

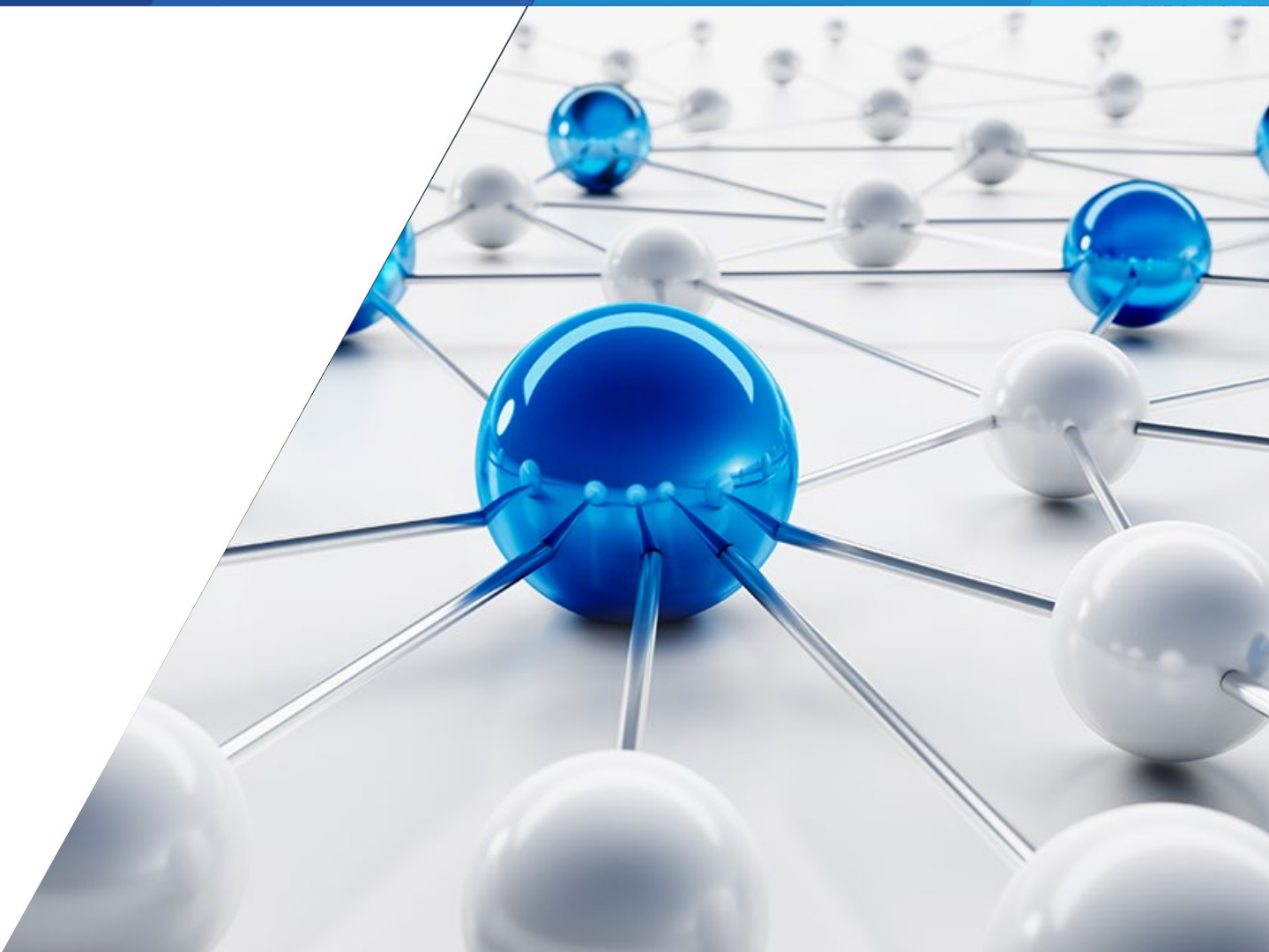


Opinion **Dynamics**

VERMONT CLEAN HEAT STANDARD

LIFECYCLE CARBON INTENSITY VALUES –
RESULTS AND METHODOLOGY

SEPTEMBER 19, 2024



BACKGROUND

- Act 18 requires the PUC to:
“establish a schedule of lifecycle emissions rates for heating fuels and any fuel that is used in a clean heat measure, including electricity, or is itself a clean heat measure, including biofuels.”
- Lifecycle emissions rates for electricity and fuels are required to characterize the carbon dioxide equivalent emissions reductions that will be produced by clean heat measures and therefore we have developed these as part of our scope

BACKGROUND

- Act 18 includes a number of explicit requirements for the development of the schedule:
 - “The schedule shall be based on transparent, verifiable, and accurate emissions accounting adapting the Argonne National Laboratory GREET Model, Intergovernmental Panel on Climate Change (IPCC) modeling, or an alternative of comparable analytical rigor to fit the Vermont thermal sector context, and the requirements of 10 V.S.A. § 578(a)(2) and (3).”*
 - “For each fuel pathway, the schedule shall account for greenhouse gas emissions from biogenic and geologic sources, including fugitive emissions and loss of stored carbon. In determining the baseline emission rates for clean heat measures that are fuels, emissions baselines shall fully account for methane emissions reductions or captures already occurring, or expected to occur, for each fuel pathway as a result of local, State, or federal legal requirements that have been enacted or adopted that reduce greenhouse gas emissions.”*

PRESENTATION OUTLINE

- Present methodology by three categories:
 - Electricity
 - Liquid and Gaseous Fuels
 - Wood Fuels
- For each category, we will discuss:
 - Methods for developing carbon intensities and any primary assumptions
 - Biogenic carbon cycle
 - Land-use change
 - Transmission and distribution

TOPICS FOR DISCUSSION

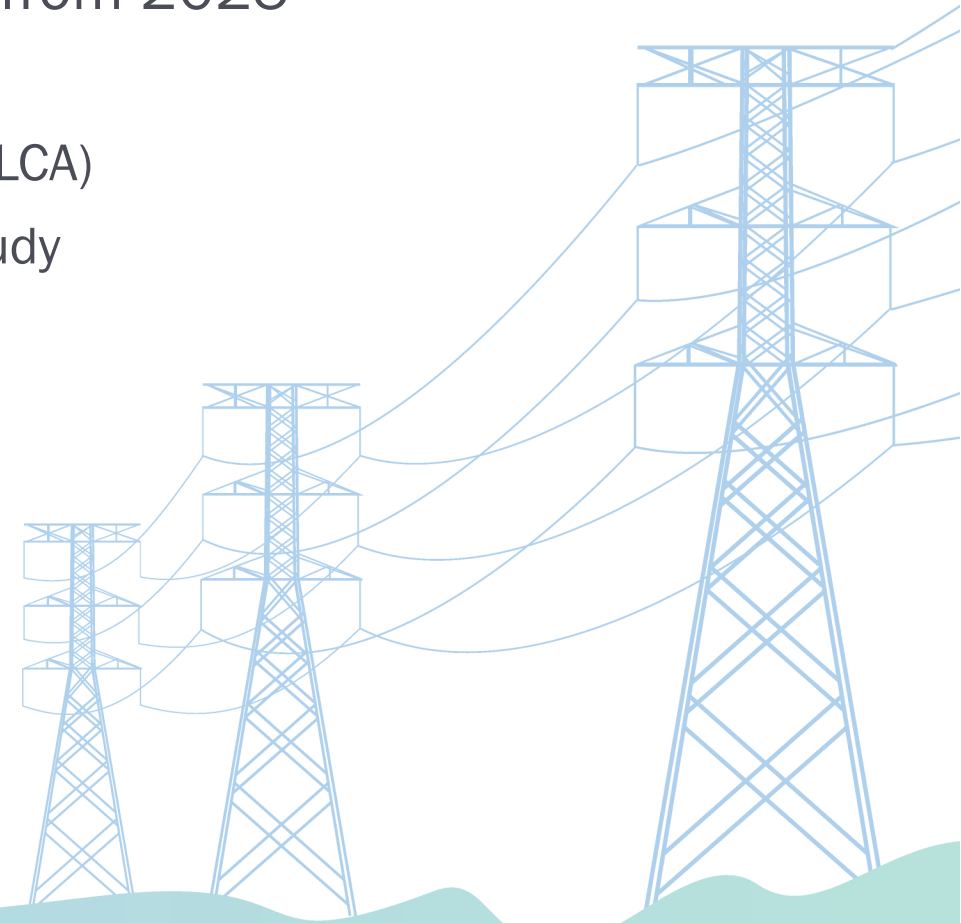
- Our analysis did not include counterfactual scenarios, such as flaring of landfill gas or handling of animal waste
- GREET1 2023 is inconsistent in accounting of land use changes in fuel production and feedstock, and we therefore did not include associated impacts
- Accounting for biogenic emissions from biomass-based fuels is challenging and done differently even within Vermont; we have proposed an approach but we understand that further discussion may be needed
- The eligible emissions limit reported was the Act 18-defined minimums only and does not include any additional analysis or recommendations from our team

CARBON INTENSITY OF THERMAL SECTOR FUELS – METHODS OVERVIEW

Fuel Pathway	Emissions Source	
	Combustion Emissions	Upstream Emissions
Grid Electricity		
Grid electricity	<ul style="list-style-type: none">CO₂, CH₄, and N₂O combustion emissions accounted for using emissions rates from U.S. EPA Emission Factors Hub	<ul style="list-style-type: none">Opinion Dynamics analysis using GREET1 2023rev1 and other sources
Liquid and Gaseous Fuels		
Natural gas	<ul style="list-style-type: none">CO₂, CH₄, and N₂O combustion emissions accounted for using emissions rates from U.S. EPA Emission Factors Hub	<ul style="list-style-type: none">Opinion Dynamics analysis using GREET1 2023rev1
Fuel oil #2		
Propane		
Kerosene		
Coal		
Hydrogen from multiple feedstocks	<ul style="list-style-type: none">No CO₂, CH₄, or N₂O combustion emissions	<ul style="list-style-type: none">Opinion Dynamics analysis using GREET1 2023rev1
Biomethane from multiple feedstock	<ul style="list-style-type: none">CH₄ and N₂O combustion emissions accounted for using emissions rates from U.S. EPA Emission Factors Hub	
Biodiesel from multiple feedstocks	<ul style="list-style-type: none">CO₂ emissions are considered biogenic and are considered zero	
Renewable diesel from multiple feedstocks		
Wood Fuels		
Wood chips	<ul style="list-style-type: none">CH₄ and N₂O combustion emissions accounted for using emissions rates from U.S. EPA Emission Factors Hub	<ul style="list-style-type: none">Opinion Dynamics analysis using GREET1 2023rev1
Wood pellets	<ul style="list-style-type: none">CO₂ emissions considered to be biogenic carbon; partially accounted for using GWP_{bio} factor	
Firewood, commercial		
Firewood, non-commercial		

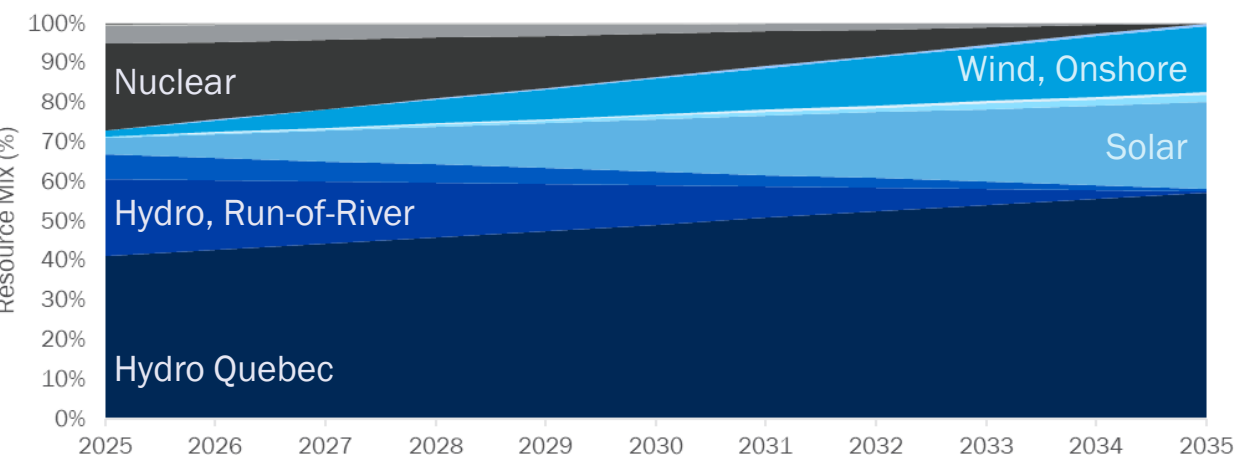
GRID ELECTRICITY

- Developed a resource mix for the Vermont electric grid from 2025 through 2050
 - 2020 Consumption Activity from VT Energy Sector LCA (VT ESLCA)
 - 2035 Projected 100% renewable generation mix from SEA study
 - Linear interpolation from 2025 to 2035, constant thereafter
- Apply emission rates:
 - Combustion – US EPA Emissions Factor Hub
 - Upstream – GREET1 2023rev1
- Transmission & Distribution
 - Accounted for in measure characterization

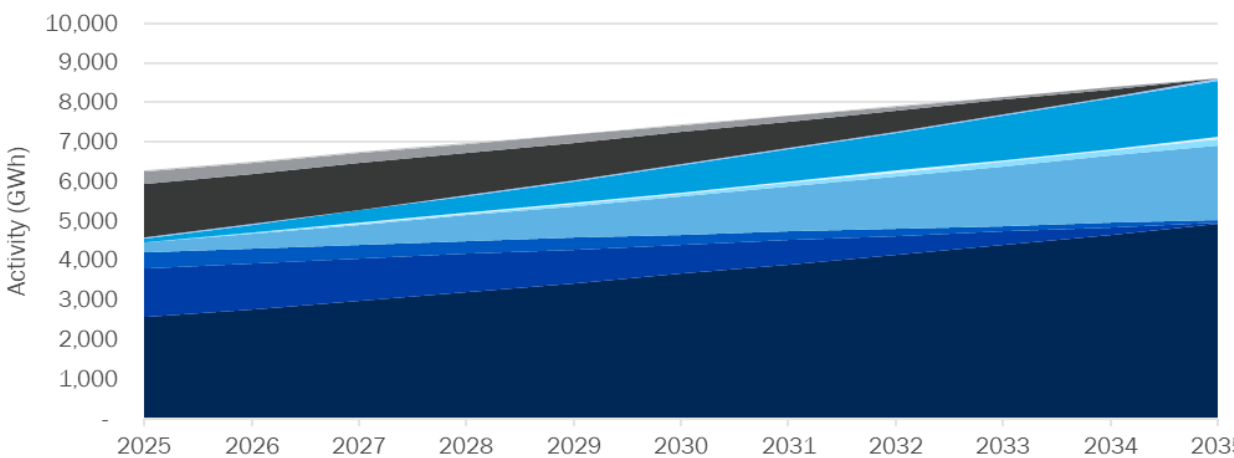


GRID ELECTRICITY

Resource Mix by Year from 2025 through 2035



Total Activity by Year from 2025 through 2035



- Hydro Quebec

■ Solar PV, Commercial/Utility, Fleet Average

■ Wind, Onshore

■ Natural Gas
- Hydro, Run-of-River

■ Hydro, Reservoir

■ RNG, Landfill

■ Petroleum
- Wood Residues

■ RNG, Animal Waste

■ Nuclear

■ Coal
- Hydro Quebec

■ Solar PV, Commercial/Utility, Fleet Average

■ Wind, Onshore

■ Natural Gas
- Hydro, Run-of-River

■ Hydro, Reservoir

■ RNG, Landfill

■ Petroleum
- Wood Residues

■ RNG, Animal Waste

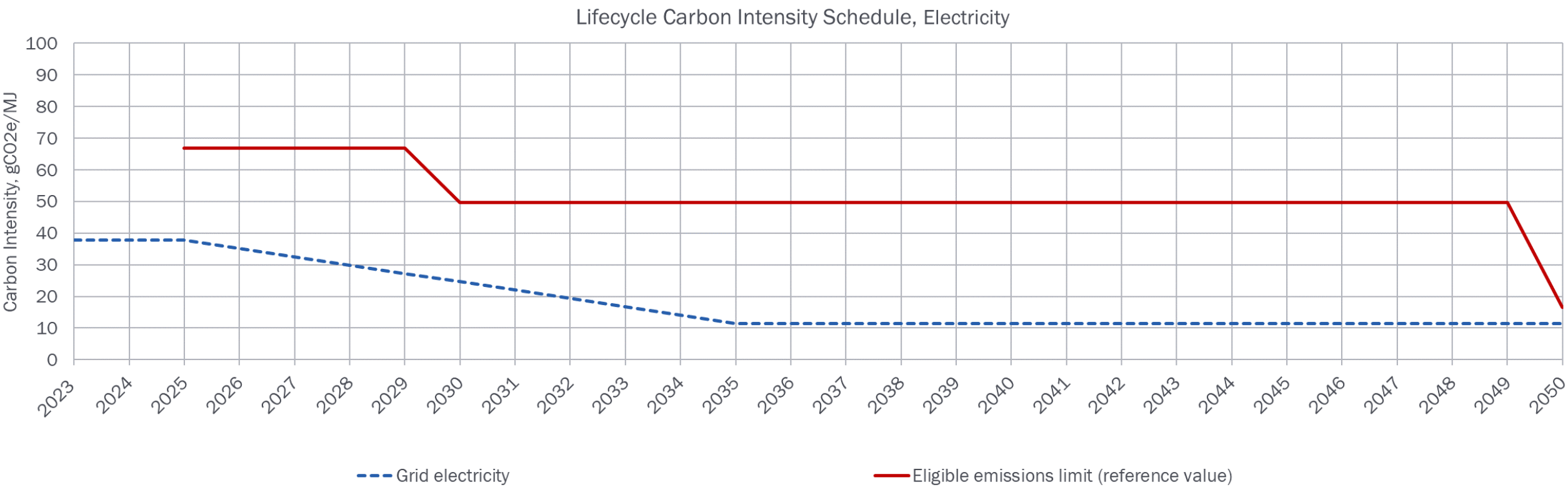
■ Nuclear

■ Coal

	2025	2035	% Change
Activity (MWh)	6,272,829	8,614,670	37.3%

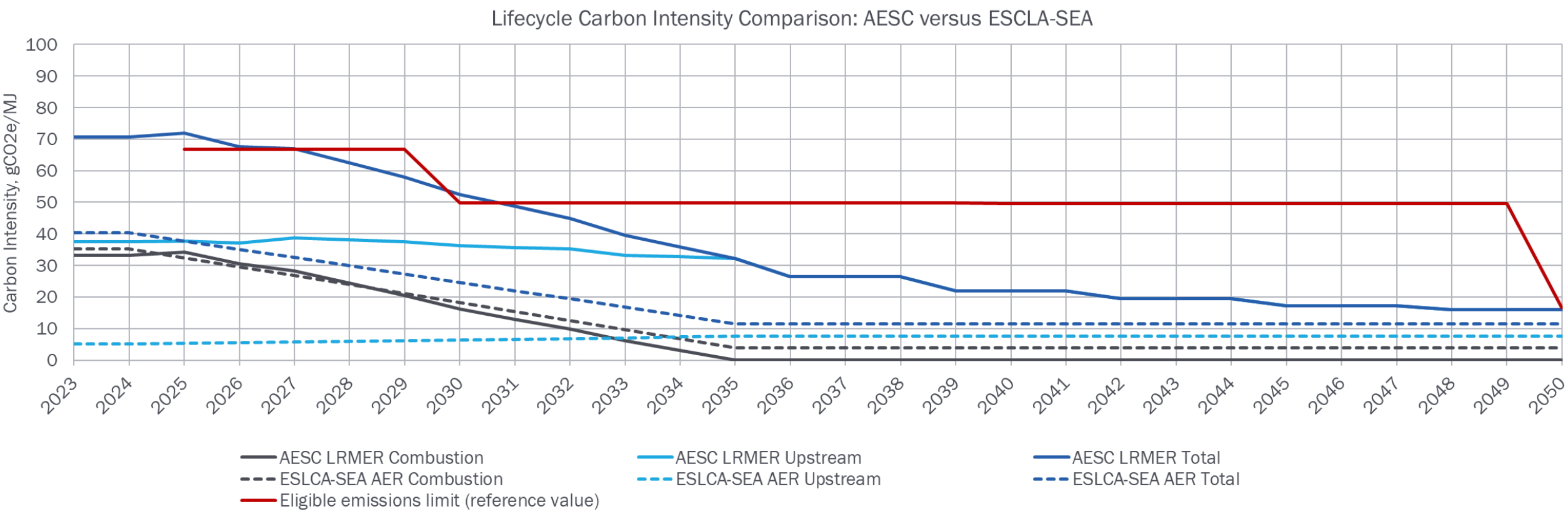
CARBON INTENSITY SCHEDULE – ELECTRICITY

	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	...	2050
Grid electricity	37.8	37.8	37.8	35.1	32.5	29.9	27.3	24.6	22.0	19.4	16.8	14.1	11.5	...	11.5
Eligible emissions limit	N/A	N/A	66.8	66.8	66.8	66.8	66.8	49.8	49.8	49.8	49.8	49.8	49.7	...	16.5



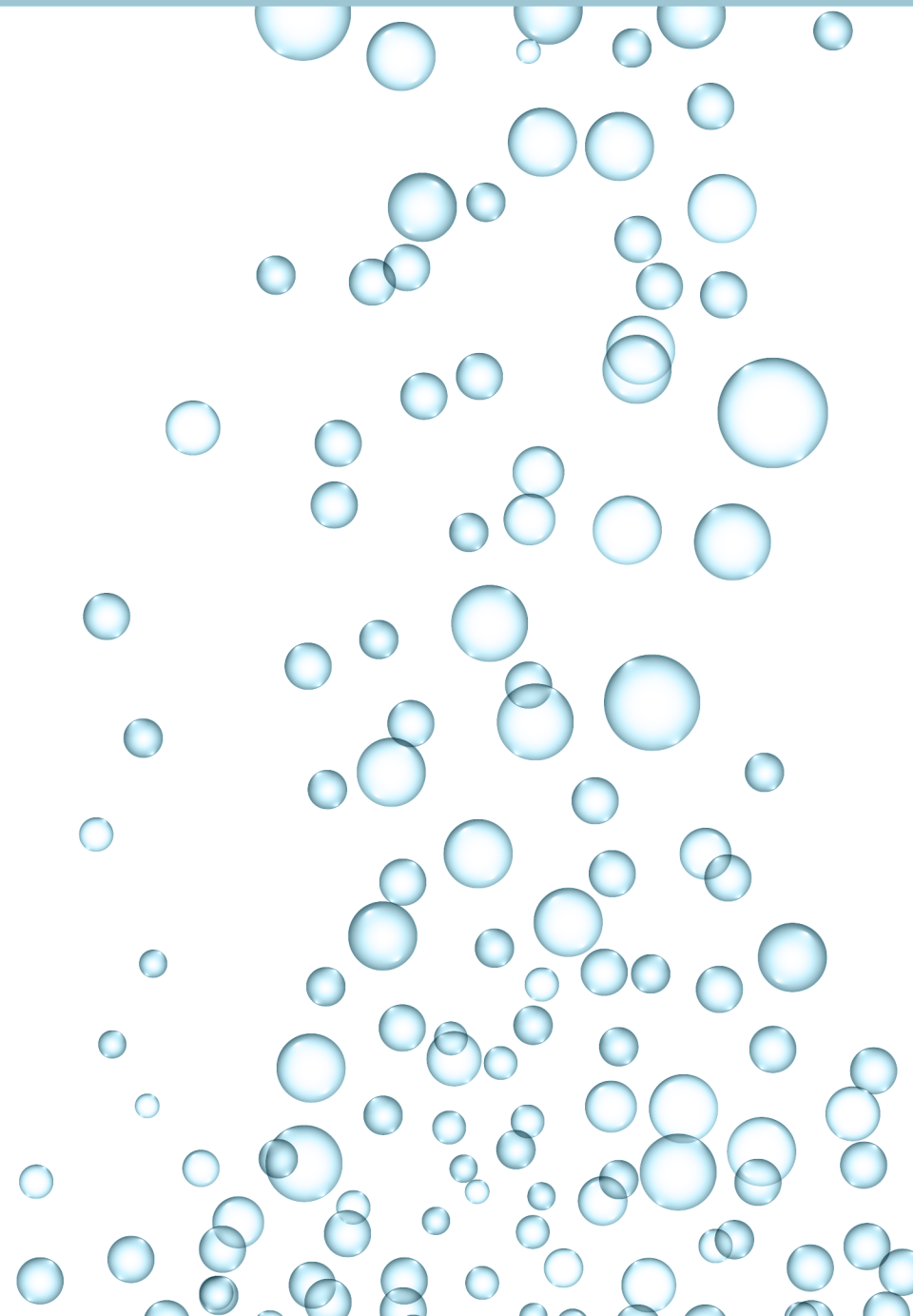
ELECTRICITY APPROACH COMPARISON

- Long-run marginal emission rate (LRMER) versus average emission rate (AER)
- Combustion CIs are relatively consistent
- Upstream CIs exhibit biggest difference



LIQUID/GASEOUS (AND COAL) FUELS

- Carbon Intensity:
 - Upstream CIs: Adopted VT ESLCA framework and updated with latest GREET1 2023rev1 model
 - Combustion CIs: US EPA Emissions Factor Hub
- Biogenic Emissions (BD, RD, Biomethane)
 - CO₂ – considered zero as a part of biogenic cycle
 - CH₄ and N₂O – included in combustion emissions
- Land Use Change
 - Biofuels from purpose grown crops:
 - Predominately from Midwest and harvested from energy-dedicated crops
 - Uncertainty around changing national demand and Vermont's influence
 - Biofuels from Animal Waste: no change in land use as these feedstocks are byproducts with low influence on land use decisions
- Transmission & Distribution
 - Accounted for in measure characterizations



LIQUID AND GASEOUS (AND COAL) FUELS – CARBON INTENSITY VALUES

Fuel	2023	2024	2025	...	2030	...	2035	...	2040	...	2045	...	2050
Natural gas	63.7	63.7	63.7	...	63.7	...	63.6	...	63.6	...	63.6	...	63.6
Fuel oil #2	83.4	83.4	83.5	...	82.9	...	82.8	...	82.8	...	82.8	...	82.7
Propane	73.3	73.7	73.8	...	73.6	...	73.2	...	73.1	...	73.1	...	73.1
Kerosene	83.6	83.6	83.7	...	83.1	...	83.0	...	83.0	...	83.0	...	82.9
Coal	94.6	94.6	94.5	...	94.5	...	94.4	...	94.4	...	94.4	...	94.4
Hydrogen from SMR, without CC	92.9	92.9	91.1	...	86.5	...	85.6	...	85.4	...	85.2	...	84.6
Hydrogen from dedicated renewables	14.2	14.2	12.5	...	8.2	...	7.3	...	7.1	...	6.9	...	6.3
Biomethane from animal waste	15.2	15.2	15.1	...	14.7	...	14.6	...	14.6	...	14.6	...	14.5
Biomethane from landfill gas	7.7	7.7	6.8	...	4.2	...	3.8	...	3.6	...	3.5	...	3.3
Biomethane from fats, oils, and greases	29.0	29.0	26.2	...	19.2	...	18.0	...	17.6	...	17.2	...	16.6
Biomethane from wastewater	40.3	40.3	37.6	...	30.2	...	29.0	...	28.6	...	28.2	...	27.6
Biodiesel from soybeans	26.4	26.4	25.9	...	25.0	...	24.8	...	24.7	...	24.7	...	24.6
Biodiesel from canola	25.8	25.8	25.5	...	24.6	...	24.4	...	24.4	...	24.3	...	24.2
Biodiesel from corn	9.9	9.9	9.3	...	8.2	...	8.0	...	8.0	...	7.9	...	7.8
Biodiesel from used cooking oil	14.8	14.8	14.3	...	13.3	...	13.0	...	12.9	...	12.9	...	12.6
Renewable diesel from soybeans	32.7	32.7	32.2	...	31.0	...	30.8	...	30.8	...	30.7	...	30.6
Renewable diesel from canola	32.3	32.3	31.9	...	30.9	...	30.7	...	30.6	...	30.6	...	30.4
Renewable diesel from corn	12.3	12.3	11.8	...	10.8	...	10.7	...	10.6	...	10.6	...	10.5
Renewable diesel from used cooking oil	17.8	17.8	17.3	...	16.0	...	15.7	...	15.6	...	15.6	...	15.4
Eligible emissions limit	N/A	N/A	66.8	...	49.8	...	49.7	...	49.7	...	49.7	...	16.5

WOOD FUELS

- Carbon Intensity:
 - Upstream CIs: Adopted VT ESLCA framework and updated with latest GREET1 2023rev1 model
 - Combustion CIs: US EPA Emissions Factor Hub
- Biogenic Emissions
 - CO₂ – apply a GWP_{bio} factor of 0.32
 - CH₄ and N₂O – included in combustion emissions
- Land Use Change
 - Assumed short rotation woody crops grown for dedicated purpose of energy sector
 - Unclear on the pathway to accounting for land use changes
- Transmission & Distribution
 - Accounted for in measure characterizations

WOOD FUELS

Fuel	2023	2024	2025	...	2030	...	2035	...	2040	...	2045	...	2050
Wood chips	31.6	31.6	31.5	...	31.2	...	31.1	...	31.1	...	31.1	...	31.0
Wood pellets	56.2	56.2	55.5	...	53.5	...	53.2	...	53.1	...	53.0	...	52.8
Firewood, commercial	32.0	32.0	31.9	...	31.8	...	31.7	...	31.7	...	31.7	...	31.6
Eligible emissions limit	N/A	N/A	66.8	...	49.8	...	49.7	...	49.7	...	49.7	...	16.5

Lifecycle Carbon Intensity Schedule, Woods



CARBON INTENSITY SCHEDULE FOR ALL FUELS

- Table is sorted by 2035 CI
 - Grid electricity is 5th cleanest fuel in 2035; 100% renewable resource mix
 - Fossil fuels and hydrogen from SMR are the least clean fuels
 - Wood fuels exhibit highest CI of clean fuels
 - Biomethane, renewable diesel, and biodiesel exhibit a range of carbon intensities for varying fuel pathways

Fuel	2025	2030	2035	2040	2045	2050
Coal	94.5	94.5	94.4	94.4	94.4	94.4
Hydrogen from SMR, without CC	91.1	86.5	85.6	85.4	85.2	84.6
Kerosene	83.7	83.1	83.0	83.0	83.0	82.9
Fuel oil #2	83.5	82.9	82.8	82.8	82.8	82.7
Propane	73.8	73.6	73.2	73.1	73.1	73.1
Natural gas	63.7	63.7	63.6	63.6	63.6	63.6
Wood pellets	55.5	53.5	53.2	53.1	53.0	52.8
Firewood, commercial	31.9	31.8	31.7	31.7	31.7	31.6
Wood chips	31.5	31.2	31.1	31.1	31.1	31.0
Renewable diesel from soybeans	32.2	31.0	30.8	30.8	30.7	30.6
Renewable diesel from canola	31.9	30.9	30.7	30.6	30.6	30.4
Biomethane from wastewater	37.6	30.2	29.0	28.6	28.2	27.6
Biodiesel from soybeans	25.9	25.0	24.8	24.7	24.7	24.6
Biodiesel from canola	25.5	24.6	24.4	24.4	24.3	24.2
Biomethane from fats, oils, and greases	26.2	19.2	18.0	17.6	17.2	16.6
Renewable diesel from used cooking oil	17.3	16.0	15.7	15.6	15.6	15.4
Biomethane from animal waste	15.1	14.7	14.6	14.6	14.6	14.5
Biodiesel from used cooking oil	14.3	13.3	13.0	12.9	12.9	12.6
Grid electricity	37.8	24.6	11.5	11.5	11.5	11.5
Renewable diesel from corn	11.8	10.8	10.7	10.6	10.6	10.5
Biodiesel from corn	9.3	8.2	8.0	8.0	7.9	7.8
Hydrogen from dedicated renewables	12.5	8.2	7.3	7.1	6.9	6.3
Biomethane from landfill gas	6.8	4.2	3.8	3.6	3.5	3.3

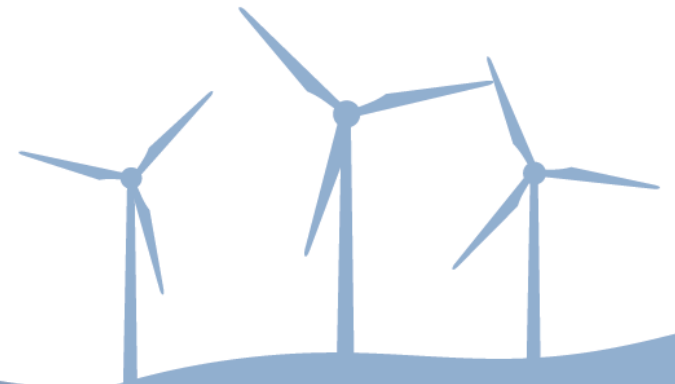
TOPICS FOR DISCUSSION

- Counterfactual scenarios
 - Interested in TAG thoughts around treatment of counterfactual scenarios
- Land use change
 - Interested in TAG thoughts around treatment of land use change and
- Treatment of wood fuels
 - Received comments from public
 - Interested in any specific TAG comments and/or guidance around treatment of wood fuels



Opinion **Dynamics**

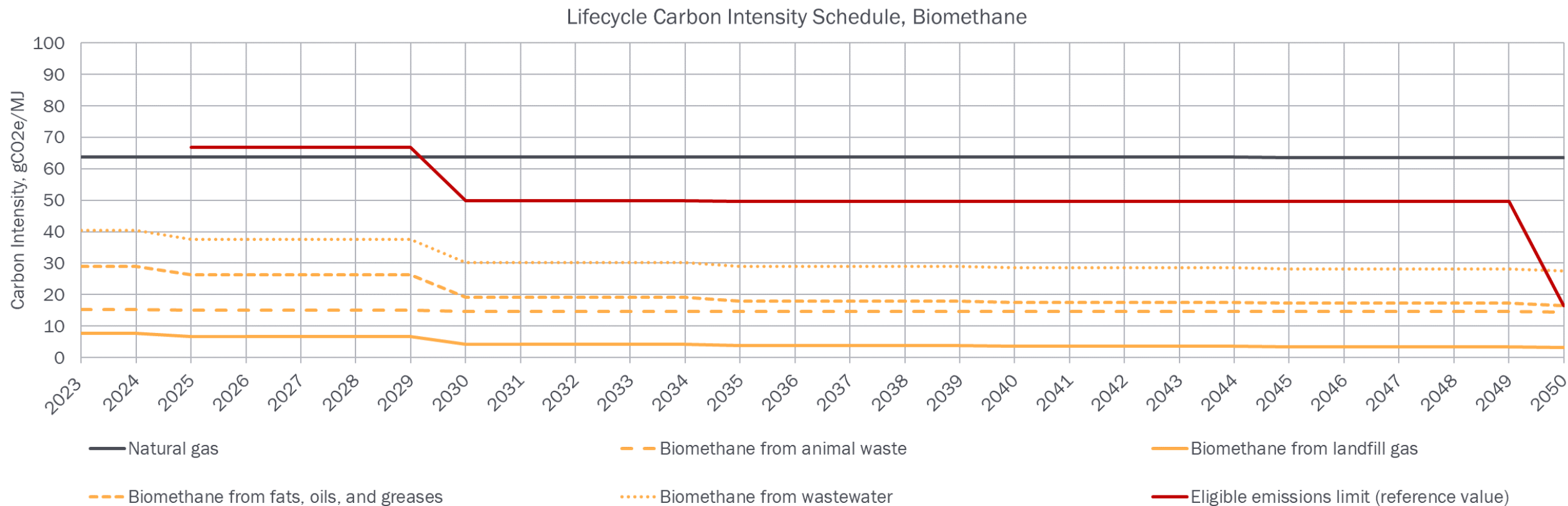
QUESTIONS?



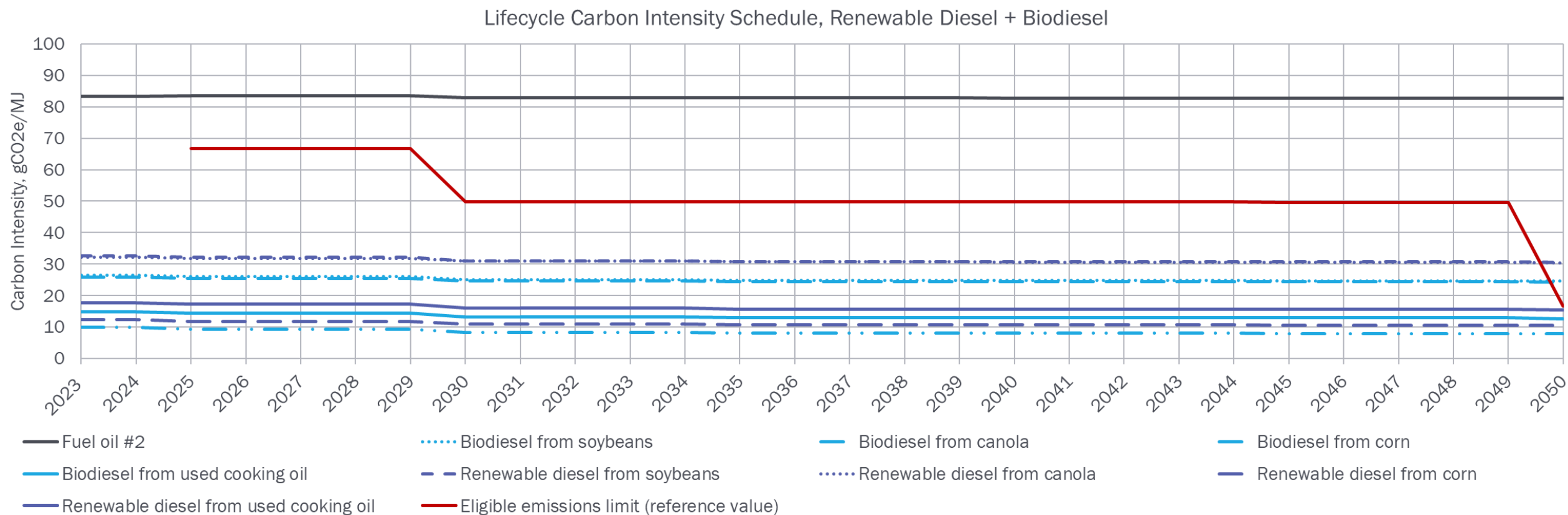
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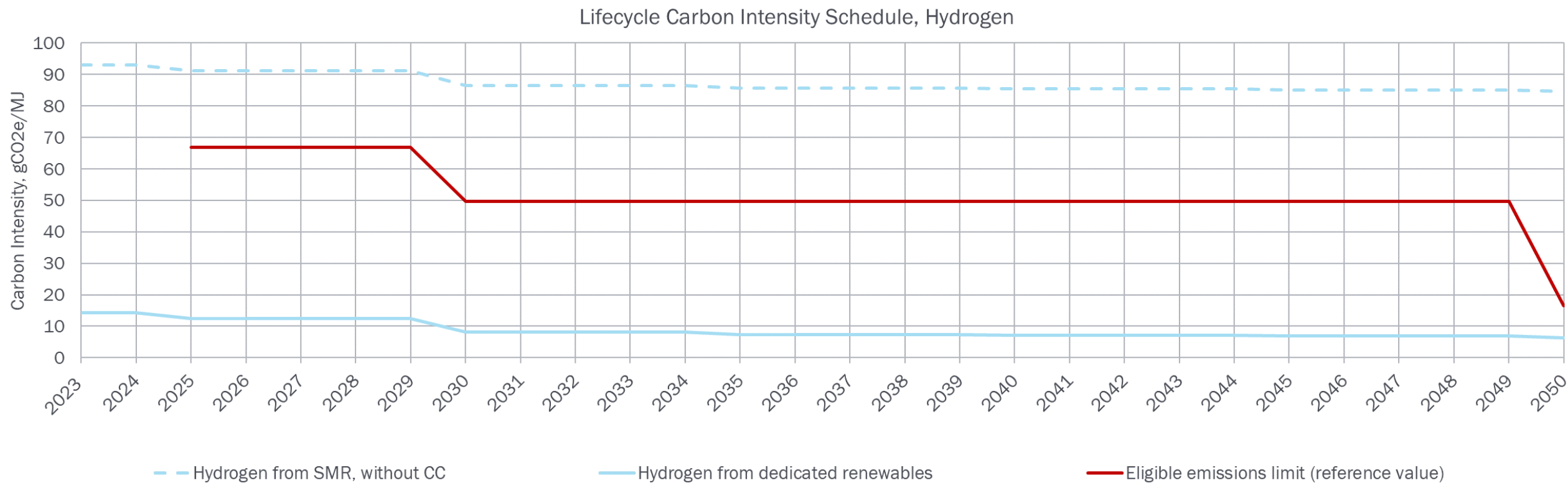
LIQUID AND GASEOUS FUELS – BIOMETHANE AND NATURAL GAS



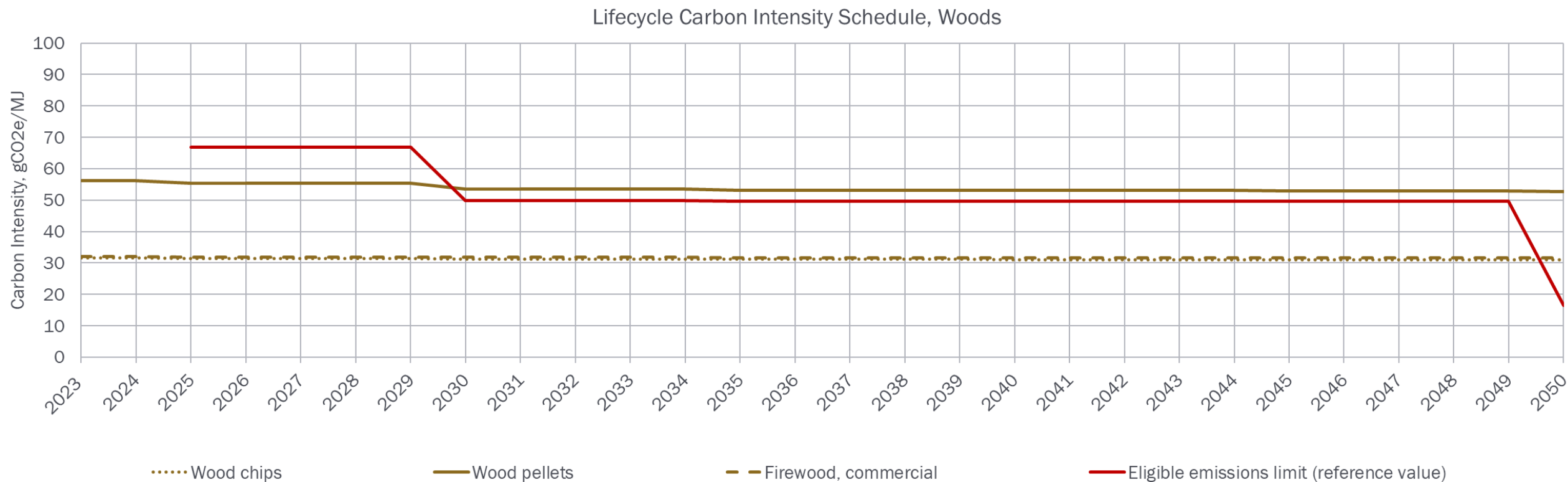
LIQUID AND GASEOUS FUELS – RENEWABLE DIESEL, BIODIESEL, AND FUEL OIL #2



LIQUID AND GASEOUS FUELS - HYDROGEN



WOOD FUELS



LIQUID AND GASEOUS FUELS – FOSSIL FUELS

