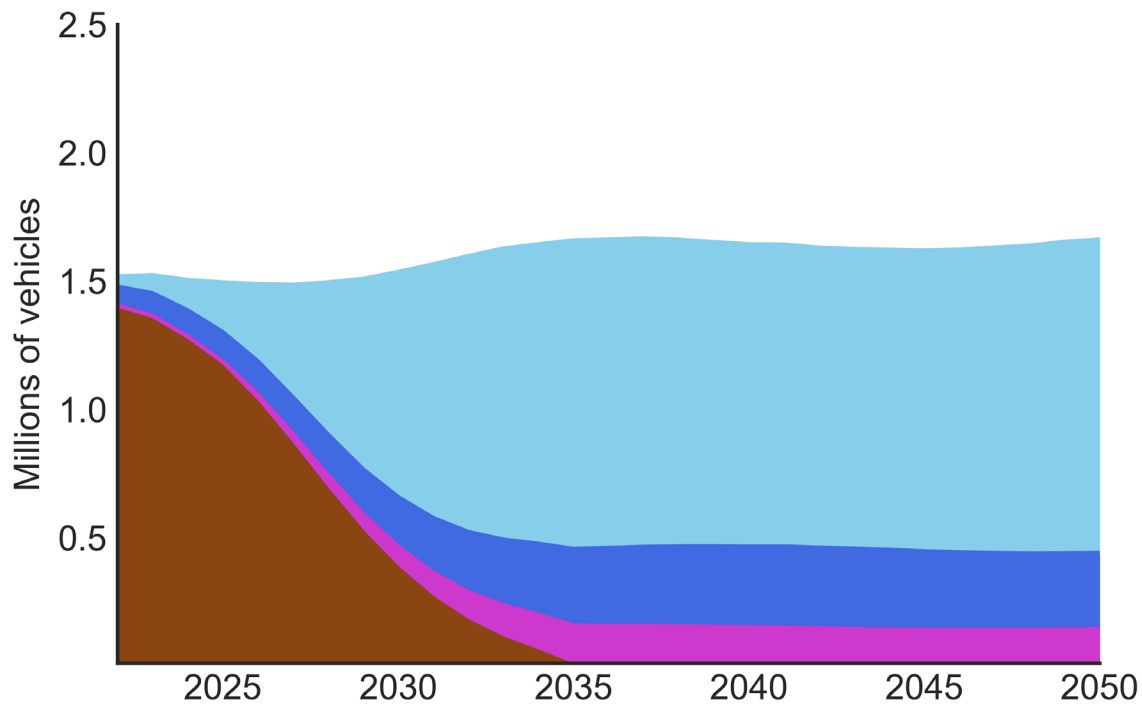




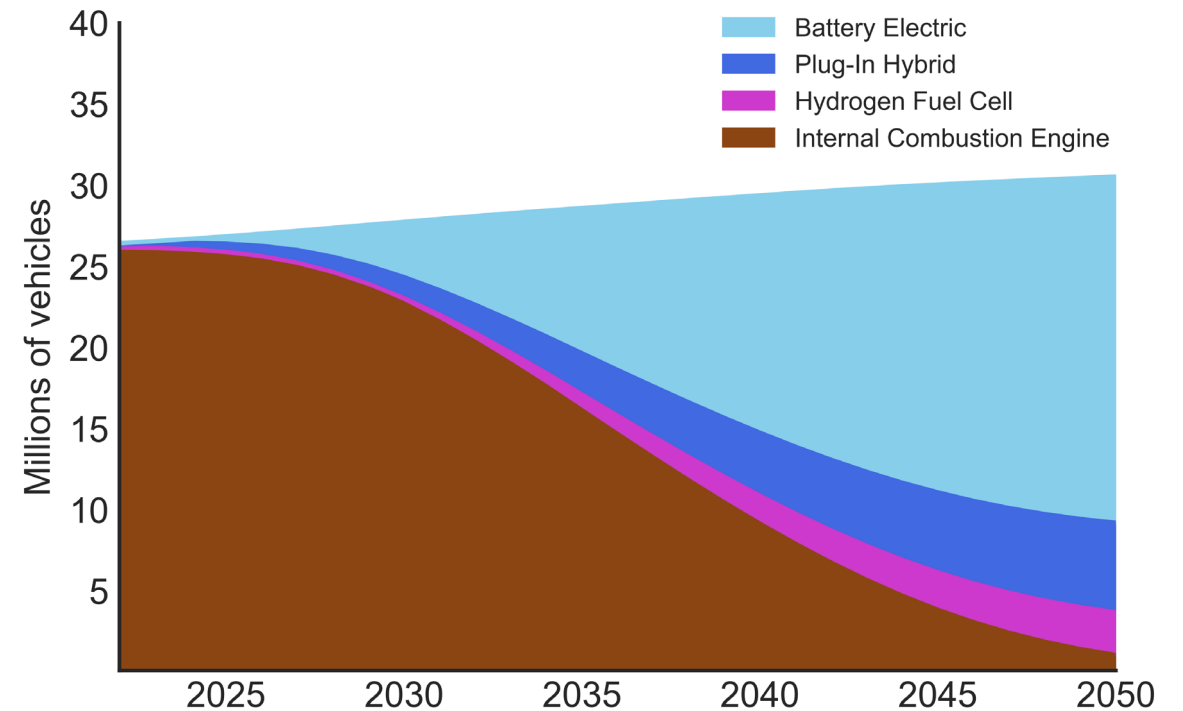
Transportation Decarbonization: Sales & Stock Rollover

1. Raw Data Inputs: Population, reference number of vehicles, vehicle lifetimes, etc.
2. Scenario Input Assumption: 100% light duty vehicle (LDV) zero emission vehicle (ZEV) sales by 2035
3. Calculated Outputs: Annual vehicle stocks by type

LDV Sales (Millions) 2020-2050



LDV Stock (Millions) 2020-2050





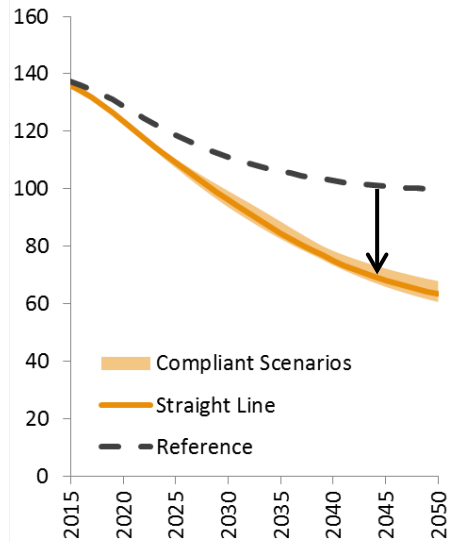
Success Requires Action in Four Areas

Efficiency & Conservation

High VMT → Low VMT
Low Efficiency → High Efficiency



Energy use per capita (MMBtu/person)

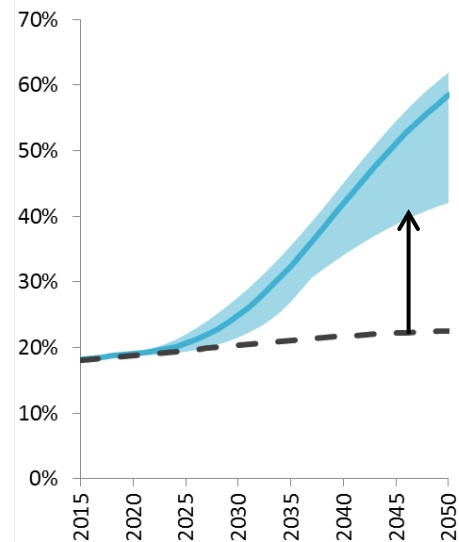


Fuel Switching

Gas Cars → Electric Vehicles
Gas in Homes → Electric Appliances
Gas Cars → Hydrogen Vehicles



Share of electricity & H₂ in total final energy (%)

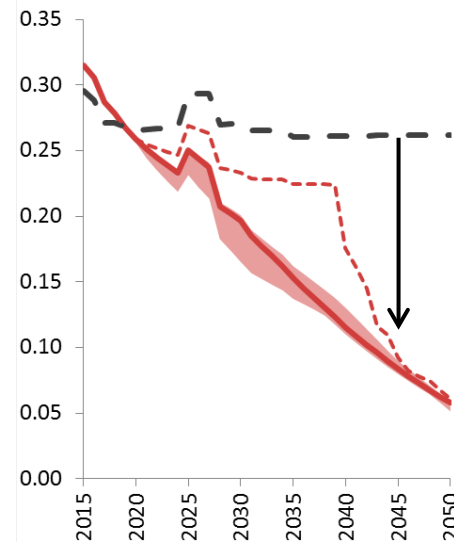


Decarbonize Electricity

Natural Gas Emissions → Clean Energy
Emissions → CCS



Emissions intensity (tCO₂e/MWh)

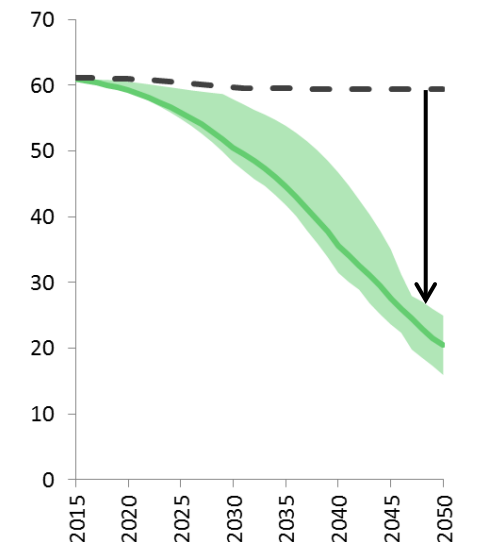


Decarbonize Fuels

Natural Gas → Biofuels
Natural Gas → Synthetic Fuels



Emissions intensity (tCO₂/EJ)



Thank You

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