Bounding the Climate Viability of Natural Gas as a Bridge Fuel

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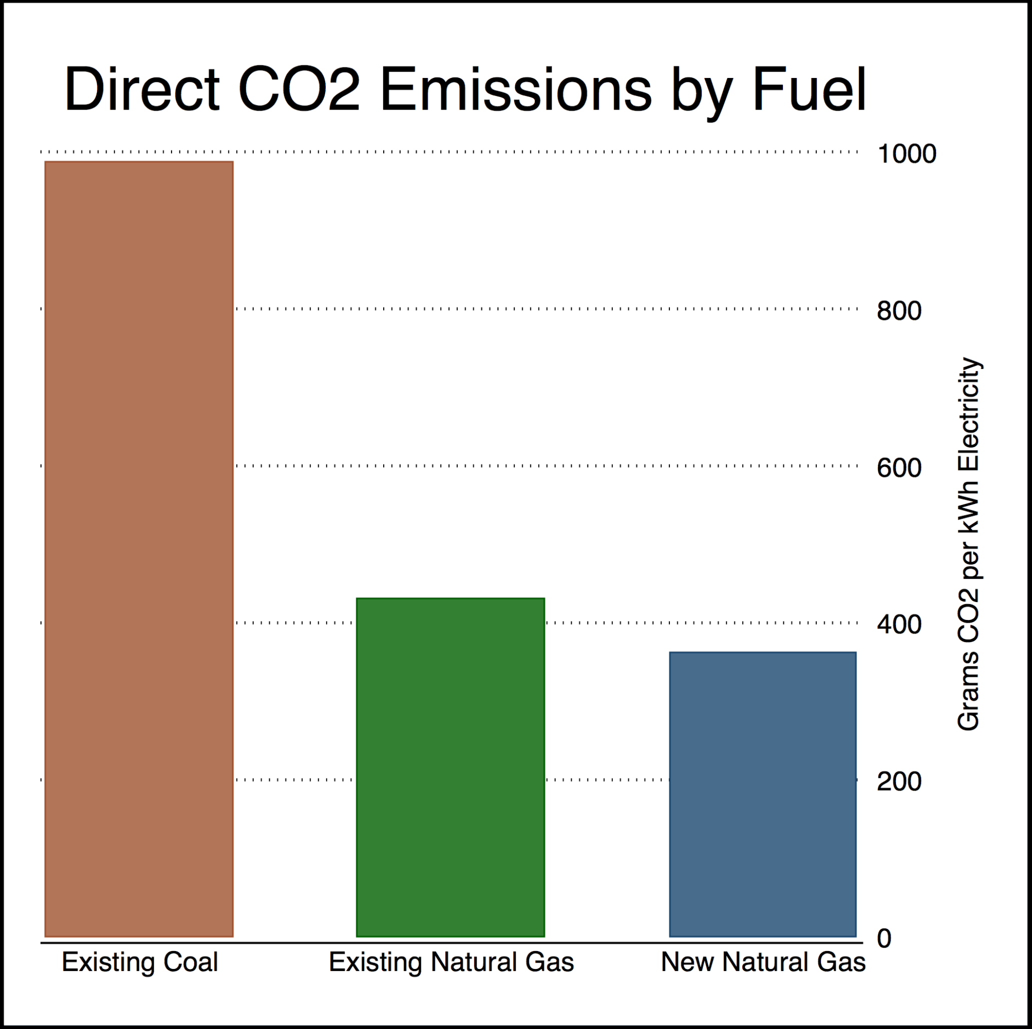
Direct Emissions - Electricity

- Current U.S. coal efficiency is 33%
- Current U.S. gas efficiency is 42%

- New U.S. coal efficiency >= 43%
- New U.S. gas efficiency >= 50% (HHV)

- Results are sensitive to scenarios; gas looks better when replacing existing coal (and generation efficiency impacts CH_4 leakage effects)

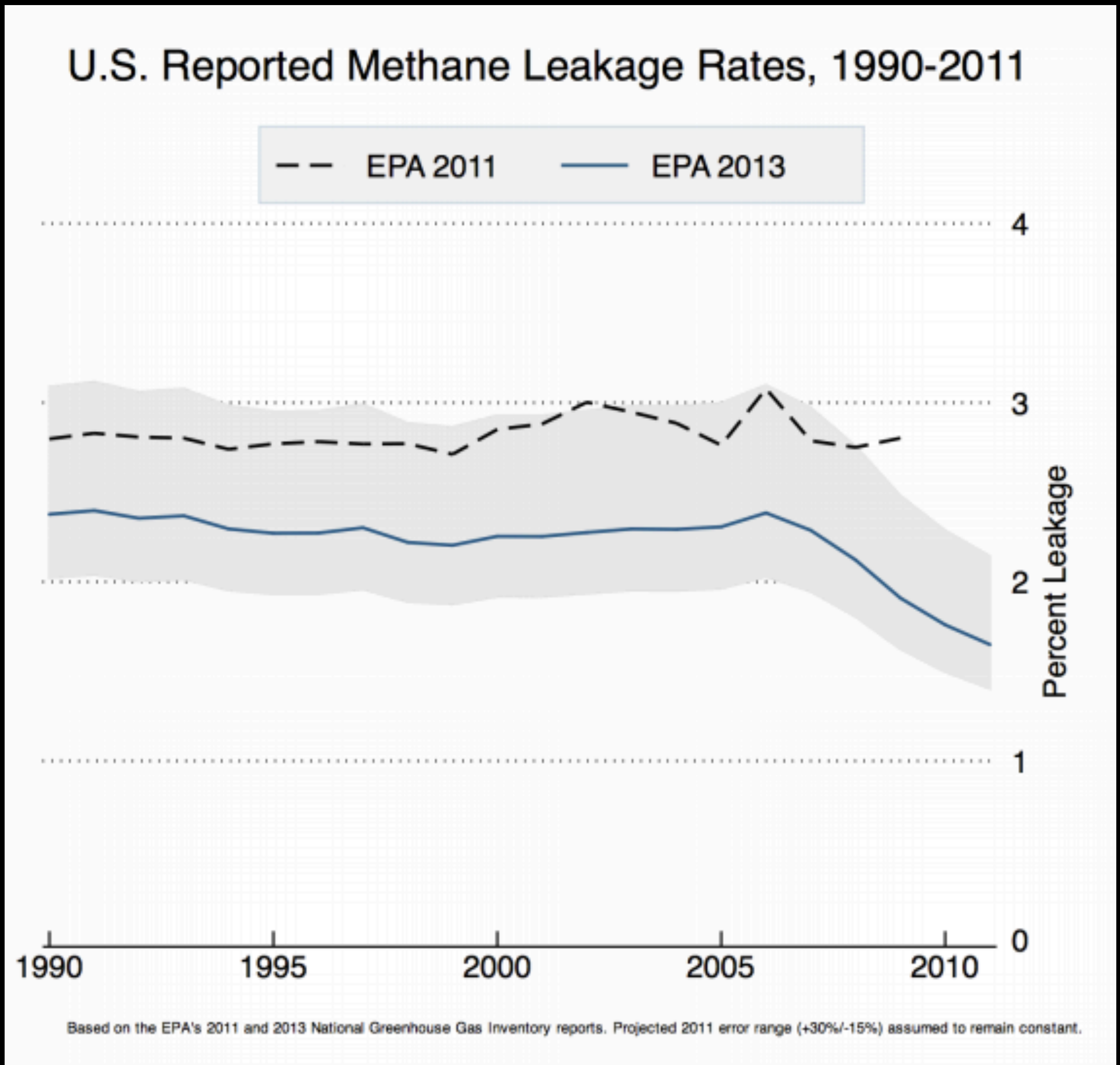


But… Methane

- CH_4 is a powerful greenhouse gas, with a global warming potential 21 to 34 times larger than CO_2 (21 is only direct effects; 34 includes ozone, stratospheric H_2O and other indirect effects).
- System-wide leakage rates are highly uncertain, with estimates ranging from 1% to 6% or more

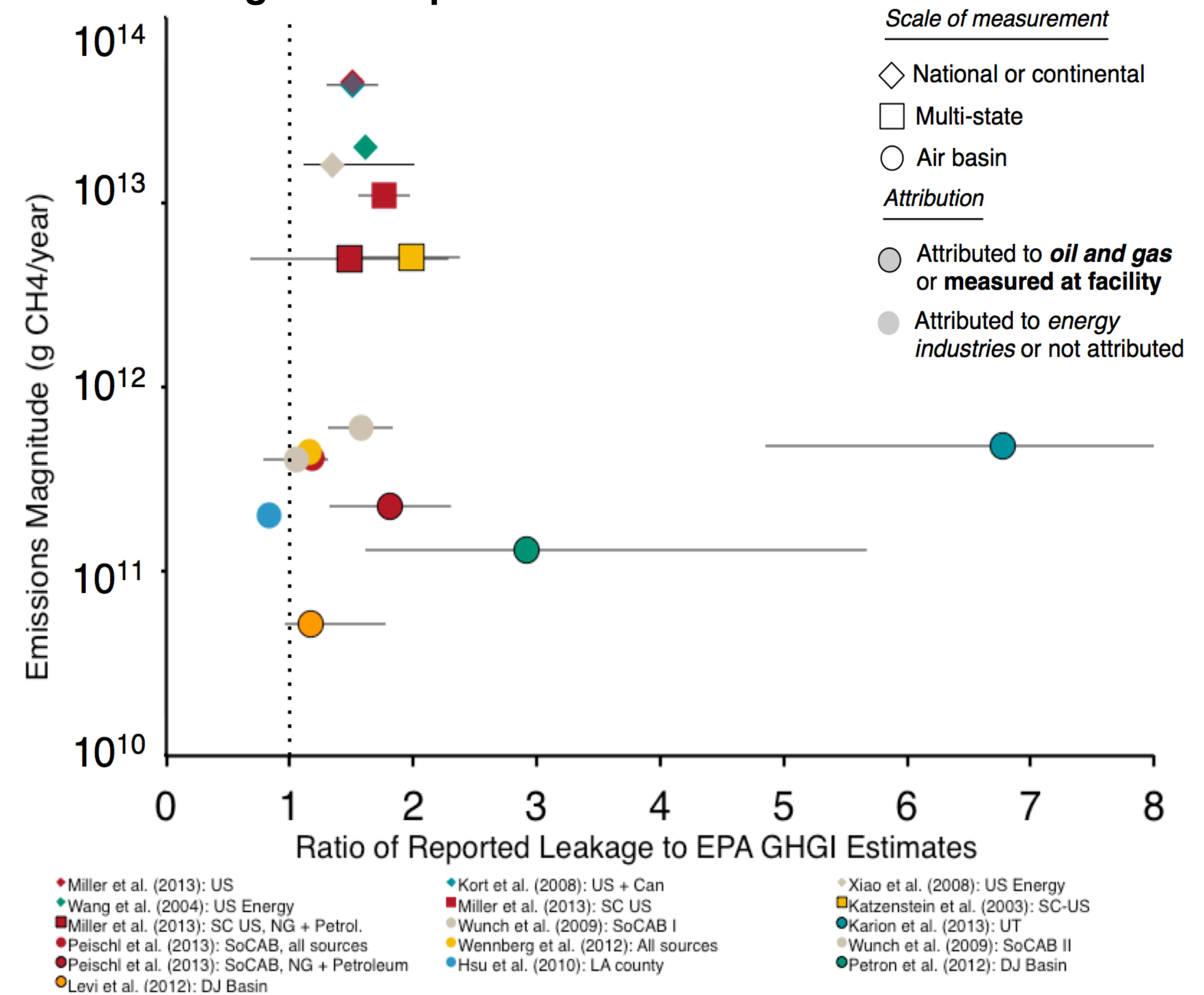
And Gas Infrastructure is Sticky

EPA GHGI Leakage Estimates are Low



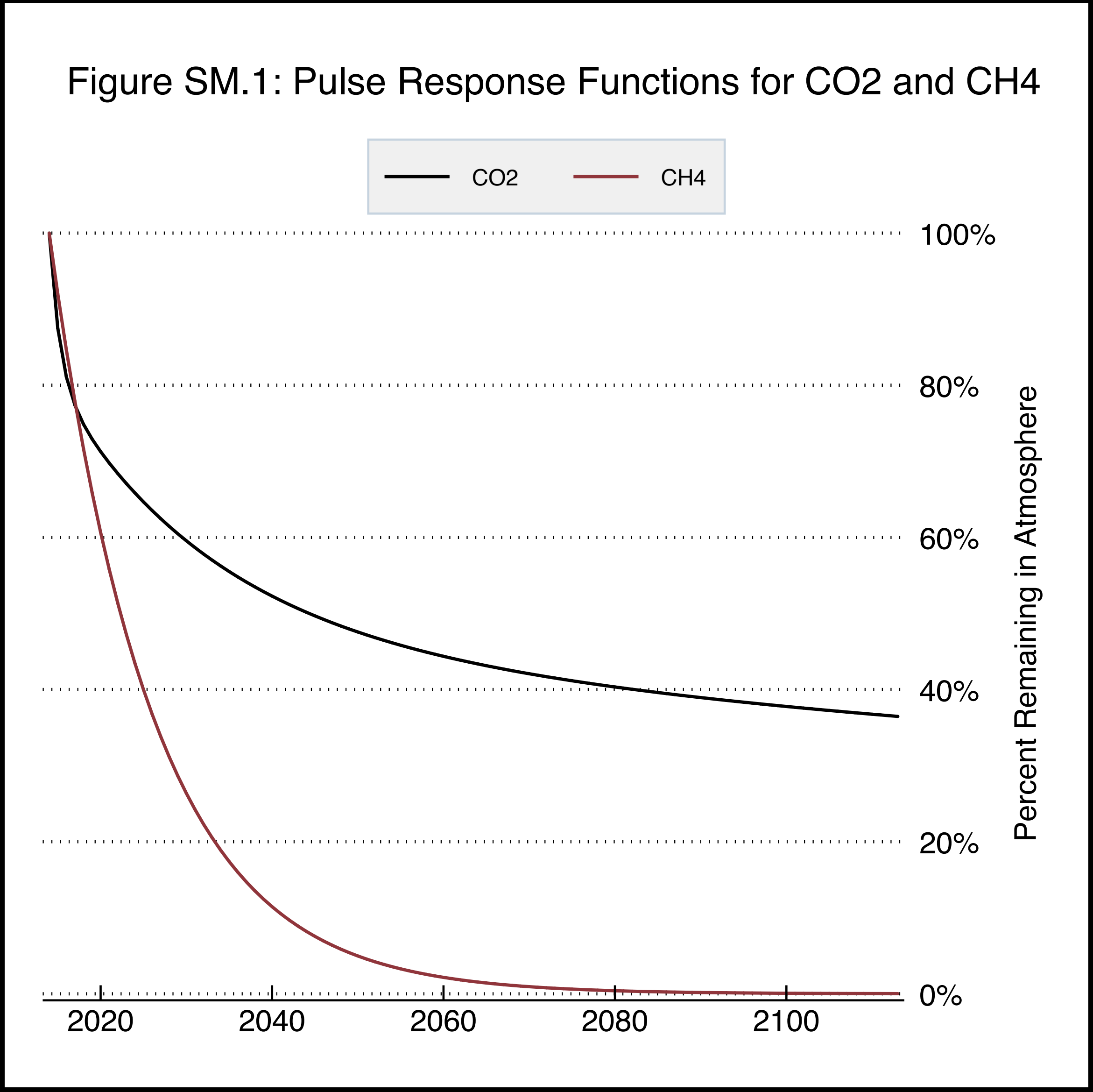
Others in the Literature are Higher

Figure 1: Top-Down Studies in Brandt et al

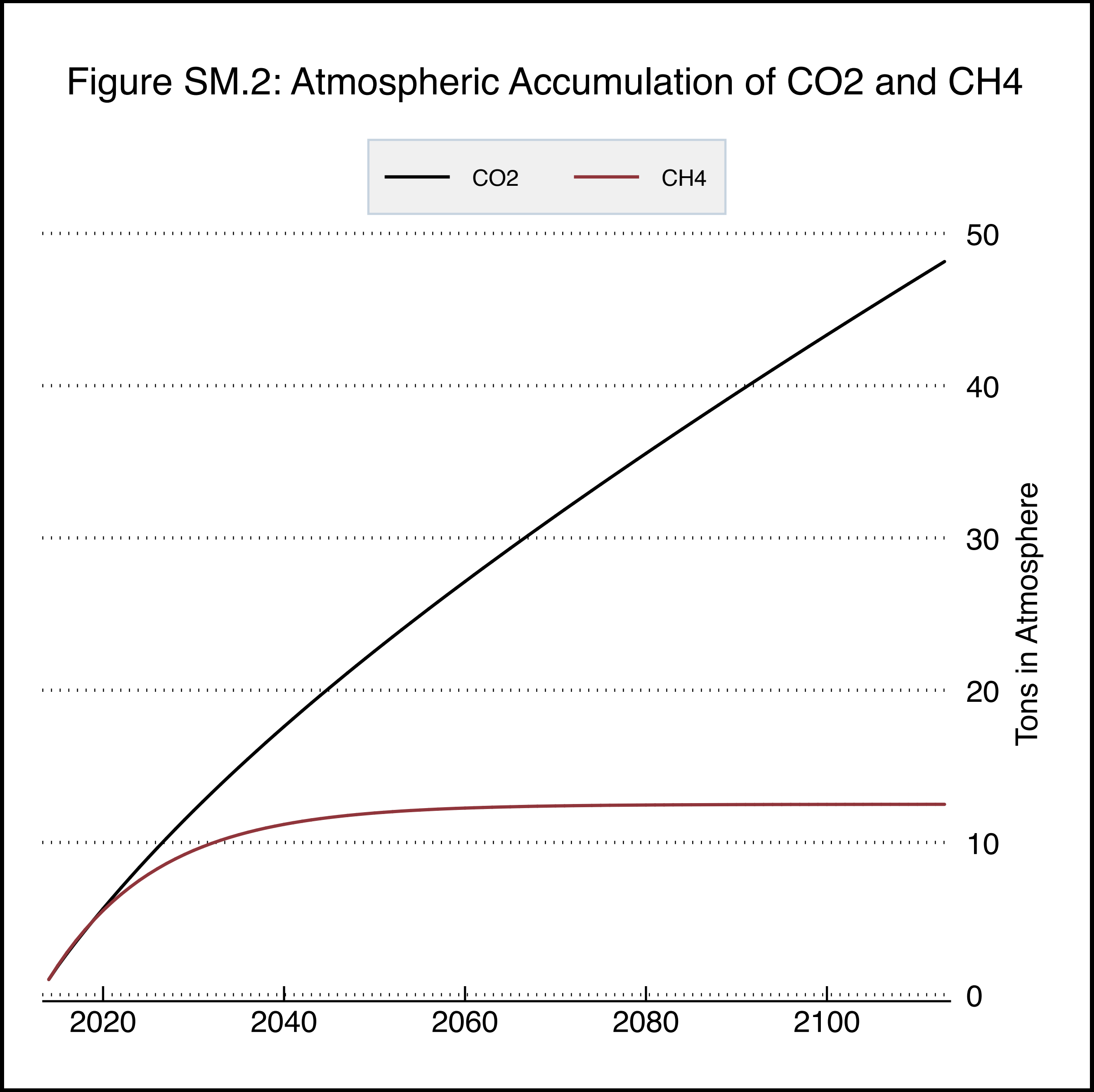


Atmospheric Dynamics of CO_2 and CH_4: Moving Beyond Global Warming Potential

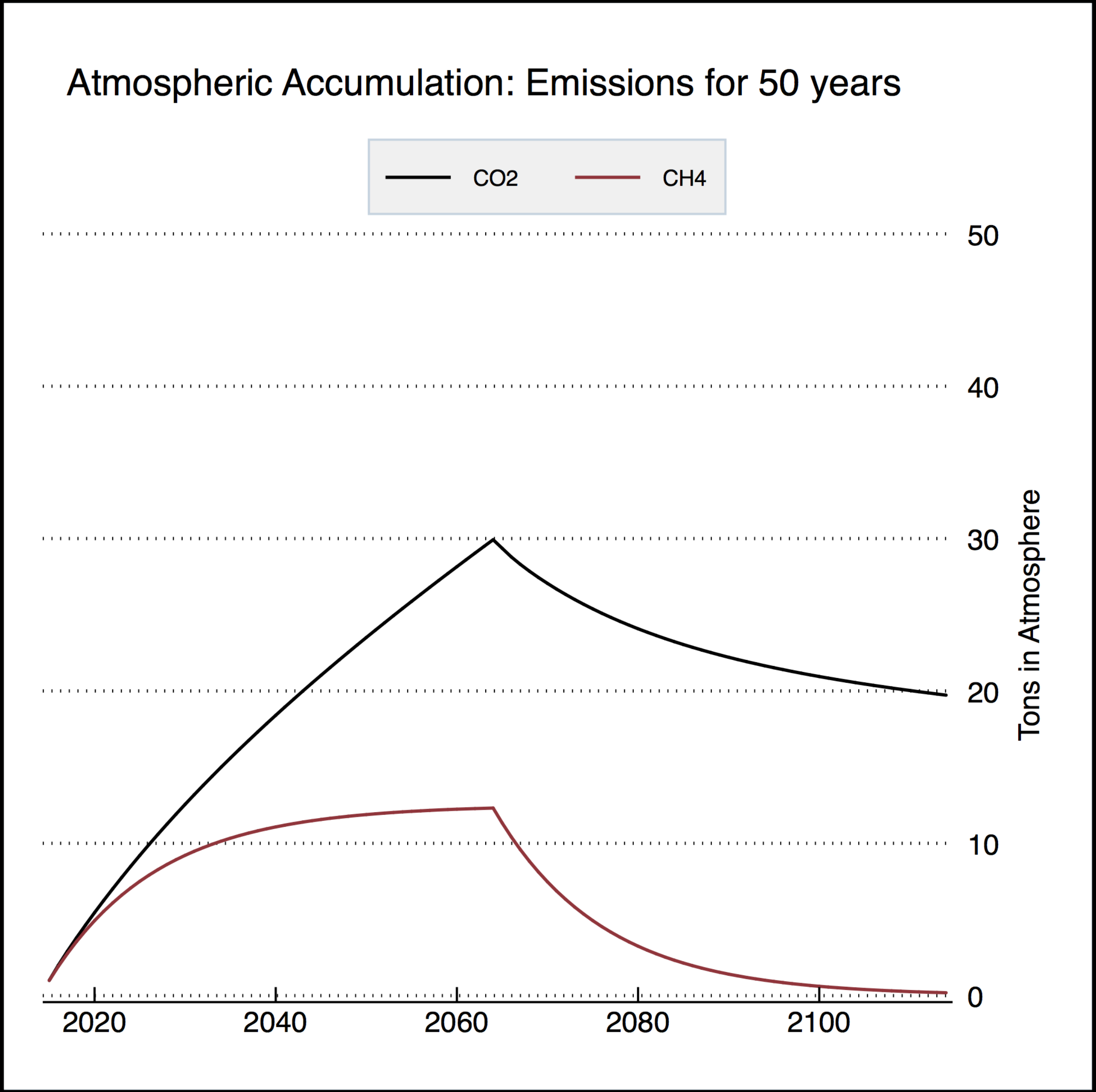
Decay functions for discrete pulses



Atmospheric Accumulation under Constant Emissions



What if Emissions Cease?



Translating Emissions to Radiative Forcing

Trace gas	Simplified expression Radiative forcing, ΔF (Wm^{-2})	Constants
CO_2	$\Delta F = \alpha \ln(C/C_0)$ $\Delta F = \alpha \ln(C/C_0) + \beta(\sqrt{C} - \sqrt{C_0})$ $\Delta F = \alpha(g(C) - g(C_0))$ where $g(C) = \ln(1 + 1.2C + 0.005C^2 + 1.4 \times 10^{-6} C^3)$	$\alpha=5.35$ $\alpha=4.841$, $\beta=0.0906$ $\alpha=3.35$
CH_4	$\Delta F = \alpha(\sqrt{M} - \sqrt{M_0}) - (f(M,N_0) - f(M_0,N_0))$	$\alpha=0.036$
N_2O	$\Delta F = \alpha(\sqrt{N} - \sqrt{N_0}) - (f(M_0,N) - f(M_0,N_0))$	$\alpha=0.12$
CFC-11[a]	$\Delta F = \alpha(X - X_0)$	$\alpha=0.25$
CFC-12	$\Delta F = \alpha(X - X_0)$	$\alpha=0.32$

$f(M,N) = 0.47 \ln[1 + 2.01 \times 10^{-5} (MN)^{0.75} + 5.31 \times 10^{-15} M(MN)^{1.52}]$

C is CO_2 in ppm

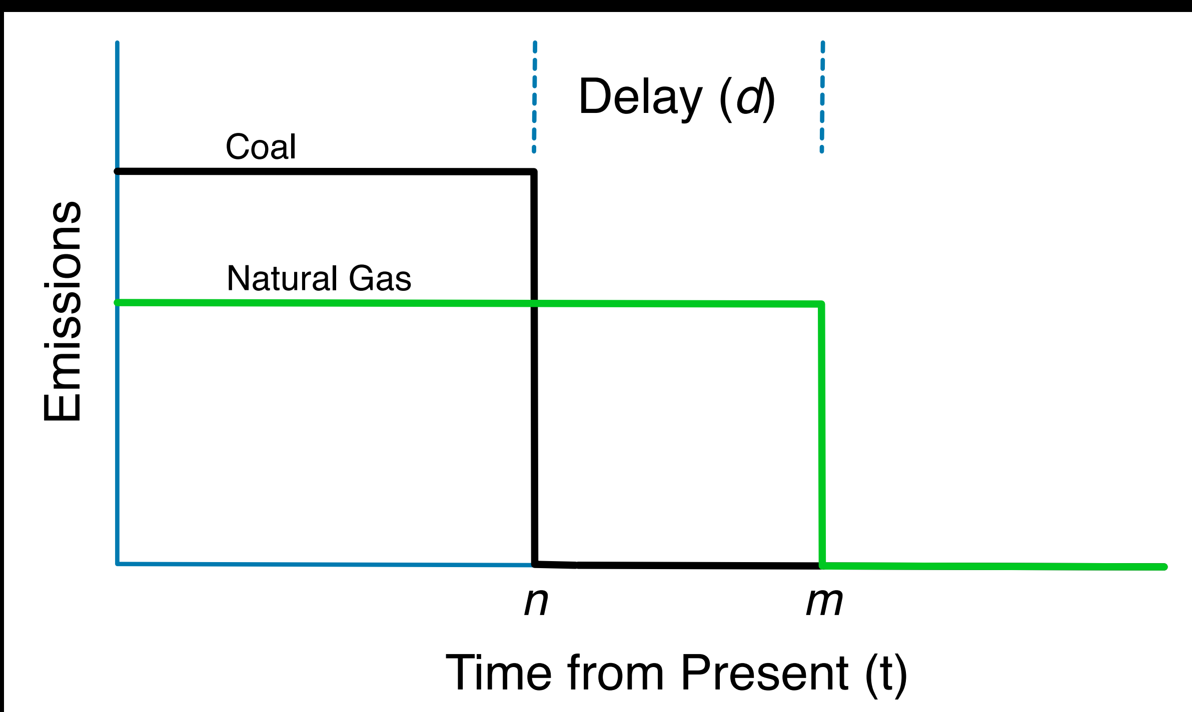
M is CH_4 in ppb

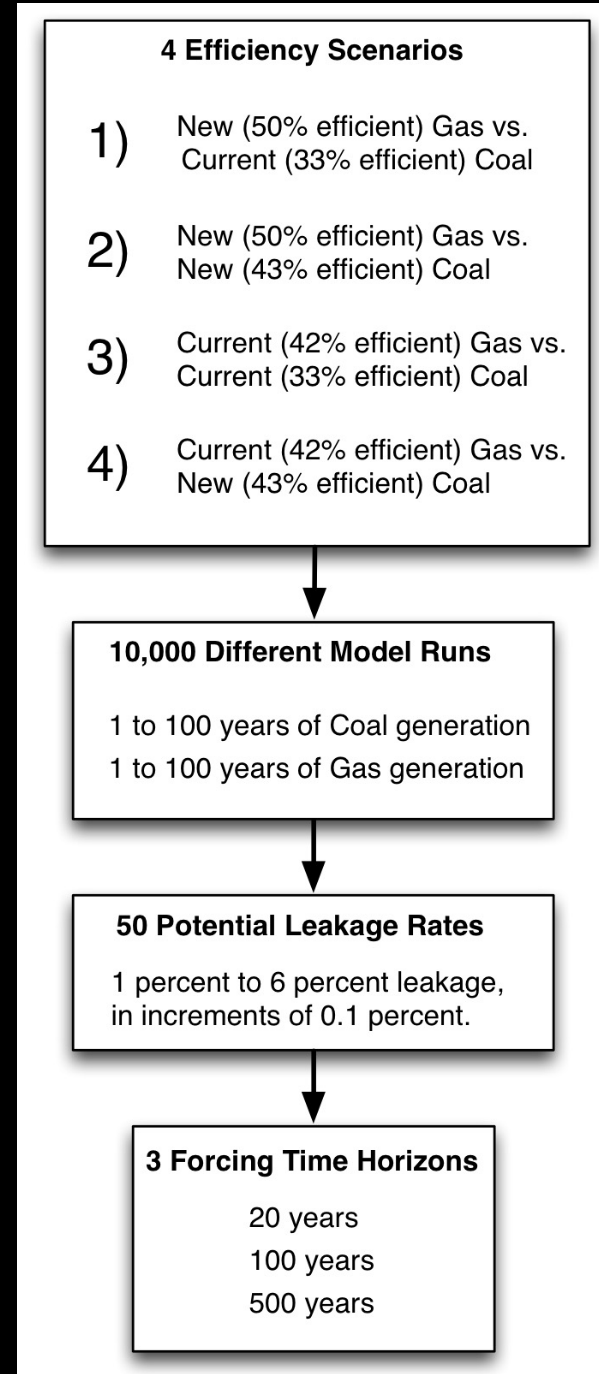
N is N_2O in ppb

X is CFC in ppb

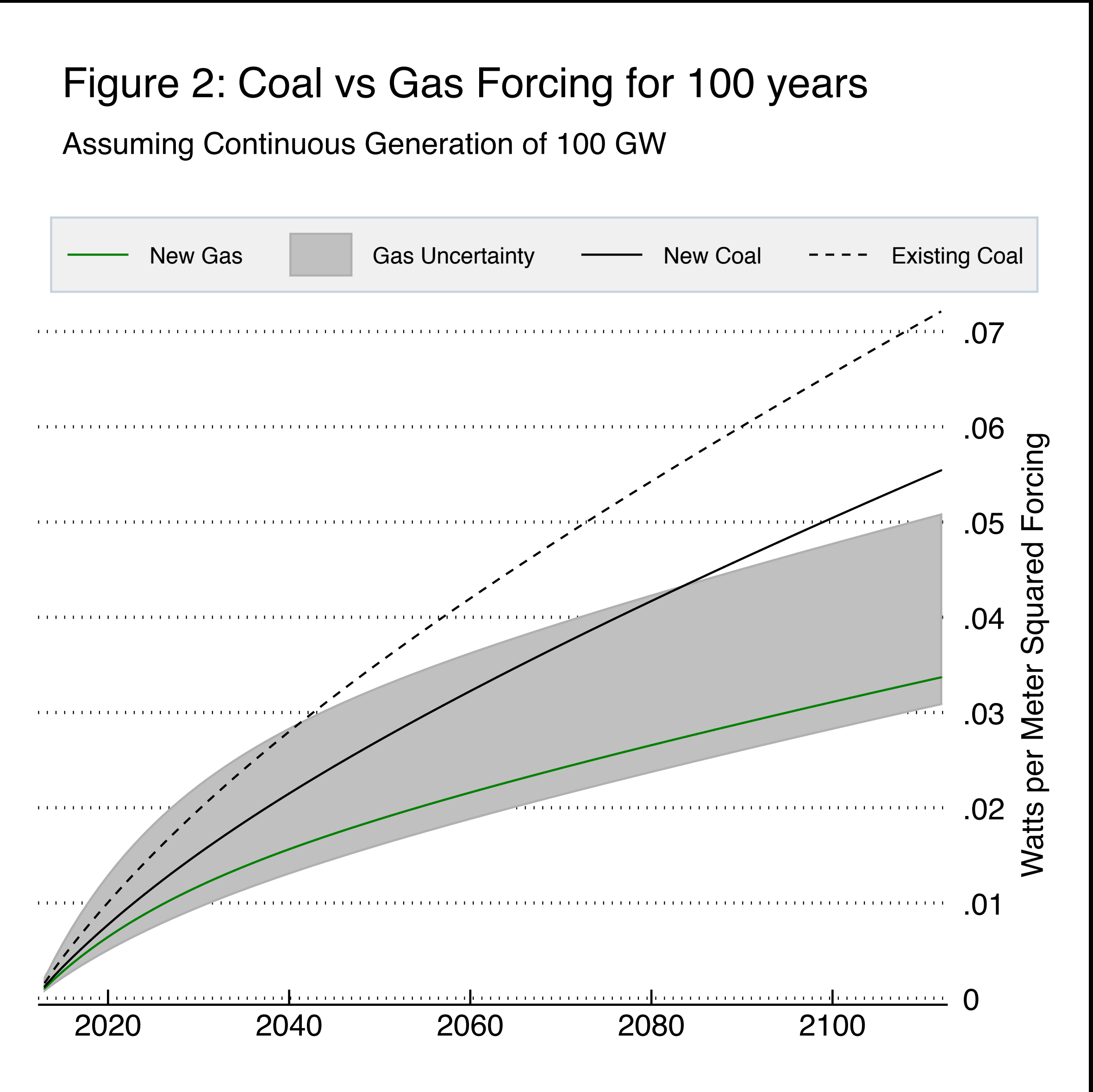
Figure from IPCC AR4

We examine the impact of leakage rates, generation efficiencies, and delays in near-zero carbon technology adoption on the viability of immediately replacing coal with natural gas generation.





100-year Constant Generation



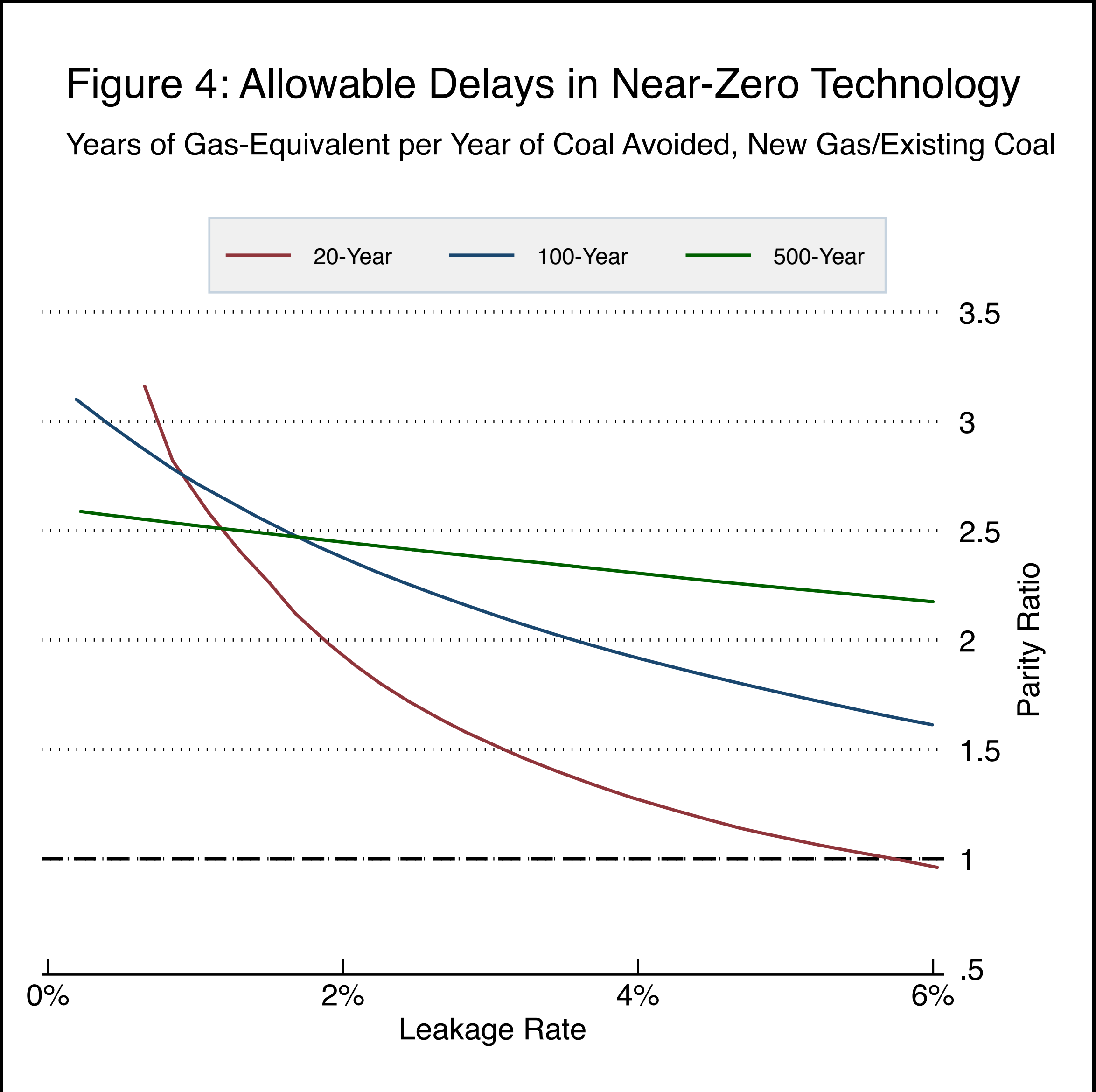
Simple case of n=m

Leakage Rates for Forcing Parity

Table 1
Leakage rates for forcing parity, 100 years generation.

Scenario	20-year (%)	100-year (%)	500-year (%)
New gas replacing current coal	5.1	9.9	36
New gas instead of new coal	3.2	6.4	24
Current gas replacing current coal	4.5	8.8	33
Current gas instead of new coal	2.7	5.2	20

What if we Delay Renewables?



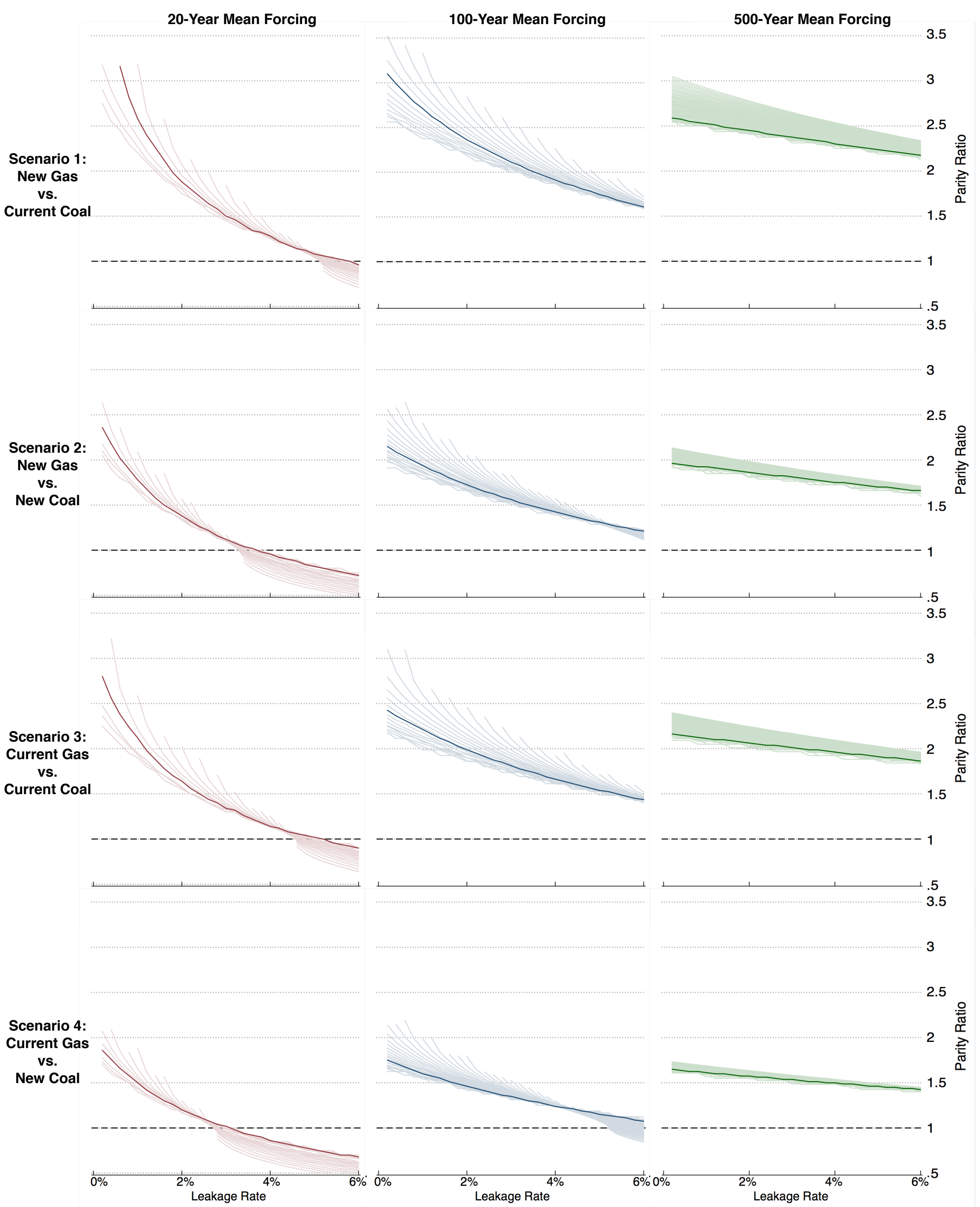
More complex case of m > n

Parity Ratios for 2% Leakage

Table 2
Allowable years of gas per years of coal displaced at 2% leakage.

Scenario	20-year	100-year	500-year
New gas replacing current coal	1.8	2.4	2.5
New gas instead of new coal	1.4	1.7	1.9
Current gas replacing current coal	1.6	2.0	2.1
Current gas instead of new coal	1.2	1.5	1.6

Figure SM.4: Parity Ratios by Leakage Rate, Scenario, and Years of Coal Displaced



Parity ratio generally insensitive to time displaced: an important finding that lets us create a more generalized solution.

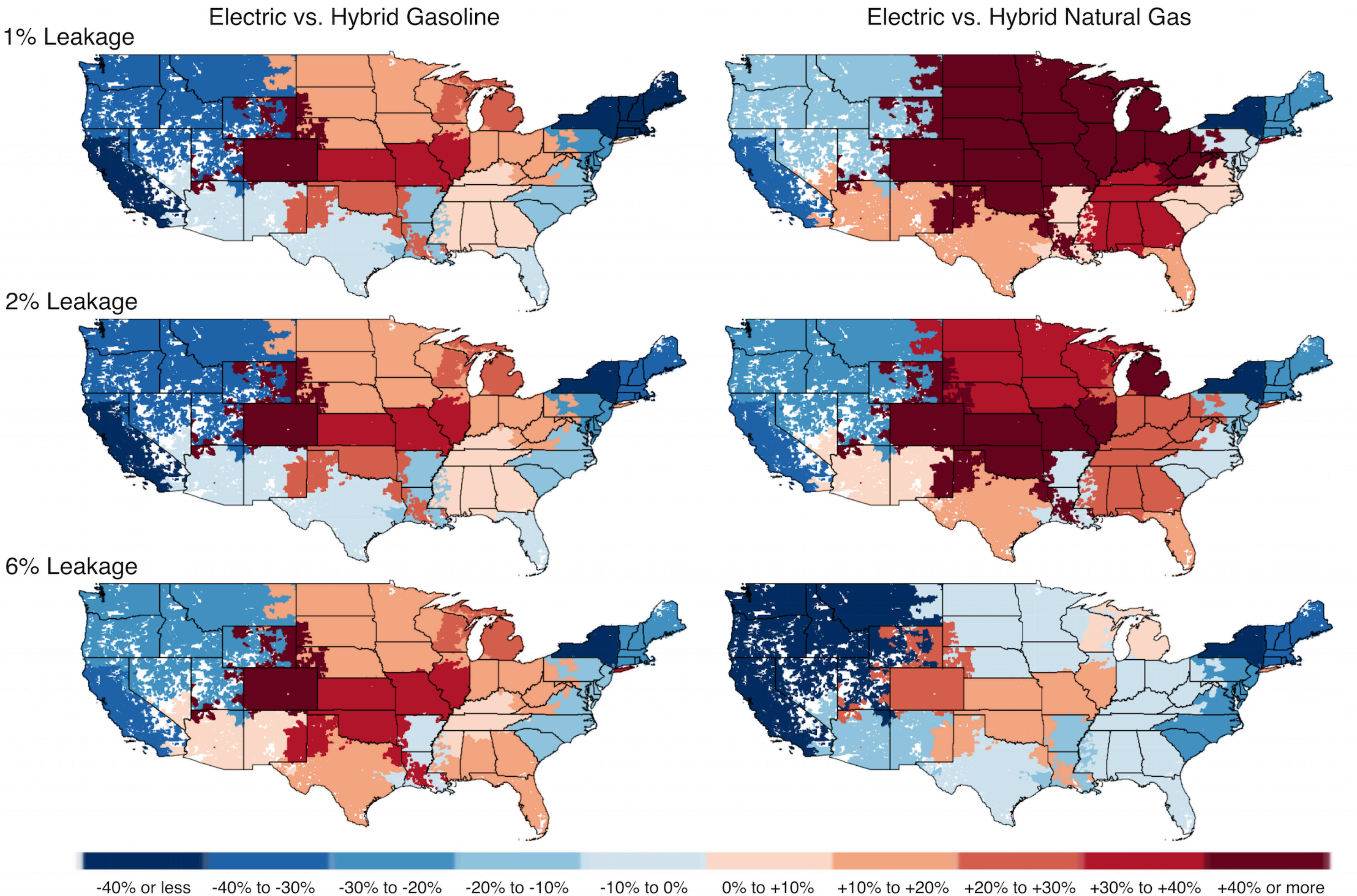
Takeaways

Gas can be a viable bridge even if it modestly delays near-zero carbon technologies IF leakage is low.

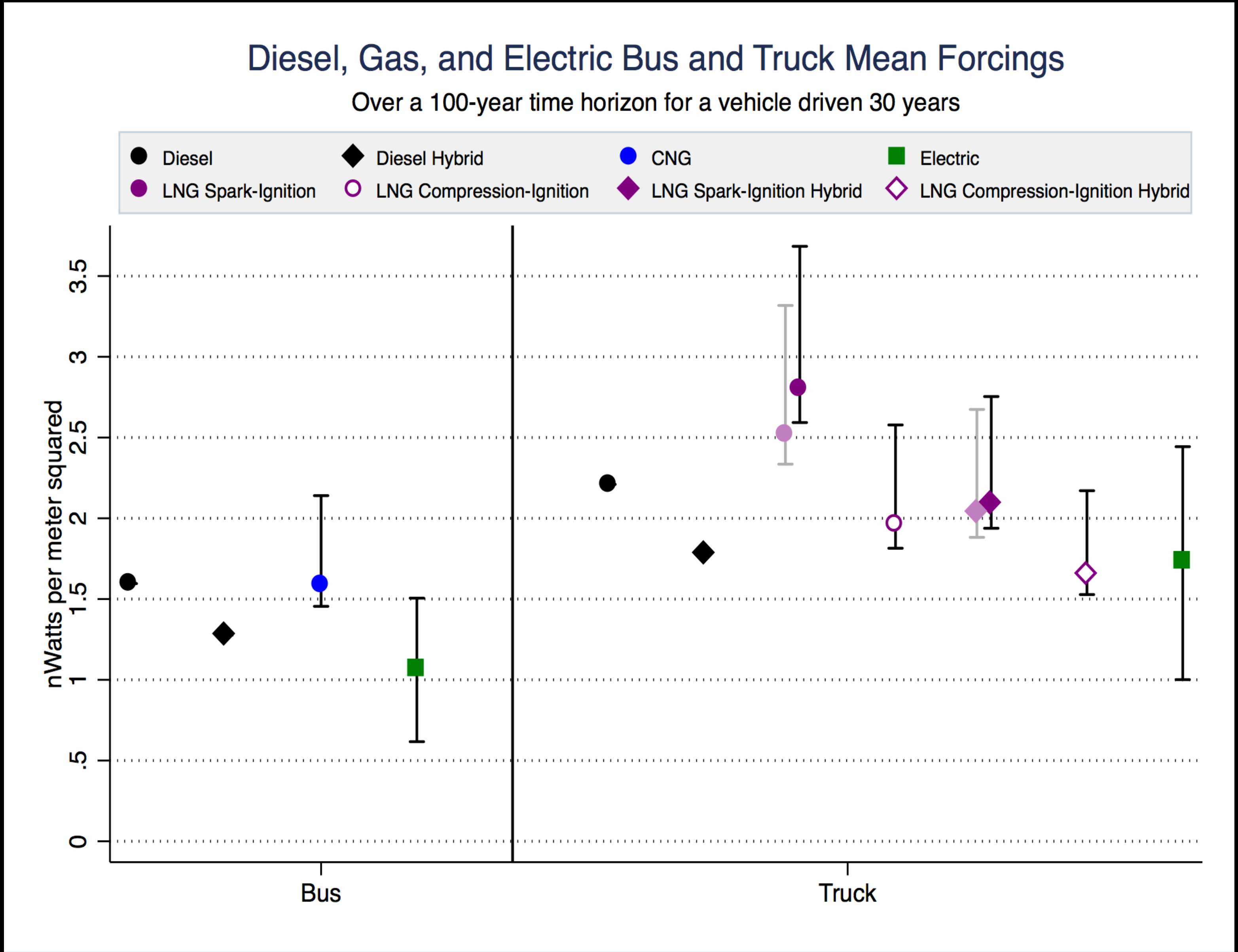
Not if large-scale replacement of coal by NZCT is expected to occur in the next ~12 years, however.

A natural gas bridge makes it much easier to avoid 3C+ warming but harder to hit ambitious 2C or below targets.

Climate Impacts of Vehicles by NERC Subregion



Heavy Vehicles



EPA IPM Clean Power Plan Scenarios