Vermont's LEAP Model: Mitigation Scenarios Results

Presentation for Climate Council Meeting

9-June-2025

Silvia Ulloa, Silvia.Ulloa@sei.org

Jason Veysey, Jason.Veysey@sei.org

Guillaume Bouchard, Guillaume.Bouchard@sei.org

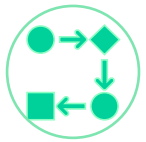
Emily Ghosh, Emily.Ghosh@sei.org

SEI Stockholm Environment Institute

Agenda


The Vermont LEAP model


Baseline scenario updates and results

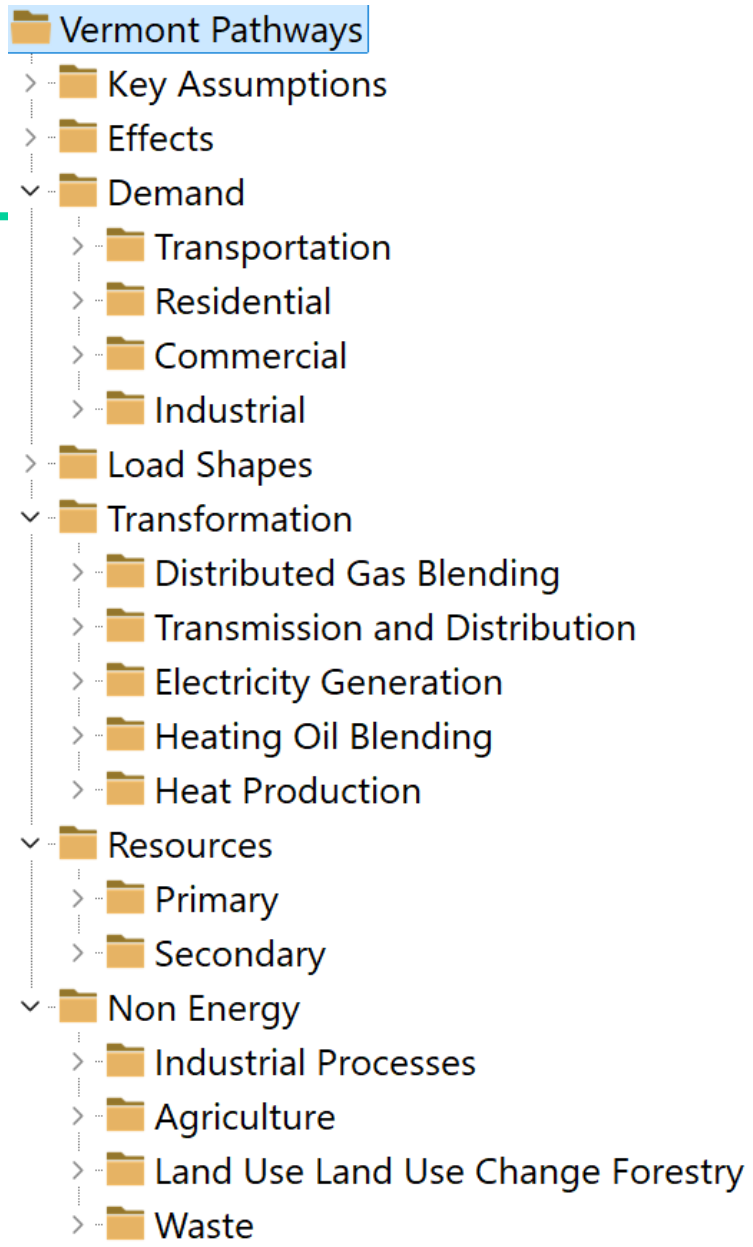

Process for modeling mitigation scenarios


Mitigation scenario results


Questions and discussion

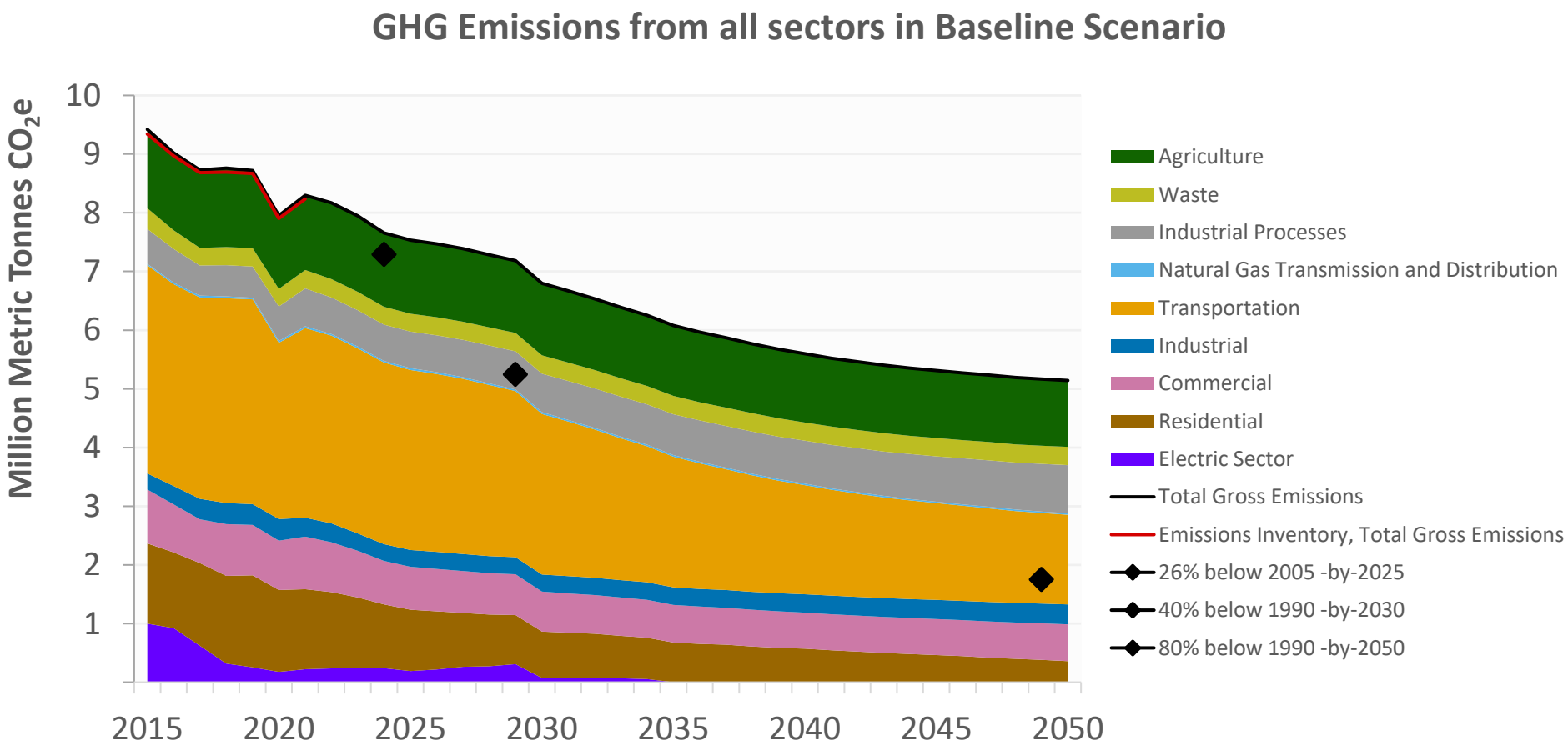
The Vermont LEAP model

- GHG emissions model for VT, developed using LEAP and NEMO
- Models energy consumption and production in all sectors, associated GHGs, non-energy GHGs, costs of one scenario vs. another
- Modeling period: 2015-2050 with projections starting in 2024
- Emissions coverage: Major GHGs (CO2, CH4, N2O), local air pollutants (CO, NOx, NMVOC, PM10, PM2.5, BC, OC, SO2, NH3), SF6



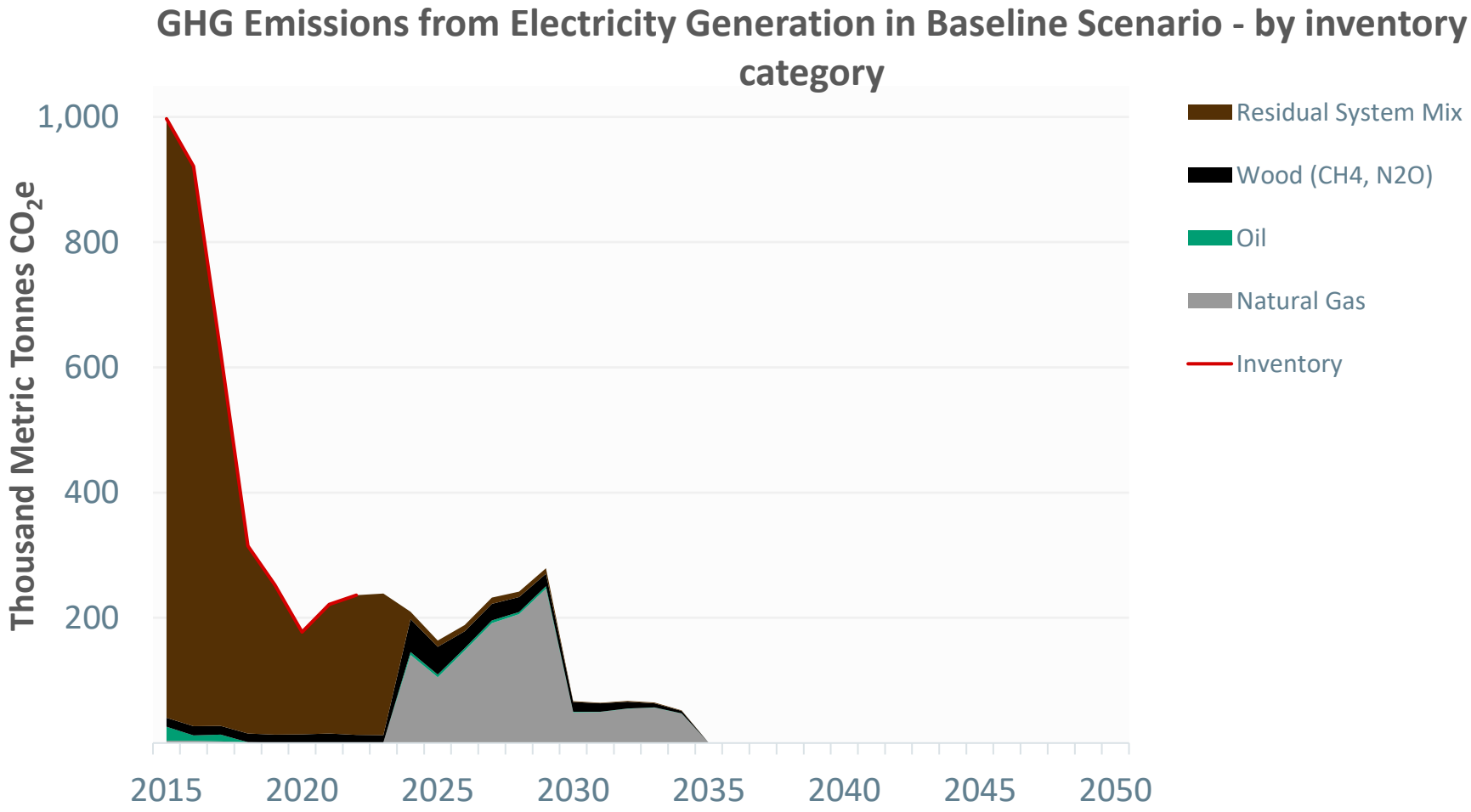
Revised Baseline Update Results

Note: Updates to the commercial sector are still underway.



Power sector results

Includes 2024 Update to Renewable Energy Standard



Modeling Mitigation Scenarios

Baseline model updates

Updating mitigation measures in model

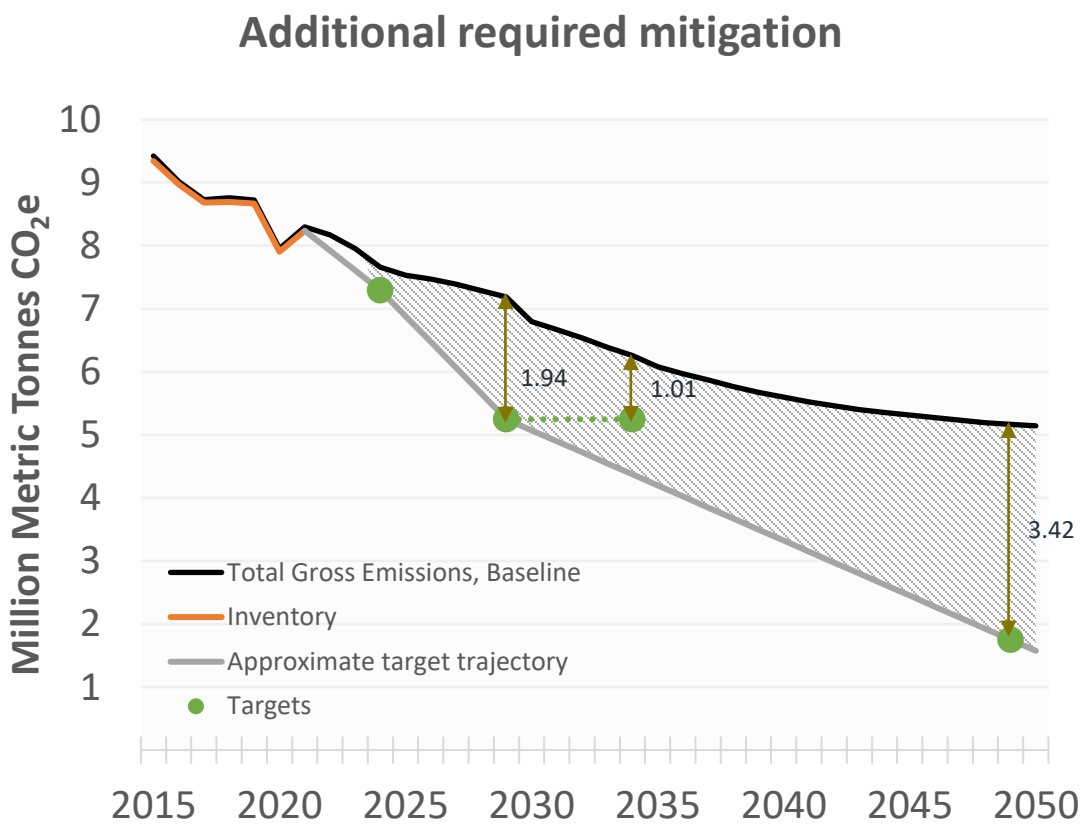
- 25 Mitigation measures covering all sectors

Develop two mitigation scenarios

- Combine individual mitigation measures into mitigation scenarios that achieve pre-set targets:

Scenario #1: 40% emission reduction by 2030 and 80% reduction by 2050 from 1990

Scenario #2: 2030 target is delayed 5 years (40% reduction by 2035), and 2050 target (80% reduction) is maintained



Mitigation measures



1. B20 Biodiesel



2. B100 Heating

3. Fossil cooking phase out by 2040

4. Fossil water heating phase out by 2040

5. Biogas

6. Weatherization at scale



2. B100 Heating

3. Fossil cooking phase out by 2040

4. Fossil water heating phase out by 2040

5. Biogas

7. District heating

8. Advanced wood heating

9. Heat pump space heating



10. B100 Heavy Duty Vehicles

11. E15 Ethanol

12. ICE Sales phase out by 2035

13. Managed EV charging

14. Sustainable aviation fuel

15. Vehicle to grid

16. VMT reductions



17. B100 in Industry

18. Renewable Industrial Gas



19. Increased BTM PV



20. Enteric Fermentation

21. Manure Management

22. ODS Substitution

23. Soils sequestration

24. Semiconductor manufacturing

25. Wastewater methane

Modeling Mitigation Scenarios

Prioritize measures based on their cost-effectiveness ($/ton CO_2 avoided) when evaluated individually

Add measures in order of increasing cost, using the ramp rates and implementation levels presented on 05/23/2025.

Compare total emission results to the desired targets

Continue adding measures until targets are met or exceeded

Adjust implementation levels and/or ramp rates for measures as needed, e.g:

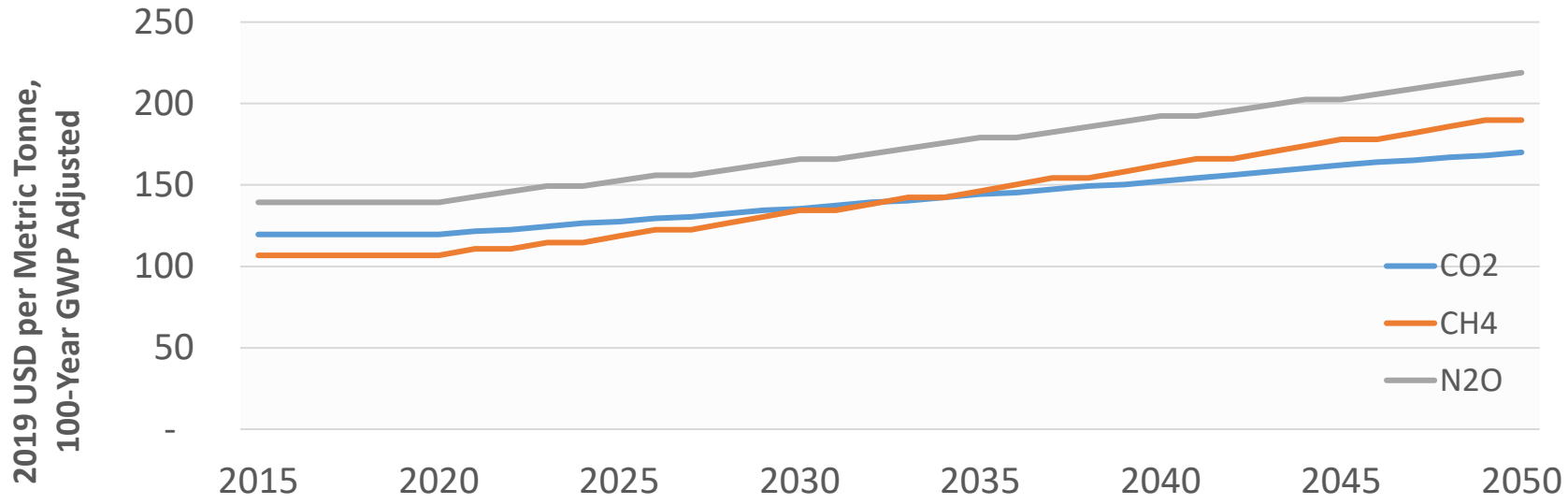
- Higher levels of ambition (up to a ceiling) starting with the least-cost measures
- Explore slower implementation rates starting with the high-cost measures

Social Costs of GHGs

Social Costs of GHGs (2019 USD per Metric Tonne)

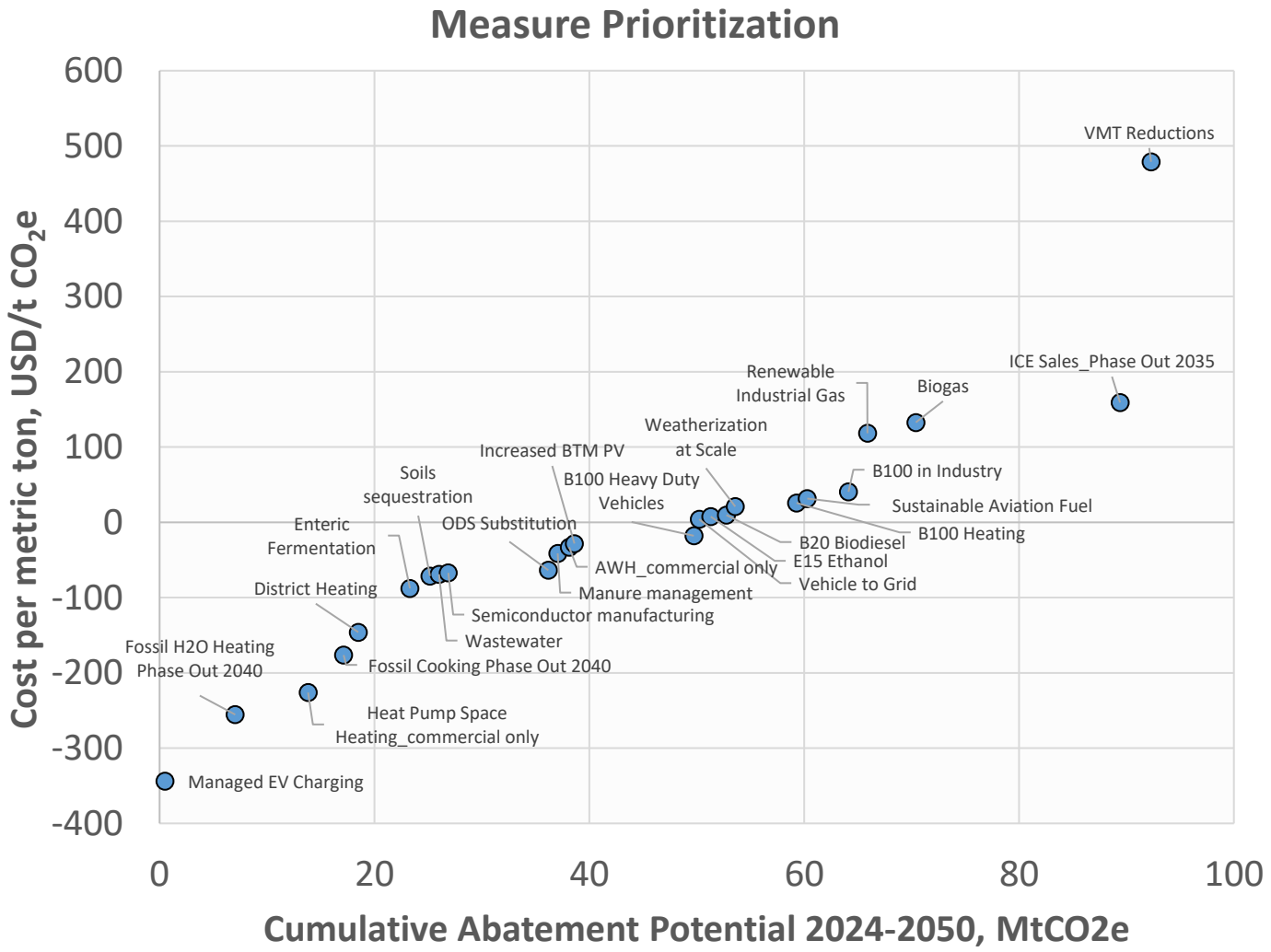
	Unadjusted Cost				100-Year GWP Adjusted			
	2020	2030	2040	2050	2020	2030	2040	2050
CO2	120	135	152	170	120	135	152	170
CH4	2,669	3,361	4,053	4,745	107	134	162	190
N2O	41,517	49,425	57,333	65,241	139	166	192	219

Source: New York DEC. Assumes 2% discount rate.



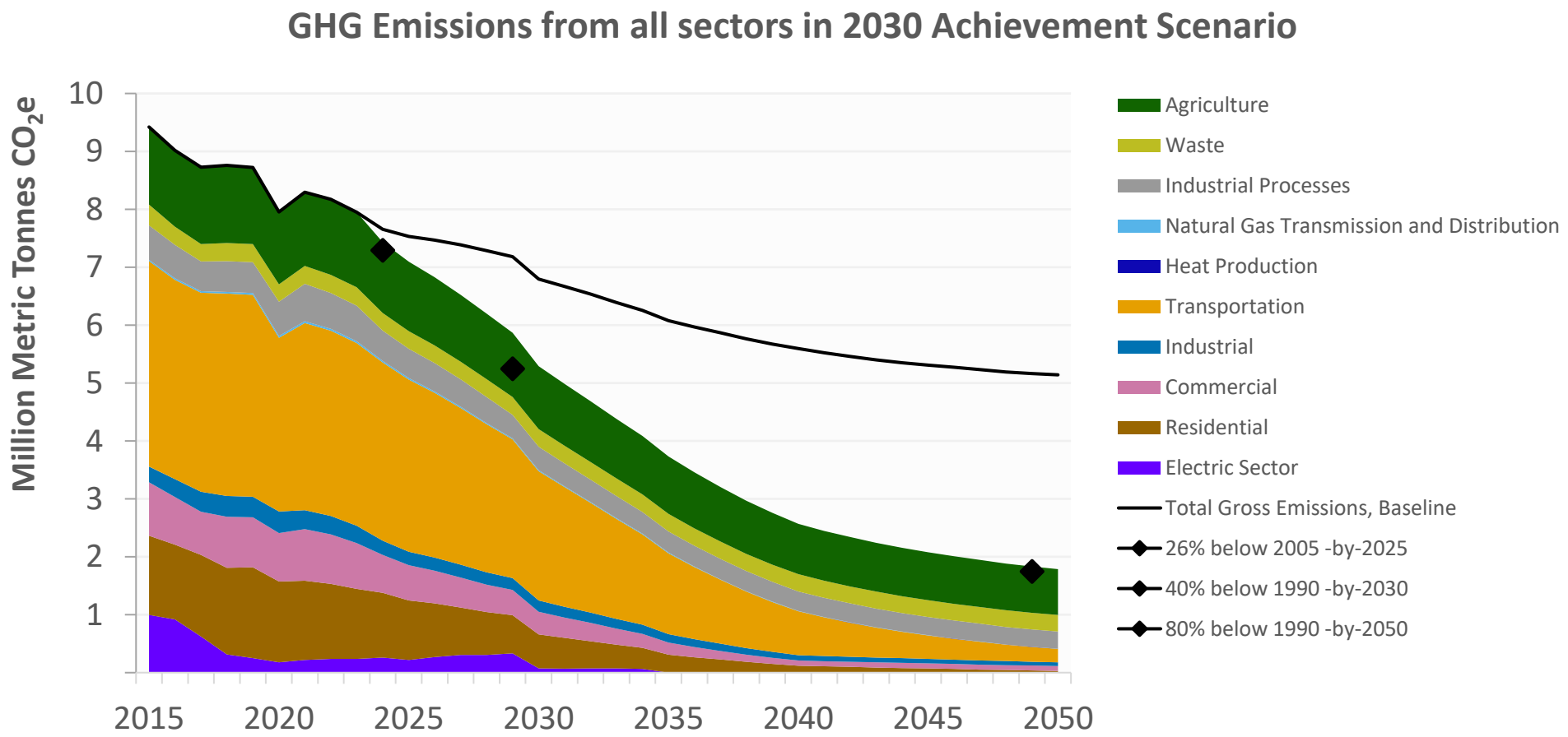
Cost effectiveness of measures

Mitigation Measure	Cumulative Abatement Potential [MtCO2e] 2024-2050	Cost per Metric Ton [USD/tCO2e]
Managed EV Charging	0.50	-343.70
Fossil H2O Heating Phase Out 2040	6.54	-255.43
Heat Pump Space Heating (commercial only)	6.78	-226.10
Fossil Cooking Phase Out 2040	3.31	-176.36
District Heating	1.37	-145.96
Enteric Fermentation	4.80	-87.68
Soils sequestration	1.87	-71.40
Wastewater	0.83	-68.97
Semiconductor manufacturing	0.87	-67.13
ODS Substitution	9.31	-63.61
Manure management	0.87	-41.17
Advanced wood heating (commercial only)	1.07	-32.97
Increased BTM PV	0.49	-28.15
B100 Heavy Duty Vehicles	11.11	-17.81
Vehicle to Grid	0.50	4.05
E15 Ethanol	1.08	7.58
B20 Biodiesel	1.45	9.71
Weatherization at Scale	0.82	20.98
B100 Heating	5.70	25.78
Sustainable Aviation Fuel	1.00	31.61
B100 in Industry	3.84	40.53
Renewable Industrial Gas	1.76	118.36
Biogas	4.51	132.77
ICE Sales Phase Out 2035	19.01	159.17
VMT Reductions	2.88	479.03



2030 Achievement Scenario

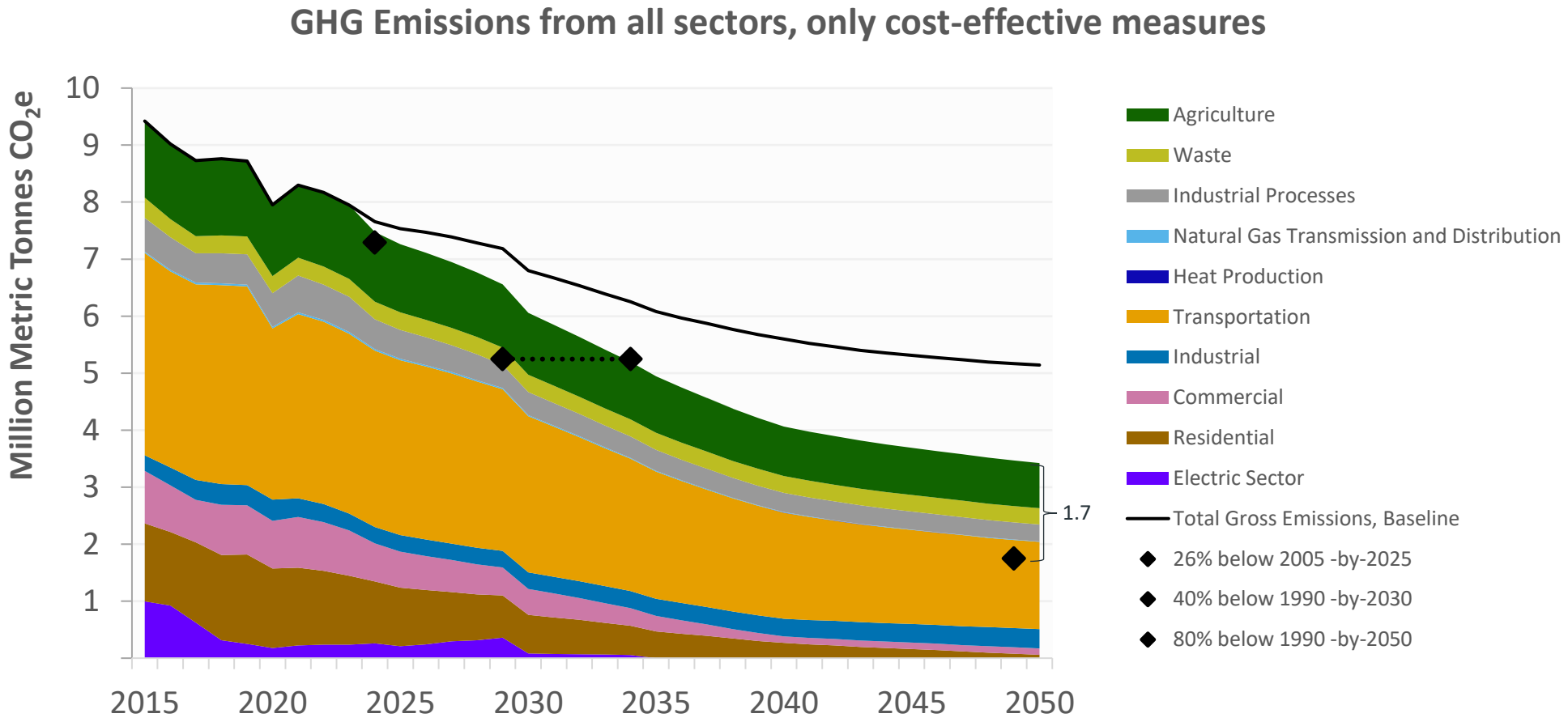
Includes all 25 measures with the original implementation rates



Cost-effective measures

Cost-effective measures:

- Managed EV Charging
- Fossil H2O Heating Phase Out 2040
- Heat Pump Space Heating (commercial only)
- Fossil Cooking Phase Out 2040
- District Heating
- Enteric Fermentation
- Soils sequestration
- Wastewater
- Semiconductor manufacturing
- ODS Substitution
- Manure management
- Advanced wood heating (commercial only)
- Increased BTM PV
- B100 Heavy Duty Vehicles



2035 Achievement Scenario

- Includes all measures
- Assumes delayed implementation of all non-cost-effective measures and B100 Heavy Duty Vehicles

Managed EV Charging
Fossil H2O Heating Phase Out 2040
Heat Pump Space Heating (commercial only)
Fossil Cooking Phase Out 2040
District Heating
Enteric Fermentation
Soils sequestration
Wastewater
Semiconductor manufacturing
ODS Substitution
Manure management
Advanced wood heating (commercial only)
Increased BTM PV

Maintain same implementation levels and ramp rates as Mitigation Scenario

B100 Heavy Duty Vehicles

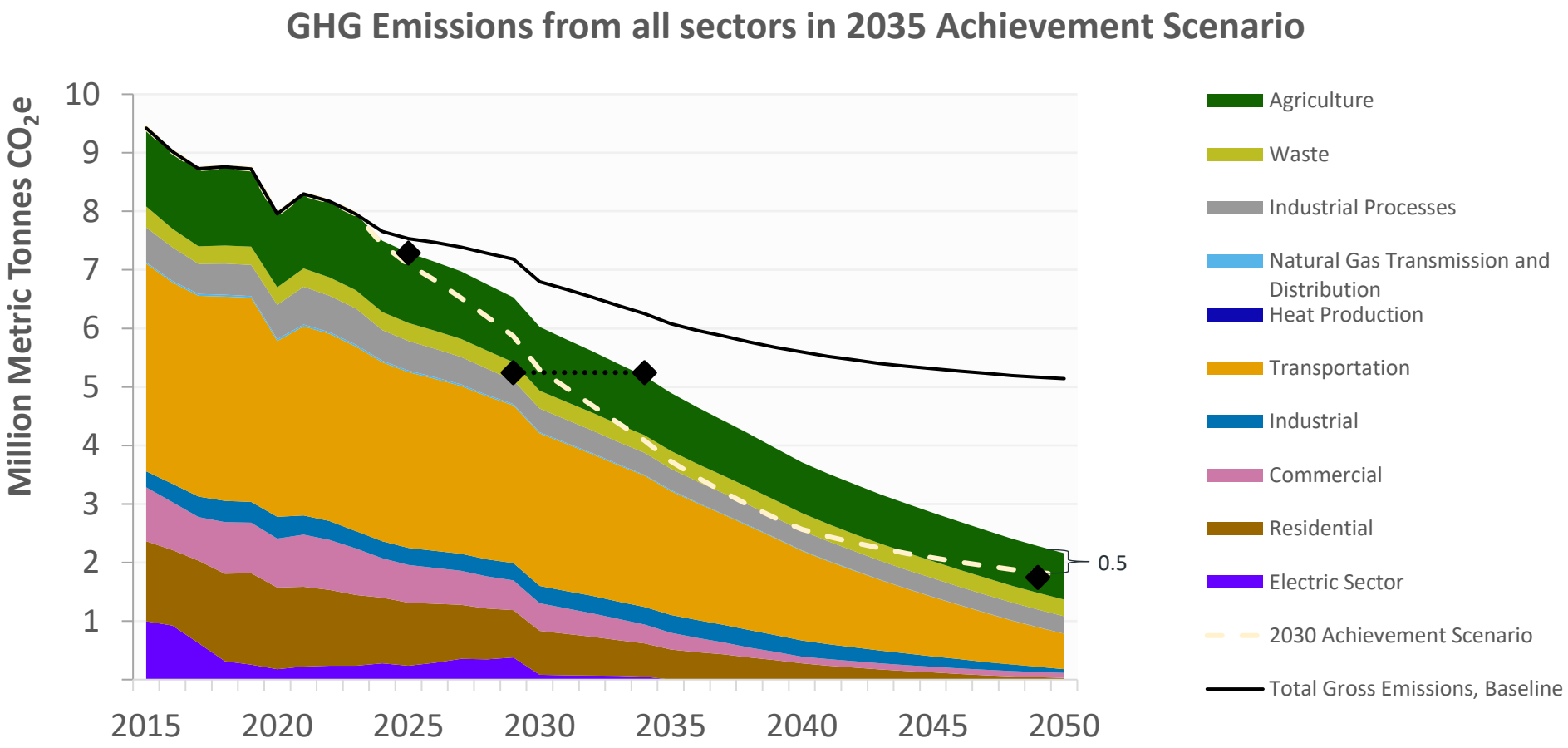
→ Start year pushed back by 10 years

Vehicle to Grid
E15 Ethanol
B20 Biodiesel
Weatherization at Scale
B100 Heating
Sustainable Aviation Fuel
B100 in Industry
Renewable Industrial Gas
Biogas
ICE Sales Phase Out 2035
VMT Reductions

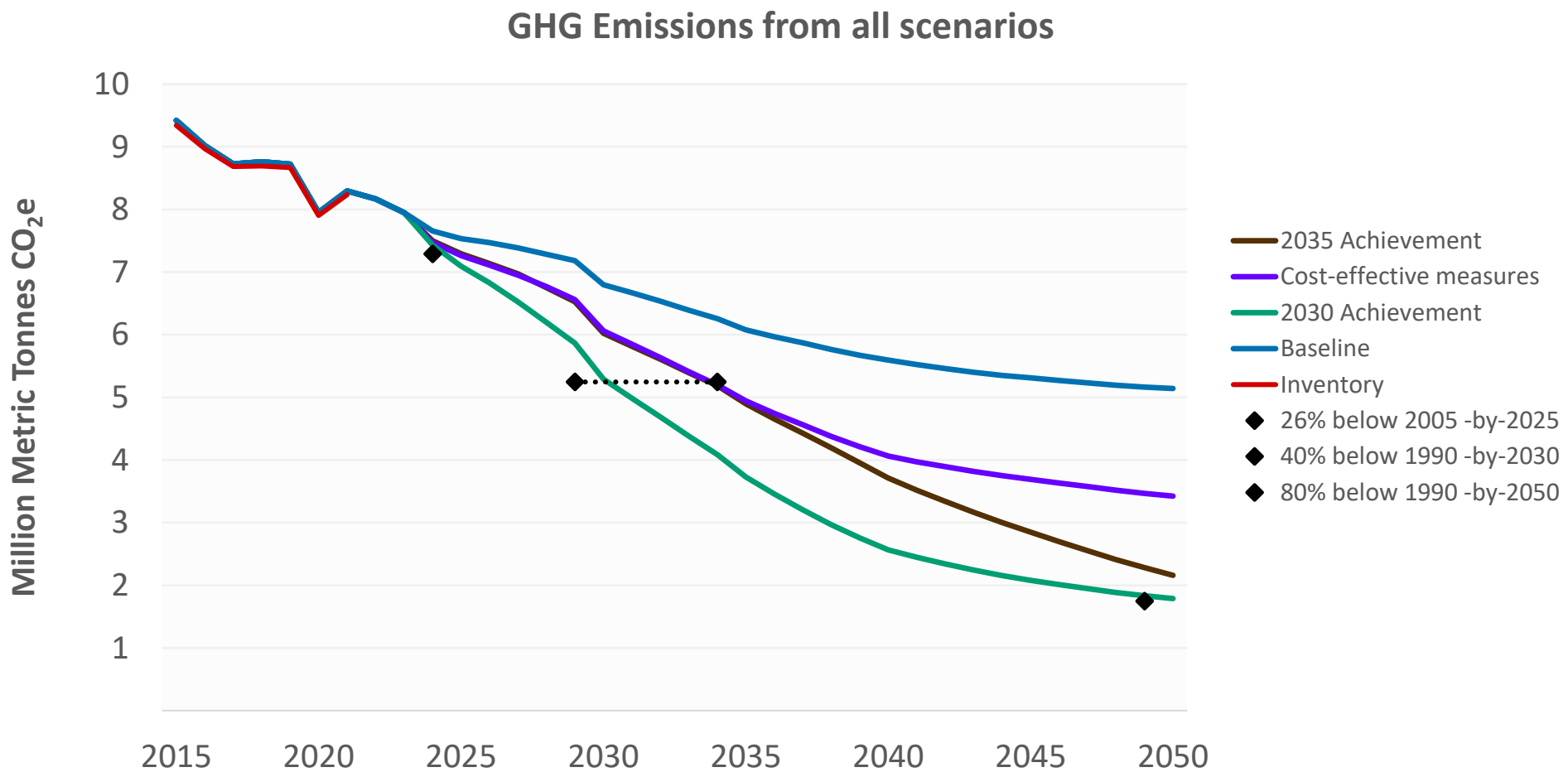
15 year delay in implementation

- *Measures with 2050 targets:* Target year remains 2050, but start year is delayed by 15 years.
- *Measures with pre-2050 targets:* Both start and end years delayed by 15 years, but end year capped at 2050.

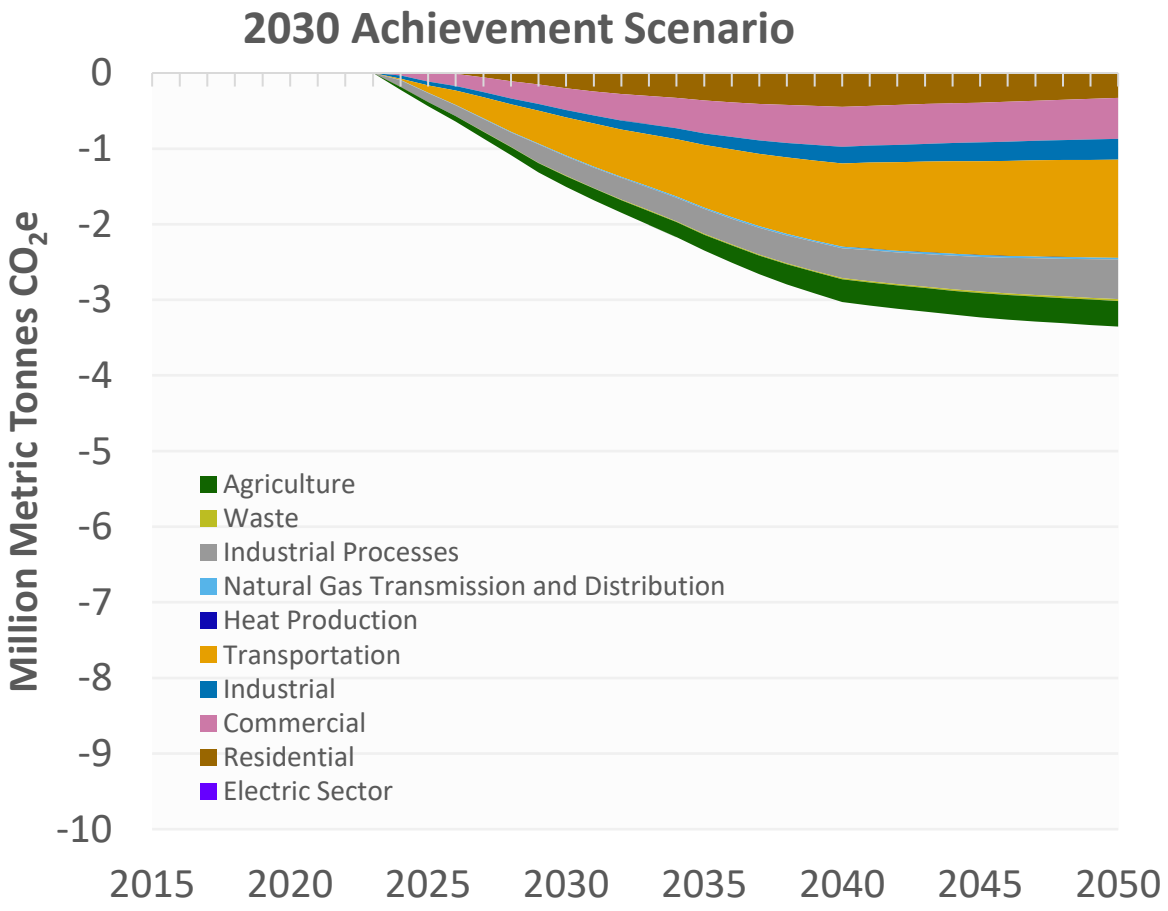
2035 Achievement Scenario

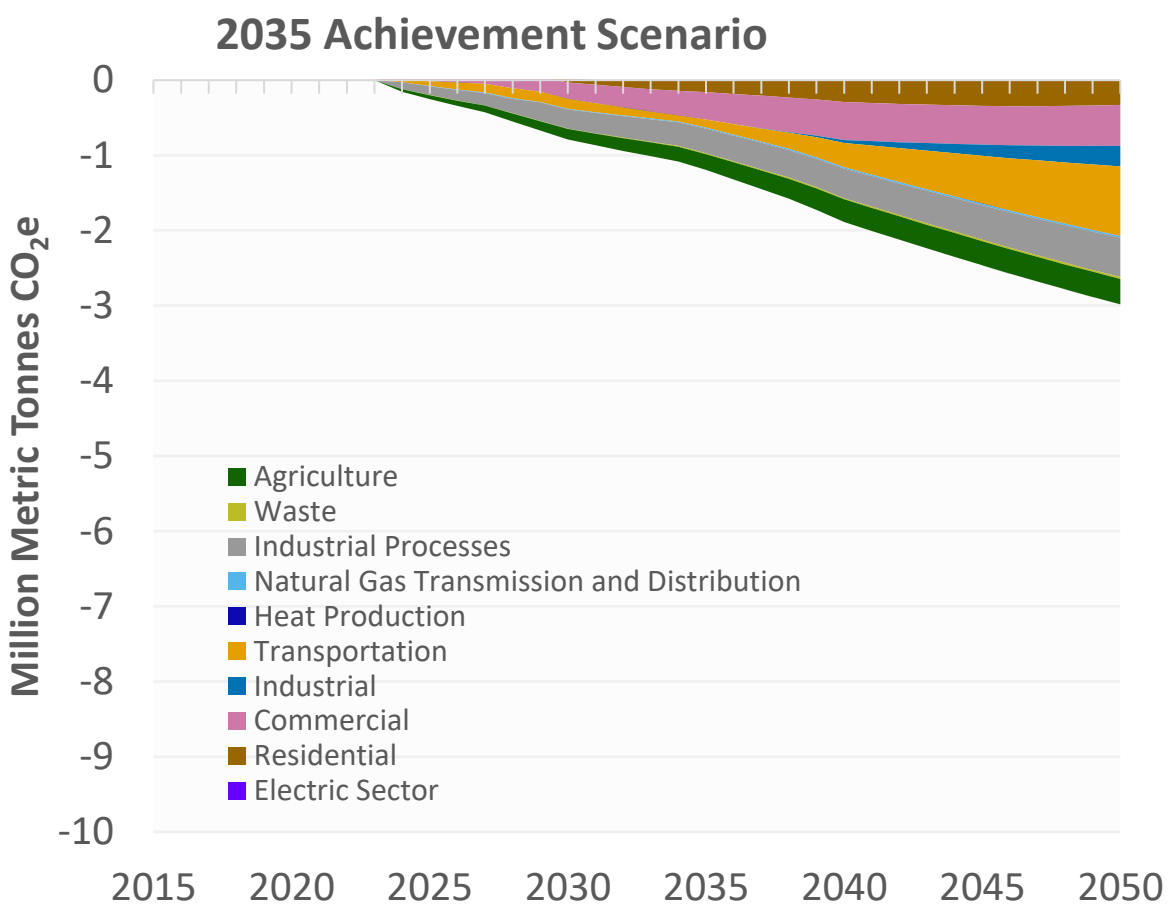


Scenario Comparison: Gross Emissions

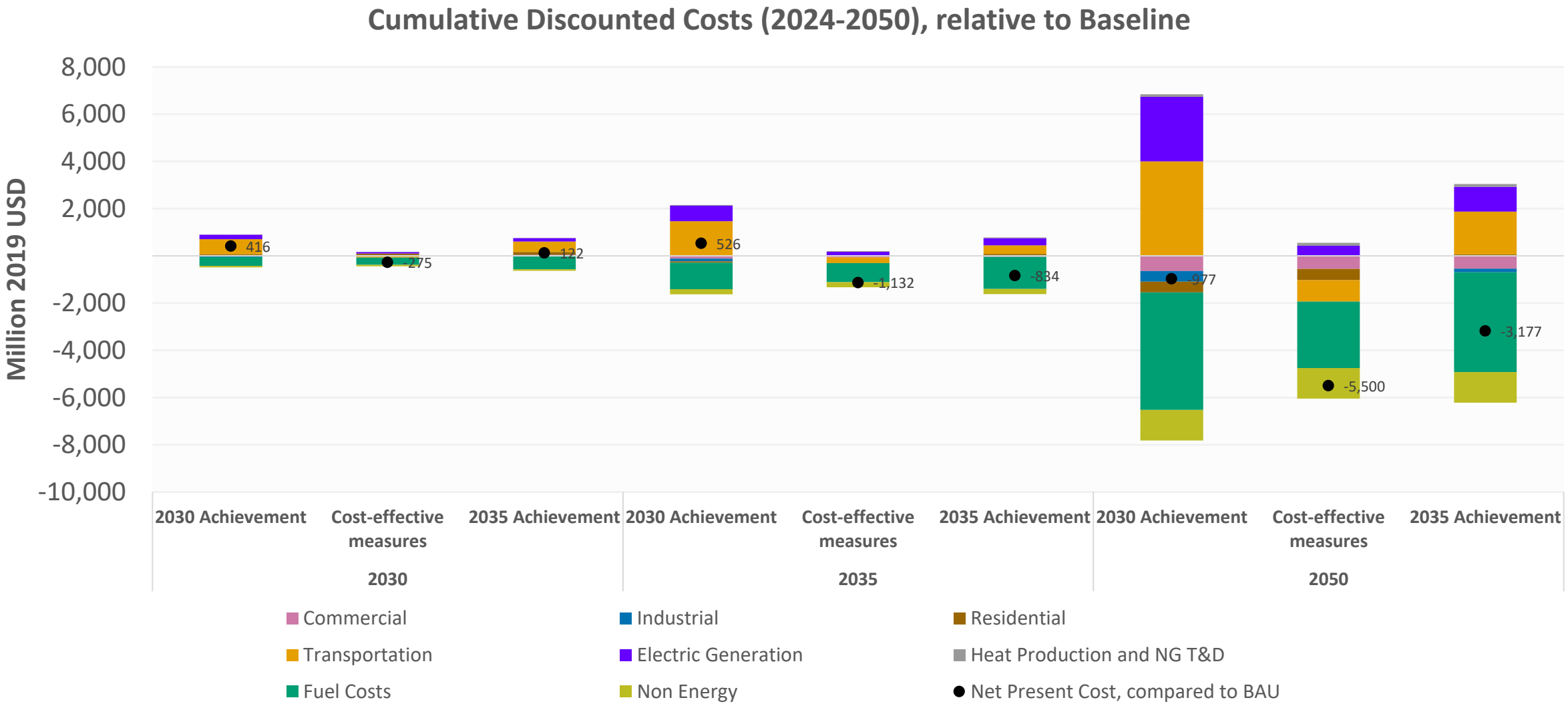


Scenario Comparison: Differences vs Baseline





Scenario Comparison: Costs vs Baseline



Scenario Comparison

Transportation Sector: Light- and Heavy-Vehicle Fleet Composition

	Scenario:	Baseline		2030 Achievement		2035 Achievement	
	As of Dec 31:	2030	2050	2030	2050	2030	2050
EVs	Light-Duty	13%	54%	17%	95%	18%	75%
	Heavy-Duty	2%	6%	11%	80%	0%	34%
PHEVs	Light-Duty	3%	10%	1%	0%	3%	5%
	Heavy-Duty	0.1%	0.4%	0.1%	0%	0%	0%
EVs + PHEVs	Light-Duty	15%	64%	18%	95%	21%	81%
	Heavy-Duty	2%	7%	11%	80%	0%	34%

Scenario Comparison

Residential Sector: Cumulative and Average Annual Weatherization Retrofits since Jan. 1, 2025

Scenario:	Baseline		2030 Achievement		2035 Achievement	
As of Dec 31:	2030	2050	2030	2050	2030	2050
Number of Retrofits	24,656	67,918	69,676	193,161	14,071	190,940
Average installed per year	4,109	2,612	11,613	7,429	2,345	7,344



Questions and discussion


Thank you!

Cross-cutting

Measure	Description
B20 Biodiesel	20% biodiesel (by volume) in transport, industrial diesel and heating oil by 2050.

Residential and commercial

Applicable to both sectors:

Measure	Description
B100 Heating	Gradual introduction of biodiesel (B100) into heating oil starting in 2024, fully replacing fuel oil in both residential and commercial sectors by 2040.
Fossil Cooking Phase Out 2040	Eliminates fossil fuel use for cooking by shifting all fossil-based residential and commercial cooking to electricity by 2040.
Fossil H2O Heating Phase Out 2040	Transitions all residential and fossil-fueled commercial water heating to electricity by 2040, primarily through heat pump technologies.
Biogas	Expands biogas use to supply 80% of distributed natural gas by volume by 2050.

Additional measures in residential sector:

Measure	Description
Weatherization at Scale	Increased weatherization, targeting ~120k households by 2050

Residential and commercial

Additional measures in commercial sector:

Measure	Description
District Heating	Expands commercial district heating using 100% renewable heat from wood waste solids, with the McNeil project in 2027 and four additional dedicated heat plants by 2040.
Advanced Wood Heating (AWH)	Introduction of high-efficiency pellet boilers to displace oil and propane boilers in buildings. By 2045, AWH displaces 20% of these systems in the commercial sector.
Heat Pump Space Heating	Accelerated adoption of high-efficiency heat pumps to replace fossil fuel heating systems. By 2040, high efficiency heat pumps meet heating demands of up to 80% of commercial buildings.

Transport

Measure	Description
B100 Heavy Duty Vehicles	Starting in 2025, all heavy duty (classes 7-8) diesel, diesel hybrids, and diesel PHEV are retrofitted with a dual tank system and subsequently run on biodiesel (B100) only.
E15 Ethanol	By 2040, 15% ethanol by volume in transport gasoline.
ICE Sales_Phase Out 2035	Starting in 2035, no ICE vehicles sold for road transport.
Managed EV Charging	By 2040, 75% of EV charging follows a load-shifting program.
Sustainable Aviation Fuel	By 2050, 50% of jet kerosene is replaced by SAF.
Vehicle to Grid	By 2040, 15% of passenger and class 1_2a vehicles provide 10kW of capacity.
VMT Reductions	By 2050, 10% reduction in VMT compared to baseline.

Industry

Measure	Description
B100 in Industry	By 2040, 100% of diesel used in industry is biodiesel.
Renewable Industrial Gas	By 2050, 80% of natural gas used in industry is biogas.

Power Generation

Measure	Description
Increased BTM PV	By 2035, 2.4x more BTM PV compared to baseline (2050 values: ~3,800MW vs ~1,500MW.)

Non-Energy

Measure	Description
Enteric Fermentation	• By 2040, Enteric Fermentation emissions are 70% of baseline scenario value.
Manure Management	• By 2030, Manure Management methane emissions are 70% of baseline scenario value.
ODS Substitution	• Emissions from ozone-depleting substances decline to 164,590 $MTCO_2e$/year by 2029, followed by continued declining trend of -5.9%/year
Soils Sequestration	• By 2050, soils sequester approx. 100,000 metric tons of CO2 annually.
Semiconductor Manufacturing	• By 2030, ~10% decrease in semiconductor manufacturing emissions.
Wastewater Methane	• By 2050, bring wastewater methane emissions to half of baseline value.