A close-up of a building

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Vermont Clean Heat Standard

Fuel Measure Characterizations

September 9, 2024

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# Measure Characterizations - Fuel Measures

## Liquid and Gaseous Fuels

### Gaseous Hydrogen from Dedicated Renewables

**CHS Measure ID:** ALL\_FUEL\_HYD

**Market Sector:** All

**End Use:** Alternative Fuels

**Applicable Building Types:** All

**Decarbonization Pathways:** Alternative Fuels

**Applicable Feedstocks:** Gaseous hydrogen from dedicated renewables

#### Measure Description

This measure involves the replacement of gaseous hydrogen produced through steam-methane reforming (SMR) without carbon capture and sequestration, commonly referred to as grey hydrogen, used in the thermal sector with gaseous hydrogen produced through electrolysis powered from dedicated renewables, commonly referred to as “green hydrogen.” Hydrogen produced through SMR or electrolysis are chemically identical and can be directly substituted for one another in thermal enduses; this measure assumes that the green hydrogen is used as a drop-in replacement for an existing use of grey hydrogen.

This measure characterizes gaseous green hydrogen produced through polymer electrolyte membrane (PEM) electrolysis at a centralized plant. This measure does not characterize the liquid forms of grey and green hydrogen, which must undergo additional energy and carbon intensive steps in production, including liquefaction and cryogenic storage, and is susceptible to boil-off of hydrogen during transport and storage.

Greenhouse gas reductions associated with this measure are derived from the difference in carbon intensity values (gCO2e/MJ) between SMR-produced gaseous hydrogen and gaseous green hydrogen.

**Baseline Conditions**

The baseline condition is the use of gaseous grey hydrogen produced through SMR in the thermal sector that is delivered to the end-user through truck delivery. Other baseline conditions are not characterized for this measure.

**Proposed Conditions**

The proposed condition is the use of gaseous green hydrogen used in the thermal sector that is distributed to end users through a truck delivery service. Green hydrogen production pathways (and therefore carbon intensity values) include feedstock collection, fuel production, and transport of fuels to distributors. Emissions resulting from the distribution of fuels from the distributor to the end user are presumed equal between the proposed and baseline conditions since truck delivery is assumed in both.

#### Eligibility Criteria

This measure characterizes gaseous hydrogen used in the thermal sector under a certain set of conditions. Specifically:

* The carbon intensity value for green hydrogen is characterized for PEM electrolysis using dedicated renewables as the energy source. Other pathways, such as nuclear-powered electrolysis are not eligible for this measure.

This measure does not characterize the use of hydrogen in the thermal sector that does not meet this above condition.

Certain uses of hydrogen are not eligible for clean heat credits:

* Hydrogen distributed to an electricity generating unit (EGU) is not part of the thermal sector and therefore is not eligible for clean heat credits.
* Hydrogen distributed to an industrial facility must be verified as being used in the thermal sector. Hydrogen itself used as a material feedstock in production of a good or otherwise used outside of the thermal sector is ineligible for clean heat credits.

#### Decarbonization Summary

Table 1 provides the estimated 2025 decarbonization range for replacement of grey hydrogen with green hydrogen under varying blends of green and conventional hydrogen. These estimates are not inclusive of all eligible conditions; other conditions may be calculated from the algorithms herein.

Table 1. Green Hydrogen CO2e Reductions

| Portion of Green Hydrogen in Delivered Hydrogen | CO2e Reduction per Kilogram [gCO2e/kg] in 2025 |
| --- | --- |
| 20% Green Hydrogen | 2,036 |
| 40% Green Hydrogen | 4,072 |
| 60% Green Hydrogen | 6,108 |
| 80% Green Hydrogen | 8,143 |
| 100% Green Hydrogen | 10,179 |

#### Decarbonization and Energy Impacts Algorithms

CO2e (g CO2e) =

CIbase = Grey hydrogen carbon intensity value (gCO2e/MJ). Varies by year; see <EMISSIONS SCHEDULE> in <FRONT MATTER SECTION>.

CIprop = Green hydrogen carbon intensity value (gCO2e/MJ). Varies by year; see <EMISSIONS SCHEDULE> in <FRONT MATTER SECTION>. If a blend of green and grey hydrogen is used, calculate the correct CIprop using the following formula.

CIprop =

%GH2 = The percentage of green hydrogen, by volume, within the delivered fuel.

CIGH2 = The carbon intensity value for green hydrogen.

CICH2 = The carbon intensity value for grey hydrogen.

Ε = The total energy of the hydrogen delivered to the end-user in units of megajoules (MJ).

##### Energy Impacts Algorithms

E =

**Input Variable Definitions**

Wdelivered = The total weight of gaseous hydrogen that is delivered to the end-user in kilograms.

LHV = Lower Heating Value of the hydrogen in units of MJ/kg. Grey and green hydrogen have the same LHV, 129.48 MJ/kg.[[1]](#footnote-1)

**Measure Life**

Green hydrogen is not subject to a measure life, as the measure characterization is based on the weight of hydrogen that is delivered to an end-user and used in the thermal sector.

**Measure Cost**

The incremental cost of green hydrogen over grey hydrogen. Use actual costs.

#### Program Data Tracking Recommendations

The key input variables for this measure are the following:

* Weight of delivered hydrogen gas to the end user
* Percentage of green hydrogen in total delivered hydrogen, by weight

#### Energy Codes and Standards

None.

### Biomethane

**CHS Measure ID:** ALL\_FUEL\_BMN

**Market Sector:** All

**End Use:** Alternative Fuels

**Applicable Building Types:** All

**Decarbonization Pathways:** Alternative Fuels

**Applicable Feedstocks:** Animal waste, landfill gas, wastewater treatment plant sludge, and fats, oils, and greases

#### Measure Description

This measure involves the replacement of natural gas used in the thermal sector with biomethane. Biomethane, also known as renewable natural gas, is biogas that has been upgraded to be fully interchangeable with fossil natural gas. Biomethane can be directly substituted for fossil natural gas in thermal enduses; this measure assumes that biomethane is used as a drop-in replacement for an existing thermal use of natural gas.

This measure characterizes four distinct pathways for the production of biomethane from waste products (animal waste, landfill gas, wastewater treatment plant sludge, and fats, oils, and greases). Greenhouse gas reductions associated with this measure are derived from the difference in carbon intensity values (gCO2e/MJ) between natural gas and biomethane.

Biomethane production pathways (and therefore carbon intensity values) include feedstock collection, fuel production, and transport of fuels to distributors. The distribution of fuels from the distributor to the end user is accounted for in the Decarbonization and Energy Impacts Algorithms.

**Baseline Conditions**

The baseline condition is the use of natural gas in the thermal sector that is delivered to the end-user through the Vermont natural gas distribution system.

**Proposed Conditions**

The proposed condition is the use of biomethane in the thermal sector that is delivered to the end-user through the Vermont natural gas distribution system.

#### Eligibility Criteria

This measure characterizes biomethane used in the thermal sector under a certain set of conditions. Specifically:

* Biomethane carbon intensity values are characterized for production pathways that reside within the continental United States. Finished biomethane or feedstocks used in production of biomethane that are imported from outside the continental United States are not eligible for this measure.
* Biomethane feedstocks not listed as one of the characterized pathways are not eligible for this measure.
* For biomethane to be eligible for this measure, it must be distributed to an end user through the Vermont natural gas distribution system. Biomethane distributed through other channels is not eligible for this measure.

This measure does not characterize the use of biomethane in the thermal sector that does not meet these above conditions.

Certain uses of biomethane are not eligible for clean heat credits:

* Biomethane distributed to an electricity generating unit (EGU) is not part of the thermal sector and therefore is not eligible for clean heat credits.
* Biomethane distributed to an industrial facility must be verified as being used in the thermal sector. Biomethane itself used as a material feedstock in production of a good or otherwise used outside of the thermal sector is ineligible for clean heat credits.

#### Decarbonization Summary

Table 2 provides the estimated 2025 decarbonization range for the proportional replacement of natural gas with biomethane in the Vermont natural gas distribution system from each of the four characterized feedstocks under varying proportionality. These estimates are not inclusive of all eligible conditions; other conditions may be calculated from the algorithms herein (e.g., natural gas proportionally replaced with biomethane from a mix of pathways).

Table 2. Biomethane CO2e Reductions

| Portion of Biomethane in Distribution System | CO2e Reduction per 100 Cubic Feet [gCO2e/CCF] in 2025 by Fuel Pathway | | | |
| --- | --- | --- | --- | --- |
| Animal Waste | Landfill Gas | Wastewater Treatment Plant Sludge | Fats, Oils, and Greases |
| 20% Biomethane | 1,010 | 1,182 | 541 | 778 |
| 40% Biomethane | 2,020 | 2,365 | 1,082 | 1,556 |
| 60% Biomethane | 3,030 | 3,547 | 1,624 | 2,334 |
| 80% Biomethane | 4,040 | 4,729 | 2,165 | 3,112 |
| 100% Biomethane | 5,051 | 5,911 | 2,706 | 3,890 |

#### Decarbonization and Energy Impacts Algorithms

CO2e (gCO2e) =

CIbase = Natural gas carbon intensity value (gCO2e/MJ). Varies by year; see <EMISSIONS SCHEDULE> in <FRONT MATTER SECTION>.

CIprop = Biomethane carbon intensity value (gCO2e/MJ), based on fuel pathway. Varies by year; see <EMISSIONS SCHEDULE> in <FRONT MATTER SECTION>. If a blend of biomethane from various pathways is used, then develop a weighted average by volume.

Ε = The total energy of the biomethane delivered to the end-user in megajoules.

##### Energy Impacts Algorithms

E =

**Input Variable Definitions**

Vdelivered = The total volume of gas that is delivered to the end-user in units of 100 cubic feet.

% Thermal = Share of gas used in the thermal sector. For residential and commercial applications, assume 100%. For industrial applications, assume 68%.[[2]](#footnote-2)

PRNG = The portion of gas that is biomethane (defined as a percentage by volume of all gas in the distribution system).

LHV = Lower Heating Value of the fuel in units of MJ/CCF. Natural gas and biomethane have the same LHV, 103.71 MJ/CCF.[[3]](#footnote-3)

PLL = Pipeline loss factor, 0.09%[[4]](#footnote-4)

**Measure Life**

Biomethane as a clean heat measure is not subject to a measure life, as the measure characterization is based on the volume of biomethane that is delivered to an end-user and used in the thermal sector.

**Measure Cost**

The incremental cost of biomethane over natural gas. Use actual costs.

#### Program Data Tracking Recommendations

The key input variables for this measure are the following:

* Volume of delivered gas to the end-user
* Share of delivered gas that is used in the thermal sector
* Percentage of biomethane in the Vermont natural gas distribution system

#### Energy Codes and Standards

None.

### Biodiesel

**CHS Measure ID:** ALL\_FUEL\_BD

**Market Sector:** All

**End Use:** Alternative Fuels

**Applicable Building Types:** All

**Decarbonization Pathways:** Alternative Fuels

**Applicable Feedstocks:** Soybeans, canola, corn, and used cooking oil

#### Measure Description

This measure involves the replacement of fuel oil #2 used in the thermal sector with biodiesel. Biodiesel is a liquid renewable fuel manufactured through the transesterification of biological feedstocks such as vegetable oils.[[5]](#footnote-5) This measure assumes that biodiesel is used as a drop-in replacement for an existing thermal use of fuel oil #2. While this measure assumes that biodiesel is used as a drop-in replacement, it is important to note that biodiesel is chemically different from fuel oil #2 and exhibits a number of different characteristics that mean it is not necessarily possible to use biodiesel as a drop-in replacement in all cases without additional steps.[[6]](#footnote-6) Replacement of fuel oil #2 with pure biodiesel may require equipment modifications; biodiesel can be blended with fuel oil #2 at various concentrations, and certain concentrations may not require equipment modifications.

This measure characterizes four distinct pathways for the production of biodiesel: three pathways for biodiesel from purpose-grown crops (soybeans, canola, and corn) as well as one biodiesel pathway from a waste product (used cooking oil).

Greenhouse gas reductions associated with this measure are derived from the difference in carbon intensity values (gCO2e/MJ) between fuel oil #2 and biodiesel.

**Baseline Conditions**

The baseline condition is the use of fuel oil #2 in the thermal sector that is distributed to end users through a truck delivery service.

**Proposed Conditions**

The proposed condition is the use of biodiesel in the thermal sector that is distributed to end users through a truck delivery service. Biodiesel production pathways (and therefore carbon intensity values) include farming activities, crop applications (e.g., pesticides, herbicides, and fertilizers), feedstock collection, fuel production, and transport of fuels to distributors. The production pathways exclude impacts relating to land use changes and the biogenic carbon cycle. Emissions resulting from the distribution of fuels from the distributor to the end user are presumed equal between the proposed and baseline conditions since truck delivery is assumed in both.

#### Eligibility Criteria

This measure characterizes biodiesel used in the thermal sector under a certain set of conditions. Specifically:

* Biodiesel carbon intensity values are characterized for production pathways that reside within the continental United States. Finished biodiesel or feedstocks used in production of biodiesel that are imported from outside the continental United States are not eligible for this measure.
* Biodiesel feedstocks not listed as one of the characterized pathways are not eligible for this measure.
* For biodiesel to be eligible for this measure, it must be distributed to an end user through a truck delivery service. Biodiesel distributed through other channels is not eligible for this measure.

Certain uses of biodiesel are not eligible for clean heat credits:

* Biodiesel used for electrical generation is not eligible.
* Biodiesel distributed to an industrial facility should be verified as being used in process or space heating. Biodiesel used as a material feedstock in production of a good or otherwise not used as a heating fuel is ineligible for this measure.

#### Decarbonization Summary

Table 3 provides the estimated 2025 decarbonization range for replacement of fuel oil #2 with biodiesel from each of the four characterized feedstocks under varying proportionality. These estimates are not inclusive of all eligible conditions; other conditions may be calculated from the algorithms herein.

Table 3. Biodiesel CO2e Reductions

| Biodiesel Blend | CO2e Reduction per Gallon [gCO2e/gallon] in 2025 by Fuel Pathway | | | |
| --- | --- | --- | --- | --- |
| Soybeans | Canola | Corn | Used Cooking Oil |
| 20% Biodiesel (B20) | 1,537 | 1,550 | 1,981 | 1,849 |
| 40% Biodiesel (B40) | 3,032 | 3,057 | 3,907 | 3,646 |
| 60% Biodiesel (B60) | 4,484 | 4,521 | 5,778 | 5,391 |
| 80% Biodiesel (B80) | 5,893 | 5,941 | 7,594 | 7,086 |
| 100% Biodiesel (B100) | 7,259 | 7,319 | 9,354 | 8,728 |

#### Decarbonization and Energy Impacts Algorithms

CO2e (gCO2e) =

CIbase = Fuel oil #2 carbon intensity value (gCO2e/MJ). Varies by year; see <EMISSIONS SCHEDULE> in <FRONT MATTER SECTION>.

CIprop = Biodiesel carbon intensity value (gCO2e/MJ), based on fuel pathway. Varies by year; see <EMISSIONS SCHEDULE> in <FRONT MATTER SECTION>. If a blend of biodiesel from various pathways is used, then develop a weighted average by volume. If a biodiesel blend (e.g., B20 – 20% biodiesel and 80% fuel oil #2) is used, refer to Table 4 for the appropriate CIprop. If the delivered biodiesel blend is not shown, calculate the correct CIprop using the following formula.

CIprop =

%BD = The percentage of biodiesel, by volume, within the fuel.

CIBD100 = The carbon intensity value for 100% biodiesel.

Ε = The total energy of the biodiesel delivered to the end-user in megajoules.

##### Energy Impacts Algorithms

E =

**Input Variable Definitions**

VBD = The total volume of biodiesel that is delivered to the end-user in gallons.

LHVBD = Lower Heating Value of biodiesel in units of MJ/gallon.[[7]](#footnote-7) Refer to Table 4 for the appropriate LHV for the biodiesel blend delivered to the end user. If the delivered biodiesel blend is not shown, calculate the correct LHVBD using the following formula.

LHVBD =

LHVBD100 = Lower Heating Value of a 100% biodiesel fuel, 126.21 MJ/gal.

LHVoil = Lower Heating Value of fuel oil #2, 135.52 MJ/gal.

Table 4. Lower Heating Values and Carbon Intensity Values for Biodiesel Blends

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Biodiesel Blend | LHVBD [MJ/gal] | 2025 Carbon Intensity Values [gCO2e/MJ] | | | |
| All BD fuels | Soybeans | Canola | Corn | Used Cooking Oil |
| 20% Biodiesel (B2O) | 133.66 | 72.0 | 71.9 | 68.6 | 69.6 |
| 40% Biodiesel (B40) | 131.80 | 60.5 | 60.3 | 53.8 | 55.8 |
| 60% Biodiesel (B60) | 129.93 | 49.0 | 48.7 | 39.0 | 42.0 |
| 80% Biodiesel (B80) | 128.07 | 37.5 | 37.1 | 24.2 | 28.1 |
| 100% Biodiesel (B100) | 126.21 | 25.9 | 25.5 | 9.3 | 14.3 |

**Measure Life**

Biodiesel as a clean heat measure is not subject to a measure life, as the measure characterization is based on the volume of biodiesel that is delivered to an end-user and used in the thermal sector.

**Measure Cost**

The incremental cost of biodiesel over fuel oil #2. Use actual costs.

#### Program Data Tracking Recommendations

The key input variables for this measure are the following:

* Volume of delivered biodiesel to the end-user
* Share of delivered biodiesel that is used in the thermal sector

#### Energy Codes and Standards

None.

### Renewable Diesel

**CHS Measure ID:** ALL\_FUEL\_RD

**Market Sector:** All

**End Use:** Alternative Fuels

**Applicable Building Types:** All

**Decarbonization Pathways:** Alternative Fuels

**Applicable Feedstocks:** Soybeans, canola, corn, and used cooking oil

#### Measure Description

This measure involves the replacement of fuel oil #2 used in the thermal sector with renewable diesel. Renewable diesel is a liquid renewable fuel manufactured from biological feedstocks such as vegetable oils through any one of a number of different technology pathways.[[8]](#footnote-8) Renewable diesel is distinct from biodiesel and is chemically similar (though not identical) to fuel oil #2; renewable diesel is generally considered to be fully interchangeable with fuel oil #2,[[9]](#footnote-9) and this measure assumes that renewable diesel is used as a drop-in replacement for an existing thermal use of fuel oil #2.

The measure characterizes four distinct pathways for the production of renewable diesel: three pathways for renewable diesel from purpose-grown crops (soybeans, canola, and corn) as well as one renewable diesel pathway from a waste product (used cooking oil). Greenhouse gas reductions associated with this measure are derived from the difference in lifecycle emission intensities (gCO2e/MJ) between fuel oil #2 and renewable diesel.

**Baseline Conditions**

The baseline condition is the use of fuel oil #2 in the thermal sector that is distributed to end users through a truck delivery service.

**Proposed Conditions**

The proposed condition is the use of renewable diesel in the thermal sector that is distributed to end users through a truck delivery service. Renewable diesel production pathways (and therefore carbon intensity values) include farming activities, crop applications (e.g., pesticides, herbicides, and fertilizers), feedstock collection, fuel production, and transport of fuels to distributors. The production pathways exclude impacts relating to land use changes and the biogenic carbon cycle. Emissions resulting from the distribution of fuels from the distributor to the end user are presumed equal between the proposed and baseline conditions since truck delivery is assumed in both.

#### Eligibility Criteria

This measure characterizes renewable diesel used in the thermal sector under a certain set of conditions. Specifically:

* Renewable diesel carbon intensity values are characterized for production pathways that reside within the continental United States. Finished renewable diesel or feedstocks used in production of renewable diesel that are imported from outside the continental United States are not eligible for this measure.
* Renewable diesel feedstocks not listed as one of the characterized pathways are not eligible for this measure.
* For renewable diesel to be eligible for this measure, it must be distributed to an end user through a truck delivery service. Renewable diesel distributed through other channels is not eligible for this measure.

Certain uses of renewable diesel are not eligible for clean heat credits:

* Renewable diesel used for electrical generation is not eligible.
* Renewable diesel distributed to an industrial facility should be verified as being used in process or space heating. Renewable diesel used as a material feedstock in production of a good or otherwise not used as a heating fuel is ineligible for this measure.

#### Decarbonization Summary

Table 5 provides the estimated 2025 decarbonization range for replacement of fuel oil #2 with renewable diesel from each of the four characterized feedstocks. These estimates are not inclusive of all eligible conditions; other conditions may be calculated from the algorithms herein.

Table 5. Renewable Diesel CO2e Reductions

|  | CO2e Reduction per Gallon [gCO2e/gallon] in 2025 by Fuel Pathway | | | |
| --- | --- | --- | --- | --- |
| Soybeans | Canola | Corn | Used Cooking Oil |
| Renewable Diesel | 6,652 | 6,688 | 9,291 | 8,583 |

#### Decarbonization and Energy Impacts Algorithms

CO2e (gCO2e) =

CIbase = Fuel oil #2 carbon intensity value (gCO2e/MJ). Varies by year; see <EMISSIONS SCHEDULE> in <FRONT MATTER SECTION>.

CIprop = Renewable diesel carbon intensity value (gCO2e/MJ), based on fuel pathway. Varies by year; see <EMISSIONS SCHEDULE> in <FRONT MATTER SECTION>. If a blend of renewable diesel from various pathways is used, then develop a weighted average by volume.

Ε = The total energy of the renewable diesel delivered to the end-user in megajoules.

##### Energy Impacts Algorithms

E =

**Input Variable Definitions**

VRD = The total volume of renewable diesel that is delivered to the end-user in gallons.

LHVRD = Lower Heating Value of renewable diesel in units of MJ/gallon, 129.65 MJ/gal.[[10]](#footnote-10)

**Measure Life**

Renewable diesel as a clean heat measure is not subject to a measure life, as the measure characterization is based on the volume of renewable diesel that is delivered to an end-user and used in the thermal sector.

**Measure Cost**

The incremental cost of renewable diesel over fuel oil #2. Use actual costs.

#### Program Data Tracking Recommendations

The key input variables for this measure are the following:

* Volume of delivered renewable diesel to the end-user
* Share of renewable diesel that is used in the thermal sector

#### Energy Codes and Standards

None.

## Wood Fuels

### Wood Chips

**CHS Measure ID:** CI\_FUEL\_WCHP

**Market Sector:** Commercial & Industrial

**End Use:** Alternative Fuels

**Applicable Building Types:** C/I, Multifamily

**Decarbonization Pathways:** Alternative Fuels

**Applicable Feedstocks:** Lumber mill wastes

#### Measure Description

This measure involves the replacement of natural gas, propane, or fuel oil #2 used in the commercial or industrial thermal sector with wood chips produced from lumber mill wastes. Wood chips cannot be directly substituted for gaseous or liquid fuels; this measure assumes that the end-user either has the ability to substitute fuels at will (e.g. multiple thermal heating systems) or has made capital investments to replace thermal equipment that uses fossil fuels with thermal equipment that uses wood chips.

Greenhouse gas reductions associated with this measure are derived from the difference in carbon intensity values (gCO2e/MJ) between the baseline heating fuel and wood chips. Due to the likely difficulty of verifying existing fuel usage, this measure allows for the use of a blended baseline carbon intensity value that assumes a default mix of energy sources based on the characteristics of the existing Vermont thermal sector.

**Baseline Conditions**

The baseline condition is the use of natural gas, propane, or fuel oil #2 in the commercial or industrial thermal sector that is delivered to the end-user through the Vermont natural gas distribution system, for natural gas, or a truck delivery service for fuel oil #2 and propane.

**Proposed Conditions**

The proposed condition is the use of wood chips in the thermal sector that are distributed to end users through a truck delivery service. The wood chip production pathway (and therefore carbon intensity value) includes feedstock collection from lumber mill wastes, fuel production, and transport of fuels to distributors. The production pathway excludes impacts relating to land use changes.

For wood fuels, it takes significant time for the regrowth of new trees to fully sequester the biogenic carbon emitted during combustion of wood fuel. A GWPbio factor of 0.32 is applied to CO2 combustion emissions for wood fuels to account for the regrowth period.[[11]](#footnote-11) This factor is embedded in the emission rate schedule in <EMISSIONS SCHEDULE> in <FRONT MATTER SECTION>.

Emissions resulting from the distribution of fuels from the distributor to the end user are presumed equal between the proposed and baseline conditions since truck delivery is assumed in both for propane and fuel oil #2. It is assumed that emissions resulting from natural gas pipeline losses are similar enough to truck delivery emissions that the net difference is negligible.

#### Eligibility Criteria

This measure characterizes wood chips used in the thermal sector under a certain set of conditions. Specifically:

* The carbon intensity value for wood chips is characterized for production pathways that reside within the northeast. Wood chips that are imported from outside the Northeast are not eligible for this measure.[[12]](#footnote-12)

This measure does not characterize the use of wood chips in the thermal sector that does not meet this above condition.

Certain uses of wood chips are not eligible for clean heat credits:

* Wood chips distributed to an electricity generating unit (EGU) are not part of the thermal sector and therefore are not eligible for clean heat credits.
* Wood chips distributed to an industrial facility must be verified as being used in the thermal sector. Wood chips used as a material feedstock in production of a good or otherwise used outside of the thermal sector are ineligible for clean heat credits.

#### Decarbonization Summary

Table 6 provides the estimated 2025 decarbonization range for replacement of natural gas, propane and fuel oil #2 with wood chips. These estimates are not inclusive of all eligible conditions; other conditions may be calculated from the algorithms herein.

Table 6. Wood Chip CO2e Reductions

| Alternative Fuel | Baseline Fuel | Building Type | CO2e Reduction per Short Ton [gCO2e/short ton] in 2025 |
| --- | --- | --- | --- |
| Wood chips | Propane | N/A | 714,330 |
| Fuel oil #2 | N/A | 877,067 |
| Natural gas | N/A | 544,038 |
| Unknown | Commerciala | 575,224 |
| Industrial | 489,981 |

a Commercial includes multifamily common area

#### Decarbonization and Energy Impacts Algorithms

CO2e (gCO2e) =

CIbase = Baseline fuel carbon intensity value (gCO2e/MJ). Varies by fuel and year; see <EMISSIONS SCHEDULE> in <FRONT MATTER SECTION>. If the baseline fuel is unknown, calculate a weighted CIbase using the formula below and the heating fuel mix in Table 7 for the applicable building type and the corresponding baseline fuel carbon intensity value from <EMISSIONS SCHEDULE> in <FRONT MATTER SECTION>.

CIbase =

%FuelOil, etc. = Relative proportion of fuel in Vermont’s thermal sector (see Table 7).

CIfueloil, etc. = Carbon intensity value (gCO2e/MJ) for each fuel, see<EMISSIONS SCHEDULE> in <FRONT MATTER SECTION>.

Table 7. Vermont Primary Heating Fuel Mix, Commercial and Industrial Sectors[[13]](#footnote-13),[[14]](#footnote-14)

|  |  |  |
| --- | --- | --- |
| Heating Fuel | Building Sector | |
| Commerciala | Industrial |
| Fuel oil #2 | 25% | 1% |
| Propane | 0% | 1% |
| Natural gas | 63% | 81% |
| Electricity | 12% | 15% |
| Coal | 0% | 2% |
| a Commercial includes multifamily common area | | |

CIprop = Carbon intensity value for wood chips (gCO2e/MJ). Varies by year; see <EMISSIONS SCHEDULE> in <FRONT MATTER SECTION>.

Ε = The total energy of the wood chips delivered to the end-user in megajoules.

##### Energy Impacts Algorithms

E =

**Input Variable Definitions**

WWCHP = The total weight of wood chips that are delivered to the end-user in short tons.

LHVWP = Lower Heating Value of wood chips in units of MJ/short ton, 16,867.81 MJ/short ton.[[15]](#footnote-15)

**Measure Life**

Wood chips are not subject to a measure life, as the measure characterization is based on the weight of wood chips that are delivered to an end-user and used in the thermal sector.

**Measure Cost**

The incremental cost of wood chips as compared to the baseline fuel. Use actual costs.

#### Program Data Tracking Recommendations

The key input variables for this measure are the following:

* Weight of delivered wood chips to the end user
* The fuel that is displaced by the wood chips

#### Energy Codes and Standards

None

### Wood Pellets

**CHS Measure ID:** RES\_FUEL\_WPEL

**Market Sector:** Residential

**End Use:** Alternative Fuels

**Applicable Building Types:** Single Family, Multifamily

**Decarbonization Pathways:** Alternative Fuels

**Applicable Feedstocks:** Lumber wood, lumber mill residues, lumber mill wastes

#### Measure Description

This measure involves the replacement of natural gas, propane, or fuel oil #2 with wood pellets in the residential thermal sector. Wood pellets cannot be directly substituted for gaseous or liquid fuels; this measure assumes that the end-user either has the ability to substitute fuels at will (e.g. multiple thermal heating systems) or has made capital investments to replace thermal equipment that uses fossil fuels with thermal equipment that uses wood pellets.

This measure assumes wood pellets are produced from a blend of lumber wood, lumber mill residues, and lumber mill wastes. Greenhouse gas reductions associated with this measure are derived from the difference in carbon intensity values (gCO2e/MJ) between the baseline heating fuel and wood pellets. Due to the likely difficulty of verifying existing fuel usage, this measure allows for the use of a blended baseline carbon intensity value that assumes a default mix of energy sources based on the characteristics of the existing Vermont thermal sector.

**Baseline Conditions**

The baseline condition is the use of propane or fuel oil #2 in the residential thermal sector that is delivered to end users through a truck delivery service.

**Proposed Conditions**

The proposed condition is the use of wood pellets that are produced from a blend of lumber wood, lumber mill residues, and lumber mill wastes. The wood pellet production pathway includes feedstock collection of lumber wood and lumber mill residues and wastes, fuel production, and transport of fuels to distributors. The production pathway excludes impacts relating to land use changes.

For wood fuels, it takes significant time for the regrowth of new trees to fully sequester the biogenic carbon emitted during combustion of wood fuel. A GWPbio factor of 0.32 is applied to CO2 combustion emissions for wood fuels to account for the regrowth period.[[16]](#footnote-16) This factor is embedded in the emission rate schedule in <EMISSIONS SCHEDULE> in <FRONT MATTER SECTION>.

Emissions resulting from the distribution of fuels from the distributor to the end user are presumed equal between the proposed and baseline conditions since truck delivery is assumed in both for propane and fuel oil #2.

#### Eligibility Criteria

This measure characterizes wood pellets used in the thermal sector under a certain set of conditions. Specifically:

* The carbon intensity value for wood pellets is characterized for production pathways that reside within the Northeast. Wood pellets that are imported from outside the northeast are not eligible for this measure.[[17]](#footnote-17)

This measure does not characterize the use of wood pellets in the thermal sector that does not meet this above condition.

#### Decarbonization Summary

Table 8 provides the estimated 2025 decarbonization range for replacement of propane and fuel oil #2 with wood pellets. These estimates are not inclusive of all eligible conditions; other conditions may be calculated from the algorithms herein.

Table 8. Wood Pellet CO2e Reductions

| Alternative Fuel | Baseline Fuel | Building Type | CO2e Reduction Per Unit [gCO2e/short ton] in 2025 |
| --- | --- | --- | --- |
| Wood pellets | Propane | N/A | 309,155 |
| Fuel oil #2 | N/A | 471,891 |
| Natural gas | N/A | 138,862 |
| Unknown | Single family | 254,158 |
| Multifamily | 60,044 |
| Unknown | 233,693 |

#### Decarbonization and Energy Impacts Algorithms

CO2e (gCO2e) =

CIbase = Baseline fuel carbon intensity value (gCO2e/MJ). Varies by year; see <EMISSIONS SCHEDULE> in <FRONT MATTER SECTION>. If the baseline fuel is unknown, calculate a weighted CIbase using the formula below and the heating fuel mix in Table 9 for the applicable building type and the corresponding baseline fuel carbon intensity value from <EMISSIONS SCHEDULE> in <FRONT MATTER SECTION>.

CIbase =

%FuelOil, etc. = Relative proportion of fuel in Vermont’s thermal sector (see Table 9).

CIfueloil, etc. = Carbon intensity value (gCO2e/MJ) for each fuel, see <EMISSIONS SCHEDULE> in <FRONT MATTER SECTION>. For wood, assume a 50-50 blend of Wood Pellets and Firewood.

Table 9. Vermont Primary Heating Fuel Mix, Residential Buildings[[18]](#footnote-18)

|  |  |  |  |
| --- | --- | --- | --- |
| Heating Fuel | Building Type | | |
| Single Family | Multifamily | Unknown |
| Fuel oil #2 | 45% | 5% | 41% |
| Propane | 17% | 5% | 16% |
| Natural gas | 23% | 66% | 27% |
| Electricity | 6% | 23% | 8% |
| Wood | 8% | 1% | 7% |

CIprop = Carbon intensity value for wood pellets (gCO2e/MJ). Varies by year; see <EMISSIONS SCHEDULE> in <FRONT MATTER SECTION>.

Ε = The total energy of the wood pellets delivered to the end-user in megajoules.

##### Energy Impacts Algorithms

E =

**Input Variable Definitions**

WWP = The total weight of wood pellet fuel that is delivered to the end-user in short tons.

LHVWP = Lower Heating Value of wood pellet fuel in units of MJ/short ton, 16,867.81 MJ/short ton.[[19]](#footnote-19)

**Measure Life**

Wood pellets are not subject to a measure life, as the measure characterization is based on the weight of wood pellets that are delivered to an end-user and used in the thermal sector.

**Measure Cost**

The incremental cost of wood pellets as compared to the baseline fuel. Use actual costs.

#### Program Data Tracking Recommendations

The key input variables for this measure are the following:

* Weight of delivered wood pellets to the end user
* The fuel that is displaced by the wood pellets

#### Energy Codes and Standards

None

### Firewood

**CHS Measure ID:** RES\_FUEL\_CW

**Market Sector:** Residential

**End Use:** Alternative Fuels

**Applicable Building Types:** Single Family, Multifamily

**Decarbonization Pathways:** Alternative Fuels

**Applicable Feedstocks:** Lumber wood

#### Measure Description

This measure involves the replacement of natural gas, propane, or fuel oil #2 with commercially produced firewood in the residential thermal sector. Firewood cannot be directly substituted for gaseous or liquid fuels; this measure assumes that the end-user either has the ability to substitute fuels at will (e.g. multiple thermal heating systems) or has made capital investments to replace thermal equipment that uses fossil fuels with thermal equipment that uses firewood.

Greenhouse gas reductions associated with this measure are derived from the difference in carbon intensity values (gCO2e/MJ) between the baseline heating fuel and firewood.

**Baseline Conditions**

The baseline condition is use of propane or fuel oil #2 in the residential thermal sector that is delivered to the end-user through a truck delivery service. Other baseline conditions are not characterized for this measure.

**Proposed Conditions**

The proposed fuel is firewood that is produced from lumber wood feedstocks. The firewood production pathway includes feedstock collection of lumber wood and transport of fuels to distributors. The production pathway excludes impacts relating to land use changes.

For wood fuels, it takes significant time for the regrowth of new trees to fully sequester the biogenic carbon emitted during combustion of wood fuel. A GWPbio factor of 0.32 is applied to CO2 combustion emissions for wood fuels to account for the regrowth period.[[20]](#footnote-20) This factor is embedded in the emission rate schedule in <EMISSIONS SCHEDULE> in <FRONT MATTER SECTION>.

Emissions resulting from the distribution of fuels from the distributor to the end user are presumed equal between the proposed and baseline conditions since truck delivery is assumed in both for propane and fuel oil #2.

#### Eligibility Criteria

This measure characterizes firewood used in the thermal sector under a certain set of conditions. Specifically:

* The carbon intensity value for firewood is characterized for production pathways that reside within the Northeast. Firewood that is imported from outside the Northeast is not eligible for this measure.[[21]](#footnote-21)

This measure does not characterize the use of firewood in the thermal sector that does not meet this above condition.

#### Decarbonization Summary

Table 10 provides the estimated 2025 decarbonization range for replacement of propane and fuel oil #2 with firewood. These estimates are not inclusive of all eligible conditions; other conditions may be calculated from the algorithms herein.

Table 10. Firewood CO2e Reductions

| Alternative Fuel | Baseline Fuel | Building Type | CO2e Reduction Per Unit [gCO2e/short ton] in 2025 |
| --- | --- | --- | --- |
| Firewood | Propane | N/A | 693,383 |
| Fuel oil #2 | N/A | 852,892 |
| Natural gas | N/A | 526,468 |
| Unknown | Single Family | 639,477 |
| Multifamily | 449,213 |
| Unknown | 619,418 |

#### Decarbonization and Energy Impacts Algorithms

CO2e (gCO2e) =

CIbase = Baseline fuel carbon intensity value (gCO2e/MJ). Varies by year; see <EMISSIONS SCHEDULE> in <FRONT MATTER SECTION>. If the baseline fuel is unknown, calculate a weighted CIbase using the formula below and the heating fuel mix in Table 11 for the applicable building type and the corresponding baseline fuel carbon intensity value from <EMISSIONS SCHEDULE> in <FRONT MATTER SECTION>.

CIbase =

%FuelOil, etc. = Relative proportion of fuel in Vermont’s thermal sector (see Table 11)

CIfueloil, etc. = Carbon intensity value (gCO2e/MJ) for each fuel, see <EMISSIONS SCHEDULE> in <FRONT MATTER SECTION>. For wood, assume a 50-50 blend of Wood Pellets and Firewood.

Table 11. Vermont Primary Heating Fuel Mix, Residential Buildings[[22]](#footnote-22)

|  |  |  |  |
| --- | --- | --- | --- |
| Heating Fuel | Building Type | | |
| Single Family | Multifamily | Unknown |
| Fuel oil #2 | 45% | 5% | 41% |
| Propane | 17% | 5% | 16% |
| Natural gas | 23% | 66% | 27% |
| Electricity | 6% | 23% | 8% |
| Wood | 8% | 1% | 7% |

CIprop = Carbon intensity value for firewood (gCO2e/MJ). Varies by year; see <EMISSIONS SCHEDULE> in <FRONT MATTER SECTION>.

Ε = The total energy of the firewood delivered to the end-user in units of megajoules (MJ).

##### Energy Impacts Algorithms

E =

**Input Variable Definitions**

WWP = The total weight of firewood that is delivered to the end-user in short tons.

LHVWP = Lower Heating Value of firewood in units of MJ/short ton, 16,533.25 MJ/short ton.[[23]](#footnote-23)

**Measure Life**

Firewood is not subject to a measure life, as the measure characterization is based on the weight of firewood that is delivered to an end-user and used in the thermal sector.

**Measure Cost**

The incremental cost of firewood as compared to the baseline fuel. Use actual costs.

#### Program Data Tracking Recommendations

The key input variables for this measure are the following:

* Weight of delivered firewood to the end user
* The fuel that is displaced by the firewood

#### Energy Codes and Standards

None.

1. Wang, Michael, Elgowainy, Amgad, Lu, Zifeng, et al. Greenhouse gases, Regulated Emissions, and Energy use in Technologies Model ® (2023rev1 Release). Computer Software. USDOE Office of Energy Efficiency and Renewable Energy (EERE). 09 Oct. 2023. Web. doi:10.11578/GREET-Net-2023/dc.20230907.2. Retrieved from <https://greet.anl.gov/> [↑](#footnote-ref-1)
2. The %Thermal factor for industrial applications is calculated as the sum of natural gas used in Conventional Boiler Use, Process Heating and Facility HVAC divided by the sum of all natural gas use in the Northeast Census Region from the US EIA Manufacturing Energy Consumption Survey (MECS), 2018. Table 5.6 End Uses of Fuel Consumption, 2018, published February 2021. <https://www.eia.gov/consumption/manufacturing/data/2018/#r5> [↑](#footnote-ref-2)
3. Wang, Michael, Elgowainy, Amgad, Lu, Zifeng, et al. Greenhouse gases, Regulated Emissions, and Energy use in Technologies Model ® (2023rev1 Release). Computer Software. USDOE Office of Energy Efficiency and Renewable Energy (EERE). 09 Oct. 2023. Web. doi:10.11578/GREET-Net-2023/dc.20230907.2. Retrieved from <https://greet.anl.gov/> [↑](#footnote-ref-3)
4. Ibid. [↑](#footnote-ref-4)
5. U.S. Department of Energy Alternative Fuels Data Center. Accessed at: <https://afdc.energy.gov/fuels/biodiesel-production> [↑](#footnote-ref-5)
6. Gerveni, M., T. Hubbs and S. Irwin. "Biodiesel and Renewable Diesel: What’s the Difference?" *farmdoc daily* (13):22, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, February 8, 2023. [↑](#footnote-ref-6)
7. Wang, Michael, Elgowainy, Amgad, Lu, Zifeng, et al. Greenhouse gases, Regulated Emissions, and Energy use in Technologies Model ® (2023rev1 Release). Computer Software. USDOE Office of Energy Efficiency and Renewable Energy (EERE). 09 Oct. 2023. Web. doi:10.11578/GREET-Net-2023/dc.20230907.2. Retrieved from <https://greet.anl.gov/> [↑](#footnote-ref-7)
8. U.S. Department of Energy Alternative Fuels Data Center. Accessed at: <https://afdc.energy.gov/fuels/renewable-diesel> [↑](#footnote-ref-8)
9. Gerveni, M., T. Hubbs and S. Irwin. "Biodiesel and Renewable Diesel: What’s the Difference?" *farmdoc daily* (13):22, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, February 8, 2023. [↑](#footnote-ref-9)
10. Wang, Michael, Elgowainy, Amgad, Lu, Zifeng, et al. Greenhouse gases, Regulated Emissions, and Energy use in Technologies Model ® (2023rev1 Release). Computer Software. USDOE Office of Energy Efficiency and Renewable Energy (EERE). 09 Oct. 2023. Web. doi:10.11578/GREET-Net-2023/dc.20230907.2. Retrieved from <https://greet.anl.gov/> [↑](#footnote-ref-10)
11. Derived from the World Wildlife Fund’s Biogenic Footprint Carbon Calculator (2020), assuming a 50/50 split of Cool Temperate | Spruce (Picea) and Pine all (Pinus) biomass sources. Retrieved on August 19, 2024 from <https://files.worldwildlife.org/wwfcmsprod/misc/climate_forest/Biogenic_Carbon_Footprint_Calculator_2020.xlsx> [↑](#footnote-ref-11)
12. The Northeast in this document includes Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont. [↑](#footnote-ref-12)
13. The distribution of fuels used in the commercial sector are calculated from a fuel’s use in space heating, water heating, and cooking divided by the sum of all fuels used those same categories for the Northeast Census Region from the US EIA Commercial Building Energy Consumption Survey (CBECS), 2018. Tables E3, E7, and E9, published December 2022. <https://www.eia.gov/consumption/commercial/data/2018/> [↑](#footnote-ref-13)
14. The distribution of fuels used in the industrial sector are calculated from a fuel’s use in Conventional Boiler Use, Process Heating, and Facility HVAC divided by the sum of all fuels used those same categories for the Northeast Census Region from the US EIA Manufacturing Energy Consumption Survey (MECS), 2018. Table 5.6 End Uses of Fuel Consumption, 2018, published February 2021. <https://www.eia.gov/consumption/manufacturing/data/2018/#r5> [↑](#footnote-ref-14)
15. Derived from the Greenhouse gases, Regulated Emissions, and Energy use in Technologies (GREET) Model (2023rev1 Release) as the weighted average lower heating value of wood feedstocks, pine and maple/beech/birch. [↑](#footnote-ref-15)
16. Derived from the World Wildlife Fund’s Biogenic Footprint Carbon Calculator (2020), assuming a 50/50 split of Cool Temperate | Spruce (Picea) and Pine all (Pinus) biomass sources. Retrieved on August 19, 2024 from <https://files.worldwildlife.org/wwfcmsprod/misc/climate_forest/Biogenic_Carbon_Footprint_Calculator_2020.xlsx> [↑](#footnote-ref-16)
17. The Northeast in this document includes Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont. [↑](#footnote-ref-17)
18. Derived from NMR Group, 2020 Vermont Single Family Existing Homes Baseline Study and NMR Group, 2020 Vermont Multifamily Residential Baseline Study. Assumes 50%/50% split between wood stoves and gas fireplaces. Gas fireplaces are split between natural gas and propane according to survey results for each fuel. The single family and multifamily results are combined for the “unknown” building type category by weighting according to the population of each building type in the respective studies. [↑](#footnote-ref-18)
19. Derived from the Greenhouse gases, Regulated Emissions, and Energy use in Technologies (GREET) Model (2023rev1 Release) as the weighted average lower heating value of wood feedstocks, pine and maple/beech/birch. [↑](#footnote-ref-19)
20. Derived from the World Wildlife Fund’s Biogenic Footprint Carbon Calculator (2020), assuming a 50/50 split of Cool Temperate | Spruce (Picea) and Pine all (Pinus) biomass sources. Retrieved on August 19, 2024 from <https://files.worldwildlife.org/wwfcmsprod/misc/climate_forest/Biogenic_Carbon_Footprint_Calculator_2020.xlsx> [↑](#footnote-ref-20)
21. The Northeast in this document includes Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont. [↑](#footnote-ref-21)
22. Derived from NMR Group, 2020 Vermont Single Family Existing Homes Baseline Study and NMR Group, 2020 Vermont Multifamily Residential Baseline Study. Assumes 50%/50% split between wood stoves and gas fireplaces. Gas fireplaces are split between natural gas and propane according to survey results for each fuel. The single family and multifamily results are combined for the “unknown” building type category by weighting according to the population of each building type in the respective studies. [↑](#footnote-ref-22)
23. Derived from the Greenhouse gases, Regulated Emissions, and Energy use in Technologies (GREET) Model (2023rev1 Release) as the weighted average lower heating value of wood feedstocks, pine and maple/beech/birch. [↑](#footnote-ref-23)