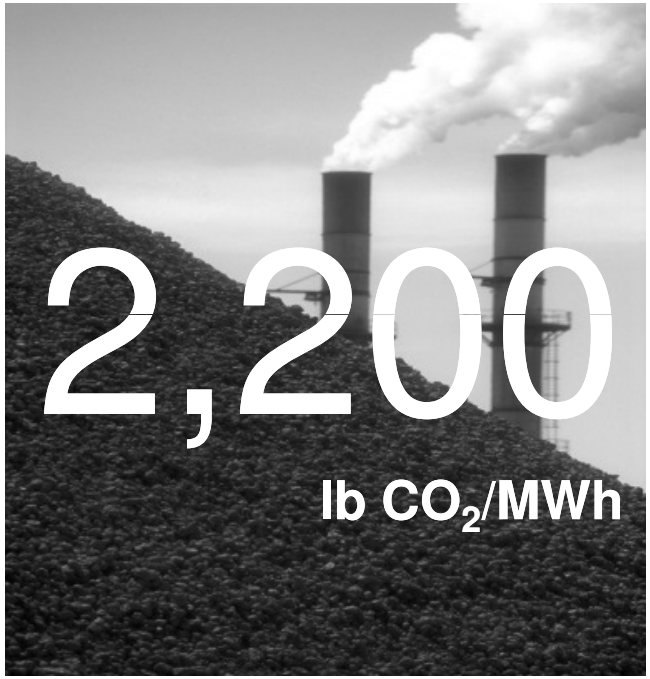
Climate implications of natural gas operations

Ramón Alvarez, Ph.D.

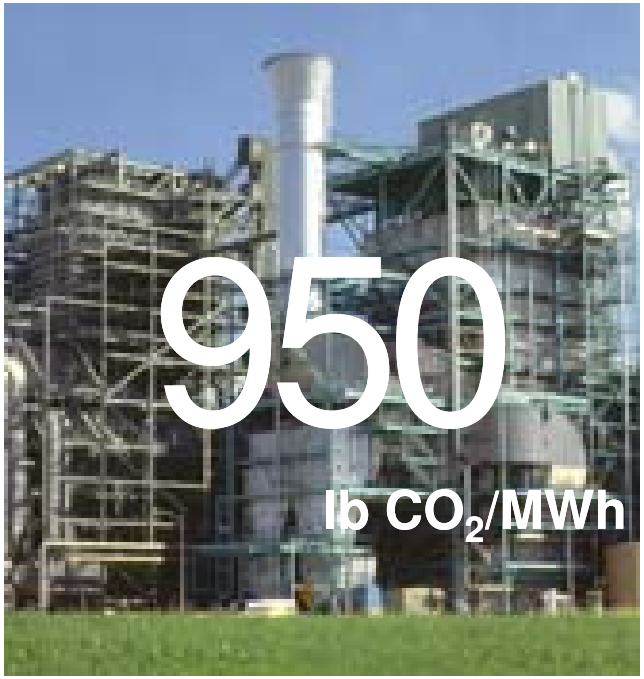
1 October 2012

EDF
ENVIRONMENTAL DEFENSE FUND®
Finding the ways that work

Power plant CO_2 emissions…



Coal



Natural Gas

Power plant emissions…aren't whole story

COAL MINING
& PROCESSING

TRANSPORTATION

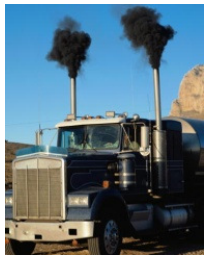
COAL
COMBUSTION

NATURAL GAS
PRODUCTION

PROCESSING

TRANSMISSION
& STORAGE

NATURAL GAS
COMBUSTION



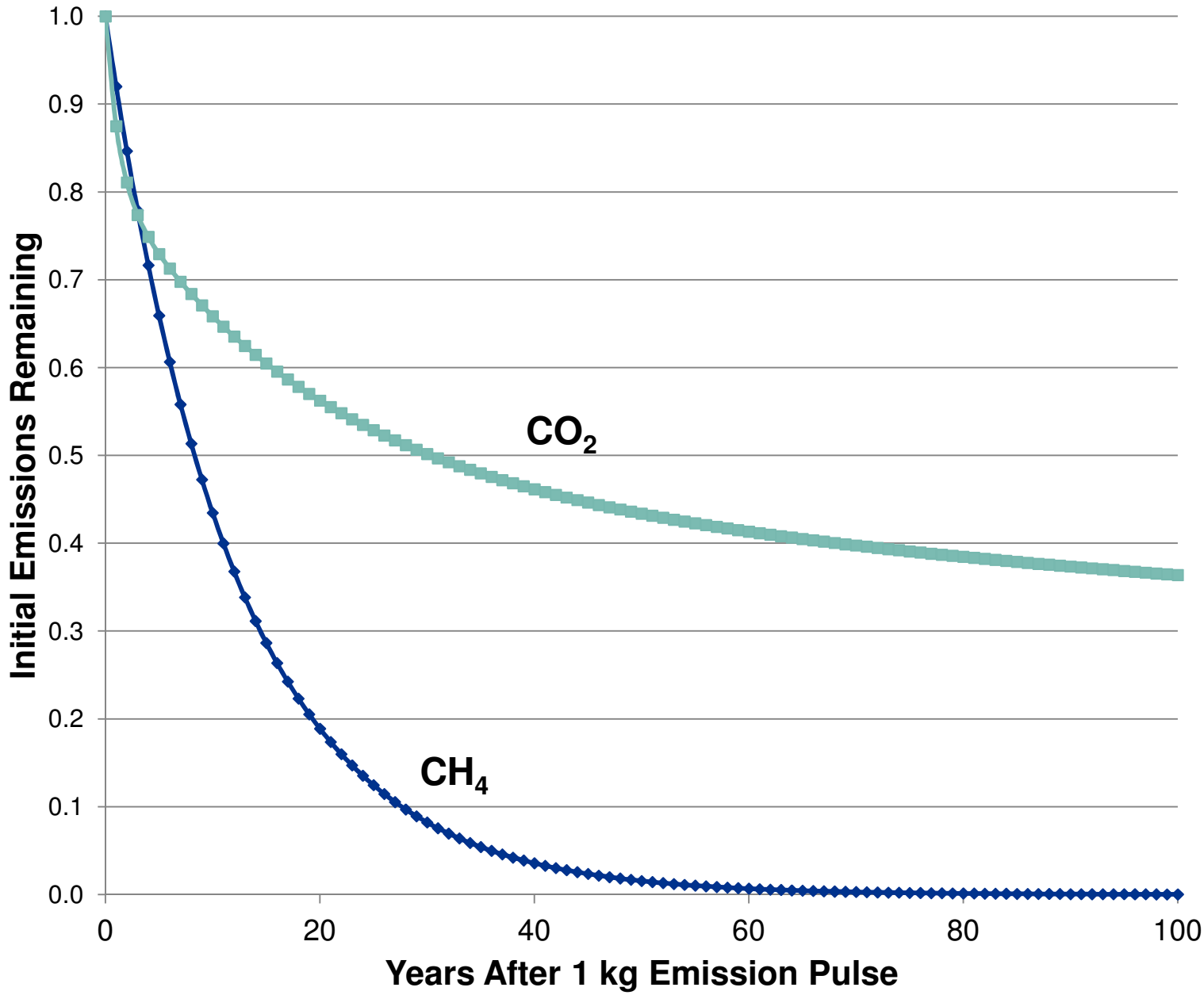
LOCAL DISTRIBUTION
TO OTHER END USERS

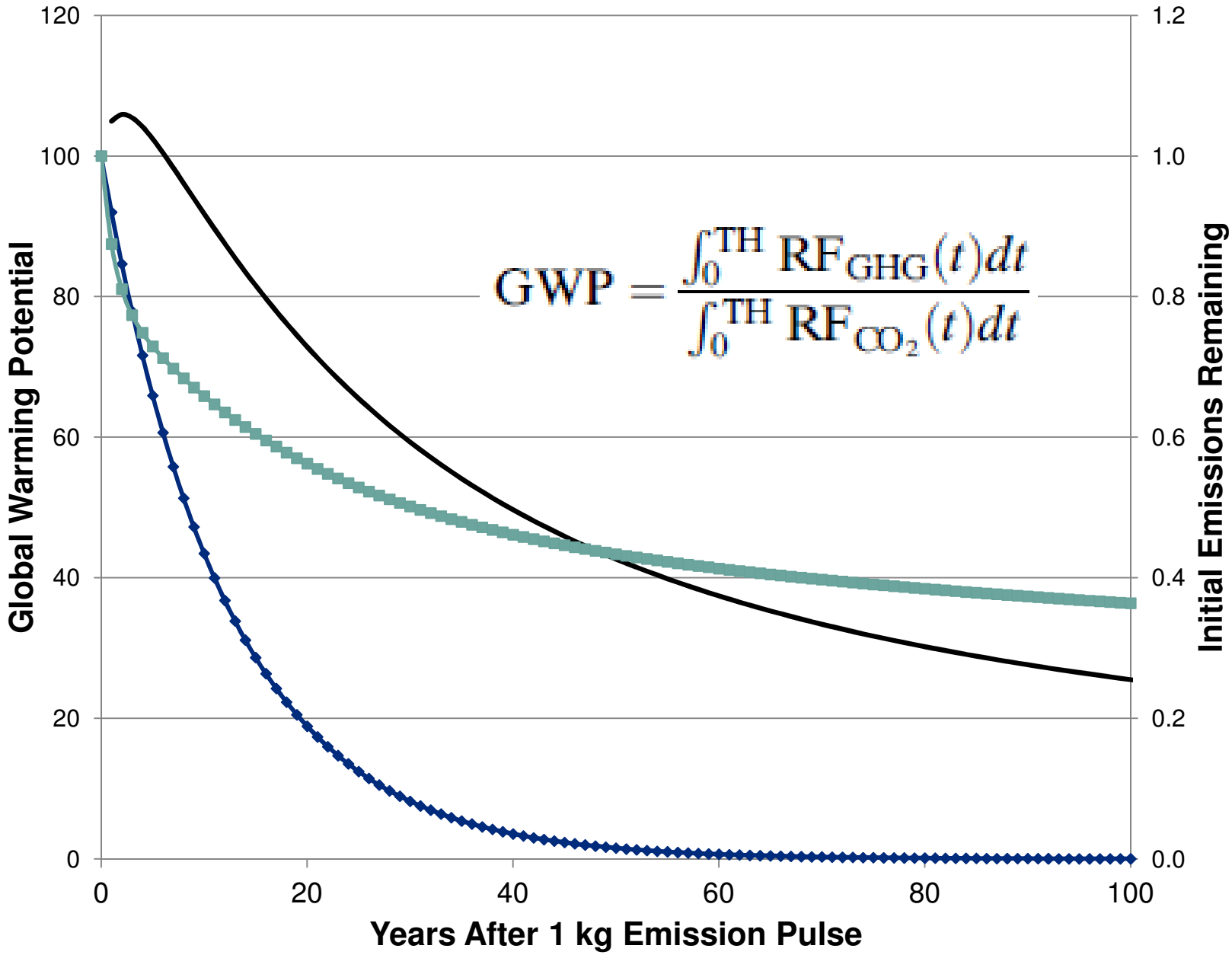
Source: Adapted from Jaramillo et al., (2007) EST 41, 6290

Greater focus needed on methane leakage from natural gas infrastructure

Ramón A. Alvarez[a,1], Stephen W. Pacala[b,1], James J. Winebrake[c], William L. Chameides[d], and Steven P. Hamburg[e]

Proceedings of the National Academy of Sciences USA (April 24, 2012) 109: 6435-6440 (doi:10.1073/pnas.1202407109)


1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Initial Emissions Remaining
CO_2
CH_4
0
20
40
60
80
100
Years After 1 kg Emission Pulse


120
100
80
60
40
20
0
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
20
40
60
80
100
Global Warming Potential
Initial Emissions Remaining
Years After 1 kg Emission Pulse
$GWP = \frac{\int_0^{TH} RF_{GHG}(t)dt}{\int_0^{TH} RF_{CO_2}(t)dt}$

Limitations of Global Warming Potential

GWPs established to compare the radiative forcing of emission *pulses* at a single point in time after emission (e.g., 20 or 100 years)

Obscures time dimension

Not suitable for emission *streams* of *multiple* pollutants

- "CO_2e" faces same limitations

"Technology Warming Potential" (TWP)

$$\mathrm{TWP}(t) = \frac{\frac{L}{L_{\mathrm{REF}}} E_{1,\mathrm{CH_4}} \mathrm{TRF}_{\mathrm{CH_4}}(t) + E_{1,\mathrm{CO_2}} \mathrm{TRF}_{\mathrm{CO_2}}(t)}{E_{2,\mathrm{CH_4}} \mathrm{TRF}_{\mathrm{CH_4}}(t) + E_{2,\mathrm{CO_2}} \mathrm{TRF}_{\mathrm{CO_2}}(t)}$$

- E's assumed to be constant; a more general formulation could be employed to reflect technology improvements over time
- L_{REF} = 2.1% for Power Plant case; 3.0% for transportation cases

"Technology Warming Potential" (TWP)

$$\mathrm{TWP}(t) = \frac{\frac{L}{L_{\mathrm{REF}}} E_{1,\mathrm{CH_4}} \mathrm{TRF}_{\mathrm{CH_4}}(t) + E_{1,\mathrm{CO_2}} \mathrm{TRF}_{\mathrm{CO_2}}(t)}{E_{2,\mathrm{CH_4}} \mathrm{TRF}_{\mathrm{CH_4}}(t) + E_{2,\mathrm{CO_2}} \mathrm{TRF}_{\mathrm{CO_2}}(t)}$$

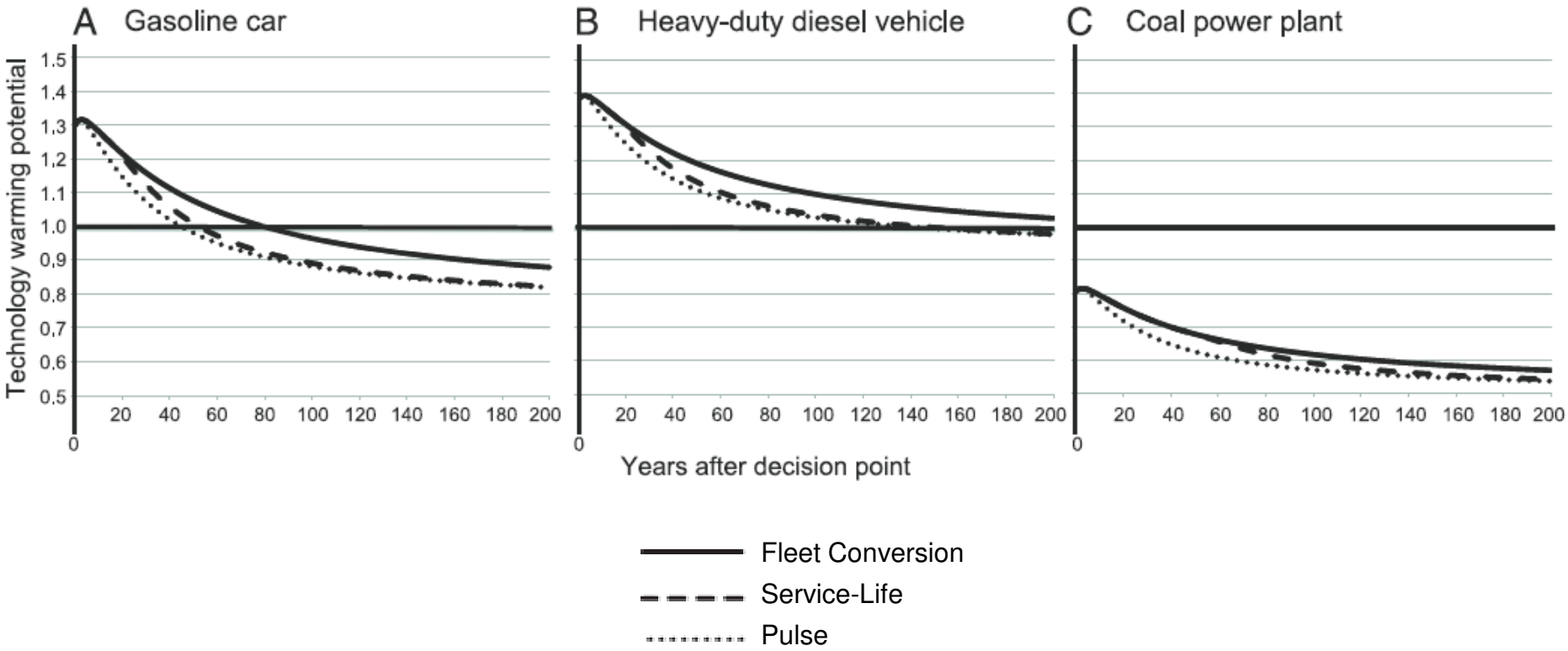
- E's assumed to be constant; a more general formulation could be employed to reflect technology improvements over time
- L_{REF} = 2.1% for Power Plant case; 3.0% for transportation cases

Case	$\mathrm{TRF}_{\mathrm{CH_4}}(t)$	$\mathrm{TRF}_{\mathrm{CO_2}}(t)$
Pulse TWP	$\mathrm{RE}\{\tau_M(1-e^{-t/\tau_M})\}$	$a_0 t + \sum_{i=1}^{3} a_i \tau_i (1-e^{-t/\tau_i})$
Service Life TWP for $t \leq \mathrm{AMAX}$	$\mathrm{RE}\{\tau_M t - \tau_M^2(1-e^{-t/\tau_M})\}$	$a_0 \frac{t^2}{2} + \sum_{i=1}^{3} a_i(\tau_i t - \tau_i^2(1-e^{-t/\tau_i}))$
Service Life TWP for $t > \mathrm{AMAX}$	$\mathrm{RE}\{\tau_M \mathrm{AMAX} - \tau_M^2 e^{-t/\tau_M}(e^{\mathrm{AMAX}/\tau_M}-1)\}$	$a_0[\mathrm{AMAX}\, t - \frac{\mathrm{AMAX}^2}{2}] + \sum_{i=1}^{3} a_i(\tau_i \mathrm{AMAX} - \tau_i^2 e^{-t/\tau_i}(e^{\mathrm{AMAX}/\tau_i}-1))$
Fleet Conversion TWP	$\mathrm{RE}\{\tau_M t - \tau_M^2(1-e^{-t/\tau_M})\}$	$a_0 \frac{t^2}{2} + \sum_{i=1}^{3} a_i(\tau_i t - \tau_i^2(1-e^{-t/\tau_i}))$

RE in these formulas is the radiative efficiency of CH_4 relative to CO_2 and equals 102.

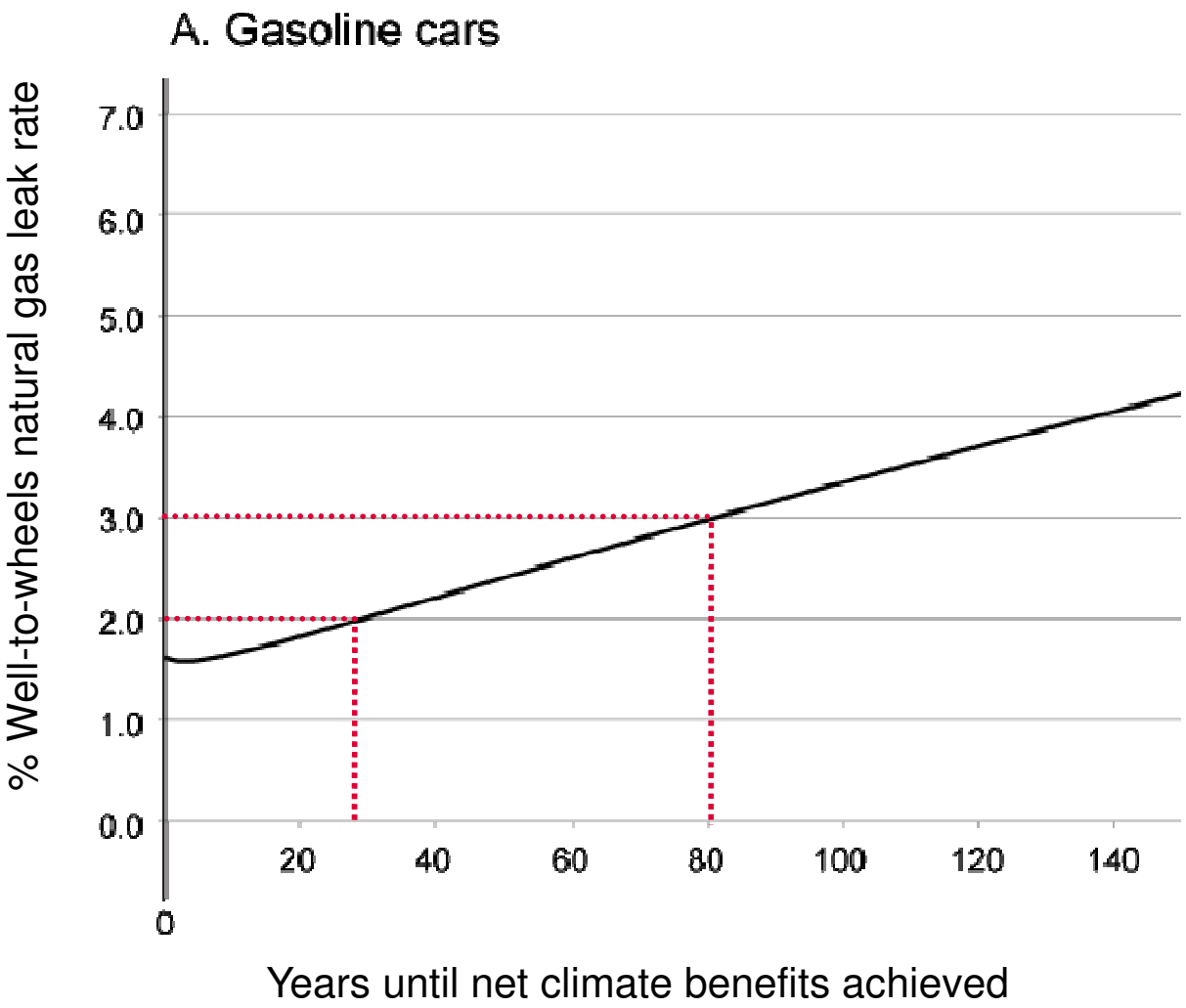
Greater focus needed on methane leakage from natural gas infrastructure

Ramón A. Alvarez[a,1], Stephen W. Pacala[b,1], James J. Winebrake[c], William L. Chameides[d], and Steven P. Hamburg[e]

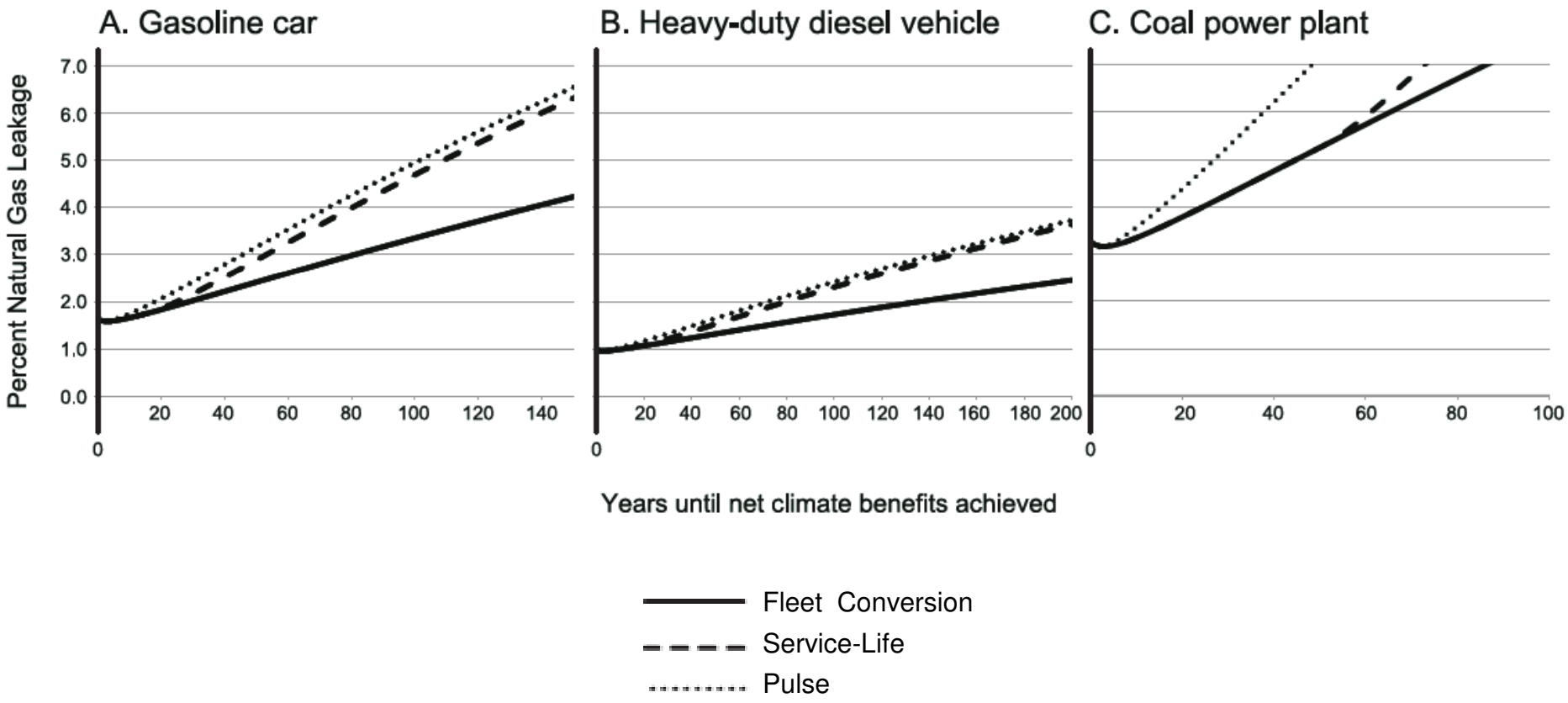


Proceedings of the National Academy of Sciences USA (April 24, 2012) 109: 6435-6440 (doi:10.1073/pnas.1202407109)

Leak rate affects time to climate benefits



What it takes to avoid climate damages



Data Gaps/Uncertainties

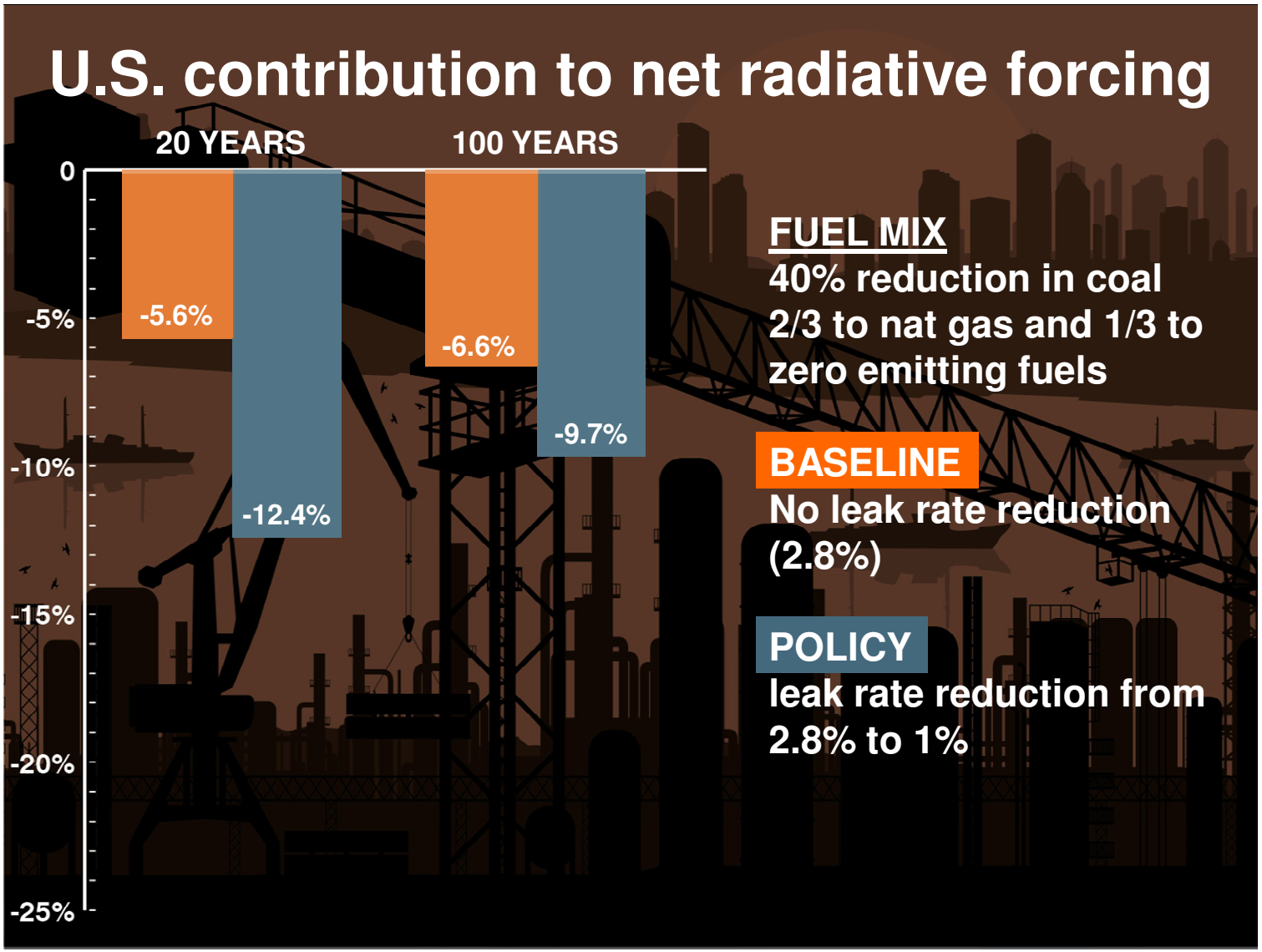
- Methane emissions across fuel cycle
- Effects of methane on climate
  - Alternative climate metrics
- Emissions of other pollutants
  - Climate implications
  - Air quality benefits
- Efficiency of NGVs

Conclusions

Improved science and data are needed to quantify CH_4 leakage

Reductions in CH_4 leakage are needed to maximize the climate benefits of natural gas

U.S. contribution to net radiative forcing



Cutting CH_4 leakage from 2.8% down to 1% produces more than twice the climate benefit in the short term as closing down 40% of the nation's coal plants and replacing with natural gas zero-emissions sources; significant benefits persist out to 100 years.

EDF's CH_4 Emissions Field Studies