

## DOCKETED

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**Renewable H2: Windpower 2016 Poster A**

Second of 6 files

*Additional submitted attachment is included below.*

# Bigger Market than Electricity Grid? Wind-source Hydrogen Fuel for California Transportation and Combined Heat and Power (CHP)

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Poster download: <http://leightyfoundation.org/w/wp-content/uploads/WP16-A.pdf>

## Hydrogen Transportation Fuel Demand California, year 2050 Million metric tons per year:

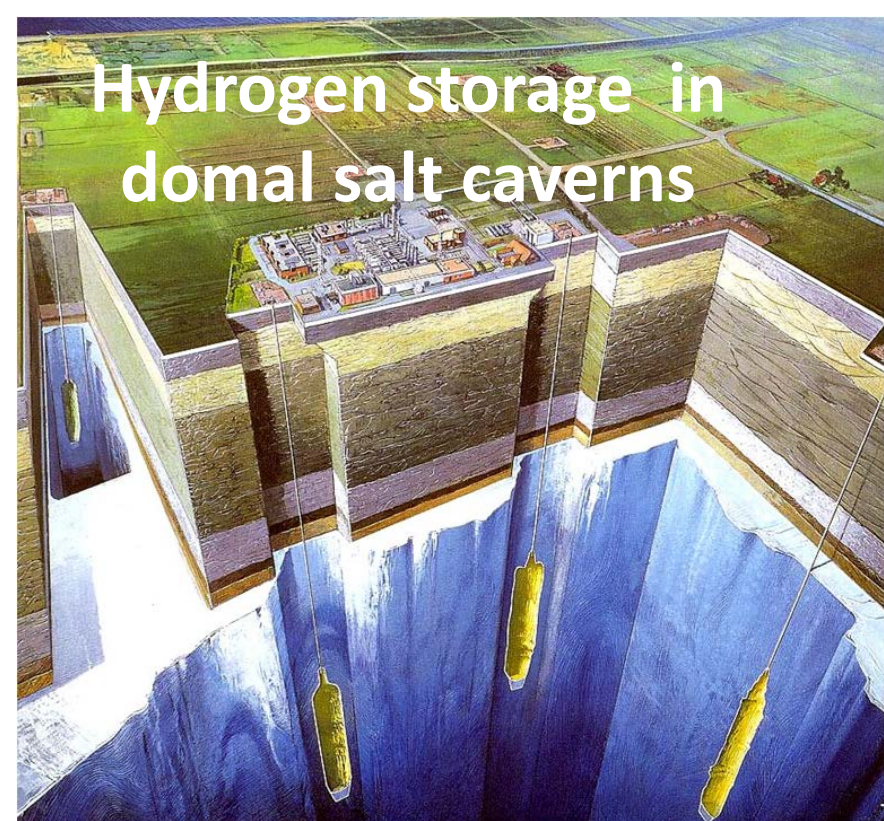
Light Duty Vehicles (LDV)	3.6
Trucking	1.6
Bus	1.4
Aviation and Other	0.8
<b>Total</b>	<b>7.4</b>

Source: interpret and extrapolate from several papers by ITS-STEPS, UC Davis

<b>Reference: Year 2015</b>	<b>GW</b>
Total installed nameplate wind generation in California (CA)	6
Total installed nameplate solar generation in California (CA)	12
<b>ELECTRICITY: CA "Power Mix"</b>	<b>GWh</b>
2014: Total electricity consumed	296,843
2050: Total electricity demand "Power Mix" is 130 % of 2014	385,896
<b>ELECTRICITY in Year 2050: CA renewables</b>	<b>GW</b>
Equivalent nameplate wind generation capacity @ 40 % CF	85
Equivalent nameplate solar generation capacity @ 35 % CF	97
<b>TRANSPORTATION Hydrogen Fuel in Year 2050: CA renewables</b>	<b>GW</b>
Equivalent nameplate wind generation capacity @ 40 % CF	126
Equivalent nameplate solar generation capacity @ 35 % CF	130
<b>TOTAL CA RENEWABLE ELECTRICITY + TRANSPORT ENERGY in Year 2050</b>	<b>GW</b>
Equivalent nameplate wind + solar + other @ CF (varies)	438

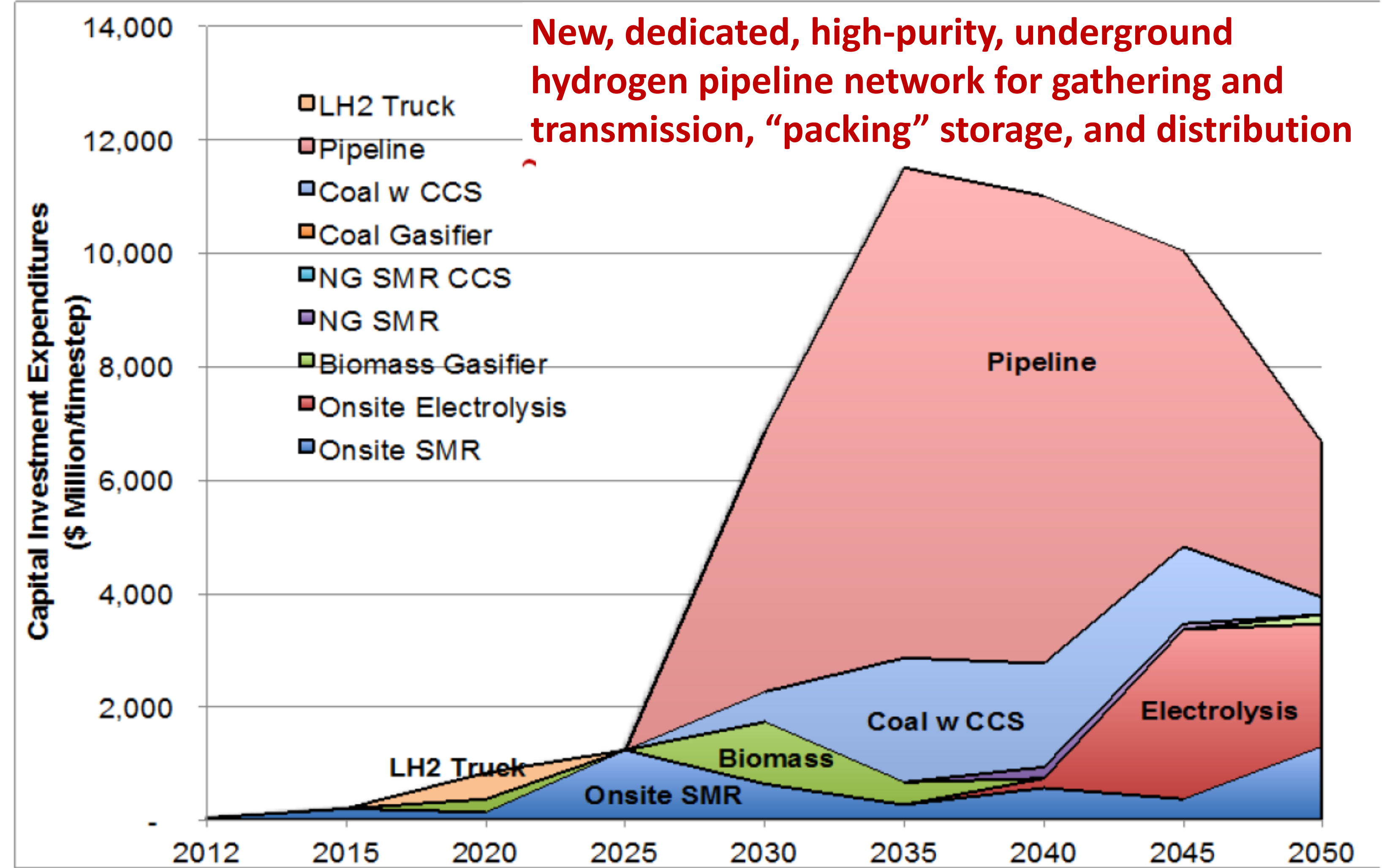
For Year 2050 Electricity + Hydrogen Transportation Fuel, California will need about:

- 210 GW = 35 times Year 2015 installed wind capacity in CA, PLUS
- 230 GW = 19 times Year 2015 installed solar electricity capacity in CA



Annual-scale firming storage for < \$ 1.00 / kWh capex  
Each domal salt cavern:

- Stores ~ 92,000 MWh as ~ 2,500 Mt "working" Hydrogen
- "Full" at 150 bar = 2,250 psi
- Cavern top ~ 700m below ground
- 860,000 cubic meters each cavern physical volume
- \$ 15 M average capex per cavern
- Capex = \$160 / MWh = \$0.16 / kWh



**Capital Investment for Hydrogen Fuel Infrastructure in California**  
\$ 50 Billion cumulative investment : Transition to "green" Hydrogen for "80 in 50"  
80 % reduction in CO2 emissions from California transportation sector by year 2050  
Source: Institute of Transportation Studies (ITS), STEPS program, UC Davis

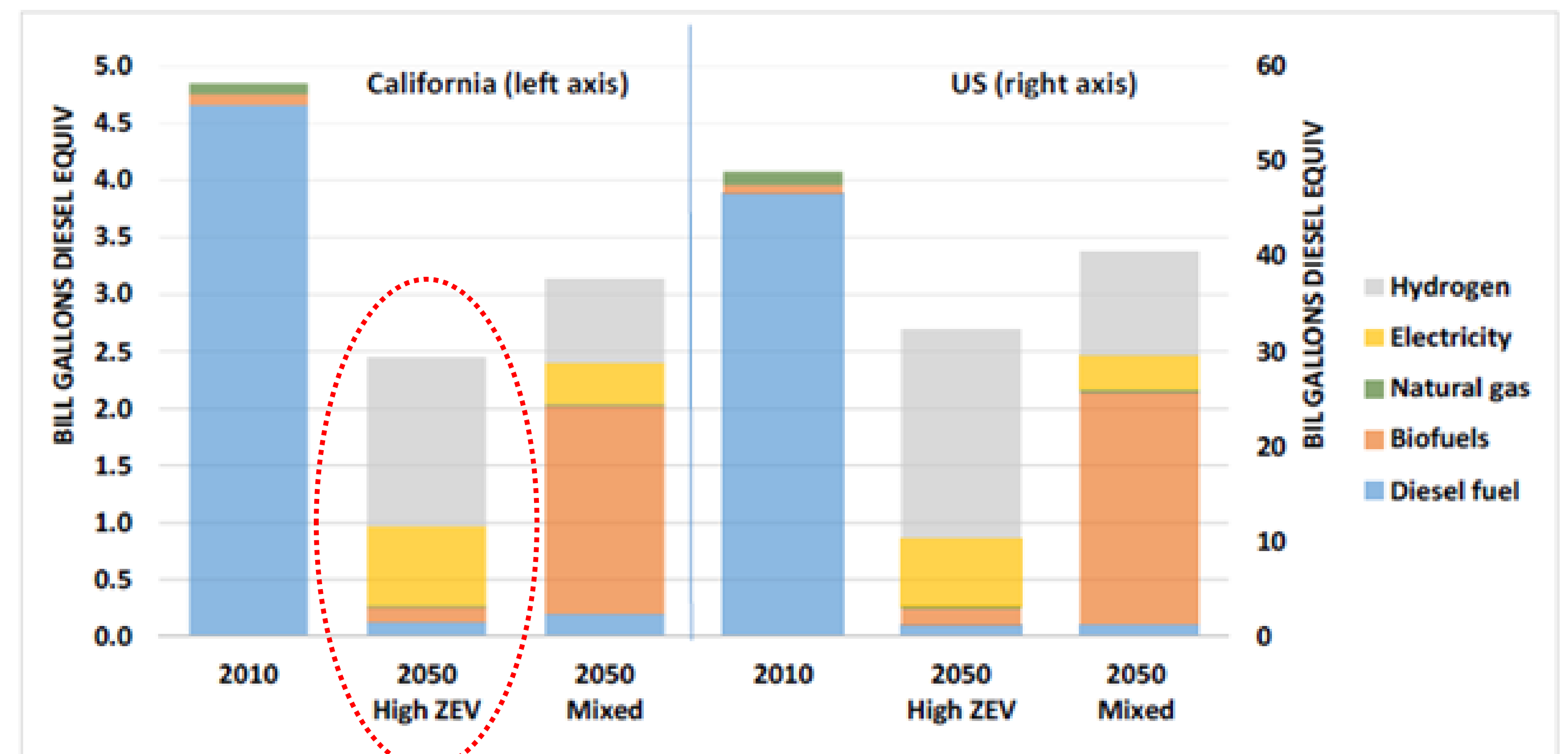
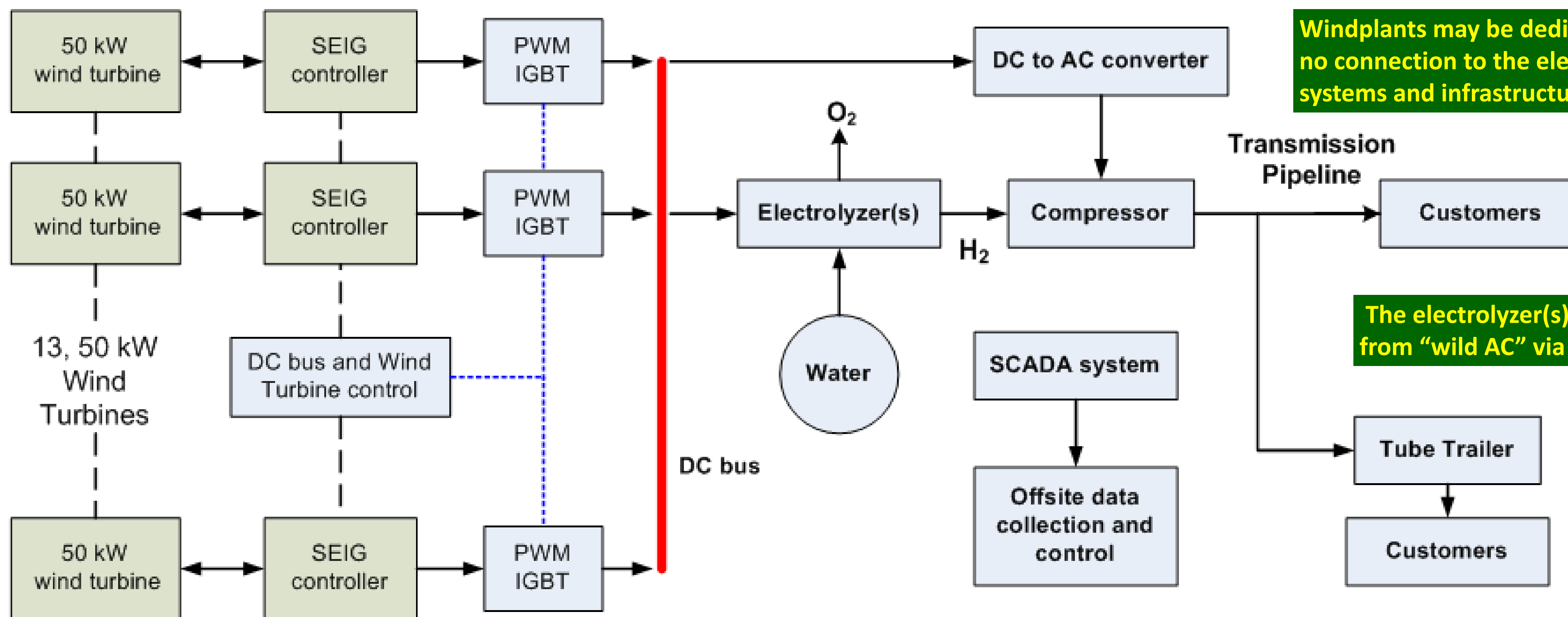


Figure ES-2. Energy use by fuel type, year and scenario, California and U.S. results

**"Goods movement" trucking diesel fuel demand in Year 2050**  
California (left, red circle) and USA (right), High Zero Emissions Vehicle (ZEV) case  
This is included in the "Hydrogen Fuel Demand" estimates on the poster's right side.  
Source: Institute of Transportation Studies (ITS), STEPS program, UC Davis



Windplants may be dedicated to Hydrogen fuel production, with no connection to the electricity grid, without costly generating systems and infrastructure to deliver grid-quality AC or DC.

The electrolyzer(s) are a dumb DC load, fed "wild DC" from "wild AC" via simple power electronics and controls



**Gaseous Hydrogen (GH2) transmission pipelines**  
Polymer-metal hybrid tubing concept sample, from Smart Pipe, Houston, [www.smart-pipe.com](http://www.smart-pipe.com) May be made up to 1 meter diam for transmission; smaller for gathering and distribution lines. Fabricated in an on-site, trenchside factory in continuous, unlimited lengths, without splices. Has not been tested for 100 bar GH2 service. Probably immune to Hydrogen embrittlement.

Turbines with simple, low-cost induction motors are modified for Self Excited Induction Generator (SEIG) mode and closely coupled via simple, smart rectification on a DC bus to the electrolyzer stacks, via a SCADA system integrating the complete wind-to-Hydrogen plant, to reduce system complexity and capital and O&M costs. This will reduce kWh per kg Hydrogen and boost energy conversion efficiency, reducing plant gate Hydrogen fuel cost in several ways.