Natural Gas and Transportation:
Diesel, Gasoline, Natural Gas, and Efficiency

Pamela Campos
December 13, 2012

EDF
ENVIRONMENTAL DEFENSE FUND™
Finding the ways that work

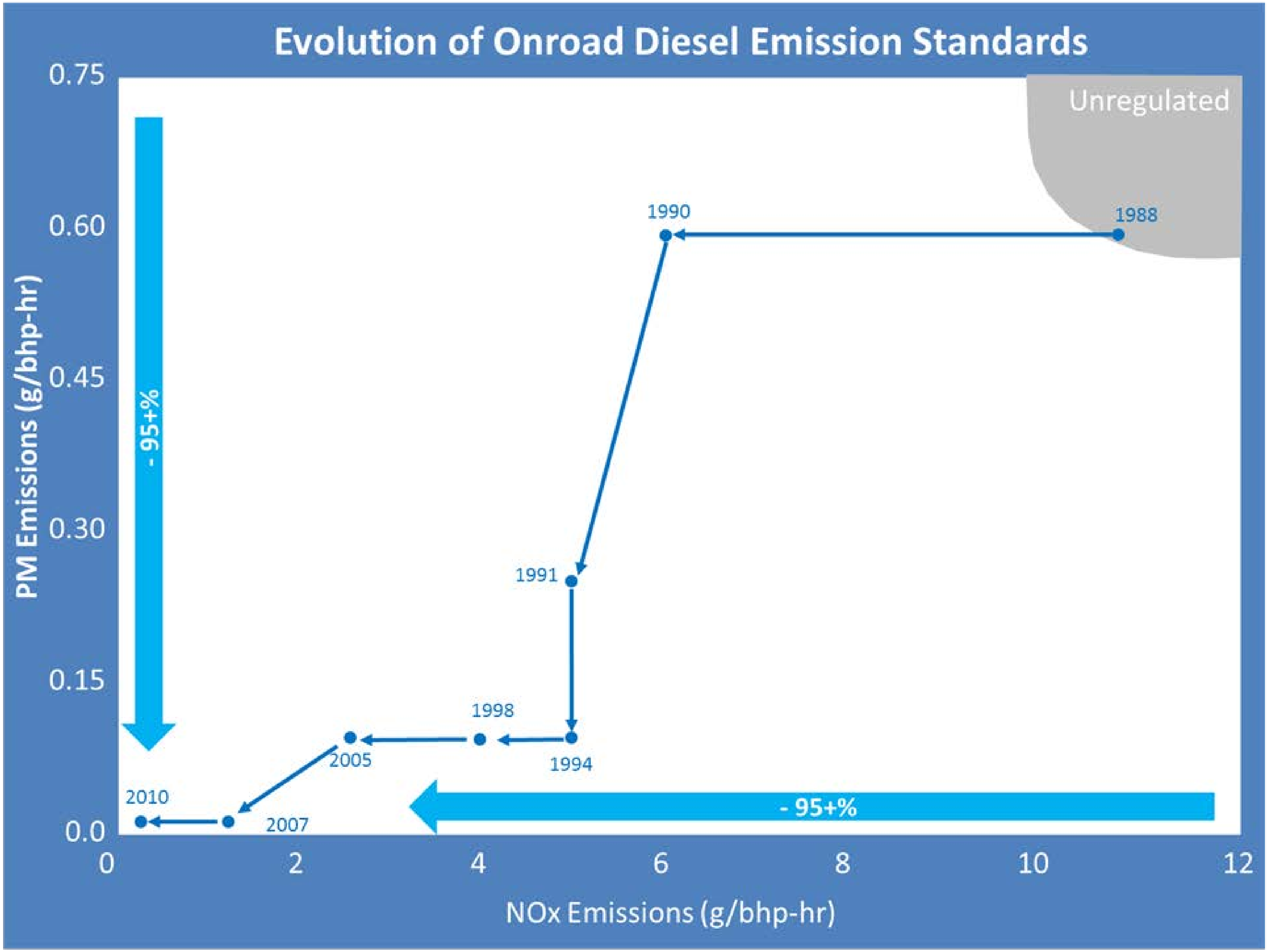
“ Natural gas could be a win-win, if— and this is a big ‘if’—we do it the right way.”

–Fred Krupp, President, EDF

Five Areas of Needed Action

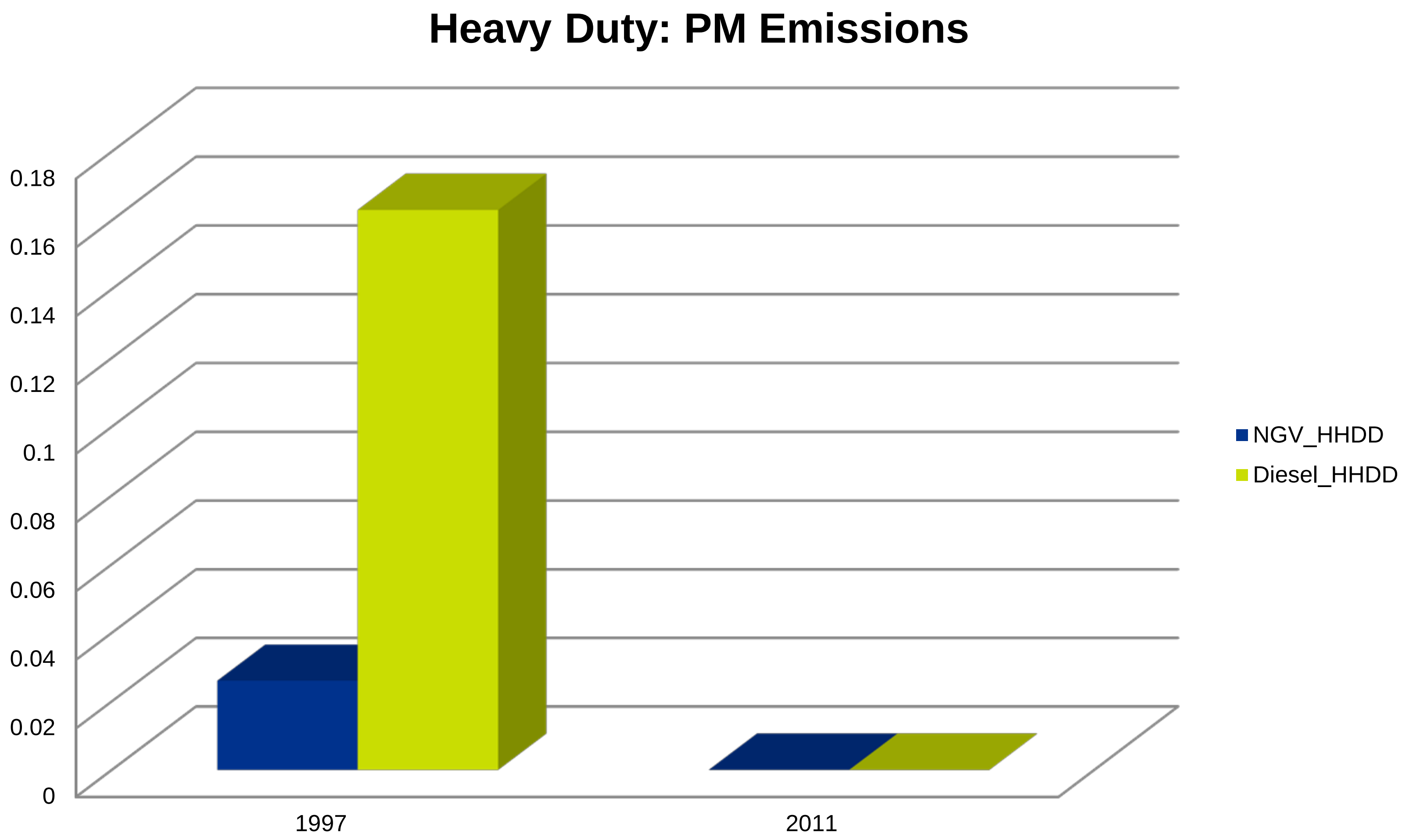
1. Mandating greater transparency in industry operations.
2. Modernizing rules for well construction and operation.
3. Strengthening regulations for waste and water management.
4. Improving regulations to protect local and regional air quality.
5. Developing innovative strategies to reduce community impacts.

History of HD Engine Standards



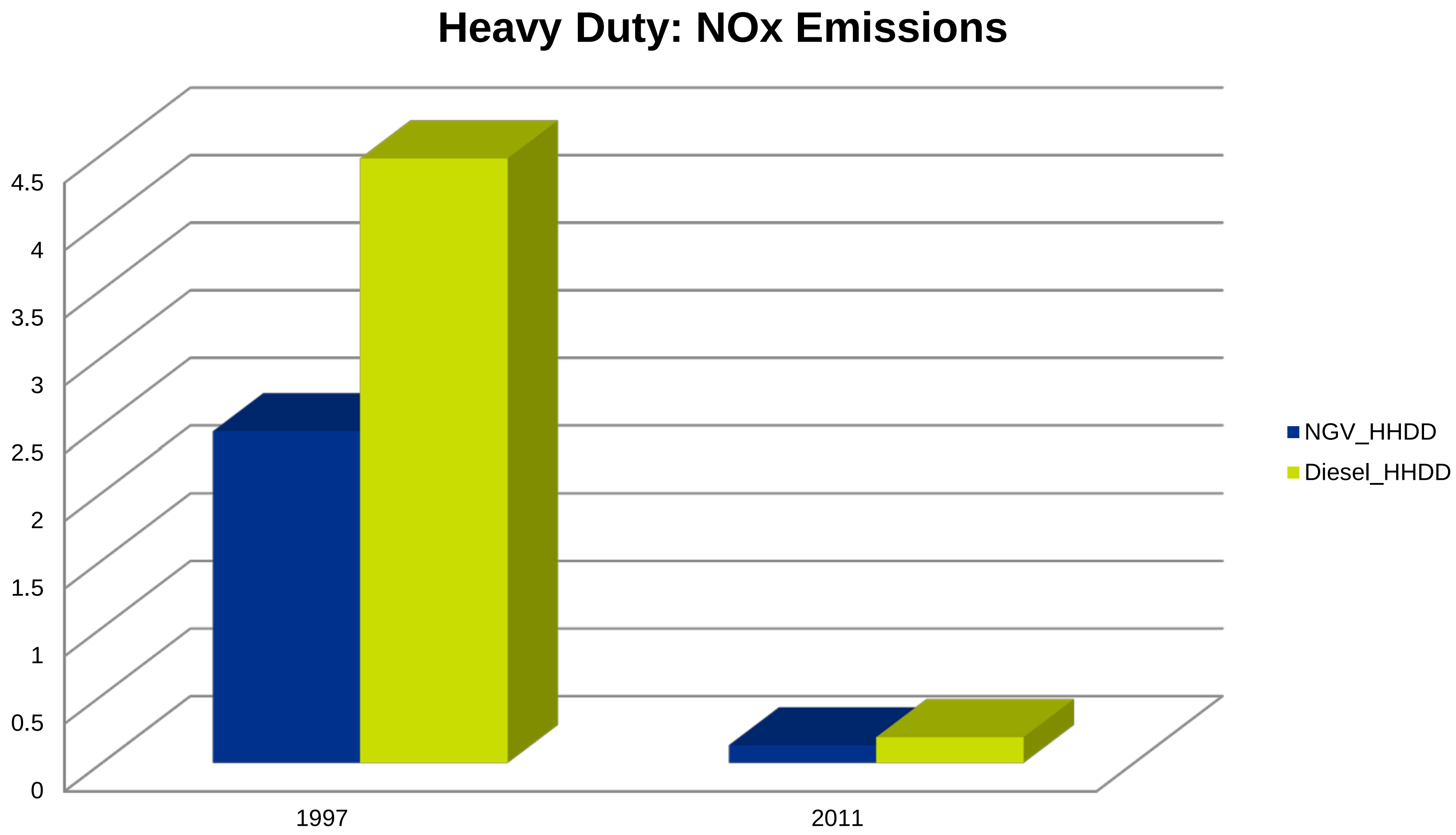
Significant Progress: PM Emissions

g/bHp-hr

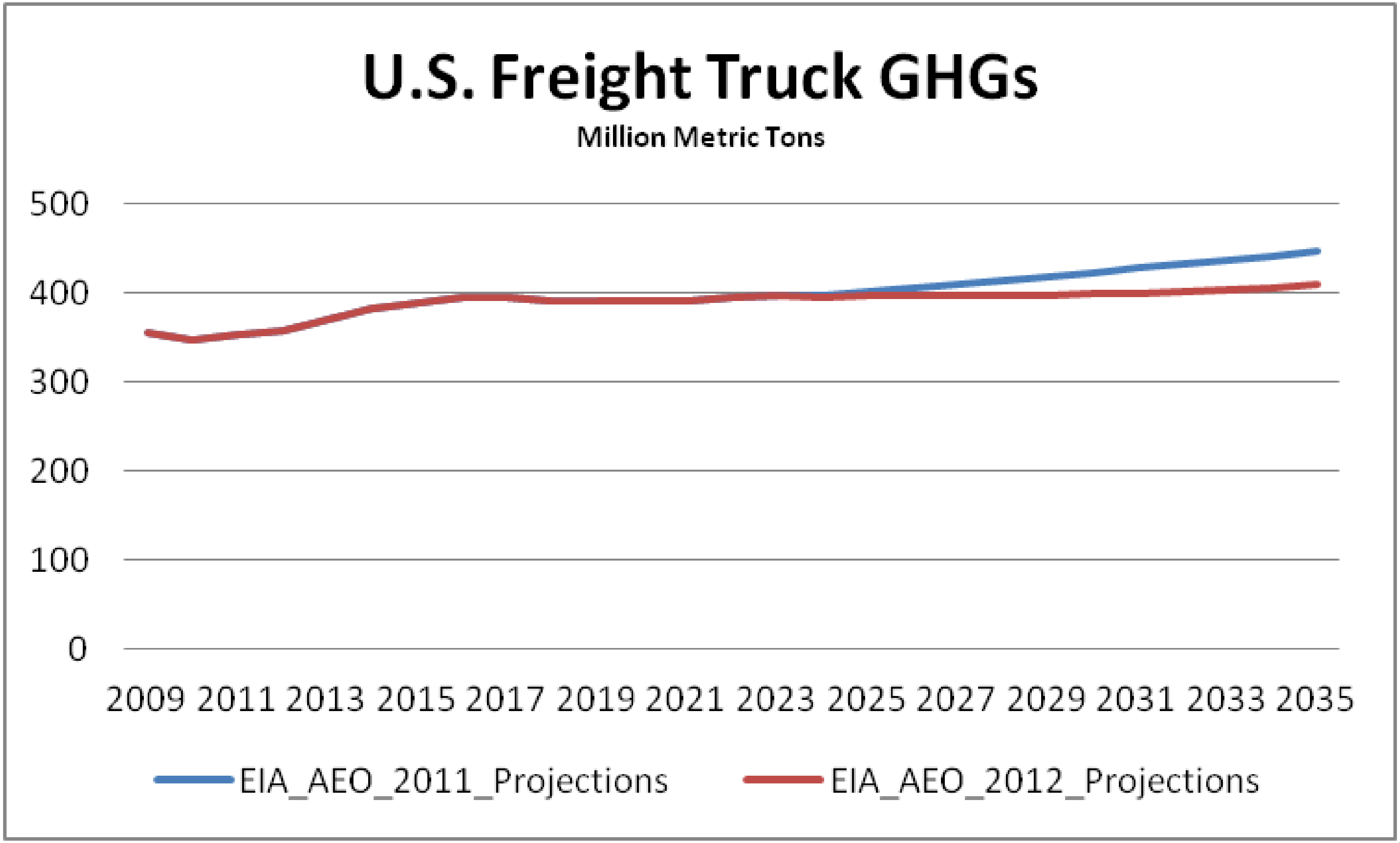


Significant Progress: NOx Emissions

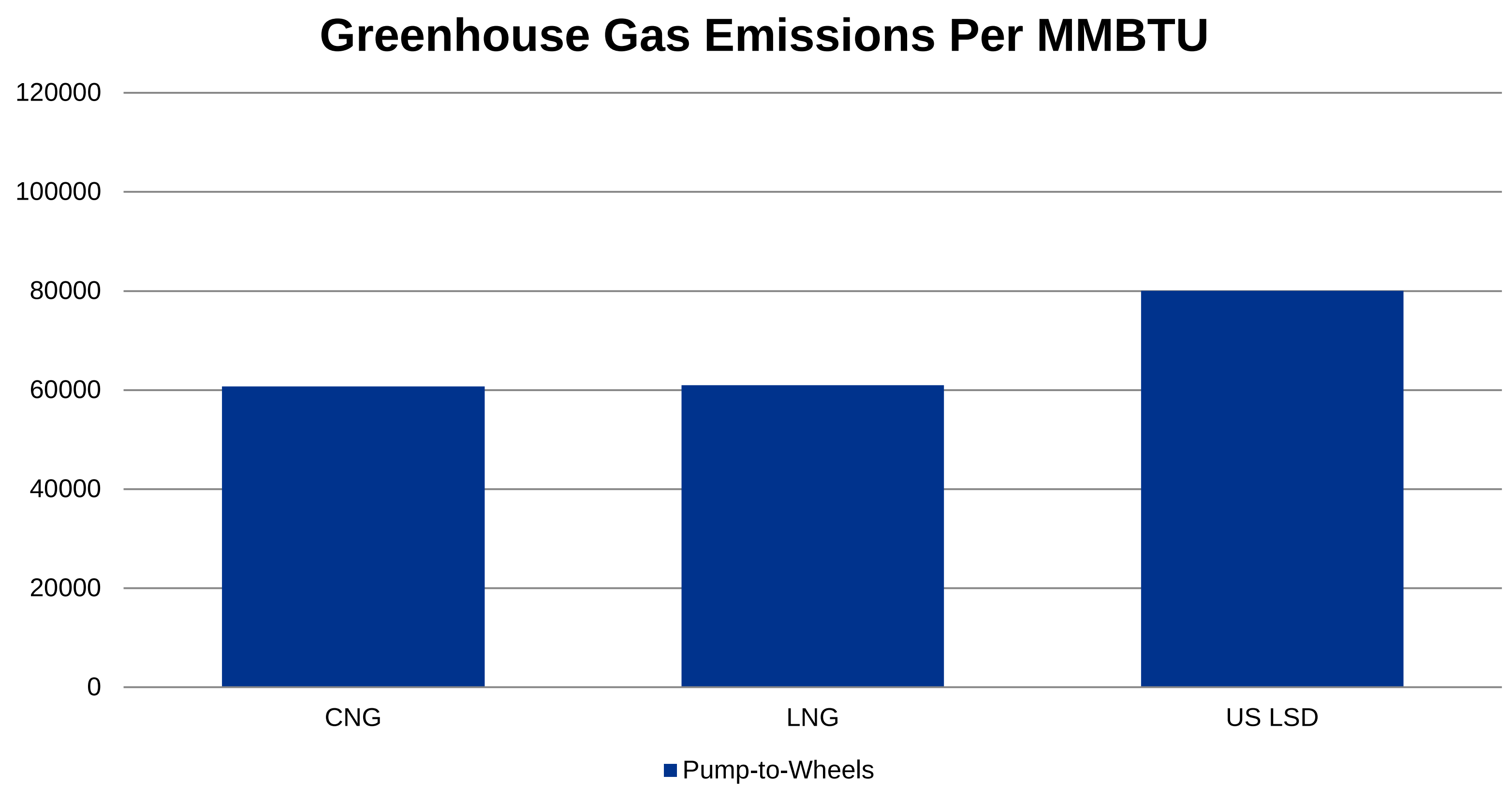
g/bHp-hr



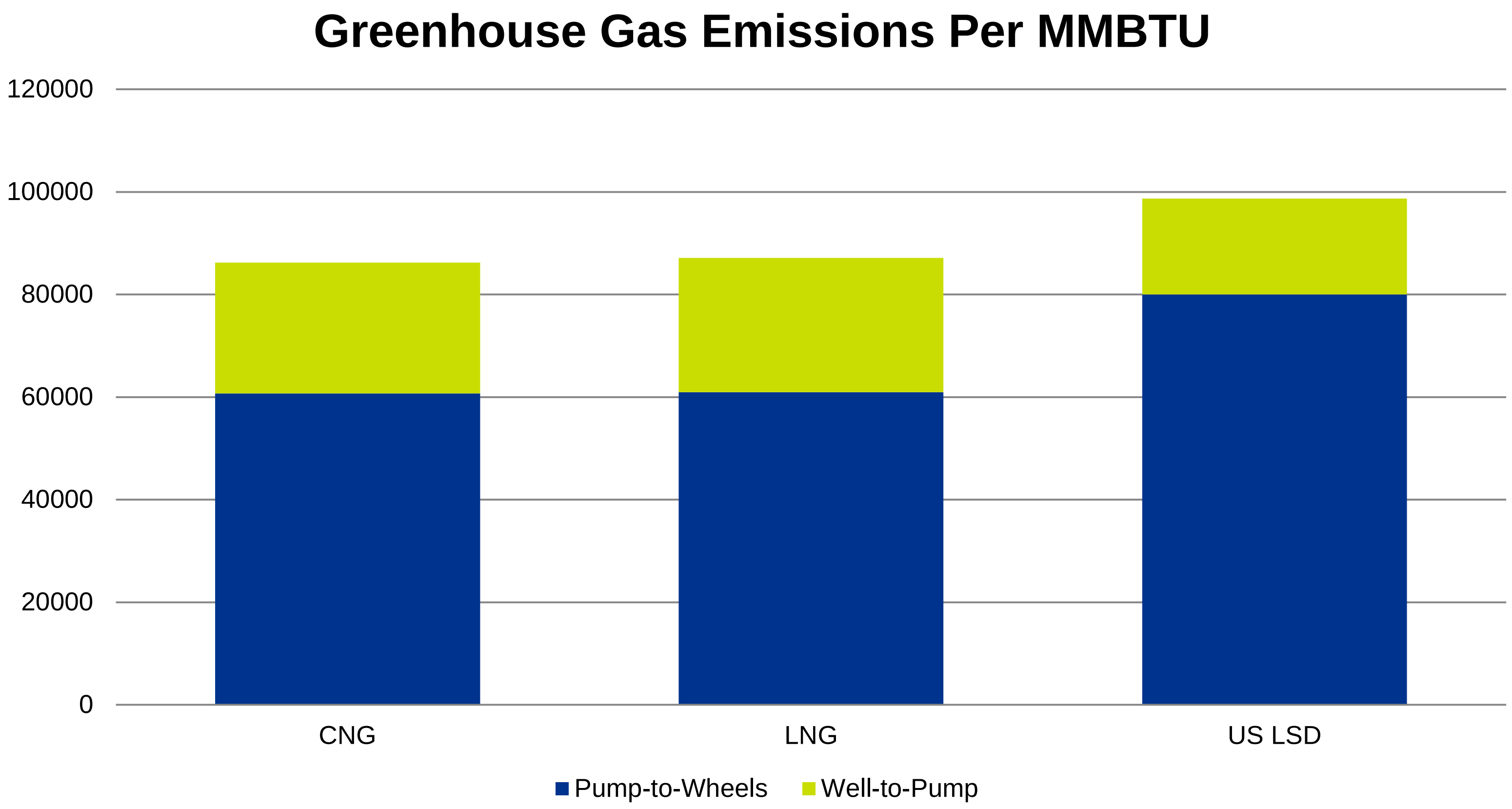
We Are Going the Wrong Way: GHGs



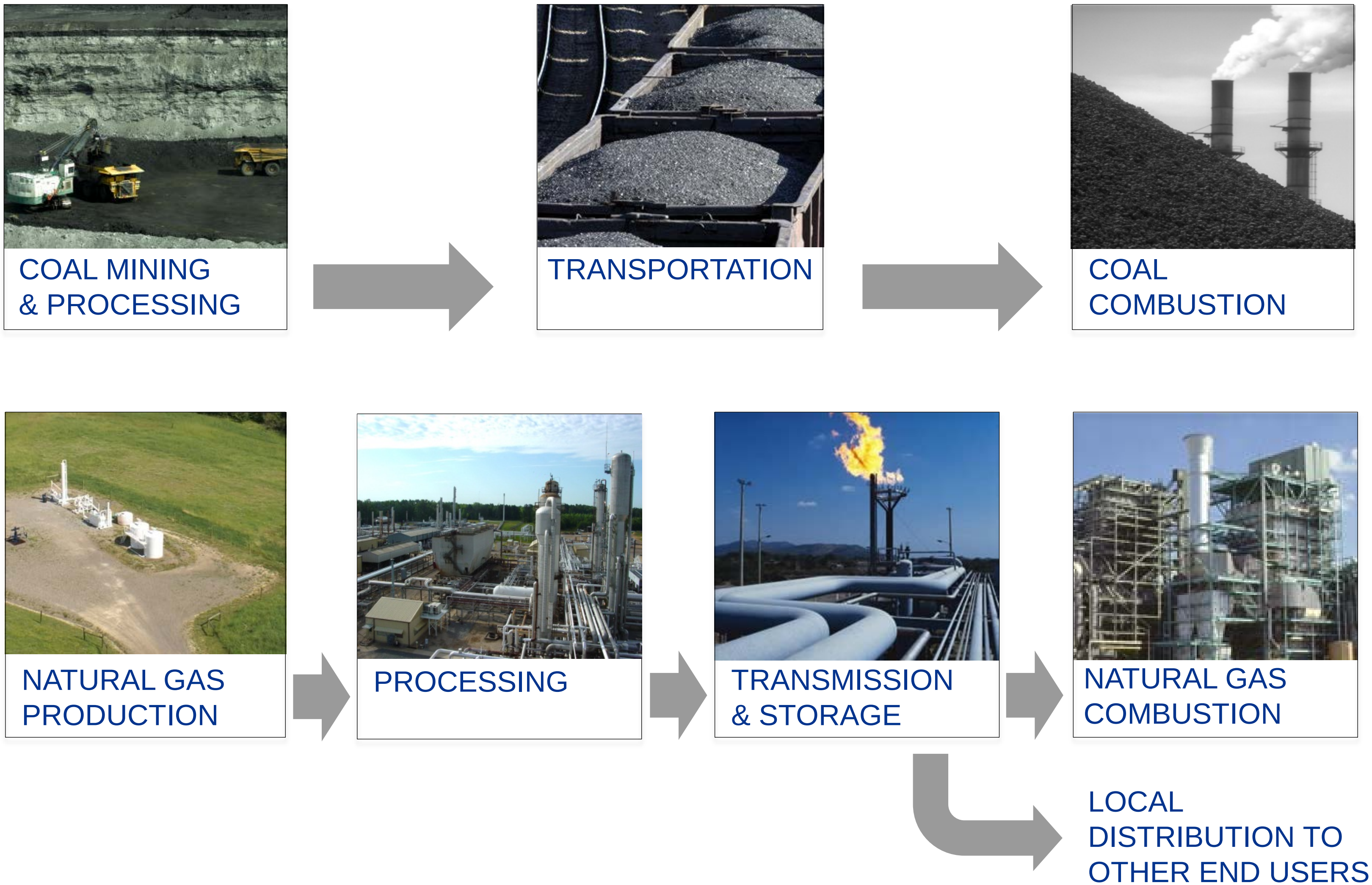
A Look at How NGVs Compare: 100 Year Scale



A Look at How NGVs Compare: 100 Year Scale



End of pipe emissions aren't whole story



Source: Adapted from Jaramillo et al., (2007) EST 41, 6290

Scientific Review

PNAS PNAS PNAS PNAS PNAS

Greater focus needed on methane leakage from natural gas infrastructure

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Contributed by Stephen W. Pacala, February 13, 2012 (sent for review December 21, 2011)

Natural gas is seen by many as the future of American energy: a fuel that can provide energy independence and reduce greenhouse gas emissions in the process. However, there has also been confusion about the climate implications of increased use of natural gas for electric power and transportation. We propose and illustrate the use of technology warming potentials as a robust and transparent way to compare the cumulative radiative forcing created by alternative technologies fueled by natural gas and oil or coal by using the best available estimates of greenhouse gas emissions from each fuel cycle (i.e., production, transportation and use). We find that a shift to compressed natural gas vehicles from gasoline or diesel vehicles leads to greater radiative forcing of the climate for 80 or 280 yr, respectively, before beginning to produce benefits. Compressed natural gas vehicles could produce climate benefits on all time frames if the well-to-wheels CH_4 leakage were capped at a level 45–70% below current estimates. By contrast, using natural gas instead of coal for electric power plants can reduce radiative forcing immediately, and reducing CH_4 losses from the production and transportation of natural gas would produce even greater benefits. There is a need for the natural gas industry and science community to help obtain better emissions data and for increased efforts to reduce methane leakage in order to minimize the climate footprint of natural gas.

With growing pressure to produce more domestic energy and to reduce greenhouse gas (GHG) emissions, natural gas is increasingly seen as the fossil fuel of choice for the United States as it transitions to renewable sources. Recent reports in the scientific literature and popular press have produced confusion about the climate implications of natural gas (1–5). On the one hand, a shift to natural gas is promoted as climate mitigation because it has lower carbon per unit energy than coal or oil (6). On the other hand, methane (CH_4), the prime constituent of natural gas, is itself a more potent GHG than carbon dioxide (CO_2); CH_4 leakage from the production, transportation and use of natural gas can offset benefits from fuel-switching.

The climatic effect of replacing other fossil fuels with natural gas varies widely by sector (e.g., electricity generation or transportation) and by the fuel being replaced (e.g., coal, gasoline, or diesel fuel), distinctions that have been largely lacking in the policy debate. Estimates of the net climate implications of fuel-switching strategies should be based on complete fuel cycles (e.g., "well-to-wheels") and account for changes in emissions of relevant radiative forcing agents. Unfortunately, such analyses are weakened by the paucity of empirical data addressing CH_4 emissions through the natural gas supply network, hereafter referred to as CH_4 leakage.* The U.S. Environmental Protection Agency (EPA) recently doubled its previous estimate of CH_4 leakage from natural gas systems (6).

In this paper, we illustrate the importance of accounting for fuel-cycle CH_4 leakage when considering the climate impacts of fuel-technology combinations. Using EPA's estimated CH_4 emissions from the natural gas supply, we evaluated the radiative forcing implications of three U.S.-specific fuel-switching scenarios: from gasoline, diesel fuel, and coal to natural gas.

A shift to natural gas and away from other fossil fuels is increasingly plausible because advances in horizontal drilling and hydraulic fracturing technologies have greatly expanded the country's extractable natural gas resources particularly by accessing gas stored in shale deep underground (7). Contrary to previous estimates of CH_4 losses from the "upstream" portions of the natural gas fuel cycle (8, 9), a recent paper by Howarth et al. calculated upstream leakage rates for shale gas to be so large as to imply higher lifecycle GHG emissions from natural gas than from coal (1). (*SI Text*, discusses differences between our paper and Howarth et al.) Howarth et al. estimated CH_4 emissions as a percentage of CH_4 produced over the lifecycle of a well to be 3.6–7.9% for shale gas and 1.7–6.0% for conventional gas. The EPA's latest estimate of the amount of CH_4 released because of leaks and venting in the natural gas network between production wells and the local distribution network is about 570 billion cubic feet for 2009, which corresponds to 2.4% of gross U.S. natural gas production (1.9–3.1% at a 95% confidence level) (6).† EPA's reported uncertainty appears small considering that its current value is double the prior estimate, which was itself twice as high as the previously accepted amount (9).

Comparing the climate implications of CH_4 and CO_2 emissions is complicated because of the much shorter atmospheric lifetime of CH_4 relative to CO_2. On a molar basis, CH_4 produces 37 times more radiative forcing than CO_2.‡ However, because CH_4 is oxidized to CO_2 with an effective lifetime of 12 yr, the integrated, or cumulative, radiative forcings from equi-molar releases of CO_2 and CH_4 eventually converge toward the same value. Determining whether a unit emission of CH_4 is worse for the climate than a unit of CO_2 depends on the time frame considered. Because accelerated rates of warming mean ecosystems and humans have less time to adapt, increased CH_4 emissions due to substitution of natural gas for coal and oil may produce undesirable climate outcomes in the near-term.

The concept of global warming potential (GWP) is commonly used to compare the radiative forcing of different gases relative

Author contributions: R.A.A., S.W.P., and S.P.H. designed research; R.A.A. performed research; R.A.A., S.W.P., and S.P.H. analyzed data; and R.A.A., S.W.P., J.J.W., W.L.C. and S.P.H. wrote the paper.

The authors declare no conflict of interest.

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*Challenges also exist in the quantification of CH_4 emissions from the extraction of coal. We use the term "leakage" for simplicity and define it broadly to include all CH_4 emissions in the natural gas supply, both fugitive leaks as well as vented emissions.

†This represents an uncertainty range between −19% and +30% of natural gas system emissions. For CH_4 from petroleum systems (35% of which we assign to the natural gas supply) the uncertainty is −24% to +149%; however, this is only a minor effect because the portion of natural gas supply that comes from oil wells is less than 20%.

‡One-hundred-two times on a mass basis. This value accounts for methane's direct radiative forcing and a 40% enhancement because of the indirect forcing by ozone and stratospheric water vapor (10).

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This article contains supporting information online at www.pnas.org/lookup/suppl/doi:10.1073/pnas.1202407109/-/DCSupplemental.

ENVIRONMENTAL SCIENCES

SUSTAINABILITY SCIENCE

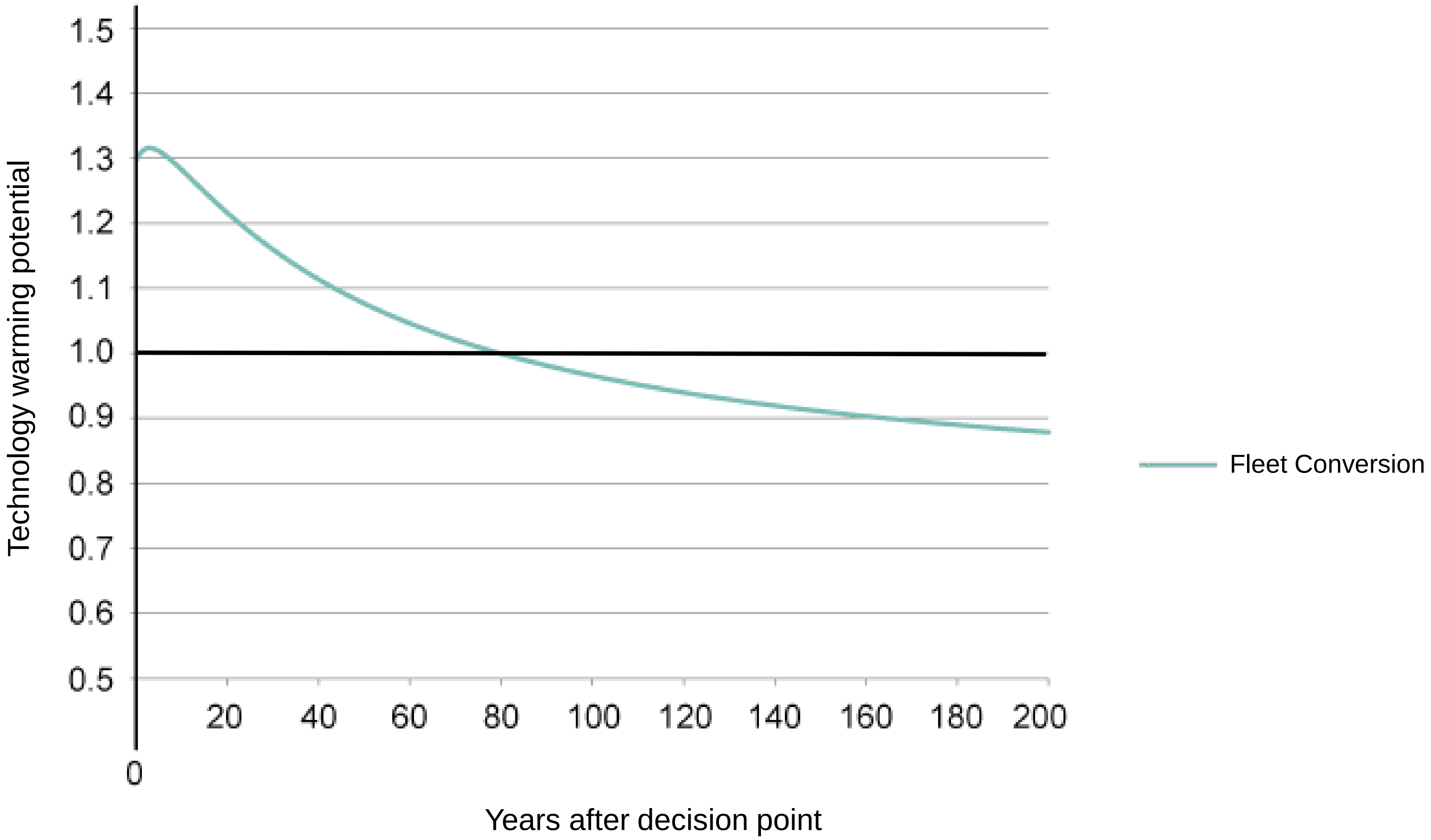
Quantifies:
What It Will Take To Get Sustained Benefits From Natural Gas

Reveals Climate Implications of Increased Use for Electricity and Transportation

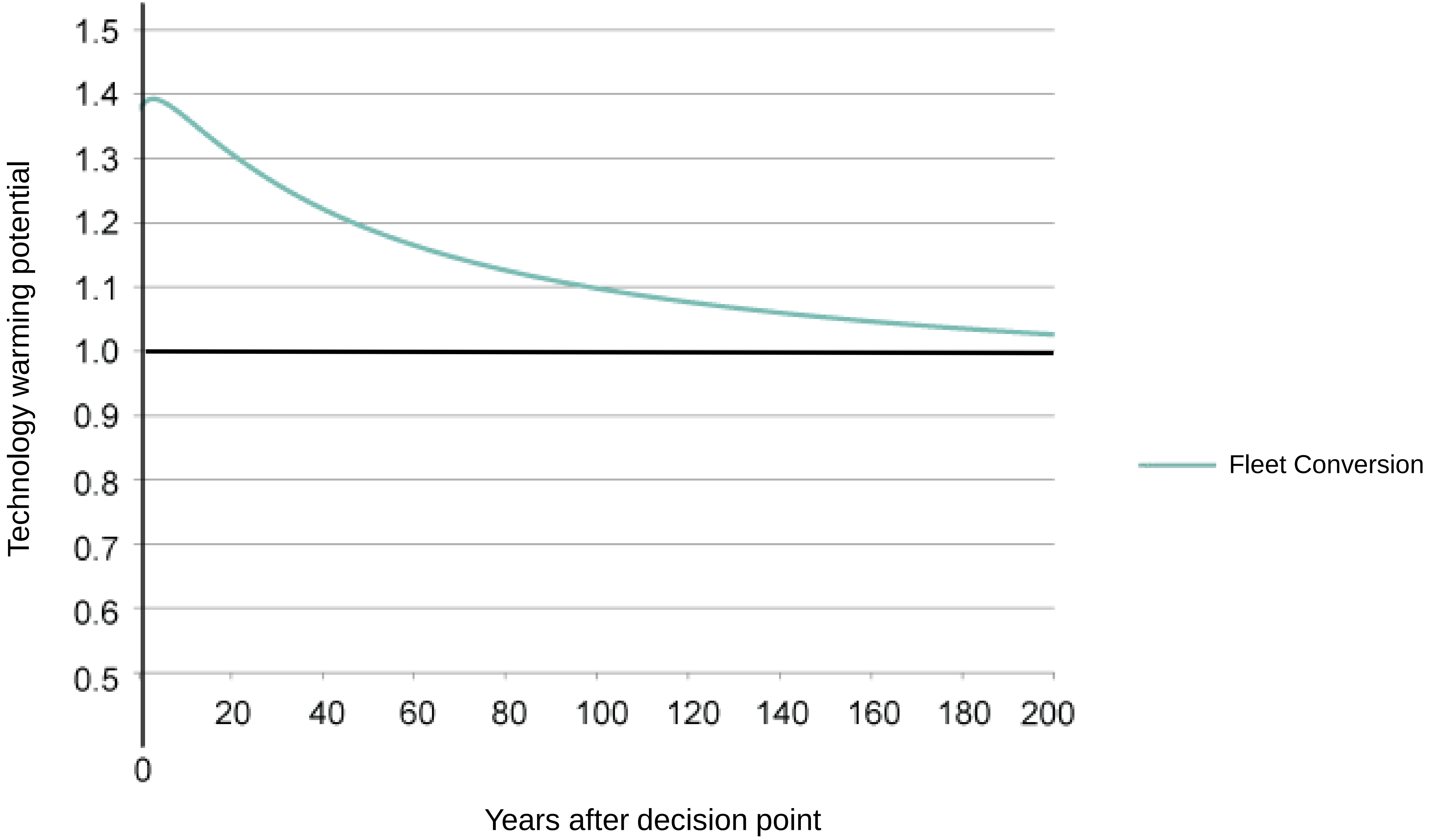
Limitations of Global Warming Potential

- GWPs established to inter-compare radiative forcing of GHG emission *pulses* at a single point in time after emission (e.g., 20 or 100 years)
- Inadequate to capture time-dependent climatic consequences of Fuel/Technology choices involving emission *streams* of *multiple* GHGs
  - We suggest: Technology Warming Potential

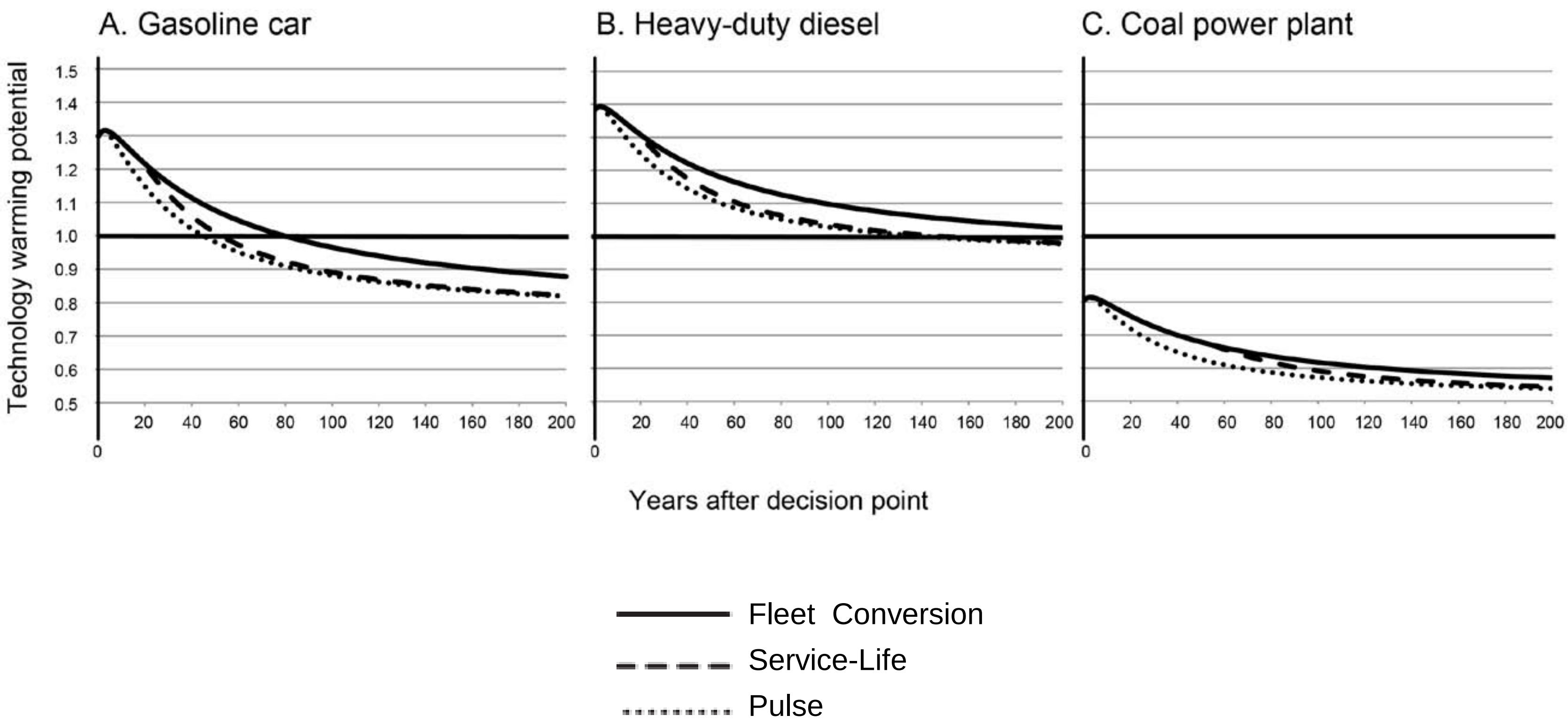
Technology Warming Potential: Natural Gas vs Gasoline



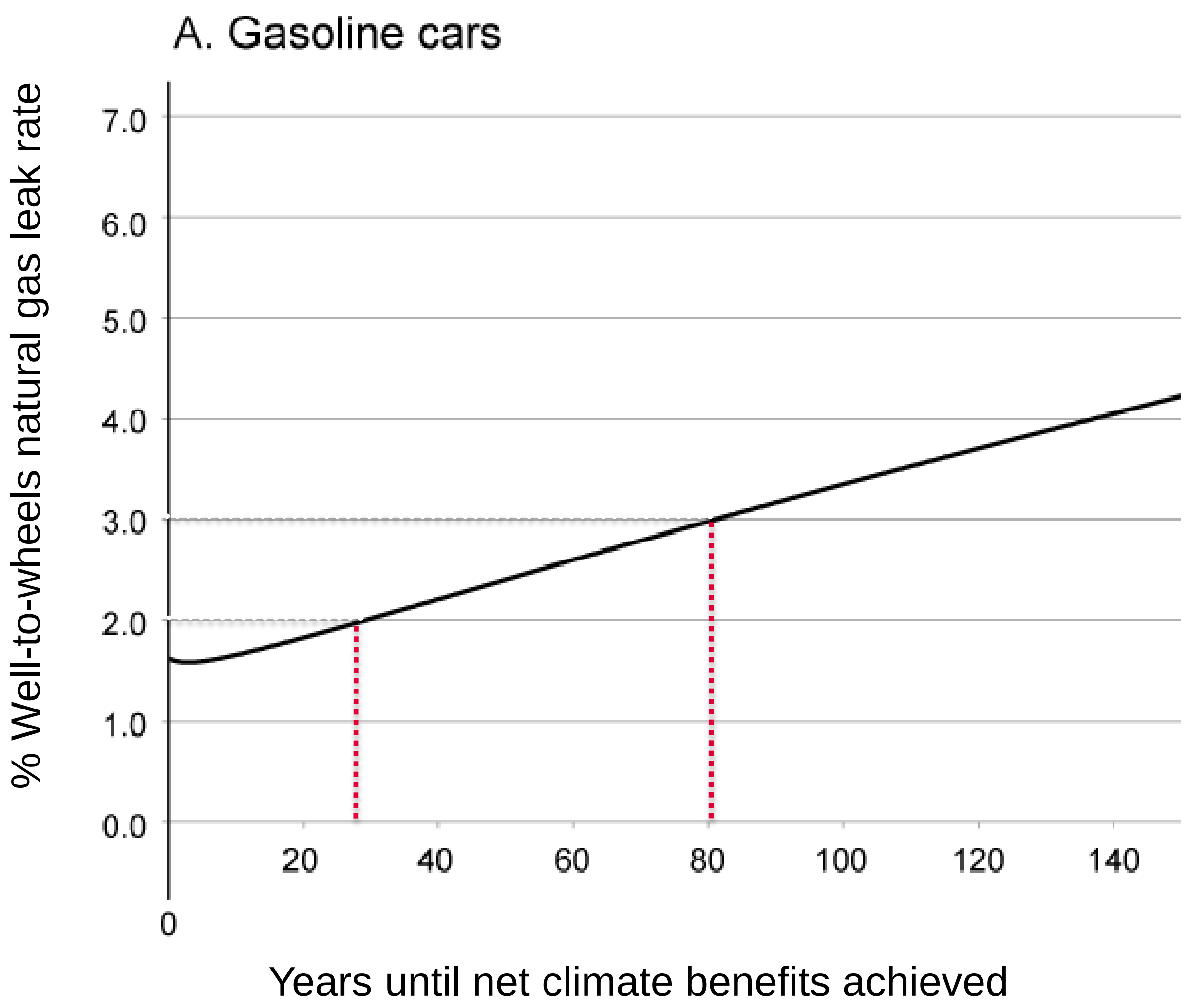
Technology Warming Potential: Natural Gas vs Diesel



Summary: Technology Warming Potential



Leak rate affects time to climate benefits



Leak rate affects time to climate benefits