

Health Impacts and Considerations for the Clean Heat Standard

Relevant Language from CHS Statute

- § 8121. INTENT
Pursuant to 2 V.S.A. § 205(a), it is the intent of the General Assembly that the Clean Heat Standard be designed and implemented in a manner that achieves Vermont's thermal sector greenhouse gas emissions reductions necessary to meet the requirements of 10 V.S.A. § 578(a)(2) and (3), minimizes costs to customers, protects public health, and recognizes that affordable heating is essential for Vermonters. It shall enhance social equity by prioritizing customers with low income and moderate income and those households with the highest energy burdens. The Clean Heat Standard shall, to the greatest extent possible, maximize the use of available federal funds to deliver clean heat measures.
- § 8127. TRADEABLE CLEAN HEAT CREDITS
(h) Review of consequences: The Commission shall biennially assess harmful consequences that may arise in Vermont or elsewhere from the implementation of specific types of clean heat measures and shall set standards or limits to prevent those consequences. Such consequences shall include environmental burdens as defined in 3 V.S.A. § 6002, public health, deforestation or forest degradation, conversion of grasslands, increased emissions of criteria pollutants, damage to watersheds, or the creation of new methane to meet fuel demand.
- § 8128. CLEAN HEAT STANDARD TECHNICAL ADVISORY GROUP
(a) The Commission shall establish the Clean Heat Standard Technical Advisory Group (TAG) to assist the Commission in the ongoing management of the Clean Heat Standard. Its duties shall include:
 - (3) Periodically assessing and reporting to the Commission on the sustainability of the production of clean heat measures by considering factors including greenhouse gas emissions; carbon sequestration and storage; human health impacts; land use changes; ecological and biodiversity impacts; groundwater and surface water impacts; air, water, and soil pollution; and impacts on food costs.
 - (8) calculating the savings associated with public health benefits due to clean heat measures.

Questions for TAG Consideration

1. If the TAG is required to “periodically” assess and report to the Commission on the sustainability of the production of clean heat measures, on what cadence should this occur? Should it be done biennially to meet the requirement for the Commission to biennially assess harmful consequences?
2. Should the first review of consequences occur prior to implementation of the CHS to inform the Commission, so it can set standards or limits to prevent harmful consequences? For example, if certain potential clean heat measures are determined to have high risks of negative consequences for human health or the environment, could they be screened out upfront?
3. What additional information regarding potential public health impacts would be helpful? What form should that information take? What (if any) formal decisions should the TAG make related to public health considerations and their application in this process? Doing a systematic and quantifiable analysis of health impacts seems beyond the capacity of the TAG to take on directly without dedicated consultant support. The available scientific evidence may also not support such an analysis, particularly for emerging fuels and technologies.
4. There is fairly solid information on the human health impacts of various clean heat measures, as detailed below. It’s less clear how to evaluate environmental impacts and impacts on food costs for clean heat measures. How should the TAG assess carbon sequestration and storage, land use changes, ecological and biodiversity impacts, impacts on groundwater and surface water, and water and soil pollution? What about impacts on food costs?

Initial Review of Public Health Impacts of Clean Heat Measures

This section provides a high-level summary of potential human health impacts and considerations for several groupings of clean heat measures, based on a non-exhaustive review of peer-reviewed scientific evidence. It also notes the degree of confidence in the conclusions based on the availability of scientific literature on related human health impacts. Unless otherwise noted, the focus of this analysis was on health impacts relating to end use at a residence, not to impacts from upstream in the life cycle.

Home weatherization (positive health benefits, high confidence)

- Reduced combustion emissions; improved temperature control and indoor air quality; reduced humidity, mold, and pest intrusion; money saved on fuel often directly supports better health; opportunities for other health and safety improvements.
 - [OEO estimated in 2024](#) an average household savings of \$1,026 per year from reduced fuel demand.
 - [VDH estimated in 2018](#) \$1,302 per year in public health savings per year from reduced outdoor air emissions and reduced resident impacts from cold, heat, and asthma.
- Need to ensure sufficient ventilation and treatment of indoor air pollutants after weatherization.

Electric heating and appliances (positive health benefits, high confidence)

- Compared to conventional liquid or solid heating fuels: avoided combustion emissions; avoided indoor exposure to nitrogen dioxide and other air toxics ([particularly from gas cook stoves](#)); avoided risk of carbon monoxide poisoning.
- Heat pumps provide health co-benefits such as increasingly necessary air conditioning and dehumidification.

Wood heating (negative health benefits, high confidence)

- Residential wood heating emits substantially more fine particulate matter and air toxics than other non-woody residential fuels. Fine particulate matter (PM_{2.5}) is a critical pollutant of concern due to decades of research establishing significant associations with human mortality and morbidity.
 - This is true for all wood fuel types and heating equipment, though there is a spectrum from most -> least polluting per heat output (uncertified wood stove -> EPA-certified wood stove (nuncatalytic) -> EPA certified wood stove (catalytic/hybrid) -> pellet stove or boiler). There is a wide range of other whole-house wood-fueled systems (boilers or furnaces using cordwood or wood chips) that are hard to place in this spectrum due to a lack of scientific emissions data.
- From 2022 VDH analysis using EPA Co-Benefits Risk Assessment (COBRA) tool:
 - 97% of the monetizable health impact from residential heating emissions in Vermont is attributable to wood fuel combustion.
 - Monetizable health impact of residential wood heating in Vermont is \$105M-\$238M (about 30x greater than for all other residential fuels combined).
 - Pollution from wood heating is associated with 10-22 early deaths (about 20x greater than for other residential fuels).

- Cancer risk from wood heating pollution is 2.5 per million (about 20x greater than for other residential fuels).
- Replacing fossil fueled heating with wood heating, especially cordwood, would likely have a harmful impact on human health as a result of increased air pollution emissions. The magnitude depends on what type of wood heating equipment is used and what is being replaced.
 - Replacing cordwood stoves and boilers with pellet stoves or boilers has the potential to provide a substantial public health benefit. Pellet stoves are very low emitting for everything except trace metals of health concern (Pb, Cd, As). In general, emissions from pellet heating systems are a much lower concern than cordwood emissions with respect to health impacts. Compared to cordwood emissions, pellet emissions have very low particulate matter, black carbon, volatile organics (including carcinogenic VOCs), and de minimus polycyclic aromatic hydrocarbons (PAHs).
- Manually operated wood stoves can continue providing heat in the event of power loss.

Biofuels and hydrogen (mixed findings, low confidence due to limited research available)

- Research on air quality and health impacts of liquid biofuels is limited. Most of that limited research is focused on analyzing biofuels v. conventional transportation fuels (diesel or gasoline). Findings differ by characteristics of the biofuel (e.g., feedstock, blend), engine type, consideration of part or all of the lifecycle impacts, etc.
- Some fairly consistent findings across the review literature include:
 - Health benefits of biofuels compared to conventional fuels include reduced particulate matter and carbon monoxide.
 - Negative health impacts of biofuels compared to conventional fuels include increased nitrogen oxides, sulfur dioxide, formaldehyde, and overall toxicity.
 - Mixed findings about polycyclic aromatic hydrocarbons (PAHs).
 - Health impacts are typically more of a concern with biofuel blends >20%.
- Research on air quality and health impacts of hydrogen fuels is extremely limited.
 - Combustion of hydrogen alone or hydrogen blended into natural gas generates more nitrogen oxide emissions than natural gas alone.
 - Other concerns seem to be related to the method of production, with harmful health effects associated with fossil-fueled production methods.
- If possible, outside expertise could help clarify health concerns related to biofuels and hydrogen.

Other considerations

- Equity considerations: Ensuring equitable access to health benefits and protection from health harms.
- Lifecycle impacts: Extraction, production, transportation, etc. impacts on emissions, environmental health; impacts related with upstream electricity generation.
- Fuel/technology used for backup power: For example, battery backup versus fossil-fueled generator.
 - Accidental CO poisoning has caused about 50 ED visits / year and 1-2 deaths / year in Vermont over the past 10 years. Common causes of accidental CO poisoning include improper generator use or the malfunction or improper use of heating equipment, cooking equipment, or other combustion-fueled appliances.

Key references

A list of references used to inform the above summary is provided below. The literature review was not exhaustive but focused strategically on reviewing the highest-quality scientific evidence related to areas of most concern and/or uncertainty. For some articles, the full-text article was not readily accessible but the abstract provided some insights.

When reviewing scientific evidence, not all published evidence carries equal weight. The strongest evidence is usually found in articles documenting a systematic and critical review and synthesis of published studies about a topic, with the article further reviewed and critiqued by scientific peers before publication. When many high-quality published studies draw similar conclusions, it increases confidence that the conclusions are valid. Contradictory findings or simply a lack of high-quality studies reduces confidence in the conclusions from individual studies. The strength of individual studies can vary widely based on the source, research methods, whether scientific peer-review occurred before publication, and other factors. For an overview of considerations when evaluating scientific evidence, see:

- [Can science help people make decisions? | National Academies](#)
- [How to Evaluate Trustworthiness in Science | National Institutes of Health \(NIH\)](#)
- [Sources of Evidence - Evidence-Based Public Health - Research Guides at University of Alabama - Birmingham \(uab.edu\)](#)

References

- Home weatherization
 - [ENV_CH_WxHealthReport.pdf \(healthvermont.gov\)](#) - 2018 Vermont Department of Health synthesis of scientific evidence describing health impacts of home weatherization. More recent studies below:
 - [Cascading benefits of low-income weatherization upon health and household well-being - ScienceDirect](#)
 - [Saving lives by saving energy? Examining the health benefits of energy efficiency in multifamily buildings in the United States - ScienceDirect](#)
 - [Health and financial benefits of weatherizing low-income homes in the southeastern United States - ScienceDirect](#)
 - [A dollar well spent: Monetizing the societal benefits of low-income weatherization programs in the United States - ScienceDirect](#)
- Electrification
 - [Heat pumps and our low-carbon future: A comprehensive review - ScienceDirect](#)
 - [Residential home heating: The potential for air source heat pump technologies as an alternative to solid and liquid fuels - ScienceDirect](#)
 - [US residential heat pumps: the private economic potential and its emissions, health, and grid impacts - IOPscience](#)
 - [Methane and NOx Emissions from Natural Gas Stoves, Cooktops, and Ovens in Residential Homes | Environmental Science & Technology \(acs.org\)](#)
 - [Population Attributable Fraction of Gas Stoves and Childhood Asthma in the United States \(mdpi.com\)](#)

- [Gas Stoves and Respiratory Health: Decades of Data, but Not Enough Progress | Annals of the American Thoracic Society \(atsjournals.org\)](#)
- Wood heating
 - [Criteria, Greenhouse Gas, and Hazardous Air Pollutant Emissions Factors from Residential Cordwood and Pellet Stoves Using an Integrated Duty Cycle Test Protocol | ACS ES&T Air](#)
 - [Particulate matter emission control from small residential boilers after biomass combustion. A review - ScienceDirect](#)
 - [Full article: Introduction to Special Issue on Residential Wood Combustion \(tandfonline.com\)](#)
 - [An overview of particulate emissions from residential biomass combustion - ScienceDirect](#)
 - [Full article: Residential wood heating: An overview of U.S. impacts and regulations \(tandfonline.com\)](#)
 - [Full article: Online measurement of PM from residential wood heaters in a dilution tunnel \(tandfonline.com\)](#)
 - [Full article: Impacts of wood species and moisture content on emissions from residential wood heaters \(tandfonline.com\)](#)
 - [An overview of particulate emissions from residential biomass combustion - ScienceDirect](#)
 - [Emission factors from small scale appliances burning wood and pellets - ScienceDirect](#)
 - [Toward the ultra-clean and highly efficient biomass-fired heaters. A review - ScienceDirect](#)
 - [Estimating State-Specific Contributions to PM_{2.5}- and O₃-Related Health Burden from Residential Combustion and Electricity Generating Unit Emissions in the United States - PubMed \(nih.gov\)](#)
 - [Air pollution and early deaths in the United States. Part I: Quantifying the impact of major sectors in 2005 - ScienceDirect](#)
 - [Indoor wood-burning from stoves and fireplaces and incident lung cancer among Sister Study participants - ScienceDirect](#)
 - [Fine particulate air pollution and human mortality: 25+ years of cohort studies - ScienceDirect](#)
 - [Woodsmoke Health Effects: A Review: Inhalation Toxicology: Vol 19 , No 1 - Get Access \(tandfonline.com\)](#)
 - [Review: Woodsmoke and emerging issues - ScienceDirect](#)
- Biofuels
 - [Biodiesel Emissions: A State-of-the-Art Review on Health and Environmental Impacts \(mdpi.com\)](#)
 - [Health effects of soy-biodiesel emissions: mutagenicity-emission factors*: Inhalation Toxicology: Vol 27, No 11 \(tandfonline.com\)](#)
 - [A Human Health Toxicity Assessment of Biogas Engines Regulated and Unregulated Emissions \(mdpi.com\)](#)
 - [Health impacts of liquid biofuel production and use: A review - ScienceDirect](#)
 - [Performance and emissions of biodiesel in a boiler for residential heating - ScienceDirect](#)

- [Fuel effects on PAH formation, toxicity and regulated pollutants: Detailed comparison of biodiesel blends with propanol, butanol and pentanol - ScienceDirect](#)
- [Technological, technical, economic, environmental, social, human health risk, toxicological and policy considerations of biodiesel production and use - ScienceDirect](#)
- [Biodiesel versus diesel exposure: enhanced pulmonary inflammation, oxidative stress, and differential morphological changes in the mouse lung - PubMed \(nih.gov\)](#)
- [Climate change and health costs of air emissions from biofuels and gasoline | PNAS](#)
- [Re-assessing the toxicity of particles from biodiesel combustion: A quantitative analysis of in vitro studies - ScienceDirect](#)
- [Biodiesel exhaust particle airway toxicity and the role of polycyclic aromatic hydrocarbons - ScienceDirect](#)
- [Environmental sustainability of biofuels: a review | Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences \(royalsocietypublishing.org\)](#)
- [Biodiesel fuels: A greener diesel? A review from a health perspective - ScienceDirect](#)
- [Evaluation of Particulate Matter \(PM\) Emissions from Combustion of Selected Types of Rapeseed Biofuels \(mdpi.com\)](#)
- [Public health benefits of strategies to reduce greenhouse-gas emissions: household energy - The Lancet](#)
- [The impacts of different heating systems on the environment: A review - ScienceDirect](#)
- [Biofuels and the Environment: Third Triennial Report to Congress \(External Review Draft\) | Biofuels | US EPA](#)
- [Effect of biodiesel fuel on “real-world”, nonroad heavy duty diesel engine particulate matter emissions, composition and cytotoxicity - ScienceDirect](#)
- [Characterization and comparison of oxidative potential of real-world biodiesel and petroleum diesel particulate matter emitted from a nonroad heavy duty diesel engine - ScienceDirect](#)
- [Breathing easier? The known impacts of biodiesel on air quality. - Abstract - Europe PMC](#)
- [Trinity-v2-Final-Report-.pdf \(cleanfuels.org\)](#) (shared by Floyd)
- Hydrogen fuel
 - [Analysis of NOx Formation in a Hydrogen-Fueled Gas Turbine Engine | J. Eng. Gas Turbines Power | ASME Digital Collection](#)
 - [Investigations on performance and emission characteristics of an industrial low swirl burner while burning natural gas, methane, hydrogen-enriched natural gas and hydrogen as fuels - ScienceDirect](#)