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New solicitations for Wind and Solar and Other in Alternative Fuel Production budget

Additional submitted attachment is included below.

Alaska Applied Sciences, Inc.
Box 20993, Juneau, AK 99802 907-586-1426

ARFVTP Colleagues, 12 Feb 16

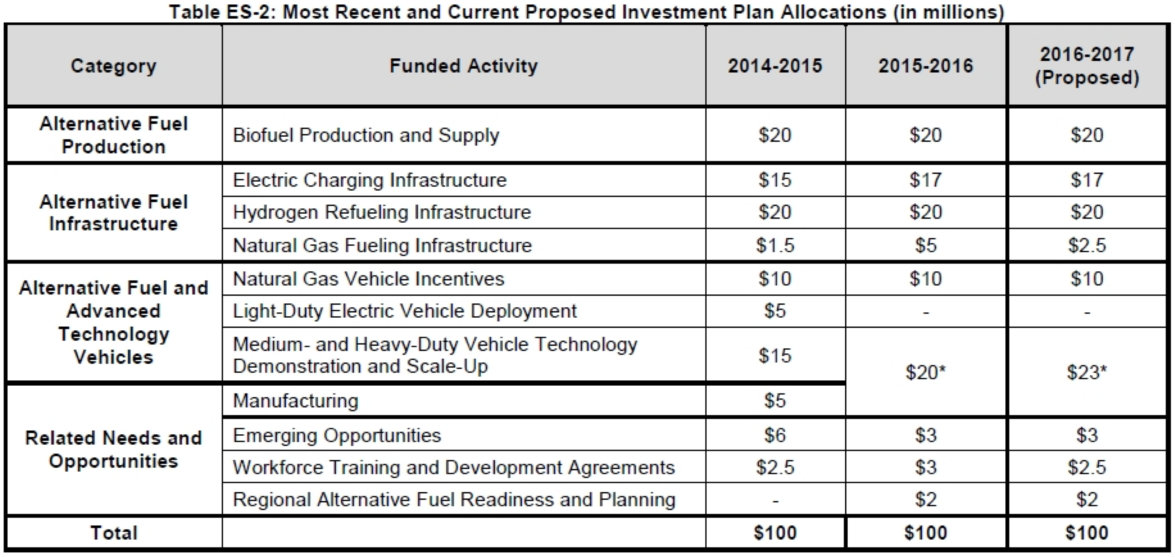
Please accept my comments for the 6 Nov 15 and 21 Jan 16 meetings of the Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP), which considered the staff draft of the "2016 - 17 Investment Plan Update … " I listened to most of the two meetings via WebEx, with my oral comment on 21 Jan. I appreciate Brian Goldstein's interest in renewable-energy-source Hydrogen fuel.
My presentation at Windpower 2015 [1] encouraged that industry to consider the large, nascent market for wind-source Hydrogen transportation fuel, especially in California (CA), where it may be larger than the electricity grid market, by year 2050.

Year 2050 estimated annual Hydrogen transportation fuel demand by sector, million tons (MMt):

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

Therefore, I suggest that the 2016 - 2017 Investment Plan Update, Table ES-2 below, allocate half of the $ 20 million Alternative Fuel Production budget, now designated as Biofuel Production and Supply, to new solicitations for Wind and Solar and Other, for the following several synergistic reasons.

Table ES-2: Most Recent and Current Proposed Investment Plan Allocations (in millions)



Category	Funded Activity	2014-2015	2015-2016	2016-2017 (Proposed)
Alternative Fuel Production	Biofuel Production and Supply	$20	$20	$20
Alternative Fuel Infrastructure	Electric Charging Infrastructure	$15	$17	$17
	Hydrogen Refueling Infrastructure	$20	$20	$20
	Natural Gas Fueling Infrastructure	$1.5	$5	$2.5
Alternative Fuel and Advanced Technology Vehicles	Natural Gas Vehicle Incentives	$10	$10	$10
	Light-Duty Electric Vehicle Deployment	$5	-	-
	Medium- and Heavy-Duty Vehicle Technology Demonstration and Scale-Up	$15	$20*	$23*
Related Needs and Opportunities	Manufacturing	$5		
	Emerging Opportunities	$6	$3	$3
	Workforce Training and Development Agreements	$2.5	$3	$2.5
	Regional Alternative Fuel Readiness and Planning	-	$2	$2
Total		$100	$100	$100

Source: California Energy Commission. *See the text of these respective sections in Chapters 5 and 6 for details on the proposal to combine these funding allocations.

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[1] https://vimeo.com/128484940

1. Figures 4, 5. Achieving CA's "80 x 50" and other statutory and regulatory goals will require ~ 4 to 8 million metric tons (MMt) per year of high-purity, zero-carbon-emissions, Hydrogen fuel for surface transportation (LDV, bus, truck and other goods movement), by year 2050. Aviation Hydrogen fuel, if that market develops, would require additional Hydrogen fuel, supporting Gov Brown's ambition to reduce CA's petroleum-source transportation fuel use. "80 x 50" cannot be achieved with BEV's alone; attempting to do so is technically and economically suboptimal: Figure 4.

2. For example, supplying ~ 8 million tons per year of Hydrogen fuel would require the full output of ~ 110 GW of nameplate wind generation at 40% capacity factor (CF), or its equivalent in solar or other CO2-emissions-free renewable energy generation. [2] Total wind generation now installed in CA is ~ 6 GW, all delivering electricity to the grid; we would also need ~ 18 times as much dedicated to transport fuel, in addition to the increased renewable electricity production required for that California energy sector 's goals.

3. Therefore, CA needs, now, via its several state laws and energy project funding programs, to:

a. Consider the implications of trying to supply the very large quantity of ~ 4-8 million tons per year of CO2-emissions-free Hydrogen transportation fuel for CA, an "8 Megaton Scenario", Figures 1 and 5:

(i) Has CA enough land and rooftops on which to harvest this amount of wind, solar, and other "green" Hydrogen fuel, in any transmission, annual-scale firming storage, and distribution scenario? What are the land use implications?

(ii) How can both "centralized" (large plants, usually far from demand centers, often without transmission) and "distributed" (connected to distribution lines for electricity or for fuels, often installed at point-of-use as rooftop solar often is) renewables generation best be accommodated ? As electricity, or as Hydrogen, Anhydrous Ammonia (NH3), or other net-zero-CO2-emission fuels ?

(iii) Figures 2, 3. How should CA consider importing a significant fraction of its Hydrogen transportation fuel ? From diverse Great Plains resources via transmission in 1- meter- diameter pipelines of ~ 8 GW capacity each ? Via marine tankers as Hydrogen-rich liquids -- cryogenic Hydrogen (LH2), NH3, Toluene (C7H8)- Methylcyclohexane (C7H14) cycle, from Alaska or other global sources ?
Japan is considering all three methods for importing CO2-emissions-free Hydrogen in large volume.

(iv) Should CA consider changing its transportation modal mix, to require less total transportation fuel in 2050, when population growth and sea level rise will have greatly changed CA demographics and probably urban topologies ?

b. Encourage large wind and solar plants dedicated to Hydrogen fuel production, with no connection to, nor energy delivery to, the electricity grid;

c. Fund R&D and Demonstration programs to design and commercialize novel wind-to-Hydrogen and solar-to-Hydrogen systems optimized for Hydrogen fuel production, transmission, storage, delivery, and end-use. This R&D, Design, and Demonstration strategy would include:

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[2] One 1 MW nameplate wind turbine will produce 8,760 MWh of electric energy per year @ 100 % capacity factor (CF); 3,500 MWh at 40 % CF. Electrolyzer efficiency may approach 50 kWh / kg Hydrogen; each MW of nameplate wind @ 40 % CF thus produces 70,000 kg H2 per year = 70 metric tons (Mt). 8 million Mt (MMt) Hydrogen fuel / year thus requires the full output of 110 GW wind generation nameplate @ 40 % CF: 14 GW per MMt H2 per year.

(i) Simplifying the wind and solar generators by eliminating the costly components necessary to deliver grid-quality electricity to AC or DC transmission lines;

(ii) Further simplifying wind generator design by replacing complex variable-speed generator systems with the Self Excited Induction Generator (SEIG), using the simple, robust, low-cost induction motor ;

(iii) Simplifying the electrolysis (Hydrogen generation) plant by eliminating the costly transformer-rectifier subsystem, driving the electrolyzer stacks directly from the SEIG system;

(iv) Both centralized and distributed “green” Hydrogen generation; considering NH3 fuel systems.
But, to satisfy this very large looming demand for "green" Hydrogen fuel, we probably do not want to:

- Build new electricity transmission, storage, and distribution infrastructure to gather, transmit, and deliver this large amount of energy from diverse, dispersed renewable resources, within and / or from beyond CA;
- Inflict on those renewable energy sources the cost of generating and delivering grid-quality AC or DC to the electricity "grid", if it is to be converted back to Hydrogen fuel at point-of-use, at considerable capital and energy conversion loss cost.

4. Figure 2. ARFVTP should recognize the Hydrogen fuel system opportunity embraced in the 2014 paper by J. Ogden, C. Yang, L. Fulton, "The Hydrogen Transition" by NEXTSteps, ITS, UC Davis, Figure 17, shown here as Figure 1. A $ 50 - 60 B investment, in CA, in Years 2025 - 2050, in new dedicated pipeline systems for gathering, transmission, storage, and distribution of high-purity Hydrogen fuel. [3]

5. Therefore, ARFVTP should begin now to encourage and fund R&D & Demonstration projects to discover and showcase paths to large-scale commercialization of high-purity Hydrogen fuel production from wind, solar, and other CO2-emissions-free energy sources to achieve:

- Lower-cost Hydrogen fuel, at the plant gate or other source terminals, and at the end-user's fueling station. At large scale, a 20 - 50 % cost reduction may be possible.
- Much larger geographic areas over which renewable energy (RE) can be harvested, without expansion of the electricity grid, assuming availability of new Gaseous Hydrogen (GH2) fuel pipeline systems. Novel polymer-metal tubing linepipe material, developed at Oak Ridge National Lab, with IP owned by Hydrogen Discoveries Inc., and with potential manufacture by Smart Pipe, Houston, may solve the hydrogen embrittlement problem of steel Hydrogen transmission pipelines at 100 bar Maximum Allowed Operating Pressure (MAOP) and the frequent pressure fluctuation characteristic of production from renewables. Figure 3. [4]
- "Free" energy storage in the GH2 pipeline system by "packing" the pipelines to MAOP when RE-source Hydrogen is available and surplus to demand, then drawing down pipeline pressure as customers withdraw Hydrogen fuel when RE-source energy production is reduced; this emulates the natural gas industry's routine pipeline "packing" storage practice which adds great value to their product and service.

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[3] http://steps.ucdavis.edu/files/08-13-2014-08-13-2014-NextSTEPS-White-Paper-Hydrogen-Transition-7.29.2014.pdf

[4] www.smart-pipe.com

- "The Hydrogen Transition" vision from ITS, UC Davis, above.

6. Therefore, the ARFVTP "2016 - 17 Investment Plan Update ..." should shift a significant fraction of the $ 20 M "Biofuel Production and Supply" in "Alternative Fuel Production" to a new solicitation for "transforming" the RE-source Hydrogen fuel supply to achieve the above goals. The new "Hydrogen Fuel Production from Wind and Solar Sources" solicitation would specifically fund R&D and Demonstrations:

- Plants and generators dedicated solely to Hydrogen fuel production, with no connection to, nor energy delivery to, the electricity grid.
- Feeding the future network of dedicated, high-purity, GH2 pipelines.
- Reducing Hydrogen fuel cost at the generator terminals, and at the plant gate, and at the end-user's fueling station.
- Increasing the geographic area in which Hydrogen fuel may be generated from diverse, rich (high intensity; large geographic area) RE resources.
- Especially synergistic public-private and other collaborations and partnerships.
- Projects that promised early production (< 12 months) of RE-source Hydrogen fuel for delivery and sale to nearby customers.
- Projects that optimize RE-source Hydrogen fuel system designs that relieve the wind and solar generators, especially, from the technical and cost burdens of delivering grid-quality AC to the electricity grid, instead optimizing the RE-to-Hydrogen system design to simplify the electrolysis system and its integration with the wind and solar generators.

Or, the ARFVTP "2016 - 17 Investment Plan Update ..." should shift funds from elsewhere in its $100 M budget, to prepare to meet the very large, looming demand for Hydrogen transportation fuel in CA. “Emerging Opportunities” may be a good vector.

7. For example, our company, Alaska Applied Sciences, Inc. (AASI) has owned a small, 13-turbine windplant in North Palm Springs for over 20 years, reliably delivering electric energy to the SCE grid, until the PPA terminated in June 2012. This would be an ideal test bed for an R&D and Demonstration project consistent with (5) and (6), above.

This project would include all 13 wind turbines, operating in experimental Self Excited induction Generator (SEIG) mode, feeding a state-of-art, custom-engineered, MW-scale electrolysis plant from a major supplier: Hydrogenics, Proton OnSite, and ITM Power were partners in our ARPA-E and NREL Small Business Voucher funding applications. NREL would do the system engineering, integrating innovative SEIG operation of the turbines using low-cost, rugged induction motors as generators, with the electrolysis plant, to reduce capital and O&M costs in a simpler wind-to-Hydrogen system which would produce about 11,000 kg of Hydrogen fuel per year. San Jose State Univ EE Department would design the novel SEIG system power electronics, integrated with NREL's engineering.

Catherine Dunwoody invited me to prepare a reduced-scale, proof-of-concept, lab-based engineering project to State of CA programs -- CARB, CEC, SCAQMD. Jim McKinney and several of his staff invited me to present and discuss this project plan at CEC on 2 Oct 15, leading to this comment letter.

AASI would propose this, or a similar project, if the "2016 - 17 Investment Plan“ included an appropriate solicitation. We imagine many others would also propose innovative and valuable projects.

8. Sunline Transit, Thousand Palms, CA, partnered with AASI on the ARPA-E application because they will need a large quantity of Hydrogen fuel when their fleet expands to about 7 fuel cell buses. They will need still more, if their public retail fueling station is upgraded and FCV's proliferate. Sunline is 15 miles from AASI's Palm Springs windplant. Sunline agreed to consider buying our wind-source Hydrogen fuel if we could deliver it to their site at acceptable purity, pressure, schedule, and price. Tube trailer transport from AASI windplant to Sunline would be required; IGX Group proposed to provide that service on contract.

9. If the Hydrogen pipeline network imagined in Figure 2 is built, and if CO2-emissions-free Hydrogen fuel is available at an attractive price, perhaps resulting from C-taxes, demand may increase beyond transportation fuel, to include stationary CHP, chemical plants, refineries, and other uses: a "Hydrogen Sector" of CA's nascent CO2-emissions-free total energy economy.

10. Conclusion: AASI suggests that the ARFVTP "2016 - 17 Investment Plan Update ..." should shift $ 5 - 10 million from elsewhere in its $ 100 M annual budget, to prepare to meet the very large, looming demand for Hydrogen transportation fuel in CA, via the strategy in (5) , (6), and (7), above. "Emerging Opportunities" seems also a good place for the wind-to-Hydrogen project described above. This may also apply to CA's "Integrated Energy Policy Report", which should include investigation of the "20 Megaton Scenario": potential CA annual demand for up to 20 million metric tons (MMt) (Megaton) of CO2-emissions-free "green" Hydrogen transportation fuel per year by Year 2050. 20 MMt of Hydrogen fuel per year would require the full output of ~ 285 GW of wind generation nameplate @ 40 % CF: 14 GW per MMT of Hydrogen fuel per year. Much would probably be imported into CA via GH2 pipeline.

CA is making great progress in Hydrogen fuel delivery. Now, CA needs to invest in CO2-emissions-free Hydrogen fuel production to achieve optimum system synergy with the large, new, necessary, Hydrogen pipeline infrastructure proposed by ITS, NEXTSteps, UC Davis. Figures 2 and 3. [3]

CA laws, regulations, and Gov Brown's ambitions will require extraordinary commitments of technology innovation, capital, and probably urban transport reconfiguration. CEC, CARB, and the ARFVTP Advisory Committee need to recalibrate now, before committing to the 2016-17 Investment Plan.

We will advise ARFVTP if AASI's application for a $ 300 K NREL Small Business Voucher for the SEIG-driven wind-to-Hydrogen R&D & Demonstration succeeds. In that case, State of CA funding would greatly enhance the project, probably enabling significant Hydrogen fuel production at, and sale of fuel from, AASI's repurposed Palm Springs windplant. [5]

Thank you for your consideration.

Bill Leighty
Principal, Alaska Applied Sciences, Inc. (AASI)
Director, The Leighty Foundation (TLF)
www.leightyfoundation.org/earth.php
Box 20993, Juneau, AK 99802-0993
907-586-1426 Cell 206-719-5554
wleighty@earthlink.net

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[5] AASI Palm Springs windplant operation video: https://vimeo.com/86851009

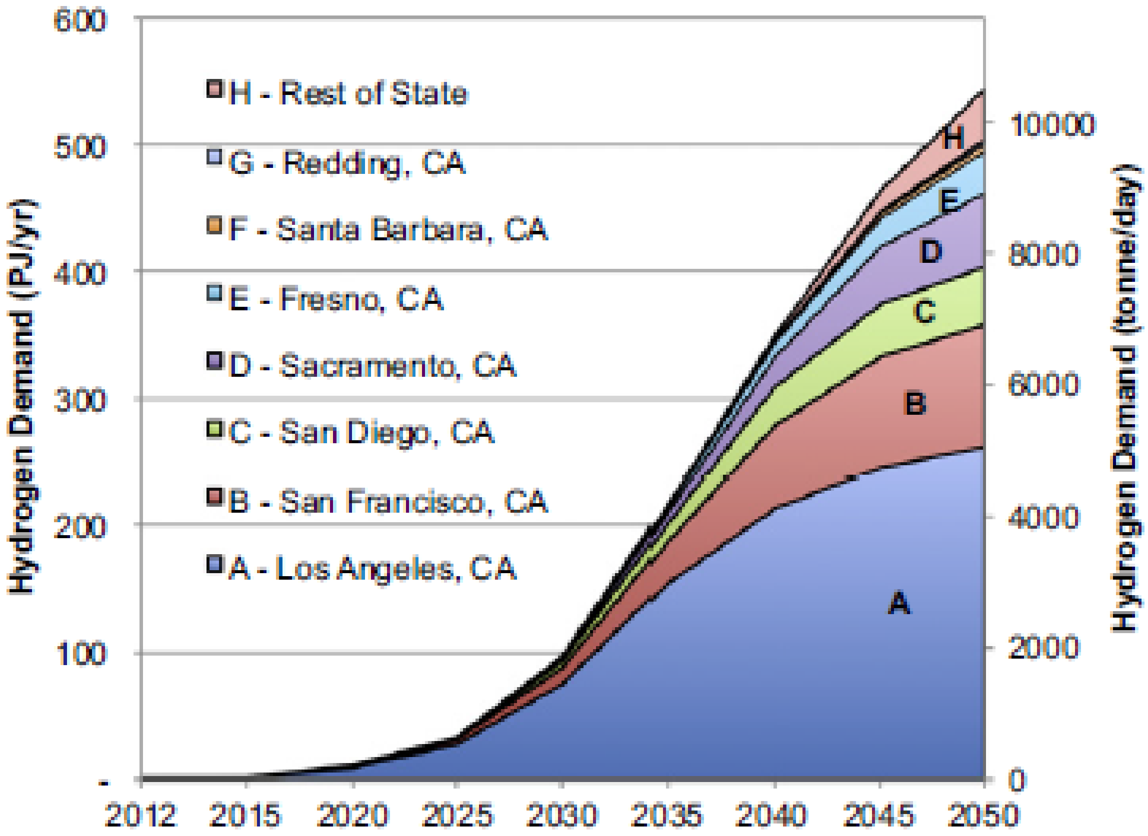

Figure 1. Exogenously specified California LDV Hydrogen fuel demand to 2050 broken out by regional cluster (1 PJ H2/yr [19.3 Mt H2/day]). 10,000 metric tons (Mt) per day is ~ 3.65 million Mt (MMt, i.e. Megaton) per year. Source: Figure 3, "Renewable and low carbon hydrogen for California: Modeling the long term evolution of fuel infrastructure using a quasi-spatial TIMES model ".

"FCVs make up 1% of vehicles in 2020, 11% of vehicles in 2030, 43% in 2040 and 65% (or 26 million LDVs) in 2050. FCVs are assumed to drive 14,000 miles per year and average FCV efficiency is 55 miles/kg H2 in 2012, 79 miles/kg H2 in 2030 and 96 miles/kg H2 in 2050." [3]

Year 2050 estimated annual Hydrogen transportation fuel demand by sector, million tons (MMt):

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

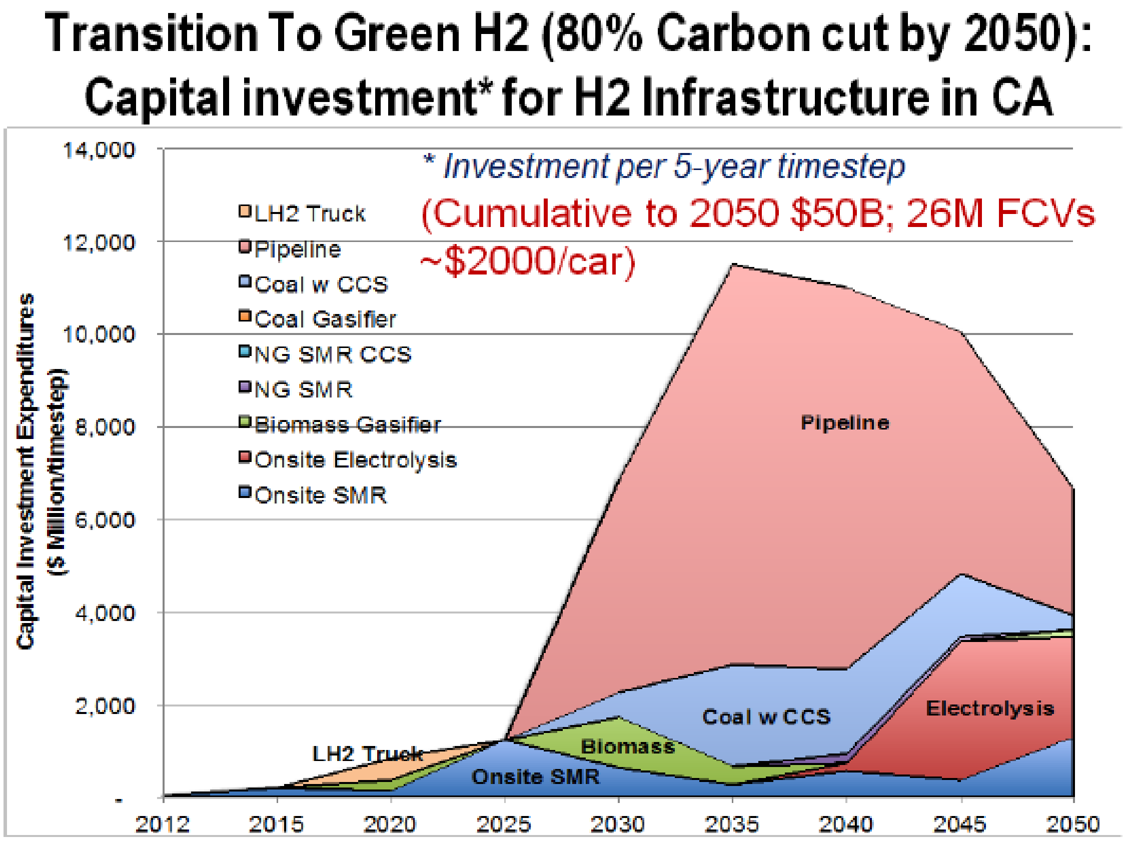

Figure 2. A possible mix for hydrogen supply over time to reduce vehicle GHG emissions by 80% compared to a gasoline reference vehicle. Source: Fig 17, "The Hydrogen Transition", ITS, UC Davis [3]

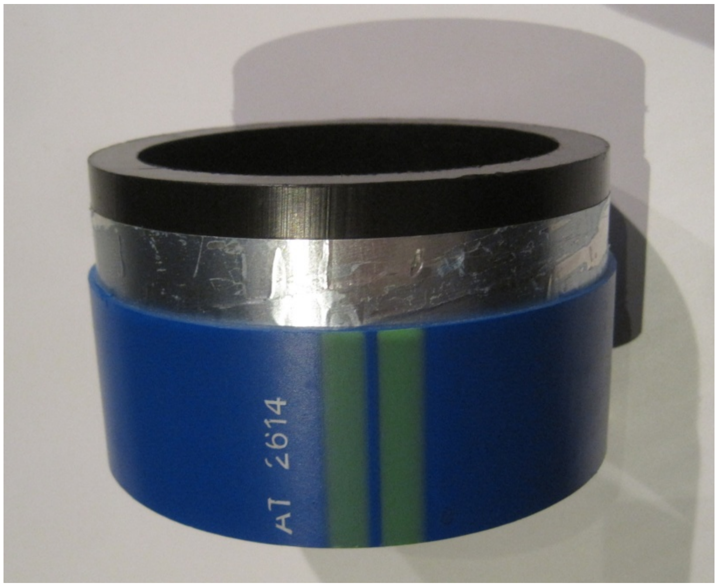

Figure 3. Polymer-metal hybrid tubing concept sample, from Smart Pipe, Houston, www.smart-pipe.com May be made up to I meter diam for GH2 transmission pipelines; smaller for gathering and distribution lines. Has not been tested for 100 bar gaseous hydrogen (GH2) service. Fabricated in an on-site, trenchside factory in continuous, unlimited lengths without splices.

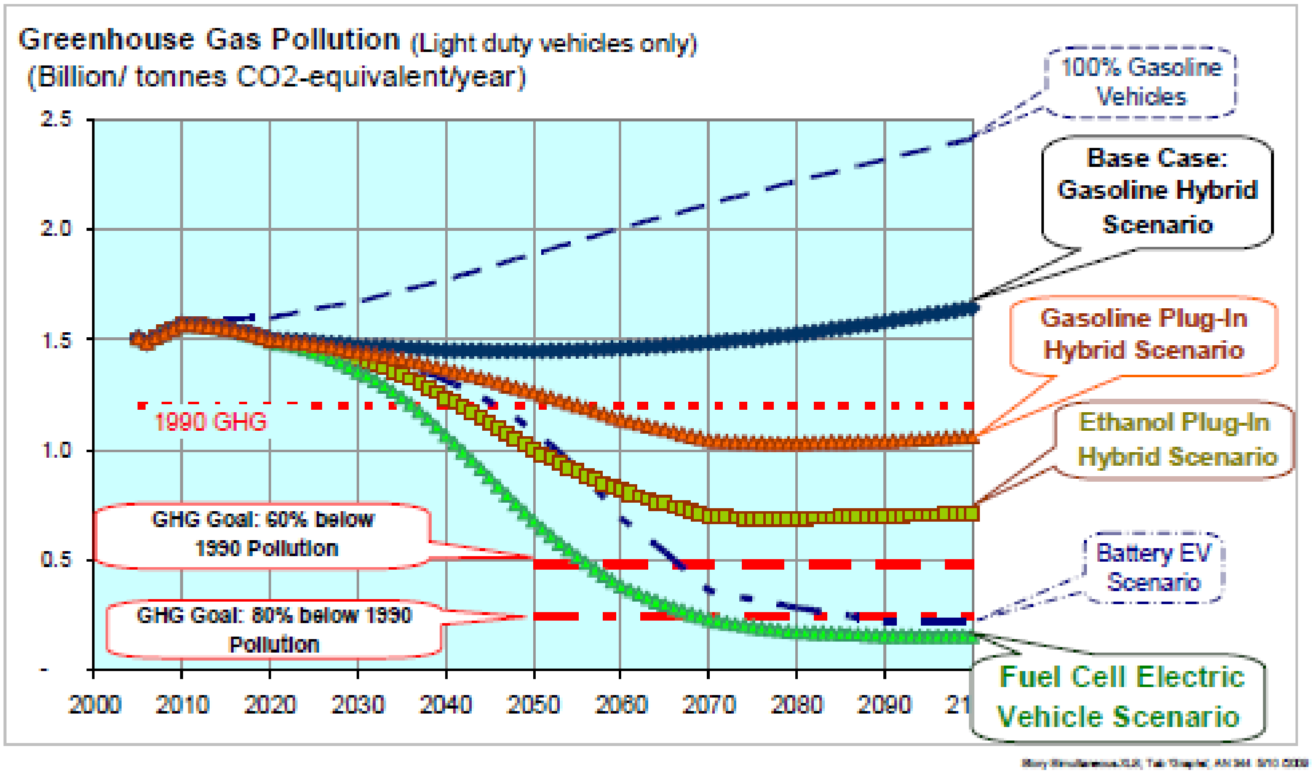

Figure 4. California's "80 x 50" goal of 80% reduction in CO2 emissions from transportation below 1990 level by 2050 cannot be achieved for LDV's by BEV's alone. FCV's will be required. Source: Sandy Thomas, 2009, IJHE

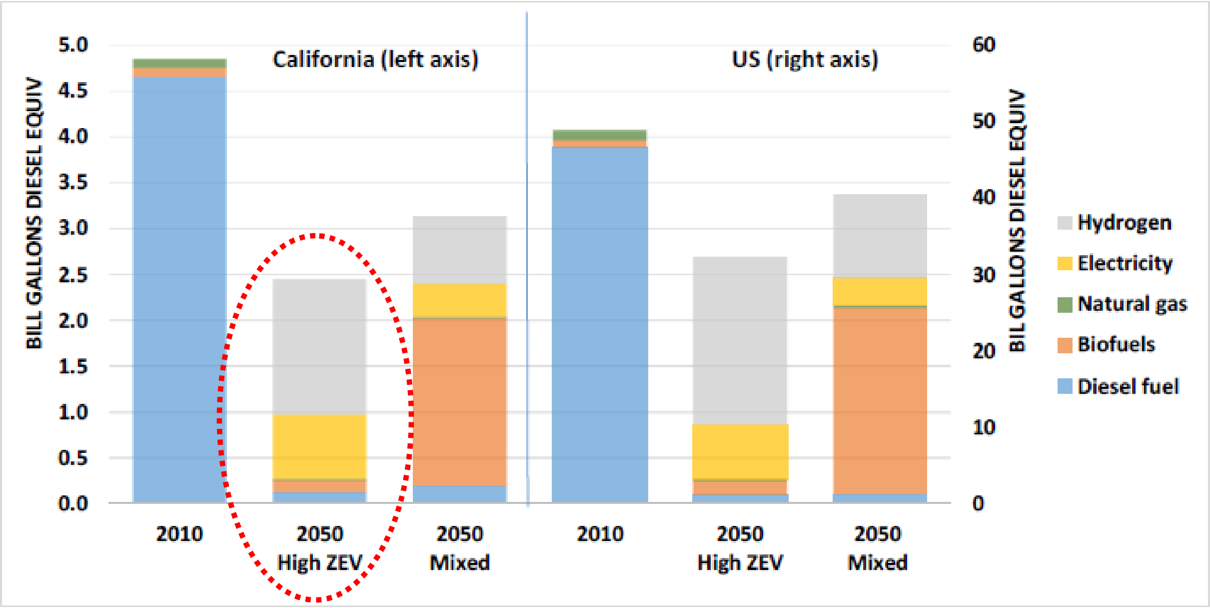

Figure ES-2. Energy use by fuel type, year and scenario, California and U.S. results

Figure 5. Left: California only , "2050 High ZEV" case, annual: ~ 1.4 billion gallons diesel equivalent is ~ 1.6 million tons Hydrogen per year.
Right: USA total annual "trucking" sector fuel. The "High ZEV" scenario requires Hydrogen fuel equivalent to ~ 22 billion gallons of diesel fuel: ~ 25 million tons of CO2-emissions-free Hydrogen fuel; diesel volumetric energy content is higher than gasoline. Source: Slide 10, Lew Fulton presentation, Asilomar , 19 Aug 15.

Source: L. Fulton, M. Miller, ITS, UC Davis, http://ncst.ucdavis.edu/white-paper/ucd-dot-wp3-1b/