Advancing the Clean Energy Future

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Via Email: DEEP.EnergyBureau@ct.gov

Connecticut Department of Energy and Environmental Protection
79 Elm Street
Hartford, CT 06106

Re: Acadia Center Comments on 2022 Comprehensive Energy Strategy, Session 4

Dear Sir or Madam:

Acadia Center appreciates the opportunity to submit written comments on the 2022 Comprehensive Energy Strategy's consideration of the potential for building decarbonization through weatherization, electrification, and other low carbon technologies.

Acadia Center is a non-profit research and advocacy organization committed to advancing the clean energy future by offering real-world solutions to the climate crisis. Acadia Center tackles complex problems, identifies clear recommendations for reforms, and advocates for policy changes that support a low-carbon economy across the Northeast. Acadia Center identifies regional, state, and local improvements that will dramatically reduce carbon pollution and improve quality of life throughout the Northeast.

In short, Acadia Center's comments rest on five main principles:

- DEEP's pathway to decarbonization in buildings (and economy-wide) must begin with substantially updated practices in its greenhouse gas accounting.
- DEEP should create a Connecticut-specific economy-wide decarbonization roadmap with decade-by-decade and sector-by-sector reduction targets and goals, supported by analysis, akin to the Massachusetts Roadmap and Clean Energy and Climate Plans.
- This roadmap should identify the pathway to building decarbonization that minimizes overall system costs and does not interfere with the ability of other states or sectors to achieve net zero emissions
- That pathway should then be pursued in the fastest and most equitable way possible through enforceable, statewide targets for electrification and weatherization of buildings, beginning with low income, high emissions homes to help improve health outcomes and lower energy burdens.
- After the Connecticut decarbonization roadmap analysis is complete, DEEP should initiate a comprehensive assessment of the future of gas in Connecticut to help get the state on the right path for phasing out fossil fuel use. In the meantime, DEEP should stop all investment in gas system expansion beyond repairs and upgrades necessary for safety.

Specific Responses

1. Recent reports and analyses that could assist DEEP in developing Connecticut deployment targets for weatherization and thermal decarbonization technologies

Connecticut needs an economy-wide decarbonization roadmap – a thorough analysis that looks at the interrelated nature of greenhouse gas pollution and consumer energy and environmental burdens, and sets interim, sector-specific targets. Such a roadmap should be supported by analysis such as the Massachusetts 2050 Decarbonization Roadmap ("MA Roadmap").[1] Given the overlap and similarities between the neighboring states, Connecticut may be able to adjust and downscale the MA Roadmap for its own purposes. However, a robust independent analysis may be more politically useful to get buy-in from stakeholders, industry, utilities, and consumers. Either way, it is likely that DEEP would reach many of the same conclusions that MA Executive Office of Energy and Environmental Affairs did – namely, that the least-cost deployment of energy system technologies that achieve deep decarbonization involves electrification, energy efficiency, and almost no role for fossil fuels or alternative fuels in buildings.

Completed in late 2020, the MA Roadmap involved a rigorous modeling process to chart the most cost-effective pathways and strategies to achieving the state's net zero by 2050 target. Key findings included:

1. **Electrification is the most cost-effective path to building decarbonization:** Widespread electrification of buildings, primarily using highly efficient heat pumps, was found to be the least-cost strategy. The "All Options" pathway calls for electrification of over 90% of residential space heating, 95% of residential water heating, and 95% of commercial heating, water heating, and cooking.[2]
2. **Energy efficiency retrofits are instrumental in making building decarbonization both feasible and cost-effective.** The "All Options" pathway found that nearly all homes in the state would need some level of efficiency upgrade by 2050, with most older homes receiving deep energy retrofits (e.g., more insulation, window replacements). The study found that by 2050, every $1 invested in efficiency returned $1.50 in avoided energy costs.[3]
3. **There is no cost-effective role for "alternative fuels" in buildings.** The study found that widespread adoption of electrification paired with increased energy efficiency measures are a lower cost decarbonization strategy in buildings than the use of "alternative fuels," including renewable natural gas (RNG), biodiesel, hydrogen, and synthetic natural gas (SNG). In the "All Options" pathway, none of these alternative fuels are used in residential and commercial buildings, as these supply-constrained fuels were found to be most efficiently used in decarbonizing the most difficult-to-electrify portions of the transportation and industrial sectors.[4]

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[1] Massachusetts 2050 Decarbonization Roadmap. https://www.mass.gov/info-details/ma-decarbonization-roadmap#final-reports-

[2] Massachusetts 2050 Decarbonization Roadmap: Buildings Sector Report, page 5 https://www.mass.gov/doc/building-sector-technical-report/download

[3] Massachusetts 2050 Decarbonization Roadmap: Buildings Sector Report, page 15 https://www.mass.gov/doc/building-sector-technical-report/download

[4] Massachusetts 2050 Decarbonization Roadmap: Energy Pathways to Deep Decarbonization, page 35 https://www.mass.gov/doc/energy-pathways-for-deep-decarbonization-report/download

4. **Electrification is the most cost-effective path to decarbonize transportation.** Due to comparatively low cost and high drive-train efficiency of battery electric vehicles (BEVs) compared to alternatives including hydrogen fuel cell electric vehicles (FCEVs), the "All Options" pathway found that BEVs made up 95% of the light-duty fleet and 50-60% of medium/heavy-duty fleet by 2050. While converting approximately 20-30% of the medium/heavy-duty vehicle fleet to FCEVs by 2050 was found to be cost effective, the study found no cost-effective role for hydrogen in decarbonizing passenger car and light-duty truck fleets.[5]

The Princeton Net-Zero America (NZA) Project is another well respected quantitative modeling study that could help inform development Connecticut's own decarbonization roadmap. While the study is at a national scale, many of the key takeaways from the modeling can help to inform state-level decarbonization pathway decision making. Similar to the MA Roadmap, Princeton's study found overwhelmingly that the most cost-effective end use of green hydrogen was in hard-to-electrify portions of the industrial and transportation sectors.

None of the five decarbonization pathways in the study found that it was cost-effective to use hydrogen or RNG in residential and commercial buildings.[6] The study also found that the two pathways with the lowest energy system costs over the next 30 years were the "High Electrification" and "High Electrification, Renewables Constrained" pathways. Both of these pathways assumed "aggressive end-use electrification" with electricity accounting for 85%-90% of total energy consumption in residential and commercial buildings.[7]

2. Variables and parameters critical to consider when developing Connecticut-specific thermal decarbonization targets

It is crucial that DEEP's economy-wide decarbonization roadmap and building decarbonization pathway are based on accurate greenhouse gas accounting. The Connecticut Greenhouse Gas Inventory ("CT Inventory") must be updated to include all emissions from the extraction and transmission of fossil fuels and lifecycle of biofuels, including differentiating between biofuels produced from crops, and utilizing up-to-date information on the frequency of methane leaks. The CT Inventory must also be updated to reflect 20-year global warming potential values that more accurately depict the true impacts of methane, and the wide ranging GHG intensity of hydrogen.

Acadia Center recommends that Connecticut account for emissions resulting from the extraction and transmission of fossil fuels (that are ultimately consumed in Connecticut) occurring outside the borders of the state. This GHG accounting change will put electricity and fossil fuels consumed in Connecticut on a more equal playing field and more accurately capture the true GHG implications of continued fossil fuel consumption in the state.

Currently, the CT Inventory only accounts for GHG emissions resulting from natural gas transmission and distribution losses occurring within state borders. In contrast, the CT Inventory accounts for GHG emissions resulting

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[5] Massachusetts 2050 Decarbonization Roadmap: Transportation Sector Report, page 13 https://www.mass.gov/doc/transportation-sector-technical-report/download

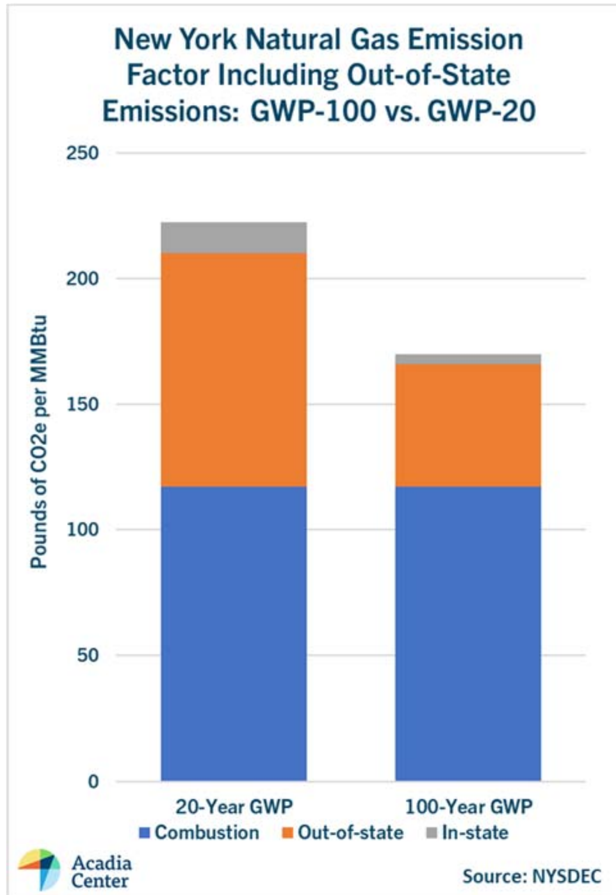
[6] Princeton University Net-Zero America Potential Pathways, Infrastructure, and Impacts Final Report. Slides 30-33. https://netzeroamerica.princeton.edu/the-report

[7] Princeton University Net-Zero America Potential Pathways, Infrastructure, and Impacts Final Report Slides 57 & 63. https://netzeroamerica.princeton.edu/the-report

from electricity transmission and distribution losses that occur outside of the state. This inconsistency between electricity and fossil fuel accounting is one of the reasons the New York Climate Leadership and Community Protection Act (CLCPA 2019) required adjustments to New York's GHG accounting practices to account for the GHG emissions resulting from both the extraction and transmission of fossil fuels imported into New York:[8]

*"The statewide greenhouse gas emissions report shall also include an estimate of greenhouse gas emissions associated with the generation of imported electricity and with the **extraction and transmission of fossil fuels imported into the state which shall be counted as part of the statewide total.**"*

In compliance with the CLCPA, the New York State Department of Environmental Conservation's (NYSDEC's) New York's 2021 Statewide GHG Emissions Report included an "upstream fuel cycle emission factor" that takes into account GHG emissions associated with out-of-state extraction, production, and transmission of fossil fuels imported into New York and in-state fugitive emissions from natural gas transmission and distribution.[9] The report also expresses all emissions using global warming potential (GWP)-20 values. The end result, as demonstrated by the figure on the right, is a *90% increase* in the natural gas emission factor compared to traditional "combustion-only" emissions accounting leveraging 100-year GWPs.[10] **This analysis in New York demonstrates why it is critical that Connecticut update outdated accounting practices that severely underestimate the actual GHG impacts of the state's continued reliance on fossil fuels.**



Greenhouse Gas Accounting Must be Updated to Reflect 20-year Global Warming Potential Values that More Accurately Depict the True Impacts of Methane

Acadia Center also recommends that Connecticut quantify GHG emissions using GWP-20 values. This approach more accurately reflects the GHG impacts of methane on timescales relevant to both state and global GHG reduction targets.

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[8] New York Senate Bill S6599 ("CLCPA") https://www.nysenate.gov/legislation/bills/2019/s6599

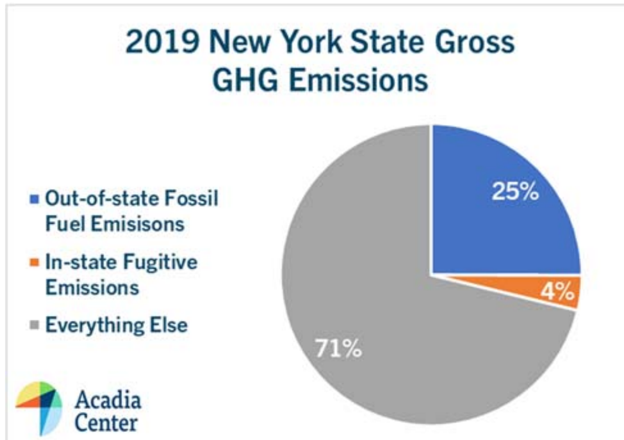
[9] NYSDEC Technical Conference: Oil and Gas Emissions Accounting webinar: https://meetny.webex.com/recordingservice/sites/meetny/recording/c70b87ddede64ec891f87fde6803080c/playback

[10] NYSDEC 2021 Statewide GHG Emissions Report, Table A1 & A3 https://www.dec.ny.gov/docs/administration_pdf/ghgsumrpt21.pdf

The CT Inventory currently relies on 100-year GWPs. In New York, the CLCPA required that the state's GHG accounting switch from utilization of 100-year GWPs to 20-year GWPs given that a 20-year time horizon is more relevant to the goal of net zero emissions by 2050:[11]

" 'Carbon dioxide equivalent' means the amount of carbon dioxide by mass that would produce the same global warming impacts as a given mass of another greenhouse gas over an integrated ***twenty-year time frame*** *after emission."*

The figure above demonstrates that switching from a 100-year GWP to a 20-year GWP, while simultaneously considering non-combustion emissions from natural gas use, results in a 31% increase in the overall natural gas emission factor. To underscore the importance of this GHG accounting change in New York, **out-of-state emissions associated with fossil fuels account for 29% of New York's statewide total gross GHG emissions, significantly more than fuel combustion in the transportation sector (20%), residential sector (11%), or commercial sector (6%).**[12]



Greenhouse Gas Accounting for Biofuels Needs to be Completely Revamped to Account for Net GHG Impacts

One of the key limitations of the CT Inventory is that it largely treats biogenic emissions as an informational item and almost entirely ignores the impact of biogenic emissions on overall statewide emissions totals. Currently, only CH_4 and N_2O GHG emissions resulting from combustion of biogas are captured in the "non-biogenic" portion of the CT Inventory. These CH_4 and N_2O emissions represent a small fraction of total biofuel combustion emissions and an even smaller fraction of the total net GHG emissions resulting from the biofuel supply chain (including production, processing, and transmission). This accounting of biofuels is gross simplification of a complex issue, particularly in instances where biofuels are derived from energy crops and in instances where emissions are released while producing, processing, and transporting biomethane.

The use of biofuels that are purported to be "low carbon" or "carbon-neutral" (Acadia Center prefers the term "alternative fuels") is likely to increase in coming years, underscoring the importance of accurate GHG accounting for these fuels. **Acadia Center recommends that Connecticut establish GHG accounting principles that clearly assert that 1) Biogenic emissions should impact total reported emissions in the CT Inventory and 2) Biogenic emissions from biofuels need to be measured against the counterfactual (e.g., not intentionally producing biogas in the first place or diverting biogas from flaring to produce biomethane).** These accounting practices are critical to establish now given the increasing interest in biofuels as a potential decarbonization strategy.

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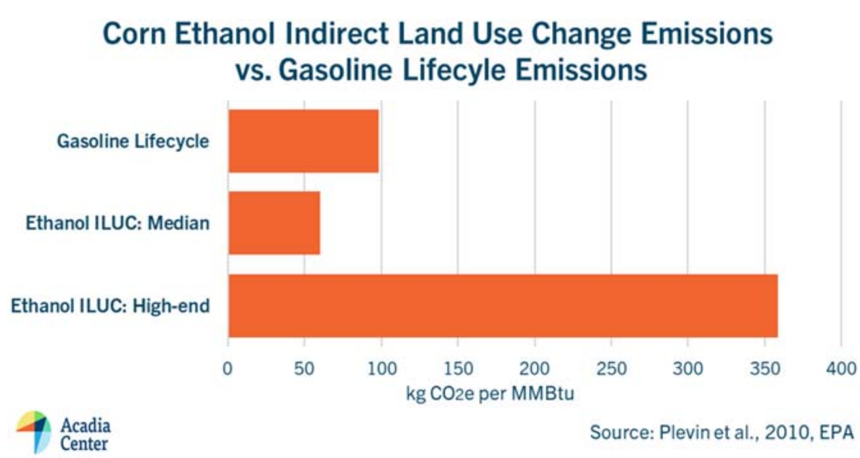
[11] New York Senate Bill S6599 ("CLCPA") https://www.nysenate.gov/legislation/bills/2019/s6599

[12] NYSDEC 2021 Statewide GHG Emissions Report, Table ES.2 https://www.dec.ny.gov/docs/administration_pdf/ghgsumrpt21.pdf

Biofuels Derived from Energy Crops Should be Specially Calculated in GHG Accounting (and play no role in Connecticut's decarbonization)

Energy crops, or crops grown solely for the purpose of energy production, are the most problematic biofuel feedstocks for a number of reasons, including the net GHG implications of indirect land use changes (ILUC). **Because of the problematic nature of biofuels derived from energy crops, any policy promoting the use of biofuels in Connecticut must make it clear that biofuels derived from energy crops are explicitly prohibited, regardless of the end use application of those biofuels.** ILUC associated with energy crop production make it particularly challenging to quantify the life-cycle GHG emissions impact of biofuels derived from these feedstocks. ILUC are the unintended consequence of the expansion of croplands for biofuels to meet increased global demand for biofuels. The U.S. is one of the world's largest agricultural exporters and shifting land in the U.S. from agricultural food production to energy crop production can have ripple effects across the globe that result in a net increase in GHG emissions.



The complexities of these ripple effects result in wide ranges of uncertainty when attempting to quantify emissions from ILUC associated with biofuels. For example, ILUC emissions associated with US corn ethanol expansion during the 2000s were estimated to fall in the range of 10.5 to 358.6 kg CO2e per million Btu (MMBtu), with a median emission factor between 58.0 and 62.2 kg CO2e per MMBtu.[13] **To put those numbers in perspective, as shown in the figure to the right, the median ethanol emission factor from that study is about 60% of the EPA's life cycle emission factor for conventional gasoline and the high-end ethanol emission factor estimate is over 3.6 times higher than the emission factor for conventional gasoline.**[14] The U.S. Department of Energy's Billion-Ton Report – which is one of the most comprehensive studies calculating potential biomass supply in the United States and the associated environmental impacts – conducted analysis assessing the GHG impacts of scenarios with expanded biofuels production but did not attempt to quantify the GHG impacts of ILUC, highlighting the extreme level of uncertainty surround the topic.[15]

One of the most widely cited sources on the GHG emission reduction benefits of biodiesel is from Argonne National Lab, but the study openly acknowledges that the GHG impacts of land use changes are so complicated that they just

[13] Plevin, et al., 2010. "Greenhouse Gas Emissions from Biofuels' Indirect Land Use Change Are Uncertain but May Be Much Greater than Previously Estimated " https://pubs.acs.org/doi/abs/10.1021/es101946t

[14] EPA "Lifecycle Greenhouse Gas Results" www.epa.gov/fuels-registration-reporting-and-compliance-help/lifecycle-greenhouse-gas-results

[15] DOE 2016 Billion-Ton Report www.energy.gov/eere/bioenergy/2016-billion-ton-report

simply ignore them in the analysis: "*Note that this study does not consider potential land use changes. Increased CO_2 emissions from potential land use changes are an input option in GREET, but it was not used in the current analysis since* ***reliable data on potential land use changes induced by soybean-based fuel production are not available**.*"[16] This is extremely concerning, considering that soybean oil accounts for over 60% of the biodiesel currently produced in the U.S.[17] .

Even more concerning is that there are troubling links between expanded biodiesel production in the U.S. and the expansion of palm oil plantations in Indonesia and Malaysia, a major driver of deforestation and global land use emissions.[18] EPA lifecycle GHG emissions analysis, which attempts to account for indirect land use changes (to a debatable level of accuracy), highlights that biodiesel is far from carbon neutral. For example, biodiesel derived from soybean oil and canola oil is estimated to have 56% and 50% lower lifecycle emissions, respectively, than conventional diesel. Some forms of biodiesel, like biodiesel derived from palm oil, only reduce lifecycle emissions of conventional diesel by 17% according to the EPA data.[19] However, it's critical to note that trying to peg the emissions reduction potential of biodiesel, or any biofuel, to a single number masks the extreme uncertainty in emissions resulting from ILUC discussed above.

As part of sHB 6412, DEEP has been tasked with *"considering…the reduction in greenhouse gas emissions resulting from low carbon fuels blends used in home heating oil on a life-cycle basis and its possible contributions to the state's greenhouse gas emissions levels."* The GHG accounting structure for biodiesel proposed by DEEP must fully account for the extreme uncertainty in lifecycle GHG emissions arising from ILUC.

Methane Leaks Along the RNG Supply Chain Must be Considered When Evaluating the GHG Impacts of RNG

Even excluding energy crops, many of the pathways for producing biomethane (often referred to as "renewable natural gas") via biogas upgrading are problematic from a GHG emissions perspective when the methane emissions along the RNG supply chain are fully considered. **Because accurate accounting of the methane leaks along RNG supply chains is critical to determining the GHG benefits, if any, of transitioning from fossil natural gas to RNG, the CT Inventory must adopt GHG accounting principles that fully consider these methane leaks.**

Typically, biogas produced at facilities, including wastewater treatment plants and landfills, is either vented or flared. While both processes release GHG emissions, flaring is much preferable from a GHG emissions perspective since it converts CH_4 to CO_2 prior to release into the atmosphere.[20] This is one of the reasons California requires all municipal

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[16] Argonne National Laboratory "Life-Cycle Assessment of Energy and Greenhous Gas Effects of Soybean-derived Biodiesel and Renewable Fuels", 2008. Page 4. https://greet.es.anl.gov/files/e5b5zeb7

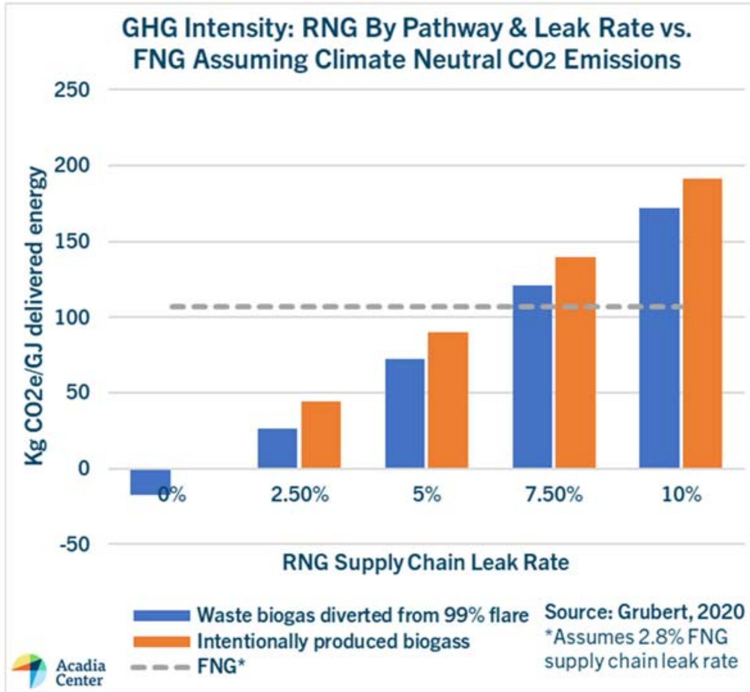
[17] EIA "Monthly Biodiesel Production Report" Table 3. https://www.eia.gov/biofuels/biodiesel/production/table3.pdf

[18] Union of Concerned Scientists "Everything You Ever Wanted to Know About Biodiesel", 2016. https://blog.ucsusa.org/jeremy-martin/all-about-biodiesel/

[19] EPA "Lifecycle Greenhouse Gas Results" www.epa.gov/fuels-registration-reporting-and-compliance-help/lifecycle-greenhouse-gas-results

[20] Greenhouse Gas Protocol "Global Warming Potential Values" www.ghgprotocol.org/sites/default/files/ghgp/Global-Warming-Potential-Values%20%28Feb%2016%202016%29_1.pdf

waste landfills to install gas collection and control systems that have a "methane destruction efficiency" of at least 99%.[21] Alternative to either venting or flaring, biogas can be captured and processed to produce biomethane.



Research suggests that total supply chain methane leakage from RNG intended for pipeline injection typically ranges from 2.8-4.8% but can range as high as 15.8%.[22] The same study assumed a reasonable fossil gas supply chain leak rate of 2.8%. Using these average leaks rates and 20-year global warming potential (GWP) values, the methane leakage GHG footprint of RNG derived from intentionally produced sources of biogas (e.g., energy crops) is 50% of the combustion plus methane leakage GHG footprint of fossil gas. Using the same assumptions, the methane leakage GHG footprint of RNG derived from waste biogas diverted from flaring is 33% of the GHG footprint of natural gas.[23] Under any scenario where the RNG supply chain leak rate exceeds 5.8% for RNG produced using intentionally created biogas or 6.8% for RNG produced using biogas diverted from flaring, the RNG GHG footprint *exceeds* that of natural gas. It's important to note that the GHG numbers cited above assumed the RNG was carbon netural in terms of CO_2, which, as discussed above is a highly suspect assumption, and the study was only focused on CH_4 emissions.

Considering the GHG implications of CH4 leaks, even if we make the generous assumption that the CO2 emitted from burning RNG is climate neutral, RNG produced through biogas upgrading can only potentially be considered a carbon-neutral replacement for natural gas if the RNG supply chain leak rate is 0% (for intentionally produced biogas) or held under 1% (for waste biogas diverted from 99% efficient flaring). Given this information, and the extreme technical challenges with achieving these low leak rates, sensible climate policy aimed at minimizing net GHG emissions would 1) Require biogas that is currently being vented to instead be captured and 2) Dictate that the biogas be flared or used in a CHP plant on-site, rather than upgraded to RNG. Understanding this concept is critical to understanding why the CT Inventory's current approach of treating all biogenic emissions as having no impact on the state's total reported emissions is problematic – the net GHG implications of biomethane are highly variable depending on the original source of the biogas and the methane leak rate along the supply chain.

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[21] California Air Resources Board, Subchapter 4, Article 4, Subarticle 6. https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2009/landfills09/landfillfinalfro.pdf

[22] Emily Grubert, 2020 Environ. Res. Lett. 15 084041 https://iopscience.iop.org/article/10.1088/1748-9326/ab9335

[23] Ibid.

Greenhouse Gas Accounting Must be Updated to Account for the Wide Ranging GHG Intensity of Hydrogen

Acadia Center recommends that, given the energy carrier nature of both hydrogen and electricity, Connecticut establish GHG accounting principles that clearly assert that imported gray hydrogen and imported green hydrogen will not both be treated as carbon neutral fuels and that the emissions resulting from the production of hydrogen, regardless of whether that production occurs in or out of state, will directly impact the reported emissions total in the CT Inventory.

Hydrogen, like electricity, is an "energy carrier" that allows the transport of energy in a usable form from one location to another. Like electricity, hydrogen must also be produced from another substance. For example, hydrogen can be produced in a carbon neutral process using electrolyzers powered by 100% renewable electricity. At the other extreme, hydrogen can be produced through the emissions-intensive process of steam methane reforming. **The emissions associated with creating 1 MMBtu of hydrogen via steam methane reforming[24], the method by which 95% of global hydrogen is produced today[25], are approximately 45% greater than the emissions resulting from the combustion of 1 MMBtu of natural gas.**[26] And like electricity, the GHG emissions associated with the production of the energy product, regardless of where that production occurs, should be captured in the CT inventory.

The CT Inventory is currently set up in such a way that the emphasis is on the eventual "end use," rather than the GHG intensity of the fuel production, where more significant concerns arise. For example, imported hydrogen from New York produced via steam methane reforming has zero impact on GHG emissions in Connecticut if the hydrogen is consumed in a fuel cell. Using this logic, there is no emissions reduction benefit to Connecticut of importing potentially carbon-neutral green hydrogen[27] versus importing carbon-intensive gray hydrogen. It's the equivalent of treating both imported electricity generated via coal and imported electricity generated via wind as carbon neutral forms of electricity from a Connecticut GHG perspective, and quite problematic.

The lack of a GHG accounting structure for hydrogen is concerning given the recent focus in Connecticut on exploring the potential of blending hydrogen into the gas distribution system. While there is currently no certification process or mechanism in place to track the GHG intensity of hydrogen production, it is likely that such a system will be needed at a state, regional, or national level if reliance on hydrogen grows as many projections expect it to. In the meantime, it's reasonable to assume that hydrogen is "grey" unless proven otherwise given that 95% of global hydrogen production is produced through steam-methane reforming.

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[24] 76.92 kg CO2 per MMBtu of hydrogen from Argonne National Laboratory "Updates of Hydrogen Production from SMR Process in GREET 2019" https://greet.es.anl.gov/publication-smr_h2_2019

[25] U.S. Department of Energy "Hydrogen Production: Natural Gas Reforming." https://www.energy.gov/eere/fuelcells/hydrogen-production-natural-gas-reforming

[26] 53.06 kg CO2 per MMBtu of fossil gas from EPA Emission Factors for Greenhouse Gas Inventories, 2018. https://www.epa.gov/sites/default/files/2018-03/documents/emission-factors_mar_2018_0.pdf

[27] Assuming no hydrogen leaks along the supply chain

3. Market Barriers & Technology-Specific Deployment Targets

As outlined above, Acadia Center believes that identification of technology-specific deployment targets is an essential step that must be informed by an economy-wide decarbonization roadmap for Connecticut. Such analysis can appropriately consider the competing needs of sectors that are harder to electrify than the buildings sector for renewable natural gas, biofuels, and green hydrogen, which other studies have determined are not appropriate for use in buildings.

Building sector decarbonization technologies are not made equal, and DEEP should not incentivize all of them equally. Instead, DEEP's plans should rely heavily on weatherization and heat pumps (including ASHPs, GSHPs, thermal storage) as well as integration with renewable energy and solar space and water heating where relevant. However, potential for enhanced geothermal in the northeast is unclear, and biodiesel, renewable natural gas, and hydrogen should not be utilized as decarbonization strategies in the building sector, but may, depending on the results of the roadmap, play a role in decarbonizing hard-to-electrify sectors.

Target the Most Energy Intensive Homes for Weatherization and Electrification

As Acadia Center highlighted in its initial CES scoping comments, it is crucial to approach building decarbonization equitably while reducing energy burdens. This can be done by first targeting the top 25% most energy-intensive homes for comprehensive retrofits and by prioritizing whole-building weatherization and electrification.

To meet Connecticut's greenhouse gas emission requirements, the state needs to rapidly weatherize and electrify its buildings. Electrifying and weatherizing housing for low- and moderate-income residents should be a top priority. In Connecticut, 23% of home energy audits are rejected because of health and safety barriers, including mold and asbestos, which must be cleared before a retrofit can take place.[28] Because removal of mold and asbestos is not deemed cost effective according to program rules, it means that those who most need retrofits are unable to receive the benefits they provide.

At the same time, 25% of Connecticut's housing units emit 54% of the state's residential greenhouse gas emissions.[29] Poorly insulated and leaky homes result in higher emissions and greater health risks. Building shell inefficiency also results in higher energy bills for residents—not just relative to household income, but in absolute terms. Acadia Center's PowerHouse Home Energy Simulator demonstrates just how expensive the highest-emitting homes can be to live in. **In Connecticut, one of the 25% highest-emitting homes would cost more than five times as much to heat in winter as a home built to that state's current building energy code.**

The highest-emitting homes are disproportionately occupied by low-income households and renters. Low-income families living in these high-emitting housing units often simply cannot pay this much for energy. Instead, they are forced to keep their homes at uncomfortable—and often, unhealthy—temperatures. This is an injustice that cannot be overstated. Moreover, renters cannot make energy efficiency improvements without the approval of a landlord.

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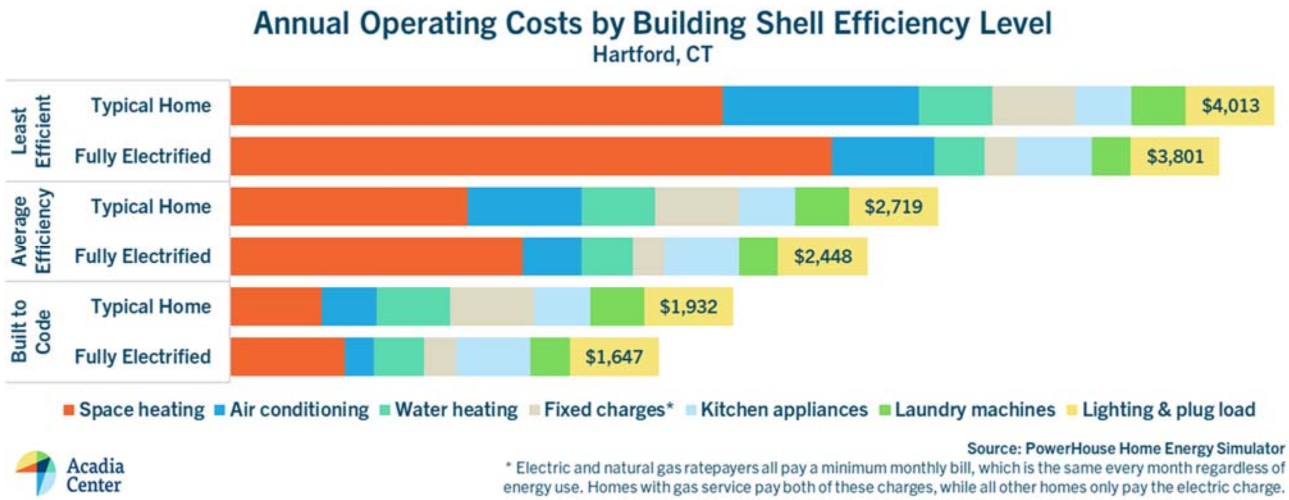
[28] Energize Connecticut and Eversource. Home Energy Solutions: Market Rate/Income Eligible presentation. November 2020

[29] EIA Residential Energy Consumption Survey https://www.eia.gov/consumption/residential/

Connecticut must leverage its clean energy and climate policies and programs to alleviate the energy burden of the families living in these homes. In doing so, Connecticut can vastly reduce emissions and improve health outcomes.



By targeting the 25% most energy-intensive homes for comprehensive retrofits, Connecticut can relieve the energy burden among low-income households and renters while substantially reducing emissions from the residential sector.

Biofuels Should Only be Used to Decarbonize Hard-to-electrify Sectors, Not Buildings

Multiple studies, including the above-referenced MA Roadmap and Princeton NZA Project, have found that electrification of all industrial end-uses, particularly those processes requiring high temperature heat, will likely not be technically feasible. For this reason, it would be prudent for states, including Connecticut, to support research and development projects aimed at expanding production and lowering the production cost of alternative fuels, including green hydrogen, but it is essential that regulations be put in place ensuring that these public funds will not support R&D efforts investigating or expanding the role of these fuels in residential and commercial buildings or passenger vehicles. **Alternative fuel R&D efforts must be limited to supporting decarbonization of the hardest-to-electrify sectors.**

The American Gas Foundation (AGF) commissioned ICF to examine the potential for expanding RNG production potential over the next 20 years while considering constraints including feedstock accessibility and the economics of production. The "high resource potential scenario," which assumes over half of eligible biomass feedstocks in the country are allocated to RNG production, concluded that by 2040 the country would be able to produce enough RNG to replace 7.3% of the U.S.'s current fossil gas consumption.[30] The same study found that RNG would also be extremely expensive to produce. For example, as production of RNG scaled up in the study, the cost or producing RNG via biomass gasification ranged from $27/MMBtu to $31/MMBtu, approximately 13 to 15 times the average cost of FNG in 2020.[31]

Biofuels intended for use in buildings, including RNG and biodiesel, are derived from the same feedstocks that will be needed to produce alternative fuels for hard-to-electrify sectors of the economy. Simply put, we won't have enough RNG to decarbonize buildings, never mind decarbonizing buildings *and* hard-to-electrify sectors. Allocating well over half the nation's limited supply of biomass feedstocks to RNG for use in buildings, as assumed in the ICF study, comes with a significant opportunity cost: Less biomass available to produce alternative fuels for decarbonizing industry, chemical production, transportation, and clean firm power generation.[32]

This is one of the reasons that none of the five decarbonization pathways modeled in Princeton Net-Zero America (NZA) Project found it cost effective to use biomass to produce RNG or biodiesel for use in residential and commercial buildings.[33] In the DOE's Billion Ton Study, the lifecycle GHG benefits for four potential end uses for biomass were analyzed: Ethanol, jet fuel, biopower, and biochemicals.[34] Using biomass feedstocks to produce RNG for pipeline injection or biodiesel for use in residential and commercial heating *was not investigated or discussed*, presumably because the authors viewed both as lower priority end uses of limited biomass feedstocks.

Green Hydrogen Should Only be Used to Decarbonize Hard-to-electrify Sectors, Not Buildings

Green hydrogen production via electrolysis requires an enormous amount of renewable energy, largely attributable to the inherent inefficiencies associated with the electrolysis process. Meeting just half of existing U.S. hydrogen needs using only renewable electricity sources would require two-thirds of all the renewable energy generated in the U.S. in 2019 to be devoted to hydrogen production.[35]

Many advocates for hydrogen blending in the gas distribution system envision a not-too-distant future in which abundant excess renewable electricity on the grid, available at times when electricity generation exceeds electricity demand, can be used to produce hydrogen via electrolysis. While this is certainly one productive use of renewable electricity generation that would otherwise be curtailed, **it's difficult to envision a scenario in which the scale of**

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[30] American Gas Foundation, "Renewable Sources of Natural Gas: Supply and Emissions Reduction Assessment", 2019. https://gasfoundation.org/2019/12/18/renewable-sources-of-natural-gas/

[31] EIA "Henry Hub Natural Gas Spot Market" https://www.eia.gov/dnav/ng/hist/rngwhhdm.htm

[32] "Clean firm electricity generation" refers to a carbon-free power sources that can be relied on whenever needed, for as long as they are needed.

[33] Princeton University Net-Zero America Potential Pathways, Infrastructure, and Impacts Final Report. Slides 30-33. https://netzeroamerica.princeton.edu/the-report

[34] DOE 2016 Billion Ton Study, Volume, 2 Chapter 4, Figure 4.20 https://www.energy.gov/sites/default/files/2017/02/f34/2016_billion_ton_report_volume_2_chapter_4.pdf

[35] Assumes an electrolysis efficiency rate of 52- 60 kWh per kilogram of hydrogen production.

excess renewable generation is enough to produce enough electrolyzed hydrogen to both decarbonize hard-to-electrify sectors (e.g., industry, shipping, etc.) and space and water heating in buildings.

There are and will continue to be many competing end-uses for the renewable electricity that green hydrogen electrolysis production is reliant on. Significant amounts of additional renewable electricity are needed to eliminate our current reliance on fossil electricity generation and even more renewable electricity will be needed as large portions of the transportation and building sectors move towards decarbonization via electrification. For example, the MA Roadmap least-cost "All Options" pathway projected that total annual electricity consumption in the state would increase by a factor of approximately 1.9x by 2050.[36]

Princeton's NZA project found overwhelmingly that the most cost-effective use of that hydrogen was in hard-to-electrify sectors. None of the pathways in the study found that it was cost-effective to use hydrogen in residential and commercial buildings.[37] The Massachusetts Roadmap "All Options" pathways reached a similar conclusion: Hydrogen electrolysis accounted for approximately 10% of electricity consumption in the state by 2050 and the hydrogen was used to decarbonize difficult-to-electrify portions of the transportation and industrial sectors, with no hydrogen used in residential and commercial buildings.[38]

One of the key reasons these studies reached this conclusion is that "directly" electrifying buildings, opposed to using that same electricity to produce green hydrogen, is significantly more energy efficient. For example, a study from the Fraunhofer Institute for Energy Economics found that compared to using electric air source heat pumps for heating buildings, relying on a hydrogen-based, low temperature heating system uses 500-600% more electricity.[39] The U.K.'s Climate Change Committee estimated that using renewable electricity to heat buildings using heat pumps has an overall efficiency between 230-410%. In contrast, using that same renewable electricity to produce hydrogen via electrolysis, transport the gas through the hydrogen distribution system, and eventually combust the hydrogen in a boiler to heat buildings has an overall efficiency of approximately 62%.[40]

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[36] Massachusetts 2050 Decarbonization Roadmap: Energy Pathways to Deep Decarbonization, Figure 11 https://www.mass.gov/doc/energy-pathways-for-deep-decarbonization-report/download

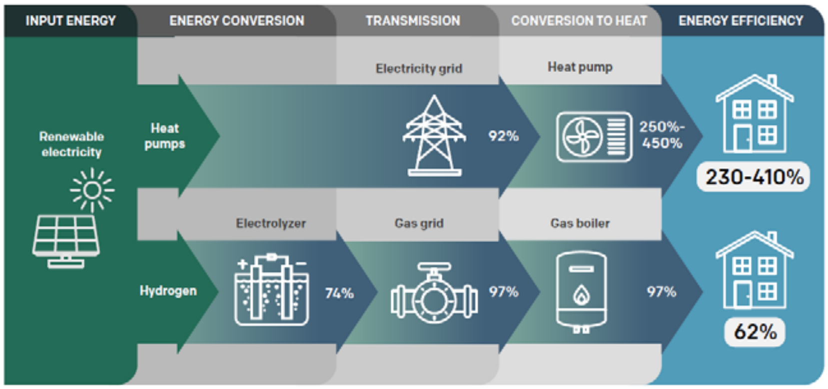
[37] Princeton University Net-Zero America Potential Pathways, Infrastructure, and Impacts Final Report. Slides 30-33. https://netzeroamerica.princeton.edu/the-report

[38] Massachusetts 2050 Decarbonization Roadmap: Energy Pathways to Deep Decarbonization, Figure 7 https://www.mass.gov/doc/energy-pathways-for-deep-decarbonization-report/download

[39] Norman Gerhardt et al., Fraunhofer Institute for Energy Economics, Hydrogen in the Energy System of the Future: Focus on Heat in Buildings, at 5 (May 2020) ("Fraunhofer Institute 2020") https://www.iee.fraunhofer.de/content/dam/iee/energiesystemtechnik/en/documents/Studies-Reports/FraunhoferIEE_Study_H2_Heat_in_Buildings_final_EN_20200619.pdf.

[40] Committee on Climate Change (CCC) "Hydrogen in a low-carbon economy" https://www.theccc.org.uk/publication/hydrogen-in-a-low-carbon-economy/

Comparison of Efficiencies for Hydrogen and Heat Pumps in Homes[41]



Using Hydrogen and Biofuels in Buildings in Connecticut Directly Makes it Harder for Industry-heavy States to Decarbonize

States like Connecticut, with relatively little heavy industry, using supply-constrained green hydrogen and biofuels for space heating in residential and commercial buildings directly inhibits the ability of industry-heavy states to achieve economy wide-decarbonization. To illustrate this point, consider the state of Louisiana. Louisiana has a population of 4.65 million people, about 30% higher than the population of Connecticut. However, industrial sector GHG emissions in Louisiana are over 65 times higher than industrial sector emissions in Connecticut.[42] **Put another way, industrial sector emissions alone in Louisiana in 2018 were over 2.9x higher than the entire state of Connecticut's emissions from all sectors in the same year.**[43] States with heavy concentrations of industry, like Louisiana, already face the most challenging path to achieving decarbonization without states with relatively light concentrations of industry, like Connecticut, competing for alternative fuels to use in a sector (buildings) that is relatively easy to decarbonize through electrification. **Connecticut has a moral imperative to ensure that the path it pursues to achieve net-zero emissions does not directly conflict with the efforts of other states (and in the bigger picture, heavily industrialized countries) to achieve net-zero emissions and decisions regarding the appropriate use of these fuels in the state should accurately reflect this imperative.**

[41] Image from Earthjustice's "Reclaiming Hydrogen for a Renewable Future" report, 2021. https://earthjustice.org/features/green-hydrogen-renewable-zero-emission Underlying data in figure from Committee on Climate Change (CCC) "Hydrogen in a low-carbon economy" report https://www.theccc.org.uk/publication/hydrogen-in-a-low-carbon-economy/

[42] U.S. Energy Information Administration, "Energy-Related CO2 Emission Data Tables" Table 4 https://www.eia.gov/environment/emissions/state/

[43] Connecticut Greenhouse Gas Reduction Progress Reports https://portal.ct.gov/DEEP/Climate-Change/CT-Greenhouse-Gas-Inventory-Reports

Conclusion

Acadia Center thanks DEEP for their work on the CES and their attention to the issue of decarbonization of buildings. We look forward to opportunities to remain engaged as the development of the CES progresses.

Sincerely,

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