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VIA ELECTRONIC FILING

Commissioner Katie Dykes
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RE: Section 16a-3d of the Connecticut General Statutes--Comprehensive Energy Strategy, Notice of Technical Meeting and Request for Written Comment on Hydrogen Opportunities

The undersigned organizations (Sierra Club, Conservation Law Foundation, Acadia Center, Eastern CT Green Action, Connecticut Citizen Action Group, and Save the Sound) submit the following comments in response to the Department of Energy and Environmental Protection's (DEEP) March 18, 2022 Notice of Technical Meeting and Request for Written Comment on Hydrogen Opportunities relating to Connecticut's Comprehensive Energy Strategy. The undersigned look forward to the opportunity to engage with DEEP regarding the role for hydrogen as part of the Comprehensive Energy Strategy. While the undersigned organizations recognize that green hydrogen shows promise in discrete applications, hydrogen as a resource cannot play a central role in decarbonizing Connecticut's economy, and the state builds its decarbonization strategy around hydrogen at great peril. A clear-eyed assessment of hydrogen's potential reveals that replacing fossil gas in the power sector, buildings, and light duty vehicles with green hydrogen would require unattainable levels of renewable energy development in the state; that relying on blue (or gray) hydrogen rather than green hydrogen would eviscerate the intended climate benefits (*increasing* rather than decreasing total greenhouse gas emissions); and that numerous other technical and practical barriers impede the safe and cost-effective deployment of hydrogen at scale.

Fundamentally, green hydrogen production is highly inefficient and makes little sense where the clean electricity that would be used for the electrolysis can directly support the desired end use. In particular, hydrogen should not be pursued today as a direct replacement for fossil fuels used in power generation, in buildings where electric air- or ground-source heat pumps can readily serve the same need, or in light duty vehicles where battery technology is far more efficient and readily available. The undersigned support efforts to identify the specific niches in which green hydrogen can play a role in Connecticut's decarbonized economy of the future, but strongly caution against building a strategy around an inflated role for hydrogen.

I. Green hydrogen cannot be supplied in sufficient quantities to replace fossil gas in the buildings or power sector.

Connecticut already must develop significant renewable energy resources at a sufficient pace to achieve the mandates of the Global Warming Solutions Act (GWSA) and to meet its target to procure 100% of its electricity from renewable energy systems by 2040.[1] Developing the incremental renewable generation that would be required to also convert Connecticut's fossil gas power plants and a significant fraction of Connecticut's residential and commercial gas combustion in buildings is not realistic.

Using green hydrogen to replace natural gas in the electric sector would require a massive and unrealistic additional buildout of renewable energy resources. Repowering even a single gas peaker plant with green hydrogen would require thousands of megawatts of new renewable generation. Because renewable generation resources typically operate at a lower capacity factor, even greater renewable capacity would be required to fully power such a facility with green hydrogen.

Attempting to also replace a meaningful fraction of gas combusted in buildings with green hydrogen would strain these renewable energy demands even further. While, as discussed below, hydrogen would likely need to be blended with methane so would not be fully replacing the gas in the pipelines, replacing even 20 percent of current fossil gas in buildings with green hydrogen would still require another massive buildout of renewable generation. There is simply no feasible path to relying on green hydrogen to anchor Connecticut's decarbonization strategies for power generation[2] or buildings.

II. Alternatives to green hydrogen, including blue hydrogen, do not produce the requisite greenhouse gas emission reductions to support Connecticut's climate commitments

Achieving Connecticut's climate goals using green hydrogen requires an unrealistic buildout of new renewable energy resources. However, blue hydrogen—i.e., hydrogen produced from fossil fuels with carbon capture—or gray hydrogen—i.e., hydrogen produced using steam reformation of methane—are not alternative climate solutions.

Professors Bob Howarth and Mark Jacobson recently studied the emissions implications of these alternative hydrogen production methods.[3] The authors found that the greenhouse gas footprint of blue hydrogen is 20 percent *greater* than burning natural gas or coal for heat and 60

[1] 2020 Integrated Resources Plan.
[2] While there is no appreciable role for hydrogen as a fuel for electric power generation, there may be a role for hydrogen in long-duration (i.e., multi-day or seasonal) energy storage. When used for long-duration storage, hydrogen could complement batteries as an emissions-free way to replace fossil fuel-fired peaker plants and reduce the extraction and transport of fracked gas. This role is far from certain, however, as other emerging technologies could potential provide these services at lower cost. Energy Innovation, Assessing the Viability of Hydrogen Proposals (Mar. 2022), at 3, available at https://energyinnovation.org/wp-content/uploads/2022/03/Assessing-the-Viability-of-Hydrogen-Proposals.pdf.
[3] Howarth & Jacobson, How green is blue hydrogen? *Energy Sci. & Eng'r* (July 2021).

percent *greater* than burning diesel oil for heat.[4] This is because, while blue hydrogen reduces direct carbon dioxide emissions (albeit incompletely), it increases fugitive emissions of methane, a far more potent greenhouse gas. In fact, due to this methane leakage, total carbon dioxide equivalent emissions from blue hydrogen were only 9-12 percent lower than gray hydrogen.[5] The authors further tested the robustness of their conclusions against different assumed leakage rates and found that the conclusion held even assuming a low methane leakage rate of 1.54 percent.[6] The authors also tested the robustness of their conclusions assuming blue hydrogen is produced with 100 percent zero emissions renewable energy—while retaining assumptions that hydrogen can be stored indefinitely without leakage—and found that total greenhouse gas emissions were still nearly half those from combusting natural gas as a fuel.[7] The emissions limitations of blue hydrogen are in addition to other challenges, including achieving high rates of carbon capture in practice[8] and the cost per ton of capturing the carbon.[9]

III. There are a host of practical difficulties with reliance on green hydrogen that also would need to be addressed and satisfactorily resolved

Even if it were possible to supply sufficient renewable energy to produce relevant quantities of hydrogen, there are numerous logistical challenges that affect the cost, feasibility, and prudence of building a climate compliance strategy around hydrogen. These challenges are well-documented,[10] but several are briefly described here.

- **Hydrogen production via electrolysis is inefficient and expensive**: Due to the inefficiency of using green hydrogen to replace electricity, cost is likely to continue to be a barrier. The use of electricity to power electrolysis results in substantial energy losses—

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[4] *Id.*
[5] *Id.*
[6] *Id.*
[7] *Id.*
[8] Carbon capture projects associated with hydrogen production to date have achieved onsite carbon dioxide capture rates below 70 percent, far below the blue hydrogen industry goal of 95 percent. David Schlissel et al. Blue Hydrogen: Technology Challenges, Weak Commercial Prospects, and Not Green, IEEFA (Feb. 2022), at Slides 18-20, available at Blue-Hydrogen-Presentation_February-2022.pdf (ieefa.org).
[9] These costs have been in excess of $63/ton for capture rates below 85 percent, and substantially higher for higher capture efficiency. *Id*. at Slide 26. These are more than double the costs that would be required to make carbon capture financially viable. *Id.*
[10] E.g., Sasan Saadat & Sara Gersen, Reclaiming Hydrogen for a Renewable Future: Distinguishing Oil & Gas Industry Spin from Zero-Emission Solutions, Earthjustice (Aug. 2021), available at https://earthjustice.org/features/green-hydrogen-renewable-zero-emission (hereinafter "Reclaiming Hydrogen"); Sierra Club, Hydrogen: Future of Clean Energy or a False Solution? (Jan. 2022), https://www.sierraclub.org/articles/2022/01/hydrogen-future-clean-energy-or-false-solution; Energy Innovation, Assessing the Viability of Hydrogen Proposals (Mar. 2022), available at https://energyinnovation.org/wp-content/uploads/2022/03/Assessing-the-Viability-of-Hydrogen-Proposals.pdf (hereinafter "Energy Innovation"); Leigh Collins, Liebreich: 'Oil sector is lobbying for inefficient hydrogen cars because it wants to delay electrification,' Recharge (June 30, 2021), https://www.rechargenews.com/energy-transition/liebreich-oil-sector-is-lobbying-for-inefficient-hydrogen-cars-because-it-wants-to-delay-electrification-/2-1-1033226 (hereinafter "Liebreich"); David Schlissel et al. Blue Hydrogen: Technology Challenges, Weak Commercial Prospects, and Not Green, IEEFA (Feb. 2022), at Slides 18-20, available at Blue-Hydrogen-Presentation_February-2022.pdf (ieefa.org).

on the order of 20 to 40 percent according to GE,[11] and even higher according to BNEF founder Michael Liebreich.[12] Indeed, Agora explained that "the production of hydrogen is associated with high conversion losses" and noted that an electric heat pump is 6 to 12 times more efficient than a hydrogen fuel cell, with hydrogen combustion applications being more inefficient still.[13] According to analysis from 2021, even a carbon price of $237/metric tonne—four times higher than the current price in Europe—would not make green hydrogen cost-competitive with other forms of hydrogen production this decade.[14]

- **Hydrogen is leakable and is an indirect greenhouse gas**: Due to its small molecular size, hydrogen is highly leakable. Leakage rates for hydrogen are expected to be 1.3-2.8 times greater than those for methane.[15] At the same time, hydrogen is an indirect greenhouse gas with a 100-year global warming potential 5.8 times greater than carbon dioxide.[16] Recent research suggests that on shorter (and more relevant) time scales, the global warming potential for hydrogen is far higher: 19 to 38 for 20-year global warming potential and 34 to 66 for 10-year global warming potential.[17] Any strategy built around hydrogen would need to consider and quantify the potential for adverse climate impacts due to hydrogen leakage during production, transport and use.

- **Hydrogen embrittles steel and cast iron pipelines, necessitating a costly replacement of existing pipeline infrastructure to accommodate hydrogen**: The small molecular size of hydrogen also enhances its diffusion through the lattice structure of pipeline materials and causes embrittlement.[18] Researchers studying the potential for leakage and embrittlement of hydrogen in steel pipes found that the "numerical obtained results have shown that using pipelines designed for natural gas conduction to transport hydrogen is a risky choice" and recommended that the "replacement of the transported gas [with hydrogen] has to be preceded by feasibility studies taking in account both aspect of

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[11] Energy Transitions Commission, Making the Hydrogen Economy Possible: Accelerating Clean Hydrogen in an Electrified Economy, at 22 (Apr. 2021), https://energy-transitions.org/wpcontent/uploads/2021/04/ETC-Global-Hydrogen-Report.pdf.
[12] Liebreich (identifying efficiency losses of at least 50 percent).
[13] Agora, The Future Cost of Electricity-Based Synthetic Fuels (Sept. 19, 2018), at 11, The Future Cost of Electricity-Based Synthetic Fuels (agora-energiewende.de).
[14] Leigh Collins, 'Not even a carbon price of €200 would make green hydrogen cost-competitive this decade,' Recharge (July 8, 2021), https://www.rechargenews.com/energy-transition/not-even-a-carbon-price-of-200-would-make-green-hydrogen-cost-competitive-this-decade/2-1-1037262.
[15] Fotis Rigas & Paul Amyotte, Myths and Facts about Hydrogen Hazards, 31 Chem. Eng'r Transactions 913, 914 (2013), available at https://www.aidic.it/cet/13/31/153.pdf.
[16] Derwent, R., Simmonds, P., O'Doherty, S., Manning, A., Collins, W. and Stevenson, D. 2006. "Global Environmental Impacts of the Hydrogen Economy." Int. J. of Nuclear Hydrogen Production and Applications. 1(1): 57-67. Available at: http://agage.mit.edu/publications/global-environmental-impacts-hydrogen-economy.
[17] Ilissa B. Ocko & Steven P. Hamburg, Climate consequences of hydrogen leakage, Atmospheric Chemistry & Physics (preprint, discussion started Feb. 18, 2022), available at https://acp.copernicus.org/preprints/acp-2022-91/acp-2022-91.pdf.
[18] Zahreddine Hafsi et al., Hydrogen embrittlement of steel pipelines during transients, Procedia Structural Integrity 13 (2018), 210-217, available at https://www.sciencedirect.com/science/article/pii/S2452321618302683#:~:text=The%20transient%20regime%20is%20created,diffusion%20through%20the%20pipeline%20wall.

fatigue of material and pipeline failure due to overpressure and also due to hydrogen embrittlement."[19]

- **End-use appliances are not made to combust hydrogen and costly appliance replacement would be required to accommodate substantial hydrogen blends**: Our current end use appliances, including gas space and water heaters, gas stoves, and gas dryers were not designed to combust hydrogen. Indeed, hydrogen cannot be readily substituted for methane for use in heating or consumer appliances above a 5 to 20 percent blend without enormous costs and disruption, while low blends achieve very few greenhouse gas emission reductions and increase emissions of nitrogen oxides.[20]

- **Hydrogen has a substantially lower energy density than methane, which means that far greater quantities must be combusted to generate the same energy or heat**: Hydrogen has a far lower heat content than methane gas: only approximately 30 percent.[21] Consequently, despite the expense and complexity, blending hydrogen into methane gas streams at low concentrations does very little to improve total greenhouse gas emissions.

- **Hydrogen is explosive and storage issues must be resolved**: Hydrogen is highly combustible, even in low concentrations, raising concerns about the safety of its increased use in homes. A study by the UK government estimated that explosions in homes would increase more than fourfold if hydrogen were to replace gas in homes.[22]

- **Hydrogen combustion results in significant air pollution**: While reaction of hydrogen in a fuel cell produces only water, combustion of hydrogen results in significant formation of harmful nitrogen oxides. Nitrogen oxides are a pollutant in their own right, and also the primary contributor to ground level ozone (smog) and a precursor of dangerous fine particulate matter. Indeed, combustion of pure hydrogen may result in far greater emissions of nitrogen oxides than burning methane.[23]

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[19] *Id.*
[20] Energy Innovation at 3.
[21] Ulf Bossel & Baldur Eliasson, Energy and the Hydrogen Econony, at 5, https://afdc.energy.gov/files/pdfs/hyd_economy_bossel_eliasson.pdf ("at any pressure, the volumetric energy density of methane gas exceeds that of hydrogen gas by a factor of 3.2 (neglecting non-ideal gas effects)").
[22] Collins, Leigh, 'Hydrogen in the home would be four times more dangerous than natural gas': government report, (RechargeNews.com, last updated August 2, 2021), available at https://www.rechargenews.com/energy-transition/hydrogen-in-the-home-would-be-four-times-more-dangerous-than-natural-gas-government-report/2-1-1047218.
[23] Reclaiming Hydrogen at 18 (citing Cellek Mehmet Salih & Ali Pınarbaşı, Investigations on Performance and Emission Characteristics of an Industrial Low Swirl Burner While Burning Natural Gas, Methane, Hydrogen-Enriched Natural Gas and Hydrogen as Fuels, 43 Int'l J. of Hydrogen Energy 1994, 1205 (Jan. 11, 2018), https://www.sciencedirect.com/science/article/abs/pii/S0360319917319791) (finding that burning pure hydrogen would emit more than six times more nitrogen oxides than burning methane).

IV. Conclusion

The undersigned support DEEP's efforts to delineate an appropriate role for hydrogen in Connecticut's climate future. To this end, Earthjustice has identified a set of criteria for deploying green hydrogen that can helpfully guide Connecticut's actions. Specifically, for green hydrogen to make sense as a climate solution all of the following criteria must be met:

(1) There are no low-cost decarbonization strategies available;
(2) There are no electric technologies being developed that could take advantage of zero-emission electricity directly;
(3) The logistics and costs of infrastructure for hydrogen transportation and storage can be contained;
(4) Technologies for using hydrogen fuel in the sector are or will be available; and
(5) Transitioning to green hydrogen could reduce air pollution.[24]

Ultimately, as Energy Innovation recommends, "state utility regulators and policymakers should be highly scrupulous and discerning of hydrogen blending proposals and avoid costly dead ends on the road to a decarbonized future."[25] These dead ends include direct power generation and replacing fossil gas in buildings. As Michael Liebreich observes, the reason why gas distribution companies are lobbying for hydrogen use in domestic heating is not because they want the world to go green, but because "they want to get us locked into using their gas pipes for decarbonisation, because that's their asset."[26] Connecticut has a chance to chart its own course for hydrogen not dictated by the preferences of the gas utilities and gas power plant owners. DEEP should approach this task objectively, fully and fairly evaluating the feasibility, economics and emissions impacts.

Thank you for your consideration.

Respectfully submitted,

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[24] Reclaiming Hydrogen at 8.
[25] Energy Innovation at 2.
[26] Liebreich.

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