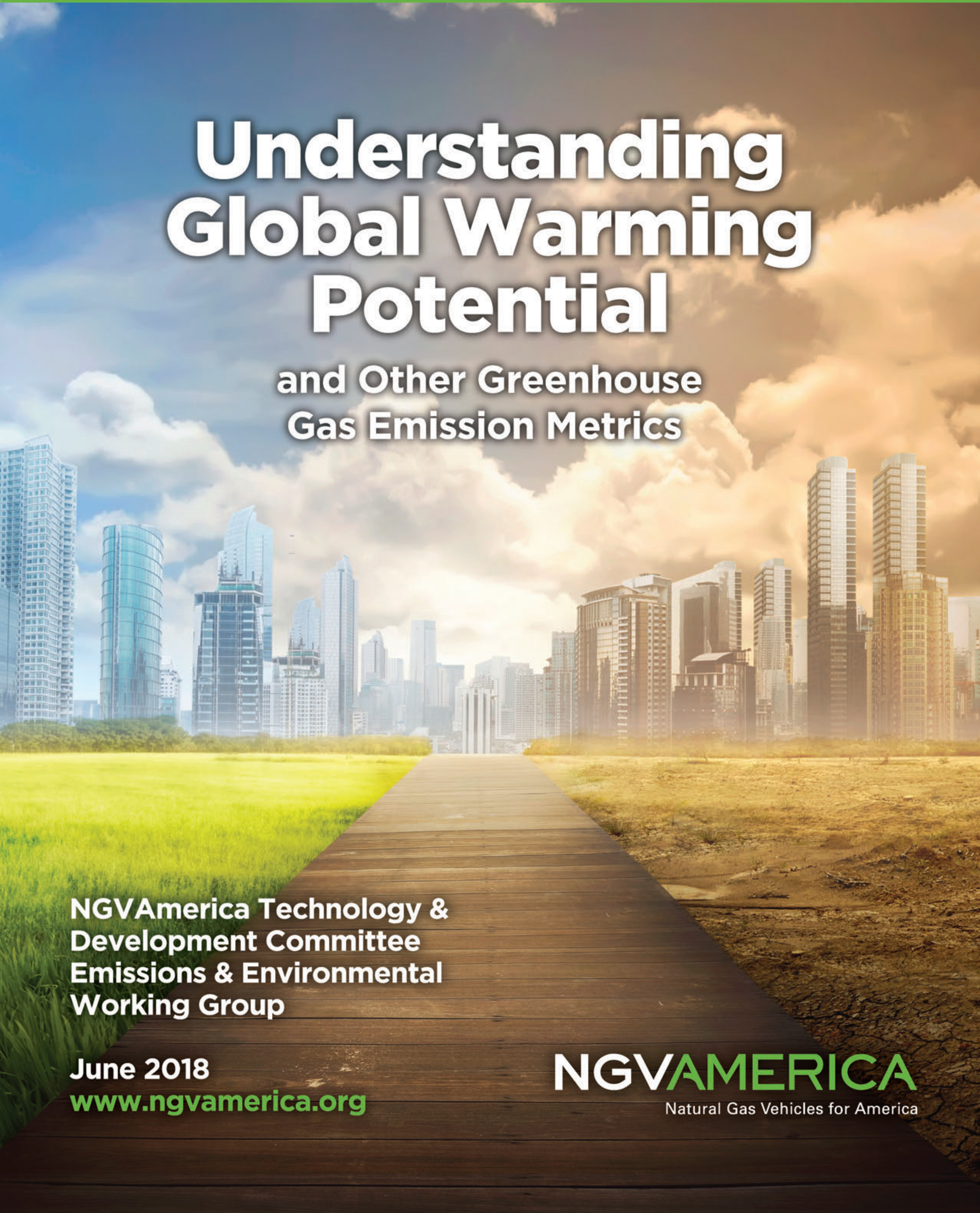

Understanding Global Warming Potential

and Other Greenhouse Gas Emission Metrics

NGVAmerica Technology & Development Committee Emissions & Environmental Working Group

June 2018
www.ngvamerica.org

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Natural Gas Vehicles for America

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Introduction

In recent years, the focus on **CLIMATE CHANGE** has become a top policy issue with nations and states aggressively planning to tackle emissions that contribute to climate change. To understand the impact of different policy options, the scientific community has devised different metrics for calculating the potential climate impacts of different molecules (e.g., greenhouse gases). There are several metrics for analyzing the impact of different greenhouse gases, and there is some debate about which methods are most appropriate. The metrics universally use carbon dioxide as a baseline for comparisons because it is the dominant greenhouse gas in terms of annual emissions.

Currently, **GLOBAL WARMING POTENTIAL (GWP)** is the most widely adopted method for comparing the impact of different greenhouse gas emissions to carbon dioxide. The GWP timeframe, or horizon, has a number of benchmark periods ranging from 20 to 100 years. Each benchmark is associated with a multiplier that is used to determine the potency of each greenhouse gas. Many, but not all, regulatory agencies throughout the world use the 100 year benchmark. The reason for using a longer timeframe is simple – by using a timeframe of 100 years, emissions calculations better aggregate all atmospheric cycling on timescales more representative of climate change (e.g., regional weather over long periods).

METHANE is a powerful greenhouse gas that is created from a number of sources including: dairy cows and other livestock manure, enteric fermentation (a digestive process), organic waste streams, termites, wetlands, rice fields, landfills, biomass burning as well as fugitive emissions from oil production, processing, and storage, as well as gas pipeline systems and industrial operations.[1] While carbon dioxide can stay in the atmosphere for thousands of years, other greenhouse gases such as methane stay in the atmosphere for much shorter durations. Methane is a short-lived climate pollutant that has a limited lifetime before it decays or oxidizes in the atmosphere. The focus on short-lived climate pollutants often is touted as a way to lower short term concentrations of greenhouse gases but it is usually never touted as an alternative to addressing emissions of long lasting pollutants like carbon dioxide. The natural gas vehicle industry's viewpoint is that it should limit methane emissions despite the fact that natural gas vehicles (NGVs) emit only a very small fraction of the global methane emissions compared to all other natural and human inspired sources. The natural gas vehicle industry has made many great advancements in recent years with improved engine and compressor systems to reduce its fraction of methane emissions.

Emission Metrics

GREENHOUSE GAS (GHG) EMISSION METRICS are used to compare molecules to each other and their overall impact on climate change. There are several potential emission metrics available today, such as the Global Warming Potential (GWP), Global Temperature change Potential (GTP) and Technology Warming Potential (TWP). Understanding each of these metrics is critical to understanding the results of any GHG comparison between fuels, vehicles, power plants, etc.

Both GWP and GTP are based on the **RADIATIVE FORCING EFFECTS** of different gases released into the atmosphere, with the heat trapping properties of different gases being the primary driver of changes in atmospheric energy balance and climate change effects.

[1] Seisler, J. (2009). Rationale for the Development of a Non-Methane Hydrocarbon Regulation for Natural Gas Vehicles. Presentation, Informal Group on Gaseous Fuel Vehicles (GFV) United Nations. Retrieved from http://www.unece.org/fileadmin/DAM/trans/doc/2009/wp29grpe/GFV-04-08e.pdf

GLOBAL WARMING POTENTIAL: This is the comparison of the impact of different greenhouse gases. All gases are compared to carbon dioxide (CO_2) as a baseline to understand their relative impact on cumulative radiative forcing changes over a given timeframe. Since this is a cumulative measurement, effects that are created early in a time period are still included for consideration even if the gas (e.g. methane) is gone before the end of the time period. Typically a time period of 100 years is utilized, but any time horizon can be used. Values for different gases consider the lifetime and the amount of energy absorbed by the gas to determine the appropriate GWP multiplier.[2] Values are created and updated by the Intergovernmental Panel on Climate Change (IPCC) and other bodies, and are used regularly in climate regulations. When emissions of different gases are summed using their GWP multiplier, the result is a total GHG metric in terms of CO_2 equivalent emissions.

GLOBAL TEMPERATURE CHANGE POTENTIAL: This comparison estimates the potential surface temperature response to emissions of different gases in a certain future year, instead of spreading the impact over many years. This is a useful metric for target based climate policies, such as keeping the temperature change below 2 °C.[3] GTP values also are based on the radiative forcing effects of different gases and are used to compare an estimate of the resulting surface temperature change to that produced by the emission of an equal mass of CO_2.

Values for both GWP and GTP are updated by the IPCC and used in academic and scientific studies.[4] Both GWP and GTP are calculated assuming that there is a single time pulse emissions of a gas into the atmosphere.

When the total emissions of different fuels are summed using either the GWP or GTP method, fuels or technologies can then be compared to each other to estimate a relative GHG benefit based on total CO_2 equivalent emissions. To be fully transparent, comparisons should state both the time horizon and the emission metric used.

TECHNOLOGY WARMING POTENTIAL: This metric relates to comparing the impacts of different technologies to each other, using their total CO_2 equivalent emissions. In this way, it is a comparison of GHG emissions, and can be used with either GWP or GTP as the multiplier for the different gaseous emissions produced by the two technologies being compared. The key benefit of this method is that it allows the user to account for the fact that when technologies are deployed, the emission of gases is really a series of pulses, be it daily or annual, over the in-service life of the technology.

[2] Understanding Global Warming Potentials. (2017, February 14). Retrieved from https://www.epa.gov/ghgemissions/understanding-global-warming-potentials. United States Environmental Protection Agency (EPA).

[3] Can global temperature change potential replace GWP in upcoming regulations? Retrieved from https://www.kth.se/en/itm/inst/energiteknik/forskning/ett/projekt/koldmedier-med-lag-gwp/low-gwp-news/vilket-matt-ska-vi-anvanda-for-koldmediernas-klimatpaverkan-1.473500. Sweden Department of Energy Technology. April 16, 2014.

[4] 2.10 Global Warming Potentials and Other Metrics for Comparing Different Emissions. (n.d.). Retrieved from https://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10.html

Chemical	Global Warming Potential (GWP)		Global Temperature Potential (GTP)		Perturbation Lifetime
	GWP_{20}	GWP_{100}	GTP_{20}	GTP_{100}	
Methane (CH_4)	84	28	67	4	12.4 years
Carbon Dioxide (CO_2)	1	1	1	1	Up to thousands of years
Nitrous Oxide (N_2O)	264	265	277	234	121 years
Chlorofluorocarbon-13 (CFC-13)	10,900	13,900	11,700	15,900	640 years

TABLE 1 Intergovernmental Panel on Climate Change Assessment Report 5 (Table 8.A.1)
Note – values presented above do not include any secondary carbon emission consideration (e.g., the degradation of CH4 to CO2). Methane's GWP100 officially could range from 28-34 times more potent than CO2 if such affects are considered.

THE IPCC has produced five different reports, starting in 1990; the most recent being the Assessment Report 5 published in 2013. The Global Warming Potential values for different gases have changed over time as new Assessment Reports have been issued. The changes reflect improvements in science and changes in the understanding of the impact of different gases. These new assessments are meant to make emission calculations more accurate and better predictors of a chemical's future impact on climate change.

By far the most common **EMISSION METRIC** used today is GWP, which looks at the potential effect of greenhouse gases on the climate. These numbers are an index comparing greenhouse gases to carbon dioxide over a specified timeframe. The timeframe typically used is 100 years, however, there are instances when shorter timeframes may be considered. Examples of common gases are shown in Table 1, but should not be considered a complete list.

Why is Global Warming Potential used?

GWP is used to show the effect of different greenhouse gases on the climate over a period of time. GWP is shown as carbon dioxide equivalents, hence carbon dioxide has a GWP of 1. By giving greenhouse gases a carbon dioxide equivalent number, users are able to compare greenhouse gases on a common basis to determine what will have more or less impact on the climate. GWPs have a timeframe built into the carbon dioxide equivalent value. The timeframe is the period of time over which the impacts are spread, or integrated, and used to compare the atmospheric energy trapped by a gas.

GWP AND TIMEFRAMES are used in a variety of applications. In transportation, the GWP feeds into vehicle emission calculations. This can be used to compare greenhouse gas emissions from different fuels.

> "The methane is like a hangover that you can get over if you stop drinking. CO_2 is more like lead poisoning — it sticks around, you don't get rid of it, and it causes irreversible harm."[5]
>
> – **Raymond T. Pierrehumbert**

[5] Picking Lesser of Two Climate Evils. (2017, December 20). Retrieved from https://www.nytimes.com/2014/07/08/science/climate-methane-global-warming.html

Why are different timeframes used?

The metrics used to evaluate different greenhouse gases allow for comparisons over different timeframes. For instance, some look at the relative impact over 20, 40, 50, or 100 years. Consideration of different timeframes allows policy makers to assess the relative importance of different control strategies over time to understand how reductions in different gases can impact short-term as well as long-term effects of greenhouse gases in the atmosphere. When looking at a shorter time horizon as has been discussed in some climate science reports, such as 20 years, GWP numbers will be higher for short-lived gases. This is due to the fact that the gas's impact on the climate is assessed over a shorter period of time. Using different timeframes does not change the amount of greenhouse gases emitted, however, it does change the climate impact being estimated. Policy makers and analysts sometimes use different years/multipliers to suit their own negative or positive views of methane so supporters and experts need to be aware of the GWP chosen to ensure that the policies or analytic conclusions being made are not skewed by the use of one GWP versus another.

CARBON DIOXIDE is the primary long lived pollutant, and while much of the CO_2 can be absorbed by the oceans within centuries, the remaining CO_2 can stay in the atmosphere for thousands of years.[6] The US EPA states that, "Atmospheric CO_2 is part of the global carbon cycle, and therefore its fate is a complex function of geochemical and biological processes. Some of the excess carbon dioxide will be absorbed quickly (e.g., by the ocean surface), but some will remain in the atmosphere for thousands of years, due in part to the very slow process by which carbon is transferred to ocean sediments."[7]

METHANE on the other hand is a short-lived climate pollutant (SLCP), which during its brief lifetime has a greater potential to capture heat, but remains in the atmosphere for a much shorter amount of time. The decision that policy makers need to address is whether reducing methane emissions should be the priority, even though methane will dissipate in a few years, or whether the focus should be on reducing carbon dioxide, which can stay in the atmosphere for thousands of years.

The California Air Resources Board (CARB), US Environmental Protection Agency (EPA), British Columbia's Low Carbon Fuel Standard, and the Fuel Quality Directive (FQD) in Europe all use **IPCC'S 4TH ASSESSMENT REPORT GWP100** value for greenhouse gases. The US EPA has chosen to update the CH_4 GWP100 value to 34 which includes consideration for the carbon feedback in the IPCC's 5th Assessment range for only the "GHG Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles – Phase2."

"SLCP mitigation is essentially useless in the absence of very stringent and immediate measures to restrict CO_2 emission."[8]

– **Raymond T. Pierrehumbert,** lead author for the IPCC Third Assessment Report

[6] Archer, D., Eby, M., Brovkin, V., Ridgwell, A., Cao, L., Mikolajewicz, U., . . . Tokos, K. (2009). Atmospheric lifetime of fossil fuel carbon dioxide. Annual Review of Earth and Planetary Sciences,37, 117-134. doi:10.1146/annurev.earth.031208.100206 (http://climatemodels.uchicago.edu/geocarb/archer.2009.ann_rev_tail.pdf

[7] Overview of greenhouse gases. Retrieved from https://www.epa.gov/ghgemissions/overview-greenhouse-gases#CO2%20lifetime

[8] Pierrehumbert, R.T. (2014). Short-Lived Climate Pollution. Annual Review of Earth and Planetary Sciences,42, 341-379. doi:10.1146/annurev.earth.060313-054843 (http://www.sequoiaforestkeeper.org/pdfs/attachments/Pierrehumbert_on_SLCPs.pdf)

How can the transportation industry reduce its carbon footprint?

NATURAL GAS consists mostly of methane and when combusted can produce about 27% less carbon dioxide than diesel on a fuel energy basis.[9] The Cummins Westport Near-Zero Natural Gas engines are certified with at least a 9% GHG improvement compared to their diesel counterparts. The Cummins Westport Near-Zero Natural Gas engines have closed crankcase ventilation systems, which reduces unburned methane emissions from the crankcase. The closed-crankcase systems and other upgrades deployed by Cummins Westport optimize operation, increase efficiency and reduce emissions. For new spark-ignited natural gas engines, these changes have resulted in a more than 70% reduction in methane emissions compared to engines produced only a few years ago.

RENEWABLE NATURAL GAS (RNG) is a domestic, renewable, clean fuel derived from organic waste resources (agriculture, landfills, waste water treatment plants, and municipal solid waste). These sources result in a fuel that can have a negative carbon intensity. In other words, using RNG as a transportation fuel is actually removing GHGs that would otherwise be emitted to the atmosphere. RNG use in the NGV industry continues to grow; over 60% of the natural gas used in transportation in California in 2017 came from renewable sources.[10] A fleet or individual who makes the transition to operating vehicles on natural gas is reducing the amount of carbon dioxide that could exist in the atmosphere for millennia.

[9] U.S. Energy Information Administration - EIA - Independent Statistics and Analysis. (n.d.). Retrieved from https://www.eia.gov/tools/faqs/faq.php?id=73&t=11

[10] https://www.sempra.com/newsroom/press-releases/socalgas-streamlines-processes-support-renewable-gas-projects

Conclusion

EMISSION METRICS are critical for governments, companies, and individuals looking to evaluate the environmental impact of local or global emissions. Global warming potential is the most common emission metric used today. By comparing greenhouse gases to carbon dioxide over a specified timeframe, the user is able to make the appropriate choice in determining the best technology available.

For transportation applications, **NATURAL GAS** is a cost effective alternative to traditional fuels. Natural gas consists mostly of methane that when it is combusted is converted to carbon dioxide. The resulting carbon dioxide emissions from burning natural gas are up to 27% less than is produced from burning diesel fuel on an energy equivalent basis. Most of the methane emissions associated with natural gas vehicles results from incomplete combustion and the release of unburnt methane. New natural gas engines deploy technology that improves efficiency and reduces unburnt methane emissions. The Cummins Westport Near-Zero Natural Gas engines are certified with a 14% reduction in CO_2, and an overall 9% reduction in greenhouse gas emissions compared to their diesel counterpart (using GWP100 from IPCC AR4), and a 70% methane emission reduction compared to similar natural gas engines produced only a few years ago.

The production of advanced biofuels, such as **RENEWABLE NATURAL GAS (RNG)**, often results in the reduction of methane and carbon dioxide emissions from organic waste streams (agriculture, landfills, wastewater treatment plants, and municipal solid waste), which has the potential to have a negative carbon intensity. Methane from organic waste streams can be collected and cleaned to pipeline quality gas, which can then be used in NGVs. In 2017, 60% of all natural gas used in vehicles in California was from renewable sources.

CARBON DIOXIDE can stay in the atmosphere for millennia, while methane stays in the atmosphere for approximately 12 years. Unfortunately, climate change is not something that will be eliminated in the near term. Emission calculations using a timeframe of 100 years aggregates all atmospheric cycling on timeframes more representative of climate (e.g., regional weather over long periods) and should be the most reliable and operative timeframe for consideration of the global warming effects of methane.

Using natural gas in transportation provides an immediate reduction in long-lived CO_2 emissions. The NGV industry is demonstrating its ability to dramatically reduce the amount of methane emitted along the whole supply chain, minimizing the short term impact of methane and leading to a stronger contribution to overall climate change mitigation than many other currently available fuels used in the transportation sector.

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