

# 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://www.leightyfoundation.org/wp-content/uploads/POSTER-SOLAR-2018.pdf>

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

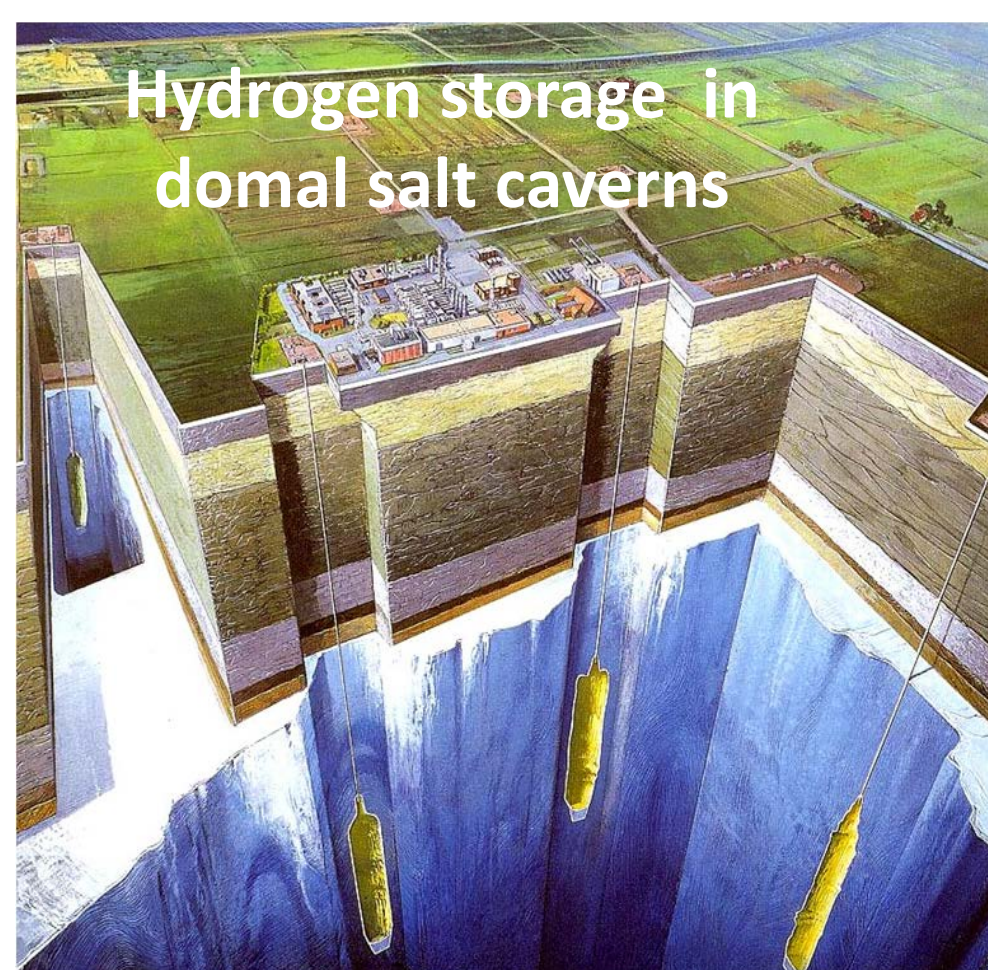
Light Duty Vehicles (LDV)	3.6
Trucking	1.6
Bus	1.4
Aviation and Other	0.8
<b>Total</b>	<b>7.4</b>

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

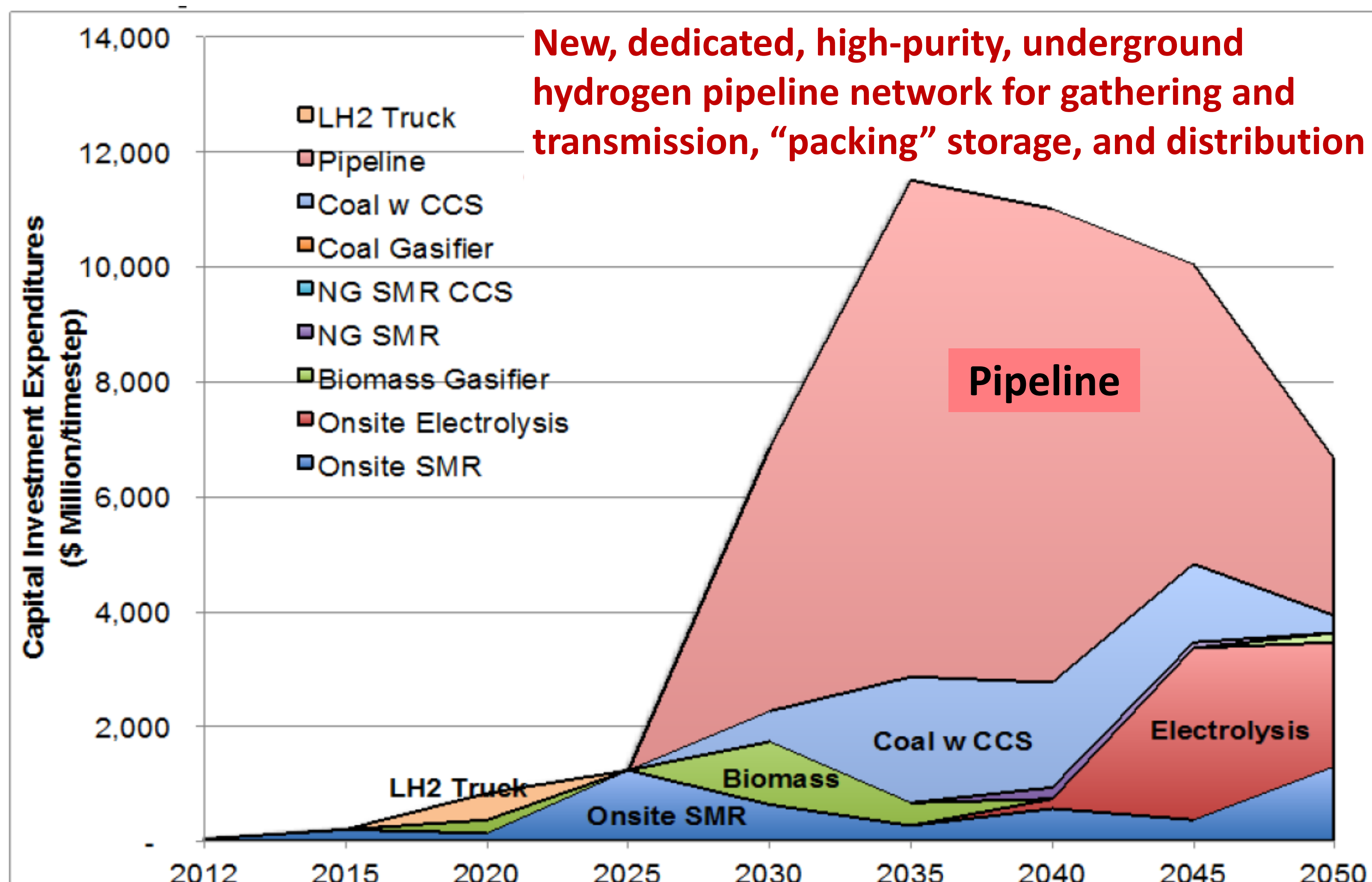
For Year 2050 Electricity + Hydrogen Transportation Fuel, California will need about:

- 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: [Mt = metric ton = 1,000 kg]

- Stores ~ 92 GWh as ~ 2,500 Mt "working" Hydrogen
- "Full" at 150 bar = 2,250 psi
- Cavern top ~ 700 m below ground
- ~ 860,000 cubic meters each cavern physical volume
- \$ 15 M average capex per cavern, with "cushion" H<sub>2</sub>
- Capex, approximate = \$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 CO<sub>2</sub> emissions from California transportation sector by year 2050  
Source: Institute of Transportation Studies (ITS), STEPS program, UC Davis

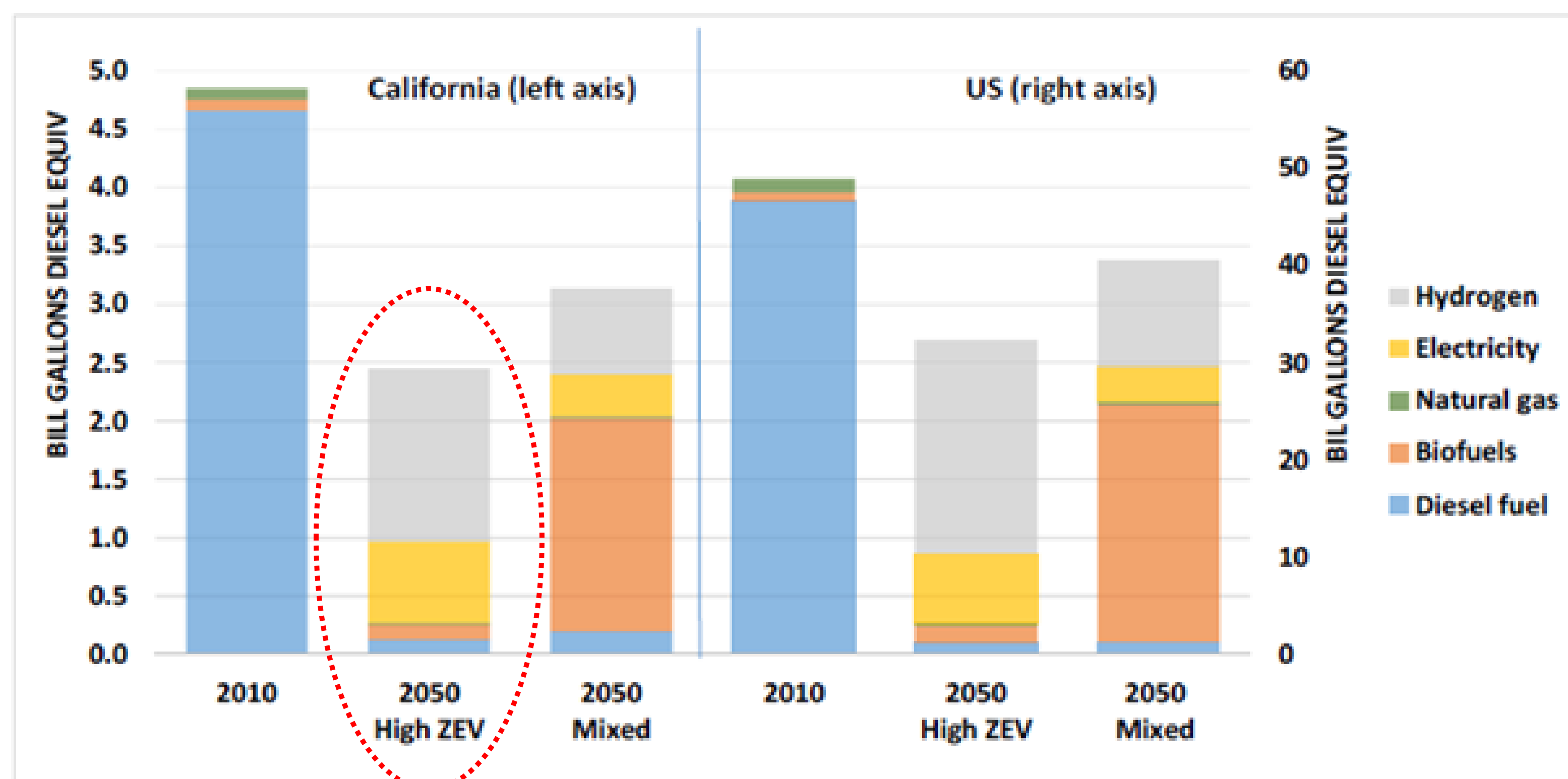
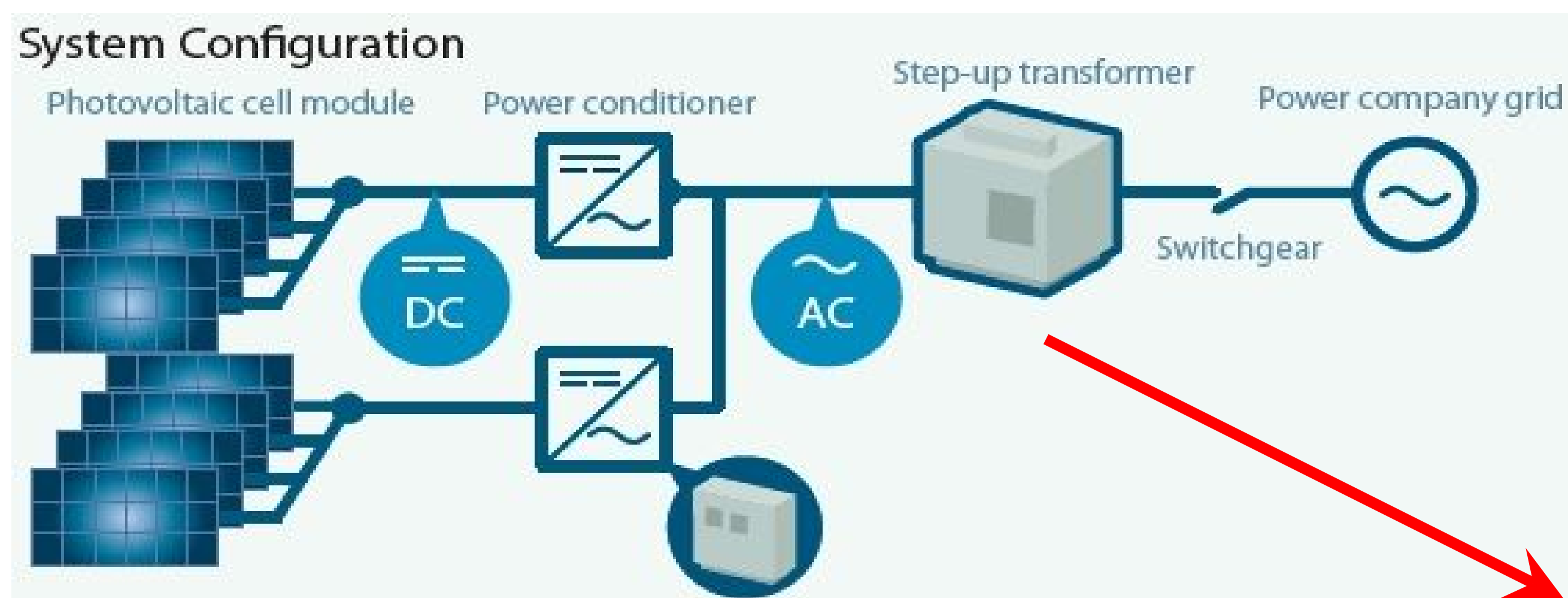
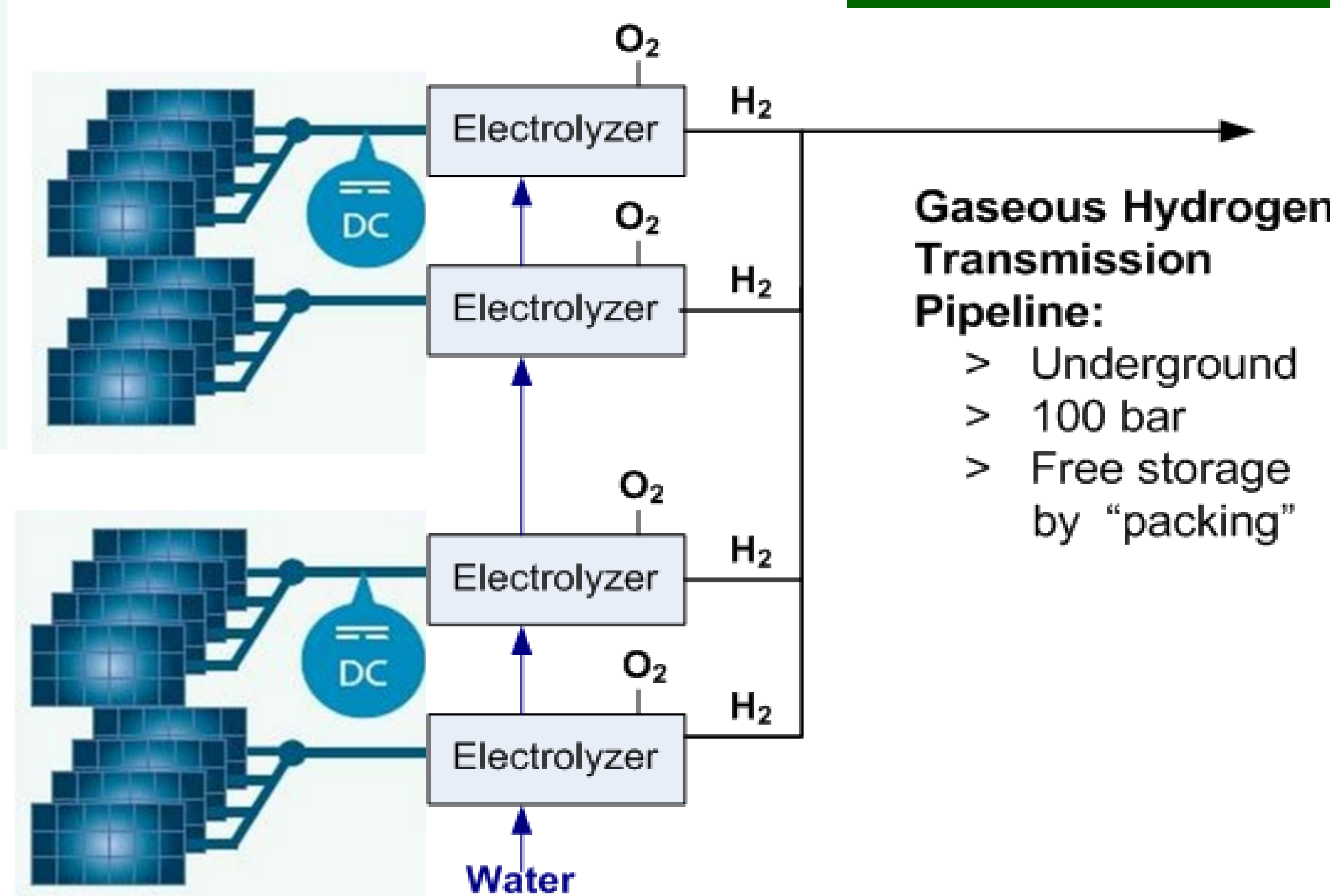


Figure ES-2. Energy use by fuel type, year and scenario, California and U.S. results

"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



**Simplified Solar plants:**  
> Dedicated to Hydrogen fuel production  
> No connection to, nor energy delivery to, Grid

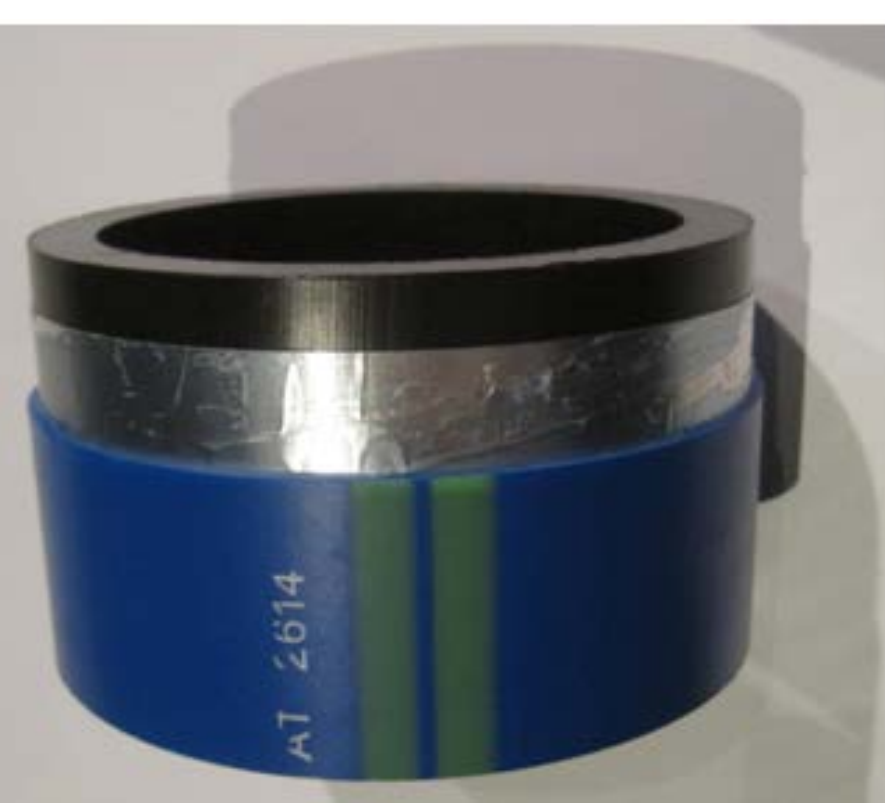


Solar plants may be dedicated to Hydrogen fuel production, with no connection to the electricity grid, without costly conversion systems and infrastructure to deliver grid-quality AC or DC.

### 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. Synergistic with "wild DC" from co-located wind plants also dedicated to Hydrogen production, without Grid connection.



**Gaseous Hydrogen (GH<sub>2</sub>) 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 GH<sub>2</sub> service. Must be 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 .