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

Colleagues,

Electricity IRP should include the prospect, presented in the attached poster presented at Windpower 2016, New Orleans, that in 2050 -- if CA succeeds in both its RPC and "80 in 50" goals -- the total annual demand for CO2-emission-free (CEF) transportation energy, as Hydrogen and / or Ammonia fuels, will exceed the total annual demand for CEF electricity for the Grid. This prospect now requires careful consideration of:
1. A large, new, dedicated, high-purity, underground, pipeline system for Gaseous Hydrogen (GH2) and / or Anhydrous Ammonia (NH3) fuels, for gathering, transmission, storage, delivery, and end-use of indigenous-source and imported CEF energy from diverse sources;
2. Given such a new pipeline system and the widespread availability of CEF GH2 and NH3 fuels, the prospect of demand for these fuels for stationary CHP and for industrial feedstocks;
3. Avoiding looming large investments in electricity Grid infrastructure as we struggle to make it larger, smarter, and resilient as we expect it to accommodate ever-larger fractions of its energy from time-variable generation (VG); such investments may be technically and economically suboptimal vis-a-vis GH2 and NH3 systems;
4. Hydrogen and / or Ammonia fuels supplying most of CA's transportation energy, especially in larger vehicles, as BEV's are limited by technical and economic forces to light-duty, short-distance duty.

Thank you for your consideration. You will find more analysis of, and support for, the above position in my co-authored work at: www.leightyfoundation.org/earth.php
Please see attached.

Additional submitted attachment is included below.

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

Bill Leighty, The Leighty Foundation, Juneau, AK wleighty@earthlink.net Poster download: http://leightyfoundation.org/w/wp-content/uploads/WP16-A.pdf

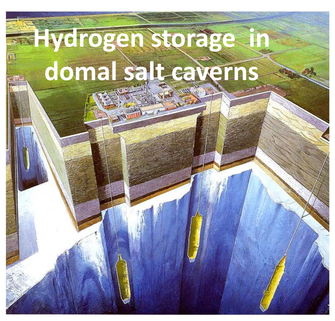
Hydrogen Transportation Fuel Demand California, year 2050 Million metric tons per year:

Light Duty Vehicles (LDV)	3.6
Trucking	1.6
Bus	1.4
Aviation and Other	0.8
Total	**7.4**

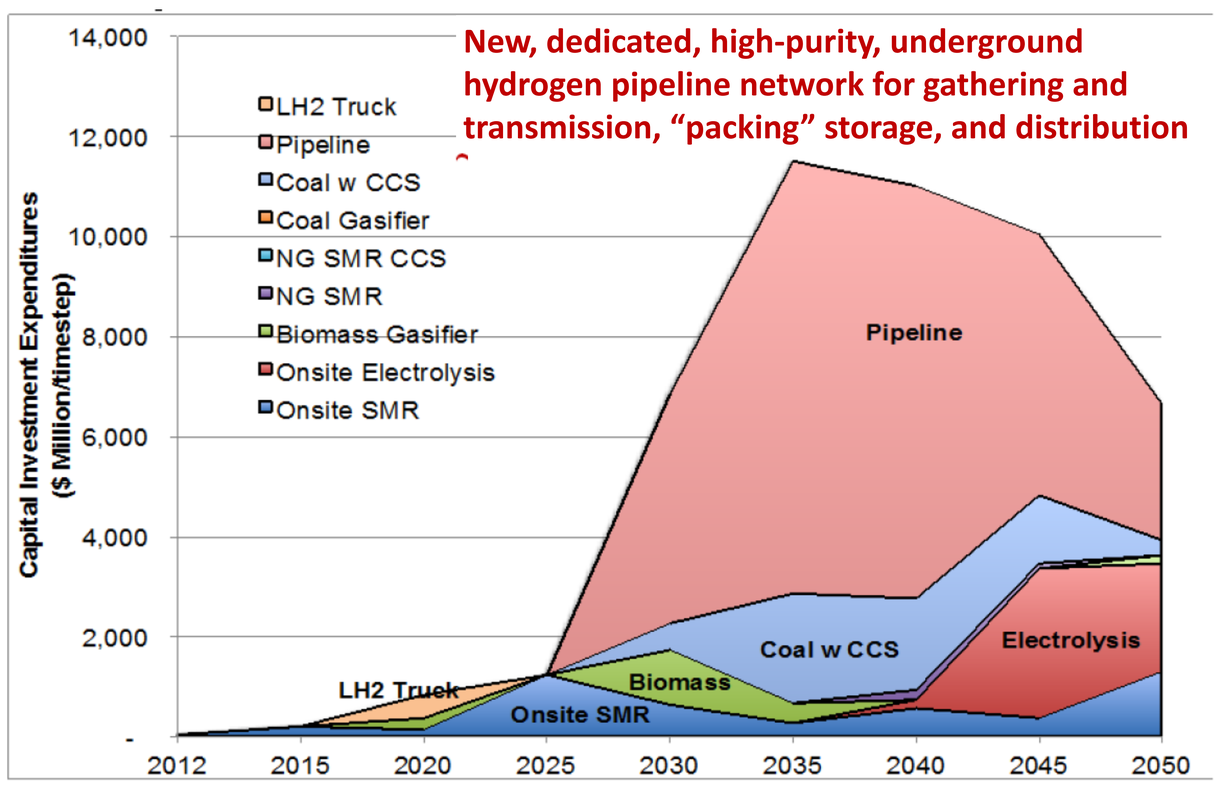
Source: interpret and extrapolate from several papers by ITS-STEPS, UC Davis

Reference: Year 2015	GW
Total installed nameplate wind generation in California (CA)	6
Total installed nameplate solar generation in California (CA)	12
ELECTRICITY: CA "Power Mix"	**GWh**
2014: Total electricity consumed	296,843
2050: Total electricity demand "Power Mix" is 130 % of 2014	385,896
ELECTRICITY in Year 2050: CA renewables	**GW**
Equivalent nameplate wind generation capacity @ 40 % CF	85
Equivalent nameplate solar generation capacity @ 35 % CF	97
TRANSPORTATION Hydrogen Fuel in Year 2050: CA renewables	**GW**
Equivalent nameplate wind generation capacity @ 40 % CF	126
Equivalent nameplate solar generation capacity @ 35 % CF	130
TOTAL CA RENEWABLE ELECTRICITY + TRANSPORT ENERGY in Year 2050	**GW**
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 CO_2 emissions from California transportation sector by year 2050
Source: Institute of Transportation Studies (ITS), STEPS program, UC Davis

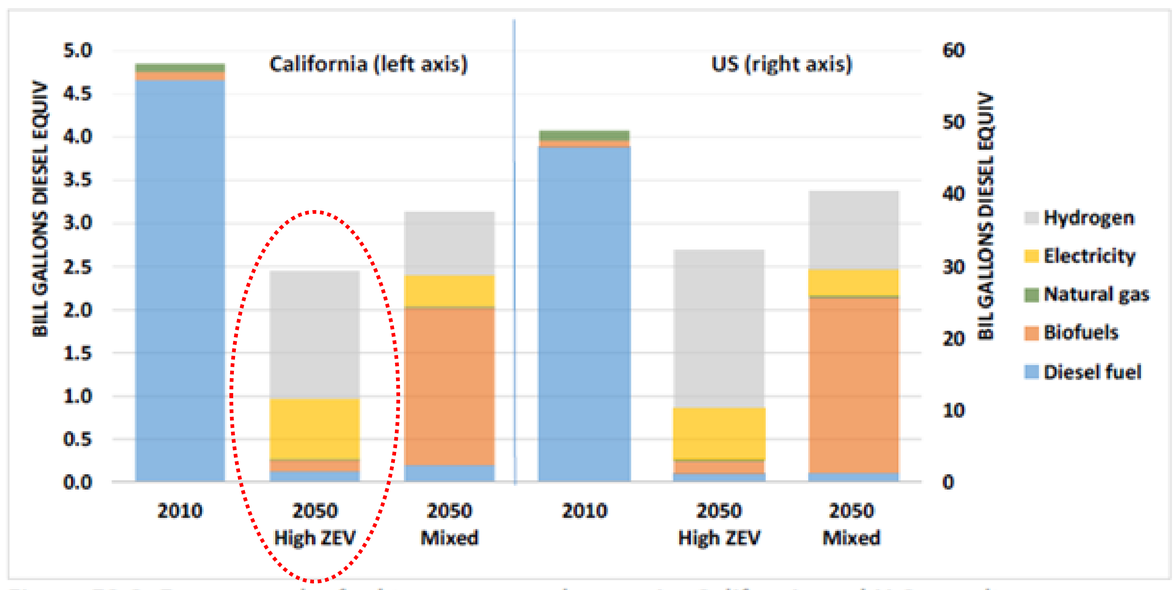
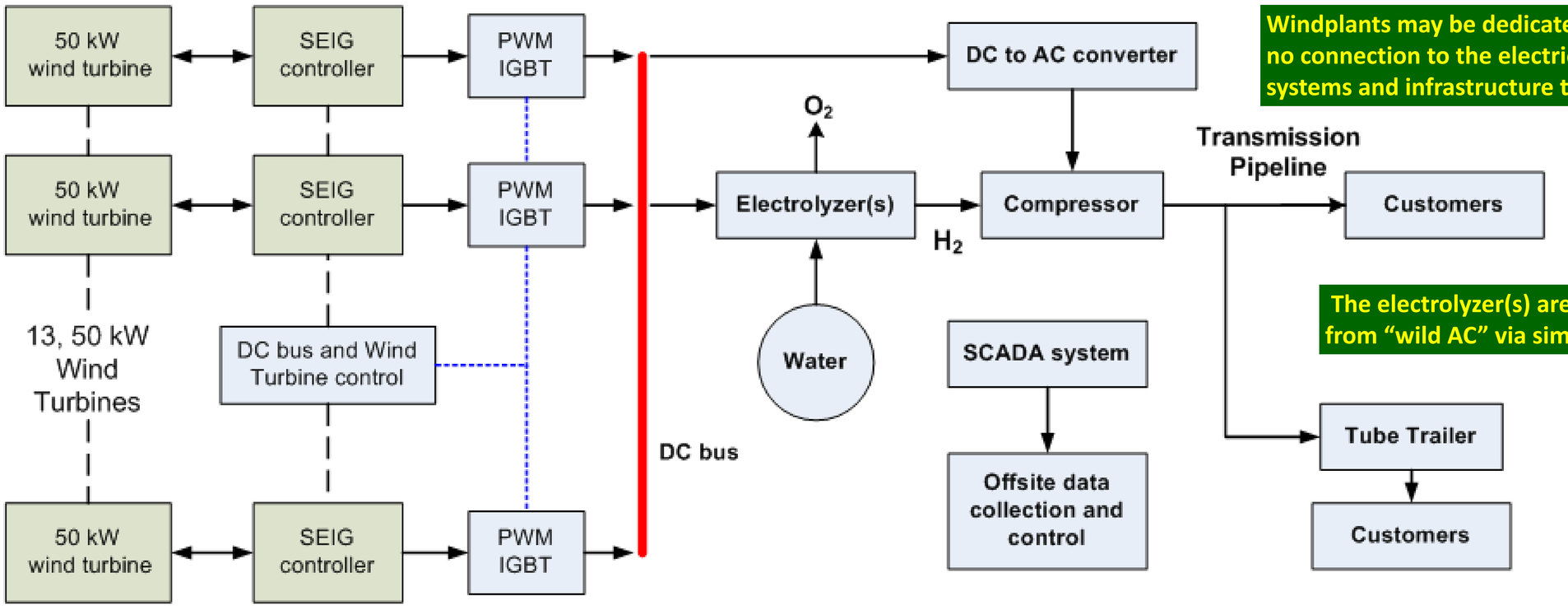


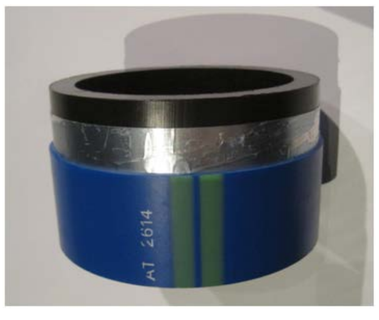
Figure ES-2. Energy use by fuel type, year and scenario, California and U.S. results

"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 May be made up to I 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 kWhe per kg Hydrogen and boost energy conversion efficiency, reducing plant gate Hydrogen fuel cost in several ways.