

## DOCKETED

<b>Docket Number:</b>	17-HYD-01
<b>Project Title:</b>	Renewable Hydrogen Transportation Fuel Production
<b>TN #:</b>	215563
<b>Document Title:</b>	Bill Leighty Comments: Renewable H2: Solar 2016 Poster
<b>Description:</b>	N/A
<b>Filer:</b>	System
<b>Organization:</b>	Bill Leighty
<b>Submitter Role:</b>	Public
<b>Submission Date:</b>	1/25/2017 1:01:00 PM
<b>Docketed Date:</b>	1/25/2017

*Comment Received From: Bill Leighty*

*Submitted On: 1/25/2017*

*Docket Number: 17-HYD-01*

## **Renewable H2: Solar 2016 Poster**

Fourth of 6 files

*Additional submitted attachment is included below.*



# Bigger Market than Electricity Grid? Solar-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:

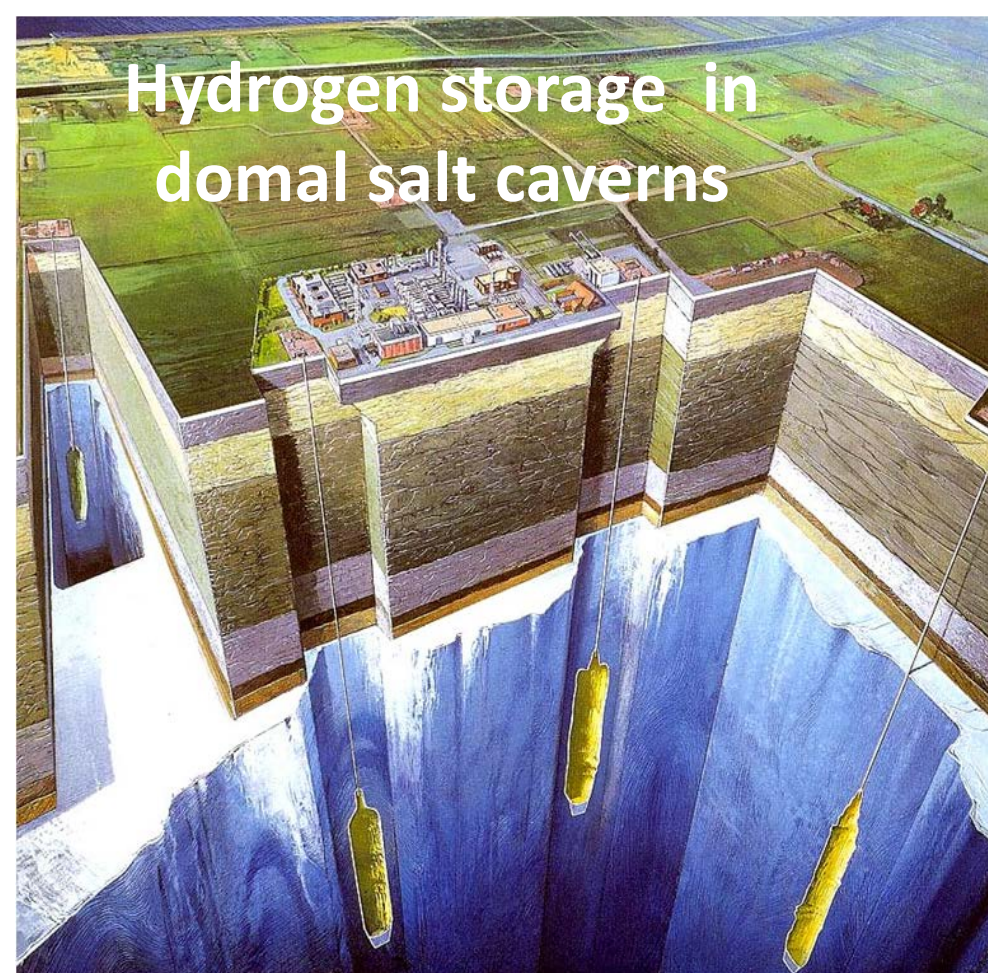
Light Duty Vehicles (LDV)	3.6
Trucking	1.6
Bus	1.4
Aviation and Other	0.8
<b>Total</b>	<b>7.4</b>

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

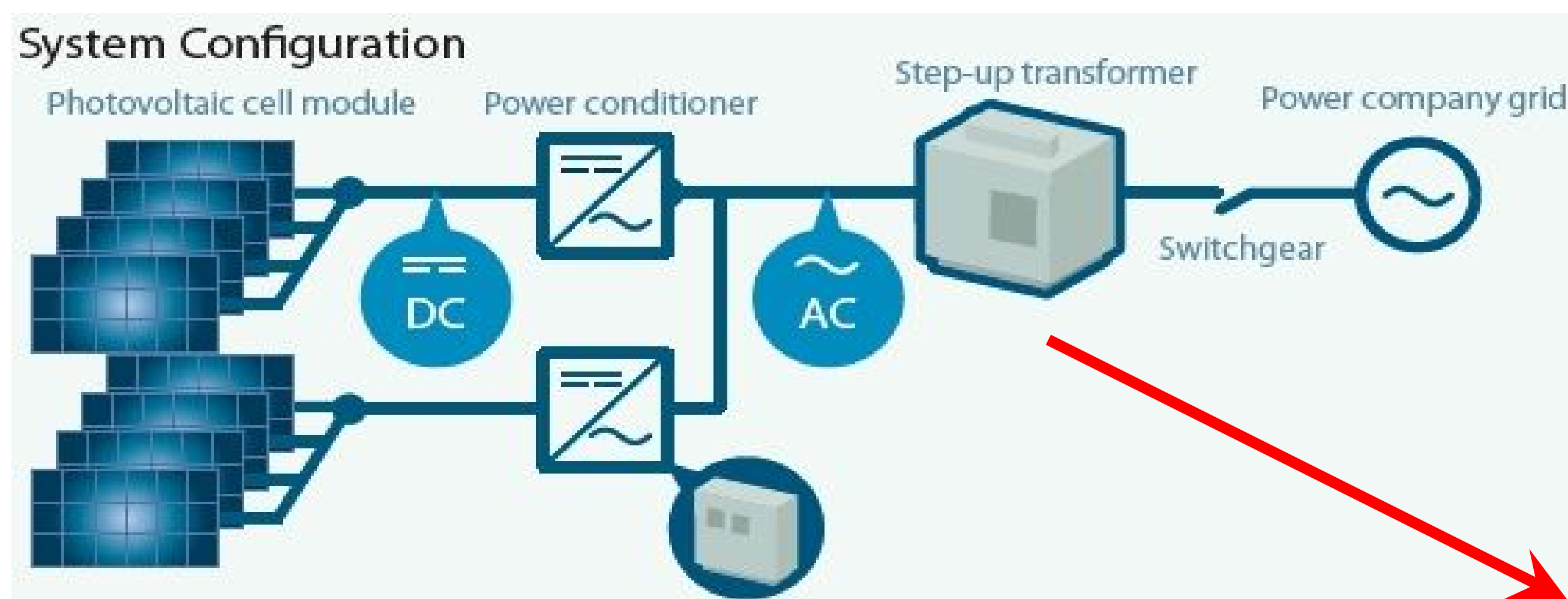
For Year 2050 Electricity + Hydrogen Transportation Fuel, California will need about:

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

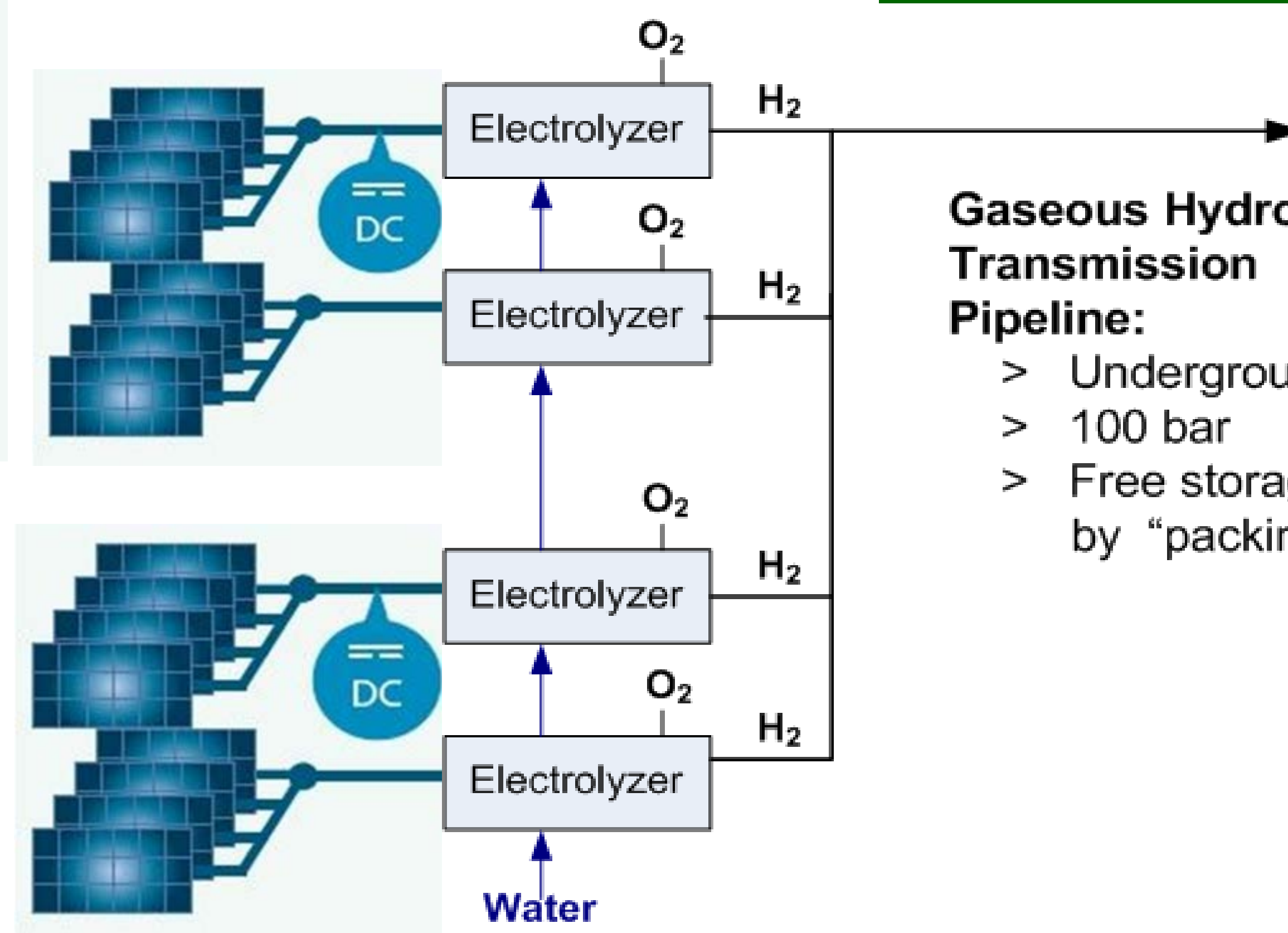


Annual-scale firming storage for < \$ 1.00 / kWh capex  
Each domal salt cavern:

- 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



**Simplified Solar plants dedicated to  
Hydrogen fuel production  
No connection to, nor energy delivery to, the Grid**

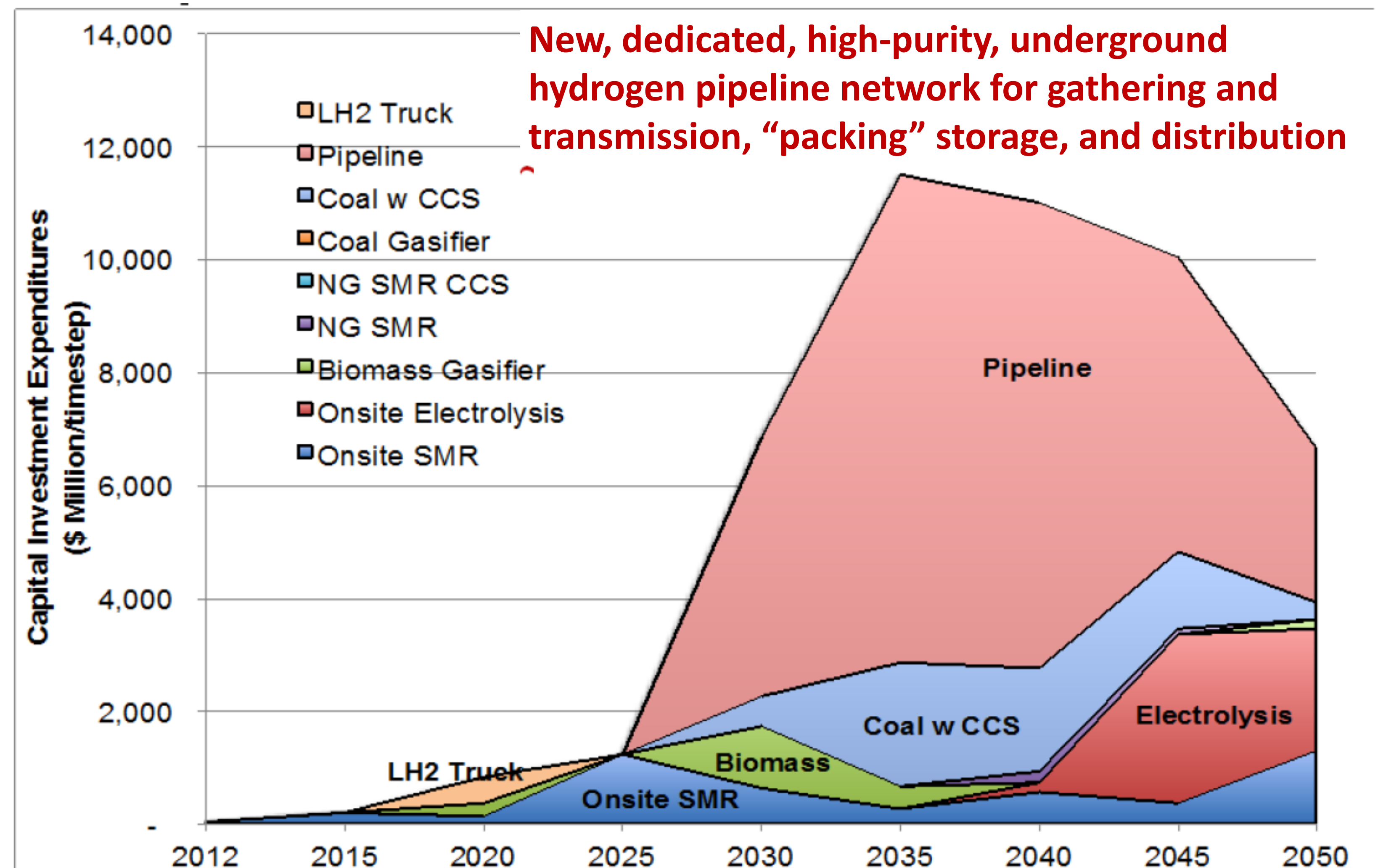


**Solar plants may be dedicated to Hydrogen fuel production, with  
no connection to the electricity grid, without costly conversion  
systems and infrastructure to deliver grid-quality AC or DC.**

### Gaseous Hydrogen Transmission Pipeline:

- > Underground
- > 100 bar
- > Free storage by "packing"

**The electrolyzer(s) are a dumb DC  
load, fed "wild DC" from PV arrays  
via simple power point tracking  
electronics and controls**



**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

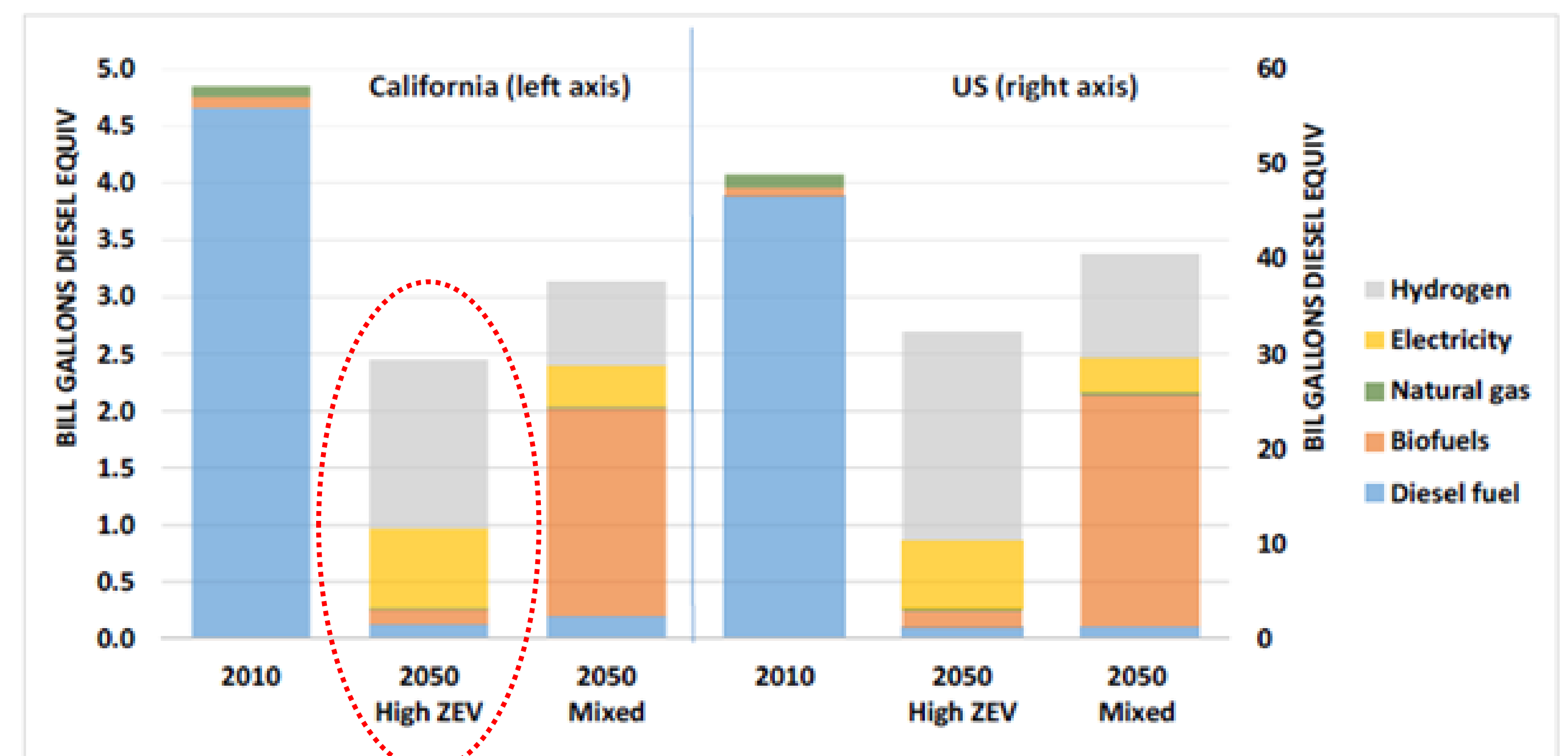


Figure ES-2. Energy use by fuel type, year and scenario, California and U.S. results

**"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

### 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.

**PV panels and arrays produce direct current (DC) which would be  
directly close – coupled to the electrolyzer stacks via power-tracking  
control . The SCADA system integrates the complete solar-to-  
Hydrogen plant, to reduce system complexity and capital and O&M  
costs, with no connection to the electricity Grid. This reduces  
electrolyzer kWh/e input per kg Hydrogen output, boosting energy  
conversion efficiency and reducing plant gate Hydrogen fuel cost .**

