CITY OF BURLINGTON, VERMONT
CITY COUNCIL TRANSPORTATION, ENERGY & UTILITIES COMMITTEE

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Councilor Mark Barlow, **Chair,** *North District*
Councilor Gene Bergman, *Ward 2*
Councilor Hannah King, *Ward 8*

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Transportation, Energy and Utilities Committee of the City Council
Tuesday July 25th, 2023 – 5PM

DPW Front Conference Room
645 Pine St, Burlington, VT 05482
Masks Optional

Join via Zoom, https://us02web.zoom.us/j/84603122855
To call into the meeting, including to speak during public comment:
Phone number: 312-626-6799, Webinar ID: 846 0312 2855
If you prefer to attend in a physical location, you may join us at 645 Pine St in the front conference room

–DRAFT AGENDA–

1. **Agenda**
2. **Minutes of 6.27.23**
3. **Public Forum**
4. **City Fleet Committee**
   - Lee Perry
   - 10 minutes
5. **Ordinance on Carbon Fee**
   - Councilors, Darren Springer
   - 30 Minutes
6. **Sewer Main Update**
   - Norm Baldwin
   - 15 minutes
7. **Director's Report**
8. **Councilors' Update**
9. **Next Meeting 8/22/23**
10. **Champlain Parkway Walkthrough**
    - Norm Baldwin
    - 45 minutes
11. **Adjourn**

City of Burlington
Fleet Committee
645 Pine Street
Burlington, VT 05401
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Date: July 26, 2023

To: Transportation, Energy & Utilities Committee

From: Chapin Spencer, Director Public Works

Lee Perry, Division Director – Maintenance Division

Ashley Parker, Capital Program Director

Subject: Developing a Sustainable Fleet Funding Strategy

REQUEST:

The Fleet Committee requests guidance from the TEUC on the questions outlined below that will inform the next steps in developing a sustainable fleet funding strategy.

BACKGROUND:

The June 12, 2023 Fleet Committee memo to City Council concluded with the following: "The Fleet team is looking to gain support from the Board of Finance and City Council to develop a long- term fleet purchasing strategy that ensures the sustainability of all existing vehicles/equipment in Fleet, as well as one that brings the City closer to reaching its NetZero 2030 goals. We have reached a pivotal moment in the long-term planning of the City's fleet where decisions on how the City funds future fleet purchases will shape its ability to continue providing the level of service required by its residents...The Fleet Committee has reached out to the Transportation, Energy, and Utilities Committee to schedule meetings to discuss fleet funding strategies. These meetings are tentatively scheduled to start in July 2023. We will also hire and work with a consultant to develop a comprehensive fleet management strategy, including recommending a sustainable funding source."

The problem statement put simply:

- The City owns 403 vehicles and pieces of equipment and the number continues to grow. Of the 403, 212 are wheeled vehicles, and 83 are wheeled equipment i.e., bucket loaders, tractors, backhoes etc.
- $2-3M is needed each year to sustainably replace General Fund vehicles and equipment at their end of life – representing an annual unmet need that is 2-3% of the entire City's GF budget.
- There is currently no ongoing base funding in the General Fund for fleet purchases.
- FY'24 budget required ~$1M of one-time money to pay for existing leases -- and those sources either dried up or are diminished as we head into FY'25 budgeting. The City will need to find ~$1M/year in FY25 & 26 for lease payments alone.
- While there are expense side strategies that will need to be employed, this is predominately a revenue side problem that requires annual baseline revenues of at least $2-3M or the level of service delivered to the public will decrease

City staff have been asked to review previous studies that were completed in 2018 and provide recommendations to the Mayor's Office for consideration as the City moves forward in creating a scope of work for a consultant to engage in a study to analyze our Fleet, as proposed during the FY24 budget process. As a result of this review, the Fleet Committee has come up with the following revenue and expense options based on these studies, work completed by a Fleet Committee Finance Work Group, and input from the Council:

REVENUE OPTIONS:

- Build fleet funding into the General Fund budget by either 1) requiring departments to budget for their own replacements or 2) carve out a General Fund-wide fleet budget by reducing other expenses. This would strengthen the Fleet Reserve, while also providing Fleet some cash to cover lease payments and more flexibility in the purchasing of Fleet.
- Consider returning to a strategy of cash purchases for Fleet versus leasing to minimize scarce City funds going to interest payments.
- Consider bonding for heavy fleet vehicles beyond just fire trucks – vehicles that are eligible for bonding due to their longer projected useful life. This would need to be incorporated into future conversations about the City's bonding capacity.
- Annually assess the existing Fleet to determine whether there are any vehicles or equipment that can be sold.
- Evaluate and track Fleet sales to pair vehicles and departments with available gains on assets.
- Coordinate with Burlington Electric on tracking the revenues from the New Carbon Fee to determine funding availability for future purchase or lease of electric vehicles. Pair this with an assessment of available rebate opportunities.
- Implement cost sharing with Enterprise departments for the purchase of shared equipment.
- Implement surcharges when departments fuel up to recoup the full cost of the maintenance and operation of the fuel depot.
- Pursue possibility of utilizing franchise fees.
- Utilize credit cards to pay City vendors and put the rebate money towards Fleet.
- Develop a Fleet Funding Policy as a subset of the Fund Balance and Debt Policies to ensure that resources are available to support the annual and long-term Fleet needs (i.e.: 5–10-year Fleet Capital Plan).

EXPENSES OPTIONS:

- Continue fleet reduction/sharing efforts. Evaluate existing Fleet by Department and determine the number of Fleet needed to maintain Department levels of service.
- Provide quarterly financial and performance information to all Departments with Fleet so they can monitor their Department's budgetary impact to Fleet during the Fiscal Year. This would include Department Fleet unit operating costs.
- Consider developing agreements by Departments utilizing Fleet services to outline services to be provided, costs to be incurred by the Department, and the responsibilities of both the Department and Fleet Team.
- Develop a policy that considers holding Departments accountable for maintaining their Fleet and provides guidance for the responsibilities that sit with Departments when Fleet is damaged and needs to be replaced.

- Coordinate with HR on a strategy to evaluate additional resource needs when considering the creation of new personnel. This would allow Fleet to weigh in on the planning and budgeting for any new vehicles or equipment that are needed as new positions are created and filled.
- Departments should identify a central location for all vehicles and equipment to ensure an accurate inventory and easier access.
- Creation of training/guidance for Department staff that provides support for proper use of Fleet to prevent damage and early replacement costs.
- For FY25, consider continued fleet moratorium on adding to the fleet without CAO approval.

<u>While there is interest in bringing in a consultant to help us evaluate our Fleet, the City Team would like to receive feedback from the TEUC that may help us refine possible tasks for a future consultant to assist us with. The above options have had limited follow-up and many could be added to a scope of work for consideration. It would be helpful to have the TEUC provide feedback on what it feels would help the City reach financial sustainability for Fleet. The questions provided below will help provide direction that will help the City get closer to meeting its sustainable funding goals.</u>

QUESTIONS FOR TEUC:

- What revenue strategies should be studied further? Are there additional strategies to consider? Should any be taken off the table?
- Should the City look at having a consultant review the Fleet Reserve and help provide guidance for establishing a better revenue system in the General Fund Operating Budget?
- Are there any Fleet Management strategies the TEUC thinks would assist the City in finding more efficiencies and should be reevaluated or evaluated by a future consultant?
- Would it be more efficient to have a consultant support the Fleet Committee in the drafting of new policies and guidance documents that are noted above?
- What process should we undertake leading up to the FY'25 budget given there will be revenue recommendations that will impact other Departments?

<u>In Conclusion:</u>

To develop a sustainable funding strategy will require new or repurposed revenue streams that will either require trade-offs within the City budget or additional financial burdens on taxpayers. Given these real political challenges, we need the Committee's early guidance on how best to proceed.

ATTACHMENT A:

History of Burlington's Fleet Purchasing Strategy:

Below is a brief timeline of how the purchasing strategies for the City's fleet have changed over time. It provides the framework for understanding how the past has shaped the present and may provide guidance for helping us determine a new strategy focused on long-term sustainability.

- FY12 – FY15: There was a moratorium on the purchase of new vehicles due to the City's financial challenges.
- FY16: The City began to purchase new vehicles again – this time utilizing a master lease. At this time, an informal fleet team started creating a list of vehicles needed each year to help the City forecast needs over time.
- FY17: A Sustainable Infrastructure bond replaced three fire trucks for $3.3 million.
- FY17 – FY18: The fleet team began creating a spreadsheet to track sustainable investment in fleet. The strategy of using master leases was working, but projections were showing financial challenges for fleet funding in out years due to increased debt payments.
- FY18: The City contracted with a fleet consultant to review how fleet was structured and recommend improvements. This resulted in a new Fleet Policy, the Fleet Committee, and a spreadsheet of needs from the consultant.
- October 24, 2019: The Fleet Policy was approved by the City Council.
- FY20: The Fleet team estimated that the sustainable fleet replacement need was approximately $2,700,000/year. Up to this point, fleet funding had been by department. As part of the Fleet Committee and Fleet Policy development, all fleet related resources were pooled across departments into one location in order to create efficiencies in purchasing and revenues.
- FY20-22: It appears due to staff transitions and focus on the pandemic that during this time, staff lost track of the strategic focus on need for General Fund money for lease payments.
- FY23: The Fleet Team requested the use of $715,000 of General Fund monies to support lease payments in FY23, as we were reaching the end of the Fleet reserve funds. At that time, the Fleet Team communicated that lease payments in FY24, & FY25 were going to require the same significant General Fund support.
- FY24: Freeze on the purchase of new vehicles for General Fund Departments and a focus on the funding of FY24 General Fund lease payments.

Over the last several fiscal years, through effective coordination and purchasing vehicles through master leases, the City was able to make significant reinvestments in its municipal fleet. Now the City is entering a very challenging multi-year fiscal year period for multiple reasons:

- As discussed above, vehicle replacement funding was pooled from Police, Public Works and Parks starting in FY20. However, not all revenues from pooling vehicle replacement funding from Police, Fire, Public Works and Parks were able to be kept each fiscal year for fleet needs due to shortfalls in General Fund operating budgets.

- Several recent revenue ballot items were not successful at the ballot box (FY'23 proposed Municipal tax increase and the fall 2021 $40M capital bond proposal).

- After multiple years of financing to purchase new vehicles, the City is now carrying significant debt service payments for vehicles previously received.

- The Fleet Team is also continuing to manage constraints within the vehicle industry related to ordering and purchasing of vehicles and equipment. This includes delays in vehicle manufacture and delivery for both internal combustion and electric vehicles.

- With funding limited to Gains, remaining Fleet Reserve, and some Impact Fees; alternative sources of funding will need to be identified to support that $1M/year in lease payments through FY25. There will continue to be a $2M/year need to replace Fleet, though this number will likely be higher as the deferred list has increased over the last two years.

ATTACHMENT B: - PROGRESSION OF FLEET ELECTRIFICATION

Vehicle/Equipment Type	FY19	FY20	FY21	FY22	FY23	FY24	AVG	TOTAL
ELECTRIC	0	1	6	7	4	3	3.5	21
HYBRID	5	3	4	6	1	2	3.5	21
TOTAL FLEET PURCHASE	13	16	28	24	18	7	17.67	106
% OF EV	**0%**	**6%**	**21%**	**29%**	**22%**	**43%**	**20%**	**20%**
TOTAL COST OF EV	$0	$23,400	$140,627	$504,000	$100,000	$124,000	$148,671	$892,027

ATTACHMENT C: DEFERRED VEHICLE LIST
Please see attachment provided in packet.

ATTACHMENT D: VEHICLE REPLACEMENT LIST

Department	Equip.#	Year	Make	Model	Purchase Cost	Replacement Interval	Replacement Date
Recycling	G03	2017	International	7400	$208,803	7 Years	2024
Stormwater	SW02	2014	Nissan	NV200	$21,000	10 Years	2024
Water Distribution	Z20	2013	Dodge	3500	$37,000	10 Years	2023
Water Distribution	Z19	2014	Ford	F250	$46,375	10 Years	2024

ATTACHMENT E: VENDOR LIST

Vehicle	Vendors
EV Vehicles	Key Chevrolet, Freedom Nissan, Berlin City
Ford Maverick & E-Transit Van	Heritage Ford, McGee Ford, Barrette Ford
Gem Car	Country Club Enterprises
One Ton Truck	Heritage Ford, McGee Ford, Barrette Ford, Goss Dodge, Key Chevrolet
Recycling Truck	Allegiance Trucks, New England Kenworth, Lucky's Peterbuilt, R.R. Charlebois

ATTACHMENT F: FLEET PURCHASE LIST & COST CHART

Please see attachment provided in packet.

CITY OF BURLINGTON

ORDINANCE ___________
Sponsor: Councilors Traverse, Barlow
Public Hearing Dates: ___________

In the Year Two Thousand Twenty-Three

First reading: _________________
Referred to: ___________________
Rules suspended and placed in all stages of passage: ______________
Second reading: ________________
Action: ______________________
Date: ________________________
Signed by Mayor: ______________
Published: ____________________
Effective: _____________________

An Ordinance in Relation to

THERMAL ENERGY SYSTEMS AND THE ASSESSMENT OF A CARBON POLLUTION IMPACT FEE

It is hereby Ordained by the City Council of the City of Burlington as follows:

That Chapter 8, Buildings and Building Constructions, Article V, Heating Systems, of the Code of Ordinances of the City of Burlington be and hereby is amended to read as follows:

ARTICLE V. THERMAL ENERGY~~HEATING~~ SYSTEMS

8-76 Purpose and Authority.

(a) Purpose. It is in the public interest and in the interest of public health and safety to achieve a high degree of conservation of energy and~~, where possible,~~ reduce emissions of greenhouse gases by requiring buildings to meet specified energy efficiency performance standards and maximum allowable heat loss standards.

(b) Authority. All provisions in this article relating to thermal energy~~heating~~ systems are adopted pursuant to the authority and powers granted by a majority of the legal voters of the City who voted at the annual City meeting on March 7, 2023, in accordance with section 48(66) of the City Charter and its provisions on the regulation of thermal energy systems in residential and commercial buildings, including the assessment of carbon impact or alternative compliance payments, for the purpose of reducing greenhouse gas emissions throughout the City. The provisions in this article are further adopted pursuant to the authority and powers granted by the Vermont Legislature in 24 V.S.A. § 3101 (Chapter 83. Building Inspectors and Regulation of Building; Bylaws and ordinances; penalties), as reasonably necessary to improve the health, safety, and welfare of the public from fuel leaks and explosions, and from air pollution, including that which is causing climate change and thereby threatens the city and its inhabitants.

8-77 Definitions.

(a) A "fossil fuel ~~renewable primary heating~~thermal energy system" shall be subject to the alternative compliance carbon fee, and shall mean any space conditioning, domestic hot water, cooking, appliance, process heat, or other building system that relies on thermal energy from fossil fuels, including coal, oil, propane, kerosene or natural gas. ~~heating system that meets at least eighty-five (85) percent of the building's design heating load calculated per the Vermont Commercial Building Energy Standards (CBES) Energy Code (Section C403.1) and is fueled by:~~

(b) A "renewable fuel which reduces greenhouse gas emissions" is, based on the vote at the annual City meeting on March 7, 2023, not subject to the alternative compliance carbon fee, and shall mean any space conditioning, domestic hot water, cooking, appliance, process heat, or other building system that relies on thermal energy from:

(1) Electric-powered thermal equipment~~ity~~, including cold-climate air source heat pumps, ground source heat pumps, and other heat pumps including district, network, grid, microgrid, and building geothermal systems; electric appliances providing thermal end uses; and heat pump water heaters (with the exception of electric resistance units prohibited by the Vermont Commercial Building Energy Standards (CBES) Energy Code (Section C403.2.3) or the Vermont Residential Building Energy Standards (RBES) Energy Code (Section 2.4b)); or

(2) ~~Wood pellets or woodchips;~~ Solar water heating systems; or

(3) ~~Other renewable fuel used by conventional primary heating systems, including renewable gas, biodiesel, and renewable district heating, if the building owner provides a contract demonstrating that the fuel required by the conventional primary heating system is fully sourced from such other renewable fuels for the life of that conventional heating system.~~Renewable energy-based district heating; or

(4) Green hydrogen sourced exclusively from renewable energy sources; or

(5) Advanced wood heating systems that meet the 2023 or subsequently issued Vermont Small Scale Renewable Energy Incentive Program (SSREIP) Advanced Wood Heating System (AWHS) terms conditions and requirements, including for efficiency and emission controls; or

(6) Sustainably-sourced biodiesel; or

(7) Renewable gas, meaning methane produced by organic material and sourced from landfills, wastewater treatment facilities, and farms as offered under a Vermont Public Utility Commission-approved tariff or supply contract from a gas utility such as Vermont Gas Systems, provided that the gas utility demonstrates that the renewable gas is purchased along with its renewable attributes and has a secured contractual pathway for the physical delivery of the renewable gas from the point of injection in the pipeline to the gas utility's delivery system; or

(8) Any other renewable fuel that reduces greenhouse gas emissions, provided the Department of Permitting and Inspections receieves sufficient analysis or documentation from the applicant that the fuel reduces greenhouse gas emisssions relative to the fossil fuel it is replacing consistent with the requirements of subsection (c) below.

(c) The Department of Permitting and Inspections may disqualify any renewable fuel that reduces greenhouse gas emission listed above from being eligible to satisfy the requirements of this section if such fuel is subsequently deemed by the Vermont Public Utility Commission not to satisfy the carbon intensity requirements of a State of Vermont Clean Heat Standard or any similar state thermal energy policy. In addition, the Department may require an applicant seeking to utilize a liquid or gaseous renewable fuel that reduces greenhouse gas emissions to submit documentation or independent analysis - utilizing the Argonne National Laboratory GREET model or modeling of similar rigor adapted to Vermont's thermal energy context - demonstrating that the renewable fuel proposed for compliance under this section reduces greenhouse gas emissions relative to the fossil fuel system or fuel it is replacing.

~~"Renewable gas" shall mean methane produced by the organic material and sourced from landfills, wastewater treatment facilities, and farms as offered under a tariff or supply contract from a utility such as Vermont Gas Systems.~~

(d) A "large existing building" shall mean a building with at least fifty thousand (50,000) feet in total floor area of enclosed conditioned space, including hotels, but excepting the following:

(1) All residential buildings; and

(2) Buildings listed, or eligible to be listed, on the National Historic Register, provided the applicant can demonstrate to the satisfaction of the Department of Permitting and Inspections that there is no thermal energy system that relies on renewable fuel available to the building due to the historic nature of the building and any limitations imposed by the National Historic Register.

(e) A "new building" shall mean the new construction of any building, excepting all additions, alterations, renovations, or repairs to an existing building.

(f) An "existing city building" means all municipal buildings constructed prior to January 1, 2023 and owned by the City of Burlington, regardless of their size or square footage.

~~(b) A "nonprimary heating system" shall include back-up heating system, water heating system, or ventilation/air tempering system.~~

8-78 Applicability.

(a) Applicants seeking permits pursuant to this chapter for a new building~~s~~ shall demonstrate that the new building will utilize ~~a renewable primary heating~~thermal energy systems that rely on a renewable fuel which reduces greenhouse gas emissions. Applicants seeking permits to replace space conditioning systems or domestic water heating systems that are in large existing buildings shall demonstrate the new space conditioning or domestic water heating systems will utilize a renewable fuel which reduces greenhouse gas emissions. Existing City buildings shall follow the requirements for large existing buildings, but are not subject to the alternative compliance carbon pollution impact fee.

(b) If an applicant for a new building is seeking to use a thermal energy system that does not rely on a renewable fuel which reduces greenhouse gas emissions, or an applicant for a large existing building is seeking to use a space conditioning or domestic water heating system that does not rely on a renewable fuel which reduces greenhouse gas emissions, the applicant shall prior to receiving a permit pursuant to subsection (a) first have to demonstrate that the renewable system is uneconomical. To be determined to be uneconomical the twenty-five (25) year capital and operational cost of the least expensive renewable primary heating system, including any available incentives from the Burlington electric department or other State or federal entities, must be more than the twenty-five (25) year capital and operational costs of a nonrenewable primary heating system, including the cost of externalities calculated by a building carbon price of one hundred fifty dollars ($150.00) per ton for the life of the nonrenewable primary heating system. The building carbon price of one hundred fifty dollars ($150.00) per ton shall be annually adjusted by the program administrator equivalent to one hundred (100) percent of the annual change in the Consumer Price Index For All Urban Consumers (CPI-U) in the Northeast Region, to go into effect January 1 of every ensuing year. A system demonstrating uneconomicability shall be assessed an alternative compliance -carbon pollution impact fee. However, an applicant building a new, residential multi-unit dwelling with four or more units shall not be subject to the alternative compliance carbon pollution impact fee as it applies to domestic water heating systems until January 1, 2026.

(c) Effective January 1, 2024, the alternative compliance carbon pollution impact fee shall be equal to one hundred fifty dollars ($150.00) per ton of greenhouse gas emissions produced by the thermal energy system over its lifetime, based on a net present value calculation at the time the permit application is submitted. For large existing building applicants, the alte~~n~~rnative compliance carbon pollution impact fee is capped at no more than 75 percent of the installed cost of the proposed space conditioning or domestic water heating system. On each subsequent January 1, the alternative compliance carbon pollution impact fee shall be increased by any percentage increase of the Consumer Price Index, CPI-U, U.S. city average, not seasonally adjusted, or successor index, as calculated by the U.S. Department of Labor or successor agency for the 12 months preceding the previous September 1, but in no event shall the increase be greater than five percent. The adjusted alternative compliance carbon pollution impact fee shall be rounded off to the nearest dollar.

(d) For compliance purposes for all thermal energy systems that are capable of utilizing either a fossil fuel or a renewable fuel that reduces greenhouse gas emissions, such as gas utility services that could utilize fossil fuel or renewable gas, or oilheat systems that could utilize oil or biodiesel, an applicant shall demonstrate compliance either via (i) a contract demonstrating that the fuel required by the thermal energy system is fully sourced from such other renewable fuels or technologies for the life of that thermal energy system; or (ii) annual compliance certification that the applicant is purchasing renewable fuel to cover the entire need of the thermal energy system. If the applicant uses the annual compliance certification, and the applicant fails to provide an annual compliance certification in any year that the applicant is using renewable fuel that reduces greenhouse gas emissions, the applicant will be assessed an alternative compliance -carbon pollution impact fee equal to a pro rata share of the remaining expected life of the thermal energy system.

(e) If an applicant with one or more buildings is seeking a permit pursuant to this chapter, and is already using one or more thermal energy systems that rely on a renewable fuel which reduces greenhouse gas emissions, the applicant may apply for a credit toward~~s~~ any alternative compliance carbon pollution impact fee equal to the carbon value of the renewable f~~f~~uel which reduces greenhouse gas emissions used for any thermal energy system since January 1, 2023.

(f) All alternative compliance carbon pollution impact fee proceeds shall be placed in a Clean Energy Fund established and managed by the Department of Permitting and Inspections with technical support from the Burlington Electric Department. Clean Energy Fund proceeds shall be made available as follows:

(i) The Department of Permitting and Inspections, with technical support from the Burlington Electric Department, shall determine which initiatives are eligible for funding for property owners or low income renters, but they may include, and shall not be limited to, the installation of new thermal energy systems that rely on renewable fuel, weatherization projects, or subsidizing any increased utility costs associated with purchasing renewable fuel rather than fossil fuel;

(ii) Half of the proceeds paid into the Clean Energy Fund by a large existing building applicant shall be available to the payor for projects to reduce greenhouse gas emissions at any site owned by the payor. The large existing building applicant must request these proceeds within one (1) year following payment of their alternative compliance carbon pollution impact fee, and any proceeds not requested within that year shall be made available under subsection (iii).

(iii) Any remaining proceeds collected from large existing building applicants and all proceeds paid into the Clean Energy Fund by new construction applicants shall be available to either:

1. Provide financial assistance to help low-income Burlington residents with the purposes described in subsection (i), either through direct payments to homeowners and renters who are income-qualified per the most recent income-qualification levels published by the Community and Economic Development Office ("CEDO"), or through payments to property owners of multi-family buildings where at least 25 percent of the tenants in the building are income-qualified, provided that the property owner must commit to not raising the rent of income-qualified tenants as a result of costs associated with the funded initiatives to reduce greenhouse gas emissions; or

2. Subsidize the cost of converting the City's vehicle fleet from fossil fuel to electric.

(g) Nothing in this section prevents or prohibits applicants from utilizing any and all available local, state, or federal incentives, rebates or tax credits that support implementation of renewable fuels listed above for their buildings, and applicants are encouraged to access available incentives or rebates or tax credits.

(h) Any applicant for a permit pursuant to this chapter, for any new or existing building regardless of size, seeking to utilize a wood chip or wood pellet heating system, must demonstrate that the system meets the 2023 or any subsequently issued Vermont Small Scale Renewable Energy Incentive Program (SSREIP) Advanced Wood Heating System (AWHS) terms conditions and requirements, including for efficiency and emission controls.

~~An applicant is permitted to install and utilize nonprimary heating systems in new buildings that use nonrenewable fuels.~~

8-79 Effective Date~~Waiver~~.

The provisions of this Article shall take effect on January 1, 2024.

~~The department of permitting and inspections may grant a waiver to Section 8-78 on the grounds that utilizing a renewable primary heating system in a new building would be uneconomical. To be deemed uneconomical, the twenty-five (25) year capital and operational cost of the least expensive renewable primary heating system, including any available incentives from the Burlington electric department or other State or federal entities, must be more than the twenty-five (25) year capital and operational costs of a nonrenewable primary heating system, including the cost of externalities calculated by a building carbon price of one hundred dollars ($100.00) per ton for the life of the nonrenewable primary heating system. The building carbon price of one hundred dollars ($100.00) per ton shall be annually adjusted by the program administrator equivalent to one hundred (100) percent of the annual change in the Consumer Price Index For All Urban Consumers (CPI-U) in the Northeast Region, to go into effect January 1 of every ensuing year.~~

False Solutions: Biofuels

What are biofuels?

Biofuels come in three main categories, and are often proposed as alternatives to fossil fuels:

- **“Renewable” natural gas (RNG), or biogas:** methane produced from decomposing manure, sewage, garbage, or other biological material.
- **Liquid biofuels:** plant oils derived from crops like canola, corn, soy, coconut, and palm.
- **Biomass:** wood pellets, wood chips, or other woody material burned for heat or to generate electricity.

What are the problems with biofuels?

- Many biofuels have the **same or worse greenhouse gas (GHG) emissions** as fossil fuels over their full life cycle (production through consumption).
- Because of limited supply, buying any kind of liquid biofuel leads to increased palm oil production, which **destroys tropical forests and soils and drives losses in biodiversity**. These associated emissions and climate harms are ignored by official GHG emissions models.
- Leaking methane from RNG processing and pipelines results in **twice as many GHG emissions as current life-cycle accounting** for RNG.
- **Our energy dollars go out of state** instead of being invested in local energy production, weatherization, and efficiency.
- Liquid biofuel crops replace food crops, putting **stress on our food system**.
- Scaled-up **biomass also increases deforestation** and biodiversity loss. Importing biomass from afar causes additional transportation emissions.
- Biofuels have the **same or worse particulate pollution** as fossil fuels, and biomass additionally emits harmful nitrogen oxides.
- Pollution, deforestation, and other harmful effects of biofuels **disproportionately impact frontline and Indigenous communities**, who already bear more than their fair share of climate burdens.

What do we want?

➔ We want heating policies that **incentivize weatherization, energy conservation, heat pumps, and thermal networks**, NOT biofuels.

More info at 350vermont.org/justtransitionforvermont.

False Solutions: Hydrogen

What is hydrogen, and why are people talking about *green* hydrogen?

Hydrogen is a proposed alternative to fossil fuels that is often claimed to be clean because it releases water rather than greenhouse gases when burned. Green hydrogen is made using renewable energy sources like solar and wind power.

What are the problems with hydrogen and green hydrogen?

Gas companies are planning to blend hydrogen into the gas that's piped to our homes and businesses, saying that it will "decarbonize" the gas system. However, the facts show:

- **Most hydrogen is not good for the climate.** Nearly 100% of hydrogen is made from fossil fuels. Even more fracked gas or coal is needed to make this fossil hydrogen energy than if we used the gas, oil, or coal directly.

- **Hydrogen is an indirect greenhouse gas and contributes to warming our planet.** Heating with hydrogen increases rather than lowers emissions. Hydrogen is a highly leaky gas that prolongs the life of other climate-warming emissions and is overall 200 times more warming than carbon dioxide.

- **Making green hydrogen wastes the solar and wind we need for clean electricity.** Diverting precious renewable sources to make hydrogen for blending into "natural" gas in pipelines and for heating buildings is inefficient, more expensive, and requires continued use of fracked gas in pipelines and homes.

- **Heating and cooking with hydrogen is not safe or healthy.** Hydrogen is much more explosive than "natural" gas and creates almost invisible flames. Burning hydrogen also releases more indoor air pollution than fracked gas.

- **Heating with hydrogen is not equitable.** Using hydrogen for heating means that those unable to afford to electrify their homes will be the ones paying more to burn explosive, polluting gases in their homes.

What do we want?

- We want policies that **incentivize weatherization, energy conservation, heat pumps, and thermal networks**, NOT hydrogen or biofuels.

- In Vermont, hydrogen produced from in-state solar and wind must be limited to:
  - Use only on the site where it is produced and for hard-to-electrify uses such as high-heat industrial processes.
  - On-site storage for excess solar and wind energy to be turned into electricity on-site when needed (and then transmitted as electricity).

More info at 350vermont.org/justtransitionforvermont.

CITY OF BURLINGTON

ORDINANCE ____________
Sponsor: Traverse, Barlow
Public Hearing Dates: ___________

In the Year Two Thousand Twenty-Three

First reading: _________________
Referred to: __________________
Rules suspended and placed in all stages of passage: ______________
Second reading: _______________
Action: ______________________
Date: ________________________
Signed by Mayor: _____________
Published: ____________________
Effective: _____________________

An Ordinance in Relation to

THERMAL ENERGY SYSTEMS AND THE ASSESSMENT OF A CARBON POLLUTION IMPACT FEE

It is hereby Ordained by the City Council of the City of Burlington as follows:

That Chapter 8, Buildings and Building Constructions, Article V of the Code of Ordinances of the City of Burlington be and hereby is amended to read as follows:

ARTICLE V. THERMAL ENERGY~~HEATING~~ SYSTEMS

8-76 Purpose and Authority.

(a) Purpose. It is in the public interest and in the interest of public health and safety to achieve a high degree of conservation of energy and~~, where possible,~~ reduce emissions of greenhouse gases by requiring buildings to meet specified energy efficiency performance standards and maximum allowable heat loss standards.

(b) Authority. ~~All ~~P~~p~~rovisions in this article relating to thermal energy~~heating~~ systems are adopted pursuant to the authority and powers granted by a majority of the legal voters of the City who voted at the annual City meeting on March 2~~7~~, 2021~~3~~, to approve a change to the City's Charter authorizing the City Council to regulate thermal energy systems in residential and commercial buildings, including assessing carbon impact or alternative compliance payments, for the purpose of reducing greenhouse gas emissions throughout the City; 24 App. V.S.A. ch. 3, § 48(66), which approved the charter change and amended it to prohibit imposition of a carbon impact or alternative compliance payment unless previously authorized by a majority of the legal voters of the City voting on the question at an annual or special City meeting duly warned for that purpose; and a majority of the legal voters of the City who voted at the annual City meeting on March 7, 2023 to authorize the City Council, pursuant to City Charter Section 48(66), to implement a carbon pollution impact fee on fossil fuel thermal energy systems in order to reduce greenhouse gas emissions in the City. ~~in accordance with section 48(66) of the City Charter and its provisions on the regulation of thermal energy systems in residential and commercial buildings, including the assessment of carbon impact or alternative compliance payments, for the purpose of reducing greenhouse gas emissions throughout the City.~~ The provisions in this article are further adopted pursuant to the authority and powers granted by the Vermont Legislature in 24 V.S.A. § 3101 (Chapter 83. Building Inspectors and Regulation of Building; Bylaws and ordinances; penalties), authorizing codes and regulations relating to heating systems as may be ~~r~~easonably necessary to improve the health, safety, and welfare of the public from fuel leaks and explosions, and from air pollution, including that which is causing climate change and thereby threatens the city and its inhabitants.

Commented [NP1]: As drafted I think this was too narrow as it referred only to the 2023 election which approved the carbon impact fee, but not the earlier action authorizing regulation of thermal energy systems.

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Commented [NP2]: I am not sure where the highlighted language comes from. It is not in the cited statute and I wonder if it needs to come out.

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8-77 Definitions.

(a) A "fossil fuel ~~renewable primary heating~~thermal energy system" shall be subject to the alternative compliance carbon fee, and shall mean any space conditioning, domestic hot water, cooking, appliance, process heat, or other building system that relies on thermal energy from fossil fuels, including coal, oil, propane, kerosene or natural gas. ~~heating system that meets at least eighty-five (85) percent of the building's design heating load calculated per the Vermont Commercial Building Energy Standards (CBES) Energy Code (Section C403.1) and is fueled by:~~

~~(b)~~ (b) A ~~"renewable fuel"~~ "low-carbon~~renewable~~ thermal energy system~~fuel~~" ~~which reduces greenhouse gas emissions" is, based on the vote at the annual City meeting on March 7, 2023, not subject to the alternative compliance carbon fee, and shall mean include the following power sources for a thermal energy system~~shall mean any space conditioning, domestic hot water, cooking, appliance, process heat, or other building system that relies on thermal energy from:

(1) Electric-powered thermal equipment~~ity,~~ including cold-climate air source heat pumps, ground source heat pumps, and water source heat pumps,~~other heat pumps~~and including district, networked, ~~grid, microgrid,~~ and building geothermal systems and systems that use waste heat from noncombustion sources such as wastewater, grocery stores and data centers;~~,~~ electric appliances providing thermal end uses;~~,~~ and heat pump water heaters (with the exception of electric resistance units prohibited by the Vermont Commercial Building Energy Standards (CBES) Energy Code (Section C403.2.3) or the Vermont Residential Building Energy Standards (RBES) Energy Code (Section 2.4b)); or

(2) Solar water heating systems; or

(3) Solar thermal ~~Renewable energy-~~based district heating; ~~Wood pellets or woodchips;~~ or

~~(4) Green hydrogen sourced exclusively from renewable energy sources; or~~

~~(5) Advanced wood heating systems that meet the 2023 or subsequently issued Vermont Small Scale Renewable Energy Incentive Program (SSREIP) Advanced Wood Heating System (AWHS) terms conditions and requirements, including for efficiency and emission controls; or~~

~~(6) Sustainably-sourced biodiesel; or~~

~~(7) Renewable gas, meaning methane produced by organic material and sourced from landfills, wastewater treatment facilities, and farms as offered under a Vermont Public Utility Commission-approved tariff or supply contract from a gas utility such as Vermont Gas Systems, provided that the gas utility demonstrates that the renewable gas is purchased along with its renewable attributes and has a secured contractual pathway for the physical delivery of the renewable gas from the point of injection in the pipeline to the gas utility's delivery system~~
~~; or~~

Commented [GB3]: I think we need to separate the rewable from the GHG issues since they are not the same.

Commented [NP4]: We should stop using the term "renewable" in city policy and ordinances directed at reducing greenhouse gas emissions. Renewable means "capable of being renewed" or "not depleted when used." It says nothing about greenhouse gas emissions. Use of the term is confusing and is often used to dupe the public and government officials into supporting measures that may be renewable but result in high greenhouse gas emissions.

Commented [GB5]: This new language does not help define electricity but lists appliances which are or may be powered by electricity. This needs work.

Commented [GB6]: I am not in favor of increased use of wood burning in the city given our current density and the hope for increased density given our housing crisis.

~~(8) Any other renewable fuel that reduces greenhouse gas emissions, provided the Department of Permitting and Inspections receieves sufficient analysis or documentation from the applicant that the fuel reduces greenhouse gas emisssions relative to the fossil fuel it is replacing consistent with the requirements of subsection (c) below.~~

(c)

~~(43) Other renewable fuel or technology used by conventional primary heating thermal energy systems, including geothermal, renewable gas, biodiesel, renewably-sourced hydrogen, and renewable district heating, or other renewable fuel or technology certified by the dDepartment of Ppermitting and iInspections as renewable, provided if the building ownerapplicant provides submits either: (i) a contract demonstrating that the fuel required by the conventional primary heatingthermal energy system is fully sourced from such other renewable fuels or technologies for the life of that conventional heatingthermal energy system; or (ii) annual compliance certification that the applicant is purchasing renewable fuel to cover the entire need of the thermal energy system.~~ ~~DThe Department of Permitting and Inspections may disqualify any renewable fuel that reduces greenhouse gas emission listed above from being eligible to satisfy the requirements of this section if such fuel is subsequently deemed by the Vermont Public Utility Commission not to satisfy the carbon intensity requirements of a State of Vermont Clean Heat Standard or any similar state thermal energy policy. In addition, the Department may require an applicant seeking to utilize a liquid or gaseous renewable fuel that reduces greenhouse gas emissions to submit documentation or independent analysis – utilizing the Argonne National Laboratory GREET model or modeling of similar rigor adapted to Vermont's thermal energy context – demonstrating that the renewable fuel proposed for compliance undert this section reduces greenhouse gas emissions relative to the fossil fuel system or fuel it is replacing.~~

~~(b) A "Renewable gas" shall mean methane produced by the organic material and sourced from landfills, wastewater treatment facilities, and farms as offered under a tariff or supply contract from a gas utility such as Vermont Gas Systems.~~

(d~~e~~) A "large existing building" shall mean a building with at least fifty thousand (50,000) feet in total floor area of enclosed conditioned space, including hotels, but excepting the following:

(1) All residential buildings~~s~~ other than hotels; and

(2) Buildings listed, or eligible to be listed, on the National Historic Register, provided the applicant can demonstrate to the satisfaction of the Department of Permitting and Inspections that there is no thermal energy system that relies on a low-carbon thermal energy system ~~renewable fuel~~ available to the building due to the historic nature of the building and any limitations imposed by the National Historic Register.

(e~~d~~) A "new building" shall mean the new construction of any building, excepting all additions, alterations, renovations, or repairs to an existing building.

(ef) An "existing city building" means all ~~all~~ municipal buildings constructed prior to January 1, 2023 and owned by the City of Burlington, regardless of their size or square footage.

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Commented [GB7]: What does "sustainably sourced" mean? Why do we need to encourage the substitution of fuel production for food production?

Commented [GB8]: How do we prove the gas used is renewable and not part of the supply created by increased fracking?

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Commented [GB9]: Doesn't this include hotels?

Commented [NP10R9]: I addressed.

Commented [GB11]: Why exempt smaller BSD buildings?

~~(b)~~

~~A "nonprimary heating system" shall include back-up heating system, water heating system, or ventilation/air tempering system.~~

8-78 Applicability.

(a) Applicants seeking ~~building~~ permits pursuant to this chapter for a new building shall demonstrate that the new building will utilize a low-carbon~~a renewable primary heating~~thermal energy system~~s that rely on a renewable renewable fuel which reduces greenhouse gas emissions~~. Applicants seeking permits to replace space conditioning systems or domestic water heating systems that are in large existing buildings shall demonstrate the new space conditioning or domestic water heating systems is~~will utilize~~ a low-carbon thermal energy system~~renewable renewable fuel which reduces greenhouse gas emissions~~. Existing City buildings shall follow the requirements for large existing buildings, but are not subject to the alternative compliance carbon pollution impact fee.

(b) If an applicant for a new building is seeking to use a fossil fuel thermal energy system~~thermal energy system that does not rely on a renewable fuel which reduces greenhouse gas emissionsrenewable fuel~~, or an applicant for a large existing building is seeking to use a ~~space conditioning or domestic water heating system that~~ fossil fuel thermal energy system for space conditioning or domestic water heating,~~does not rely on a renewable fuel which reduces greenhouse gas emissionsrenewable fuel.~~ the applicant shall be assessed an alternative compliance -carbon pollution impact fee. However, an applicant building a new, residential multi-unit dwelling with four or more units shall not be subject to the alternative compliance carbon pollution impact fee as it applies to domestic water heating systems until January 1, 2026.

(c) Effective January 1, 2024, the alternative compliance carbon pollution impact fee shall be equal to one hundred fifty dollars ($150.00) per ton of greenhouse gas emissions produced by the thermal energy system over its lifetime, based on a net present value calculation at the time the permit application is submitted. For large existing building applicants, the altenrative compliance carbon pollution impact fee is capped at no more than 75 percent of the installed cost of the proposed space conditioning or domestic water heating system. On each subsequent January 1, the alternative compliance carbon pollution impact fee shall be increased by any percentage increase of the Consumer Price Index, CPI-U, U.S. city average, not seasonally adjusted, or successor index, as calculated by the U.S. Department of Labor or successor agency for the 12 months preceding the previous September 1, but in no event shall the increase be greater than five percent. The adjusted alternative compliance carbon pollution impact fee shall be rounded off to the nearest dollar.

Commented [GB12]: Explain how this cap is needed please. How is this cap related to the cost of installing a system fueled by fuel which reduces greenhouse gas emissions?

(d) ~~For compliance purposes for all thermal energy systems that capable of utilizing either a fossil fuel or a renewable fuel that reduces greenhouse gas emissions, such as gas utility services that could utilize fossil fuel or renewable gas, or oilheat systems that could utilize oil or biodiesel, an applicant shall demonstrate compliance either via (i) a contract demonstrating that the fuel required by the thermal energy system is fully sourced from such other renewable fuels or technologies for the life of that thermal energy system; or (ii) annual compliance certification that the applicant is purchasing renewable fuel to cover the entire need of the~~

~~thermal energy system. If an applicant demonstrates the use of a thermal energy system that relies on fuel which reduces greenhouse gas emissions renewable fuel by providing If the applicant uses thean annual compliance certification that the applicant is purchasing renewable fuel to cover the entire need of the thermal energy system, and the applicant fails to provide an annual compliance certification in any year that the applicant is using renewable fuel that reduces greenhouse gas emissions, the applicant will be assessed an alternative compliance carbon pollution impact fee equal to a pro rata share of the remaining expected life of the thermal energy system~~.

(e) ~~If an applicant with one or more buildings is seeking a permit pursuant to this chapter, and is already using one or more thermal energy systems that rely on a renewable fuel which reduces greenhouse gas emissionsrenewable fuel, the applicant may apply for a credit towards any alternative compliance carbon pollution impact fee equal to the cost carbon value of the renewable ffuel which reduces greenhouse gas emissionsrenewable fuel used for any thermal energy system since January 1, 2023.~~

(f) All alternative compliance carbon pollution impact fee proceeds shall be placed in a Clean Energy Fund established and managed by the Department of Permitting and Inspections with technical support from the Burlington Electric Department. Clean Energy Fund proceeds shall be made available to property owners or low-income renters for eligible initiatives to reduce greenhouse gas emissions produced by buildings, as follows:

(i) The Department of Permitting and Inspections, with technical support from the Burlington Electric Department, shall determine which initiatives are eligible for funding, but they may include, and shall not be limited to, the installation of new low-carbon thermal ~~thermal~~ energy systems, ~~that rely on renewable fuel,~~ weatherization projects, or subsidizing any increased utility costs associated with using a low-carbon thermal energy system ~~purchasing renewable fuel~~ rather than a fossil fuel thermal energy system;

(ii) Half of the proceeds paid into the Clean Energy Fund by a large existing building applicant shall be available to the payor for projects to reduce greenhouse gas emissions at any site owned by the payor located in the City of Burlington. The large existing building applicant must request these proceeds within one (1) year following payment of their alternative compliance carbon pollution impact fee, and any proceeds not requested within that year shall be made available under subsection (iii).

(iii) Any remaining proceeds collected from large existing building applicants and all proceeds paid into the Clean Energy Fund by new construction applicants shall be available to provide financial assistance to help low-income Burlington residents with the purposes descrbied in subsection (i), either through direct payments to homeowners and renters who are income-qualified per the most recent income-qualification levels published by the Community and Economic Development Office (“CEDO”), or through payments to property owners of multi-family buildings where at least 25 percent of the tenants in the building are income-qualified, provided that the property owner must commit to not raising the rent of income-qualified tenants as a result of costs associated with the funded initiatives to reduce greenhouse gas emissions.

Commented [NP13]: The ballot measure specified that the buildings be in the City and I assume that is the City's preference.

(g) Nothing in this section prevents or prohibits applicants from utilizing any and all available local, state, or federal incentives, rebates or tax credits that support implementation of low-carbon thermal energy systems~~renewable fuels listed above~~ for their buildings, and applicants are encouraged to access available incentives or rebates or tax credits.

(h) ~~Any applicant for a permit pursuant to this chapter, for any new or existing building regardless of size, seeking to utilize a wood chip or wood pellet heating system, must demonstrate that the system meets the 2023 or any subsequently issued Vermont Small Scale Renewable Energy Incentive Program (SSREIP) Advanced Wood Heating System (AWHS) terms conditions and requirements, including for efficiency and emission controls.~~

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~~An applicant is permitted to install and utilize nonprimary heating systems in new buildings that use nonrenewable fuels.~~

8-79 Effective Date~~Waiver~~.

The provisions of this Article shall take effect on January 1, 2024.

~~The department of permitting and inspections may grant a waiver to Section 8-78 on the grounds that utilizing a renewable primary heating system in a new building would be uneconomical. To be deemed uneconomical, the twenty-five (25) year capital and operational cost of the least expensive renewable primary heating system, including any available incentives from the Burlington electric department or other State or federal entities, must be more than the twenty-five (25) year capital and operational costs of a nonrenewable primary heating system, including the cost of externalities calculated by a building carbon price of one hundred dollars ($100.00) per ton for the life of the nonrenewable primary heating system. The building carbon price of one hundred dollars ($100.00) per ton shall be annually adjusted by the program administrator equivalent to one hundred (100) percent of the annual change in the Consumer Price Index For All Urban Consumers (CPI-U) in the Northeast Region, to go into effect January 1 of every ensuing year.~~

Commented [GB14]: I agree with the deletion of the waiver.

Advanced Wood Heating

Burning Wood Emits Fine Particulate Matter and Other Pollutants Which are Harmful to Human Health

Burning wood pellets or chips to generate heat in homes emits pollutants that are harmful to people's health, including fine particulate matter, carbon monoxide, nitrogen oxides, and volatile organic compounds, including benzene and formaldehyde. Residential Wood Burning, American Lung Association (attached); *See A. Marin, et al., Residential wood heating: An overview of U.S. impacts and regulations, 72 Journal of the Air & Waste Management Ass'n* 619 (2022) (attached). These harmful emissions occur both indoors and outdoors. American Lung Association, *supra.* They can cause coughing, wheezing, asthma attacks, heart attacks, and premature death, among other health effects. *Id.* For these reasons, the American Lung Association recommends that people "[a]void burning wood . . . to heat the home or water," and "[l]ook for alternatives to heat your home." *Id.* A recent Vermont Department of Health presentation agrees that "[r]educing home heating emissions (especially from biomass) is good for health," indicates that residential biomass burning is the state's largest source of harmful fine particulate matter emissions, and estimates that the direct health impacts associated with current emissions from residential biomass burning in Vermont are between approximately $105 and $235 million per year. J. Ulmer, *Health considerations for home energy strategies in Vermont* (January 27, 2023) (attached).

Natural gas stoves and heaters have lower particle pollution emissions than wood-burning devices. Residential Wood Burning, American Lung Association.

The Environmental Protection Agency adopted more stringent standards for wood heater particulate matter emissions, which became effective in 2020. A. Marin, supra at 620. Compliance with emission limits is determined through certification testing of prototype units. *Id.* at 624. However, both the Northeast States for Coordinated Air Use Management and EPA's Inspector General have identified serious flaws in the federal certification program. *Report: The EPA's Residential Wood Heater Program Does Not Provide Reasonable Assurance that Heaters Are Properly Tested and Certified Before Reaching Consumers* (February 28, 2023), https://www.epa.gov/office-inspector-general/report-epas-residential-wood-heater-program-does-not-provide-reasonable; NESCAUM, *Assessment of EPA's Residential Wood Heater Certification Program* (March 2021), https://www.nescaum.org/resource-library/stationary_sources. NESCAUM determined that "the existing program provides no confidence that new residential wood heaters are performing in a manner that better protects public health than the heaters they replace, and at the level required by federal standards." NESCAUM, at x – xi.

Larger wood fired boilers used in commercial or institutional settings also emit more harmful particulate matter than fossil fuel burning systems. *See* L. Rector, P. Miller, S. Snook and M. Ahmadi, *Comparative emissions characterization of a small-scale wood chip-fired boiler and an oi-fired boiler in a school setting* (2017) (attached) (total particulate matter emissions from wood-fired boiler were almost 30 times higher than from an oil-fired burner)

Numerous cities and towns, large and small, suffer from harmful fine particulate matter emissions due to residential wood burning. There is currently less residential wood burning in Burlington than in more rural areas of Vermont. However, residential wood burning in the City may increase if the City continues to permit it and incentivizes it. *See* D. Carrington, The Guardian, *Wood burning air pollution in UK has doubled in a decade* (Feb. 14, 2023) https://www.theguardian.com/environment/2023/feb/14/wood-burning-air-pollution-uk-doubled-decade (wood burners "have become middle-class status symbols, which harm the quality of our air, damage the environment and threaten public health.") This would detract from the City's efforts to reduce greenhouse gas emissions and put the health of City residents at risk. Every "advanced" wood burning device put into service eliminates the opportunity to obtain greenhouse gas emissions reductions from electrification and heat pumps. The ordinance under consideration applies to new construction and new construction can be built with sufficient weatherization to ensure that heat pumps can meet all heating needs.

Burning Wood is Worse for the Climate than Burning Fossil Fuels

Burning wood emits more carbon dioxide per unit of energy generated than burning fossil fuels. J. Sterman, W. Moomaw, J. N. Rooney-Varga & L. Siegel, *Does wood bioenergy help or harm the climate?,* Bulletin of the Atomic Scientists, Vol 78, No. 3 (2022) (attached); Gunn, et al, *Scientific Evidence Does Not Support The Carbon Neutrality of Woody Biomass,* A Review of Existing Literature 3 (attached). Professors William Moomaw and Juliette Rooney-Varga described at length at the TEUC symposium on McNeil how burning wood results in direct emissions of carbon dioxide, and harvesting trees for wood burning impairs the ability of forests to play their vital role in storing carbon. Harvesting trees for wood burning also impairs forest biodiversity and impairs the ability of forests to prevent water runoff which contributes to water quality impairment and flooding. Due to a lack of time, and because I think you have heard it before, I will not try to explain or further document these impacts here. The adverse climate and forest health impacts caused by harvesting and burning trees for electricity at McNeil, also result from harvesting trees and burning them in wood and pellet stoves to heat homes, businesses and institutions.

The greenhouse gas emission reductions achievable from electrification and heat pumps are undercut to the extent that the city relies on electricity generated from facilities such as McNeil, which burn high-carbon fuels.

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< Indoor Air Pollutants and Health

Residential Wood Burning

Burning wood produces emissions that are widely recognized as harmful to human health. Many of these harmful emissions can occur both indoors and outdoors and many devices operate around the clock. People with lung disease face special risks, but so do children, older adults, people with cardiovascular disease and diabetics.

Wood-Burning Emissions Threaten Lung Health

Emissions from wood smoke, discussed below, can cause coughing, wheezing, asthma attacks, heart attacks, and premature death, among other health effects.[1] Many of these pollutants can worsen air quality indoors and outdoors.

- Particle pollution. In some places, wood-burning is the major source of particle pollution.
- Carbon monoxide. Wood smoke add to the outdoor levels of carbon monoxide, as well as increasing indoor concentrations
- Nitrogen oxides. Nitrogen oxides harm health indoors and outdoors, and helps create particle pollution.
- Volatile organic compounds. These gases include harmful pollutants and contribute to creating ozone pollution. Some of these gases are carcinogens, including benzene and formaldehyde.
- Climate change pollution. Wood smoke adds carbon dioxide and methane to the air, two pollutants that contribute significantly to climate change.

Protect Yourself from Wood-Burning Emissions

Wood stoves, hydronic heaters and other appliances are often used 24-hours a day, which can substantially worsen air quality outdoors. If wood-burning is affecting air quality in your neighborhood:

- **Stay indoors**: Children, older adults and people with lung disease, cardiovascular disease or diabetes should remain indoors and avoid breathing smoke, ashes and other pollution in the area.
- **Don't count on a dust mask:** Ordinary dust masks, designed to filter out large particles, will not help. They still allow the more dangerous smaller particles to pass through. Special, more expensive dust masks with true HEPA filters will filter out the damaging fine particles but are difficult for people with lung disease to use. Consult with your doctor before using a mask, especially if you have a lung disease.

- **Put air conditioners on recirculate**: Stay inside as much as possible, with doors, windows and fireplace dampers shut and preferably with clean air circulating through air conditioners and air cleaners. Use air conditioners in the recirculation setting to keep from pulling outside air into the room.
- **Don't exercise outdoors** especially if you smell smoke or notice eye or throat irritation.

Reduce Your Pollution

Avoid burning wood

Avoid burning wood, corn, switchgrass or other products to heat the home or water. Especially during high pollution days, burning can add pollution to the outdoor air. Look for alternatives to heat your home. More and more homes are shifting to alternatives such as solar panels and electric or geothermal heat pumps. Find information on these heat sources for your home at www.energy.gov.

Choose a cleaner device

If you must burn a fuel to heat your home or water, natural gas stoves and heaters have lower particle pollution emissions than wood-burning devices. However, they need to be fully vented to the outdoors as they also produced some of the same pollutants indoors and out, including carbon monoxide.

If you decide to burn wood, then look for the cleanest burning devices. The U.S. Environmental Protection Agency adopted new standards for wood-burning devices in 2015, but manufacturers will have until 2020 to phase them in and make their equipment cleaner and more energy efficient. Some devices currently meet the 2020 standards and have hangtags showing this certification.

- **Woodstoves, pellet stoves, and hydronic heaters**: Retailers should only sell stoves that meet the 2015 or 2020 standards. Look for a permanent label that indicates they are certified to meet the 2015 standards. Even cleaner and more fuel efficient stoves will be phased in through 2020. Some already meet those 2020 standards, according to EPA.
- **Wood-fired forced air furnaces**. Cleaner warm air furnaces are being phased in now and will be fully in place for all devices manufactured in 2020. 2

Choose a better fuel

If you cannot switch to solar, heat pumps or natural gas and still need to burn fuel in your device, then make sure your fuel burns as cleanly as possible. Pellets and dry wood can burn cleaner and more efficiently than other woods. For tips on burning wood, see tips at the EPA's Burn Wise information.

Implement a Wood Stove Change-out Program

EPA estimates that 65 percent of the woodstoves in use in the U.S. are older devices that produce significant pollution and do not burn efficiently.[3] Some communities have put in place woodstove change out programs to help communities, especially low-income families, benefit from cleaner air and more efficient heating. EPA has guidance to help communities put such program in place.

The Lung Association is working with some local communities to implement woodstove change-out programs to help residents upgrade to cleaner-burning, more energy-efficient heating appliances and technologies. Learn more about Lung Association woodstove change-out programs.

References

3. U.S. EPA. *Strategies for Reducing Residential Wood Smoke*, March 2013, EPA-456/B-13-001

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Residential wood heating: An overview of U.S. impacts and regulations

Arthur Marin, Lisa Rector, Barbara Morin, and George Allen

NESCAUM, Boston, Massachusetts, USA

ABSTRACT

Air pollution from residential wood heating poses a significant public health risk and is a primary cause of PM nonattainment in some areas of the United States. Those emissions also play a role in regional haze and climate change. While regulatory programs have focused on emissions reductions from large facilities, the residential heating sector has received limited attention. The failure to develop effective programs to address this emission source hampers the ability of state and local air quality programs to meet clean air goals. An updated New Source Performance Standard (NSPS) for Residential Wood Heaters was promulgated in 2015, which includes more stringent emissions standards for wood stoves and broadens its scope to regulate additional types of wood heating appliances. However, weaknesses in the test methods and programs used to certify compliance with the NSPS limits hamper the efficacy of those requirements. Current emissions certification tests measure stove performance under defined laboratory conditions that (1) do not adequately reflect operation and performance of appliances in homes, (2) are not sufficiently repeatable to allow for comparison of emissions of different appliances, and (3) allow manufacturers leeway to modify critical test fueling and operating parameters which can significantly impact performance outcomes. These foundational regulatory issues present substantial challenges to promoting the cleanest and most efficient wood heating systems. This paper provides an overview of the air quality and public health impacts of residential wood heating and discusses the weaknesses in the current emission certification approaches and work by the Northeast States for Coordinated Air Use Management (NESCAUM) and the New York State Energy Research and Development Authority to develop improved testing methods. Other articles in this issue discuss the development and testing of those methods in detail.

Implications: Air pollution from residential wood heating poses a significant public health risk and is a primary cause of PM nonattainment in some areas of the United States. Those emissions also play a role in regional haze and climate change. While regulatory programs have focused on emissions reductions from large facilities, the residential heating sector has received limited attention. The failure to develop effective programs to address this emission source hampers the ability of state and local air quality programs to meet clean air goals. This paper provides an overview of the issue.

PAPER HISTORY
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Introduction

While many view wood as a cleaner non-fossil energy source, wood combustion is responsible for a large portion of US particulate matter pollutant emissions. According to US EPA's National Emission Inventory, residential wood heating emitted approximately 340,000 tons of primary (directly emitted) $PM_{2.5}$ in the United States in 2017 (US EPA 2017). After road and agriculture dust and fires (wildfire and prescribed), residential wood heating was the largest source of primary $PM_{2.5}$ in the country, exceeding emissions from the highway and off-highway motor vehicle sectors, as shown in Figure 1.

In all but eight states,[1] residential wood heating is one of the top three contributors to PM2.5. Figure 2 provides emissions per year by state from residential wood heating based on 2017 NEI data. Residential wood heating is also a significant source of polycyclic aromatic hydrocarbons (PAH), carbon monoxide (CO), nitrogen oxides (NOx), black carbon, methane, benzene, acrolein, and formaldehyde. While the determination of carbon benefits of wood heating is influenced by the time horizon used in that calculation, it is clear is that wood combustion emits other climate-warming pollutants of concern, including methane, black carbon, and ozone precursors, which are indirect greenhouse gas emissions – NOx, and volatile organic compounds (VOCs).

From an air quality and public health perspective, the relative importance of emissions from wood heating has grown as regulations for other air pollution source categories such as motor vehicles, power plants, and industrial sources have effectively reduced emissions from those sources (Ciaizzo et al. 2013; Penn et al. 2017). By contrast, effective regulation of emissions from the wood heating sector has been limited. In 1988, US EPA adopted

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[1]Based on 2017 NEI data District of Columbia, Hawaii, Louisiana, North Dakota, Tennessee, Texas, Utah, Wyoming

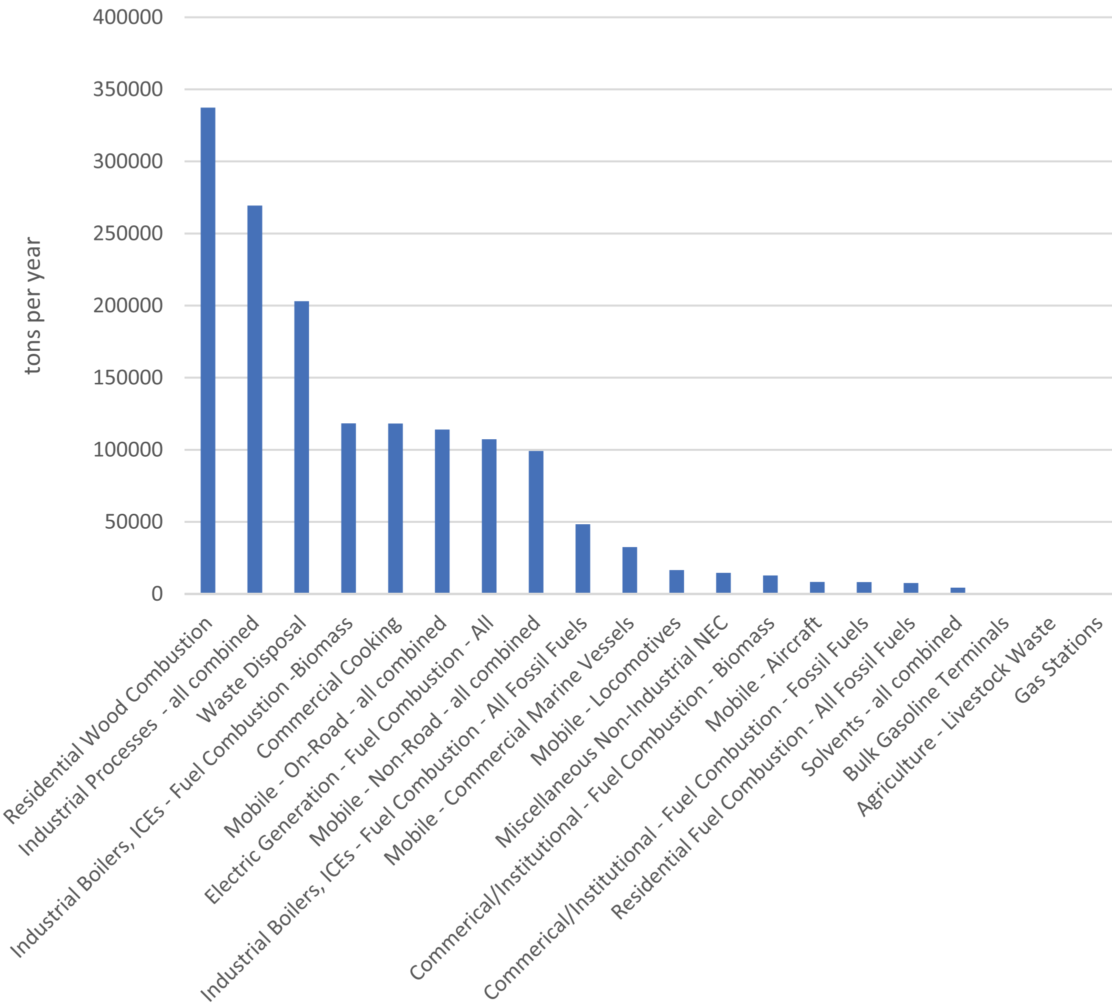

Figure 1. National $PM_{2.5}$ inventory by sector, excluding dust and fire categories (2017 NEI).

New Source Performance Standards (NSPS) for Residential Wood Heaters, which were limited to wood stoves (Federal Register 1988). Revisions of the NSPS in 2015 established more stringent limits and expanded the universe of regulated devices to include single burn-rate and adjustable burn-rate wood stoves, pellet stoves and furnaces, outdoor and indoor wood boilers, and indoor wood-burning forced air furnaces. Those requirements became fully effective in 2020 (Federal Register 2015). The 2015 rule continues to exempt other solid fuel appliances, such as coal units, which can burn wood, and nonresidential appliances.

Emission testing is a highly technical aspect of residential wood heating regulatory requirements, but those tests are critical to identifying low emitting technologies. Certification tests that do not reflect in-use appliance performance hamper the effectiveness of state consumer incentive programs in promoting the cleanest and most efficient wood-fired heating and maximizing emissions reductions.

Current test methods used in the U.S., Canada, and Europe measure emissions under defined laboratory conditions that are not representative of real-world appliance operation. Typically, those tests measure emissions only under steady-state conditions and allow the manufacturer or testing laboratory broad discretion in determining fueling and other testing parameters. When operated in a home, an appliance responds to calls for heat from thermostats or, for manually operated appliances, is subject to homeowner fueling and operating practices. Therefore, appliance operation is characterized by highly variable loads and transitory conditions over the course of a day, including warm and cold starts and burnout periods, which affect efficiency and emissions. (Ahmadi et al. 2020) To reflect in-use operations, testing protocols for manually operated technologies must measure emissions under a range of fueling load and operating conditions, including cold start-ups, varying fuel load sizes, and piece configurations. Protocols that accurately measure emissions from

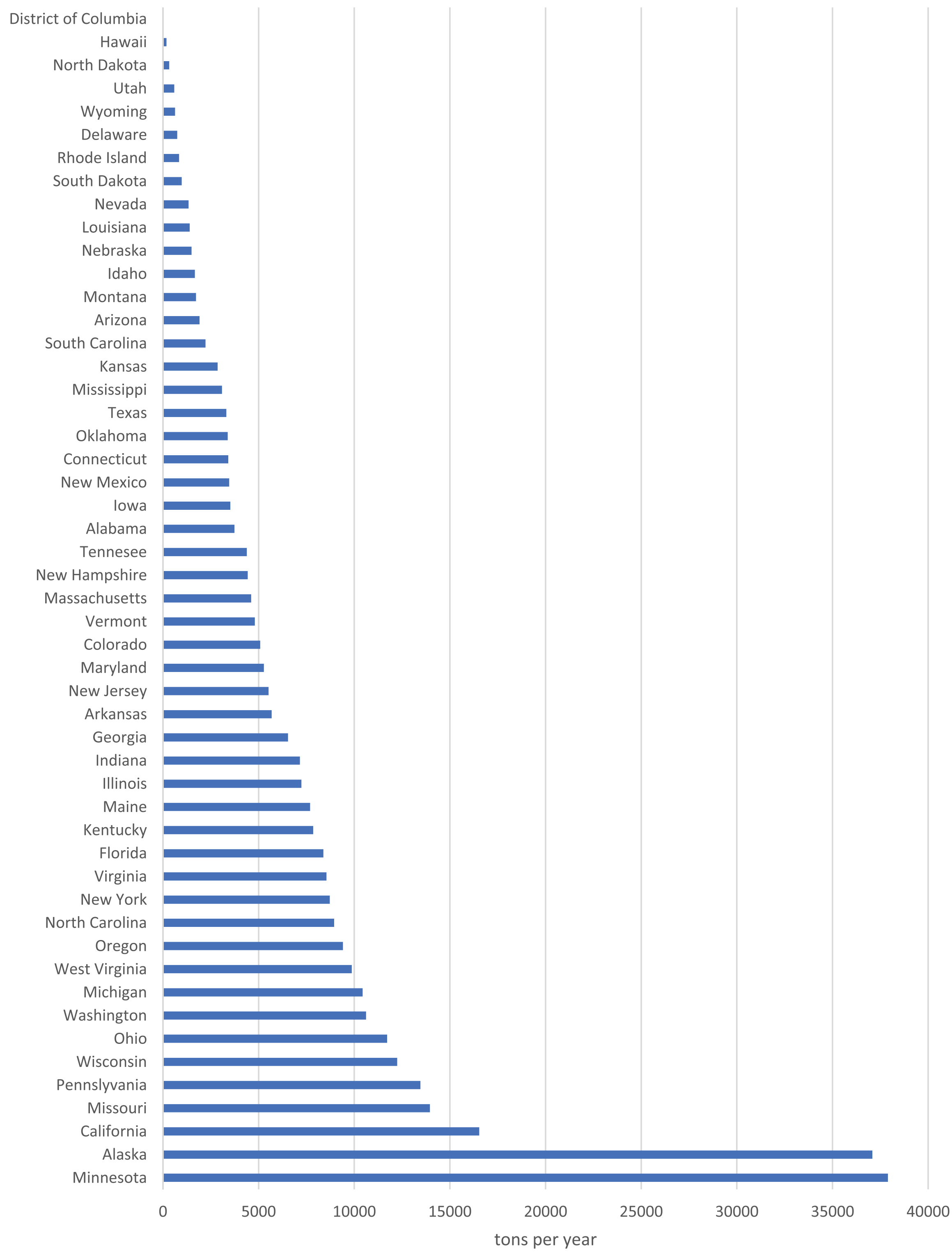

Figure 2. Residential wood heating $PM_{2.5}$ emission by state in tons per year (EPA 2017 NEI).

thermostatically controlled devices must mimic the cyclic operation patterns typical of those appliances, including start-up, cyclic and low load performance periods.

The papers in this issue primarily focus on work supported by NYSERDA to improve the understanding of residential wood heating impacts, evaluate existing test methods, and develop and evaluate improved procedures. However, compliance monitoring is also an essential element of an effective and robust certification program. US EPA has conducted little compliance oversight or audit testing to confirm the effectiveness of their residential wood heating regulations. Lack of proper oversight and auditing gives manufacturers an incentive to conduct tests under unrealistic conditions, which minimize emissions. Without that oversight, the current federal certification program provides little confidence that new residential wood heaters will improve air quality and public health protections than the heaters they replace.

Air quality impacts of residential wood burning

Cordwood, wood pellets, and wood chips are important residential heating fuels in the United States. Of the 12.5 million homes using wood fuel for heating, data indicate that use is more common in rural versus urban households. Data suggests that 27% of rural households used wood for heating while 6% of urban households use wood heating (US Energy Information Administration 2018). The US EPA estimates that residential wood combustion sources emitted approximately 340,000 tons of $PM_{2.5}$ in 2017. That year, wood-burning provided only 2.2% of residential energy in the United States (US EIA, 2020) but was responsible for 98% of fine particulate matter ($PM_{2.5}$) emissions from residential fuel combustion sources. (US EPA 2017) Residential wood heating emissions contribute significantly to nonattainment of the National Ambient Air Quality Standard (NAAQS) for $PM_{2.5}$ in some areas and are also seen as an increasingly important contributor to cold season regional haze in some areas of the country, including the Northeast and Mid-Atlantic regions.

Emissions from wood-burning contain polycyclic organic matter (POM), benzene, aldehydes, and other carcinogenic compounds. The US EPA estimates that residential wood heating accounts for 44% of POM emitted by all stationary and mobile sources (US EPA 2015). Wood heating appliances also emit CO, VOC, NOx, and other gaseous pollutants (McDonald et al. 2000; Johansson et al. 2004; Glasius et al., 2008; Bari et al. 2009; Schmidl et al. 2011; Pettersson et al. 2011; Piazzalunga et al. 2011). In 2017, New York State residential wood heating appliances emitted 17,217 tons of $PM_{2.5}$ and 13,103 tons of VOCs, accounting for 51% and 69%, respectively, of emissions of these pollutants from all fuel combustion in the commercial, industrial, institutional, and residential sectors combined. (US EPA 2017).

Wood heating is a significant source of ambient PM concentrations in many cities, towns, and villages in the northeast states and elsewhere. In the NESCAUM region (New England, New Jersey, and New York), residential wood combustion has a disproportionate impact on air quality due in large part to the Northeast's colder climate and the relative abundance of wood for fuel. Croft et al. (2017) determined that residential wood combustion contributed up to 30% of ambient PM levels in Rochester, New York during cold weather periods. Blanchard et al. (2021a) found that four source types showed declining contributions to EC and OC at the Pinnacle State Park location between 2001 and 2015: (1) fossil-fuel combustion associated with SO_2, (2) combustion not associated with SO_2 (tentatively identified as mobile sources), (3) crustal OC and EC, and (4) sulfate-associated OC and EC. However, OC and EC improvements from emission reductions were partly offset by increasing concentrations of biomass-burning. Biomass burning contributions increased the mean EC and OC concentrations by 13–18% and 23–30%, respectively at the monitoring location. Blanchard et al. (2021b) found that while PM 2.5 emissions decreased 29% in New York State between 2007 and 2019, biomass burning and photochemical secondary aerosol are the critical areas for further reductions. The study also found that wood heating emissions decreased from 2015 through 2019. These decreases could be associated with lower costs for home heating oil during this period.

Studies conducted by the Vermont Department of Environmental Conservation and NESCAUM found that, during the coldest and calmest winter days in Rutland, Vermont, wood combustion accounted for half or more of measured ambient $PM_{2.5}$ concentrations (Allen, Babich, and Poirot 2004). In the first two months of 2014, Rutland experienced daily $PM_{2.5}$ concentrations of almost 20 micrograms per cubic meter (μg/m^3), nearly twice the level of the annual $PM_{2.5}$ NAAQS of 12 μg/m3. During this same period, the area also experienced maximum hourly concentrations greater than the 35 μg/m3 daily NAAQS on more than half the days, with peak hourly concentrations exceeding 90 μg/m^3 at the Rutland $PM_{2.5}$ monitoring site.

More than 90% of ambient carbonaceous PM2.5 is from wood combustion in rural counties in New York State, and winter nighttime town/village peak levels can exceed 100 μg/m^3 (Graham and Johnson 2008; Allen et al., 2020). These results are consistent with a field study by NESCAUM in the Adirondacks region that found significant localized pollution from wood heating was closely associated with the higher population densities of the towns and villages (Allen et al. 2011). Since many rural areas lack air quality monitors, the true magnitude of this problem is difficult to quantify, but wood heating presents a public health risk in many areas. Since there is no clear evidence to the contrary, for the purposes of this work, we are assuming the health risks from wood smoke exposure on a mass concentration basis are similar to the risks of ambient PM2.5 and that the magnitude of the health risks quantified in the epidemiological literature applies to wood smoke PM2.5 also. Wood combustion pollution is not isolated to mountainous areas where valley temperature inversions exacerbate PM emission levels. Studies in

Connecticut have found that, on cold winter days, observed wood smoke contributes over 50% of hourly $PM_{2.5}$ when ambient concentrations are elevated (CT-DEP, 2011). These data suggest that residential wood heating emissions substantially contribute to elevated daily and long-term average $PM_{2.5}$ levels in these and similar areas across the country.

Wood heating also has been identified as a contributor to regional haze in some parts of the country (NESCAUM 2012). Wood combustion particles are generally smaller than 1 μm, with a peak in the size distribution between 0.15 and 0.4 μm (Kleeman, Schauer, and Cass 1999). Wood heating emissions contain many ultrafine particles, less than 100 nm, which rapidly agglomerate as they cool and age. Particles below 0.5 μm are not easily removed by gravitational settling and, therefore, can be transported over long distances (Echalar et al. 1995).

Public health impacts of residential wood burning

Wood combustion emission constituents, including $PM_{2.5}$, CO, and NOx, are associated with adverse respiratory and cardiac health effects and increased mortality. (Boman 2006; Naeher et al. 2007; Pope and Dockery 2006). Short-term exposures to wood combustion emissions aggravate many types of lung diseases, can cause asthma attacks and acute bronchitis, and may increase susceptibility to respiratory infections. Low-level exposure to wood combustion products can reduce pulmonary function and lower blood oxygen concentrations (Environment & Human Health, Inc 2018). Those exposures are especially harmful to children, the elderly, and people with lung and heart disease.

Wood heating emissions also contain a number of carcinogenic compounds, including POM, benzene, and aldehydes. US EPA estimates that this source is responsible for 25% of cancer risk and 15% of all non-cancer respiratory effects attributed to area source air toxics emissions (US EPA 2018). Given that rates of wood heating appear to be underestimated by the sources used to develop these risk assessments, the actual impact may be more significant.

Exposure to wood smoke is associated with a risk of developing COPD due to airway obstruction. Among women and smokers exposed to wood combustion emissions, the prevalence of COPD is especially high. The incidence of COPD in individuals exposed to wood combustion emissions increases significantly with the duration of exposure. These emissions also exacerbate asthma symptoms with higher rates in areas where wood burning takes place over a sustained period (Naeher et al. 2007). Hopke et al. (2020) found a positive association between asthma emergency department visits and biomass burning.

Tsiodra et al. (2021) found that local winter biomass burning for heating purposes was one the most important contributors to the carcinogenic toxicity of PAH emissions in their inventory. The wintertime exposure from wood heating was identified as the most important contributor (76%) to increased excess lifetime cancer risk. The increased risk was attributed to nineteen of the 105 evening episodes measured.

Exposure to wood smoke causes the arteries to become stiffer, which raises the risk of dangerous cardiac events. (Unosson et al. 2013). For pregnant women, wood combustion exposure can result in a higher risk of hypertensive pregnancy disorders, including preeclampsia and gestational high blood pressure (Assibey-Mensah et al. 2019).

The impacts of wood smoke are not distributed equally across the population base, and likely have disproportionate impacts on rural and some low-income communities. Reliance on wood heating as a primary fuel source is most prevalent in rural communities. While wood heating devices are more likely to be found in homes with higher incomes, the amount of wood burned during the heating season is highest in households with annual incomes less than $40,000 per year. The amount of wood used for heating decreases with increasing income, suggesting a heavier reliance on wood heating in lower-income households. (US EIA, 2018) Consequently, residents of rural and low-income communities are more likely to be affected by adverse public health outcomes associated with exposure to wood smoke. Rogalsky et al. (2014) estimated that between 500,000 and 600,000 low-income people in the United States are likely exposed to hazardous air pollutants from burning solid fuels in their homes.

Disparities in exposures across communities were further demonstrated in the Oregon Department of Environmental Quality Project (Portland Air Toxics Solutions – PATS). Exposure modeling of the Portland metro region in that study determined that residential wood heating was the second-largest source of air toxics in the area, after gasoline and diesel engines, largely due to emissions of 15 PAH (polycyclic aromatic hydrocarbons) and naphthalene. The PATS study also found that three of the four major residential wood heating pollutants analyzed negatively impacted children's health. In addition, the PATS study found that Hispanics/Latinos and Asian communities tended to be disproportionately impacted by residential wood combustion in the Portland metro area (Oregon DEQ 2018).

Regulating emissions from wood burning devices

The 2015 NSPS for residential wood heaters established emission limits for new wood-fired stoves and wood-fired central heating systems. Compliance with emissions limits is determined by testing a prototype unit. There are no emission limits or stack testing requirements for installed appliances in the US. Compliance certificates are granted for five-year periods but are typically renewed every five years without retesting if the manufacturer did not make design changes. US EPA regulations require the agency to review NSPS requirements every eight years and revise the emissions standards accordingly if improved technology has been demonstrated. However, the 2015 revisions to the NSPS for residential wood heating devices were the first revisions since the original promulgation of the NSPS in 1988. Some state and local governments have also implemented strategies intended to reduce exposure from wood heater emissions.

The 2015 NSPS established two sets of emission limits; Step 1 standards, which were in effect from May 2015 to May 2020, and more stringent Step 2 standards, which became effective in May 2020. In most areas of the country, the Step 1 standards provided minimal emission reductions because 90% of appliances sold already met that standard when the rule took effect. Step 1 was included to allow the industry five years to develop and test new appliances to meet the Step 2 standards. The 2015 revisions also broadened the universe of residential wood heating devices subject to emission standards, including central heating devices such as hydronic heaters (outdoor wood boilers) and other appliances not previously covered by the NSPS. In November 2018, the US EPA proposed extending the sale of non-Step 2 compliant units until November 30, 2020, but this proposal was withdrawn (Federal Register 2020).

The federal emission certification program requires manufacturers to demonstrate under laboratory conditions that a prototype wood-burning device can meet applicable emissions standards. The test methods used for certifying compliance prescribe the fuel use and configuration in the firebox, the burn cycle, and emission measurement techniques. States, industry, and US EPA are all on record supporting changing the procedures used to test wood heat devices in order to make the emission certification process more representative of real-world emissions than with the current test methods.

Given the long useful life of these devices, the benefits of new emissions standards accrue slowly over time, as new cleaner and more efficient units replace older, high-emitting appliances. Problems with the efficacy of the current testing and enforcement approach hamper the assessment of the performance of new models and further reduce actual emission reductions attributable to the standards (NESCAUM 2021). Under the provisions of the Clean Air Act, the next NSPS review for this source category should be completed by 2023, providing an important opportunity for updating and improving the certification testing and compliance and enforcement elements of the program. Recommendations for strengthening the program are discussed in the following sections of this article.

US EPA's certification testing program

Currently, the only assessment of an appliance's emissions performance occurs during the certification test. Tests are conducted by US EPA-approved laboratories on prototype appliances before a model line is in production. Appliances available in the retail market may also be subject to random tests to ensure that production models meet the standards. Third-party certifiers accredited by the International Standards Organization (ISO) and paid by the manufacturer are charged with reviewing certification test reports, conducting compliance inspections, and issuing certificates of conformity for test reports. The NSPS allows the same company to conduct the certification test and complete third-party review activities. Applications for certification must include a quality assurance program, but those programs' details and efficacy are often submitted to US EPA as confidential business information.

The US EPA has the authority to conduct random compliance audit testing but has not done so in the seven years since the promulgation of the 2015 NSPS. Industry unsuccessfully challenged the compliance audit provisions of the 2015 NSPS in 2021 (US Court of AppealsCir, D. C. 2021). In 2021, NESCAUM issued a report evaluating the effectiveness of the ISO-accredited, third-party system for emission test certification and review created under the 2015 NSPS, and assessing US EPA oversight and enforcement of this process (Rector et al. 2021). The study completed a "screening" level desk audit of certification test reports which evaluated the following elements: (1) completeness of the data sets, (2) consistency of the test results, and (3) error magnitudes where they can be estimated. The evaluations identified models that require additional review by the US. EPA due to significant problems in their certification tests. The analysis found widespread failures in the third-party review system and a lack of effective oversight and enforcement by US EPA. The review concluded that the current state of US EPA's federal certification program provides little confidence that new residential wood heaters will meet the NSPS limits when operated in the field. Rector et al. (2021) is a report prepared by some of the authors that provides a detailed treatment of the issues raised in this paragraph.

Wood device emissions and test methods

Emission certification testing procedures are critical to designing, manufacturing, and selling cleaner-burning wood heating appliances. According to US EPA, "the fueling and operating test methods prescribed by the 2015 NSPS represent a step in the process toward better test methods, rather than the end goal." (US EPA 2016).

This source category poses unique regulatory challenges because emissions from wood heating devices are far more variable in their performance than from burning other fuels. Natural gas and heating oil are homogeneous fuels with consistent physical and chemical parameters. By contrast, the wood burned in residential wood heaters is highly heterogeneous, encompassing a range of species, moisture contents, piece sizes, densities, bark, and resin contents. Gas and oil fuels are mechanically fed to the heating appliances. The user manually fills cordwood stoves and central heating units, which introduces the potential for load-to-load variability in fueling. Further, users control many operating parameters, including door position, airflow, and other settings, which affect appliance performance and emissions.

Existing test protocols vary significantly in their design and rigor and do not all measure the same performance parameters. Because the NSPS allows multiple test methods, emission and efficiency results are often not comparable across models even within the same appliance category. While no test procedure can capture the full range of factors that affect emissions from wood heating devices in the real world, effective emission certification test methods must include some common practices that ensure appliances can operate well and within similar parameters under various conditions.

The current federal reference method (FRM) for certification of woodstoves, US EPA's Method 28 R (M28R) crib wood test, is a "hot-to-hot" steady-state test that burns a specified configuration of dimensional Douglas fir lumber with spacers, rather than typical cord firewood. Emissions are not measured during start-up or reload periods. The fueling and operating conditions specified in that test method are designed to increase the consistency of results. However, the results measured using this test method are not representative of in-use emissions. Moreover, "tuning" of stoves to minimize emissions in M28R laboratory tests can result in suboptimal performance during in-field operating conditions.

The 2015 NSPS acknowledged that, "Cord wood testing is a better measure of how the heaters will perform on the type of fuel commonly used in homes" and set a less stringent NSPS limit for stoves tested using a cordwood test method. The US EPA has approved the Canadian CSA B415.1–10 cordwood test as a FRM for emissions testing of furnaces and for calculating efficiency and carbon monoxide for all appliances. ASTM International has developed cordwood testing procedures for residential wood stoves (ASTM E3053) and central heating appliances (ASTM E2618-13). US EPA has accepted the central heating protocol as a FRM. In 2018, US EPA designated ASTM's woodstove protocol – ASTM E3053 – as a broadly applicable Alternative Test Method (ATM) in early 2018, which means it can be used in lieu of the FRM, M28R, for certifying wood stoves. However in January 2022 EPA revoked the broadly applicable ATM status to ASTM 3053- based test methods and withdrew its approval to use these test methods to demonstrate compliance with EPA emission standards. (Federal Register 2022)

The companion papers in this issue report on research that demonstrates that moving from a dimensional lumber-based test to a cordwood test is not sufficient to generate laboratory results that correlate with field performance. Like M28R, the ASTM and CSA cordwood test methods rely on steady-state testing under single load conditions. In addition, those protocols allow manufacturers significantly leeway in determining the fueling and operating conditions used in laboratory testing, allow for the elimination of high-emitting valid runs, permit the use of alternative data to calculate efficiency values, and lack replicate runs that could be used to assess the reproducibility of the results and the consistency of the appliance's performance. Independent ASTM E3053 tests performed at a US EPA approved laboratory on seven stoves that had been Step 2 certified using that method measured emissions considerably higher than both the certification result and the NSPS emissions limit. In May 2021, nine state Attorneys General submitted a request to US EPA to revoke the Broadly Applicable ATM status granted to the ASTM 3053 test method. In January 2022, EPA formally revoked the broadly applicable use of ASTM 3053-based test method, but allowed the appliances certified with this test method to remain in the marketplace.

Currently, EPA only sets emission standards for total particulate matter. One of the primary approaches used to reduce PM from this source category are change-out programs, which remove old technology and replace it with newer technologies. Little data has been gathered to assess the greenhouse gas and air toxics impacts of new technologies. Other companion papers provide data on emissions that are not currently regulated but perhaps should be considered to provide a comprehensive assessment of appliance performance.

Several of the papers in this issue report on the development and evaluation of a new set of testing protocols for stoves and central heating units known as Integrated-Duty Cycle (IDC) tests. Those protocols are designed to produce accurate results that are representative of in-use conditions, repeatable, affordable, and address many of the shortcomings of the US EPA, ASTM, and CSA test methods. The IDC procedure for cordwood stoves, which US EPA approved as a broadly applicable ATM in 2021, assesses appliance emissions over a range of operating and fueling conditions representing typical consumer use patterns in a single integrated test run. Similarly, the IDC procedure for testing hydronic heaters, which is still in development, tests appliance performance under a range of heat demands and includes multiple fueling events, typical of field use patterns.

To effectively characterize in-use emissions in a reproducible manner, the IDC protocols address the three primary components of testing procedures: (1) fueling, (2) operations, and (3) PM measurement. The protocol requires emissions measurements under typical in-use fueling practices, including a range of piece sizes, loading densities, configurations, and fuel characteristics, such as species, moisture content, and bark content. The operating parameters in the protocols are also designed to reflect the range of conditions that the appliance will experience in field operations, including variable air settings and cold and warm start-up events. Real-time PM measurement methods, which allow for the assessment of peak short-duration emissions and the single value for a test run measured in traditional tests, are used in those methods. The protocols are designed to complete a run in a single day, making it feasible to conduct three replicate runs to assess the variability of stove performance.

Test method development is complex and requires significant resources for data gathering and analysis. NYSERDA and NESCAUM have conducted more than 500 tests on over 30 residential wood heating appliances. That research, presented in this issue and in subsequent journal articles, addresses US EPA's direction in their 2016 Discussion Paper on Cordwood test methods that "the goal of robust new test methods should be to assess an appliance's ability to operate cleanly under highly variable conditions, both in terms of fueling and operations." (US EPA 2016).

Conclusion

Reducing emissions from new residential wood heating appliances is essential to address the public health and environmental impacts associated with wood combustion. The 2015 NSPS update for this source category was an important step toward that goal. However, as described in this paper, weaknesses in the design and implementation of that program limit the potential benefits of the regulatory requirements. The NSPS Step 2 emission standards, which became effective in May 2020, are designed to promote the manufacture of cleaner-burning residential wood heating appliances. However, current federal emissions certification testing methods provide little confidence that the program can identify devices that will consistently operate well in the field. US EPA has announced its intent to promulgate new test methods as part of the next NSPS update, which is due to be completed in 2023. The pending NSPS review represents an important opportunity to address the weaknesses in the federal program by implementing new certification procedures and strengthening administrative and enforcement components of the residential wood heating program.

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Data Availability

The data that support the findings of this study are available from NESCAUM, upon reasonable request.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Health considerations for home energy strategies in Vermont

Jared Ulmer
Climate & Health Program Manager
January 27, 2023

VERMONT
DEPARTMENT OF HEALTH

Key points about health considerations for home energy strategies

1. Equitable and affordable resource access to stay sufficiently warm (or cool) is paramount
2. Home weatherization is a win-win-win-win-win…
3. Reducing home heating emissions (especially from biomass) is good for health
4. Vermont homes need to adapt to increasingly hot weather

Home weatherization is a win-win-win-win-win...

- reduces greenhouse gas emissions
- improves fuel affordability
- improves occupant health
- improves air quality
- helps Vermont homes adapt to a warming climate

Reduced energy costs contribute to better health

Average energy costs after weatherization ↓ 20-30%

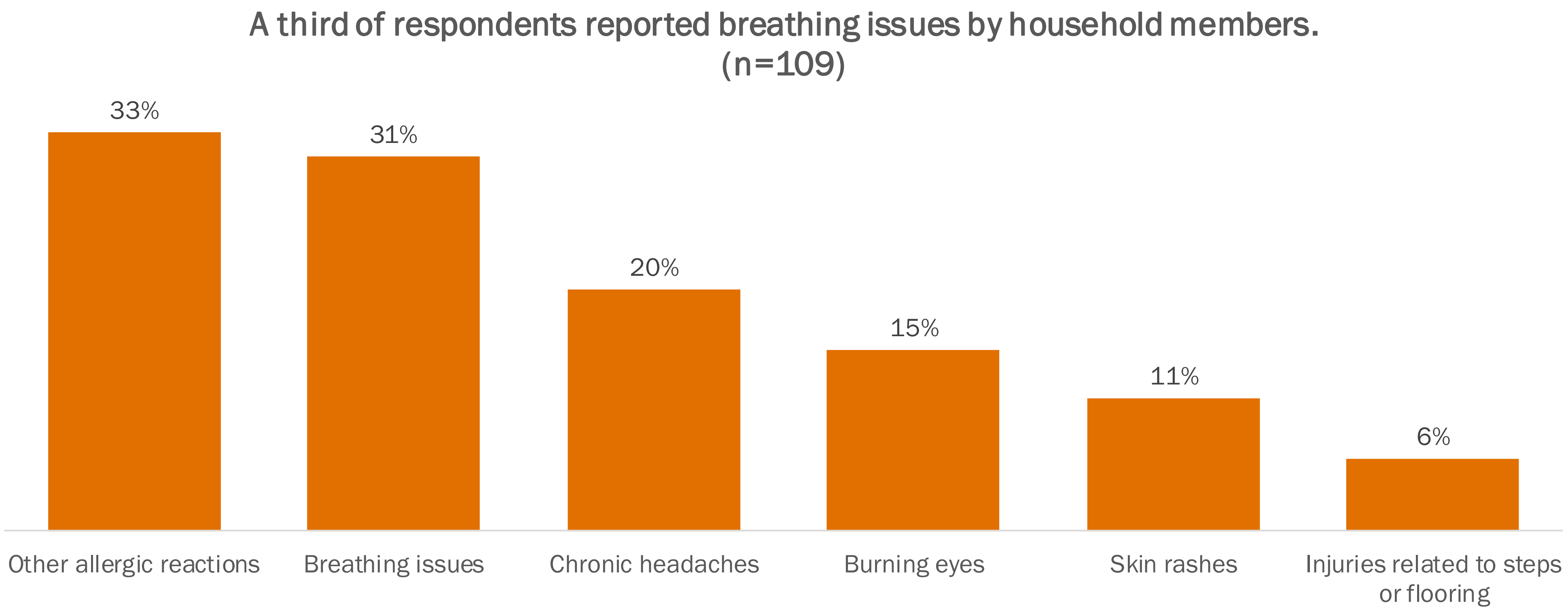
(State weatherization program data)

Surveyed NeighborWorks customers have reported spending some of their energy savings to:

- Buy health insurance could not previously afford
- Make a doctor's appointment could not do before
- Pay off existing medical expenses
- Purchase healthy foods could not afford before

Many Vermont homes are inefficient, uncomfortable, and unhealthy

NeighborWorks of Western Vermont surveyed customers in 2017:



Weatherization also improves home conditions that affect health

Wx improves the home

- $ Reduced energy bills
- Improved temperature control
- Improved indoor air quality
- Enhanced safety
- Reduced humidity
- Reduced mold
- Reduced pest intrusion

**Published evidence about the indoor environmental quality and health impacts of Wx was reviewed to identify the expected effects. The strength of evidence for each finding was based on the quality and amount of evidence available.*

Wx benefits health in many ways

Health benefits...	...are associated with these improvements to home conditions.							Strength of evidence*
General Health	$	✓	✓	✓	✓	✓	✓	High
Productivity		✓	✓	✓	✓	✓	✓	High
Social Health		✓	✓		✓	✓	✓	High
Upper Respiratory		✓	✓		✓	✓	✓	High
Asthma		✓	✓		✓	✓	✓	Medium
Cardiovascular		✓	✓					Medium
Financial Stress	$	✓	✓	✓	✓	✓	✓	Medium
Mental Health	$	✓	✓	✓	✓	✓	✓	Medium
Health Care Utilization & Costs		✓	✓	✓	✓	✓	✓	Medium
Accidental Injury				✓				Low
Infectious Disease		✓					✓	Low
Neurological					✓	✓		Low

What weatherization can do for Vermonters' health

The estimated 10-year economic benefit per household is nearly three times greater than the initial expense.

Benefit category	Primary beneficiary	First-year benefit	10-year benefit
Thermal and electric energy cost savings	Household	$1,174	$11,740
Reduced impacts of asthma, cold, and heat*	Household	$276	$2,762
Reduced fine particulate emissions	Public	$1,026	$10,255
Total	**Household + public**	**$2,476**	**$24,757**

**More benefits are expected but could not be quantified, such as better mental and social health, fewer accidental injuries, and increased productivity.*

Weatherization + Health approaches provide further health benefits

WEATHERIZATION PLUS HEALTH

Wx+Health

Mold remediation
Advanced ventilation
Pest & dust mite remediation
Walk-off mats • Carpet removal
Accessibility • Resident education
Asbestos, lead & radon remediation

Basic Weatherization

Insulation • Space heating • Water heating
Air sealing • Windows/doors • Basic ventilation
Programmable thermostats • Carbon monoxide monitors
Evaluate presence of moisture & mold • Combustion safety

Photo source: NeighborWorks

Reducing home heating emissions (especially from biomass) is good for health

Emissions of health concern from fuel combustion

- **Particulate matter** – tiny solid & liquid particles
- Gases
  - Carbon monoxide
  - Sulfur oxides
  - Nitrogen oxides
- Hazardous air contaminants
  - Volatile organic compounds (ex., Benzene, Formaldehyde)
  - Polycyclic aromatic hydrocarbons (ex. Naphthalene)
  - Heavy metals (ex., Arsenic, Lead)
- Greenhouse gases (ex. Carbon dioxide, Methane)

There is no “safe level” of air pollution

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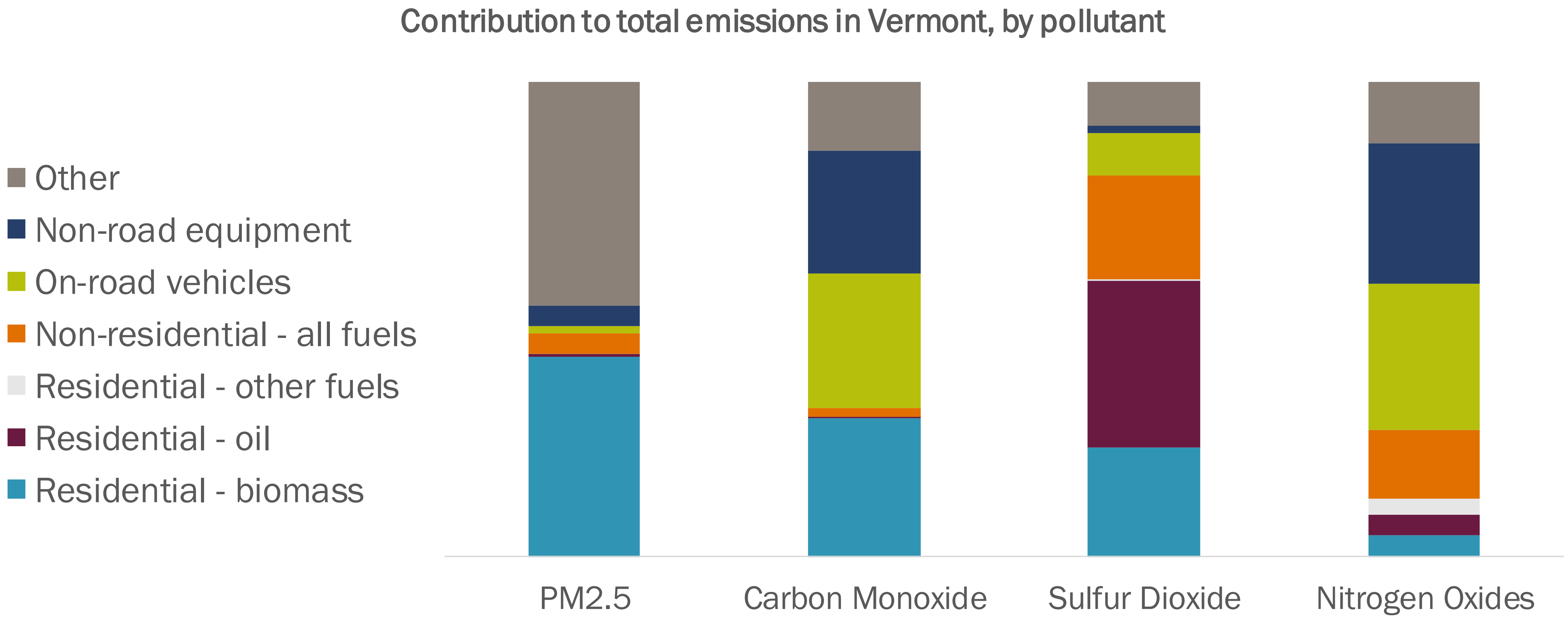
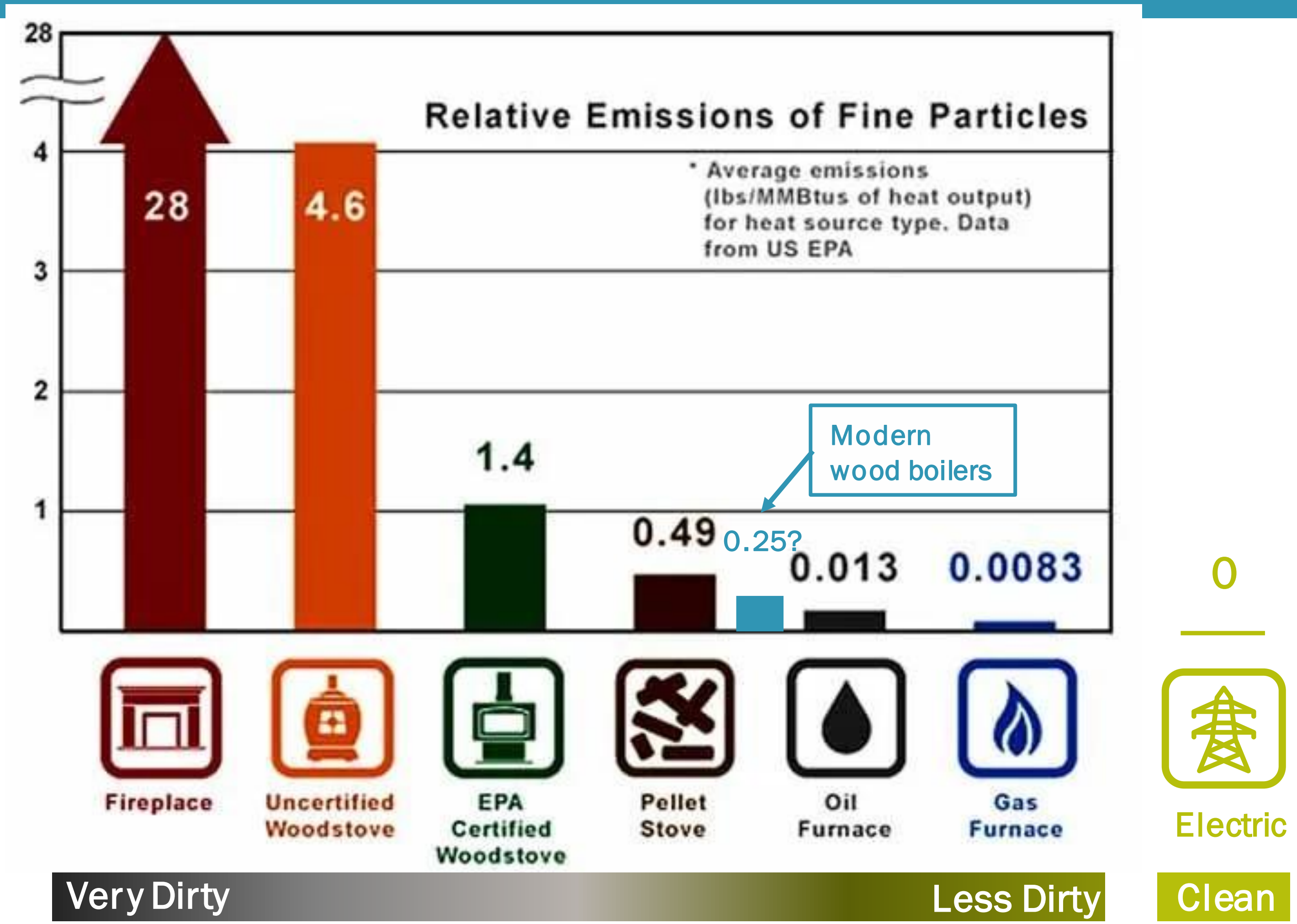
Major pollutant emissions sources in Vermont



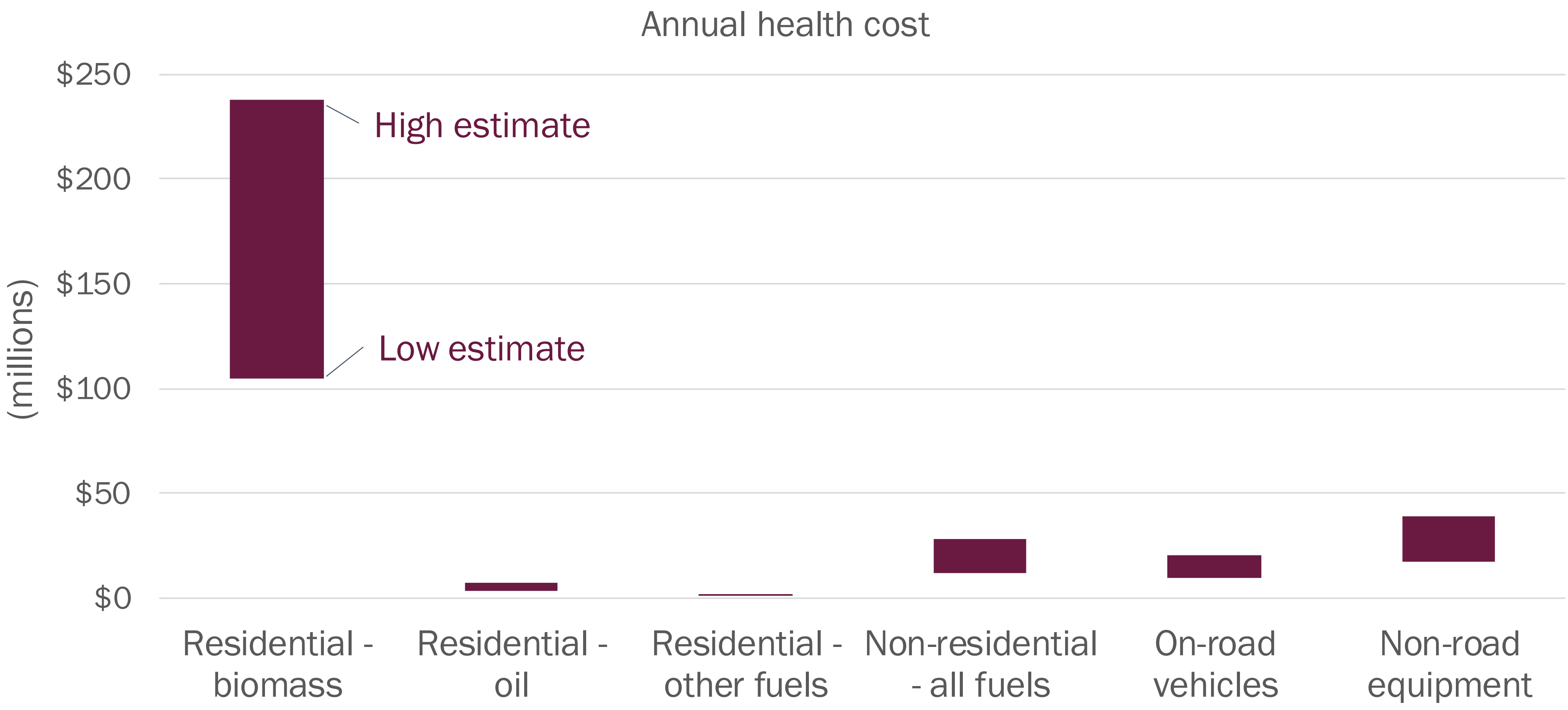
*Based on 2017 National Emissions Inventory data for Vermont

Residential fine particle emissions by type of heating equipment



Sources: EPA emissions factors for heating devices, modified to add peer-reviewed emissions factors for boilers and electric

Estimated direct health impacts associated with current emissions

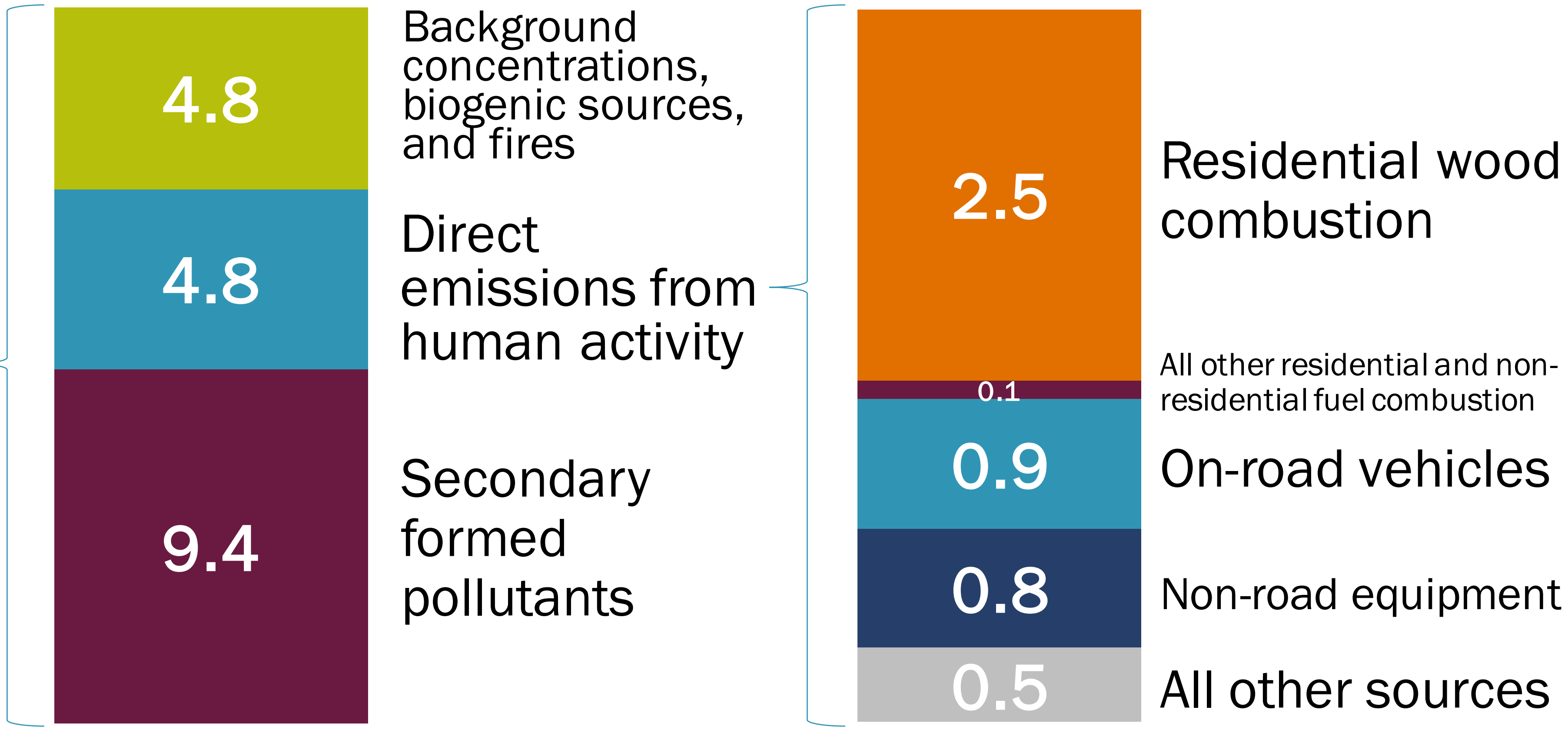


*Estimated using 2017 National Emissions Inventory data and EPA's Co-benefits Risk Assessment model

Cancer risk from toxic emissions in Vermont

Vermont's total air toxic lifetime cancer risk:

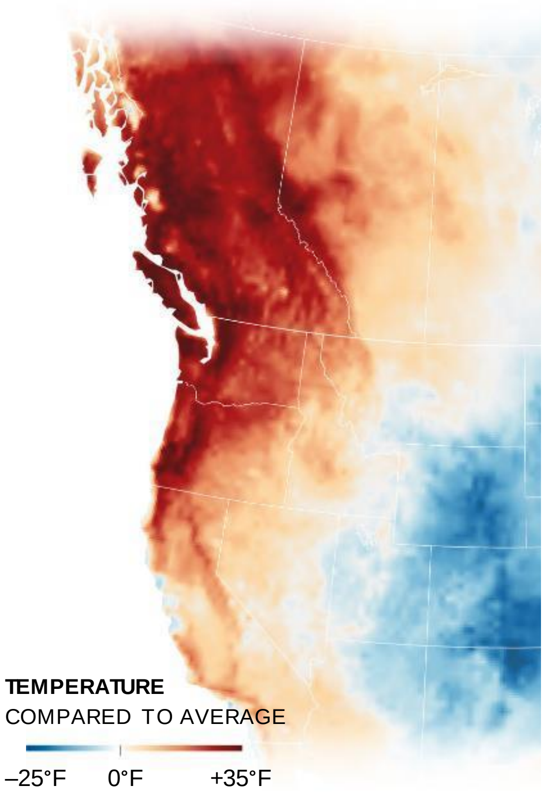
19 per million



*Based on 2017 National Air Toxics Assessment data for Vermont

Vermont homes need to adapt to increasingly hot weather

2021 “Heat Dome” in Northwestern USA & Western Canada



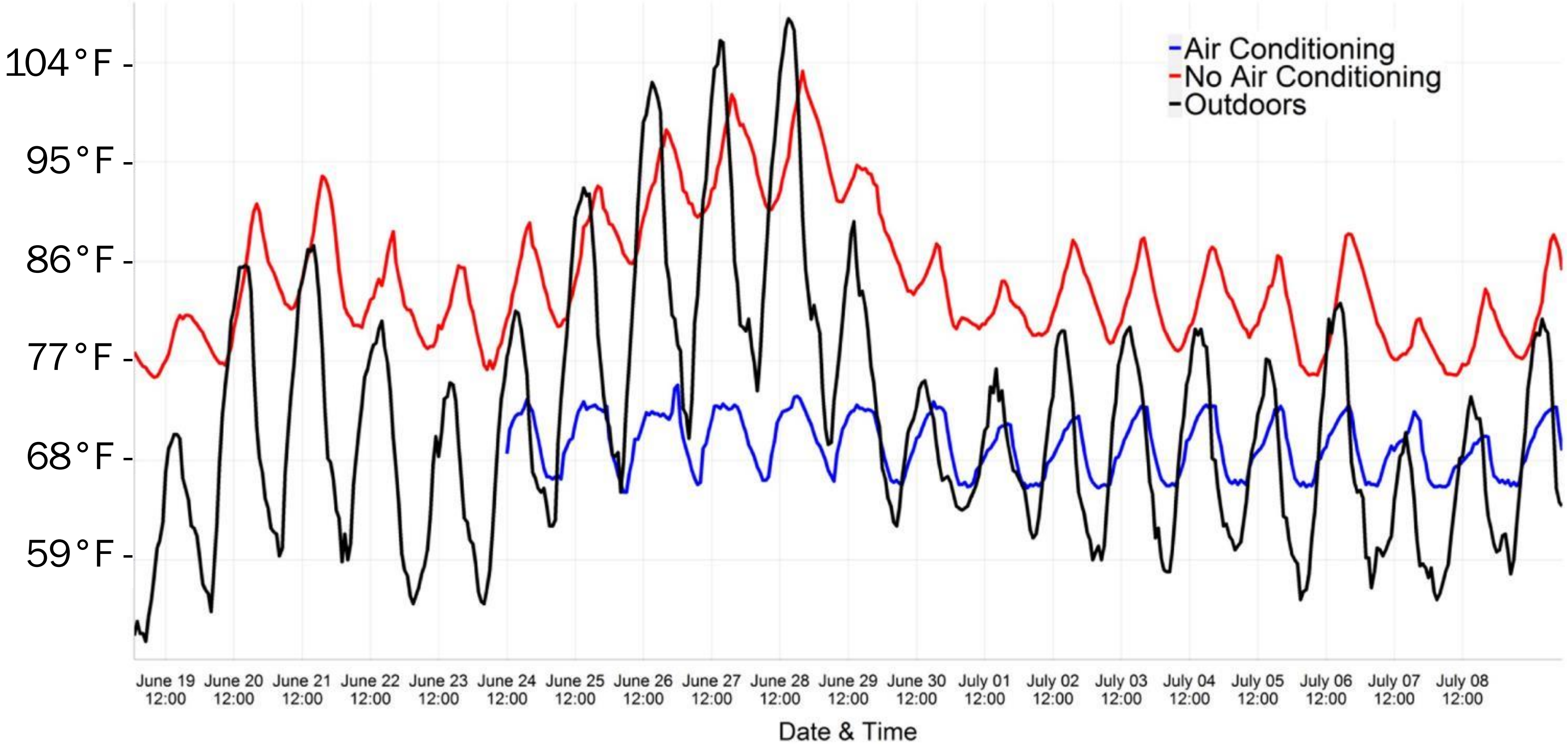
SOURCE: GODDARD EARTH OBSERVING SYSTEM MODEL, NASA, JUNE 27, 2021.

City	Average high (May-June)	Average low (May-June)	Record high (before Heat Dome)
Seattle, WA	65	48	103
Portland, OR	68	49	107
Victoria, BC	64	46	98
Burlington, VT	67	46	101

City	June 26, 2021	June 27, 2021	June 28, 2021
Seattle, WA	102	104	108
Portland, OR	108	112	116
Victoria, BC	96	99	103

Sources: Popovich & Choi-Schagrin, Hidden Toll of the Northwest Heat Wave, NY Times, 2021.
National Oceanic and Atmospheric Administration, Environment and Climate Change Canada.

Average temperatures in Greater Vancouver, BC, 2021 “Heat Dome”



Source: Henderson SB et al. Analysis of community deaths during the catastrophic 2021 heat dome. Environmental Epidemiology, 2022, Vol 6(1), p e189. (note: scale converted from Celsius to Fahrenheit)

Nearly all (98%) Heat Dome deaths in B.C. occurred in a residence

Table 7: Heat-Related Deaths by Place of Injury

Place of Injury	Count	Percent
Private Residence - Multi-unit	242	39.1%
Private Residence - Detached	210	33.9%
SRO/Social Housing/Supportive Housing	62	10.0%
Trailer Home/Mobile Home/RV/Camper	40	6.5%
Senior/Long-Term Care Home	40	6.5%
Outside	13	2.1%
Other Residential	12	1.9%
Total	619	

About 1,400 people died as a result of the 2021 Heat Dome

	Estimated excess deaths
Washington	450
Oregon	160
British Columbia	740

A similar extreme heat wave in Vermont would result in about

50 deaths

...assuming a similar mortality rate as the 2021 Heat Dome

4 Vermont adults died at home during June-July 2018 heat wave

LOCAL

Vt. heat wave: Essex Junction woman died in home where temperature reached 115 degrees

Elizabeth Murray and Will DiGravio Burlington Free Press

Published 4:16 p.m. ET July 6, 2018 | Updated 5:32 p.m. ET July 10, 2018

View Comments

Vermont's death toll from last week's extreme heat wave has risen to four, state Department of Health Spokesman Ben Truman said Monday.

Among the deceased is Mary Myott, 79, of Essex Junction, who died in a home where the temperature had risen to 115 degrees.

Key points about health considerations for home energy strategies

1. Equitable and affordable resource access to stay sufficiently warm (or cool) is paramount

2. Home weatherization is a win-win-win-win-win…

3. Reducing home heating emissions (especially from biomass) is good for health

4. Vermont homes need to adapt to increasingly hot weather

VERMONT
DEPARTMENT OF HEALTH

Thank you!

Let's stay in touch.

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Research paper

Comparative emissions characterization of a small-scale wood chip-fired boiler and an oil-fired boiler in a school setting

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ARTICLE INFO

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Particulate matter
Metals
Woodsmoke

ABSTRACT

To investigate the differences in emissions performance between wood chip and oil-fired boilers under real-world operating conditions, a series of stack tests were performed to measure air pollutant emissions at a wood chip stoker boiler with multi-cyclone emission controls. This type of wood combustion boiler technology (inclined grate stoker boiler with a heat input rating between 880 and 4700 kW) represents the largest number of installations in the northeastern United States. The monitored air pollutant stack emissions from the wood chip boiler were compared to those from an oil-fired boiler used as backup at the same location. The stack test results found that total particulate matter emissions from the wood-fired boiler with a multi-cyclone emission control device were almost 30 times higher on a mass per energy input basis than the oil-fired boiler burning No. 2 distillate oil with 2.2 g kg^{-1} sulfur content under similar real-world operating conditions.

1. Introduction

Under the U.S. Clean Air Act, small combustions boilers are regulated for air pollution control purposes as “area sources” if they emit or have the potential to emit less than 9070 kg per year of a single “hazardous air pollutant,” or less than 22,700 kg per year of combined hazardous air pollutants (see slide 4 in Ref. [1]). The specific “hazardous air pollutants” are listed under the U.S. Clean Air Act, and examples include benzene and a number of metal compounds. Small boilers also emit other regulated pollutants not listed as hazardous air pollutants, such as nitrogen oxides (NOx), carbon monoxide (CO), sulfur oxides (SOx), volatile organic compounds (VOC), and particulate matter (PM).

In the United States, there are approximately 1.3 million boilers installed at area sources such as industrial, commercial, and institutional settings. Within this universe of boilers, an estimated 53% are installed in institutional settings (e.g., hospitals, schools, churches, government buildings), 47% are installed in commercial settings (e.g., shopping malls, apartment buildings, hotels), and less than 1% are located in industrial settings (e.g., manufacturing, refining, mining) (see slide 14 in Ref. [1]).

The U.S. Environmental Protection Agency (U.S. EPA) sets specific air pollution control requirements, such as operational practices or numerical emission standards, for different types and sizes of area source boilers [2]. For area source boilers subject to numerical emission standards, air pollutant emissions are evaluated through stack emissions testing conducted according to established U.S. EPA test methods. PM emissions from oil-fired and wood-fired area source boilers are tested according to the same test methods (see Table 4 in Ref. [2]). For regulatory compliance purposes, the test methods are applied under high-load steady-state conditions, and the emissions testing is typically required to be conducted while the air pollution source is operating at its maximum operating load (see Table 6, Item 4 in Ref. [2]). We note that the U.S. PM emission limits are set on an emissions per energy input basis, although if expressed in terms of emissions per unit of energy output, operation under part load may have higher emission rates due to poorer combustion conditions.

For oil-fired boilers, the maximum operating load typically produces the greatest gross amount of emissions. Gross emissions of wood-fired boilers, however, typically are higher under low-load operating conditions rather than at maximum load. Therefore, the high-load steady-state test conditions used for determining compliance with the numerical emission limits may not well represent “typical use” operating conditions for area source wood-fired boilers. This has also been seen with advanced residential wood stove technologies where measured air emissions under real-world operating conditions were higher than observed under standard test conditions [3,4].

Higher total emissions under typical operating conditions that are

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Available online 05 November 2017

Table 1
Load conditions and fuel characteristics during individual test runs.

Test Run	Load Conditions	Fuel Characteristics
Bole Chip Run#1	• low load (35–43% capacity) for entire run	12.4 MJ kg^{-1}, 0.85% ash, 41% moisture
Bole Chip Run#2	• high load (70% capacity) for 101 min • medium load (51%–69% capacity) for 150 min	12.1 MJ kg^{-1}, 0.85% ash, 42% moisture
Bole Chip Run#3	• low load (35–48% capacity) for entire run	12.6 MJ kg^{-1}, 0.78% ash, 43% moisture
Mill Chip Run#1	• high load (70% capacity) for 101 min • medium load (54%–69% capacity) for ∼162 min	11.6 MJ kg^{-1}, 0.45% ash, 45% moisture
Mill Chip Run#2	• high load (70% capacity) for ∼216 min • medium load (62%–69% capacity) for 90 min	12.1 MJ kg^{-1}, 0.53% ash, 43% moisture
Mill Chip Run#3	• medium load (53%–69% capacity) for ∼63 min • low load for ∼160 min	11.8 MJ kg^{-1}, 0.41% ash, 44% moisture

Table 2
Listing of test methods applied in wood chip and oil boiler emissions testing.

Test Method	Description
US EPA Method 1	Sample and Velocity Traverses for Stationary Sources
US EPA Method 2	Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube)
US EPA Method 3A	Determination of Oxygen and Carbon Dioxide Concentrations in Emissions from Stationary Sources (Instrumental Analyzer Procedure)
US EPA Method 4	Determination of Moisture Content in Stack Gases
US EPA Method 5	Determination of Particulate Matter Emissions from Stationary Sources
US EPA Method 6C	Determination of Sulfur Dioxide Emissions from Stationary Sources (Instrumental Analyzer Procedure)
US EPA Method 7E	Determination of Nitrogen Oxide Emissions from Stationary Sources (Instrumental Analyzer Procedure)
US EPA Method 10	Determination of Carbon Monoxide Emissions from Stationary Sources (Instrumental Analyzer Procedure)
US EPA Method 18	Determination of Gaseous Organic Compound Emissions by Gas Chromatography
US EPA Method 0010	Modified Method 5 Sampling Train for Measurement of Semivolatile Compounds
US EPA Method 25A	Determination of Total Gaseous Organic Concentration Using a Flame Ionization Analyzer
US EPA Method 26	Determination of Hydrogen Halide and Halogen Emissions from Stationary Sources
US EPA Other Test Method 28	Dry Impinger Method for Determining Condensable Particulate Emissions from Stationary Sources
CARB Method 430	Determination of Formaldehyde and Acetaldehyde in Emissions from Stationary Sources

Table 3
CEMS specifications.

Calibration Error	Less than ± 2% of span for the zero, mid-and hi-range calibration gases
System Bias	Less than ± 5% of span for the zero, mid-or hi-range calibration gases
Zero Drift	Less than ± 3% of span over the period of each test run
Calibration Drift	Less than ± 3% of span over the period of each test run

not captured by high-load emissions compliance test methods have public health implications as wood smoke is known to contain a number of health-damaging pollutants, including several carcinogens [5,6], with sensitive subpopulations, such as the elderly, being at higher risk [7]. Because installations of wood-fired boilers are occurring at locations with local populations that can be more sensitive to emitted air pollutants, such as schools and hospitals, a better understanding of the real-world performance of these technologies is needed to provide greater information on their local health impact implications. This is particularly salient in light of advanced wood combustion systems increasingly being promoted as low-carbon renewable fuel technologies as well as an emerging market for the use of locally-produced biomass [8], with significant opportunities in highly populated areas [9]. The positive aspects of these efforts can be undermined if operational practices associated with wood fuel combustion result in increased human exposures to higher concentrations of health-damaging air pollutants [10,11].

To further investigate the differences in emissions performance between wood chip and oil-fired boilers under real-world operating conditions, a series of stack tests was conducted in this study to measure air pollutant emissions at a wood chip stoker boiler with multi-cyclone emission controls installed at a school location in the northeastern United States. This type of wood boiler (inclined grate stoker boiler with a heat input rating between 880 and 4700 kW) represents the largest number of installations in this region. Two types of wood chips were tested, mill end and bole, with moisture mass fraction ranging from 41% to 45%. The monitored air pollutant stack emissions from the wood chip boiler were compared to those from a distillate oil-fired boiler burning No. 2 distillate oil with 2.2 g kg^{-1} sulfur content used as backup at the same school setting. We also compare the wood chip stoker boiler PM emissions to reported results from other wood chip boiler technologies installed in the northeastern U.S. and in Europe.

2. Material and methods

We measured air pollutant emissions from a 2050 kW wood chip stoker boiler with a multi-cyclone for emission control installed for primary heating purposes at a northeastern U.S. school setting. The wood boiler is a Messersmith combustor coupled to a Hurst Model SI-265 boiler that typically consumes approximately 725 t of wood per year at the school. The combustor is an inclined grate stoker with two augers to feed wood chip fuel to the top of the grate. There are five zones of primary combustion air (under-fire air), and a refractory shelf that separates the primary combustion zone from the boiler. As unburned wood gases leave the primary combustion zone, secondary combustion air (over-fire) is introduced to the gases so the combustion is completed in the combustion chamber of the Hurst boiler. The Hurst boiler is a fire tube unit with a three-pass design.

The combustion control system employs a step modulated fuel feed rate, having three stoking rates, plus a pilot mode in which stoking occurs intermittently at the lowest rate. The low fire, medium fire, and high fire stoking rates are manually adjustable by potentiometers.

Table 4
Individual test run results and three-run averages of total, filterable, and condensable PM emissions rates for stoker boiler combusting 40% moisture mass fraction wood chips and boiler combusting heating oil. Rates in mg MJ^{-1} are on energy input basis.

	Run 1	Run 2	Run 3	Average
Bole Chip Test Load	low	high to medium	low	–
Total PM (g h^{-1})	419.6	1032.4	546.6	666.2
Filterable	393.7	1003.8	517.1	638.2
Condensable	25.9	28.6	29.5	28.0
Total PM (mg MJ^{-1})	99.7	159.4	114.3	124.4
Filterable	93.7	155.1	108.3	119.0
Condensable	6.0	4.3	6.0	5.4
Mill End Chip Test Load	high to medium	high to medium	medium to low	–
Total PM (g h^{-1})	551.1	695.8	250.4	499.1
Filterable	467.7	676.8	225.0	456.5
Condensable	83.5	19.1	24.9	42.5
Total PM (mg MJ^{-1})	97.1	155.9	84.2	112.4
Filterable	82.5	151.6	75.6	103.2
Condensable	14.6	4.3	8.6	9.2
Heating Oil Test Load	medium	medium	high	–
Total PM (g h^{-1})	17.2	9.5	11.3	12.7
Filterable	13.6	5.9	6.4	8.6
Condensable	3.6	4.1	5.0	4.2
Oil Total PM (mg MJ^{-1})	6.0	3.4	3.0	4.2
Filterable	4.7	2.1	1.7	2.9
Condensable	1.3	1.3	1.3	1.3

Programmable logic controllers automatically select the proper fuel feed rate by differencing the boiler supply water temperature and the supply water temperature operating point.

The wood boiler was fired with two types of wood chips – mill end and bole. Mill end chips have bark removed before chipping while bole tree chips do not. The bole chips underwent processing to remove "fines" (particles less than ~ 3 mm in size) prior to delivery to the testing site.

Wood chip samples were collected at the school site and sent to an analytical laboratory at Clarkson University (Potsdam, New York) operated by Prof. Phil Hopke. Wood sample analysis included carbon, oxygen, hydrogen, nitrogen, sulfur, trace elements including metals, ash and moisture content, and heating value. The chip samples were finely ground and pressed into pellets for analysis. Standard ASTM test methods were applied, which were ASTM E870-82 for preparation [12], ASTM E711-87 for calorific content [13], ASTM D1102–84 for ash content [14], and ASTM E871-82 for moisture analysis [15] Basic elemental analysis was conducted using ASTM methods D-3176 modified (ICP-MS) [16]. Trace elements in the wood chip samples were determined from a sample of ash. A wood sample was placed in a muffle furnace to ash the sample. The ash samples were then acid digested in nitric acid using a CEM MARS 5 microwave digestion system. The resulting solution was filtered and analyzed using a Thermo X-Series ICP-MS with collision cell technology (CCT). Only relevant elements that had detectable levels in most samples are reported. Variability across samples was large, with standard deviations approaching or exceeding the averages. The wood chip characteristics used in this study are provided in Table 1, with additional details of test results in the Supplementary Material (Tables S1–S5). We note that moisture mass fraction ranged from 41 to 43% for the bole chips and 43–45% for the mill chips, which was at or below the upper end of the woodchip boiler manufacturer's recommended maximum content of 45%.

Table 6
Measured emission rates of NOx, CO, SO_2, and VOC from wood chip and oil boilers (mg MJ^{-1} energy input).

	Bole Chip	Mill End Chip	No. 2 Distillate Oil, 0.22% Sulfur
NOx	124.2	126.0	56.7
CO	193.0	193.9	0.4
SO_2	15.0	5.6	92.9
VOC	21.1	6.4	0.4

A sample of No. 2 distillate oil was obtained during the testing for analysis of trace metal and sulfur content by a certified and accredited testing laboratory (Intertek). Oil samples were shipped to the Intertek laboratory in Deer Park, TX for analysis. Sample chain of custody was maintained such that metals analyses and sulfur results could be tracked to each sample. Trace element analysis other than sulphur was done by ICP-MS using the laboratory's standard test method (ITM_1051), with minimum detection levels between 1 and 10 μg kg^{-1} depending on the element. Oil sulfur content was tested using energy-dispersive X-ray fluorescence spectrometry according to ASTM Method D4294 [17]. This method is typically applied to a concentration range of 150 to 50,000 mg kg^{-1} sulfur in fuel oils. Sulfur content averaged

Table 5
Comparison of U.S. particulate matter regulatory standards (gray-shaded rows) with measured emission rates at wood combustion and oil-fired boilers.

Boiler type	Fuel	Boiler size (kW)	PM emissions rate[a] (g MJ^{-1})	Control technology
U.S. EPA new small biomass boiler PM standard#1	Biomass	2930–8792	30.1	–
U.S. EPA new small biomass boiler PM standard#2	Biomass	≥8792	12.9	–
School stoker, this study	Bole chip	2050	120.4	Multi-cyclone
School stoker, this study	Mill end chip	2050	112.6	Multi-cyclone
Gammie [20], school#1 gasification combustion	Mill end hardwood chip	2667	67.9	Multi-cyclone
Gammie [21], school#2 gasification combustion	Mill end hardwood chip	1348	28.4	Multi-cyclone
Chandrasekaran et al. [22] Walker Center gasification staged combustion	Pellet	146	25.8	Mono-cyclone
Chandrasekaran et al. [22] Cayuga gasification staged combustion	Wood chip residue	146	41.3	Mono-cyclone
Chandrasekaran et al. [22] Wild Center gasification staged combustion	Pellet	498	26.2	Mono-cyclone
Sippula et al. [23] "boiler A" rotating grate	Sawdust + bark	5011	34.8	Multi-cyclone, wet scrubber
Sippula et al. [23] "boiler B" rotating grate	Wood chips (forest residue)	15,005	15.9	Multi-cyclone, ESP
Sippula et al. [23] "boiler C" rotating grate	Sawdust + bark	9994	34.8	Multi-cyclone, ESP
Sippula et al. [23] "boiler D" gasification combustion	Wood chips (forest residue)	7004	52.0	Mono-cyclone
U.S. EPA new oil boiler	Oil	2930	12.9	–
School oil boiler, this study	No. 2 distillate oil 2.2 g kg^{-1} sulfur	1170	3.44	none
McDonald [24] conventional cast iron boiler	No. 2 distillate oil 11 mg kg^{-1} sulfur	58.6	0.026	none
McDonald [24] conventional warm air furnace	No. 2 distillate oil 11 mg kg^{-1} sulfur	29.3	0.056	none

[a] Emission rates are based on energy input. For boilers with installed control technologies, emission rates are post-control.

2.2 g kg^{-1}, which is consistent with a 2.0 g kg^{-1} average sulfur content in a larger 2010 regional analysis of No. 2 distillate oil sold in the northeastern U.S [18]. Trace metal content was also consistent with the 2010 distillate oil regional analysis. Full results are presented in the Supplementary Material (Table S6).

Three test runs for each fuel type were carried out, for a total of nine runs (three mill chip, three bole chip, and three distillate oil). A listing of U.S. EPA and other test methods used for the combustion species measured during the test runs is provided in Table 2.

Air emission sampling for the wood chip boiler was performed using the existing 61 cm internal diameter vertical stack (Supplemental Material Fig. S1). Two 15 cm diameter sampling ports were located 90° apart approximately 2 m above the school roof (~6 stack diameters downstream of the nearest flow disturbance), and a second tier of two 15 cm diameter ports were installed approximately 2.5 m above the lower pair. During each run of approximately 4 h in total duration, combustion species were measured in the stack with six sampling trains that were switched in and out at the four ports according to the species being measured, typically in periods of 2 h or less. A single sampling port was installed approximately 1 m below the existing ports for use with a continuous emission monitoring system (CEMS) probe. The CEMS probe blocked less than 3% of the stack area and therefore did not represent a flow disturbance. Additional details on sampling train arrangements and schematics are given in Rector et al. [19].

Emissions from the wood chip boiler performance testing were compared to a conventional distillate oil-fired boiler with no emission control equipment (which is typical for conventional oil-fired boilers burning distillate in the U.S.) that serves as a backup to the wood chip boiler at the same location. The 1170 kW boiler was manufactured in 1993 by Industrial Combustion, Inc. (Highland Automatic Boiler Model 508-5), and installed at the school location in 2002 to serve as the primary heat source at the school, but was replaced by the woodchip boiler in 2007.

Sampling for the oil boiler was performed using a temporary horizontal stack that was set up to satisfy the requirements of EPA sampling Test Method 1. This stack was 38 cm square. Two sets of 10 cm diameter sampling ports were installed that were accessible from the school roof. Each set of sampling ports was located ~8 equivalent duct diameters downstream of the nearest flow disturbance.

During testing, the wood chip boiler operated under normal conditions and under a variety of typical loads. Fuel load varied from high to low throughout the testing periods. Table 1 provides the load conditions and fuel characteristics during each wood chip boiler test run. Load on the oil boiler during testing ranged from medium to high.

The CEMS was used to quantify nitrogen oxides (NOx), sulphur oxides (SOx), carbon monoxide (CO), volatile organic compounds (VOC), O_2, and CO_2 emissions. The system consisted of a heated stainless-steel probe of sufficient length to allow a three-point traverse during sampling and a heated Teflon® sample line (0.95 cm OD, 0.016 cm wall) to transport the sample gas from the probe to the sample gas conditioning system. The CEMS met or exceeded all specifications listed in Table 3.

The sample gas conditioning system consisted of an in-stack sintered filter located at the probe inlet to remove particulates from the sample gas stream, and a thermoelectric condenser/electronic chiller sample gas conditioning system for moisture removal. A diaphragm-type vacuum pump was used to draw the sample gas from the probe through the conditioning system to the analysers. The pump head was stainless steel, the valve disks were Viton® rubber, and the diaphragm was Teflon® coated.

A three-way fitting, located at the base of the probe, was utilized to allow the operator to select sampling from either the sample stream or the calibration gas stream. The sample or conditioned gas was distributed to the analysers using a series of flow meters, valves, and backpressure regulators. These allowed the operator to maintain constant sample flow and pressure during sampling and calibration.

NOx was measured in accordance with US EPA Method 7E using a Thermo Environmental Instruments Inc. (TEI) Model 42H NOx chemiluminescent monitor in a range from 0 to 500 $cm^3\ m^{-3}$ dry basis NOx. SOx was measured with a continuous emissions analyzer according to US EPA Method 6C, and set at a range of 0–250 $cm^3\ m^{-3}$ dry basis SO_2. CO was measured according to US EPA Method 10 using a TEI Model 48 gas filter correlation infrared analyzer set at a range of 0–1000 $cm^3\ m^{-3}$ CO. A VOC gas sample was continuously extracted from the exhaust stack through a heated Teflon sample line routed to a TECO 51 flame ionization analyser in accordance with US EPA Method 25A. VOC measurements were expressed in equivalents to the calibration gas, propane. Calibration was done with three concentrations of propane in a balance of high purity nitrogen: 85.8, 50.1 and 30.4 $cm^3\ m^{-3}$ as propane. O_2 and CO_2 were measured according to US EPA Method 3A using a California Analytical Model 100F O_2 analyzer with a range of 0–25% volume fraction for O_2, and a California Analytical Model ZRH non-dispersive infrared CO_2 analyzer with a range of 0–20% volume fraction for CO_2.

A PC-based data logger system with digital strip chart recorder (Monarch Instrument DataChart 4600) was used to record analyser responses to the sample and calibration gas streams. The chart recorder was operated continuously while the personal computer recorded the test run data in 15-s interval averages.

A NOx and O_2 stratification test was completed prior to testing. The eight traverse points determined by U.S. EPA Method 1 were sampled to ensure no deviation greater than 10% of the mean concentration at any point (or greater than 3 mg kg^{-1} NOx or 0.3% O_2 absolute difference). The CEMS sampling was conducted at a single point due to the lack of stratification.

Raw data averages collected for each pollutant or diluent gas concentration for each test run were determined by exporting the collected data from the data logger into an Excel™ spreadsheet file. The raw data were then corrected to determine the final concentrations by the calibration drift and bias test results.

For the stack PM measurements, filterable PM is defined as emitted directly by the boiler as a solid or liquid at stack conditions and captured on the filter of the stack test train. Condensable PM exists in the vapor phase at stack conditions, then condenses and/or reacts upon cooling and dilution in the ambient air to form solid or liquid PM immediately after discharge from the stack. For both filterable and condensable PM sampling, filters were collected during each of three 60 min test runs. Collected filterable and condensable PM samples from each run were sent to a third-party commercial laboratory (Maxxam Analytics, Inc.) for analysis.

Total filterable PM was quantified in the front-half of the sampling train according to US EPA Reference Test Method 5. Total condensable PM was measured in the back-half of the sampling train according to US EPA Other Test Method 28. The front-half for sampling filtered PM consisted of a glass button hook nozzle, a heated glass lined sample probe, and a tared glass fiber filter in a holder in an oven box. The sample probe and oven box were maintained at a temperature greater than 120C during sampling to prevent moisture condensation. After a post-test leak check, the front-half of the sampling train was disassembled, all open ends were sealed, and the sampling train components were moved to a cleanup area for recovery. The filter was carefully removed with forceps and placed in a labeled plastic petri dish. Any particulate matter or filter fragments that adhered to the filter holder gasket were also transferred to the petri dish. The petri dish was then sealed for laboratory analysis. In addition, the nozzle, probe liner, cyclone bypass, and filter holder front half were rinsed and brushed three times (or until there was no discoloration in the rinse) with acetone. These rinses were collected in a labeled glass or Nalgene® sample jar. The sample jar was sealed with the liquid level marked for laboratory analysis.

The back-half sampling train for condensable PM collection consisted of a condenser and a condensate dropout impinger without bubbler tube following the out-of-stack filterable PM heated filter assembly. A modified Greenburg Smith impinger with no taper followed and served as a backup dropout impinger. The first two impingers were placed in an insulated “cold box” containing water at less than 30C which was recirculated through the condenser during sampling. The condenser was capable of cooling the stack gas to less than 30C. The condensable PM filter holder containing a Teflon® filter followed and was equipped with a thermocouple measuring the temperature of the sample gas. The temperature of the sample gas was maintained at or below 30C. A modified Greenburg Smith impinger containing 100 cm^3 of water followed, serving as the moisture trap to collect the moisture that passed through the condensable PM filter. A fourth impinger contained a known quantity of indicating silica gel. The temperature at the outlet of the fourth impinger was maintained below 20C during sampling by an ice bath containing the third and fourth impingers. A vacuum line connected the outlet of the fourth impinger to a control module consisting of a leak free sampling pump, a calibrated critical orifice, an inclined manometer, and a calibrated dry gas meter. As soon as possible following the post-test leak check, the front-half of the sampling train was removed from the back-half, and the back-half was configured for a post-test nitrogen purge. If no visible water or condensate was collected before the condensable PM filter (in the condensate dropout impinger or backup dropout impinger) the nitrogen purge cycle was eliminated. The CPM filter sample was carefully removed from the filter holder with forceps and placed in a labeled plastic petri dish. Any particulate matter or filter fragments that adhered to the filter holder gasket were transferred to the petri dish using the forceps. The petri dish was then sealed for transport to the analytical laboratory.

The aqueous liquid contents of the dropout and backup dropout impingers were quantitatively transferred into a clean glass or plastic sample bottle. The probe extension, condenser, each impinger and the connecting glassware, and the front-half of the condensable PM filter holder were rinsed twice with water. The rinse water was recovered into the same bottle as the impinger contents and the liquid level marked. This sample container held the water soluble condensable PM captured in the sampling train.

Following the water rinses the sampling train components were rinsed with acetone, then twice with methylene chloride. These solvent rinses were collected in a glass sample bottle with the liquid level marked. This sample container held the organic condensable PM sample fraction captured in the sampling train.

The condensable PM sample fractions were maintained at or below 30C during overnight delivery transport to the analytical laboratory.

3. Results and discussion

3.1. Particulate matter emission rates from the combustion of wood chips and heating oil

Table 4 provides a summary of the filterable and condensable results of the PM testing for each test run and the average across the three runs for each fuel type. On average, total PM emissions on an energy input basis from the bole and mill end chips were about 30 times higher than those of the oil test at the same location. Review of the filterable PM versus the condensable PM shows similar results between the bole and mill end chip fuels. Approximately 8% of the PM in the mill chip was emitted in the condensable fraction, while 5% of the PM in the bole chips was emitted in the condensable fraction. The condensable PM fraction from the oil boiler was significantly higher than that from the wood chips, with 37.5% of the PM found in the condensable fraction. We would expect the condensable PM fraction from oil combustion to be lower than from the wood chip boiler due to higher combustion temperatures in the oil boiler. We are uncertain for the higher relative condensable fraction with oil in this study, but note that the oil boiler is used as backup to the chip boiler, and may not have been maintained for optimal operation.

Table 5 compares the PM emission results from this study to results appearing in previously published studies. Included in the table are results from two close-coupled gasification boilers burning mill end chips with high efficiency multi-cyclone for PM emission control located at two different school locations in the northeastern U.S. [20,21]; three different wood gasification staged combustion boilers at different institutional settings also in the northeastern U.S. [22]; wood chip combustion results at district heating systems in Europe [23]; and two conventional oil devices burning 11 mg kg^{-1} sulfur No. 2 distillate oil [24]. Table 5 also includes for comparison more recent PM emission standards established by the U.S. EPA after the completion of these stack tests that would apply to new wood- and oil-fired boiler installations in the United States.

As seen in Table 5, wood-fired boilers equipped with ESPs tend to reduce PM emissions by approximately 90% while units using multi- or mono-cyclone technologies only reduce PM emissions by 10% [25], although the PM results of the close-coupled gasification mill end chip boiler #2 with a high-efficiency multi-cyclone compare well to ESPs.

Hopke and Holsen [26] concluded that without emission controls, staged combustion wood chip boilers burning 30% moisture mass fraction wood chip (much lower than typically available) could achieve PM emissions of 47.3 mg MJ^{-1}. The study concluded that staged combustion systems in the U.S. represent a significant improvement over the stoker design. The study's staged units, however, did not represent state-of-the-art in boiler design, and therefore additional opportunities may exist to improve combustion efficiency with the potential of lower emissions and higher thermal efficiencies.

Lowest PM emissions in this study were observed with the oil-fired boiler burning distillate (No. 2) fuel oil with 2.2 g kg^{-1} sulfur content.

3.2. Other emission rates from the combustion of wood chips and heating oil

The CEMS results for emission rates of NOx, CO, SO_2 and VOC are shown in Table 6 for the wood chip stoker and oil boiler measurements. The bole chip and the mill end chip results showed fairly similar NOx emission rates of 124.2 mg MJ^{-1} for the bole chips and 126.0 mg MJ^{-1} for the mill end chips. The NOx emission rate for the oil boiler was 56.7 mg MJ^{-1}, which was 55% lower than the wood chips.

For CO, the results showed fairly similar emission rates of 193.0 mg MJ^{-1} for the bole chip and 193.9 mg MJ^{-1} for the mill end chip. The 2.2 g kg^{-1} S distillate heating oil CO emission rate was significantly lower at 0.4 mg MJ^{-1}. The CEMS data collected over the course of several days indicated that CO emissions from the wood chip boiler are highly variable and dependent on load, state of operation, fuel moisture content, and air to fuel ratios. Emission rates varied from levels less than 10 mg kg^{-1} to more than 1.5 g kg^{-1}. We reviewed CO rates in comparison to load or changes in wood chip boiler operation and did not find any correlation between these rates. Based on these results for the wood chip boiler, we conclude that current U.S. regulatory testing requirements, which only capture CO emissions at high load for a 60 min time period, are not likely to present a realistic picture of typical performance.

The SO_2 emission rates based on the CEMS data for the all three fuels were fairly consistent across various sampling periods. Mill end chip had the lowest emission rate (5.6 mg MJ^{-1}). The SO_2 emission rate for bole chip was 60% higher (15.0 mg MJ^{-1}). In contrast, the oil-fired boiler had a much higher SO_2 emission rate of 92.9 mg MJ^{-1}. By 2018, most northeastern U.S. states will limit distillate fuel oil sulfur content to 15 mg kg^{-1}, which should significantly lower SO_2 emissions from oil boilers.

The VOC emission rates based on the CEMS data for all three fuel-technology combinations were fairly variable across the different sampling periods. In general, bole chip tended to have the highest emission rate (21.1 mg MJ^{-1}), followed by mill end chip (6.4 mg MJ^{-1}). The VOC emission rate for the oil boiler was significantly lower at 0.4 mg MJ^{-1}.

Table 7
Summary of metals in PM emission results for three fuel types (ND = non-detect; mg MJ^{-1} energy output basis).

	Metric	Bole Chip	Mill End Chip	Heating Oil
Arsenic	$g\ h^{-1}$	ND	ND	ND
	$g\ MJ^{-1}$	ND	ND	0.0003
Barium	$g\ h^{-1}$	0.272	0.363	0.136
	$g\ MJ^{-1}$	0.030	0.032	0.012
Beryllium	$g\ h^{-1}$	ND	ND	ND
	$g\ MJ^{-1}$	ND	ND	ND
Cadmium	$g\ h^{-1}$	0.045	0.045	ND
	$g\ MJ^{-1}$	0.003	0.002	0.000
Chromium	$g\ h^{-1}$	0.045	0.045	0.045
	$g\ MJ^{-1}$	0.005	0.004	0.005
Copper	$g\ h^{-1}$	0.181	0.136	0.045
	$g\ MJ^{-1}$	0.016	0.012	0.003
Lead	$g\ h^{-1}$	0.136	0.136	0.045
	$g\ MJ^{-1}$	0.014	0.010	0.004
Manganese	$g\ h^{-1}$	1.32	2.31	0.045
	$g\ MJ^{-1}$	0.124	0.193	0.006
Nickel	$g\ h^{-1}$	0.045	0.045	0.045
	$g\ MJ^{-1}$	0.003	0.003	0.037
Potassium	$g\ h^{-1}$	170.1	157.9	0.862
	$g\ MJ^{-1}$	16.9	13.4	0.085
Selenium	$g\ h^{-1}$	ND	ND	ND
	$g\ MJ^{-1}$	ND	ND	ND
Silver	$g\ h^{-1}$	ND	ND	ND
	$g\ MJ^{-1}$	ND	ND	0.0002
Zinc	$g\ h^{-1}$	5.1	2.6	3.6
	$g\ MJ^{-1}$	0.537	0.219	0.365

3.3. Trace element emission rates from the combustion of wood chips and heating oil

Results of the emissions testing for trace elements during combustion of bole chip, mill end chip, and distillate heating oil are presented in Table 7. Overall, there was significant variation in trace element emission rates across the three fuel-technology combinations. Stack analysis showed higher emission rates for heating oil than the wood chip fuels for arsenic, nickel and silver. In contrast, the wood chip fuels had higher emission rates for barium, cadmium, chromium, copper, lead, manganese, and potassium. Mercury was not tested, but a wood chip fuel elemental analysis found that commercially sold wood chips in New York State and Vermont purchased during the time of this study contained 2.5 μg kg^{-1} of fuel [19]. This can be compared to an average mercury content of 2.0 μg kg^{-1} in No. 2 distillate oil sold in the northeastern U.S. [18], and noting that No. 2 distillate oil has about three times higher energy content than wood on an equivalent mass basis. This suggests the distillate oil likely emitted lower mercury than the wood chip fuels on an equivalent delivered energy basis for space heating.

When comparing emissions among the two wood chip fuels, bole chips overall tended to have higher emission rates than mill end chips for cadmium, chromium, copper, lead, nickel, and zinc. We note that Sippula et al. [23] measured metal emissions in wood chip-fired boiler stacks before and after installed controls, one with a scrubber and one with an ESP, and reported decreases in the measured metals after the controls. While mercury emissions were not measured, use of advanced pollution controls, such as scrubbers, ESPs, and fabric filters, would likely also capture some portion of the mercury emissions (e.g., particle-bound), as has been seen with coal combustion controls [27].

4. Conclusions

Our results suggest that wood chip stoker boilers with multi-cyclone emission controls (the most common chip boiler type in the northeastern U.S.) installed to replace No. 2 distillate oil boilers will increase local exposure to elevated PM concentrations, which may be of particular concern at institutional settings with sensitive populations, such as schools and hospitals.

CO emissions from the wood chip boiler were highly variable and dependent on load, state of operation, fuel moisture content, and air to fuel ratios. Current U.S. regulatory testing requirements only capture CO emissions at high load for 60 min, therefore do not fully capture CO emissions performance under typical woodchip operating conditions.

In general for PM, NOx, CO, SO_2, and VOC emissions, only SO_2 had higher emissions from the oil combustion compared to the wood chip fuels. We note that sulfur content in No. 2 distillate oil will be reduced to 15 mg kg^{-1} or less by 2018 due to state regulations in the northeastern U.S. Therefore, we expect SO_2 emissions from conventional oil-fired boilers and furnaces to decrease significantly from what was measured in this study using No. 2 distillate oil with 2.2 g kg^{-1} sulfur content.

In sum, these results provide for increased awareness of potential human exposures to higher concentrations of air pollutants from wood combustion in settings with sensitive populations, such as schools and hospitals. This can help shape considerations of local health implications from heating technology and fuel use choices, and the additional measures, such as advanced pollution controls, that can help mitigate their impacts.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.biombioe.2017.10.017.

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Update

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The authors regret a labelling error in a Table 5 column heading. The correct units for the “PM emissions rate” column should be mg MJ^{-1}, and not g MJ^{-1}.

The authors would like to apologise for any inconvenience caused.

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Does wood bioenergy help or harm the climate?

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Does wood bioenergy help or harm the climate?

John Sterman, William Moomaw, Juliette N. Rooney-Varga and Lori Siegel

ABSTRACT
The EU, UK, US, and other nations consider wood to be a carbon neutral fuel, ignoring the carbon dioxide emitted from wood combustion in their greenhouse gas accounting. Many countries subsidize wood energy – often by burning wood pellets in place of coal for electric power – to meet their renewable energy targets. But can wood bioenergy help cut greenhouse emissions in time to limit the worst damage from climate change? The argument in favor seems obvious: wood, a renewable resource, must be better than burning fossil fuels. But wood emits more carbon dioxide per kilowatt-hour than coal – and far more than other fossil fuels. Therefore, the first impact of wood bioenergy is to increase the carbon dioxide in the atmosphere, worsening climate change. Forest regrowth might eventually remove that extra carbon dioxide from the atmosphere, but regrowth is uncertain and takes time – decades to a century or more, depending on forest composition and climatic zone – time we do not have to cut emissions enough to avoid the worst harms from climate change. More effective ways to cut greenhouse gas emissions are already available and affordable now, allowing forests to continue to serve as carbon sinks and moderate climate change.

KEYWORDS
Biomass; bioenergy; carbon dioxide; climate change; forestry; greenhouse emissions; wood combustion

In the 2015 Paris climate accord, 197 countries agreed to limit warming to "well below 2 degrees Celsius," and to strive for 1.5 degrees Celsius. To have even a roughly 50 percent chance of achieving this goal, net global greenhouse gas emissions must be cut by nearly half from 2010 levels this decade and reach zero by mid-century (UNFCCC 2021). Consequently, at least 140 countries, accounting for about 90 percent of global greenhouse gas emissions, have pledged to reach net zero emissions around the middle of this century (Climate Action Tracker 2021). But few have specified how they will do so. A growing number, including the European Union, the United Kingdom, and the United States, have declared wood bioenergy to be carbon neutral, allowing them to exclude the carbon dioxide generated from wood bioenergy combustion in their greenhouse gas accounting. Many subsidize wood bioenergy to help meet their renewable energy targets (Norton et al. 2019). The appeal is intuitive: burning fossil fuels adds carbon that has been sequestered underground for millions of years to the atmosphere, while forests might regrow, eventually removing carbon dioxide from the atmosphere.

But can burning trees – including not just the trunk, but also the bark, branches, needles or leaves, roots, stumps, mill waste, sawdust, and all the other vegetative materials known as "biomass" that make up a forest – help cut carbon emissions in time to prevent climate catastrophe?

The bioenergy industry and many governments argue that wood bioenergy is carbon neutral. Table 1 lists some of the common claims the industry makes together with the science showing these claims to be incorrect. For example, the UN Food and Agriculture Organization claims that "While burning fossil fuels releases CO_2 that has been locked up for millions of years, burning biomass simply returns to the atmosphere the CO_2 that was absorbed as the plants grew" (Matthews and Robertson 2001). But the fact that the carbon in wood was previously removed from the atmosphere as the trees grew is irrelevant: A molecule of carbon dioxide added to the atmosphere today has the same impact on radiative forcing – its contribution to global warming – whether it comes from fossil fuels millions of years old or biomass grown last year. When burned, the carbon in those trees immediately increases atmospheric carbon dioxide above what it would have been had they not been burned.

To illustrate, consider a forest that was harvested for lumber, pulpwood, or energy 50 years ago, and has been regrowing since then. (Few forests in the United States and Europe are mature, "old growth" – most are "working forests" and go through cycles of harvest, regrowth, and reharvest [see US Forest Service 2014]). What happens if that forest is now cut and burned for energy? When the wood is burned, the carbon it contains is emitted as carbon dioxide into the atmosphere. If the forest regrows, after another 50 years it will have removed

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Table 1. Claims made about bioenergy and facts that counter those claims.

Claim: To stop climate change, it is necessary to replace fossil fuels with renewable energy, including wood bioenergy. "Well, that's the prime objective, to go to full renewables. But simply looking at how fast we need to do that, we just can't reach the levels of renewables we would need to have [to stop burning fossil fuels and meet European Union energy needs] to completely exclude biomass." Frans Timmermans, Vice President, European Commission, speaking at the 2021 UN Climate Summit, Glasgow (COP 26) (Catanoso 2021).	**Fact**: To stop climate change, greenhouse gas emissions including carbon dioxide must drop rapidly, reach net zero by approximately 2050 and be net negative after that. Burning wood for bioenergy emits carbon dioxide. Trees harvested for bioenergy may regrow, but regrowth is not certain and even if it occurs, would not remove the excess carbon dioxide from burning wood for many decades to a century or longer. In the meantime, the excess carbon dioxide remains in the atmosphere and worsens global warming. To meet our climate goals, steep carbon dioxide emission cuts from all sources are needed now (IPCC 2022; IPCC 2021).
Claim: Wood bioenergy only adds carbon that was recently taken up by trees back to the atmosphere. "While burning fossil fuels releases CO_2 that has been locked up for millions of years, burning biomass simply returns to the atmosphere the CO_2 that was absorbed as the plants grew." UN Food and Agriculture Organization (Matthews and Robertson 2001)	**Fact**: A molecule of carbon dioxide added to the atmosphere causes the same global warming whether it came from fossil fuels, trees, or other plants. "burning biomass for energy provision increases the amount of carbon in the air just like burning coal, oil or gas if harvesting the biomass decreases the amount of carbon stored in plants and soils, or reduces carbon sequestration." The result is a "fundamental accounting error" that "will likely have substantial adverse consequences" (Haberl et al. 2012).
Claim: Wood bioenergy is carbon neutral. Carbon that is emitted now and reabsorbed later has no impact on the climate. "Jen Jenkins, vice president at Enviva, the world's largest pellet producer, said her industry helped solve the climate crisis: The pellets displace coal, and even though their combustion releases carbon emissions, those would be sucked out of the atmosphere by replanted trees" (Ouzts 2019).	**Fact**: Eventual carbon neutrality is not climate neutrality. The climate damage caused by adding carbon dioxide to the atmosphere when wood is burned is not reversed even if forest regrowth eventually removes that carbon dioxide. Even if trees grow back, the additional warming creates irreversible changes: the Greenland and Antarctica ice sheets will not return, sea level will not drop, and thawing permafrost will have released more methane. These changes are not undone even if trees grow back (Solomon et al. 2009, Sterman, Siegel, and Rooney-Varga 2018b, IPCC 2022).
Claim: If trees are burned at the same rate that the forest grows, the amount of carbon stored in the forest remains constant. Therefore, wood bioenergy is carbon neutral. "In the Southeast U.S., privately owned and well managed forests produce one-fifth of the world's wood products. And even as they produce these harvested wood products, forests in the region are adding more carbon." (Enviva n.d.) " . . . the carbon neutrality of biomass harvested from sustainably managed forests has been recognized repeatedly by numerous studies, agencies, institutions, and rules around the world . . . ." US Senator Susan Collins (R, Maine) on the amendment to the Energy Policy Modernization Act, S. 2102 in 2016. "We are enormously grateful to . . . all co-sponsors of this amendment, which accurately reflects the carbon beneficial impacts of power from forest biomass," Bob Cleaves, President and CEO of Biomass Power Association (Voegele 2016).	**Fact**: Growing use of wood bioenergy removes carbon from existing forests and emits it as carbon dioxide into the atmosphere. The stock of carbon on the land immediately falls. If wood for bioenergy is harvested at a constant rate and the land is replanted and allowed to regrow, regrowth may eventually equal the harvest. Until then, carbon removal exceeds carbon sequestration, causing the stock of carbon on the land to fall. If the carbon added from regrowth eventually equals the carbon removed by harvest and other losses, then the stock of carbon in the forests would stabilize and the harvest might be deemed "sustainable." But the total stock of carbon on the land stabilizes at a level lower than before wood bioenergy use began. The carbon lost from the land is added to the atmosphere, worsening climate change (Sterman, Siegel, and Rooney-Varga 2018a; Sterman, Siegel, and Rooney-Varga 2018b). When wood is taken from growing forests, the carbon that those growing trees would have removed from the atmosphere is also lost. And if bioenergy harvest grows over time, as projected, then emissions will exceed regrowth every year, even if replanting equals the harvest every year (Sterman, Siegel, and Rooney-Varga 2018a).
Claim: New trees will be planted that offset the carbon emitted from wood used for bioenergy. Dale Greene, dean of forestry at the University of Georgia, and an advisor to Drax (said) "If we harvest more (for bioenergy), we plant more and there is more carbon in the forest" (Pearce 2020).	**Fact**: Regrowth is uncertain. Land harvested for bioenergy may be converted to other uses (pasture, cropland, development). Newly planted trees may be reharvested as soon as it is economically worthwhile to do so (Newman 1988), releasing the carbon they accumulated back into the atmosphere. The result is lower stocks of carbon on the land and more in the atmosphere, worsening climate change. Newly planted trees have a high mortality rate, contain very little carbon and do not accumulate much carbon for decades (Besnard et al. 2018; Stephenson et al. 2014). Fire, drought, extreme weather, insects, and disease would cause the carbon accumulating in forests harvested for bioenergy to return to the atmosphere, worsening climate change. Climate change increases these risks (Brecka, Shahi, and Chen 2018; Xu et al. 2019), making it less likely that forests will fully recover carbon lost.
Claim: Wood bioenergy is carbon neutral when waste wood, thinnings, and wood that is not suitable for timber are burned. "Wood biomass is sourced from industrial wood waste (like sawdust), or low-grade wood, including 'thinnings,' limbs, tops or crooked and knotted trees that would otherwise not get used for lumber or other higher-value products." Seth Ginther, Executive Director, U.S. Industrial pellet Association (Booth 2018; Ginther 2018).	**Fact**: (i) Wood waste take years or decades to decompose, while burning it releases carbon immediately (Booth 2018). Allowing wood waste to decompose provides nutrients important for forest health. (ii) Much 'waste wood' unsuitable for lumber can be used in other long-lived wood-based products, like cellulose building insulation and oriented strand board keeping it out of the atmosphere for decades (Reuse Wood 2020).
Claim: Young trees grow faster than older trees. Therefore we should harvest older trees that are not accumulating much carbon, use them for bioenergy, and replace them with faster growing younger trees. " . . . young forests grow rapidly, removing much more CO_2 each year from the atmosphere than an older forest covering the same area" (NCASI 2021).	**Fact**: Harvesting and burning old trees releases large amounts of carbon immediately. The young trees that may grow if the land is reforested will not accumulate as much carbon as the existing forest emitted for a century or more. Older forests accumulate more carbon in trees and soils per year than do younger forests (Stephenson et al. 2014).

(*Continued*)

Table 1. (Continued).

Claim: Forests that are growing today are removing carbon dioxide from the atmosphere, which makes wood bioenergy carbon neutral and justifies omitting the carbon dioxide from burning wood from carbon accounting. " . . . since the state [North Carolina] has increasing overall timber volumes per acre and in total, we are sustainable, and we are carbon neutral or better" (Cubbage and Abt 2020). "The continued forest carbon gain across the landscape . . . means that products from the Southeast U.S., including wood bioenergy, are not adding carbon emissions to the atmosphere. As a result, when wood pellets from this region are used to generate energy, we can set stack emissions to zero." (Enviva n.d.)	**Fact**: the carbon dioxide ("stack emissions") from burning wood for energy does not instantly increase forest growth on the harvested land or in forests miles away. Whether forests are growing now at landscape scale is irrelevant. What counts is the incremental impact of bioenergy on atmospheric carbon dioxide and climate change, i.e., how the amount of carbon dioxide in the atmosphere is changed by using wood bioenergy. Burning wood for energy emits carbon dioxide, increasing the amount of carbon dioxide in the atmosphere above what it would have been, even if the wood displaces coal or other fossil fuels (Sterman, Siegel, and Rooney-Varga 2018a). Harvesting wood from forests that are growing also prevents the growth of the forests that would have occurred but for harvesting and burning that wood. The faster the forests harvested for bioenergy are growing, the worse the climate impact of bioenergy (Sterman, Siegel, and Rooney-Varga 2018b).

about the same amount of carbon dioxide it emitted when it was cut and burned for energy. Until then, there's more carbon dioxide in the atmosphere than if it had not been burned, accelerating climate change.

But the situation is worse: If the forest had not been cut, it would have continued to grow, removing additional carbon from the atmosphere. Compared to allowing the forest to grow, cutting it for bioenergy would increase carbon dioxide emissions and worsen global warming for at least half a century – time we do not have to reach net-zero emissions and avoid the worst harms from climate change.

But what if the wood used to generate electricity reduces the use of fossil fuels? Wouldn't total carbon dioxide emissions then fall? That depends on how much carbon dioxide is emitted from wood relative to the fuel being displaced. To determine whether wood bioenergy can slow climate change, we therefore need to know the answers to a series of questions:

How much carbon dioxide does burning wood for energy add to the atmosphere?

Burning wood to generate electricity emits more carbon dioxide per kilowatt-hour generated than fossil fuels – even coal, the most carbon-intensive fossil fuel. Although wood and coal contain about the same amount of carbon per unit of primary energy – the raw energy in the fuel – (US EPA 2018), wood burns less efficiently, in part because it contains more water than coal. The higher the water content, the larger the fraction of the energy of combustion goes into vaporizing that water and up the flue instead of producing the heat needed to make the steam that powers the turbines and generators (Dzurenda and Banski 2017, 2019; Food and Agriculture Organization 2015). Carbon dioxide emissions from the wood supply chain also exceed those from coal. Wood must be harvested, transported to a mill, dried, processed into chips or pellets, and transported to a power plant (Figure 1). These activities emit carbon dioxide from fossil fuel-powered vehicles and machinery, plus emissions from burning wood or fossil fuels to reduce the water content of chips and pellets from approximately 50 percent for raw wood to about 10 percent for dried pellets. About 27 percent of the harvested biomass is lost in the wood pellet supply chain, of which the largest share – 18 percent – arises from burning some of the biomass to generate heat to dry pellets (Röder, Whittaker, and Thornley 2015). In contrast, coal processing adds only about 11 percent to emissions (Sterman, Siegel, and Rooney-Varga 2018a).

The situation is worse if wood displaces other fossil fuels: Wood releases about 25 percent more carbon dioxide per joule of primary energy than fuel oil, and about 75 percent more carbon dioxide than fossil (so-called "natural") gas (EPA 2018). Wood bioenergy therefore emits more carbon dioxide per kilowatt-hour of power generated than all fossil fuels, including coal (PFPI 2011), incurring a "carbon debt" – an immediate increase in carbon dioxide in the atmosphere, worsening climate change every year, unless and until that carbon debt is repaid later by forest regrowth.

Will the forests harvested for bioenergy regrow? If so, how long will it take?

The wood bioenergy industry claims to practice sustainable forestry and be carbon neutral (e.g., Drax 2021; Enviva 2021). The most important claim is that wood bioenergy is carbon neutral because the harvested forests will regrow, removing the carbon they add to the atmosphere when burned (Table 1). However, regrowth is uncertain, and regrowth takes time.

Regrowth is uncertain: Land harvested for bioenergy might be converted to pasture, cropland, or development, preventing regrowth. The carbon dioxide emitted

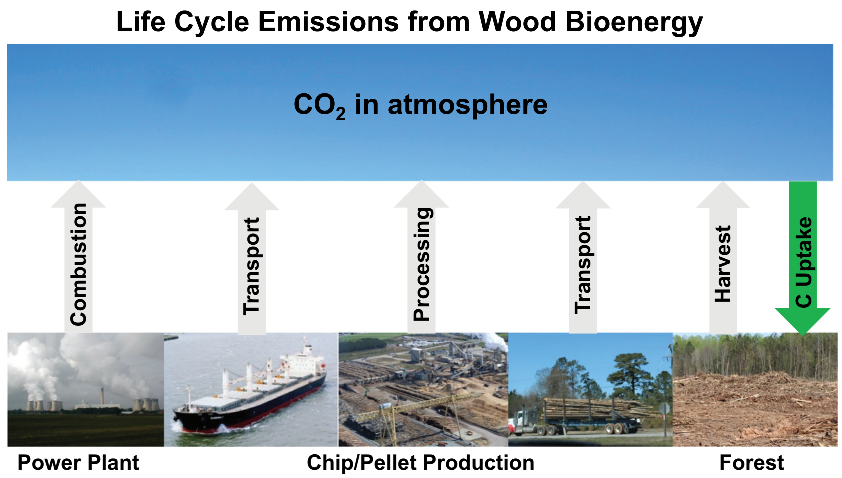

Figure 1. Life cycle emissions from wood bioenergy. Every stage of the supply chain adds carbon dioxide to the atmosphere, from cutting the trees through transport, processing the wood into chips or pellets, transporting them to a power plant, and combustion. Carbon dioxide is removed only later, and only if, the harvested land regrows. Photo credits, left to right: Power Plant, courtesy of Paul Glazzard, Creative Commons Attribution-ShareAlike 2.0 license. Transport: Handymax bulk carrier, courtesy of Nsandel/Wikimedia/Public Domain. Pellet mill, Truck Transport, and Forest images all courtesy of Dogwood Alliance, used with permission.

when the trees are burned is then never taken back up by forest regrowth on that land. Even if the harvested land is allowed to regrow, the trees may be harvested again, legally or illegally. The carbon dioxide released in each rotation returns to the atmosphere, where it worsens climate change.

Even if the recovering forest is somehow protected against all future harvest, the trees face risks from wildfire, insects, disease, extreme weather, and drought, all increasing as the climate warms (Brecka, Shahi, and Chen 2018; Xu et al. 2019; Boulton, Lenton, and Boers 2022). These factors slow or prevent carbon dioxide removal from the atmosphere by forests and may even convert forests from carbon sinks to carbon sources (Gatti et al. 2021). These growing risks to regrowth would limit the future removal of the carbon dioxide emitted by burning wood, permanently worsening climate change.

Regrowth takes time: Even if land conversion, repeated harvests, fire, drought, disease, and other adverse events never arise, regrowth takes time. The time required for regrowth to remove the carbon dioxide emitted when wood is burned for energy is known as the "carbon debt payback time."

Are the forests harvested for bioenergy growing and removing carbon dioxide now?

The US bioenergy industry uses the fact that many US forests are growing today to claim that wood bioenergy is carbon neutral. For example, Enviva, the largest US pellet producer, with multiple mills in the Southeast United States, falsely argues that " … continued forest carbon gain across the landscape … means that products from the Southeast U. S., including wood bioenergy, are not adding carbon emissions to the atmosphere. As a result, when wood pellets from this region are used to generate energy, we can set stack emissions to zero." (Enviva n.d.; see Table 1).

It is true that forests in the Southeast US are acting as carbon sinks today as the result of intensive management and recovery from prior harvests. But these and other forest carbon sinks are already accounted for in the national greenhouse gas emissions inventories required under the United Nations Framework Convention on Climate Change, which sets the rules for greenhouse gas accounting under international agreements (e.g. UNFCCC 2014). Therefore, what counts is what happens to emissions on the margin – that is, the incremental impact of harvesting forests for bioenergy compared to allowing those forests to continue to grow and serve as carbon sinks. Typical rotation periods for working forests are far shorter than the time required for them to reach maturity and maximum carbon storage (Moomaw, Masino, and Faison 2019; Sohngen and Brown 2011; US Forest Service 2014). The younger the forest and faster it is growing when harvested for bioenergy, the more future carbon sequestration is lost.

A dynamic lifecycle assessment of wood bioenergy

To determine the impact of wood bioenergy on carbon dioxide emissions we developed a model for dynamic lifecycle assessment of wood bioenergy (Sterman, Siegel, and Rooney-Varga 2018a, 2018b). The model includes carbon dioxide emissions from bioenergy, carbon dioxide uptake by regrowth, and carbon dioxide emissions avoided if wood displaces fossil fuels. Supply chain emissions for both wood and fossil fuels are included. Model parameters were estimated from data on forest regrowth in a wide range of forests in the southern and eastern USA, regions increasingly supplying wood for pellets, much of which is exported to Europe and the United Kingdom.

Figure 2 shows the impact of wood harvested for bioenergy from an oak-hickory forest, "perhaps the most extensive deciduous forest type of eastern North America" (Dick 2016). The simulation parameters are estimated for oak-hickory forests in the south central US, among the forests used to supply wood pellets for bioenergy, including exports to the United Kingdom (Buchholz and Gunn 2015; Sterman, Siegel, and Rooney-Varga 2018a, 2018b report results for other forests in the southern and eastern US). Most forests in the United States have been cut multiple times. We assume the last prior harvest was 50 years ago. To assess the dynamic impact of wood bioenergy use, Figure 2 traces the impact of a single harvest in 2025, showing the stocks of carbon in the biomass and soil and the resulting change in the concentration of carbon dioxide in the atmosphere. We consider two scenarios:

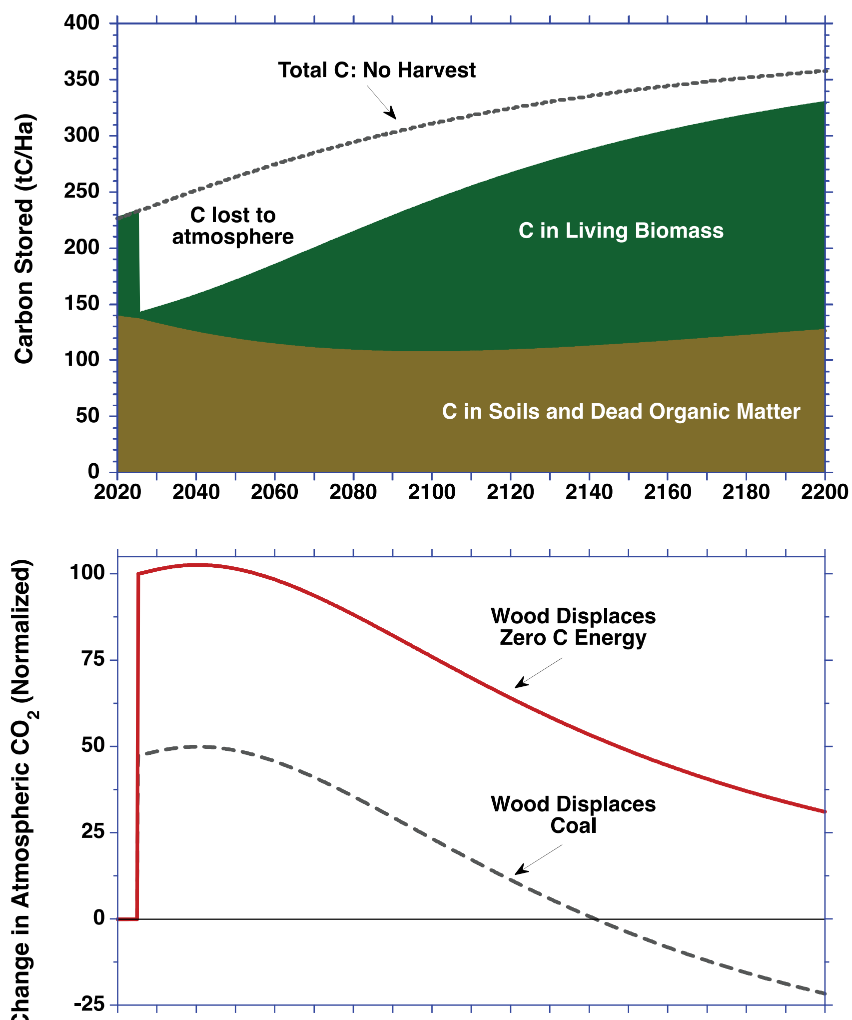

Figure 2. Impact of harvesting wood for bioenergy in 2025 from a 50-year-old oak-hickory forest in the south central USA. Top: Change in carbon on the harvested land (tons carbon per hectare). Brown: carbon in soils and dead organic matter; Green: carbon in living biomass. Dotted line: the total carbon stock (living biomass and soils) if the forest were not harvested in 2025. The forest would have continued to grow and remove carbon from the atmosphere but for being cut for bioenergy. The difference between the dotted no-harvest line and the top of the green band is the carbon emitted into the atmosphere by the harvest. Bottom: Change in atmospheric carbon dioxide resulting from the harvest and combustion of the wood. Solid line: wood displaces a zero-carbon energy source. Dotted line: wood displaces coal. Scale: the initial rise in atmospheric carbon dioxide when wood displaces zero-carbon energy is normalized to 100 percent. The initial rise in atmospheric carbon dioxide when wood displaces coal is about 50 percent less due to the emissions avoided by the reduction in coal use.

- The harvested wood is used to generate electric power that replaces an equivalent amount of energy generated from coal, the most carbon-intensive fossil fuel.
- The harvested wood is used to generate electric power that replaces an equivalent amount of energy produced by zero-carbon sources (e.g. wind and solar).

The top panel of Figure 2 shows the stock of carbon on the land harvested for bioenergy (metric tons of carbon per hectare), including the carbon in the living biomass and in soils and dead organic matter. The harvest and combustion of wood for energy immediately reduces the stock of carbon in living biomass on the land and increases atmospheric carbon dioxide. The stock of carbon in dead biomass and soil also begins to drop: the wood harvest reduces the flux of carbon from living biomass to soils, while heterotrophic respiration by bacteria, fungi, and other organisms continues to release the carbon in dead biomass and soils into the atmosphere. After the harvest, the forest begins to recover. Soil carbon continues to drop for some time, however, until the flux of carbon transferred to the soils from living biomass exceeds the flux of carbon emitted to the atmosphere from the soil by heterotrophic respiration.

The simulation assumes the land is harvested 50 years after the last rotation. The forest at that time is still recovering. The dotted line in the top panel of Figure 2 shows that the total stock of carbon on that land would have continued to grow through 2200 (and beyond), but for the harvest for bioenergy. The difference between the no-harvest and harvest cases is the quantity of carbon lost to the atmosphere due to the bioenergy harvest. The bioenergy harvest not only adds the carbon extracted and burned to the atmosphere, but prevents the additional growth that would have occurred had the forest not been harvested.

The bottom panel of Figure 2 shows the change in the concentration of carbon dioxide in the atmosphere for the two scenarios above. The figure shows the evolution of atmospheric carbon dioxide relative to the no-harvest case, scaled relative to the magnitude of the initial change in carbon dioxide when the wood displaces zero-carbon energy such as wind and solar (the absolute change in atmospheric carbon dioxide depends on the amount of wood harvested and burned). Cutting and burning trees for bioenergy immediately increases the concentration of carbon dioxide in the atmosphere. The jump in atmospheric carbon dioxide when wood displaces coal is approximately half as much as when the wood displaces zero-carbon energy. The impact of displacing other fossil fuels such as fuel oil or fossil ("natural") gas lies between the coal and zero-carbon scenarios because these fuels emit less carbon dioxide per kilowatt-hour than coal, but of course more than wind or solar.

Note that, in both cases atmospheric carbon dioxide continues to increase through approximately 2040, 15 years after the assumed harvest in 2025. Although the harvested land begins to regrow immediately, seedlings and saplings have much smaller leaf area for photosynthesis and accumulate carbon slower than older trees. Consequently, the carbon sequestered by regrowth is initially less than the carbon the forest would have stored had it not been harvested.

After approximately the year 2040, the excess carbon dioxide in the atmosphere from the harvest and combustion of the wood begins to fall as regrowth outpaces the growth in carbon in the no-harvest case. However, atmospheric carbon dioxide remains above the level it would have had but for the harvest well beyond the year 2100. Even when wood displaces coal, the excess carbon dioxide is not taken back up by forest regrowth until after the year 2140: The carbon debt payback time in this scenario is approximately 115 years. When the wood displaces zero-carbon energy, atmospheric carbon dioxide remains above its initial level well past the year 2200.

The simulation shows the impact of clearing a stand of forest and using the wood for bioenergy. The bioenergy industry claims that they practice what they call "sustainable" forestry – avoiding clearcutting, taking only residues from lumber and pulpwood harvests, or thinning forests by taking only small or diseased trees. Environmental groups, however, have documented the harvest of large trees and clear-cutting by the industry (Norton et al. 2019; Stashwick, Frost, and Carr 2019; Stashwick, Macon, and Carr 2017). To address this issue, we also simulated the impact of thinning, in which only 25 percent of the living biomass is removed from the harvested forest (Sterman, Siegel, and Rooney-Varga 2018a, 2018b). Across all the forests examined, thinning reduces the carbon debt payback times somewhat. For example, in the scenario shown in Figure 2, thinning reduces the carbon debt payback year from 2140 to 2115 – still too late.

The simulations favor wood bioenergy. We assume that the land remains forested, that the forest grows back without any subsequent harvest, and that it suffers no losses from wildfire, disease, insects, extreme weather or other threats to regrowth. We do not consider additional carbon loss from soils due to the disturbance caused by the harvest. We do not consider non-climate harms from wood harvest and bioenergy production, including habitat fragmentation, loss of biodiversity, and the health effects of exposure to particulates and other pollutants from wood processing and power plants.

To track the impact of wood bioenergy, the simulation shows the impact of harvesting and burning wood for energy in a single year. But the bioenergy industry is growing rapidly, stimulated by the false declaration that wood is carbon neutral and resulting subsidies in many nations. The International Energy Agency reports primary energy from biomass for electricity generation grew at an average rate of more than 6 percent per year between 1990 and 2018 (IEA 2020). The IEA's "Net-Zero by 2050" scenario projects modern bioenergy – which includes wood – will grow by more than a factor of four by 2050 (IEA 2021b).

What happens to atmospheric carbon dioxide in the realistic case of growing wood bioenergy use? Each year the carbon dioxide emissions from cutting and burning wood would exceed the removal of carbon dioxide by regrowth, continually increasing the concentration of carbon dioxide in the atmosphere, just as filling your bathtub faster than it drains will continually raise the level of water in the tub (until it overflows and damages your home).

The situation is analogous to a government that runs a continually growing fiscal deficit. The outstanding debt rises every year even if the government fully repays every bond it issues at maturity. In the same way, the growing use of wood bioenergy adds more carbon dioxide to the atmosphere every year, increasing the outstanding carbon debt, even if the forests are managed sustainably and all harvested lands eventually recover enough to fully repay the carbon debt incurred when the wood was extracted and burned.

Eventual carbon neutrality is not climate neutrality

Even under the best case where wood displaces coal, regrowth does not remove the excess carbon dioxide emitted by wood for many decades or more, and far longer if the harvested forests are growing today – as most are – and far more if wood displaces other fossil fuels. At that future time wood bioenergy could be said to have achieved carbon neutrality. Until then, wood bioenergy increases the level of carbon dioxide in the atmosphere above what it would have been, accelerating global warming.

But is the climate impact of that additional warming reversed if regrowth finally removes the excess carbon dioxide? Is eventual carbon neutrality the same as climate neutrality?

The answer is "No."

Even temporarily elevated levels of atmospheric carbon dioxide cause irreversible climate damage (IPCC 2022; Solomon et al. 2009). The excess carbon dioxide from wood bioenergy begins warming the climate immediately upon entering the atmosphere. The harms caused by that additional warming are not undone even if the carbon debt from wood energy is eventually repaid: The Greenland and Antarctic ice sheets melt faster, sea level rises higher, wildfires become more likely, permafrost thaws faster, and storms intensify more than if the wood had not been burned. Eventual full forest recovery will not replace lost ice, lower sea level, undo climate disasters, put carbon back into permafrost, or bring back homes lost to floods or wildfires. The excess warming from wood bioenergy increases the chances of going beyond various climate tipping points that could lead to runaway climate change: emissions "pathways that overshoot 1.5°C run a greater risk of passing through 'tipping points,' thresholds beyond which certain impacts can no longer be avoided even if temperatures are brought back down later on" (IPCC 2018, 283). *Carbon* neutrality is not *climate* neutrality.

Why does it matter? We have already raised global average surface temperatures about 1.1 degrees Celsius (2 degrees Fahrenheit) above preindustrial levels, and most of humanity already suffers from its effects (Callaghan et al. 2021; IPCC 2022). The consequences of warming beyond 2 degrees Celsius are expected to be devastating. Sea levels could rise by well over a meter by the end of this century, exposing millions of people to coastal flooding (Kulp and Strauss 2019). More than half the world's people would be exposed to deadly heat waves (Mora et al. 2017). The yields of crops including wheat, maize, rice, and soy would fall even as the United Nations projects that world population will grow by billions (Zhao et al. 2017; United Nations 2019). Droughts, wildfires, and intense storms will become more frequent and extreme (IPCC 2018). Warming could push the Earth beyond various tipping points that could lead to irreversible harm (IPCC 2018). These impacts would intensify hunger, economic disruption, mass migration, civil conflict, and war (Burke, Hsiang, and Miguel 2015; Hsiang and Burke 2014; Koubi 2019; Levy 2019). Scientists and nearly all nations on Earth therefore agree that global greenhouse gas emissions must fall as deeply and quickly as possible, reaching net zero by approximately midcentury.

Wood bioenergy moves the world in the wrong direction.

Policy implications

What can be done? First, policies that treat wood bioenergy as carbon neutral must end. These policies allow power plants and nations to ignore the carbon dioxide they emit by burning wood on the false assumption that those emissions are quickly offset by forest growth somewhere else, creating a "critical climate accounting error" (Searchinger et al. 2009). The carbon dioxide emitted from wood should be counted the same way emissions from other fuels are: fully, at the point of combustion.

Second, subsidies for wood bioenergy must end. Subsidizing wood bioenergy means taxpayers are paying pellet and power producers to make climate change worse.

Third, the fact that wood bioenergy is worse than coal in no way justifies the continued use of coal or any fossil fuel. To avoid the worst harms from climate change we must not only keep the vast majority of remaining fossil carbon in the ground, we must also keep the vast majority of the carbon in our forests on the land.

The good news is that existing technologies such as energy efficiency, solar, wind, and geothermal energy can meet people's needs for comfort, light, mobility, communication, and other purposes. The costs of these technologies are falling rapidly, and in many places are already lower than fossil fuels (IEA 2021a). Innovations in clean energy, energy storage, smart grids, and other technologies are expanding our ability to meet everyone's energy needs affordably. Unlike wood bioenergy, these technologies allow forests to continue growing and sequestering atmospheric carbon dioxide. Investments in energy efficiency and clean energy also generate multiple co-benefits including increased community resilience, jobs, and improved health and economic well-being, especially for low-income individuals and households (Belesova, Heymann, and Haines 2020; Burke, Davis, and Diffenbaugh 2018; IEA 2021a; IPCC 2018; Pollin et al. 2014; Shindell et al. 2018). In contrast, particulate emissions and other pollutants from wood bioenergy damage human health (Allergy & Asthma Network, American Academy of Pediatrics, American Lung Association, American Public Health Association, Asthma and Allergy Foundation of America, National Association of County & City Health Officials et al. 2016).

To keep global warming under 2 degrees Celsius, net greenhouse gas emissions must fall to net zero by approximately mid-century, less than 30 years from now. Wood bioenergy increases greenhouse gas emissions and makes climate change worse during these critical years and beyond, even if the wood displaces coal. More effective ways to cut greenhouse gas emissions and meet human needs are available and affordable now. Ending subsidies and policies that promote wood bioenergy will reduce emissions and allow forests to continue to grow, preserving their vital role as carbon sinks that moderate climate change.

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2018

Scientific Evidence Does Not Support the Carbon Neutrality of Woody Biomass Energy

A REVIEW OF EXISTING LITERATURE

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Contents

Summary Conclusions

Based on a comprehensive review of the published scientific literature on forest-derived woody biomass greenhouse gas (GHG) emissions from energy production, we conclude:

- *a priori* assumptions regarding categorical emissions benefits from forest-derived woody biomass energy production are not supported, and an assumption of "carbon neutrality" is fundamentally flawed.
- There is no scientific basis for the presumed carbon neutrality of biomass from managed forests.
- IPCC Guidelines do not automatically consider biomass used for energy as 'carbon neutral,' even if the biomass is thought to be produced sustainably.
- Carbon impacts of forest-derived woody biomass vary and depend on many established factors (including feedstocks, alternate fate, time horizon and age of the trees used for fuel, production methods, and forest management regimes).
- The assessment of potential GHG emissions associated with woody biomass energy must account for these factors.

Introduction

In this paper, we assess whether a policy to treat biogenic CO_2 emissions as carbon neutral, as stated below, has a defensible scientific foundation.

> *"EPA's policy is to treat biogenic CO_2 emissions resulting from the combustion of biomass from managed forests at stationary sources for energy production as carbon neutral." - pg. 75, EPA ...*

Where "managed forest" is defined by the US Environmental Protection Agency (EPA) as "a forest subject to the process of planning and implementing practices for stewardship and use of the forest aimed at fulfilling relevant ecological, economic and social functions of the forest. Also … it specifically comprises lands that are currently managed or those that are afforested, to ensure the use of biomass for energy does not result in the conversion of forested lands to non-forest use." In this report, we assume the term "carbon neutral" to mean there are zero net emissions of greenhouse gases to the atmosphere from energy generation when all life-cycle components (including forest growth elsewhere in the landscape) are considered at the time of energy generation (e.g., from forest wood sources to energy combustion).
Here, we provide a brief summary of key findings from the peer-reviewed published literature, the Intergovernmental Panel on Climate Change Fifth Assessment Report, and material published in the EPA's 2014 Draft Framework for Assessing Biogenic CO2 Emissions from Stationary Sources[1].

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[1] U.S. EPA, Office of Air and Radiation, Framework for Assessing Biogenic CO2 Emissions from Stationary Sources (November, 2014).
https://yosemite.epa.gov/sab/sabproduct.nsf/0/3235DAC747C16FE985257DA90053F252/$File/Framework-for-Assessing-Biogenic-CO2-Emissions+(Nov+2014).pdf

Section I below assesses the validity of an *a priori* assumption of carbon neutrality of woody biomass energy. Section II discusses how carbon emissions impacts vary in timing and extent and depend on many established factors.

I. *a priori* assumptions about the categorical carbon neutrality of forest biomass are not supported in the published literature.

a) Peer-reviewed Literature

Based on a comprehensive review of the published scientific literature on biomass emissions from energy production, we conclude that there is no defensible scientific foundation for EPA's carbon neutrality policy. The vast majority of all published quantitative assessments have concluded that there are net greenhouse gas (GHG) emissions associated with the use of forest-derived woody biomass for electricity production when compared to generating an equivalent amount of energy from fossil sources, even when accounting for subsequent biomass regrowth and avoided fossil emissions.[2]

Two "meta-analyses" (i.e., compiling and summarizing data from multiple studies across a given discipline) have been produced on the topic of GHG emissions from forest-derived woody biomass energy. These two analyses, Buchholz et al. (2016) and Bentsen (2017), summarize the full breadth of quantitative studies conducted over the previous two-plus decades that assess the extent of carbon impacts/benefits incurred by burning biomass to produce energy (not limited to electricity).

Buchholz, T., Hurteau, M.D., Gunn, J., Saah, D., 2016. A global meta-analysis of forest bioenergy greenhouse gas emission accounting studies. GCB Bioenergy 8, 281–289.
https://doi.org/10.1111/gcbb.12245

Buchholz et al. (2016) reviewed outcomes of 66 published forest biomass GHG emissions research studies published between 1991 and 2014, including 59 peer-reviewed studies and seven in the "gray" literature. These studies yielded 149 different scenarios for bioenergy generation that included a range of forest ecosystems, a range of feedstocks (for example, mill wastes, forests residues, thinnings, etc.), benchmark fossil energy sources (e.g. coal, mix, natural gas, oil), or energy conversion efficiency (e.g. electricity, liquid transportation fuel, combined heat and power, heat), and were geographically distributed to most global forest regions.

[2] The timing and degree of net emissions vary widely but depend upon fairly consistent factors. For example, the type of woody feedstock used to make energy matters greatly. Projected emissions from the tops and limbs of harvests that would have otherwise been left in the woods or at the roadside are less than emissions estimated from woody material that market forces dictate could either be used to make paper or energy. The impact to the atmosphere is different depending upon the product pathway. This topic is addressed in more detail in Section II below.

Of these 149 cases, 123 quantified a carbon payback period.[3] Buchholz et al. found that payback periods ranged from zero years to 4,500 years. More than 80 percent of the examined cases found a payback period greater than zero years (101 of 123), illustrating that the majority of studied scenarios produced a carbon debt. In 14 cases where biomass was used to generate electricity, the mean payback period was 1,827 years. The figure below illustrates the variability of carbon payback periods, but also highlights the overwhelming number of cases where the payback period was not zero years.

Bentsen, N.S., 2017. Carbon debt and payback time – Lost in the forest? Renew. Sustain. Energy Rev. 73: 1211-1217. doi:10.1016/j.rser.2017.02.004

The Bentsen (2017) meta-analysis followed a similar approach to Buchholz et al. (2016) and evaluated 245 case studies conducted and published over the past 20 years. Bentsen's results also show that the vast majority of bioenergy cases generate a payback period that is much greater than zero years (see Figure 1 below). Based on Bentsen, the mean payback periods by feedstock were: roundwood (102 years); whole trees (74 years); residues (18 years); stumps (14 years), and mixed feedstocks (~75 years). As discussed in Section II, the reasons for variability are consistent and relevant to a policy discussion on biomass energy emissions.

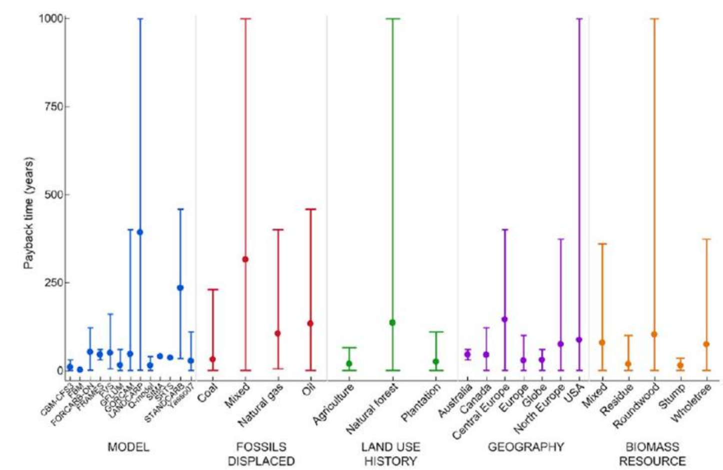

Figure 1. Figure 4 from Bentsen 2017, mean and range of carbon payback times (years) across five influential variables.

[3] The concept of a "payback" of carbon dioxide emissions is generally attributed to Fargione et al. (2008) who calculated a potential carbon "debt" accrued to the atmosphere from switching from fossil fuels to biofuels. Studies use some version of this accounting approach and an articulation of timing to reach parity. That is, the time when carbon in the replacement or post-harvest growing forest *plus* the substitution benefits of using wood instead of a fossil fuel for energy equals the amount that would have been emitted in the fossil fuel energy scenario; *or*, the time when the full amount of emitted carbon is returned to the forest in comparison to a scenario where wood had not been used for energy (Ter-Mikaelian et al., 2015). The latter typically requires a longer period of time to reach parity. The use of parity and payback times has become the norm in studies of biomass energy emissions in the 10 years since Fargione et al. (Bentsen, 2017; Buchholz et al., 2016). Note that the concepts of parity and carbon debt payback are not the same as "zero carbon" emissions in that energy generation that combusts wood as a fuel releases carbon dioxide to the atmosphere at the time of generation.

The significant and compelling conclusion to be drawn from these two comprehensive assessments is that **published research does not support *a priori* assumptions regarding categorical emissions benefits from biomass energy, and an assumption of "carbon neutrality" is fundamentally flawed**.

Several new peer reviewed studies have been published since the two meta-analyses discussed above. The new studies that focus on the production of electricity from woody biomass feedstocks are highlighted below (Table 1). This new work continues to bolster the conclusion that there is no scientific basis for the presumed carbon neutrality of biomass from managed forests. Time frames for payback (or "parity") range from 0 to greater than 100 years for a range of feedstock and forest types, and forest management regimes.

Table 1. Summary of relevant studies published since Buchholz et al. 2016 and Bentsen 2017.

Study	Payback Time Frame	Energy Substituted	Feedstock
(Torssonen et al., 2016)	10 - > 20 years	Coal Electricity	Harvest Residue
(Hanssen et al., 2017)	0-29 years	EU Fossil Grid Electricity	Harvest Residue; Mill Residue; Pulpwood
(Laganière et al., 2017)	0 - > 100 years	Coal, Oil, Natural Gas Electricity	Harvest Residue; Mill Residue; Pulpwood
(Sterman et al., 2018)	44- 104 years	Coal Electricity	Whole trees; Harvest Residues.
(Cintas et al., 2016)	0 (coal) – 45 years (natural gas)	Coal and Natural Gas Electricity	Harvest Residues ("slash")
(Madsen and Bentsen, 2018)	1 year	Coal, Combined Heat and Power	Harvest Residues
(Law et al., 2018)	No payback by 2100	Coal and Natural Gas Electricity	Harvest Residues
(Booth, 2018)	> 50 years	Coal Electricity	Harvest Residue

b) IPCC Emission Estimates of Bioenergy Production Systems

Intergovernmental Panel on Climate Change (IPCC) has warned that, "IPCC Guidelines do not automatically consider biomass used for energy as 'carbon neutral,' even if the biomass is thought to be produced sustainably."[4]

The IPCC's 5th Assessment Report states,

> "The combustion of biomass generates gross GHG (greenhouse gas) emissions roughly equivalent to the combustion of fossil fuels. If bioenergy production is to generate a net reduction in emissions, it must do so by offsetting those emissions through increased net carbon uptake of biota and soils. The appropriate comparison is then between the net biosphere flux in the absence of bioenergy compared to the net biosphere flux in the presence of bioenergy production. Direct and indirect effects need to be considered in

[4] IPCC Task Force on National Greenhouse Gas Inventories, Frequently Asked Questions, https://www.ipcc-nggip.iges.or.jp/faq/faq.html, Q2-10

calculating these fluxes."[5]

The section then lists six direct sources of GHG emissions associated with bioenergy and one indirect source:

1. GHG emissions associated with biomass production harvest, transport and conversion into secondary energy carriers (wood pellets or liquid or gaseous fuels)
2. Carbon dioxide and other GHGs released during combustion
3. Releases of carbon dioxide associated with land disturbance
4. Short lived GHGs associated with combustion like nitrogen oxides, carbon monoxide, and black carbon
5. Alteration of physical properties that affect surface energy balance including albedo or land reflectivity
6. GHGs from land management and alteration of soil biogeochemistry including emissions of nitrous oxide from fertilizer and methane emissions
7. Indirect effects include emissions associated with induced land use changes elsewhere

The assessment then addresses whether "… the CO_2 (carbon dioxide) emitted from biomass combustion is climate neutral because the carbon that was previously sequestered from the atmosphere (before combustion) will be re-sequestered if the growing stock is managed sustainably. The assessment finds that "[t]he shortcomings of this assumption have been extensively discussed in environmental impact studies and emission accounting mechanisms"[6] and states that "the neutrality perception is linked to a misunderstanding of the guidelines for GHG inventories."[7]

The assessment cites references that demonstrate that if forests are allowed to continue to grow rather than being cut and burned, "forest bioenergy systems have higher cumulative carbon dioxide emissions than a fossil reference system (for a time period ranging from a few decades to several centuries)."

II. Carbon impacts of forest-derived woody biomass vary and depend on many established factors (including feedstocks, alternate fate, time horizon, age of harvested forest, production methods, and forest management regimes).

a) Peer-Reviewed Literature

Instead of supporting *a priori* assumptions of carbon neutrality, the established findings in the studies summarized above firmly recognize that carbon emissions impacts from biomass energy

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[5] Working Group 3 (2013), first paragraph of section 11.13.4

[6] Fifth Assessment Report, IPCC, Agriculture, Forestry and Other Land Use (AFOLU) (IPCC AR5) http://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_chapter11.pdf pg 879

[7] Fifth Assessment Report, IPCC, Agriculture, Forestry and Other Land Use (AFOLU) http://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_chapter11.pdf pg 879, footnote 14

vary in extent and depend on many established factors including biomass feedstock type, geographic regions, timeframes, production methods, forest management regimes, energy type (and displaced energy source), and alternative fates, among others. Further, the climate impacts of biogenic carbon dioxide are identical to geologic (i.e., fossil) carbon dioxide, so it is imperative to understand the relative contribution of emissions from both sources to the atmospheric carbon pool and to assess the atmospheric residence time.

Consistent with the common biomass energy accounting principles, Walker et al. (2013) proposed that to understand GHG emissions associated with biomass energy generation we need to know something about the woody feedstock being used (e.g., harvest residues or pulpwood), the form of biomass energy being generated (e.g., heat or electricity), the fossil fuel being displaced (e.g., coal or natural gas), and finally, how forests are managed[8] or harvested to produce the desired feedstock. In addition, understanding the alternative potential fates of the feedstock is also critical. This framework plays out in the conclusions of both Buchholz et al. (2016) and Bentsen (2017) when categorizing the observed differences in carbon payback periods in published literature. Bentsen concludes that the use of harvest residues (the tops and limbs produced as a result of harvesting wood for other products) for energy generation results in shorter times until atmospheric carbon is removed by regrowth (mean = 18 years) than the use of roundwood and whole trees (102 and 74 years respectively). This is important to note and highlights the need for broadly-accepted definitions of forest-derived woody biomass feedstocks, such as “residues” and “whole trees.”

Forest ecosystems with typically long time frames between natural disturbance events (such as fires in parts of the Pacific Northwest) also tend to have longer payback periods. Studies of short-rotation plantation systems had mixed results in Buchholz et al., but tended to have shorter payback periods than natural forest systems in Bentsen’s analysis. In studies where an increase in harvest is required to meet biomass demands (e.g., Holtsmark 2012; Walker et al. 2013), the time to emissions parity with the fossil fuel alternative can be long or never occur. Additionally, studies that attribute land-use decisions where additional land becomes forested typically show short-term emissions in excess of the fossil fuel baseline. However, those benefits can be negated when “leakage” in the form of displaced production of existing forest products (e.g., paper) is accounted for (Galik et al. 2016). Benefits also rely on assumptions

[8] It has been long known that older forests sequester more carbon than younger ones (Harmon et al., 1990). More recently, a study of all types of forests found that one-half of living biomass (and carbon) was in the largest one percent diameter trees regardless of forest type or location (Lutz et al., 2018). Intensively-managed forests keep the mean age of trees in the range of decades to centuries well below their natural lifespan (Gunn et al., 2014; Gunn and Buchholz, 2018). Hence, forest management that includes removals of bioenergy feedstocks not only releases CO_2 soon after harvest into the atmosphere, but changes forest structure and age class distribution with long-term implications for carbon storage on the landscape.

about future landowner behavior changes that result in non-forest land being converted to establish tree plantations.

Birdsey et al. (2018) also recently summarized the range of outcomes from specific case studies for woody biomass electricity generation in the southeast US. The results are affected by the type of woody feedstock used, accounting practices, and how forests are managed (Birdsey et al., 2018). As Searchinger et al. (2018) and many others have frequently pointed out, electricity generated from wood combustion releases substantially more CO_2 (per kilowatt hour) than coal or natural gas because of the inefficient conversion of heat to electricity.

b) EPA 2014 Biogenic Assessment Factor (BAF) Case Studies (Appendix M)

The EPA Scientific Advisory Board (SAB) was asked by the EPA to provide a peer review of its Framework for assessing the biogenic emissions from stationary sources that burn biomass. The EPA's Framework was developed to generate the "Biogenic Assessment Factor" (BAF), which is a factor that weights the stack emissions to account for the biological carbon cycle effects associated with their growth, harvest, and processing. According to the SAB (2012), "[t]he BAF is an accounting term developed in the Framework to denote the offset to total emissions (mathematical adjustment) that reflects a biogenic feedstock's net carbon emissions after taking into account its sequestration of carbon, in biomass or soil, or emissions that might have occurred with an alternate fate had it not been used for fuel."[9]

The EPA's Framework for Assessing Biogenic CO2 Emissions from Stationary Sources presents two relevant case studies. The cases studied feature softwood roundwood (i.e., the merchantable trunk of a tree that may have other market uses, such as for pulp-making) as a biomass energy feedstock in the southeast US and residues from logging/harvesting (i.e., tops and limbs not typically merchantable for other products) in the Pacific Northwest (Fig. 2). These case studies illustrate a temporal component to potential emissions associated with generating electricity from woody biomass compared to the same energy derived from fossil fuels: the BAF begins > 0 (indicating net emissions of biomass energy greater than the baseline) and declines to < 0 (indicating net emissions of biomass energy less than the baseline) over time. For the southeast US roundwood case study (where round wood is used as the feedstock), this transition to < 0 happens at around year 40. When logging residues are the feedstock, the transition happens sooner (20-25 years). Both results are consistent with the summary findings of the two meta-analyses described above.

[9] SAB Review of EPA's Accounting Framework for Biogenic CO2 Emissions from Stationary Sources (September 2011), (September 28, 2012)

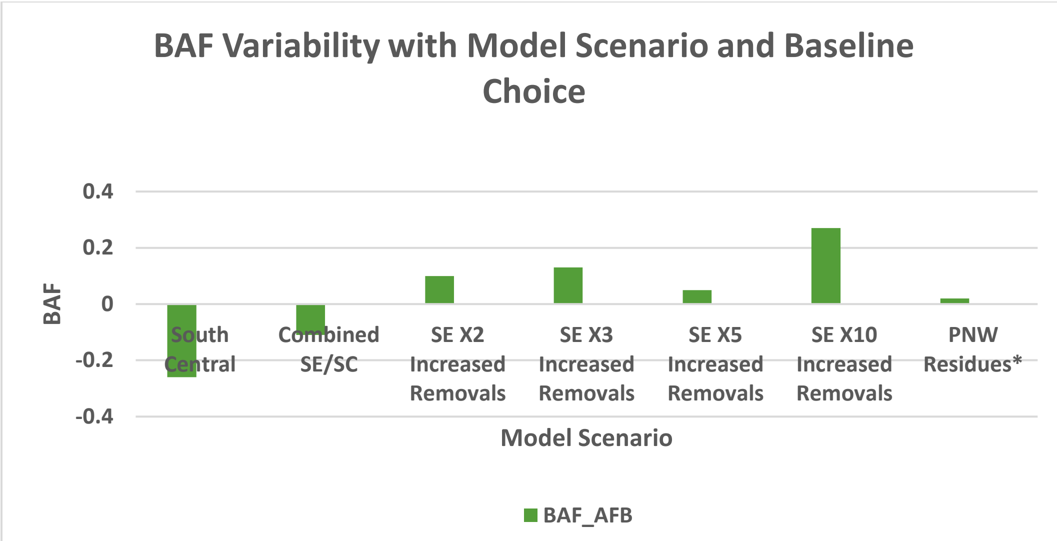

Figure 2. EPA Biogenic Assessment Factors (BAF) for EPA Scenarios (southeast roundwood, PNW harvest residues). AFB = Anticipated Future Baseline. Data from table M-2 in EPA 2014.

The EPA (2014) sums up this dynamic well in Appendix B:

> *"In general, accounting for temporal effects will be most significant when considering future potential fluxes related to long rotation feedstocks (e.g., roundwood), activities that affect the equilibrium storage in soil carbon pools, decay rates, or in cases of significant land use change, where biogenic feedstock production has implications for long-term emissions changes in terrestrial carbon stocks."*

Published case studies continue to emphasize the statement above and support the conclusion that the assessment of potential GHG emissions associated with woody biomass energy must account for all of these factors.

Conclusion

Declaring bioenergy to be carbon neutral will not change the fact that the "combustion of biomass generates gross GHG emissions roughly equivalent to fossil fuels" (IPCC AR5). The critical concern is concentrations of GHGs in the atmosphere. Neither the declaration of carbon neutrality, nor the guarantee of a sustainably-managed forest can assure that the amount of carbon dioxide in the atmosphere will avoid "dangerous anthropogenic interference with the climate system."[10] Accounting for the contribution of forest-derived woody biomass energy GHG emissions to the atmosphere is clearly a complex endeavor and methods are evolving rapidly in the scientific literature. Indeed, it has more recently been demonstrated that there is a need for full lifecycle assessments and systems dynamics accounting. Such an accounting framework tracks all of the carbon at all times throughout the entire cycle of harvesting, fuel

[10] UN Framework Convention on Climate Change Article 2, 1992. https://unfccc.int/resource/docs/convkp/conveng.pdf

production and transportation and combustion of the wood. This provides a time-evolving accounting system not only for carbon, but for other GHGs associated with forest-derived biomass energy such as N_2O from fertilizing reforestation and especially plantations, and any methane emissions associated with the storage of wood pellets or wood chips (e.g., Sterman et al., 2018). This system also does away with the need for specific time frames or even the use of arbitrary time dependent global warming potentials.

Published studies to date provide a great deal of insight on the potential risks and benefits of using wood for energy. Based on our comprehensive review of the published scientific literature on forest-derived woody biomass greenhouse gas (GHG) emissions from energy production, we conclude:

1) *a priori* assumptions regarding categorical emissions benefits from forest-derived woody biomass energy production are not supported, and an assumption of "carbon neutrality" is fundamentally flawed.;
2) There is no scientific basis for the presumed carbon neutrality of biomass from managed forests.
3) IPCC Guidelines do not automatically consider biomass used for energy as 'carbon neutral,' even if the biomass is thought to be produced sustainably.
4) Carbon impacts of forest-derived woody biomass vary and depend on many established factors (including feedstocks, alternate fate, time horizon, production methods, and forest management regimes).
5) The assessment of potential GHG emissions associated with woody biomass energy must account for these factors.

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“Green” hydrogen

Green hydrogen is hydrogen made from 100% renewable electricity using electrolysis to break water into hydrogen and oxygen. Statement of Robert W. Howarth, Ph.D., Hearing on Senate Bill 5, Committee on Natural Resources and Energy, Vermont State Senate 1 (February 8, 2023) 2 (attached). Hydrogen is the smallest molecule in the Universe, and it is difficult to keep it from leaking. *Id.* Green hydrogen has a lower greenhouse gas impact than hydrogen made from fossil fuels, but its impact is significant. Although hydrogen itself is not a greenhouse gas, it contributes to global warming when leaked by prolonging the time that methane stays in the atmosphere and adding more water vapor to the stratosphere. *Id.*

The downsides to using hydrogen for home heating were recently summarized by Cornell Professor Robert Howarth in testimony on S.5:

- Hydrogen is very leaky, much more so than methane, and hydrogen leakage from pipelines will contribute to global warming.
- Only small quantities of hydrogen can be blended with fossil gas in distribution pipelines, since hydrogen makes pipelines more brittle, potentially increasing methane emissions and leading to greater catastrophic risk.
- Most existing gas appliances in homes and apartments (furnaces, cooking stoves, water heaters, dryers) are not designed to burn hydrogen-methane blends, and increasing the hydrogen content can decrease the efficiency of combustion and lead to increased air pollution, particularly of nitrogen oxides.
- Most engineering studies indicate greatly increased risk of mixing more than 20% hydrogen into fossil gas systems, and the California Air Resources Board has concluded that no more than 5% hydrogen should be blended until further study shows higher amounts are sufficiently safe.
- The energy density of hydrogen is far less than for methane, so blending 20% hydrogen into a fossil-fuel distribution pipeline reduces the combustion emissions of carbon dioxide by only 7%.
- Hydrogen is significantly more expensive than fossil gas, and so blending any hydrogen into the distribution system increases costs.
- Using renewable electricity to produce green hydrogen which is then used to heat homes and apartments diverts this electricity from more efficient uses, such as using heat pumps. For the same quantity of electricity, a heat pump can deliver 6 to 10 times more heat in a home than could burning green hydrogen.
- Inefficient uses of renewable electricity drive up costs and slow the transition from fossil fuels, since renewable electricity will remain a relatively scarce and precious commodity for the next few decades.

Id. at 3.

All independent studies have argued against using hydrogen for home heating, including peer reviewed papers and reports from the International Energy Agency and the UN's Intergovernmental Panel on Climate Change. *Id.* (citing Rosenow, Joule, *Is heating hydrogen with homes all but a pipedream? An evidence review* (2022), https://doi.org/10.1016/j.joule.2022.08.015. This includes 33 different studies. *Id.* at 4.

"[U]sing hydrogen in homes and buildings is fraught with economic, logistical and safety challenges, capable of reducing greenhouse gas emissions less than 7% before encountering potentially insurmountable roadblocks." Energy Innovation Policy and Technology & D. Esposito, *Gas Utilities Are Promoting Hydrogen, But It Could Be a Dead End for Consumers and the Climate* (March 29, 2022), .https://www.forbes.com/sites/energyinnovation/2022/03/29/gas-utility-hydrogen-proposals-ignore-a-superior-decarbonization-pathway-electrification/?sh=34575dfa76a1 Natural gas utilities are promoting hydrogen to maintain market share and profit from the new infrastructure it would require, however, such plans are "a bad bet for consumers and the environment." *Id.* Using more than a 5-20% blend would require replacement of pipelines and replacement of household heaters and appliances designed to run on natural gas. *Id.* Electrification is a much better strategy for reducing greenhouse gas emissions. *Id.*

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Statement of
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Hearing on Senate Bill 5

Committee on Natural Resources and Energy
Vermont State Senate

February 8, 2023

My name is Robert Howarth. I am an Earth systems scientist with a B.A. from Amherst College and a Ph.D. from MIT and the Woods Hole Oceanographic Institution. I have been a tenured faculty member at Cornell University in Ithaca, NY since 1985 and an endowed professor at Cornell since 1993 (*the David R. Atkinson Professor of Ecology & Environmental Biology*). I have also served as an Adjunct Senior Scientist in the Ecosystems Center of the Marine Biological Lab in Woods Hole, MA for the past 23 years. For decades, I have worked on the consequences of global climate change, on emissions of methane from the oil & gas industry as a driver of climate change, on the production and use of hydrogen, and on alternative energy policies. I have published over 200 peer-reviewed papers, and these have been cited more than 79,000 times in other peer-reviewed literature, making me one of the most highly cited environmental scientists in the world.

Throughout my career, I have been engaged in energy and environmental policy, and I have given briefings and testimony at the White House, at the U.S. Congress and to committees of the US Senate, to the Canadian Senate, to the European Parliament, to the Irish Parliament, to the Senate and Assembly of the State of New York, and in New York courts. I have served on many committees of the US National Academy of Sciences and the International Council of Science, having chaired several of these. Currently, I am one of 22 members of the New York State Climate Action Council, which is the body charged by law with the development of the implementation blueprint ("Scoping Plan") for New York's progressive climate law, the Climate Leadership & Community Protection Act of 2019.

Today, I want to address the proposal that "clean heat credits" be given by the State of Vermont for green hydrogen and for renewable natural gas. In my professional opinion, it would be unwise for Vermont to encourage the use of either hydrogen or renewable natural gas for heating of homes and commercial buildings. These uses were debated extensively by the New York Climate Action Council and its advisory panels and sub-groups over the past 2 to 3 years. In our final Scoping Plan from the Council (passed by a strong 19-3 vote on December 19, 2022), the Council fully rejected the use of hydrogen for heating homes, and put aside the issue of RNG saying it needed further study. Renewable natural gas was certainly not endorsed, though, and I note that renewable natural gas is not mentioned at all in the Executive Summary of the Scoping Plan.

Let me first address renewable natural gas (RNG). RNG is made by processing biogas, making a fuel that is composed mostly of methane and that can be mixed with fossil natural gas in gas pipeline systems. Biogas is a mixture of methane and carbon dioxide as well as other impurities that is produced from anaerobic digesters (including some wastewater treatment plans as well as farm-based systems using manure) and can be captured from landfills. The biogas can itself be used as a fuel, for instance to generate electricity or heating, but biogas is not suitable for use in pipeline distribution systems. In the final Scoping Plan for the New York Climate Action Council, we specified that whenever possible, biogas should be used directly at the site of production, and preferably used in fuel cells rather burned to generate electricity. Our plan further stated that the use of biogas as biogas was to be preferred to processing it into RNG. There are two reasons for this: 1) it takes energy to process biogas into RNG, and so this is inherently inefficient and increases greenhouse gas emissions; and 2) the latest peer-reviewed science shows that methane emissions from processing biogas into RNG can be substantial, as shown in a review paper published last year (see: Bakkaloglu, Cooper, and Hawkes. 2022. Methane emissions along biomethane and biogas supply chains are underestimated. *One Earth* 5: 724-736, doi:10.1016/j.oneear.2022.05.012). Converting biogas into renewable natural gas is wasteful and further contributes to greenhouse gas emissions, with no benefit other than to allow the gas to be pumped into the traditional fossil gas distribution systems.

Please let me note that Vermont Gas Systems currently has contracted to buy RNG from the Seneca Meadows Landfill in central-western New York State, with an expectation of a significant increase in purchase in coming years. This gas is not actually delivered to Vermont, nor will it ever be: rather, the gas enters a general pipeline system moving gas to the west, away from Vermont. Vermont Gas Systems apparently gets financial credits for this scheme through trading mechanisms established by the California Air Resources Board (CARB). The CARB's policy on RNG is based on old, out-of-date science. They simply are wrong that there is any greenhouse-gas benefit from using RNG, and in fact the use of RNG may lead to greenhouse gas emissions that exceed those from using fossil natural gas. The State of New York will now be discouraging the production of RNG such as that from Seneca Meadows Landfill, based on the Climate Action Council's final Scoping Plan. I respectfully ask that the State of Vermont not encourage a policy that runs counter to the policy of New York, and do so based just on paper credits without even any actual delivery of any RNG to Vermont. California started a bad policy in this area, and one that we in New York hope to reverse at least within our State. This issue is close to my heart, as I live only 40 miles from the Seneca Meadows Landfill, the largest active landfill still active in New York, and an environmental travesty with a height of 28 feet over 400 acres. I hate to think that Vermont citizens who buy gas from Vermont Gas Systems will continue to contribute to our environmental problems in the Finger Lakes of New York.

Second, let me address hydrogen. I am pleased to see that Vermont is apparently not favoring any hydrogen made from fossil natural gas, even if with carbon capture. In 2021 I published the first peer-reviewed analysis showing why that is a bad idea for climate when methane emissions are considered (see: Howarth and Jacobson. 2021. How green is blue hydrogen? *Energy Science and Engineering* 9: 1676-1687, doi: 10.1002/ese3.956).

The "clean heat credit" being considered in this bill by Vermont is for green hydrogen, that is hydrogen made from 100% renewable electricity using electrolysis to break water into hydrogen and oxygen. Green hydrogen has a far lower greenhouse gas impact than does the hydrogen made from fossil fuels, but it is still significant: hydrogen gas is the smallest molecule in the Universe, and as such is very hard to retain and keep from leaking. And while hydrogen is not itself a greenhouse gas, when more hydrogen is leaked to the atmosphere it does significantly increase global warming through prolonging the time methane stays in the atmosphere and adding more water vapor to the stratosphere (See: Ocko and Hamburg. 2022. Climate consequences of hydrogen emissions. *Environmental Science & Technology* 22: 9349–9368, doi.org/10.5194/acp-22-9349-2022).

In addition to the role of hydrogen as an agent of global warming, there are many reasons not to put hydrogen into gas pipeline systems and use hydrogen for heating homes and commercial buildings. These are summarized in the table below which I produced for the New York State Climate Action

Council in my final statement accompanied my "yes" vote for our the Scoping Plan we adopted on December 19, 2022. That full statement is appended at the end of my testimony below and includes detailed referencing to support the table. These reasons against hydrogen include safety concerns, greenhouse gas emissions, inefficiencies, and high costs to consumers. With regard to safety, there is widespread recognition that most current pipelines designed and built to deliver fossil natural gas are simply not suitable for carrying hydrogen except at very low blends with the fossil gas. Exactly what level of blending is safe remains unknown, but based on a study they commissioned from the University of California at Riverside, the California PUC recommends that no more than 5% hydrogen be blended with 95% fossil natural gas (see: Pearl. 2022. Hydrogen blends higher than 5% raise leak, embrittlement risks for natural gas pipelines: California PUC. Utility Dive, https://www.utilitydive.com/news/hydrogen-blends-higher-than-5-percent-raise-leak-embrittlement-risks/627895/). With regard to inefficiencies, green hydrogen should be viewed as a precious and expensive resource made from renewable electricity, and using the electricity directly to heat homes with high-efficiency heat pumps generates 6 to 10 times more heat than does the green hydrogen can produce.

Concerns with Blending Hydrogen into Gas Pipelines that Serve Homes & Apartments

- Hydrogen is very leaky, much more so than methane, and hydrogen leakage from pipelines will contribute to global warming.
- Only small quantities of hydrogen can be blended with fossil gas in distribution pipelines, since hydrogen makes pipelines more brittle, potentially increasing methane emissions and leading to greater catastrophic risk.
- Most existing gas appliances in homes and apartments (furnaces, cooking stoves, water heaters, dryers) are not designed to burn hydrogen-methane blends, and increasing the hydrogen content can decrease the efficiency of combustion and lead to increased air pollution, particularly of nitrogen oxides.
- Most engineering studies indicate greatly increased risk of mixing more than 20% hydrogen into fossil gas systems, and the California Air Resources Board has concluded that no more than 5% hydrogen should be blended until further study shows higher amounts are sufficiently safe.
- The energy density of hydrogen is far less than for methane, so blending 20% hydrogen into a fossil-fuel distribution pipeline reduces the combustion emissions of carbon dioxide by only 7%.
- Hydrogen is significantly more expensive than fossil gas, and so blending any hydrogen into the distribution system increases costs.
- Using renewable electricity to produce green hydrogen which is then used to heat homes and apartments diverts this electricity from more efficient uses, such as using heat pumps. For the same quantity of electricity, a heat pump can deliver 6 to 10 times more heat in a home than could burning green hydrogen.
- Inefficient uses of renewable electricity drive up costs and slow the transition from fossil fuels, since renewable electricity will remain a relatively scarce and precious commodity for the next few decades.

Of note, all independent studies have argued against using hydrogen for home heating, including peer-reviewed papers as well as reports from the International Energy Agency and the UN's Intergovernmental Panel on Climate Change (see: Rosenow. 2022. Is heating hydrogen with homes all but a pipe dream? An evidence review. Joule. doi :10.1016/j.joule.2022.08.015). This includes 33 different studies as of today. Only studies funded by or carried out on behalf of industry groups with a vested interest in promoting hydrogen have ever suggested the use of hydrogen for heating. Based on this science, the New York State Climate Action Council strongly recommended against delivery of green hydrogen through the gas pipeline system to heat homes in our final Scoping Plan (see Chapter 18, https://climate.ny.gov/resources/scoping-plan/).

In conclusion, I urge the State of Vermont to not promote issue "clean heat credits" that would promote the use of renewable natural gas and hydrogen for home heating and use in gas delivery systems.

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Statement of
Robert W. Howarth, Ph.D.
The David R. Atkinson Professor of Ecology & Environmental Biology
Cornell University

and

Member of the New York Climate Action Council
by appointment of the Honorable Carl Heastie, Speaker of the Assembly

December 19, 2022

I fully support the Scoping Plan enacted today by the Climate Action Council, and I am honored and proud to have served on the Climate Action Council since its inception. I thank Speaker Carl Heastie and other members of the Assembly for this opportunity to have served. In my comments that follow, I speak as a member of the Council and as an Earth systems scientist and faculty member at Cornell University who has worked for over 40 years on issues of global change. My comments should not be construed as official positions taken by my employer, Cornell University.

Assembly Person Steven Englebright was hugely instrumental in the passage of the Climate Leadership & Community Protection Act that established the Climate Action Council. I thank him for his leadership on this, and particularly for his support of the progressive approach on greenhouse gas emissions that is a central part of the CLCPA. I originally proposed this to Assembly Person Englebright in 2016, and he enthusiastically endorsed and supported it through multiple versions of the bill that finally led to passage of the CLCPA in 2019. In this accounting for greenhouse gases, a major government for the first time ever fully endorsed the science demonstrating that methane emissions are a major contributor to global climate change and disruption. Further, in passing the CLCPA New York recognized that consumption of fossil fuels (and not simply geographic boundaries) is what matters in addressing the climate crisis. New York wisely banned the use of high-volume hydraulic fracturing ("fracking") to develop shale gas in our State. But since the time of that ban, the use of fossil natural gas has risen faster in our State than any other in the Union. Methane emissions from this use of shale gas are high, but much of that occurs outside of our boundaries in the nearby states of Pennsylvania, West Virginia, and Ohio. Through the CLCPA, the citizens of New York are taking responsibility for these out-of-state emission caused by our use of fossil fuels, particularly for fossil natural gas. The way to reduce these emissions is to rapidly reduce our use of fracked shale gas.

The Assembly and Senate specified in the CLCPA that many of the agency heads of New York's government be members of the Climate Actions Council, and also stated that the Council take input from a set of advisory panels. Both of these requirements led to the leadership of the State being heavily engaged and invested in the implementation of the CLCPA. And the panels brought in a large number of experts and key stakeholders who worked diligently to advise the Council on our Scoping Plan. The Plan benefitted immensely from their efforts and input, and all New Yorkers owe them our thanks.

In the well over one hundred meetings of the Council, advisory panels, and working groups since March of 2020, all viewpoints have been respectfully heard and debated. The tone set by our co-Chairs, NYSERDA President Doreen Harris and DEC Commissioner Basil Seggos was a critical part of this. I thank them and all of the members of the Council for our sense of community through deliberations in which we often had major differences of opinion. I also thank the staff who contributed so much to the background information provided to the Council and to the drafting of our final report. A large number of individuals participated and contributed in major ways, but I want to particularly thank and acknowledge our Council Executive Director Sarah Osgood, Maureen Leddy and Jared Snyder from DEC, Carl Mas from NYSERDA, and Jessica Waldorf of DPS.

I further wish to acknowledge the incredible role that Prof. Mark Jacobson of Stanford has played in moving the entire world towards a carbon-free future, including New York State. A decade ago, Jacobson, I and others laid out a specific plan for New York (Jacobson et al. 2013). In that peer-reviewed analysis, we demonstrated that our State could rapidly move away from fossil fuels and instead be fueled completely by the power of the wind, the sun, and hydro. We further demonstrated that it could be done completely with technologies available at that time (a decade ago), that it could be cost effective, that it would be hugely beneficial for public health and energy security, and that it would stimulate a large increase in well-paying jobs. I have seen nothing in the past decade that would dissuade me from pushing for the same path forward. The economic arguments have only grown stronger, the climate crisis more severe. The fundamental arguments remain the same.

Our final Scoping Plan from the Climate Action implicitly endorses the vision of the Jacobson et al. paper and is quite clear: we can meet the goals of the CLCPA and we can and will do so in way that is affordable and that will benefit all New Yorkers. Our State will be stronger as this plan is implemented, the health and well being of our citizens improved. Economic uncertainties and vulnerabilities will be reduced. Energy security will be enhanced. Our plan is also clear that the #1 priorities are to continue to move towards wind, solar, and hydro as our source of electricity; to move rapidly towards beneficial electrification as a source of heating and cooling in our homes and commercial buildings; and to move rapidly towards beneficial electrification in our personal and commercial vehicles.

Although I strongly support our final Scoping Plan, I have some disappointments. Chief among these is the decision to postpone the dates by which the State will move away from fossil fuel use for construction of new homes and commercial buildings, which are now one year later than in our draft plan passed in December 2021. For single family homes, for example, our final Scoping Plan calls for the prohibition of fossil fuels in new construction in 2025, not the 2024 specified in the draft plan. The building sector is the largest single source of greenhouse gas emissions, as I discuss further in the next paragraph below. Therefore, the greatest priority for meeting the goals of the CLCPA should be to reduce emissions from the building sector. I urge the Assembly and Senate to act to mandate that the State move away from fossil fuels more quickly than called for in the Council's Scoping Plan., using the guidance from the December 2021 draft Scoping Plan.

Exactly how important are emissions from the building sector in New York State? The Scoping Plan states this sector is the single largest emitter, accounting for 32% of the total (closely trailed by transportation at 28%). However, I believe the Plan understates the importance of the building-sector emissions for two reasons. First, methane emissions from the operations of the fossil natural gas industry in New York are included as part of the "industry" sector in the Scoping Plan, whereas they should have been included in the building and electric sectors according to the accounting specified in the CLCPA (these emissions would not occur if the fossil natural gas were not being used in our buildings and electric power plants). Making this correction, the building sector is seen to contribute 36% of all emissions, followed by 28% for transportation, 14% for electricity, 12% for waste, 6% for agriculture, and only 4% for industry. Second, the greenhouse gas inventory for the State released by the DEC in December 2021 understates methane emissions from the use of fossil natural gas, in my professional opinion, using an emission factor of 2.49% of gas production. The preponderance of peer-reviewed literature reviewed in my recent paper suggests the factor should be 4.8% (Howarth 2022), a value that is 1.9-times greater than that used by the DEC. Correcting by this factor, I estimate that the building sector is responsible for more than 40% of all greenhouse gas emissions in New York State.

The Scoping Plan strongly calls for beneficial electrification with heat pumps as the best way forward to reduce greenhouse gas emissions from the building sector in New York. I completely agree, but I feel the Plan could have made an even stronger case by including several recent papers and reports. Further, the Plan tends to favor air-sourced heat pumps over ground-sources heat pumps. While the initial cost of the air-sourced pumps is less, they have higher energy and maintenance costs. One recent study examining heat pumps for new home construction in the context of New York State concluded that ground-sourced heat pumps are actually less expensive when these energy and maintenance costs are included (Shron et al. 2022). This was true across the State, in both the coldest and warmest regions. The study also concluded that both air-sourced and ground-sourced heat pumps are almost always less expensive than building new homes heated by fossil natural gas or propane, although air-sourced heat pumps cannot quite out compete fossil natural gas (at average prices over the past decade) in the warmest part of the State, Long Island, according to this report. However, the Long Island Power Authority (2022) has produced a brochure arguing that air-sourced pumps are cost effective for new homes over fossil natural gas on Long Island. And of course the cost of fossil natural gas has increased dramatically since these studies were produced, and may well stay high indefinitely into the future according to many energy economists. If so, anyone building a new home in 2023 or 2024 using natural gas for heating will soon wish they had instead built a fossil-fuel-free home with heat pumps. Further, these costs are from the perspective of the new home owner. I have repeatedly urged in meetings of the Climate Action Council over the past 18 months that we consider the entire energy system when considering the question of heat pumps: ground-sourced heat pumps require far less electricity during peak winter heating times, meaning that encouraging their use over air-sourced pumps lessens the need for electricity storage and for total renewable generating capacity, which could benefit consumers immensely.

As a Council, we spent a disproportionate amount of time in debating what I believe are side issues such as renewable natural gas (RNG) and hydrogen for heating of homes. The oil & gas industry globally has pushed such ideas very heavily as a way to keep their massive fossil-gas pipelines system profitably in operation (Lowes and Cebon 2022). At the Climate Action Council, we have regularly heard suggestions that pipelines in the future can deliver hydrogen and RNG. I and others on the Council have pushed back with objective, scientifically based evidence. In the end, the Council fully rejected the use of hydrogen for heating homes, and somewhat put aside the issue of RNG saying it needed further study. I am pleased to say that RNG is not mentioned at all in the Executive Summary of the Scoping Plan, and hydrogen is mentioned only once, in this case appropriately in the context of its use with fuel cells (not combustion) in transportation (not home heating or use in pipelines).

While the Scoping Plan does not endorse the use of hydrogen for heating or in pipelines, it also does not fully explain the reasons for this decision. And in some places in the text, there is a suggestion for more research on hydrogen. In fact, there is a large amount of information that clearly demonstrates why hydrogen for delivery to homes for heating is a bad idea (Kurmayer 2021; Rosenow 2022; Pearl 2022; Prieto and Henchen 2022; Collins 2022; Lowes and Cebon 2022). There simply is no need for further research on this bad idea. Some of the major reasons for rejecting the use of hydrogen for heating for homes are outlined in the following table.

Concerns with Blending Hydrogen into Gas Pipelines that Serve Homes & Apartments

- Hydrogen is very leaky, much more so than methane, and hydrogen leakage from pipelines will contribute to global warming.
- Only small quantities of hydrogen can be blended with fossil gas in distribution pipelines, since hydrogen makes pipelines more brittle, potentially increasing methane emissions and leading to greater catastrophic risk.
- Most existing gas appliances in homes and apartments (furnaces, cooking stoves, water heaters, dryers) are not designed to burn hydrogen-methane blends, and increasing the hydrogen content can decrease the efficiency of combustion and lead to increased air pollution, particularly of nitrogen oxides.
- Most engineering studies indicate greatly increased risk of mixing more than 20% hydrogen into fossil gas systems, and the California Air Resources Board has concluded that no more than 5% hydrogen should be blended until further study shows higher amounts are sufficiently safe.
- The energy density of hydrogen is far less than for methane, so blending 20% hydrogen into a fossil-fuel distribution pipeline reduces the combustion emissions of carbon dioxide by only 7%.
- Hydrogen is significantly more expensive than fossil gas, and so blending any hydrogen into the distribution system increases costs.
- Using renewable electricity to produce green hydrogen which is then used to heat homes and apartments diverts this electricity from more efficient uses, such as using heat pumps. For the same quantity of electricity, a heat pump can deliver 6 to 10 times more heat in a home than could burning green hydrogen.
- Inefficient uses of renewable electricity drive up costs and slow the transition from fossil fuels, since renewable electricity will remain a relatively scarce and precious commodity for the next few decades.

As with hydrogen, the Scoping Plan does not endorse any widespread use of RNG. In fact, the Plan specifies that it is generally preferable to use biogas (the unrefined mixture of methane and carbon dioxide produced in anaerobic digesters and landfills) directly and at the site of production rather than refining the biogas to produce RNG. However, the Plan does not fully explain the strong science behind this conclusion. Briefly, it takes energy to refine RNG, and this comes either from fossil natural gas with the associated greenhouse gas emissions or from using some of the biogas to power the refining (resulting in a loss of some useful energy, and a lower overall efficiency of using the energy of the biogas). Further, biogas itself can have substantial methane emissions, and the refining of biogas into RNG can substantially increase these methane emissions (Bakkaloglu et al. 2022). In a memorandum I wrote to the Alternative Fuels Working Group of the Climate Action Council in July 2022, I calculated that using the CLCPA accounting methodology and mean emissions from the Bakkaloglu et al. study, methane emissions for RNG are 156 g CO_2-equivalents/MJ, or 1.7-times greater than the combined methane and carbon dioxide emissions for fossil natural gas. Unless these methane emissions can be greatly reduced, New York should clearly discourage the use of RNG.

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Gas Utilities Are Promoting Hydrogen, But It Could Be A Dead End For Consumers And The Climate

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Daniel Esposito Contributor

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Natural gas utilities are increasingly promoting hydrogen—which emits no greenhouse gases (GHG) emissions when burned—as a promising path to preserve their business model while meeting demands to cut emissions. This trend is accelerating, with at least 26 projects proposed across more than a dozen states since 2020.

The utility vision seems clear: Blend hydrogen with natural gas using existing pipeline networks, eventually switching entirely to hydrogen or blending it with other low- or zero-carbon fuels.

But it's not that simple. New Energy Innovation research finds using hydrogen in homes and buildings is fraught with economic, logistical, and safety challenges, capable of reducing GHG emissions less than 7% before encountering potentially insurmountable roadblocks.

Natural gas meters are fixed to the outside of residential townhouses and apartments at a building ... [+] GETTY IMAGES

Gas utilities may view hydrogen as an attractive path to continue business-as-usual and a lifeline to maintain their market share. While utilities generally pass fuel costs on to their customers, they profit by investing in infrastructure—needed to entice private investors to lend utilities their capital. A decarbonization strategy centered around maintaining, retrofitting, and building new pipelines to increase hydrogen use thus makes these companies more valuable.

However, these hydrogen-centric plans are a bad bet for consumers and the climate. Regulators approving new utility hydrogen projects could forestall the electrification of buildings—a far more cost-effective and safer pathway to reducing GHG emissions that necessarily sees gas utilities' role, and profits, shrink over time.

State utility regulators should thus be highly skeptical of ratepayer-funded gas utility proposals to advance hydrogen as a primary strategy to cut emissions from buildings. Separately, policymakers should consider carefully how hydrogen fits in with carbon reduction goals to avoid supporting dead-end pathways, instead advancing more viable options such as a managed transition to all-electric buildings.

Hydrogen may be a myopic path with little to gain

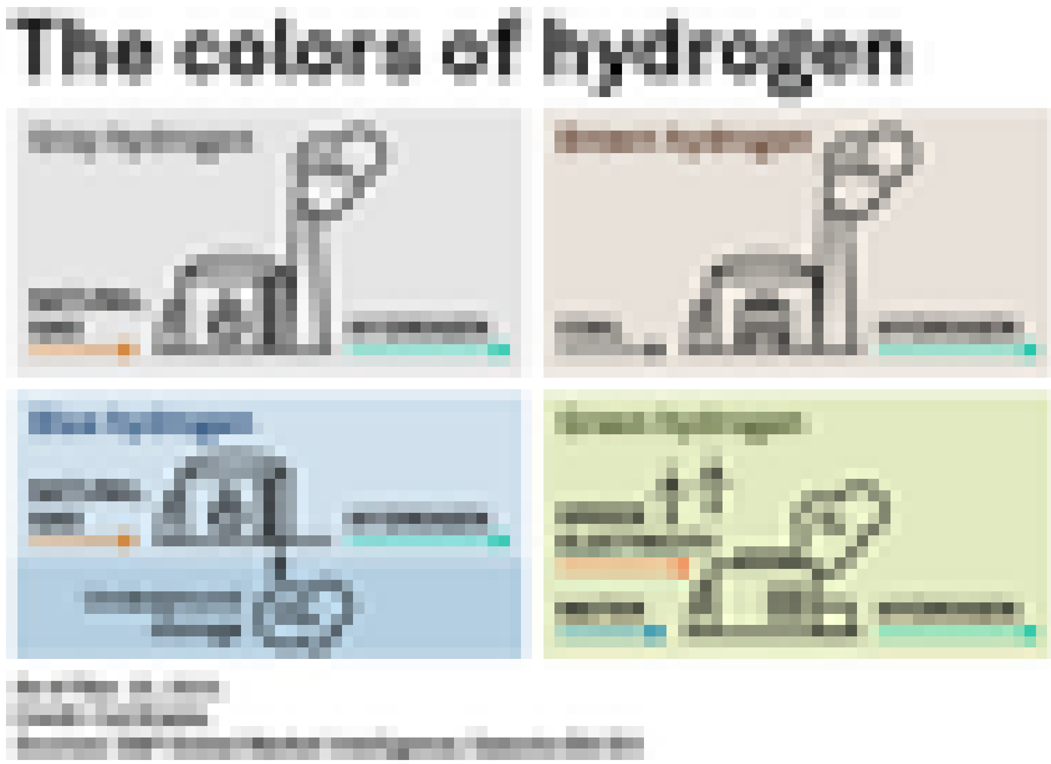
Gas utilities and their regulators should seek cost-effective GHG emissions reductions using measures that enhance—or at least don't compromise—public health and safety, reliability, and service quality. Even where states have less-ambitious climate targets than a zero-emissions gas system, regulators should consider pathways that wouldn't require utilities to dramatically change course if the latter becomes law.

Utilities can produce zero-carbon “green” hydrogen from renewable electricity and water, a process called electrolysis which emits oxygen as its only byproduct. By blending green hydrogen with natural gas, utilities can reduce the carbon intensity of their delivered fuel. However, research suggests utilities can only safely blend up to 20% hydrogen with natural gas using today’s pipelines and appliances, even after extensive testing and targeted pipeline retrofits.

Because burning hydrogen releases less energy than methane—the primary component in natural gas—a 20% blend only reduces GHG emissions 6%-7%, and green hydrogen’s higher production costs today would raise the price of this blended fuel two to four times above standard natural gas.

Utilities aware of hydrogen blending’s bad value proposition are favoring a more expansive strategy. Some are exploring “blue” hydrogen, which strips hydrogen from methane and attempts to capture most of the carbon dioxide emissions for storage underground. Many are also pursuing chemically identical sources of methane, whether synthetically produced or derived from sources like landfills and pig farms.

However, blue hydrogen faces the same blending limits as green hydrogen without the same depth of emissions reductions. Other “clean fuels” can directly substitute for natural gas but suffer from methane leaks throughout the pipeline network. They are also either expensive or can’t scale—for example, waste-derived biogas in the United States can only supply 1.5% of national consumption.



Fuel inputs of hydrogen production. S&P GLOBAL MARKET INTELLIGENCE

When climate policy requires utilities to make deeper emissions reductions for a net-zero economy, hydrogen blends and "clean fuels" will eventually reach their limits. But in that time, utilities could spend many years investing in a system only capable of handling 20% hydrogen at great consumer expense and with little upside. Continuing down this path toward a 100% green hydrogen-capable distribution system, replete with compliant consumer appliances, promises high utility profits but sidelines the more effective electrification strategy.

The expensive, logistical nightmare of a hydrogen transition

Hydrogen is a smaller and much more flammable molecule than methane, and itself is a climate-warming compound (though less so than methane). This means it can leak more easily through pipes and embrittle them, accumulating either in the atmosphere or in enclosures—including homes—which can cause explosions. This means any gas utility aiming for 100% hydrogen would need to upgrade its distribution system depending on each pipe's age, size, material, and operating pressure.

Household appliances pose an even bigger hurdle, because they're optimized for natural gas and are generally incapable of safely handling more than a 5%-20% hydrogen blend. Manufacturers would need to develop furnaces, water heaters, stoves, dryers, and industrial equipment capable of handling pure hydrogen, pure natural gas, *and* any blend in between. Utilities would then need to coordinate replacing *every single appliance* in their service area before increasing their blend beyond 5%-20% as any missed appliances would cause an explosion.

A photo illustration shows gas burning stove. (Photo by Paul ELLIS / AFP) (Photo by PAUL ELLIS/AFP ... [+] AFP VIA GETTY IMAGES

If manufacturers can't find a way to design these hybrid appliances and can only build appliances capable of burning 100% hydrogen, this switchover would be impossible without long and severe gaps in gas service. Utilities would have to keep hydrogen blending levels low so long as any old appliances remained on its system; however, consumers wouldn't be able to operate any new hydrogen-only appliances until utilities switched to a 100% hydrogen fuel system.

By contrast, a quarter of U.S. homes are already all-electric, and about half of single-family homes are already wired for all-electric appliances. Switching from gas to electric equipment can happen incrementally with existing infrastructure, and electrified buildings connect directly to an increasingly clean electricity grid, thus supporting decarbonization. Some homes would need new electrical panels or wiring, and utilities might need to upgrade distribution system equipment, but these investments also support the ongoing transition to electric vehicles while boosting grid reliability.

Now we're cooking with electricity

Energy-efficient electric appliances would bring lower energy bills compared to hydrogen-burning counterparts—and already do on average relative to today's natural gas-burning appliances. These lower costs result from two inherent advantages: using more efficient processes than combustion, and avoiding the energy lost from electrolysis to produce green hydrogen.

Today's electric heat pumps, which heat *and* cool air, would use electricity three to six times more efficiently than hydrogen-compatible heating equipment. This has serious implications for how much renewable generation the U.S. will need to build to support the decarbonization of our buildings. For example, one estimate shows heating a home with green hydrogen would require five times more renewable electricity than doing so with an efficient electric heat pump.

Even in cold climates when heat pumps perform at their lowest efficiency, they still operate more efficiently than gas alternatives.

These thermodynamics won't change, with 15 independent studies finding hydrogen is too costly and inefficient to consider as a means to heat buildings.

Heat pump mini split system next to home with painted brick wall and space for text copy GETTY

Induction stoves are also highly efficient, with about 90% of the electrical energy transferred to directly heat pots and pans. Hydrogen stoves would be around 30% efficient after losing energy from electrolysis and again by indirectly heating food when much of the combustion heat escapes. Induction stoves also perform far better than today's gas and electric resistance stoves, with impeccable temperature control and the ability to boil water in minutes.

Public health is another important consideration. We know natural gas stoves leak methane indoors even when turned off and release harmful toxins like nitrous oxides (NOx) and formaldehyde when burned. These emissions harm health and climate alike, with one study finding children in homes with gas stoves have a 42% increased risk of developing asthma symptoms. Hydrogen emits even more NOx than natural gas when burned, which would likely exacerbate this problem if utilities blend or switch to hydrogen. Induction and electric stoves avoid combustion altogether, improving family health.

Getting it right the first time

Regulators should be highly skeptical of utilities seeking ratepayer funds to blend hydrogen into gas distribution systems as part of a decarbonization strategy—especially with proven ways of slashing near-term emissions, like reducing methane leaks from pipelines or funding building efficiency and electrification.

State policymakers should look to reduce gas demand via building electrification. For example, the Colorado legislature recently passed a “Clean Heat Standard” directing the state’s regulated gas utilities to file emissions reduction plans with state regulators, and permitting gas utilities to use “non-pipes alternatives,” such as replacing gas with electric equipment. However, regulatory oversight is needed to prevent utilities from promoting pathways that do not meaningfully reduce emissions, protect public safety, or ensure consumers don’t get left with the bill for stranded assets.

State policymakers should also advance electrification by adopting all-electric building codes for new construction, funding rebates for efficient electric appliances and heating equipment, and providing additional assistance to low-income customers. Together, these policies can kickstart an intentional transition, driving down electric equipment costs and capitalizing on their higher performance.

Green hydrogen may have an important role in the clean energy economy, but we need not force its use in buildings. Electrification can decarbonize our buildings today while delivering affordable, safe, reliable, and higher-quality services. Let's not waste our time and money looking elsewhere.

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“Renewable” Gas

Renewable gas, like natural gas, is primarily methane. However, rather than being taken out of the ground it is made by processing biogas generated by landfills, methane digesters at farms and wastewater treatment facilities. Statement of Robert W. Howarth, Ph.D., Hearing on Senate Bill 5, Committee on Natural Resources and Energy, Vermont State Senate 1 (February 8, 2023) (attached). The biogas can be used on site for heating or to generate electricity. *Id.* For example, biogas generated by the Coventry and Moretown landfills has been burned on-site to generate electricity. *See* https://www.vtenergydashboard.org/stories/landfill-methane-powers-local-utilities-generators#:~:text=For%20ten%20years%2C%20Washington%20Electric%20Co-op%20has%20been,year%20and%20over%20half%20of%20WEC%E2%80%99s%20power%20mix.

Because “renewable” gas, like natural gas, is primarily methane, it has essentially the same greenhouse gas emissions as natural gas when burned. Biogas must be processed into “renewable” gas before it can be mixed with natural gas in distribution pipelines. Howarth, *supra*, at 2. The processing is inefficient and emits substantial amounts of methane, a potent greenhouse gas. *Id.* Thus, use of “renewable” gas “may lead to greenhouse gas emissions that exceed those from using fossil natural gas.” *Id.* While generation of biogas should not be encouraged, it is best to use biogas at the source of generation, rather than processing it for mixing with natural gas in pipelines. *Id.*

Much “renewable” gas is from landfills. Federal law requires landfills over a certain size to install and maintain a landfill gas collection and control system. 40 C.F.R. Part 60, Subparts WWW and XXX. And Vermont law seeks to minimize generation of methane in landfills by banning landfill disposal of food waste, the decomposition of which generates methane. *See* https://dec.vermont.gov/waste-management/solid/materials-mgmt/organic-materials.

Incentivizing use of "renewable" gas for home heating is at cross purposes with the State's effort to reduce the amount of biogas containing methane generated by decomposition of food wastes in landfills.

Nor should the City be incentivizing the generation of biogas at farms through the use of biodigesters. At dairy farms methane is emitted by liquid manure systems, where the manure decomposes anaerobically, and out of the mouths of dairy cows through a process known as enteric fermentation. Biodigesters generate biogas from liquid manure. Biodiogesters are a false climate solution because they incentivize an increase in herd size. R. Spector, Center for Food Safety, *The Dairy Digester Dilemma: A False Climate Solution* (October 4, 2021), https://www.centerforfoodsafety.org/blog/6457/the-dairy-digester-dilemma-a-false-climate-solution. Even if a digester were to capture 100% of the methane from a dairy's liquid manure system, an increase in herd size increases methane emissions because the digester cannot capture the emissions from enteric fermentation. Enteric fermentation is responsible for substantially more methane emissions than liquid manure systems. *See* *https://www.epa.gov/ghgemissions/overview-greenhouse-gases#methane* (the agriculture sector is the largest source of methane emissions in the United States, enteric fermentation is responsible for 25% of emissions and manure management is responsible for 8% of emissions).

Furthermore, most small and mid-scale dairy operations do not produce enough manure to justify the costs of installing a digester, which cost between $2 million and $9 million to build. R. Spector, supra. Proliferation of biodigesters may speed up the ongoing consolidation of the dairy industry into fewer, larger operations.

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Hearing on Senate Bill 5

Committee on Natural Resources and Energy
Vermont State Senate

February 8, 2023

My name is Robert Howarth. I am an Earth systems scientist with a B.A. from Amherst College and a Ph.D. from MIT and the Woods Hole Oceanographic Institution. I have been a tenured faculty member at Cornell University in Ithaca, NY since 1985 and an endowed professor at Cornell since 1993 (*the David R. Atkinson Professor of Ecology & Environmental Biology*). I have also served as an Adjunct Senior Scientist in the Ecosystems Center of the Marine Biological Lab in Woods Hole, MA for the past 23 years. For decades, I have worked on the consequences of global climate change, on emissions of methane from the oil & gas industry as a driver of climate change, on the production and use of hydrogen, and on alternative energy policies. I have published over 200 peer-reviewed papers, and these have been cited more than 79,000 times in other peer-reviewed literature, making me one of the most highly cited environmental scientists in the world.

Throughout my career, I have been engaged in energy and environmental policy, and I have given briefings and testimony at the White House, at the U.S. Congress and to committees of the US Senate, to the Canadian Senate, to the European Parliament, to the Irish Parliament, to the Senate and Assembly of the State of New York, and in New York courts. I have served on many committees of the US National Academy of Sciences and the International Council of Science, having chaired several of these. Currently, I am one of 22 members of the New York State Climate Action Council, which is the body charged by law with the development of the implementation blueprint ("Scoping Plan") for New York's progressive climate law, the Climate Leadership & Community Protection Act of 2019.

Today, I want to address the proposal that "clean heat credits" be given by the State of Vermont for green hydrogen and for renewable natural gas. In my professional opinion, it would be unwise for Vermont to encourage the use of either hydrogen or renewable natural gas for heating of homes and commercial buildings. These uses were debated extensively by the New York Climate Action Council and its advisory panels and sub-groups over the past 2 to 3 years. In our final Scoping Plan from the Council (passed by a strong 19-3 vote on December 19, 2022), the Council fully rejected the use of hydrogen for heating homes, and put aside the issue of RNG saying it needed further study. Renewable natural gas was certainly not endorsed, though, and I note that renewable natural gas is not mentioned at all in the Executive Summary of the Scoping Plan.

Let me first address renewable natural gas (RNG). RNG is made by processing biogas, making a fuel that is composed mostly of methane and that can be mixed with fossil natural gas in gas pipeline systems. Biogas is a mixture of methane and carbon dioxide as well as other impurities that is produced from anaerobic digesters (including some wastewater treatment plans as well as farm-based systems using manure) and can be captured from landfills. The biogas can itself be used as a fuel, for instance to generate electricity or heating, but biogas is not suitable for use in pipeline distribution systems. In the final Scoping Plan for the New York Climate Action Council, we specified that whenever possible, biogas should be used directly at the site of production, and preferably used in fuel cells rather burned to generate electricity. Our plan further stated that the use of biogas as biogas was to be preferred to processing it into RNG. There are two reasons for this: 1) it takes energy to process biogas into RNG, and so this is inherently inefficient and increases greenhouse gas emissions; and 2) the latest peer-reviewed science shows that methane emissions from processing biogas into RNG can be substantial, as shown in a review paper published last year (see: Bakkaloglu, Cooper, and Hawkes. 2022. Methane emissions along biomethane and biogas supply chains are underestimated. *One Earth* 5: 724-736, doi:10.1016/j.oneear.2022.05.012). Converting biogas into renewable natural gas is wasteful and further contributes to greenhouse gas emissions, with no benefit other than to allow the gas to be pumped into the traditional fossil gas distribution systems.

Please let me note that Vermont Gas Systems currently has contracted to buy RNG from the Seneca Meadows Landfill in central-western New York State, with an expectation of a significant increase in purchase in coming years. This gas is not actually delivered to Vermont, nor will it ever be: rather, the gas enters a general pipeline system moving gas to the west, away from Vermont. Vermont Gas Systems apparently gets financial credits for this scheme through trading mechanisms established by the California Air Resources Board (CARB). The CARB's policy on RNG is based on old, out-of-date science. They simply are wrong that there is any greenhouse-gas benefit from using RNG, and in fact the use of RNG may lead to greenhouse gas emissions that exceed those from using fossil natural gas. The State of New York will now be discouraging the production of RNG such as that from Seneca Meadows Landfill, based on the Climate Action Council's final Scoping Plan. I respectfully ask that the State of Vermont not encourage a policy that runs counter to the policy of New York, and do so based just on paper credits without even any actual delivery of any RNG to Vermont. California started a bad policy in this area, and one that we in New York hope to reverse at least within our State. This issue is close to my heart, as I live only 40 miles from the Seneca Meadows Landfill, the largest active landfill still active in New York, and an environmental travesty with a height of 28 feet over 400 acres. I hate to think that Vermont citizens who buy gas from Vermont Gas Systems will continue to contribute to our environmental problems in the Finger Lakes of New York.

Second, let me address hydrogen. I am pleased to see that Vermont is apparently not favoring any hydrogen made from fossil natural gas, even if with carbon capture. In 2021 I published the first peer-reviewed analysis showing why that is a bad idea for climate when methane emissions are considered (see: Howarth and Jacobson. 2021. How green is blue hydrogen? *Energy Science and Engineering* 9: 1676-1687, doi: 10.1002/ese3.956).

The "clean heat credit" being considered in this bill by Vermont is for green hydrogen, that is hydrogen made from 100% renewable electricity using electrolysis to break water into hydrogen and oxygen. Green hydrogen has a far lower greenhouse gas impact than does the hydrogen made from fossil fuels, but it is still significant: hydrogen gas is the smallest molecule in the Universe, and as such is very hard to retain and keep from leaking. And while hydrogen is not itself a greenhouse gas, when more hydrogen is leaked to the atmosphere it does significantly increase global warming through prolonging the time methane stays in the atmosphere and adding more water vapor to the stratosphere (See: Ocko and Hamburg. 2022. Climate consequences of hydrogen emissions. *Environmental Science & Technology* 22: 9349–9368, doi.org/10.5194/acp-22-9349-2022).

In addition to the role of hydrogen as an agent of global warming, there are many reasons not to put hydrogen into gas pipeline systems and use hydrogen for heating homes and commercial buildings. These are summarized in the table below which I produced for the New York State Climate Action

Council in my final statement accompanied my "yes" vote for our the Scoping Plan we adopted on December 19, 2022. That full statement is appended at the end of my testimony below and includes detailed referencing to support the table. These reasons against hydrogen include safety concerns, greenhouse gas emissions, inefficiencies, and high costs to consumers. With regard to safety, there is widespread recognition that most current pipelines designed and built to deliver fossil natural gas are simply not suitable for carrying hydrogen except at very low blends with the fossil gas. Exactly what level of blending is safe remains unknown, but based on a study they commissioned from the University of California at Riverside, the California PUC recommends that no more than 5% hydrogen be blended with 95% fossil natural gas (see: Pearl. 2022. Hydrogen blends higher than 5% raise leak, embrittlement risks for natural gas pipelines: California PUC. Utility Dive, https://www.utilitydive.com/news/hydrogen-blends-higher-than-5-percent-raise-leak-embrittlement-risks/627895/). With regard to inefficiencies, green hydrogen should be viewed as a precious and expensive resource made from renewable electricity, and using the electricity directly to heat homes with high-efficiency heat pumps generates 6 to 10 times more heat than does the green hydrogen can produce.

Concerns with Blending Hydrogen into Gas Pipelines that Serve Homes & Apartments

- Hydrogen is very leaky, much more so than methane, and hydrogen leakage from pipelines will contribute to global warming.
- Only small quantities of hydrogen can be blended with fossil gas in distribution pipelines, since hydrogen makes pipelines more brittle, potentially increasing methane emissions and leading to greater catastrophic risk.
- Most existing gas appliances in homes and apartments (furnaces, cooking stoves, water heaters, dryers) are not designed to burn hydrogen-methane blends, and increasing the hydrogen content can decrease the efficiency of combustion and lead to increased air pollution, particularly of nitrogen oxides.
- Most engineering studies indicate greatly increased risk of mixing more than 20% hydrogen into fossil gas systems, and the California Air Resources Board has concluded that no more than 5% hydrogen should be blended until further study shows higher amounts are sufficiently safe.
- The energy density of hydrogen is far less than for methane, so blending 20% hydrogen into a fossil-fuel distribution pipeline reduces the combustion emissions of carbon dioxide by only 7%.
- Hydrogen is significantly more expensive than fossil gas, and so blending any hydrogen into the distribution system increases costs.
- Using renewable electricity to produce green hydrogen which is then used to heat homes and apartments diverts this electricity from more efficient uses, such as using heat pumps. For the same quantity of electricity, a heat pump can deliver 6 to 10 times more heat in a home than could burning green hydrogen.
- Inefficient uses of renewable electricity drive up costs and slow the transition from fossil fuels, since renewable electricity will remain a relatively scarce and precious commodity for the next few decades.

Of note, all independent studies have argued against using hydrogen for home heating, including peer-reviewed papers as well as reports from the International Energy Agency and the UN's Intergovernmental Panel on Climate Change (see: Rosenow. 2022. Is heating hydrogen with homes all but a pipe dream? An evidence review. Joule. doi :10.1016/j.joule.2022.08.015). This includes 33 different studies as of today. Only studies funded by or carried out on behalf of industry groups with a vested interest in promoting hydrogen have ever suggested the use of hydrogen for heating. Based on this science, the New York State Climate Action Council strongly recommended against delivery of green hydrogen through the gas pipeline system to heat homes in our final Scoping Plan (see Chapter 18, https://climate.ny.gov/resources/scoping-plan/).

In conclusion, I urge the State of Vermont to not promote issue “clean heat credits” that would promote the use of renewable natural gas and hydrogen for home heating and use in gas delivery systems.

Cornell University

Department of Ecology and Evolutionary Biology

Statement of
Robert W. Howarth, Ph.D.
The David R. Atkinson Professor of Ecology & Environmental Biology
Cornell University

and

Member of the New York Climate Action Council
by appointment of the Honorable Carl Heastie, Speaker of the Assembly

December 19, 2022

I fully support the Scoping Plan enacted today by the Climate Action Council, and I am honored and proud to have served on the Climate Action Council since its inception. I thank Speaker Carl Heastie and other members of the Assembly for this opportunity to have served. In my comments that follow, I speak as a member of the Council and as an Earth systems scientist and faculty member at Cornell University who has worked for over 40 years on issues of global change. My comments should not be construed as official positions taken by my employer, Cornell University.

Assembly Person Steven Englebright was hugely instrumental in the passage of the Climate Leadership & Community Protection Act that established the Climate Action Council. I thank him for his leadership on this, and particularly for his support of the progressive approach on greenhouse gas emissions that is a central part of the CLCPA. I originally proposed this to Assembly Person Englebright in 2016, and he enthusiastically endorsed and supported it through multiple versions of the bill that finally led to passage of the CLCPA in 2019. In this accounting for greenhouse gases, a major government for the first time ever fully endorsed the science demonstrating that methane emissions are a major contributor to global climate change and disruption. Further, in passing the CLCPA New York recognized that consumption of fossil fuels (and not simply geographic boundaries) is what matters in addressing the climate crisis. New York wisely banned the use of high-volume hydraulic fracturing ("fracking") to develop shale gas in our State. But since the time of that ban, the use of fossil natural gas has risen faster in our State than any other in the Union. Methane emissions from this use of shale gas are high, but much of that occurs outside of our boundaries in the nearby states of Pennsylvania, West Virginia, and Ohio. Through the CLCPA, the citizens of New York are taking responsibility for these out-of-state emission caused by our use of fossil fuels, particularly for fossil natural gas. The way to reduce these emissions is to rapidly reduce our use of fracked shale gas.

The Assembly and Senate specified in the CLCPA that many of the agency heads of New York's government be members of the Climate Actions Council, and also stated that the Council take input from a set of advisory panels. Both of these requirements led to the leadership of the State being heavily engaged and invested in the implementation of the CLCPA. And the panels brought in a large number of experts and key stakeholders who worked diligently to advise the Council on our Scoping Plan. The Plan benefitted immensely from their efforts and input, and all New Yorkers owe them our thanks.

In the well over one hundred meetings of the Council, advisory panels, and working groups since March of 2020, all viewpoints have been respectfully heard and debated. The tone set by our co-Chairs, NYSERDA President Doreen Harris and DEC Commissioner Basil Seggos was a critical part of this. I thank them and all of the members of the Council for our sense of community through deliberations in which we often had major differences of opinion. I also thank the staff who contributed so much to the background information provided to the Council and to the drafting of our final report. A large number of individuals participated and contributed in major ways, but I want to particularly thank and acknowledge our Council Executive Director Sarah Osgood, Maureen Leddy and Jared Snyder from DEC, Carl Mas from NYSERDA, and Jessica Waldorf of DPS.

I further wish to acknowledge the incredible role that Prof. Mark Jacobson of Stanford has played in moving the entire world towards a carbon-free future, including New York State. A decade ago, Jacobson, I and others laid out a specific plan for New York (Jacobson et al. 2013). In that peer-reviewed analysis, we demonstrated that our State could rapidly move away from fossil fuels and instead be fueled completely by the power of the wind, the sun, and hydro. We further demonstrated that it could be done completely with technologies available at that time (a decade ago), that it could be cost effective, that it would be hugely beneficial for public health and energy security, and that it would stimulate a large increase in well-paying jobs. I have seen nothing in the past decade that would dissuade me from pushing for the same path forward. The economic arguments have only grown stronger, the climate crisis more severe. The fundamental arguments remain the same.

Our final Scoping Plan from the Climate Action implicitly endorses the vision of the Jacobson et al. paper and is quite clear: we can meet the goals of the CLCPA and we can and will do so in way that is affordable and that will benefit all New Yorkers. Our State will be stronger as this plan is implemented, the health and well being of our citizens improved. Economic uncertainties and vulnerabilities will be reduced. Energy security will be enhanced. Our plan is also clear that the #1 priorities are to continue to move towards wind, solar, and hydro as our source of electricity; to move rapidly towards beneficial electrification as a source of heating and cooling in our homes and commercial buildings; and to move rapidly towards beneficial electrification in our personal and commercial vehicles.

Although I strongly support our final Scoping Plan, I have some disappointments. Chief among these is the decision to postpone the dates by which the State will move away from fossil fuel use for construction of new homes and commercial buildings, which are now one year later than in our draft plan passed in December 2021. For single family homes, for example, our final Scoping Plan calls for the prohibition of fossil fuels in new construction in 2025, not the 2024 specified in the draft plan. The building sector is the largest single source of greenhouse gas emissions, as I discuss further in the next paragraph below. Therefore, the greatest priority for meeting the goals of the CLCPA should be to reduce emissions from the building sector. I urge the Assembly and Senate to act to mandate that the State move away from fossil fuels more quickly than called for in the Council's Scoping Plan., using the guidance from the December 2021 draft Scoping Plan.

Exactly how important are emissions from the building sector in New York State? The Scoping Plan states this sector is the single largest emitter, accounting for 32% of the total (closely trailed by transportation at 28%). However, I believe the Plan understates the importance of the building-sector emissions for two reasons. First, methane emissions from the operations of the fossil natural gas industry in New York are included as part of the "industry" sector in the Scoping Plan, whereas they should have been included in the building and electric sectors according to the accounting specified in the CLCPA (these emissions would not occur if the fossil natural gas were not being used in our buildings and electric power plants). Making this correction, the building sector is seen to contribute 36% of all emissions, followed by 28% for transportation, 14% for electricity, 12% for waste, 6% for agriculture, and only 4% for industry. Second, the greenhouse gas inventory for the State released by the DEC in December 2021 understates methane emissions from the use of fossil natural gas, in my professional opinion, using an emission factor of 2.49% of gas production. The preponderance of peer-reviewed literature reviewed in my recent paper suggests the factor should be 4.8% (Howarth 2022), a value that is 1.9-times greater than that used by the DEC. Correcting by this factor, I estimate that the building sector is responsible for more than 40% of all greenhouse gas emissions in New York State.

The Scoping Plan strongly calls for beneficial electrification with heat pumps as the best way forward to reduce greenhouse gas emissions from the building sector in New York. I completely agree, but I feel the Plan could have made an even stronger case by including several recent papers and reports. Further, the Plan tends to favor air-sourced heat pumps over ground-sources heat pumps. While the initial cost of the air-sourced pumps is less, they have higher energy and maintenance costs. One recent study examining heat pumps for new home construction in the context of New York State concluded that ground-sourced heat pumps are actually less expensive when these energy and maintenance costs are included (Shron et al. 2022). This was true across the State, in both the coldest and warmest regions. The study also concluded that both air-sourced and ground-sourced heat pumps are almost always less expensive than building new homes heated by fossil natural gas or propane, although air-sourced heat pumps cannot quite out compete fossil natural gas (at average prices over the past decade) in the warmest part of the State, Long Island, according to this report. However, the Long Island Power Authority (2022) has produced a brochure arguing that air-sourced pumps are cost effective for new homes over fossil natural gas on Long Island. And of course the cost of fossil natural gas has increased dramatically since these studies were produced, and may well stay high indefinitely into the future according to many energy economists. If so, anyone building a new home in 2023 or 2024 using natural gas for heating will soon wish they had instead built a fossil-fuel-free home with heat pumps. Further, these costs are from the perspective of the new home owner. I have repeatedly urged in meetings of the Climate Action Council over the past 18 months that we consider the entire energy system when considering the question of heat pumps: ground-sourced heat pumps require far less electricity during peak winter heating times, meaning that encouraging their use over air-sourced pumps lessens the need for electricity storage and for total renewable generating capacity, which could benefit consumers immensely.

As a Council, we spent a disproportionate amount of time in debating what I believe are side issues such as renewable natural gas (RNG) and hydrogen for heating of homes. The oil & gas industry globally has pushed such ideas very heavily as a way to keep their massive fossil-gas pipelines system profitably in operation (Lowes and Cebon 2022). At the Climate Action Council, we have regularly heard suggestions that pipelines in the future can deliver hydrogen and RNG. I and others on the Council have pushed back with objective, scientifically based evidence. In the end, the Council fully rejected the use of hydrogen for heating homes, and somewhat put aside the issue of RNG saying it needed further study. I am pleased to say that RNG is not mentioned at all in the Executive Summary of the Scoping Plan, and hydrogen is mentioned only once, in this case appropriately in the context of its use with fuel cells (not combustion) in transportation (not home heating or use in pipelines).

While the Scoping Plan does not endorse the use of hydrogen for heating or in pipelines, it also does not fully explain the reasons for this decision. And in some places in the text, there is a suggestion for more research on hydrogen. In fact, there is a large amount of information that clearly demonstrates why hydrogen for delivery to homes for heating is a bad idea (Kurmayer 2021; Rosenow 2022; Pearl 2022; Prieto and Henchen 2022; Collins 2022; Lowes and Cebon 2022). There simply is no need for further research on this bad idea. Some of the major reasons for rejecting the use of hydrogen for heating for homes are outlined in the following table.

Concerns with Blending Hydrogen into Gas Pipelines that Serve Homes & Apartments

- Hydrogen is very leaky, much more so than methane, and hydrogen leakage from pipelines will contribute to global warming.
- Only small quantities of hydrogen can be blended with fossil gas in distribution pipelines, since hydrogen makes pipelines more brittle, potentially increasing methane emissions and leading to greater catastrophic risk.
- Most existing gas appliances in homes and apartments (furnaces, cooking stoves, water heaters, dryers) are not designed to burn hydrogen-methane blends, and increasing the hydrogen content can decrease the efficiency of combustion and lead to increased air pollution, particularly of nitrogen oxides.
- Most engineering studies indicate greatly increased risk of mixing more than 20% hydrogen into fossil gas systems, and the California Air Resources Board has concluded that no more than 5% hydrogen should be blended until further study shows higher amounts are sufficiently safe.
- The energy density of hydrogen is far less than for methane, so blending 20% hydrogen into a fossil-fuel distribution pipeline reduces the combustion emissions of carbon dioxide by only 7%.
- Hydrogen is significantly more expensive than fossil gas, and so blending any hydrogen into the distribution system increases costs.
- Using renewable electricity to produce green hydrogen which is then used to heat homes and apartments diverts this electricity from more efficient uses, such as using heat pumps. For the same quantity of electricity, a heat pump can deliver 6 to 10 times more heat in a home than could burning green hydrogen.
- Inefficient uses of renewable electricity drive up costs and slow the transition from fossil fuels, since renewable electricity will remain a relatively scarce and precious commodity for the next few decades.

As with hydrogen, the Scoping Plan does not endorse any widespread use of RNG. In fact, the Plan specifies that it is generally preferable to use biogas (the unrefined mixture of methane and carbon dioxide produced in anaerobic digesters and landfills) directly and at the site of production rather than refining the biogas to produce RNG. However, the Plan does not fully explain the strong science behind this conclusion. Briefly, it takes energy to refine RNG, and this comes either from fossil natural gas with the associated greenhouse gas emissions or from using some of the biogas to power the refining (resulting in a loss of some useful energy, and a lower overall efficiency of using the energy of the biogas). Further, biogas itself can have substantial methane emissions, and the refining of biogas into RNG can substantially increase these methane emissions (Bakkaloglu et al. 2022). In a memorandum I wrote to the Alternative Fuels Working Group of the Climate Action Council in July 2022, I calculated that using the CLCPA accounting methodology and mean emissions from the Bakkaloglu et al. study, methane emissions for RNG are 156 g CO_2-equivalents/MJ, or 1.7-times greater than the combined methane and carbon dioxide emissions for fossil natural gas. Unless these methane emissions can be greatly reduced, New York should clearly discourage the use of RNG.

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ANR Flood Recovery Resources

Find updates and information on the recent flood.

Food Scraps

State law bans food scraps from the trash.

See our Food Scrap Ban Guidance with requirements for residents, businesses, and haulers.

LET'S SCRAP FOOD WASTE Check out Compost with Confidence for a quick (printable) summary.
Print a handy food scrap guide for your fridge.
See tips for reducing food waste at scrapfoodwaste.org.
Find a Food Scrap Hauler.
Read the Dirt on Compost for info on backyard composting.
Learn about requirements and options for Rental Properties.
Still have questions? Check out our Food Scrap Management FAQ.

Food scraps are:

- Parts of food items that are typically **discarded rather than eaten**: peels, rinds, cores, eggshells, seeds, pits, bones, coffee grounds and paper filters, loose-leaf tea & paper tea bags, and fats/oils/grease.
- Food that was **not finished**: "plate scraps" or leftovers that went bad. Any type of food can become scraps--bread, pasta, soup, veggies, fruit, sauces, meat, dairy, sweets, etc.

These items can go in your food scrap collection container. You may be able to put other items in with your food scraps depending where your scraps end up. Read on to learn more.

What do I have to do?

If it was once part of something alive, like a plant or animal, it does not belong in the landfill. Food scraps and yard debris (leaves, grass, brush clippings, etc.) will need to be managed separately from trash.

The first step is to collect your food scraps in a container. There's no right way to do this. You can reuse a large yogurt tub or bucket, buy a food scrap container, or keep a plastic bag in the freezer--find a method that works for you based on how much food scraps you generate, how often you want to empty and wash your container, etc. You'll empty your container regularly into a backyard bin if you compost in your yard, you hauler will empty your food scrap tote or bucket if you subscribe to a pick-up, or you'll dump your scraps into a food scrap cart at a drop-off.

Kitchen Tips:

- Unless you empty your kitchen container every day or two, use a container with a lid.

- Wash or rinse your container regularly or each time you empty it.
- To store your food scraps for a while between trips to a drop-off or your pick-up:
    - Keep them in a bag or container in your freezer (bread bags work well).
    - Try the bokashi process, which ferments the food scraps so they don't smell.
    - If you don't mind emptying and cleaning a messier bin, you can simply store scraps in a larger container with a tight lid (like a 5-gallon bucket) in an out-of-the-way place, like an entryway or garage. To contain odors, you can cover the food scraps with a thin layer of dried, brown leaves or wood shavings each time you empty your kitchen container into the larger container.
- Learn more tips in the Food Scrap Management FAQ for Residents.

Why separate food scraps from the trash?

Food scraps and yard debris make up ~30% of a typical Vermont family's waste; at restaurants and cafeterias, food scraps can be over

half the waste. Keeping these materials out of the landfill has a big impact:

- When it is trapped in a landfill, food waste decomposes slowly, and without oxygen. This process produces methane, which is a greenhouse gas 84 times more powerful than CO2 over a 20-year period.
- Food scraps contain valuable nutrients that are good for the soil. Finished compost can be used in gardens, farms, and landscaping.
- Generating less trash conserves landfill space.
- Composting puts your waste to work supporting composters, local farmers, and food scrap haulers.
- Without food scraps in it, garbage is cleaner and less smelly.

How does food waste relate to climate change?

BrighterVermont
CommunityEnergyDashboard
BUILDING A BETTER ENERGY FUTURE. TODAY.

Landfill Methane Powers Local Utilities Generators

Methane gas from the Coventry landfill produces electricity. Photo credit: Washington Electric Coop

Source: *Jenna Koloski - VCRD*

For ten years, Washington Electric Co-op has been generating power from the stuff that Vermonters throw away. Their system channels methane gas from deep within the Coventry landfill to fuel the five Caterpillar engines that produce enough electricity to power 8,000 houses a day. That's about 50,000 MWH a year and over half of WEC's power mix.

This represents a sizeable investment for WEC, approved in stages by its owner-members. The benefits are tangible. The Coventry power is affordable (5.3 cents per kilowatt-hour) and environmentally sound, making good use of methane that would otherwise have to be flared to prevent it from escaping into the atmosphere and intensifying global warming.

"The Coventry plant is a tremendous success story and a perfect example of how we can produce electricity in a sustainable and responsible way," explains Co-op General Manager

Feedback

Patricia Richards. "This local, stable, and renewable source of electricity produces power 24 hours a day at a very affordable price."

For more about how Vermont's new recycling rules may impact WEC's future Coventry operations, see the July 2015 edition of WEC's newsletter, Co-op Currents.

For more Climate Innovator Stories and info on the Vermont Climate Economy Initiative visit: http://vtrural.org/programs/climate-economy or contact Jenna Koloski at jenna@vtrural.org

Relevant Categories

- Electricity
- Community Based Organization

Communities

Orleans County

Caledonia County

Washington County

Orange County

Action Date

Oct 2016

Methane Emissions

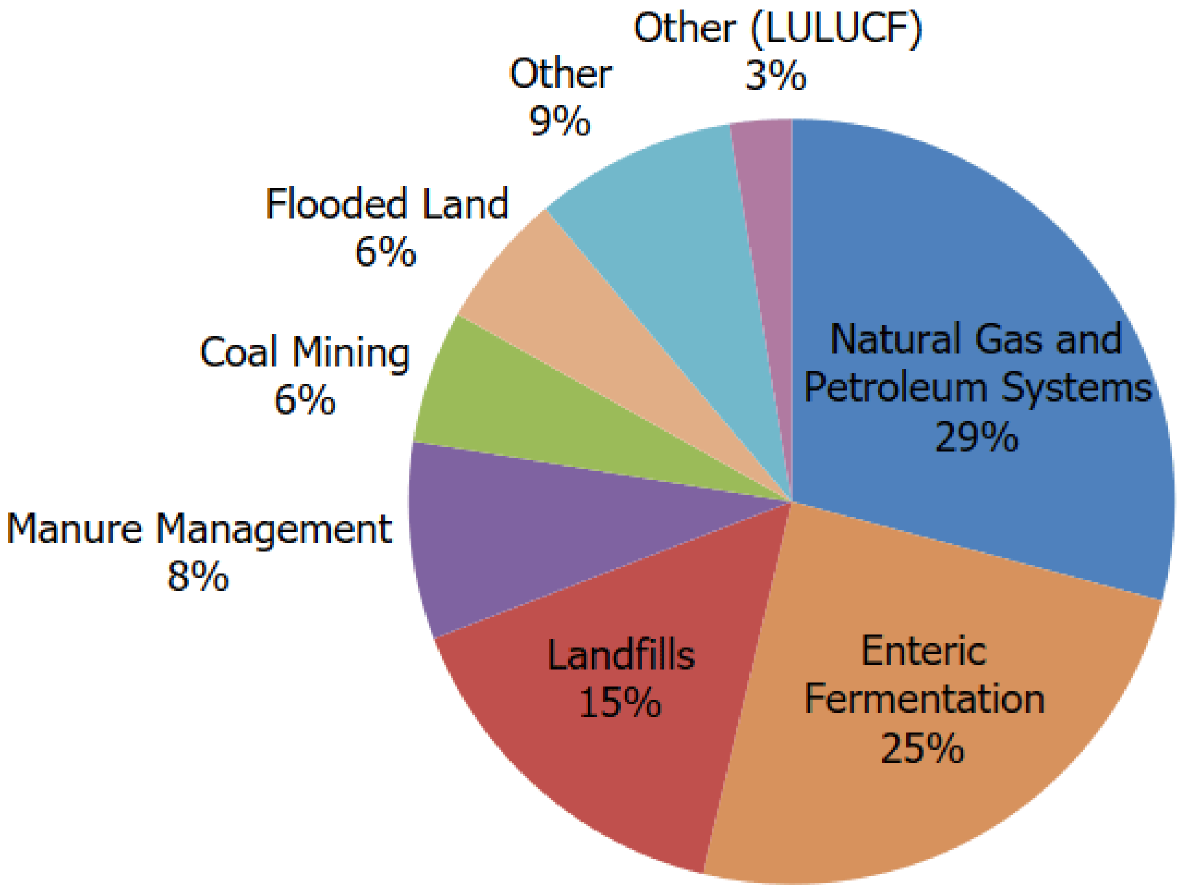
Properties of Methane

Chemical Formula: CH_4
Lifetime in Atmosphere: 12 years
Global Warming Potential <https://epa.gov/ghgemissions/understanding-global-warming-potentials> **(100-year)**: 28[1]

In 2021, methane (CH_4) accounted for 12% of all U.S. greenhouse gas emissions from human activities. Human activities emitting methane include leaks from natural gas systems and the raising of livestock. Methane is also emitted by natural sources such as termites. In addition, natural processes in soil and chemical reactions in the atmosphere help remove CH_4 from the atmosphere. Methane's lifetime in the atmosphere is much shorter than carbon dioxide (CO_2), but CH_4 is more efficient at trapping radiation than CO_2. Pound for pound, the comparative impact of CH_4 is 28 times greater than CO_2 over a 100-year period.[1] <https://epa.gov/ghgemissions/overview-greenhouse-gases#ch4-reference>

Globally, 50-65% of total CH_4 emissions come from human activities.[2] Methane is emitted from energy, industry, agriculture, land use, and waste management activities, described below.

U.S. Methane Emissions, By Source



Note: All emission estimates from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2021* *<https://epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks>.*

Image to save or print <https://epa.gov/system/files/images/2023-04/gases-by-ch4-2023-caption.png>

- **Agriculture** <https://epa.gov/ghgemissions/sources-greenhouse-gas-emissions#agriculture>. Domestic livestock such as cattle, swine, sheep, and goats produce CH4 as part of their normal digestive process. Also, when animal manure is stored or managed in lagoons or holding tanks, CH_4 is produced. Because humans raise these animals for food and other products, the emissions are considered human-related. The Agriculture sector is the largest source of CH_4 emissions in the United States. For more information, see the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* <https://epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks> Agriculture chapter.
- **LULUCF** <https://epa.gov/ghgemissions/sources-greenhouse-gas-emissions#land-use-and-forestry>: While not shown in the figure, emissions of CH_4 also occur as a result of land use and land management activities in the Land Use, Land-Use Change, and Forestry <https://epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks#land-use-and-forestry> sector (e.g. forest and grassland fires, management of flooded lands such as reservoirs, decomposition of organic matter in coastal wetlands).
- **Energy and Industry** <https://epa.gov/ghgemissions/sources-greenhouse-gas-emissions#industry>. Natural gas and petroleum systems are the second largest source of CH_4 emissions in the United States. Methane is emitted to the atmosphere during the production, processing, storage, transmission, distribution, and use of natural gas, and the production, refinement, transportation, and storage of crude oil. Coal mining is also a source of CH_4 emissions. For more information, see the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* <https://epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks> sections on Natural Gas Systems and Petroleum Systems.
- **Waste from Homes and Businesses** <https://epa.gov/ghgemissions/sources-greenhouse-gas-emissions#commercial-and-residential>. Methane is generated in landfills as waste decomposes and in the treatment of wastewater. Landfills are the third-largest source of CH_4 emissions in the United States. Methane is also generated from domestic and industrial wastewater treatment and from composting and anaerobic digestion. For more information, see the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* <https://epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks> Waste chapter.

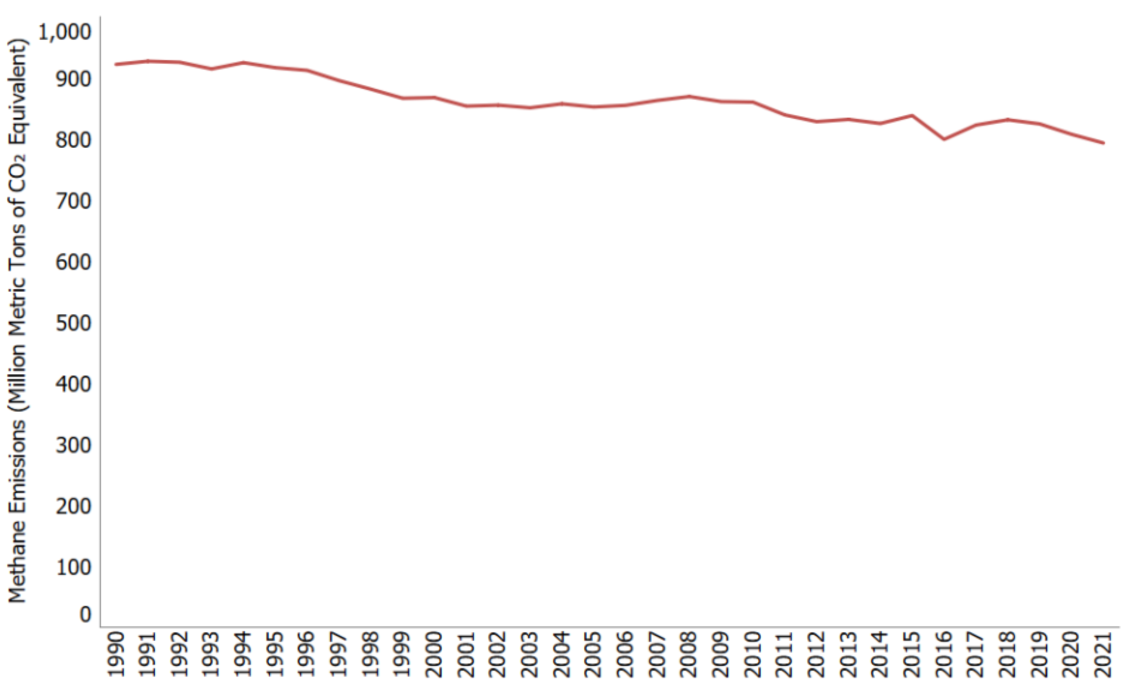
Methane is also emitted from a number of natural sources. Natural wetlands that are not managed or changed by human activity are the largest source, emitting CH_4 from bacteria that decompose organic materials in the absence of oxygen. Reservoirs and ponds with high organic matter and low oxygen levels also produce methane through the microbial breakdown of organic matter. Smaller sources include termites, oceans, sediments, volcanoes, and wildfires.

To find out more about the role of CH_4 in warming the atmosphere and its sources, visit the Climate Change Indicators <https://epa.gov/climate-indicators> page.

Trends

Methane emissions in the United States decreased by 16% between 1990 and 2021. During this time period, emissions increased from sources associated with agricultural activities, while emissions decreased from other sources including landfills and coal mining and from natural gas and petroleum systems.

U.S. Methane Emissions, 1990-2021



Note: All emission estimates from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021* <https://epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks>. These estimates use a global warming potential <https://epa.gov/ghgemissions/understanding-global-warming-potentials> for methane of 28, based on reporting requirements under the United Nations

Framework Convention on Climate Change.

Image to save or print <https://epa.gov/system/files/images/2023-04/gases-by-ch4-2023-line-caption.png>

Reducing Methane Emissions

There are a number of ways to reduce CH_4 emissions. Some examples are discussed below. EPA has a series of voluntary programs for reducing CH_4 emissions, in addition to regulatory initiatives <https://epa.gov/controlling-air-pollution-oil-and-natural-gas-industry>. EPA also supports the Global Methane Initiative <https://www.globalmethane.org/>, an international partnership encouraging global methane reduction strategies.

Examples of Reduction Opportunities for Methane

Emissions Source	How Emissions Can be Reduced
Industry	Upgrading the equipment used to produce, store, and transport oil and natural gas can reduce many of the leaks that contribute to CH_4 emissions. Methane from coal mines can also be captured and used for energy. Learn more about the EPA's Natural Gas STAR Program <https://epa.gov/natural-gas-star-program> and Coalbed Methane Outreach Program <https://epa.gov/cmop>.
Agriculture	Methane from manure management practices can be reduced and captured by altering manure management strategies. Additionally, modifications to animal feeding practices may reduce emissions from enteric fermentation. Learn more about improved manure management practices at EPA's AgSTAR Program <https://epa.gov/agstar>.

Emissions Source	How Emissions Can be Reduced
Waste from Homes and Businesses	Capturing landfill CH_4 for destruction in a flare or conversion to renewable energy are both effective emission reduction strategies. Learn more about these opportunities and the EPA's Landfill Methane Outreach Program <https://epa.gov/lmop>. Additionally, managing waste at a higher tier on the waste management hierarchy can reduce CH_4 generation at landfills. Learn more about Sustainable Materials Management <https://epa.gov/sustainable-management-food/food-recovery-hierarchy>.

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The Dairy Digester Dilemma: A False Climate Solution

By Rebecca Spector, West Coast Director & Dashel Murawski, Communications and Development Associate

OCTOBER 04, 2021

In a better-late-than-never move, the Biden administration recently announced an international initiative to reduce global methane emissions by at least 30 percent from 2020 levels by 2030. The pledge, which was announced ahead of its full unveiling at COP26 in Glasgow this November, is particularly important given that methane is 84 times more potent than carbon dioxide (over a 20-year period) in terms of contributing to the climate crisis. Researchers have calculated that a serious push to cut methane emissions could slow the rate of climate chaos by as much as 30 percent.

But the key is in the execution of such an ambitious goal. While the pledge offers a good start to tackling our global methane emissions, it does not go far enough. In the announcement, the Biden administration discusses new regulations and stronger standards targeting oil, gas, and landfill operations. However, current plans for methane reductions in the agriculture sector are completely voluntary.

The agriculture sector is the largest emitter of methane in the United States, accounting for about 36 percent of all methane emissions (compared to 30 percent for oil and natural gas). Since 1990, methane emissions from manure management programs have almost doubled. It's therefore quite clear that in order to achieve meaningful reductions of methane emissions in the United States, aggressive reduction goals and strategies for agriculture must be included.

Unfortunately, the federal government and many states such as California are banking on a Band-Aid fix to cutting methane emissions from agriculture: methane (dairy) digesters. Dairy digesters capture methane from dairy manure lagoons and convert it to biogas. While this sounds promising, **the fact is that**

dairy digesters are a false climate solution that actually increase environmental burdens and may even increase methane emissions. Here are just a few reasons why:

- The biogas created from digesters is neither renewable nor clean. It emits significant pollutants, including particulate matter, carbon monoxide, sulfur dioxide, and ozone-forming criteria pollutants (i.e. nitrogen oxides (NOx)).
- Most small and mid-scale dairy operations do not produce enough manure to warrant the costs of installing a digester, as they cannot maintain one full time and are unlikely to have the capital for such an investment.
- Digesters incentivize increased herd sizes, and therefore increased emissions, as subsidies and credit schemes create a network of perverse incentives for dairies to create more waste and more methane from cows. Along with it comes more air and water pollution in already environmentally-burdened communities and regions.
- Dairy digesters are expensive, costing between $2 million to $9 million to install, often requiring public subsidies to build, and there are concerns about their long-term economic viability and environmental benefit.

Rather than clean up its act by addressing the issue of our destructive industrial agricultural system at its core, the industry (supported by government agencies) has fixated on using this technology-based false solution of dairy digesters to capture and process methane in the hopes of turning it from a climate liability into marketable biomethane gas.

Not only are digesters a false solution when reducing methane emissions, they can also cause further harm to vulnerable communities. As noted above, dairy digesters incentivize increased herd sizes and lead to more mega-dairies. Mega-dairies produce serious environmental impacts by contaminating groundwater, emitting air contaminants beyond methane, attracting heavy-duty truck traffic, and producing odors. Digesters do nothing to address nitrogen in manure, which seeps into groundwater, causing and contributing to groundwater pollution which will impact drinking water sources for disadvantaged communities for decades. Mega-dairies are a large source of volatile organic compounds (VOCs) and ammonia, which contribute to harmful ozone (smog) and fine particulate matter (PM2.5), respectively.

These harmful air pollutants, a direct result of industrial agriculture, have been attributed to 17,900 deaths a year in the United States. The resulting pollution, public health, and social equity effects fall especially on disadvantaged rural communities where these operations are located. For example, California's San Joaquin Valley, home to a number of large dairy operations, already does not meet state and federal air quality standards and cannot bear ongoing combustion of dirty fuels. Thus, incentives for digesters are perversely encouraging the expansion of unsustainable practices (i.e., large herd sizes, confinement, and manure lagoons) that create environmental and public health harms in the first instance, resulting in the production of new pollutants and emissions that may not have otherwise occurred.

Many states such as California require some polluters, such as the oil and gas industry, to pay for the environmental damage they cause, or at the very least, regulate them for such degradation. This is not the case for factory farm dairies. Industrial agriculture's harmful practices are often directly subsidized using tax and ratepayer money. A new United Nations report found that a staggering 90% of global agricultural subsidies support practices that harm the health of both people and the planet. Rather than subsidizing the technologies that perpetuate these polluting practices, the U.S. and individual state governments should invest in transitioning these dairies to more sustainable and socially just methods and help rebuild robust agricultural economies which nurture existing systems rather than cause harm.

Center for Food Safety and many other organizations advocate for a more diversified approach to manure management that is appropriate for a wider range of dairies and livestock operations. Those approaches include advanced solids separation, scrape systems, composted manure, compost pack barns, and pasture-based strategies. Properly incentivized with public funds, these practices can help create dairy systems that benefit people and the environment and reduce the harms caused by mega-dairies that are disproportionally impacting the health of people living in those vulnerable communities. Currently, programs like the California Department of Food and Agriculture's (CDFA) Alternative Manure Management Program (AMMP) provide a model for supporting production practices that reduce methane emissions in more environmentally sustainable ways. According to CDFA, 114 projects have already been funded by the AMMP which collectively are expected to reduce greenhouse gas emissions by an estimated 1.1 million metric tons of CO_2 equivalent over the next five years.

In addition to incentivizing alternative manure management practices rather than polluting digesters, the Biden administration must take immediate action to regulate methane created by agriculture. In April, a group of organizations including Center for Food Safety, led by Public Justice, petitioned the EPA to reduce methane by regulating industrial hog and dairy operations under the Clean Air Act, and to reject so-called solutions such as factory farm gas championed by the industrial agriculture industry. The petition calls on the EPA to set emissions limits based on well-established pasture-based farms which provide myriad co-benefits including reducing climate, air, and water pollution while supporting rural economies to build back better.

This groundbreaking legal petition calls for immediate action from the EPA to exercise its existing authority under the Clean Air Act and fulfill its obligation to protect public health, rural communities, and our land, air, and water by listing and regulating industrial dairy and hog operations. Industrial dairy and hog operations are defined in the petition as facilities that confine at least 500 cows or 1,000 hogs without access to pasture while liquefying manure. As major sources of the super pollutant methane, the category endangers public health and welfare and now accounts for 33 percent of agricultural methane emissions, 13 percent of total U.S. methane emissions, and 1.3 percent of total U.S. greenhouse gas emissions.

The Biden administration will be taking a bold and critically necessary step by committing to reducing methane emissions, thus helping to save the planet from climate chaos. How it actually does this has the power to transform agriculture toward one that benefits vulnerable communities, ecosystems, and the planet at large.

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Transportation, Energy and Utilities Committee of the City Council
Tuesday July 25th, 2023 – 5PM

DPW Front Conference Room
645 Pine St, Burlington, VT 05482
Masks Optional

Meeting Starts 5:01PM

–DRAFT MINUTES–

1. **Agenda**

Councilor Bergman moves to approve the agenda striking items 6 and 7. Seconded by Councilor King. All in favor, passes unanimously.

2. **Minutes of 6.27.23**

Councilor Bergman moves to approve the minutes. Seconded by Councilor King. All in favor, passes unanimously.

3. **Public Forum**

Jack Hanson – Ordinance on Carbon fee is very timely and needs to progress quickly. Policy changes – renewable natural gas for new construction should not be permitted. Building Electric from the start is most sustainable. If VGS can't comply with going renewable they should pay carbon impact fee to city.

Connor Wertz – Speak Ordinance on Carbon Fee. Green Hydrogen has danger concerns

Ashley Adams – Thankful for VTANG resolution support. Ordinance on Carbon Fee, not supportive of language proposed. Nic Persampiers language should be adopted.

Nick Persampiers – Proposed revisions to Ordinance.

Phil Merrik – Support Nick. Support presentations at McNeil symposium from third party experts.

Pike Porter – Ordinance on Carbon Fee. Remove any combustion from this ordinance. Line 76 neglects to include solids, suggest adding this. TEUC should insure NetZero accounts for all carbon dioxide.

Catherine Bock – Ordinance on Carbon Fee – need to remove GHG emission potentials.

Steve Goodkind – Need to define exactly what impact of wood is as fuel source.

Peter Duval – Underhill resident. Trees being cut for McNeil impact lake health among other things. Biogenic Emissions for McNeil are not sustainable.

Dan Castrigano – Listen to the science on carbon emissions.

Item closes at 5:41PM

4. **City Fleet Committee**
    - Lee Perry, Ashley Parker
    - Memorandum

Lee Perry provides overview of memo. Looking for input for how to move forward with fleet funding.

Councilor Gene Bergman – Revenue options: Not in favor of cash purchases, bonding bullet is problematic with current state of City bonding, new carbon fee bullet is long term and there will be a lot of demands for this on thermal sector, should not count on this. Franchise fee and enterprise Depatments is unclear. Need a capital program for City's fleet. All expense options make sense.

Ashley Parker– Looking for gaps in existing study to see what we can implement. Looking to bring someone on to implement strategies in the near term and look at long term goals.

Chair Mark Barlow – Would like to look into studies and then have that inform recommendations.

LP to provide studies to committee. Schedule another meeting or two before budget cycle kicks off in October. Committee can provide more input prior to City Fleet Committee meeting August 17th, LP to send invite to councilors.

GB – Is there any ability to connect with CCRPC or other municipalities to collaborate? Any intermunicipal agreement potential?

Item ends 6:01PM

5. **Ordinance on Carbon Fee**
    - Councilors, Darren Springer
    - 30 Minutes
    - Ordinance

Darren Springer – Does not agree with greenwashing claims from public. Here to answer questions on behalf of proposed language. There has been serious policy development at the state level, City should work within the constructs the State has set up.

Councilor Gene Bergman – Ambiguity of fossil fuel needs to be address to determine what does and does not qualify for fee. Polluting/emitting sources that are not fossil fuel but are also not good to promote, how do we charge a fee. Should we go back to voters in march to clean this up? Can we regulate things as building heating systems without bringing it into the fee to need voters? Need conversation on renewable gas. Could we say that certain energy types are not allowed to be able to address it now.

Chair Mark Barlow– Asks for clarification on Subsection C lines 72-76 Renewable Fuels.

DS – Intended to address how to know if a building that says they are getting renewable fuel is actually getting the renewable gas. This is accounted for through renewable credits. Also intended to allow this to be disqualified and subject to a fee.

MB – Like the alignment with state regulation and policy. Fee should be used to offset emissions in thermal sector.

DS – Think this fee will range from year to year based on buildings permitted that year and what options they have at the time. Supportive of NetZero efforts in thermal and ground transportation sectors. Having it go to emission reduction in either section is intended.

GB – Line 72 – seeing implementation issues. 'Subsequently deemed by utility' may lead to problems in terms of implementation if we grant a permit and then there are issues. This needs to be worked on.

DS – Fee charged at the time of permit. This was intended so the Dept. can update what is qualified and applied prospectively to new applicants. Can add clarifying language.

GB – Green Hydrogen, why is this listed as a fuel?

DS – In symmetry with State Clean Heat Standard. Future proofing if it becomes a viable option. It can be excluded in future if it no longer meets requirements.

GB – Advanced wood heating, why is this in definition of renewable fuel.

DS – Consistent with State Clean Heat Standard and program. Don't see large use of this type of heating system in Burlington, especially within new construction. It is renewable in state context. Added language on 197-201 to add stipulations to wood heating. Would be consistent with state. For benefit of applicant to have as listed technology.

GB – Line 60 – 65. Does this language require that all of the gas that goes to power a building in Burlington, would have to be renewable and that amount of gas would consistently have to be renewable?
DS – Appliance by appliance. Needs to be lifetime contract for system they are putting in for renewable gas or an annual certification that shows they are purchasing the renewable gas for the appliance they are using. If they stop this purchasing they have to start paying.

GB – This system is very different than other building ordinance that we have in place which is permit, build, inspect. This ongoing administrative ask for this and we need to make sure that in structure we are set up to do this administratively and in law.

Councilors Plan Special Meeting to continue discussion for Ordinance on Carbon Fee – August 1st, 5PM in the Bushor Conference Room at City Hall.

Item ends 6:51 PM

6. ~~**Sewer Main Update**~~
    - ~~Norm Baldwin~~
    - ~~15 minutes~~
7. ~~**Director's Report**~~
8. **Councilors' Update**

Councilors attending forest tours with foresters following McNeil Symposium.

Chair Barlow – Airport coming to August meeting for VTANG. Nic Longo to attend.
Still have a pending resolution at Council level on roundabout commemoration.

Item closes 6:54PM

9. **Next Regular Meeting 8/22/23**

Next Special Meeting for Ordinance on Carbon Fee – August 1st, 5PM in the Bushor Conference Room at City Hall.

10. **Champlain Parkway Walkthrough**
    - Corey Mims
    - 45 minutes

Corey Mims (City's Project Manager) and Ken Robie (Municipal Project Manager with Dubois and King) lead walkthrough starting at 645 Pine and then heading down Pine St.

11. Adjourn

Councilor Bergman moves to adjourn. Councilor King seconds. 8PM meeting adjourns.