



Chair Mary Nichols
California Air Resources Board
1001 I St.
Sacramento, CA 95814

November 16, 2020

Dear Chair Nichols:

The California Hydrogen Business Council (CHBC)¹ greatly appreciates CARB taking the lead on examining how to achieve carbon neutrality economy wide by 2045, as called for in Executive Order B-55-18. **We welcome the general inclusion of hydrogen in E3's analysis for heavy duty vehicles, rail, electricity generation, industry, and agriculture. We also appreciate that the latest analysis recent reflects more optimistic electrolytic hydrogen costs than prior work, but it is still somewhat higher than other sources, so we suggest that E3 additionally apply optimistic cases that reflect optimistic forecasts by industry and other sources. We also suggest they apply more optimistic analyses of marginal abatement costs. Lastly, we urge hydrogen to also be considered as an important solution for reducing emissions in additional applications, such as passenger vehicles, shipping, aviation, and building energy. These concerns are elaborated on below.**

We suggest E3 apply most recent optimistic cost assumptions for electrolysis.

In the Carbon Neutrality report's cost data supplement, E3 assumes the 2045 price of electrolytic hydrogen for power generation will be between \$14.50/MMBtu (optimistic) and \$25.00/MMBtu (conservative). They project the 2045 price of electrolytic hydrogen for industry use to be between \$10.50 (optimistic) and \$21.00 (conservative). These projections, especially for electricity generation, are significantly higher than those of some global analysts. UC Irvine wrote in their recent white paper, *The Potential Impact of Renewable Gaseous Fuel on Optimizing the California Renewable Portfolio, RESOLVE Model Analysis*, "a growing number of forecasts project that electrolytic renewable hydrogen cost could reach levels as low as \$1/kg

¹ The CHBC is comprised of over 100 companies and agencies involved in the business of hydrogen. Our mission is to advance the commercialization of hydrogen in the energy sector, including transportation, goods movement, and stationary power systems to reduce emissions and dependence on oil. The views expressed in these comments are those of the CHBC, and do not necessarily reflect the views of all of the individual CHBC member companies. Members are listed here: www.californiahydrogen.org/aboutus/chbc-members/



(\$8/MMBtu) by 2050 with some projecting that cost point by 2030.^{2,3} More conservative forecasts project cost in the \$3/kg (\$24/MMBtu) range by 2030 declining to \$2/kg by 2050.”⁴ Below is a graphic representing the cost of renewable hydrogen injected onto the natural gas grid, using UC Irvine Advanced Power and Energy Program analysis for the CEC-sponsored Renewable Hydrogen Roadmap.⁵

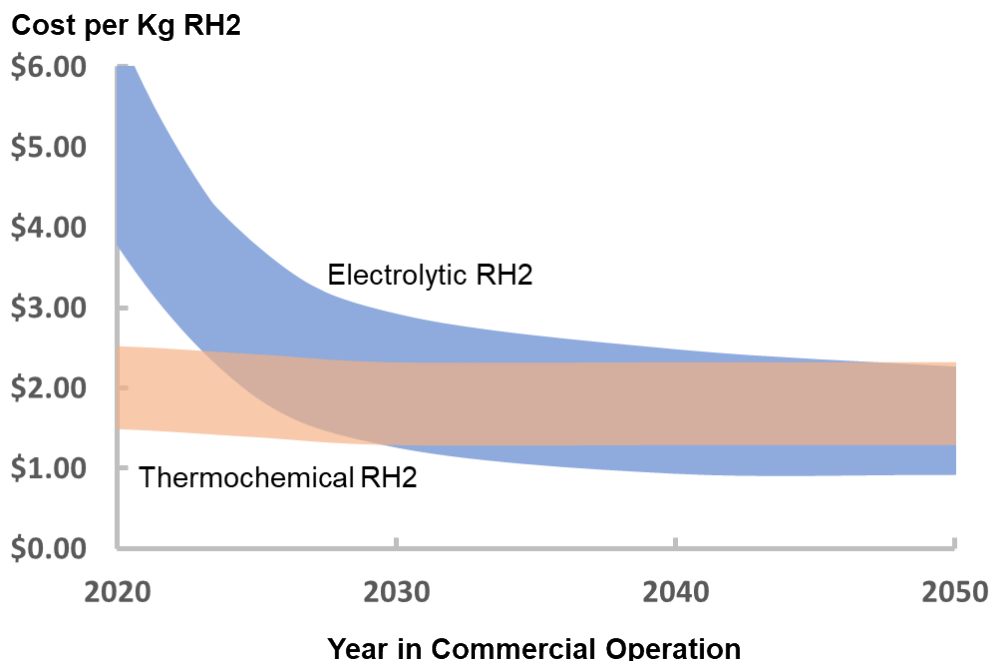


Figure 3. Evolution of Gas-System Injected Renewable Hydrogen Cost

² Bloomberg New Energy Finance, *Hydrogen Economy Outlook, Key Messages*, p.4; March 2020

<https://data.bloomberglp.com/professional/sites/24/BNEF-Hydrogen-Economy-Outlook-Key-Messages-30-Mar-2020.pdf>

(footnote copied from Dr. Jeffrey Reed, September 2020 *The Potential Impact of Renewable Gaseous Fuel on Optimizing the California Renewable Portfolio, RESOLVE Model Analysis*)

³ Using analysis by McKinsey, the Hydrogen Council’s *Path to Hydrogen Competitiveness – A Cost Perspective*, on p. 15, concludes: “Within five to ten years – driven by strong reductions in electrolyser capex of about 70 to 80 per cent and falling renewables’ levelised costs of energy (LCOE) – renewable hydrogen costs could drop to about USD 1 to 1.50 per kg in optimal locations, and roughly USD 2 to 3 per kg under average conditions.” (footnote copied from Dr. Jeffrey Reed, September 2020 *The Potential Impact of Renewable Gaseous Fuel on Optimizing the California Renewable Portfolio, RESOLVE Model Analysis*)

⁴ p. 4,

http://www.apep.uci.edu/PDF_White_Papers/Impact_of_Renewable_Gaseous_Fuels_on_Grid_Resource_Optimization_Using_RESOLVE.pdf

⁵ Reed, Jeffrey G, Emily E Dailey, Brendan P Shaffer, Blake A Lane, Robert J Flores, Amber A Fong, and G Scott Samuelsen. 2020. “Roadmap for the Deployment and Buildout of Renewable Hydrogen Production Plants in California.”



Likewise, E3's assumed marginal abatement cost (\$151-350/tCO₂e) to decarbonize firm power is high compared to other global analyses.

As stated in our comments on the draft E3 Carbon Neutrality report, this is vastly higher than an assessment by Bloomberg New Energy Finance (BNEF), which estimates that over the long term, a carbon price of \$32/tCO₂ would be enough to drive fuel switching from natural gas to hydrogen, and generate clean, dispatchable power at a competitive price.”⁶ Notably, another study finds that by optimizing renewable electricity with electrolytic hydrogen and synthetic methane, California can achieve to carbon neutrality five years ahead of the state's 2045 target, saving eight billion dollars and minimizing land use.⁷ Lawrence Berkeley National Laboratory found in a recent study that gasification of biomass to produce hydrogen is actually the lowest cost pathway to reach net negative carbon. We urge the agencies to rigorously review cost assumptions of achieving zero carbon firm power to achieve carbon neutral electricity system wide.

The CHBC continues to support CARB taking a more comprehensive modeling approach to its carbon neutrality effort.

As the CHBC and several others opined in our initial comments on the draft Carbon Neutrality Report, CARB ought to consider other modeling approaches in its carbon neutrality planning for the state of California. Other approaches to consider include National Renewable Energy Laboratory's analysis for the Los Angeles Department of Water and Power's transition to 100% renewable energy, which integrates multiple additional data points missing from the E3 study, like reliability and environmental justice.⁸ Notably, all scenarios in the study include green electrolytic hydrogen used in fuel cells and combustion turbines, as soon as 2030. The “LA Leads” scenarios use green electrolytic hydrogen to displace all fossil natural gas and achieve a 100 percent zero-carbon electricity system for Los Angeles by 2035.⁹ The European Commission also took a holistic, technology inclusive approach to studying optimal roadmaps to greenhouse gas reduction for the European Union, which merits review. The study found that to reduce greenhouse gas reductions by more than 80% economy wide by 2050, single pathways such as

⁶ <https://data.bloomberglp.com/professional/sites/24/BNEF-Hydrogen-Economy-Outlook-Key-Messages-30-Mar-2020.pdf> (pg. 7)

⁷ <https://www.path100.org/wp-content/uploads/2020/03/path-to-100-renewables-for-california.pdf>

⁸ <https://www.nrel.gov/analysis/los-angeles-100-percent-renewable-study.html>

⁹ https://www.ladwp.com/cs/idcplg?IdcService=GET_FILE&dDocName=OPLADWPCCB726105&RevisionSelectionMethod=LatestReleased



electrification, efficiency or hydrogen will not work, but rather this will require deploying a cost-efficient combination of hydrogen and electrolytic fuel with electrification, efficiency, and resource use efficiency.¹⁰ This finding contributed to the European Commission including hydrogen as a pillar of its proposed carbon neutrality policy program¹¹ and as one of the main solutions that holds a “key to Europe’s future” in its green stimulus plan.¹² The CHBC supports such approaches, like those in Europe and Los Angeles, to rigorously consider all zero carbon fuels and electricity options and how they can be optimized in different combination to achieve greenhouse gas reductions, cost-effectiveness, reliability, justice, resource use, air quality and other state priorities.

The CHBC appreciates the report recognizing in the Balanced and Zero Carbon scenarios that hydrogen fuel cell technology stands to play a major role in heavy duty transportation and rail, but strongly disagrees with the omission of hydrogen fuel cell options for light duty vehicle (LDV)/medium duty vehicle (MDV) from all scenarios.

We are heartened that two out of three scenarios E3 presents in the Carbon Neutrality report recognize the importance of hydrogen fuel cell electric technology in reaching carbon neutrality in California’s Heavy Duty ZEV (HDV) sector, and that all scenarios acknowledge the importance of hydrogen for rail applications. However, omitting hydrogen fuel cell options for LDVs is inconsistent with state policy, which has long included both BEVs and FCEVs and their respective infrastructure in ZEV policy, nor with global forecasts regarding cost competitiveness. Numerous state policies, including Governor Brown’s and Governor Newsom’s ZEV Executive Orders, AB 8 and SB 1505, include hydrogen fuel cell vehicles and fueling as a pillar of California’s strategy to transition to zero emissions transportation. The Hydrogen Council with McKinsey also projects that hydrogen fuel cell passenger vehicles will be cost competitive in the next 5-10 years, particularly for larger weight models like SUVs and longer ranges of over about 125 miles.¹³ This is particularly significant since the California vehicle sales market is trending toward SUVs.¹⁴ Similar findings were made in a European Union multi-

¹⁰ https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_analysis_in_support_en_0.pdf

¹¹ https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf

¹² p. 8 https://eur-lex.europa.eu/resource.html?uri=cellar:4524c01c-a0e6-11ea-9d2d-01aa75ed71a1.0003.02/DOC_1&format=PDF

¹³ p. 34 https://hydrogencouncil.com/wp-content/uploads/2020/01/Path-to-Hydrogen-Competitiveness_Full-Study-1.pdf

¹⁴ This was reported by presenters at a June 11 IEPR Update workshops focused on Transportation Trends and a Light-Duty Zero-Emission Vehicle Market Update. See, e.g., Presentation by Jesse Gage, CEC Energy Assessments



stakeholder study on the role of BEVs, PHEVs, and FCEVs, which reported that FCEVs in larger passenger vehicle applications cost less to abate CO₂ than BEVs or PHEVs.¹⁵

It is also important to bear in mind that FCEVs are key to enabling equitable and affordable access to ZEVs because multi-unit dwellings and on-street parking do not typically provide easy access to EV charging, making centralized hydrogen refueling the more pragmatic ZEV fueling option for many Californians, including many if not most low-income drivers. More than 80% of EV drivers charge at home, due to convenience and cost effectiveness.¹⁶ However, many Californians live in homes where EV charging is not easy or affordable. Nearly half of homes in the state are not single detached units.¹⁷ Moreover, low-income people are most likely to live in rental units where EV charging is unavailable and cost prohibitive to install. Hydrogen refueling for FCEVs, by contrast, is centralized and with capital investment can be similar in convenience and accessibility to conventional gasoline fueling. To ensure that driving a ZEV will be equitably available to all California drivers, state policy must equally support advancement of FCEVs and hydrogen fueling along with BEVs and EV charging.

We also urge future reporting to examine the potential for hydrogen-based fuels to decarbonize shipping and aviation.

We furthermore disagree with the report's omission of hydrogen-based fuels to achieve carbon neutrality in shipping and aviation. Hydrogen has been gaining interest as a solution in these hard to abate applications for some time and is now a major piece of international developments. A study by the Global Maritime Forum (GMF) tracked 66 zero emissions shipping projects and found 19 of the 21 related to fuel production used some form of hydrogen.¹⁸ Airbus recently announced it aims to make three hydrogen fueled aircraft that seat up to 200 people by 2035.¹⁹ We urge CARB to include hydrogen solutions for shipping and aviation in future analysis.

Division *Light-duty vehicle trends Heavier, yet more efficient* <https://www.energy.ca.gov/event/workshop/2020-06/session-1-light-duty-zev-update-and-trends-larger-vehicles-iepr-commissioner>

¹⁵ *A Portfolio of Power Trains for Europe: A Fact-based Analysis, Executive Summary*, European Climate Foundation et al. See p. 42 https://www.fch.europa.eu/sites/default/files/documents/Power_trains_for_Europe.pdf

¹⁶ <https://www.energy.gov/eere/electricvehicles/charging-home>

¹⁷ <https://www.infoplease.com/us/census/california/housing-statistics>

¹⁸ <https://gcaptain.com/shipping-hydrogen-net-zero/>

¹⁹ <https://www.airbus.com/newsroom/press-releases/en/2020/09/airbus-reveals-new-zeroemission-concept-aircraft.html>



Omission of zero carbon fuel, including hydrogen, for all building scenarios is also short sighted, and future analysis ought to consider zero carbon hydrogen technologies for buildings where direct electricity for all end uses risk negative cost and reliability impacts.

State carbon neutrality analysis ought, first of all, to include flexible indirect electrification solutions like fuel cells that use hydrogen to produce electricity and electrolyzers that use clean electricity to make hydrogen. Including fuel cell and electrolyzer technology in programs that seek to maximize opportunities for demand flexibility would also be aligned with research being done at the federal level.²⁰

A growing group of experts champion hydrogen as an important solution to consider for building decarbonization. For example:

- E3's study on *Residential Building Decarbonization in California* suggests that close to half new single-family homes and a third of multi-family homes would potentially have increased energy bills of \$100 or more a year, if they are built all electric.²¹ This suggests that what may be most efficient or economic for some homes may be uneconomical for others, and that a more diverse set of options to decarbonize, beyond all electrification, would be more appropriate. The report specifically recommends that California ought to presently pursue developing both electrification *and* renewable gas pathways in the near-term because of the fact that both depend on nascent technology markets.²² The report also suggests that in the long-term, the cost-effectiveness of this approach depends on progress being made on commercialization of electrolytic hydrogen technology²³
- NRDC supports green hydrogen for buildings as a part of a climate and green jobs strategy.²⁴
- A recent ICF study (2019)²⁵ to evaluate the role of gas utilities in a decarbonized world evaluated that the high cost of building electrification would likely "crowd out" other cost-effective alternatives to help reduce building related emission. The analysis further points out that the annual cost per household under technology neutral decarbonization is cheaper than full residential electrification (the annual estimated cost per house hold

²⁰ See, e.g. NREL research on *Dynamic Modeling and Validation of Electrolyzers in Real Time Grid Simulation* https://www.hydrogen.energy.gov/pdfs/review18/tv031_hovsapien_2018_o.pdf

²¹ p. 69, *Residential Building Decarbonization in California*, E3; April 2019

²² p. 2, *Building Electrification in California*, E3; April 2019 https://www.ethree.com/wp-content/uploads/2019/04/E3_Residential_Building_Electrification_in_California_April_2019.pdf

²³ Ibid.

²⁴ <https://www.nrdc.org/experts/rachel-fakhry/green-hydrogen-critical-powering-carbon-free-future>

²⁵ ICF webinar on the analysis is available at: <https://www.icf.com/resources/webinars/2019/gas-utilities-in-a-decarbonizing-world>



increased by \$1,420 per customer under residential electrification versus \$1,200 per customer under technology neutral decarbonization scenario).²⁶

- RMI writes that hydrogen can be used for a number of applications, including electricity and heat, and *“With its zero-carbon potential and the role it can play in increasing demand for renewable energy, hydrogen has an important role in our energy transition and is a key complement to electrification.”*²⁷
- The International Energy Agency declares that *“now is the time to scale up technologies and bring down costs to allow hydrogen to become widely used...But for hydrogen to make a significant contribution to clean energy transitions, it needs to be adopted in sectors where it is almost completely absent, such as transport, buildings and power generation.”*²⁸

A technology neutral approach is also prudent, given the virtually impossible task of currently calculating a realistic future cost comparison between all- electric homes and those that rely on renewable gas for some uses because of the uncertainty of wildfire impacts on future electricity rates. Utility rate increase requests are already reaching nearly 22% over the next few years to help pay for the costs of wildfire liability and prevention.²⁹ Fundamentally, however, current uncertainty around wildfires, utility liability, and associated cost to ratepayers make it difficult, if not impossible, to compare future gas and electricity rates, and alternate building decarbonization pathways dependent on them, in any reliable way. This lack of certainty regarding future electricity rates reinforces the importance of diversifying approaches to building decarbonization beyond those that depend entirely on the electricity system.

It is also critical for policymakers to consider the reliability, safety, and public health concerns related to increased reliance on the electricity grid, given its vulnerability with respect to disasters like wildfires and earthquakes, as well as the need for solutions that can supply clean energy 24/7 under all circumstances. All-electric buildings create increased dependence on the electric grid for all building end uses. While this may present benefits for some buildings, it also carries significant risks, including to reliable energy service and resilience in the face of wildfire and other disaster prevention and management. Underground gas lines, which may carry increasing amounts of hydrogen, are comparatively less vulnerable with respect to fire and other natural disasters than overhead power grids. As Californians plan for and try to cope with power shutdowns, the demand for combustion-based fossil fuel backup generators also has

²⁶ Slide 17 of the ICF webinar available at: <https://www.icf.com/resources/webinars/2019/gas-utilities-in-a-decarbonizing-world>

²⁷ <https://rmi.org/the-truth-about-hydrogen/>

²⁸ See *Future of Hydrogen* Summary, IEA, <https://www.iea.org/hydrogen2019/>

²⁹ <https://calmatters.org/economy/2019/08/pges-rate-increases-what-you-need-to-know/>



been rising as much as 1400%, which is detrimental to decarbonization and air quality efforts.³⁰ Fuel cells, on the other hand, are capable of providing zero emissions long-duration storage and electricity generation onsite or on microgrids, even under extreme conditions. When powered zero carbon hydrogen, fuel cells are free of critical pollutant, greenhouse gas and toxic emissions over their lifecycle.

Renewable hydrogen is notably being pursued for building heating and appliance applications in countries and regions around the world, where it is being recognized that a diverse approach will be required to achieve deep decarbonization that includes efficiency, electrification, renewable hydrogen, and other renewable gas, among other strategies. Examples in Europe include:

- The H100 Fife project in Scotland is being considered to switch 300 homes from natural gas to green electrolytic hydrogen for heating and appliances.³¹
- H21 Leeds City Gate seeks to transition the UK's fourth largest city to 100% hydrogen for heating.³²
- 200 residents in the village of Rozenberg in the Netherlands have their homes heated by hydrogen made from wind power and injected into the existing gas network.³³
- Blending hydrogen with natural gas across the U.K. is estimated to reduce 6 million tons of carbon annually, the equivalent of taking 2.5 million cars off the roads.³⁴
- Leeds, one of the largest cities in the U.K., also launched the Leeds H21 City Gate hydrogen project³⁵ in 2016, targeting the conversion of the existing natural gas supply and distribution system to deliver hydrogen to consumers.
- Northern Germany is blending 20% hydrogen produced by renewable electricity into the gas distribution grid, in order to fuel heating systems and appliances for 400 homes.³⁶
- South Australia plans to transition to a renewable hydrogen economy to achieve low emissions across sectors and become a global hydrogen market leader.³⁷

Lastly, opinions (like E3) that advocate for 100% electrification of all buildings tend to rely heavily on heat pumps for all space and water heating. The CHBC supports heat pumps and

³⁰ <https://www.sfchronicle.com/business/article/Demand-for-generators-lights-up-as-PG-E-power-14054242.php>

³¹ <https://sgn.co.uk/H100Fife>

³² <https://www.h21.green/projects/h21-leeds-city-gate/>

³³ <https://fuelcellsworld.com/news/bdr-thermea-group-showcases-the-worlds-first-hydrogen-powered-domestic-boiler/>

³⁴ <https://www.telegraph.co.uk/business/2018/01/06/hydrogen/>

³⁵ <https://www.northerngasnetworks.co.uk/2016/07/12/watch-our-h21-leeds-city-gate-film/>

³⁶ <https://www.eon.com/en/about-us/media/press-release/2019/hydrogen-levels-in-german-gas-distribution-system-to-be-raised-to-20-percent-for-the-first-time.html>

³⁷ <http://www.renewablesa.sa.gov.au/content/uploads/2019/09/south-australias-hydrogen-action-plan-online.pdf>



other electrification solutions, but also cautions against being overly reliant on this – or any one technology – in order to mitigate risks inherent to nascent markets, as well as risks of unintended environmental consequences. The likelihood of the California heat pump market being able to serve all homes for all heating needs is questionable. The European heat pump market³⁸ is far ahead of California's,³⁹ yet as promising a solution as they are for efficient heating and cooling, the European Commission forecasts that even in its high electrification scenario for deep decarbonization, only two thirds of buildings would adopt heat pumps by 2050.⁴⁰ Electric heat pumps also contain hydrofluorocarbons, a potent greenhouse gas, which risk leaking over its lifecycle to the detriment of the climate. Hydrogen by contrast, when produced with zero carbon feedstock, emits zero greenhouse gas over its lifecycle. We hope, therefore, that CARB will consider hydrogen as an important option for fuel switching from natural gas for building end uses.

In conclusion, we believe the E3 Carbon Neutrality Report is an important first step in CARB's effort to study how California can fulfill its carbon neutrality objective and hope future steps will take a more comprehensive approach that more deeply examines optimized combinations of all zero carbon solutions, including hydrogen-based technologies.

Once again, the CHBC wholly supports CARB spearheading California's analysis of how to achieve economy-wide carbon neutrality. By tackling this challenge, the state joins several other climate protection frontrunner regions from around the world in advancing one of the most urgently needed efforts of our time. We look forward to continuing to work with CARB to pursue a holistic, thorough approach that helps build better understanding of how various greenhouse gas neutral solutions, including zero carbon hydrogen and its derivatives, can be optimized and combined to achieve the most reliable, economical, just and resource efficient carbon neutral energy system for California.

³⁸ *European Heat Pump Statistics and Market Report 2018* finds a growing market four years in succession, with over 10 million units sold. https://www.researchandmarkets.com/research/6sgzkn/european_heat?w=5

³⁹ *Decarbonization of Heating Energy Use in California Buildings*, Synapse Energy Economics, Inc; October 2018; p. 1 – States that heat pumps “today represent a small share of California's market, due to regulatory barriers and higher upfront costs in older homes.”

⁴⁰ p. 104 https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_analysis_in_support_en_0.pdf



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Respectfully,

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