September 9, 2022

Sent via email to: DEEP.EnergyBureau@ct.gov

Connecticut Department of Energy and Environmental Protection
Bureau of Energy and Technology Policy
10 Franklin Square
New Britain, CT 06051

Re: Environmental Advocates' Joint Written Comments for 2022 CES Technical Session 4: Building decarbonization ─ Economic potential and technology targets

Dear Bureau of Energy and Technology Policy,

Thank you for the opportunity to submit preliminary comments for the 2022 Comprehensive Energy Strategy (CES) Technical Session 4. Conservation Law Foundation, Sierra Club, the Nature Conservancy in Connecticut, Save the Sound, Connecticut Citizen Action Group, Eastern Connecticut Green Action, and People's Action for Clean Energy are public interest organizations that are working to align Connecticut's energy policies with the state's statutory climate commitments and to decarbonize the electric sector, transportation sector, and buildings sector, which are the three major sources of Connecticut's greenhouse gas (GHG) emissions. We appreciate the opportunity to provide these joint comments and look forward to engaging further in development of the 2022 CES.

1. **Please share links to any recent reports or analyses that could assist DEEP in developing Connecticut deployment targets for weatherization and thermal decarbonization technologies such as those listed in the table below (i-xi). If you have any concerns about a recent report or analysis related to thermal decarbonization technologies (including but not limited to concerns about methodology or applicability to Connecticut), please describe your concerns.**

- Northeast Energy Efficiency Partnerships, *Northeast/Mid-Atlantic Air-Source Heat Pump Market Strategies Report 2016 Update* (Jan. 2017), https://neep.org/sites/default/files/NEEP_ASHP_2016MTStrategy_Report_FINAL.pdf
    - "Installed Costs" and "Market Research Insights" may be especially useful.
- American Council for an Energy-Efficient Economy, *Residential Deep Energy Retrofits* (March 2014), https://www.aceee.org/sites/default/files/publications/researchreports/a1401.pdf
    - Description and analysis of weatherization pilot programs across the United States, starting at page 13.
- American Council for an Energy-Efficient Economy, *Building Electrification: Programs and Best Practices* (Feb. 2022), https://www.aceee.org/sites/default/files/pdfs/b2201.pdf
    - Analysis of 42 electrification programs, mainly rebates for heat pumps. Tables A.4 "Funding sources and program spending" and A.5 "Participation, energy savings, and GHG impacts" may be useful.

- J.J. Buonocore, J.J. et al. *Inefficient Building Electrification Will Require Massive Buildout of Renewable Energy and Seasonal Energy Storage*. Sci Rep 12, 11931 (2022). https://doi.org/10.1038/s41598-022-15628-2
    - Discussion of seasonal fluctuations in energy consumption, how building electrification models must account for this fluctuation, and how ASHPs and GSHPs can reduce it.
- Rocky Mountain Institute, *The Economics of Electrifying Buildings* (2018), https://rmi.org/insight/the-economics-of-electrifying-buildings/
    - Comparison of electric space and water heating for new construction and retrofits across four cities. See an updated report here: https://rmi.org/all-electric-new-homes-a-win-for-the-climate-and-the-economy/.
- American Council for an Energy-Efficient Economy, *Pathways to Healthy, Affordable, Decarbonized Housing: A State Scorecard* (Aug. 18, 2022), https://www.aceee.org/research-report/h2201.
    - "This scorecard identifies state policies, programs, and investments aimed at advancing a coordinated approach in support of healthy, affordable, decarbonized housing, focusing specifically on energy efficiency, electrification, and renewable energy."

2. Describe the variables and parameters that you believe are critical for DEEP to consider when developing Connecticut-specific economic potential estimates and/or technology deployment targets for thermal decarbonization technologies such as those listed in the table below (i-xi).

- <u>GHG reduction potential</u>, using the best available scientific research and considering the emissions associated with each technology.
- <u>Cost effectiveness</u> based on a cost-benefit analysis that includes estimated climate costs using the social cost of carbon and/or the social cost of methane as applicable.
- <u>Equity and environmental justice</u>, including data on environmental justice communities[1] and distressed municipalities[2] as defined under state law.
- <u>Demographics and population projections</u> at the state and local level, including income, age, race and ethnicity, and primary language spoken.
- <u>Building sector data</u> (including, e.g., the total number of single-family dwellings, multi-unit dwellings and number of units, and the average age of buildings in each building category), for the residential, commercial, and industrial building sectors.

3. For weatherization and each of the thermal decarbonization technologies listed in the Notice, DEEP requests written comments.

We appreciate that DEEP has identified a broad array of technologies that could contribute to thermal decarbonization in this request for comments. Starting from such a broad lens is appropriate at this stage of the proceeding so DEEP can fully consider perspectives on all potential options. However, it is critical for DEEP to prioritize these technologies as the process

[1] Conn. Gen. Stat. § 22a-20a.
[2] Conn. Gen. Stat. § 32-9p.

moves forward. Including a full laundry list of every possible option in the draft CES would be a mistake as it could suggest that all options are equally worthy of consideration in decarbonizing the buildings sector. This is not the case. Building sector decarbonization modeling and analysis demonstrates that some of these technologies will be critical, others will play more of a niche or supporting role, and some likely will not be useful in Connecticut and should be monitored, but not incentivized at this time.

The undersigned encourage DEEP to prioritize these technologies as follows:

- First, weatherization and heat pumps (including ASHPs, ASHPs and thermal storage, and GSHPs) should be identified as primary pathways to decarbonizing the buildings sector. Weatherization is key to improving the energy efficiency of existing buildings, which is especially critical in Connecticut given the age of existing building stock and limited new construction. Heat pumps should become the primary heating source for most buildings due to their superior efficiency, availability, and climate benefits.
- Second, solar space and water heating should also be included as decarbonization technologies. However, because these technologies have more limited application than weatherization and heat pumps, they will likely play a smaller role in decarbonization (for example, solar space heating is most relevant in the context of new construction).
- Third, compost heat recovery is a niche technology, so it should be a lower priority, but it warrants further consideration and should be discussed in the 2022 CES.

Four of the identified technologies should be monitored but should not be prioritized as thermal decarbonization technologies. First, potential for enhanced geothermal in the northeast is unclear, so DEEP should monitor developments in this area. Second, available research does not support pursuing biodiesel, renewable natural gas, or hydrogen as decarbonization technologies for the buildings sector at this time. DEEP should continue monitoring these technologies, but the 2022 CES should not include them as thermal decarbonization strategies.

i. Weatherization

Weatherization is fundamental to decarbonizing the building sector, especially in a state like Connecticut with aging housing stock, because it has enormous potential to increase the energy efficiency of people's homes and businesses and to do so at a lower cost relative to other strategies. Leaky, inefficient buildings that rely on fossil fuel heating use more fuel, leading to higher emissions and higher heating bills. Likewise, the heating costs and emissions associated with an inefficient electrified building always exceed those associated with an efficient one. Weatherization is a key first step to drive down buildings sector heating costs and emissions and should be a top priority in the 2022 CES.

a. Assessment of market barriers

Common weatherization barriers include the presence of health or safety hazards that must be remediated before weatherization upgrades can be made, the upfront cost of upgrades (which may put them out of reach for residents of limited means, even if the resulting energy

savings would save them money in the long run), and limited public awareness of state and federal weatherization incentives that can substantially lower the cost of these upgrades.[3]

b. Assessment of economic potential for 2030 and 2050 (i.e., deployment potential given installation cost, operational cost, and market conditions).

The cost and energy savings associated with weatherization make these upgrades appealing for those with adequate financial means, but the upfront cost remains a barrier for many, including low-income residents with high energy burden who could most benefit from weatherization. Building on existing programs like the Weatherization Assistance Program, the Home Energy Solutions (HES) program, and the HES Income-Eligible program will be critical to make upgrades more affordable for Connecticut residents. Additional federal incentives like those included in the Inflation Reduction Act will help reduce these costs, but the state should also ramp up incentives as needed to rapidly accelerate the pace of weatherization.

A related problem is the cost of remediating health and environmental hazards like mold and asbestos that must be addressed before weatherization upgrades can be made. These costs can be prohibitive and must be mitigated to improve the economic potential of weatherization upgrades in "barriered" homes, which disproportionately house low-income residents.[4]

c. Assessment of non-climate environmental, equity, and energy justice implications of this deployment.

Older and poorly insulated buildings disproportionately house low-income and minority residents who already face a high energy burden and can least afford to pay more for their utility bills. As DEEP discussed in the Equitable Energy Efficiency proceeding, these buildings often require remediation to address health and environmental hazards like mold and asbestos before weatherization upgrades can be made. These unhealthy conditions compound other inequitable impacts (including higher energy costs) associated with these buildings.

A targeted approach to weatherization that prioritizes low-income and minority residents and considers the needs of both renters and homeowners is needed to mitigate the inequitable cost, energy, health, and environmental impacts of inefficient buildings. These impacts are greatest in the residential buildings sector, which should remain the state's primary focus; however, opportunities to weatherize commercial buildings should also be discussed.

d. Appropriate deployment targets and the reasoning and analyses that support these targets.

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[3] *See, e.g.*, Elizabeth Bourguet and Richard Faesy, Energy Futures Group, *Overcoming Weatherization Barrier*s (Dec. 23, 2020), https://e4thefuture.org/wp-content/uploads/2021/01/Weatherization-Barriers-White-Paper-1-6-21.pdf ("Common barriers to weatherization include the presence of asbestos, knob and tube wiring, mold, lead, structural issues, and venting and combustion safety issues, among others.").

[4] *Id.* at 2 ("According to data from Connecticut's utilities, 165,000 homes in the state are barriered from weatherization work … the average cost of a job to remediate a barrier was about $20,000. The problem disproportionately impacts low-income households.").

Connecticut already has a statutory goal of weatherizing 80% of the state's residential units by 2030.[5] This existing goal should be reflected in the 2022 CES deployment targets. In addition, the CES should: (1) establish interim targets for meeting the 2030 goal and (2) establish a deployment goal for weatherizing 100% of the state's residential units. Closely monitoring and reporting on progress towards these goals will be critical to hold the state accountable, as there has been limited progress to date.

ii. Air-source heat pumps (ASHP)

Heat pumps are crucial to decarbonizing the buildings sector in Connecticut, and DEEP should prioritize strategies that will facilitate widespread deployment of this technology in residential, commercial, and industrial buildings.

a. Assessment of market barriers

Significant barriers to more widespread heat pump adoption in Connecticut include lack of public knowledge about heat pumps, a lack of experienced contractors to install heat pumps, and the high upfront cost of the technology. Additional barriers exist for residents who live in rental housing, particularly low-income families and individuals.

First, there remains a major gap between the public's knowledge and understanding of heat pumps, which is very limited, and the increasing consensus among energy experts that heat pumps are critical to decarbonizing the buildings sector. Many people have never heard of heat pumps, and those who have may have outdated knowledge. For example, they may believe that heat pumps cannot operate effectively in cold climates, even though cold-weather heat pumps are now widely available and perform well in Connecticut and other northeastern states without any backup source of heating. Educating the public about the availability, effectiveness, efficiency, climate benefits, and upfront and operating costs of heat pumps, including state and federal financial incentives, is crucial to accelerate adoption of this technology.

Second, a related problem is a lack of contractors who understand heat pump technology, can install heat pumps, and can educate potentially interested customers about the technology. It is promising that DEEP is moving forward with contractor training programs, which will be key to ensure that Connecticut has a skilled workforce ready to deploy this technology. Among other things, the training programs should create opportunities for low-income, minority, and female workers who historically have had fewer opportunities to participate in the workforce.

Third, the high upfront cost of ASHPs remains a steep barrier, despite the existence of financial incentives. New federal support for heat pumps under the Inflation Reduction Act should significantly mitigate this barrier, but increased support at the state level is also needed. Currently, many families and individuals who are or may be interested in converting to a heat pump are unable to do so because of the high upfront cost, regardless of how cost-effective the switch may be over a longer time period. Low-income and many moderate-income Connecticut families and individuals are already struggling financially due to high energy costs and inflation. The upfront cost of ASHPs remains prohibitive for many. To mitigate these financial barriers,

[5] Conn. Gen. Stat. § 16-245m (d)(1).

Connecticut should increase financial incentives for heat pumps and consider a tiered incentive structure based on income. People with very high incomes should not be eligible for financial incentives. DEEP should provide an opportunity for the public to comment on the incentive structure and appropriate income thresholds.

Moreover, significant time and resources are needed for people to research heat pumps, incentives, and qualified contractors, and to meet with contractors, obtain quotes, and select an installer. A concierge-type service could help streamline this process and make it easier for both families and businesses to get the support they need in converting their buildings to heat pumps.

There are additional barriers specific to people who live in rental housing. As DEEP has observed in the context of the Equitable Energy Efficiency proceeding and the Conservation and Load Management Plan, split landlord-tenant incentives remain a persistent barrier to energy efficiency improvements in rental properties. This is a serious equity issue because renters are more likely to be low-income and/or minority, whereas homeowners are wealthier and whiter. Renters cannot be left behind as Connecticut decarbonizes the buildings sector. DEEP should build on existing efforts to bridge these gaps and incentivize landlords to adopt energy efficiency improvements and convert to more efficient technologies like ASHPs to ensure that tenants across the state can access the benefits of cleaner and more efficient buildings.

b. Assessment of economic potential for 2030 and 2050 (i.e., deployment potential given installation cost, operational cost, and market conditions).

There are growing expectations that heat pumps will become more widely available and affordable in the coming years as we scale up manufacturing and deployment of this critical decarbonization technology. The Inflation Reduction Act, recently passed federal legislation, contains provisions intended to boost manufacturing and reduce costs for heat pumps. At the state and regional level, there is increasing recognition that heat pumps will play a critical role in decarbonizing the buildings sector, and states are responding with an array of incentives.

We expect that some level of subsidization for heat pumps will be necessary in the coming years, but eventually these financial incentives will no longer be needed and can be phased out. The economic viability of heat pumps should be reevaluated in future iterations of the CES as market conditions change.

c. Assessment of non-climate environmental, equity, and energy justice implications of this deployment.

The environmental impacts of heat pumps are minimal relative to other heating alternatives that rely on fossil fuels. ASHPs are extremely efficient and run on electricity. As Connecticut and the rest of New England continue making progress in decarbonizing the electric grid, the emissions associated with electricity generation in the region will continue to fall.

In contrast, there are negative externalities associated with fossil fuels at every stage of their lifecycle, from extraction, refining and processing, transportation, and end uses, notably including combustion in power plants or home appliances such as boilers, furnaces, and stoves.

The harmful health impacts of fossil fuels, in particular, fall disproportionately on low-income and minority populations who historically have borne the brunt of fossil fuel pollution.

Connecticut residents who convert to heat pumps from oil, gas, or propane heating systems will save money on their winter heating fuel bills, eliminating this cost entirely if they do not maintain a fossil-fuel powered backup heating system. However, they will see an increase in their electric bills. People who convert from electric resistance heating to heat pumps should see a reduction in their electric bills due to heat pumps' superior efficiency. Heating assistance programs should be available for any low- or moderate-income customers whose total heating costs increase as a result of conversion.

DEEP should work with the Energy Efficiency Board and the utilities to develop a tool that can estimate the expected economic impact of each type of conversion, including whether a given customer's *total heating costs* are likely to increase or decrease after converting to a heat pump, and make this tool publicly available online.

d. Appropriate deployment targets and the reasoning and analyses that support these targets.

DEEP should establish deployment targets for heat pumps based on how many heat pumps will be necessary for Connecticut to achieve the GHG reductions required under the Global Warming Solutions Act (GWSA).[6] Modeling must be done to determine what level of reductions are needed to achieve these targets. This modeling should be updated regularly (at least every three years, in line with each iteration of the CES), and DEEP should develop several scenarios as pathways to achieving these goals. A deployment goal that will not result in meeting state climate targets would not comply with the GWSA and must be avoided.

In addition to ensuring that heat pump deployment targets align with the GWSA, equity considerations should play a role in setting these targets. For example, targets specifically for deployment in low- and moderate-income households, rental properties (for ASHPs), and in environmental justice populations should be developed.

iii. ASHP + thermal storage (and heat pump water heaters)

Combining thermal storage with an ASHP can improve the heat pump's operating efficiency: the ASHP can operate very efficiently when it is warmer outside, while the thermal storage system can store that heat for later use when it is cooler. Because heat pumps are already highly efficient, the increased efficiency of an ASHP plus thermal storage should be assessed in the 2022 CES to determine how valuable these efficiency gains are relative to the increased cost of installing a thermal storage system.

DEEP did not specifically request comments on heat pump water heaters, but the 2022 CES should certainly include this technology. Heat pump water heaters are a key component to building electrification because most homes currently rely on conventional water heaters (which

[6] Conn. Gen. Stat. § 22a-200a(a).

typically run on gas), and even homes with solar water heaters usually have a backup fossil fuel-based system. Heat pump water heaters can therefore significantly reduce emissions.

The operational cost of heat pump water heaters is low but wiring upgrades needed to install the heater can be costly, which has limited the deployment of this technology. However, this barrier seems likely to decrease because newer heat pump water heaters that can plug into standard 120-volt outlets—and therefore do not require costly wiring upgrades—are increasingly available.[7] Financial incentives to defray the upfront cost of heat pump water heaters, such as the rebate authorized in the federal Inflation Reduction Act, will continue to be important tools to encourage consumers to choose heat pump water heaters over fossil fuel-based alternatives.

iv. Ground source heat pumps (GSHP)

Most of the comments provided for ASHPs in Section 3.ii, *infra*, also apply to ground-source heat pumps (GSHPs). A few distinctions, however, are worth mentioning. First, because GSHPs cost more upfront than ASHPs, the financial barriers for this technology are greater. In addition, GSHPs require a certain amount of space to install and may not be a viable option for certain types of properties, including homes in dense neighborhoods, rental properties, and multi-family buildings. Deployment targets for GSHPs should reflect these constraints. GSHPs have even lower emissions than ASHPs due to their extremely high level of efficiency, and these climate benefits should also be considered in determining GSHP deployment targets.

v. Enhanced geothermal

As noted above, the potential for enhanced geothermal in the northeast is unclear. DEEP should continue monitoring developments in this area but it likely will not play a significant role in decarbonizing the state's buildings sector in the immediate future.

vi. Solar space and water heating

Solar space and water heating should play a role in decarbonizing Connecticut's building sector but will not be as central as weatherization and heat pumps. Passive solar space heating is most relevant for new construction or extensive retrofits. It may not be a realistic option for a lot of Connecticut's existing building stock. Active solar space heating may be an option for more buildings. The 2022 CES should assess the relevance and potential for both active and passive solar space heating in Connecticut.

Solar water heating can also help decarbonize the buildings sector but seems likely to play a supporting role because "[s]olar water heating systems almost always require a backup system for cloudy days and times of increased demand."[8] In most cases, this backup system would be a conventional storage water heater that runs on gas. This should be considered in analyzing the emissions profile of solar water heating.

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[7] Jeff St. John, Canary Media, *Finally, a heat-pump water heater that plugs into a standard outlet* (Aug. 29, 2022), https://www.canarymedia.com/articles/heat-pumps/finally-a-heat-pump-water-heater-that-plugs-into-a-standard-outlet.

[8] U.S. Department of Energy, *Solar Water Heaters*, https://www.energy.gov/energysaver/solar-water-heaters.

vii. Biodiesel

The 2022 CES should not include biodiesel as a strategy to decarbonize the buildings sector because biodiesel emits GHGs at the point of combustion and has substantial lifecycle emissions, and therefore is not a solution to meeting Connecticut's climate goals. The GHG emissions associated with biodiesel, can, in some cases, *exceed* the emissions from fossil fuels: "[d]epending on the feedstock and production process and time horizon of the analysis, biofuels can emit even more GHGs than some fossil fuels on an energy-equivalent basis."[9]

Incentivizing biodiesel would set Connecticut back in meeting its GHG reduction goals not only because biodiesel directly produces emissions, but also because biodiesel would prolong the state's reliance on heating oil. Biodiesel is blended with petroleum prior to use in almost all circumstances, and the American Society for Testing and Materials D396 heating oil specification limits biodiesel blends to 20% in most circumstances.[10] There are numerous obstacles to the use of pure biodiesel:

> Pure biodiesel has limited direct-use applications and faces supply logistics challenges because of its physical properties and characteristics. Biodiesel is a good solvent that can degrade rubber in fuel lines and loosen or dissolve varnish and sediments in petroleum diesel fuel tanks, pipelines, and in engine fuel systems . . . [it] gels at higher temperatures than petroleum diesel, which creates problems for its use in cold temperatures. Therefore, biodiesel cannot be stored or transported in regular petroleum liquids tanks and pipelines and it has to be transported by rail, vessel and barge, or truck.[11]

While technological advances may eventually permit higher blends of biodiesel for use as a home heating fuel, Connecticut cannot afford to prolong the use of home heating oil for years while awaiting these developments. The urgent need to decarbonize the buildings sector in line with state climate commitments demands that Connecticut phase out fossil fuel heating as soon as possible—including home heating oil *and* biodiesel. The 2022 CES should determine that biodiesel is not a viable pathway to decarbonization.

Incentivizing biodiesel has no place in the state's Comprehensive Energy Strategy given the incompatibility of this fuel with state climate requirements. Subsidies for biodiesel would also support the continued use of heating oil and would simply prolong the state's reliance on fossil fuels, contravening state climate goals. Connecticut should instead facilitate a managed transition away from fossil fuel heating as quickly as possible. Oil dealers can participate in the transition to electrification by changing their business model and services, and they should have access to workforce development and training opportunities that will enable this shift. If they

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[9] US EPA, Economics of Biofuels, https://www.epa.gov/environmental-economics/economics-biofuels ("Depending on the feedstock and production process and time horizon of the analysis, biofuels
can emit even more GHGs than some fossil fuels on an energy-equivalent basis.") See also, International Council on Clean Transportation, Biodiesel carbon intensity, sustainability and effects on vehicles and emissions (January

[10] American Society for Testing and Materials, Standard Specification for Fuel Oils D396.

[11] U.S. Energy Information Administration, *Biodiesel, renewable diesel, and other biofuels,* *https://www.eia.gov/energyexplained/biofuels/biodiesel-rd-other-use-supply.php*.

instead choose to continue selling home heating oil while claiming that biodiesel is a climate solution, the state should not support their efforts.

viii. Renewable natural gas

Gas companies around the country, including local gas distribution companies that operate in Connecticut, often argue that continued investment in gas infrastructure is warranted because refined biogas, known as "renewable" natural gas (RNG) or biomethane, can be used to decarbonize gas operations. These claims are not supported by current research. The 2022 CES should make it clear that Connecticut will not invest in RNG as a decarbonization strategy for the buildings sector.

Biogas is usually 50-70% methane and 30-50% carbon dioxide—both greenhouse gases—with some trace materials.[12] Critically, biogas cannot be used in pipelines or appliances in place of fossil gas unless the non-methane components are removed.[13] Refined biogas is typically considered RNG when it contains at least 90% methane.[14] However, pipelines often require RNG to contain 96-98% methane.[15]

Methane is an extremely potent greenhouse gas that contributes significantly to climate change.[16] Methane is 84 times more potent than carbon dioxide in the first 20 years after its release,[17] and is still 28-36 times as potent after 100 years.[18] Methane leakage is pervasive throughout the gas system,[19] including in Connecticut.[20] Injecting biogas from anaerobic digesters—which is mostly methane—into gas pipelines would simply contribute to this problem, and moreover would prolong the state's reliance on fossil gas and leaky gas infrastructure.

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[12] National Renewable Energy Laboratory (NREL), *Biogas Potential in the United States*, 1 (Oct. 2013), https://www.nrel.gov/docs/fy14osti/60178.pdf (hereafter NREL Report).
[13] EPA, *Renewable Natural Gas*, https://www.epa.gov/lmop/renewable-natural-gas.
[14] *Id.*
[15] *Id.*
[16] U.N. Environment Programme, *Global Assessment: Urgent steps must be taken to reduce methane emissions this decade* (May 6, 2021), https://www.unep.org/news-and-stories/press-release/global-assessment-urgent-steps-must-be-taken-reduce-methane ("Rick Duke, Senior Advisor to the U.S. Special Presidential Envoy on Climate Change, said: 'Methane accounts for nearly one-fifth of global greenhouse gas emissions and . . . it is by far the top priority short-lived climate pollutant that we need to tackle to keep 1.5˚C [of warming] within reach.'").
[17] U.N. Economic Commission for Europe, *Methane Management: The Challenge*, https://unece.org/challenge.
[18] U.S. EPA, *Greenhouse Gas Emissions: Understanding Global Warming Potentials*, https://www.epa.gov/ghgemissions/understanding-global-warming-potentials.
[19] *See, e.g.*, Maryann R. Sargent, *Majority of US Urban Natural Gas Emissions Unaccounted for in Inventories*, https://www.pnas.org/content/118/44/e2105804118 (measured methane leakage around Boston and estimated total supply chain losses of 3.3 to 4.7% for natural gas consumed in urban areas, which significantly increases the climate impacts of natural gas compared to existing U.S. EPA estimates); Ramon A. Alvarez, *Assessment of Methane Emissions from the U.S. Oil and Gas Supply Chain*, Science, Vol 361, Issue 6398 (July 13, 2018) (finding that supply chain emissions were approximately 60% higher than the U.S. EPA inventory estimate).
[20] Patrick Skahill, Connecticut Public Radio, *New Study Shows Methane Leaks Prevalent in Connecticut Cities* (Nov. 19, 2020), https://www.ctpublic.org/environment/2020-11-19/new-study-shows-methane-leaks-prevalent-in-connecticut-cities.

In addition, there is no evidence that refined biogas can be utilized at a broad scale in Connecticut or regionally. New England has minimal biogas potential. Five of the six New England states, including Connecticut, rank among the twelve states with the least biogas potential.[21] The sixth state, Massachusetts, also has limited potential,[22] with one study finding that Massachusetts' annual RNG potential could displace just 10% of its fossil gas demand.[23]

Nationally, it is estimated that biogas potential could replace just 5% of fossil gas consumption in the electric sector.[24] Other studies estimate that RNG could meet around 12%[25] or 14%[26] of the United States' total gas demand in a high resource potential scenario, with estimates of environmentally sound biogas being as low as 2-5%.[27]

RNG is also expensive, with high startup costs and variable production costs. As a result, RNG is expensive to produce or procure, and its consumer price is approximately three times the price of fossil gas.[28] All three of New England's current RNG projects had high startup costs.[29] Production and procurement costs for RNG vary widely. It costs between $3.00 and $30.00 per MMBtu to produce RNG.[30] At its cheapest, RNG production costs less than fossil gas, which ranges from $2.52 to $4.37 per MMBtu.[31] However, RNG production estimates often exclude the cost of removing siloxanes from RNG produced with consumer waste, so the lower costs may not be feasible.[32] Importing RNG is also costly because procurement costs are high: imported RNG costs between $12 and $25 per Mcf, while imported fossil gas costs $3 per Mcf.[33]

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[21] NREL Report at 3.
[22] *Id.*
[23] National Grid, *Renewable Gas - Vision for a Sustainable Gas Network*, 2 (2010), https://www9.nationalgridus.com/non_html/NG_renewable_WP.pdf.
[24] NREL Report at 3.
[25] The American Gas Foundation found that in a "high resource potential scenario", 4,510 trillion Btus of RNG would be available in 2040. American Gas Foundation, *Renewable Sources of Natural Gas: Supply and Emissions Reduction Assessment*, 2 (2019), https://gasfoundation.org/2019/12/18/renewable-sources-of-natural-gas/. Assuming, as reported by the EIA, the US used 31.5 quadrillion btus of gas in 2020, that amounts to about 12% of current US gas demand. U.S. Energy Information Administration. *Natural Gas Explained*, https://www.eia.gov/energyexplained/natural-gas/use-of-natural-gas.php.
[26] Philip Sheehy *et al.*, *Exploring renewable natural gas as a decarbonization strategy* (2021)
[27] Natural Resources Defense Council, *A Pipe Dream or Climate Solution? The Opportunities and Limits of Biogas*
[28] Programs Manual – Vermont Gas Systems, 10 (Aug. 20, 2019), https://www.vermontgas.com/wp-content/uploads/2018/09/VGS-RNG-Manual-Final-V-1.01.pdf.
[29] University of New Hampshire, *Cogeneration and EcoLine*, https://www.unh.edu/sustainability/operations/energy/ecoline (landfill RNG project cost $49 million); Elizabeth Gribkoff, VT Digger, *Partners Hail Groundbreaking of Salisbury Biodigester* (Aug. 20, 2019) https://vtdigger.org/2019/08/20/partners-hail-groundbreaking-of-salisbury-biodigester/ (Goodrich Farm project cost $20 million); Summit Natural Gas Maine, *Summit Announces Renewable Natural Gas Initiative*, (May 23, 2019), https://summitnaturalgasmaine.com/SummitAnnouncesRenewableNaturalGasInitiative (Summit Maine project projected to cost $20 million).
[30] Rebecca Gasper & Tim Searchinger, World Resources Institute, *The Production and Use of Waste-Derived Renewable Natural Gas as a Climate Strategy in the United States*, 24 (Apr. 2018), https://www.wri.org/publication/renewable-natural-gas.
[31] *Id.* at 23.
[32] Gregory Von Wald *et al.*, *Biomethane in California Common Carrier Pipelines: Assessing Heating Value and Maximum Siloxane Specifications*, 70 (June 2018), https://ccst.us/wp-content/uploads/2018biomethane.pdf.
[33] Vermont Public Service Board, Docket No. 8667, Petition of Vermont Gas Systems, Prefiled Testimony of Thomas Murray on Behalf of Vermont Gas Systems, 8-9:21-1 (Oct. 23, 2015).

There is limited potential to replace fossil gas with RNG in Connecticut, regionally in New England, and across the country. The high costs and scarcity of this resource do not support further investment in gas infrastructure in Connecticut, and the 2022 CES should conclude that the state will not invest in biogas or RNG as a decarbonization strategy for the buildings sector.

ix. Green hydrogen

While the undersigned organizations recognize that green hydrogen shows promise in discrete applications, the CES should not build a decarbonization strategy for the buildings sector around hydrogen as it is not a viable pathway to decarbonization. A clear-eyed assessment of hydrogen's potential reveals that replacing fossil gas in the buildings sector with green hydrogen is not viable, as it would require unattainable levels of renewable energy development; that relying on blue (or gray) hydrogen rather than green hydrogen would eviscerate the intended climate benefits (increasing rather than decreasing total GHG emissions); and that numerous other technical and practical barriers impede the safe and cost-effective deployment of hydrogen at scale and especially in the buildings sector. 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.

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 buildings where electric air- or ground-source heat pumps can readily serve the same need. Hydrogen is not a viable pathway to decarbonization in the buildings sector due to the scarcity of "green" hydrogen and the large amounts of renewable energy required to produce it, the high costs and safety concerns associated with hydrogen, the inability to utilize hydrogen in existing gas infrastructure and appliances, the nascent state of hydrogen research and development, and diminishing climate benefits when hydrogen is injected into a leaking distribution system.

Green hydrogen cannot provide substantial greenhouse gas reductions in the buildings sector because it leaks easily due to its small molecular size and it is an indirect greenhouse gas. Leakage rates for hydrogen are expected to be 1.3-2.8 times greater than those for methane.[34] At the same time, hydrogen is an indirect greenhouse gas with a 100-year global warming potential 5.8 times greater than carbon dioxide.[35] 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.[36] Further,

[34] 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.
[35] 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.
[36] 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.

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 also has a far lower heat content than methane gas: only approximately 30 percent.[37] Consequently, despite the expense and complexity, blending hydrogen into methane gas streams at low concentrations does very little to improve total GHG emissions. The undersigned note that alternatives to green hydrogen, including 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, as these have been shown to have even higher GHG footprints than burning natural gas, coal, or diesel for heat.[38]

Hydrogen is also inappropriate for the buildings sector because it is incompatible with existing infrastructure. 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.[39] 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 fatigue of material and pipeline failure due to overpressure and also due to hydrogen embrittlement."[40]

In addition, 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 GHG emission reductions and increase emissions of nitrogen oxides.[41]

Lastly, hydrogen is not safe in homes, both because it is explosive and because its combustion contributes to significant air pollution. 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.[42] In addition, while reaction of hydrogen in a fuel cell

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[37] Ulf Bossel & Baldur Eliasson, Energy and the Hydrogen Economy, 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)").
[38] Howarth & Jacobson, How green is blue hydrogen? *Energy Sci. & Eng'r* (July 2021).
[39] 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.
[40] *Id.*
[41] Energy Innovation at 3.
[42] 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.

produces only water, combustion of hydrogen results in significant formation of harmful nitrogen oxides. Nitrogen oxides are a pollutant in their own right, and are 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.[43]

Consequently, the 2022 CES should prioritize viable decarbonization strategies for the buildings sector such as electrification; hydrogen should not be included as a building sector decarbonization strategy. The CES should identify opportunities for hydrogen that are currently recognized, such as utilizing hydrogen in hard-to-decarbonize industrial applications. Discussion should include exploration of the different ways hydrogen can be produced and the GHG and cost implications of each method, the availability of green hydrogen versus hydrogen that is produced from fossil fuels, demonstrated uses of hydrogen, safety issues associated with hydrogen, and commitment to revisiting the viability of green hydrogen as a decarbonization strategy in future iterations of the CES.

x. Compost heat recovery

The potential for compost heat recovery to contribute to decarbonizing the buildings sector should be explored in the CES, including the potential for alignment with the state's waste management strategies and efforts to divert compostable materials from the waste stream. There will be more limited potential for this niche technology to reduce emissions than more broadly available and applicable technologies, however, and this should be reflected in the CES.

Respectfully submitted,

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[43] 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)(finding that burning pure hydrogen would emit more than six times more nitrogen oxides than burning methane).

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