Cornell University
College of Agriculture and Life Sciences

Global Warming Impacts of Shale Gas Development by Hydraulic Fracturing

Bob Howarth
Cornell University

Greenhouse Gas and Environmental Impacts of Shale Gas, Transportation Research Board

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Climatic Change
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LETTER

Methane and the greenhouse-gas footprint of natural gas from shale formations

A letter

Robert W. Howarth · Renee Santoro · Anthony Ingraffea

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Abstract We evaluate the greenhouse gas footprint of natural gas obtained by high-volume hydraulic fracturing from shale formations, focusing on methane emissions. Natural gas is composed largely of methane, and 3.6% to 7.9% of the methane from shale-gas production escapes to the atmosphere in venting and leaks over the lifetime of a well. These methane emissions are at least 30% more than and perhaps more than twice as great as those from conventional gas. The higher emissions from shale gas occur at the time wells are hydraulically fractured—as methane escapes from flow-back return fluids—and during drill out following the fracturing. Methane is a powerful greenhouse gas, with a global warming potential that is far greater than that of carbon dioxide, particularly over the time horizon of the first few decades following emission. Methane contributes substantially to the greenhouse gas footprint of shale gas on shorter time scales, dominating it on a 20-year time horizon. The footprint for shale gas is greater than that for conventional gas or oil when viewed on any time horizon, but particularly so over 20 years. Compared to coal, the footprint of shale gas is at least 20% greater and perhaps more than twice as great on the 20-year horizon and is comparable when compared over 100 years.

Keywords Methane · Greenhouse gases · Global warming · Natural gas · Shale gas · Unconventional gas · Fugitive emissions · Lifecycle analysis · LCA · Bridge fuel · Transitional fuel · Global warming potential · GWP

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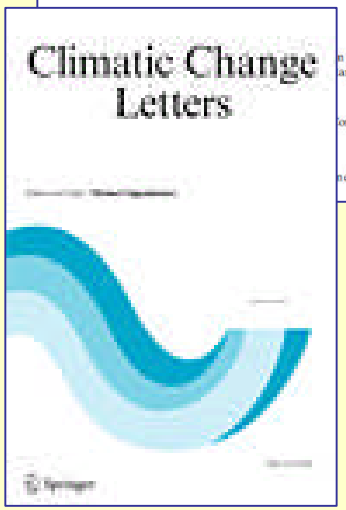
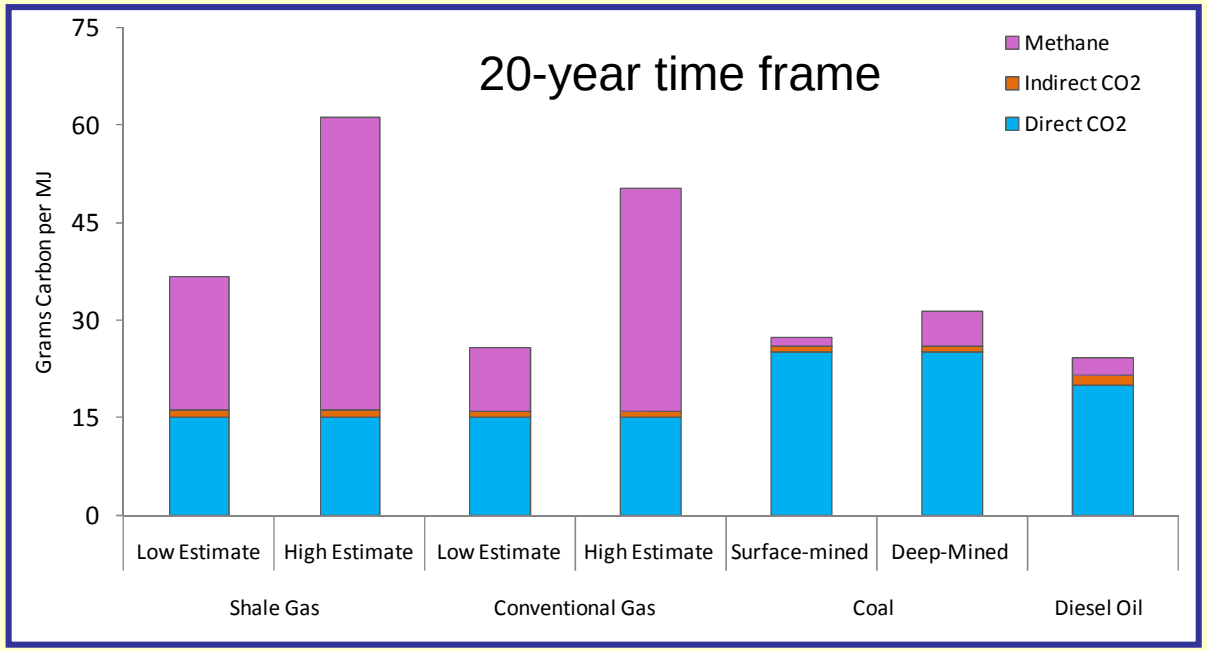
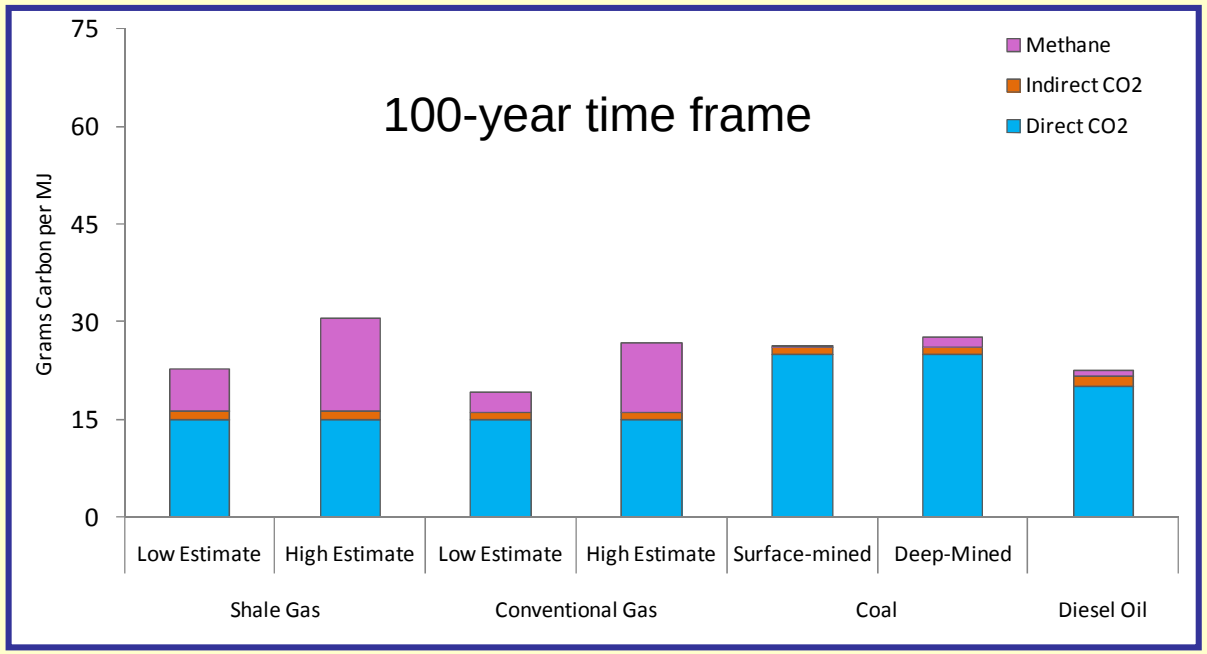


Published in April 2011





TIME Person of the Year

People who Mattered

Mark Ruffalo, Anthony Ingraffea, Robert Howarth
By Bryan Walsh Wednesday, Dec. 14, 2011

The biggest environmental issue of 2011 — at least in the U.S. — wasn't global warming. It was hydraulic fracturing, and these three men helped represent the determined opposition to what's more commonly known as fracking. Anthony Ingraffea is an engineer at Cornell University who is willing to go anywhere to talk to audiences about the geologic risks of fracking, raising questions about the threats that shale gas drilling could pose to water supplies. Robert Howarth is his colleague at Cornell, an ecologist who **produced one of the most controversial scientific studies of the year: a paper arguing that natural gas produced by fracking may actually have a bigger greenhouse gas footprint than coal. That study — strenuously opposed by the gas industry and many of Howarth's fellow scientists — undercut shale gas's major claim as a clean fuel**. And while he's best known for his laidback hipster performances in films like *The Kids Are All Right*, Mark Ruffalo emerged as a tireless, serious activist against fracking — especially in his home state of New York.

Comparison of published estimates for methane emissions from conventional and shale gas development, expressed per unit of Lower Heating Value (gC MJ^{-1}).

	Conventional gas	Shale gas
Hayhoe et al. (2002)	0.57	*
Jamarillo et al. (2007)	0.15	*
Howarth et al. (2011)	0.26 - 0.96	0.55 - 1.2

* Estimates not provided in these papers and reports.

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Roughly 40% more methane

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Marcellus Well Being "Finished"
Outside Dimock, PA, June 2011

Photo and FLIR Methane-Tuned Video Courtesy Frank Finan

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Very good agreement

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Low, since based on old and low emissions factors from a 1996 EPA study

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Hultman et al. (2011)	0.35	0.57
Skone et al. (2011)	0.27	0.37
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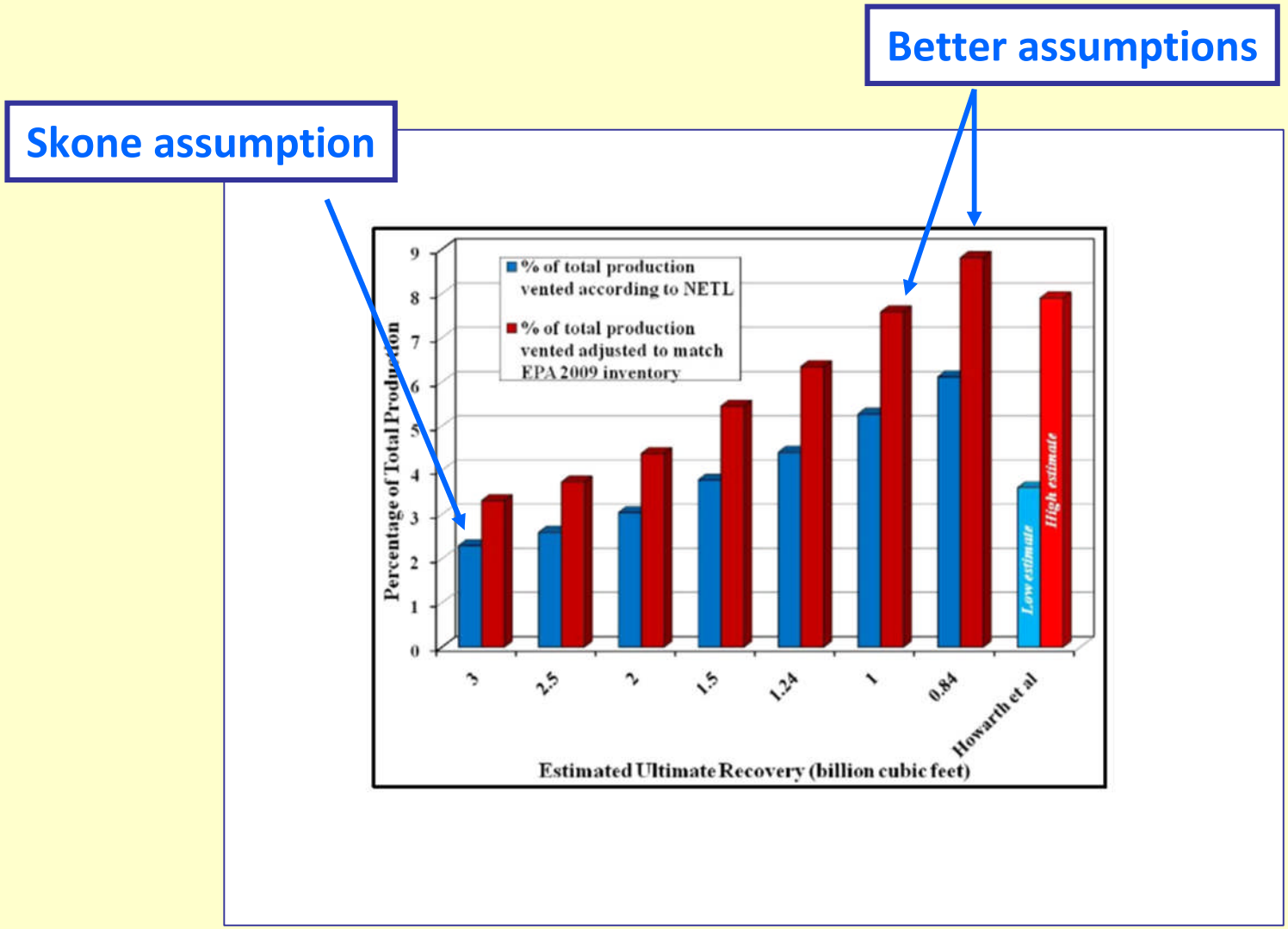

Skone estimates may be low, when normalized to energy, since gas production for well was likely over-estimated (Hughes 2011).

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	Conventional gas	Shale gas	Time frame?
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Jamarillo et al. (2007)	0.15	*	100
Howarth et al. (2011)	0.26 - 0.96	0.55 - 1.2	20 & 100
EPA (2011a)	0.38	0.60	100
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PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A

Phil. Trans. R. Soc. A (2007) **365**, 1925–1954
doi:10.1098/rsta.2007.2052
Published online 18 May 2007

Climate change and trace gases

By James Hansen[1,*], Makiko Sato[1], Pushker Kharecha[1], Gary Russell[1], David W. Lea[2] and Mark Siddall[3]

[1]*NASA Goddard Institute for Space Studies and Columbia University Earth Institute, 2880 Broadway, New York, NY 10025, USA*
[2]*Department of Earth Science, University of California, Santa Barbara, CA 93106, USA*
[3]*Lamont-Doherty Earth Observatory, Columbia University, Palisades, NY 10964, USA*

"Only intense simultaneous efforts to slow CO_2 emissions and reduce non-CO_2 forcings can keep climate within or near the range of the past million years. **<u>The most important of the non-CO_2 forcings is methane</u> (CH_4)……"**

Hansen et al. (2007) identified critical threshold in climate system, to avoid melting of natural methane hydrates, leading to runaway positive feedback of global warming = 1.8° C.

Control of methane and other short-lived radiatively active materials has more immediate benefits than CO_2 controls, but both are important long term.

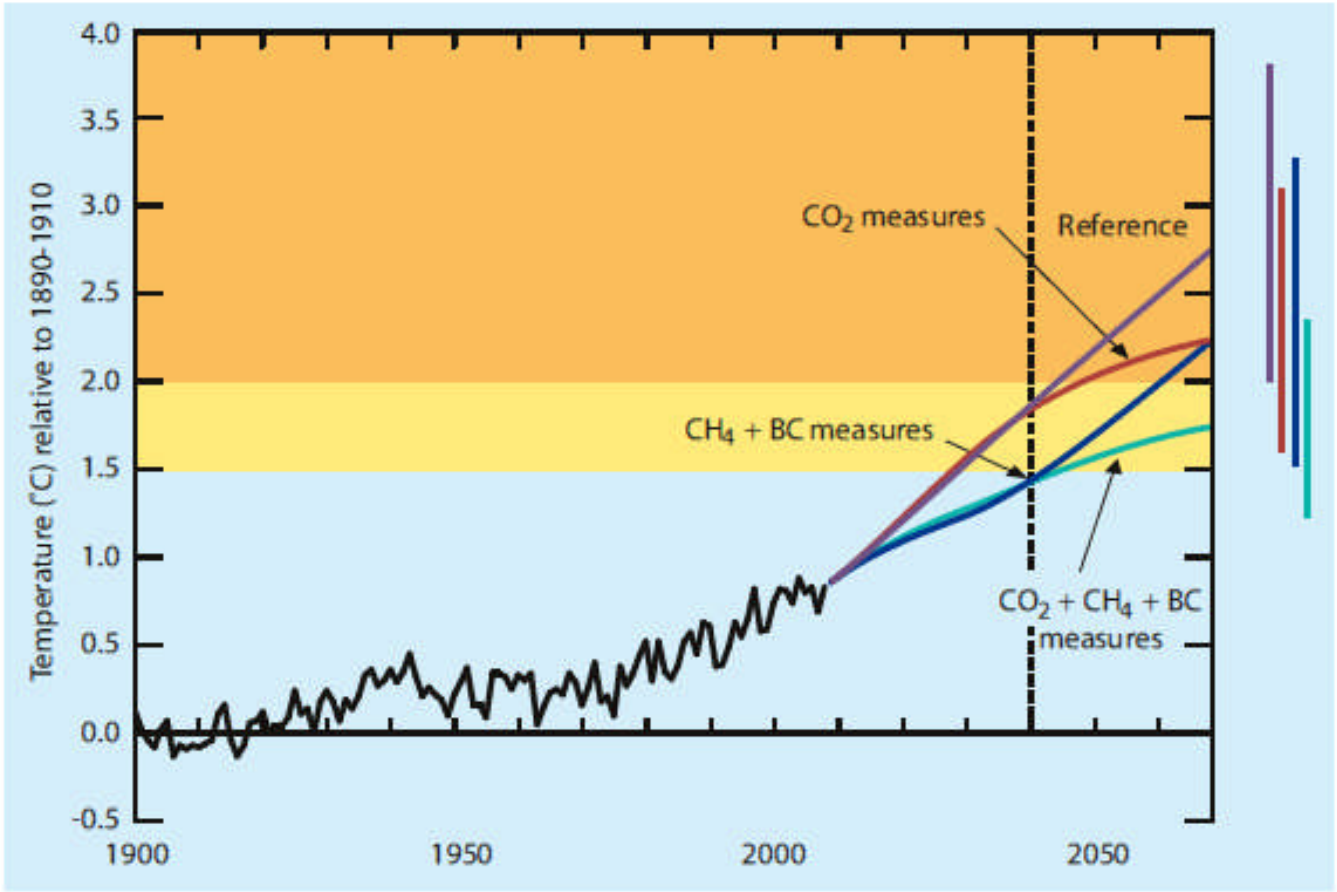
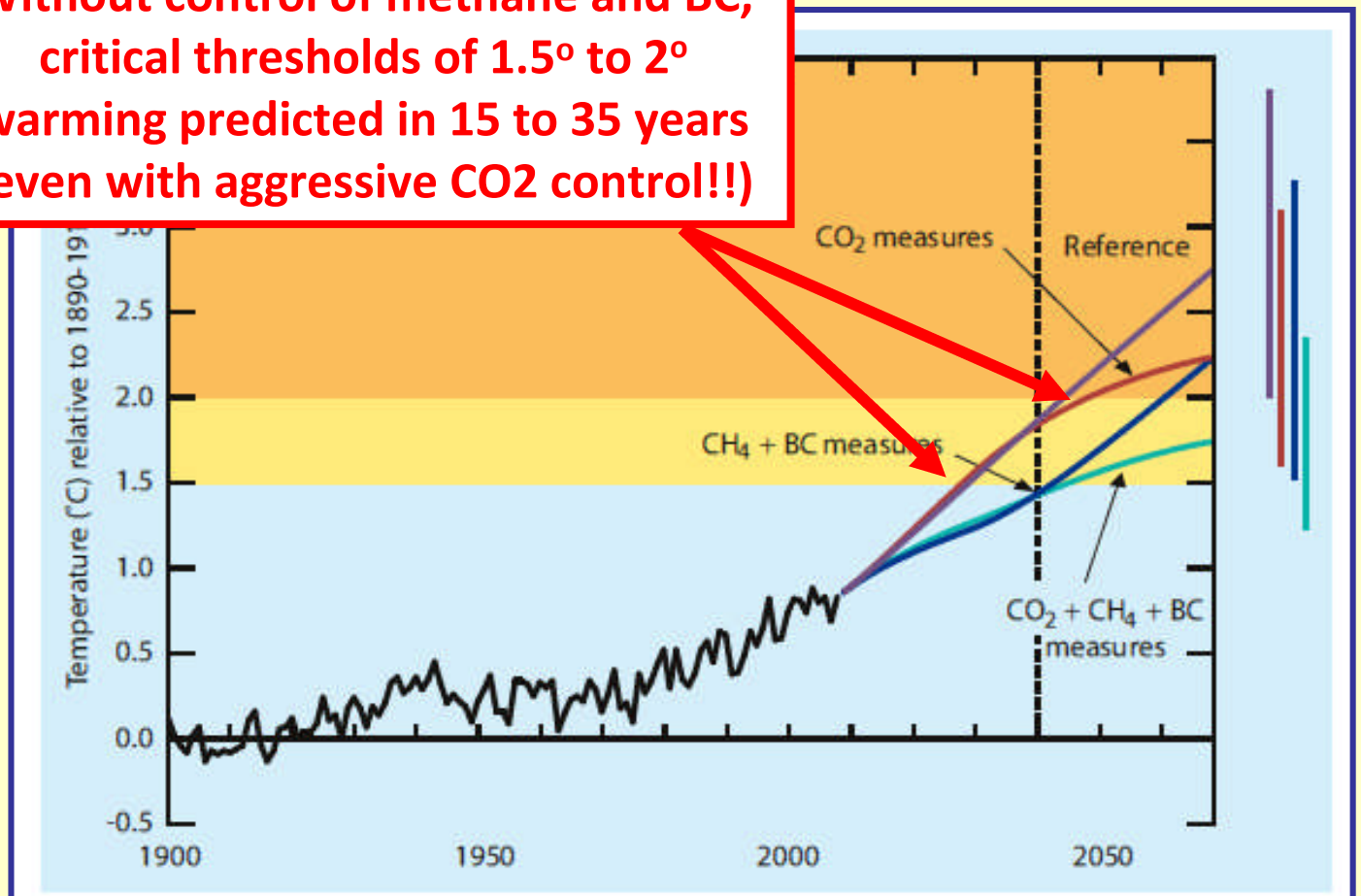


Figure 3. Observed deviation of temperature to 2009 and projections under various scenarios. Immediate implementation of the identified BC and CH_4 measures, together with measures to reduce CO_2 emissions, would greatly improve the chances of keeping Earth's temperature increase to less than 2°C relative to pre-industrial levels. The bulk of the benefits of CH_4 and BC measure are realized by 2040 (dashed line).

UNEP/ WMO (2011) and Shindell et al. (2012)

Without control of methane and BC, critical thresholds of 1.5º to 2º warming predicted in 15 to 35 years (even with aggressive CO2 control!!)



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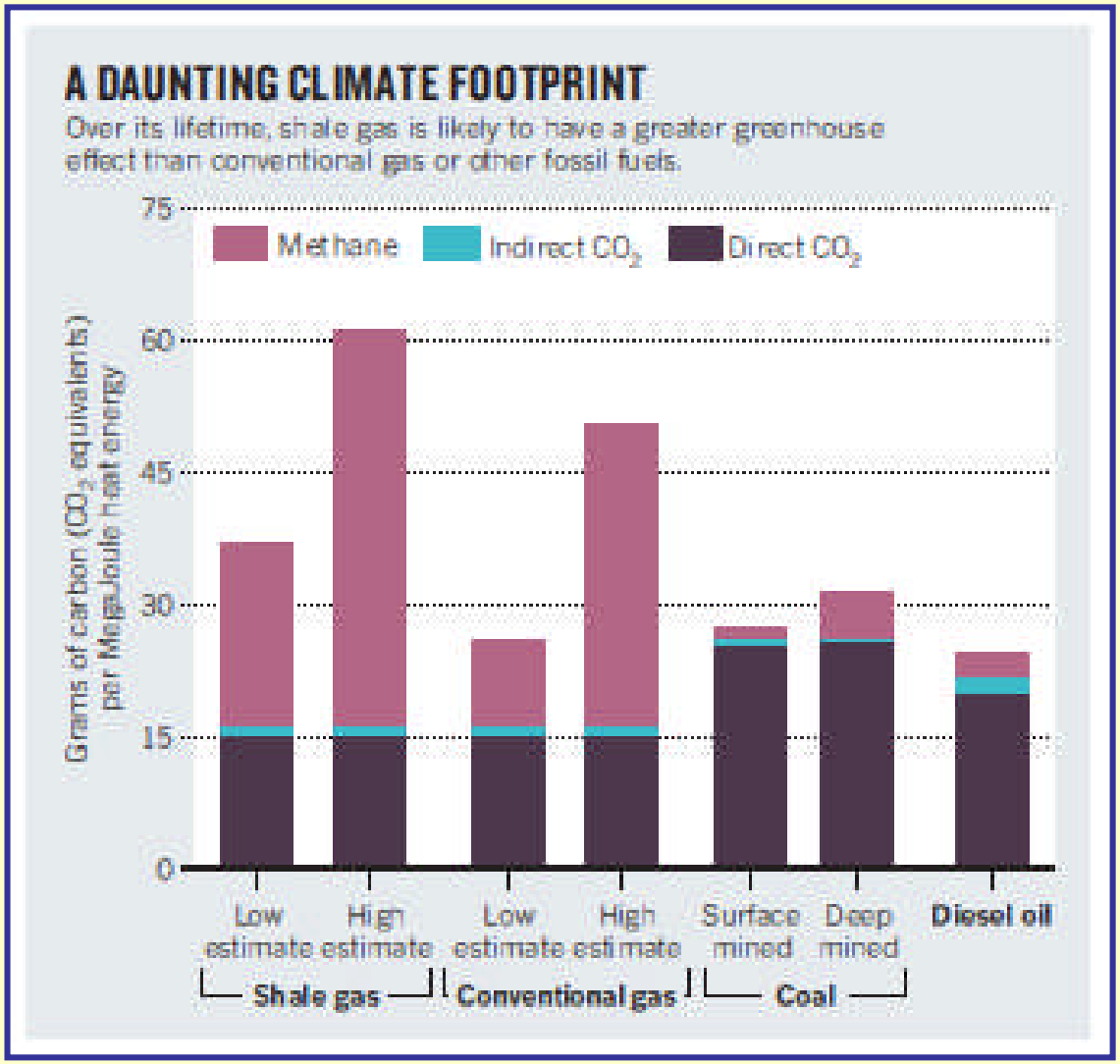
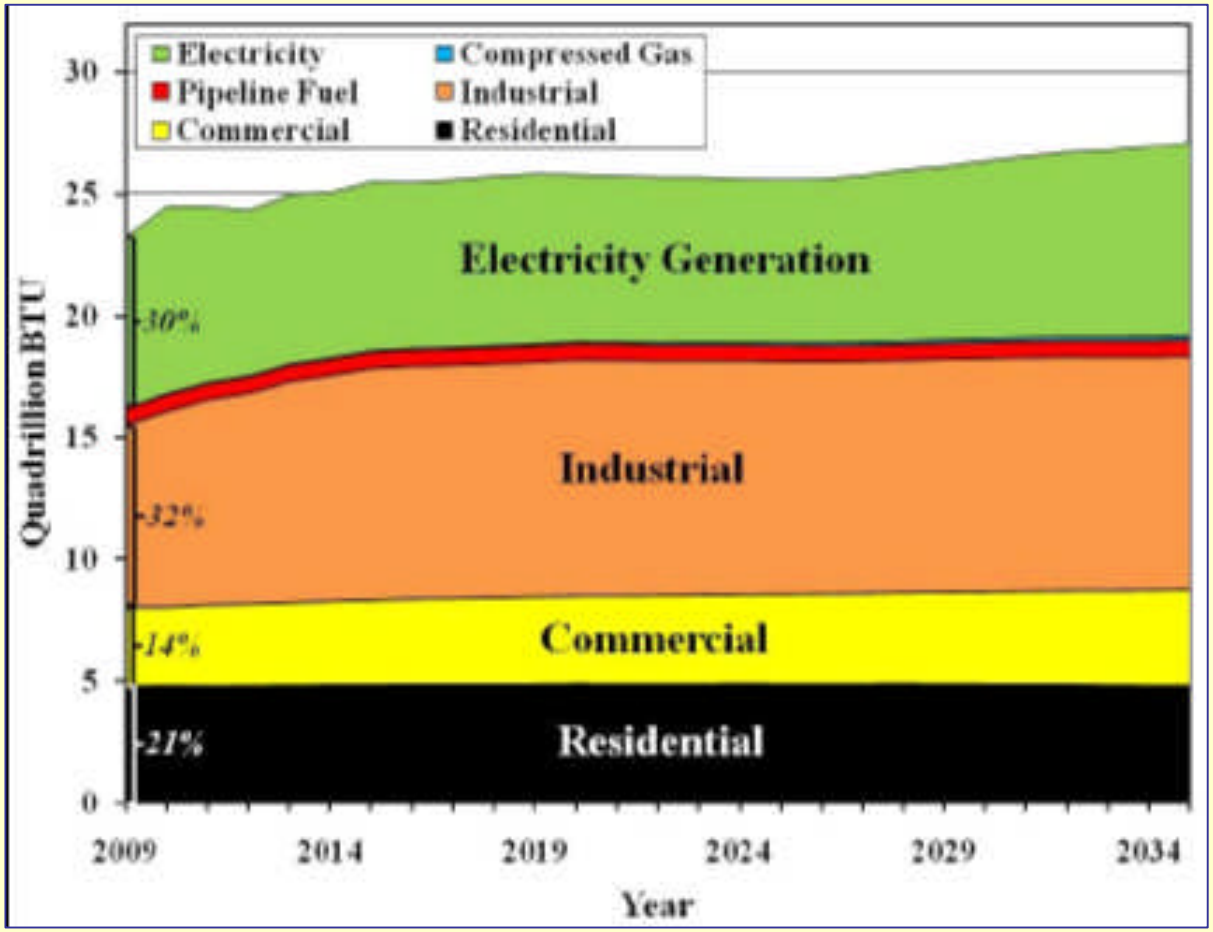
Greenhouse gas footprint of shale gas compared to other fossil fuels (20-year integrated global warming potential for methane)



Howarth & Ingraffea, *Nature*, 15 September 2011

Heat use and not electricity generation dominates natural gas use in the United States

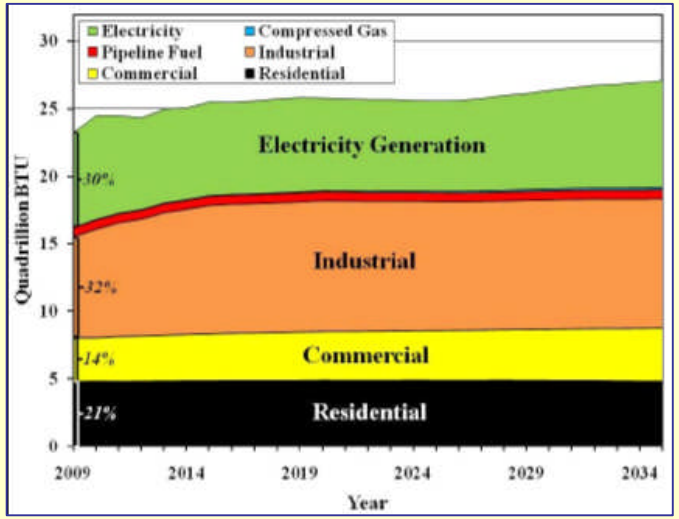


Energy Information Agency (2011)

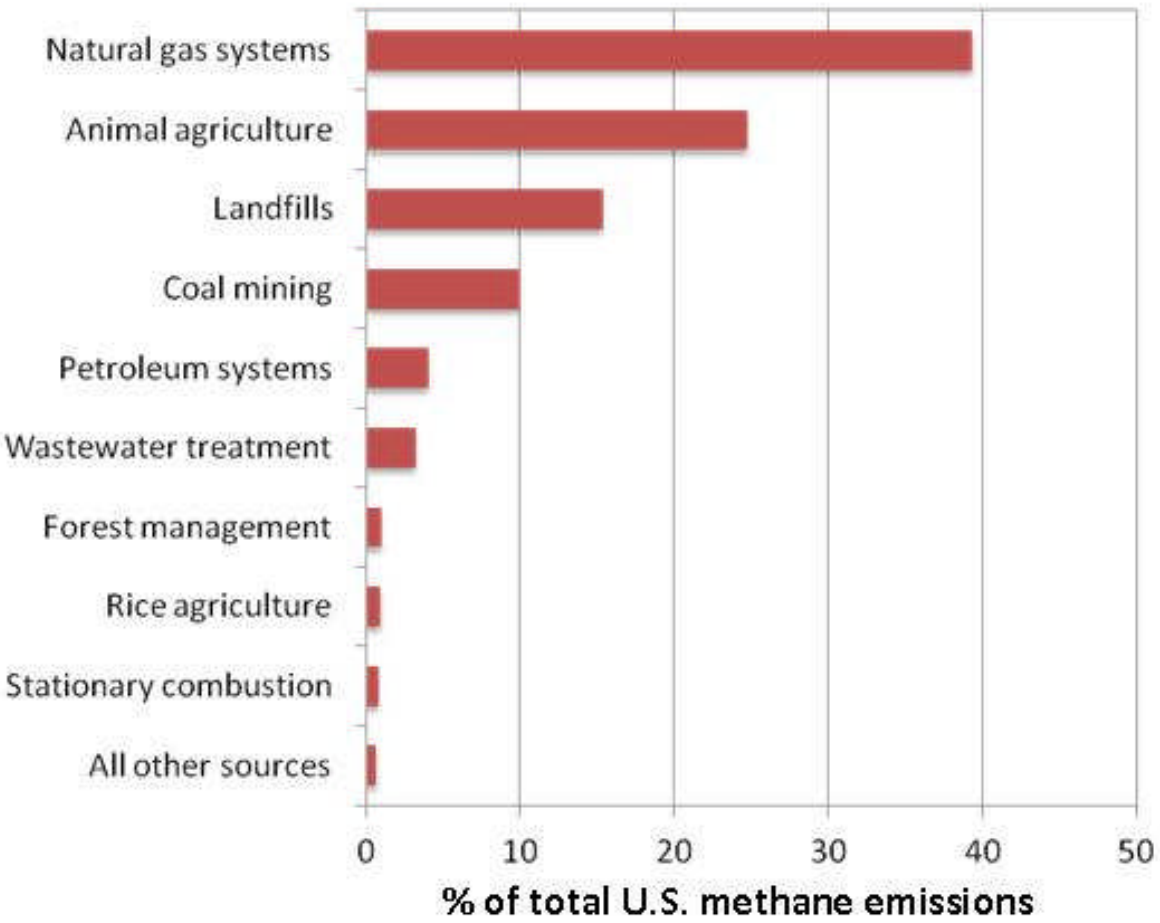
When generating electricity, natural gas has some efficiency advantage over coal or oil (but not enough to fundamentally change our conclusion).

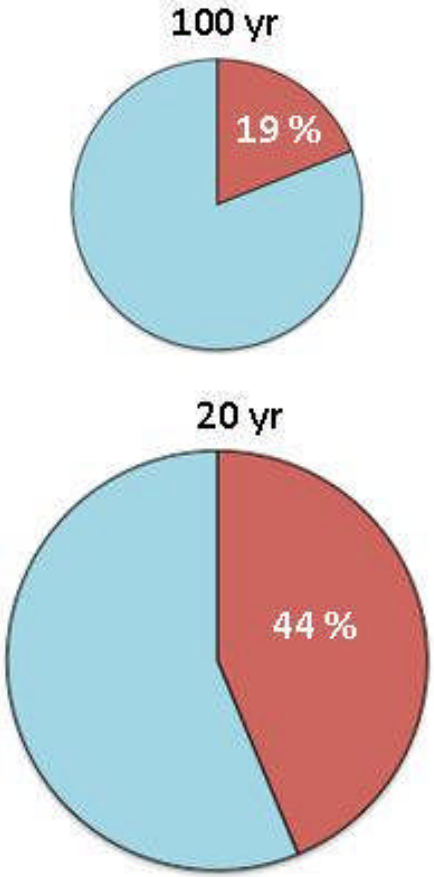
Natural gas has no efficiency advantage over oil or coal, when used for heat and industrial energy.

Transportation? Methane emissions probably far higher than we (or others) have estimated so far, due to venting of CNG and LNG in storage (necessary for safety).



Latest information from U.S. national greenhouse gas inventory





(Howarth et al. 2012, using EPA reports from 2011)

Can methane emissions be reduced?

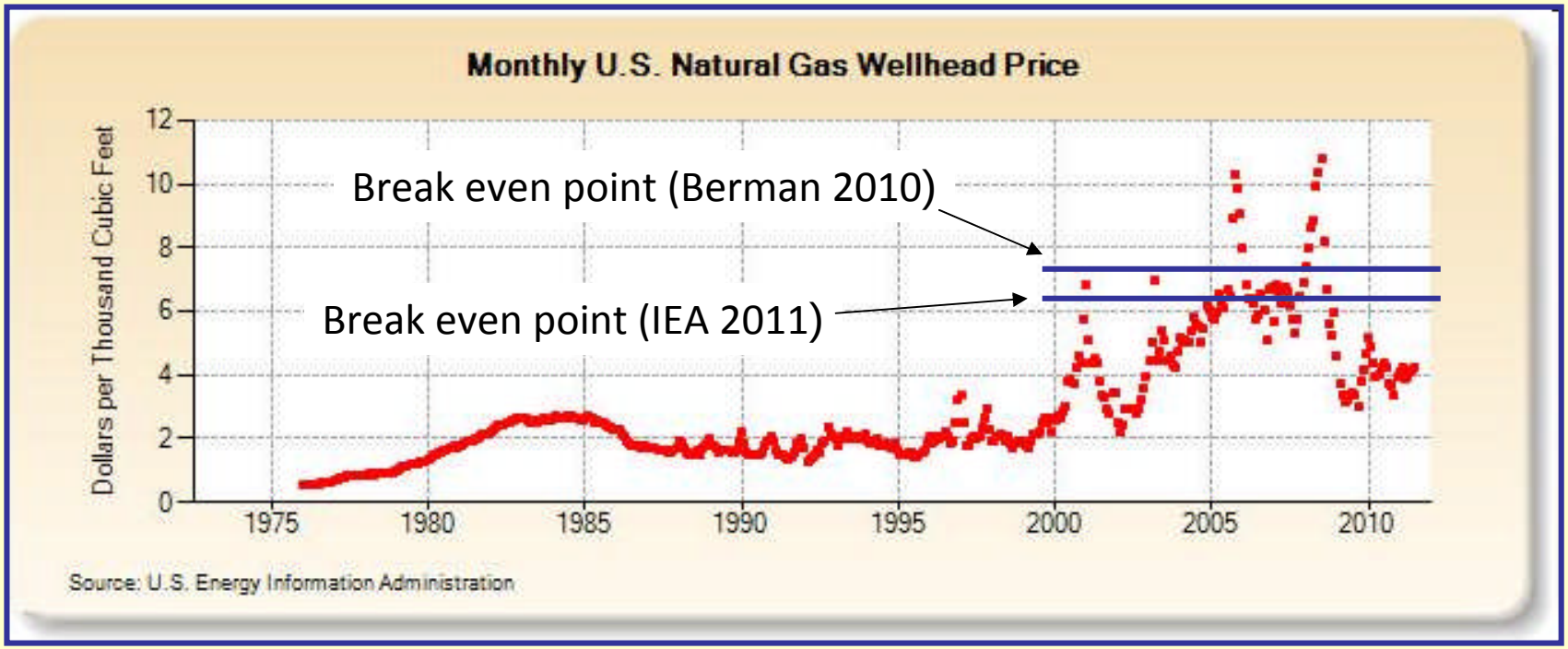
Yes, but:

-- a lot are purposeful venting (economic decision)

-- leakage from old tanks and pipelines would be very expensive to fix. Is it worth the investment for a "transitional fuel?"

-- would require regulation; industry is strongly opposed to regulation, and has a history of getting around regulation when imposed.

Energy Information Agency, U.S. Department of Energy



http://205.254.135.24/dnav/ng/hist/n9190us3m.htm
(downloaded October 11, 2011)

Shale gas will:

- **aggravate global warming over next many decades**
- **distract politicians and the public from needed action**

(and of course cause massive pollution and disruption at local scale, across the globe)

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Thanks to my co-authors, Renee Santoro and Tony Ingraffea.

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