Cornell University
College of Agriculture and Life Sciences

Greenhouse gas emissions from shale gas: How clean is natural gas?

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Earthworks' People's Oil and Gas Summit Pittsburgh, PA

November 20, 2010

"40 years of reducing our carbon footprint"

American Gas Association

“From a CO_2 emissions standpoint, it’s 60 percent cleaner than coal”

William Colton, VP of Exxon Mobil for corporate planning, explaining why they have invested so heavily in natural gas in recent years.

Green: A Big Bet on Natural Gas By CLIFFORD KRAUSS Published: October 30, 2010
http://green.blogs.nytimes.com/2010/10/30/betting-big-on-natural-gas/

Paucity of objective, science-based information to back up claims on natural gas as a clean, bridging fuel

In past 10 years, only 3 pertinent articles in peer-reviewed scientific journals on greenhouse gas emissions from natural gas compared to coal

(and none on emissons from development of natural gas from shale formations)

October 2009 report from the National Research Council, US National Academy of Sciences:

"*Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use*"

"[Unconventional] processes have a considerably greater potential for causing air-quality degradation than do conventional recovery technologies. . . ." p. 84

"Beyond emissions from engines, there are also significant GHG emissions of methane . . . from fugitive emissions. . . ." p.86.

"The prospect of this [Marcellus Shale] gas, however, is balanced against the deeper drilling and more complicated extraction, which would increase the life-cycle energy use and associated emissions of using this resource." p.91

COUNCIL OF SCIENTIFIC SOCIETY PRESIDENTS

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May 4, 2010

We represent the leadership of over 1.4 million scientists in over 150 scientific disciplines.

The acceleration of greenhouse gas (GHG) emissions from human activity is increasingly leading to harmful climate change and ocean acidification. Societies must act urgently to reduce these emissions to protect the life-sustaining biophysical systems of the Earth. As noted by DoE Secretary Steven Chu in his April 28, 2010 testimony to the Senate Subcommittee on Energy and Water Development, the necessary transitions "will require nothing short of a new industrial revolution." We agree with this assessment of the scale of response needed. We need to work aggressively to conserve energy and increase the efficiency of energy use, and we need rapidly to develop less polluting energy systems. Objective science has a critical role to play, and we urge that the nation fully use and incorporate the best available science in designing and implementing the energy and environmental policies necessary to guide the revolution.

America should move ahead quickly to develop a comprehensive energy policy to greatly reduce our GHG emissions. We urge that any potential approach be first evaluated in terms of the net benefits on environmental integrity, including a full analysis of GHG emissions, recognized by the Supreme Court as air pollutants, as well as other environmental concerns. The analysis of GHG emissions should include indirect land use effects and emissions of methane and nitrous oxide as well as carbon dioxide. No policy should be implemented without a full understanding of the consequences on the environment. Uncertainties will remain, which points to the necessity of also having the ability to reverse a policy action if unintended consequences are discovered.

Some energy bridges that are currently encouraged in the transition away from GHG-emitting fossil energy systems have received inadequate scientific analysis before implementation, and these may have greater GHG emissions and environmental costs than often appreciated. We find that their environmental impact studies and EPA determinations necessary to proceed are absent or inadequate. These include the production of ethanol from corn, where recent, more inclusive research concludes this is a poor option. As scientists we are concerned about the impact of the ethanol scale-up on water supply and quality, land use, GHG emissions, and net energy gain. In 2007, the nation used 27% of its corn harvest to produce 1.3% of total liquid fuels. One unintended result is greater nutrient flows down the Mississippi River, aggravating the ecological disaster underway in the Gulf of Mexico. Other biomass fedstocks produce more energy from less land, with less environmental harm. A recent report from the National Academy of Sciences lists many topics that deserve further scientific scrutiny before the nation further expands the role of ethanol as a fuel.

The production of natural gas (methane)from shales represents a major new domestic energy resource that can reduce reliance on imported crude oil. However, the development of methane from shale formations is another example where policy has preceeded adequate scientific study. Economic recovery of methane from shales requires the drilling of long-reach horizontal wells and the high-pressure injection of millions of gallons of water with chemical additives to release the gas through a process called hydrofracking. Despite the utilization of millions of gallons of water and the flow back to the surface of these injected fluids, hydrofracking is exempted from the Clean Water Act. Exploitation of the Marcellus Shale Formation in the Appalachian basin, recognized as the largest shale-gas reserve in the U.S., could occur across a five-state region. Prior, thorough science-based studies are required to evaluate the impact of massive shale development on rural land uses, water supply and quality, and full-life-cycle greenhouse gas emissions.

Sincerely,

"The acceleration of greenhouse gas (GHG) emissions from human activity is increasingly leading to harmful climate change and ocean acidification. Societies must act urgently to reduce these emissions to protect the life-sustaining biophysical systems of the Earth."

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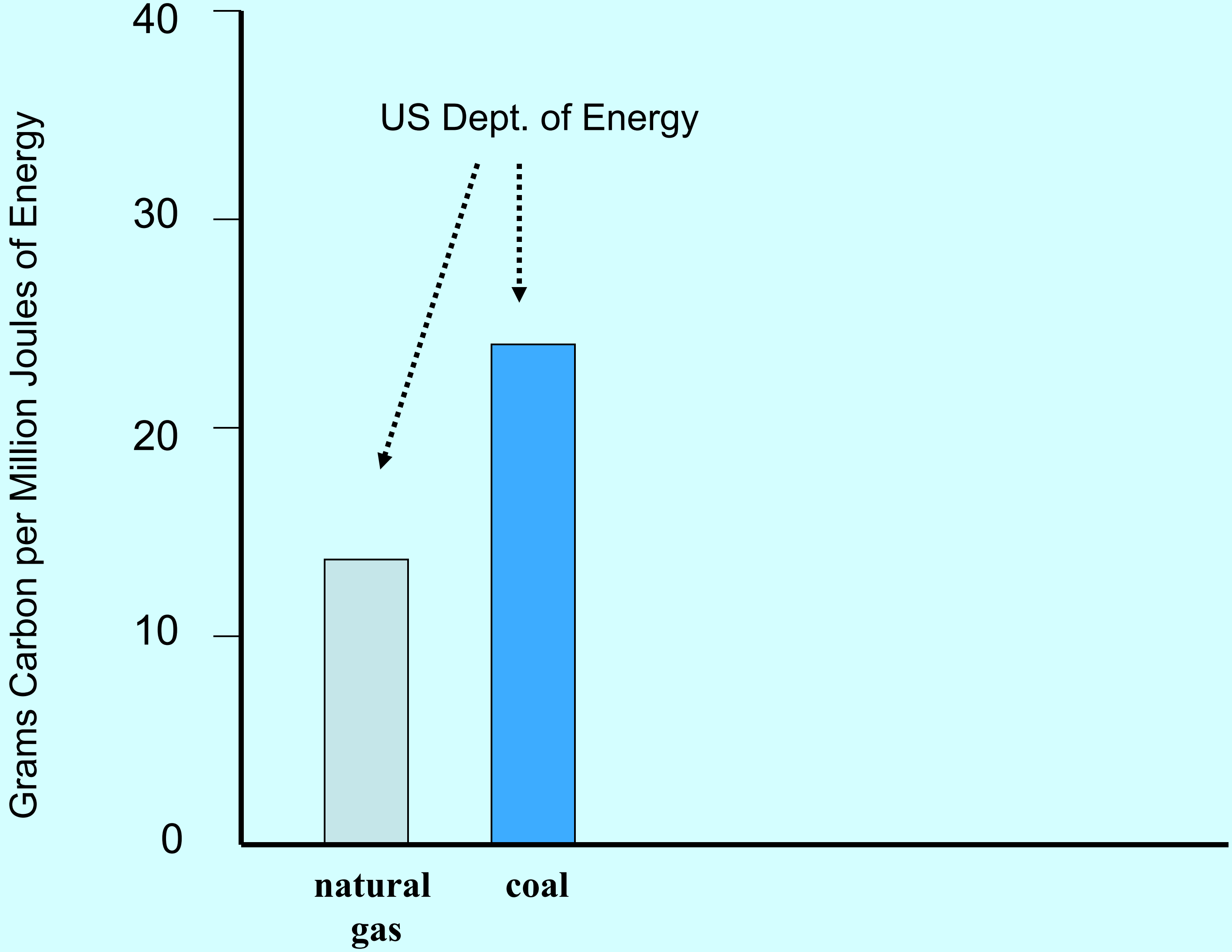
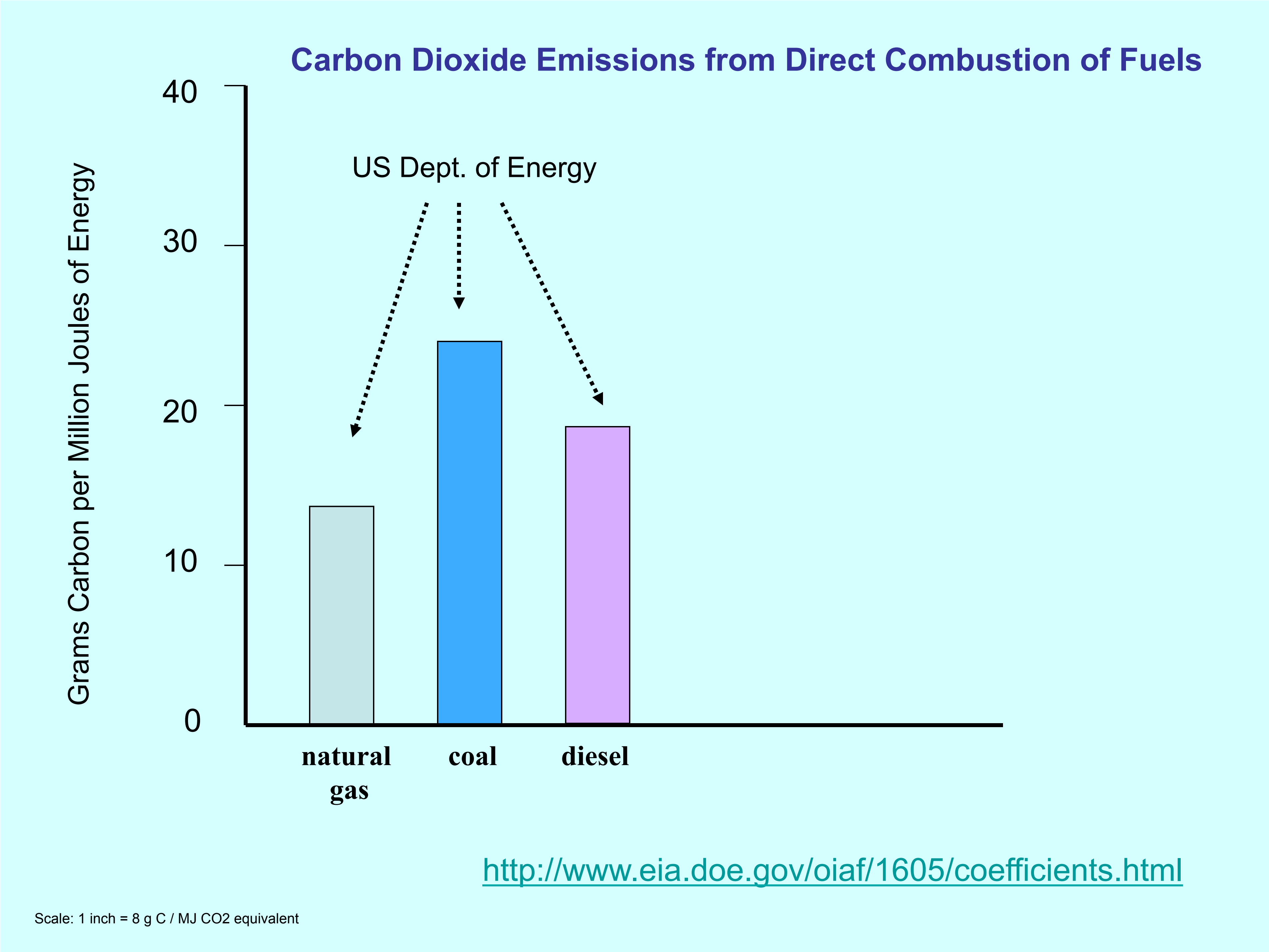
"…. …**the development of methane from shale formations is another example where policy has preceeded adequate scientific study."**

Carbon Dioxide Emissions from Direct Combustion of Fuels



http://www.eia.doe.gov/oiaf/1605/coefficients.html

Scale: 1 inch = 8 g C / MJ CO2 equivalent


Carbon Dioxide Emissions from Direct Combustion of Fuels
40
30
20
10
0
Grams Carbon per Million Joules of Energy
US Dept. of Energy
natural gas
coal
diesel
http://www.eia.doe.gov/oiaf/1605/coefficients.html
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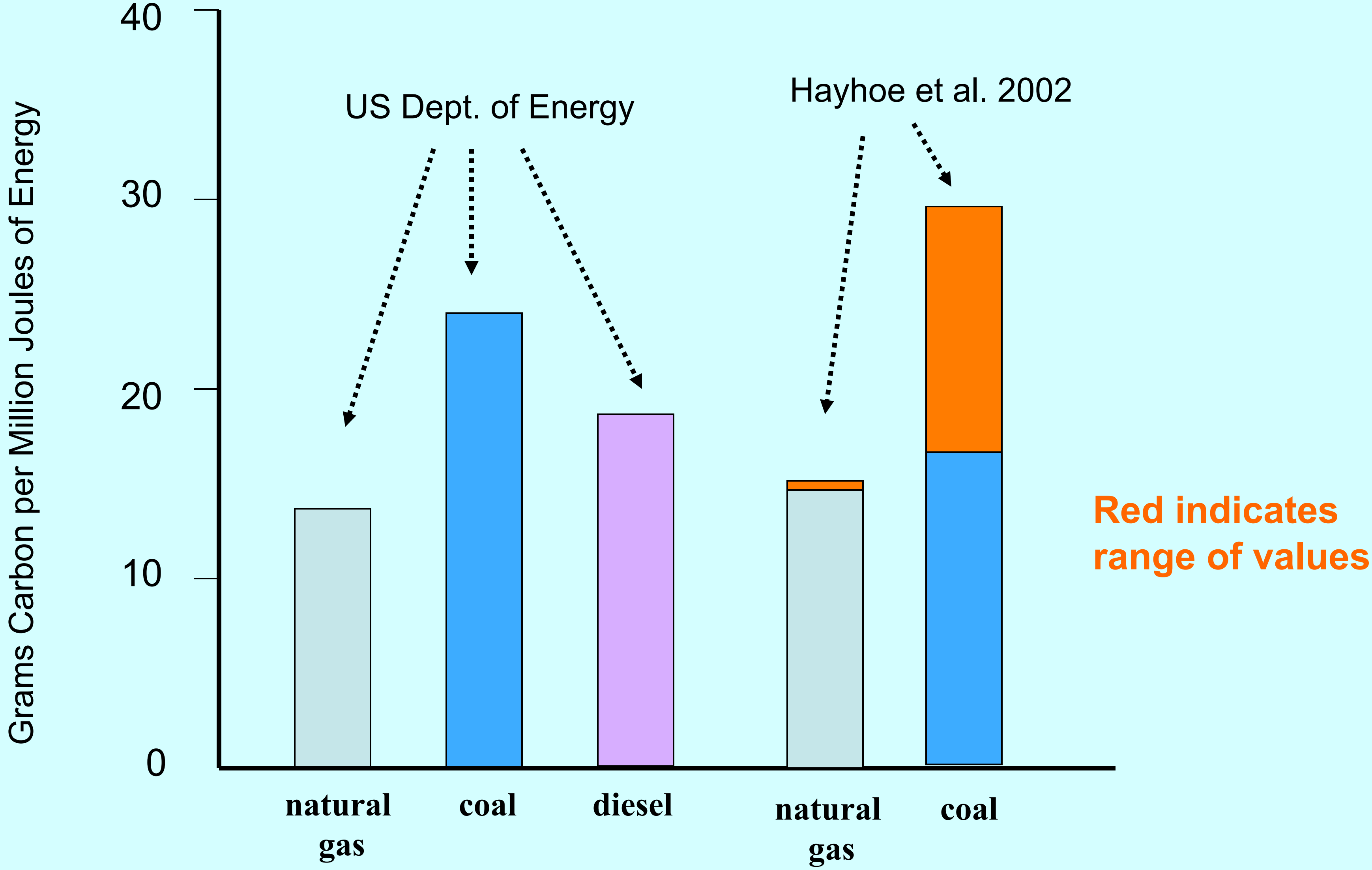

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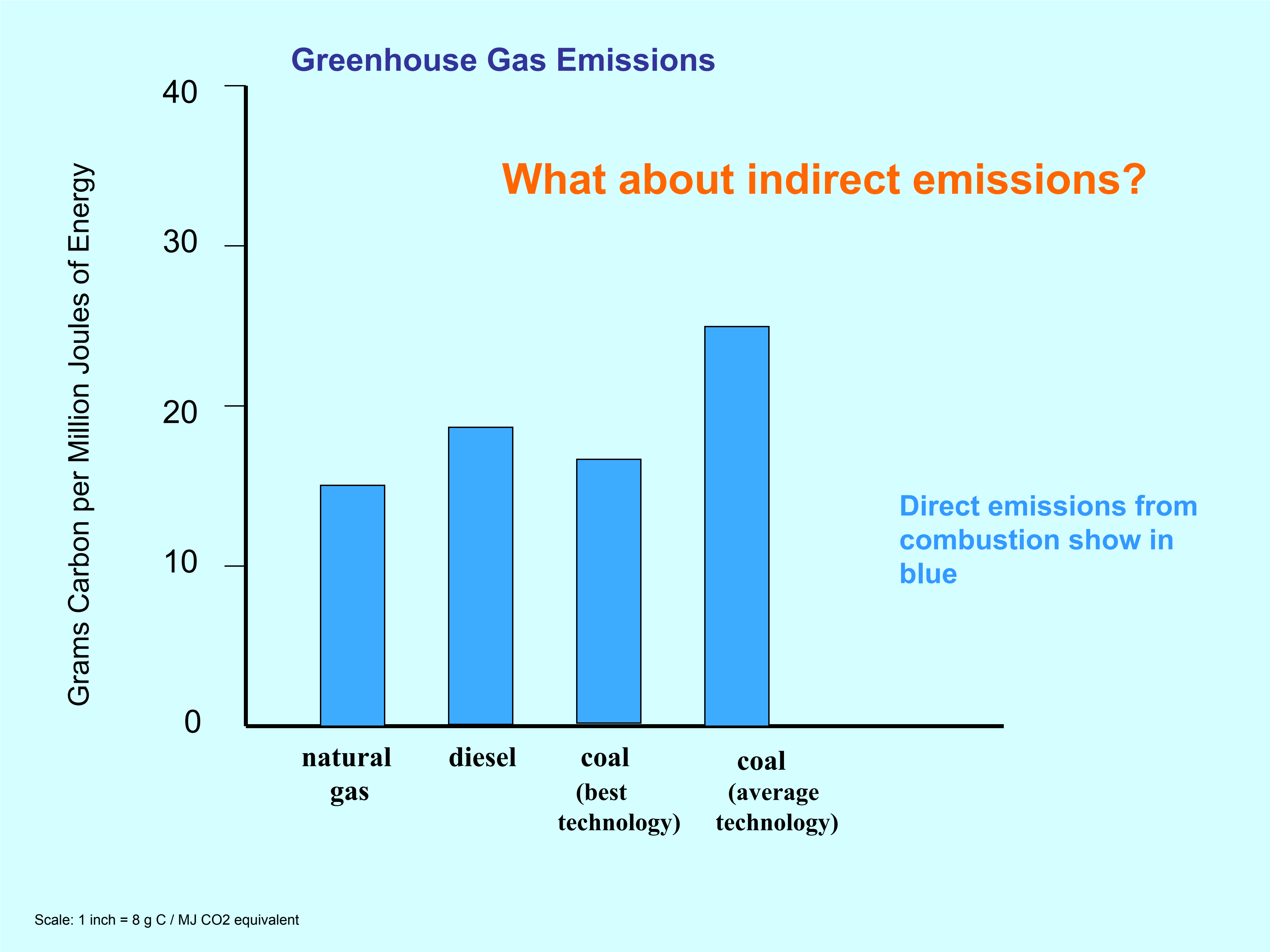
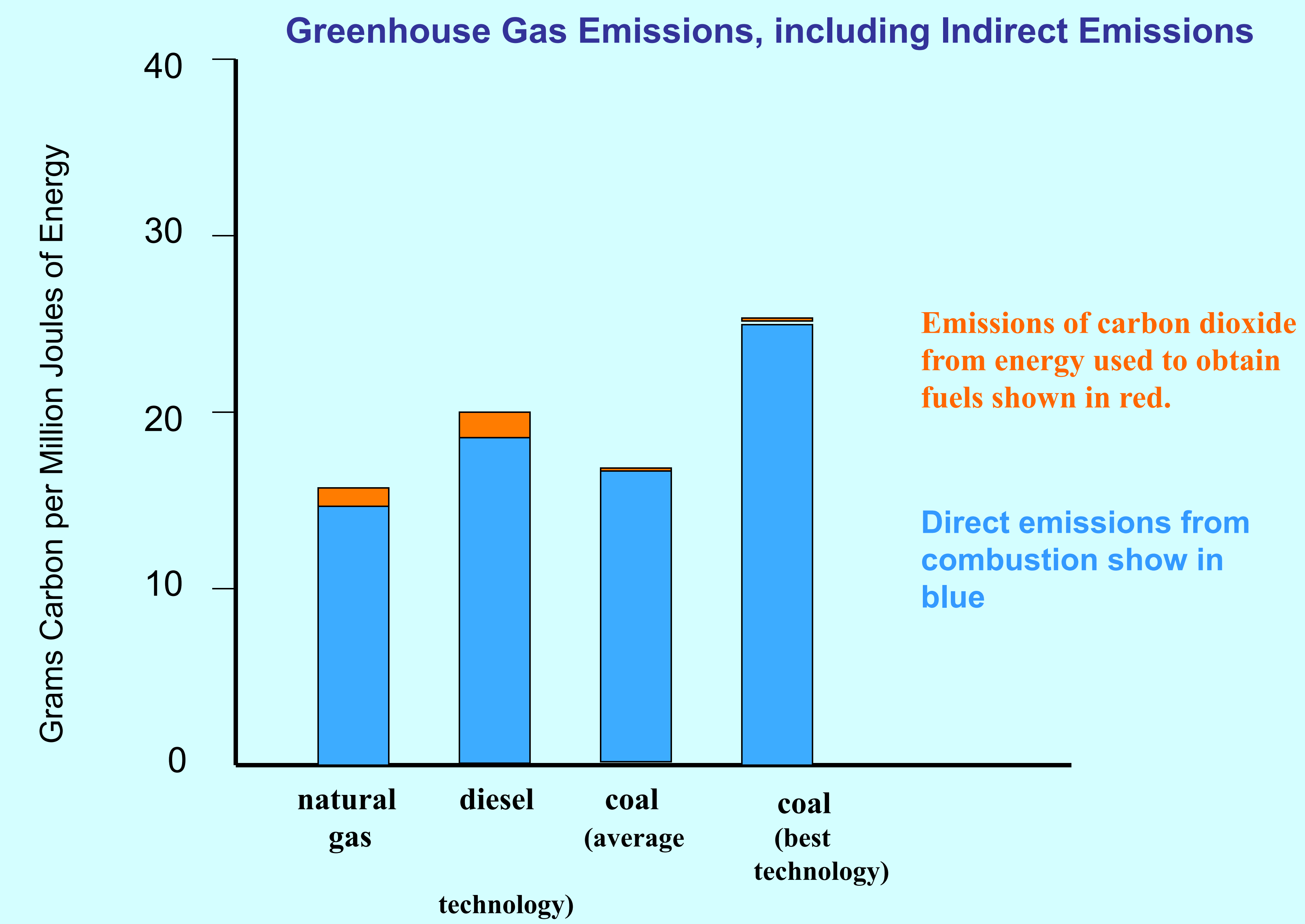
Hayhoe et al. 2002. Climatic Change 54: 107-139



Greenhouse Gas Emissions
40
30
20
10
0
Grams Carbon per Million Joules of Energy
What about indirect emissions?
Direct emissions from combustion show in blue
natural gas
diesel
coal (best technology)
coal (average technology)
Scale: 1 inch = 8 g C / MJ CO2 equivalent



Scale: 1 inch = 8 g C / MJ CO2 equivalent

Natural gas is mostly methane…… Methane is 2nd most important greenhouse gas, responsible for about one quarter of current global warming.

What is the appropriate time scale to compare methane with carbon dioxide? **Kyoto Protocol suggested 100-year time frame……**

But if natural gas is to serve as a bridge fuel for the next 2 to 3 decades, need to make sure we avoid tipping points in the climate system.

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Global Warming Potential of Methane relative to Carbon Dioxide

twenty year time horizon = 105-fold

one hundred year time horizon = 33-fold

(Shindell et al. 2009 *Science* 326: 716-718)

White arrows show methane emissions

As seen with naked eye

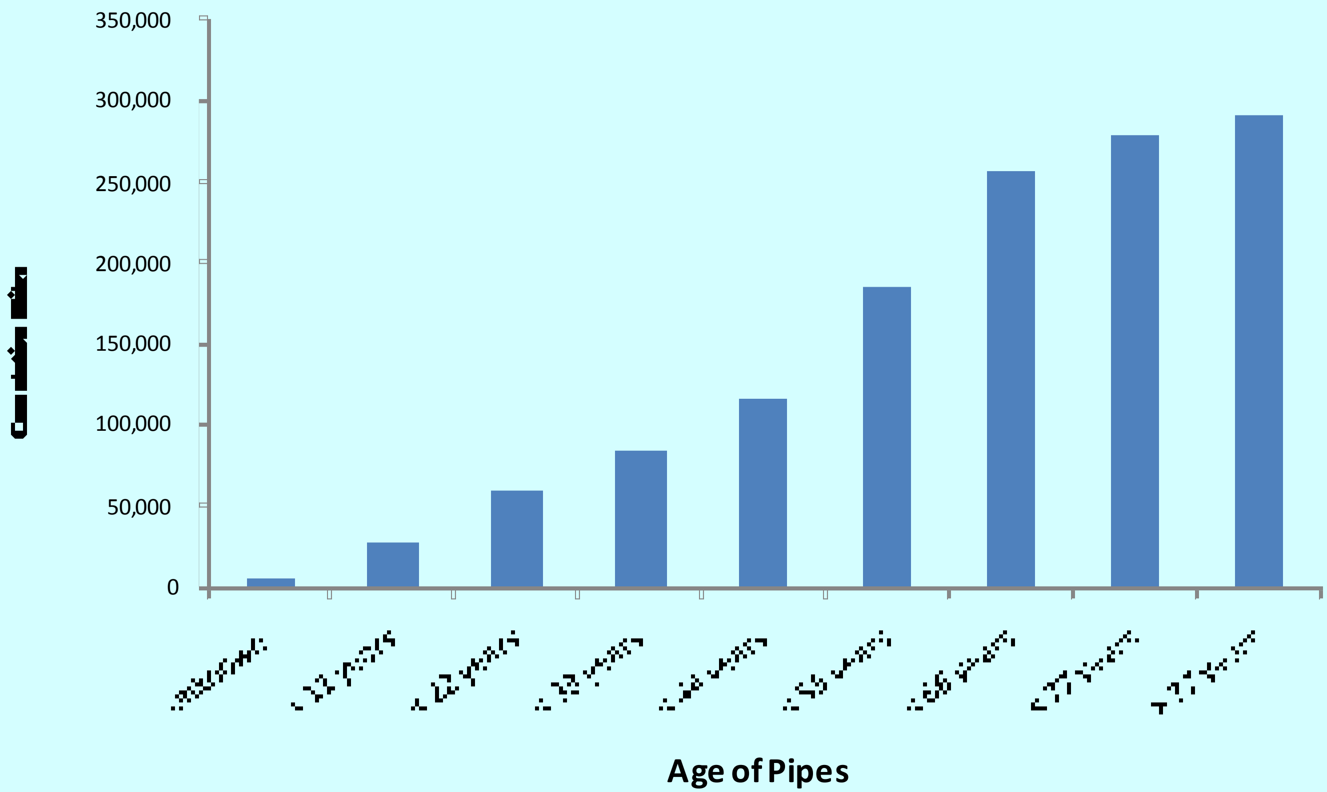
FLIR IR camera shows emissions

Pennsylvania DEP – Nov. 1, 2010
(Energy Corp compressor station)

Southwestern Pennsylvania Marcellus Shale Short-Term Ambient Air Sampling Report

http://files.dep.state.pa.us/RegionalResources/SWRO/SWROPortalFiles/Marcellus_SW_11-01-10.pdf

Half of the natural gas transmission pipelines in the US are more than half a century old



Sources: PHMSA 2009 Transmission Annual Data

Sources of methane leaks (as percentage of gas delivered to market):

Gas in flow-back waters from hydraulic fracturing = 0.04%

Initial venting of well (vs. flaring) = 0.2%

Routine leaks at well site = 0.28%

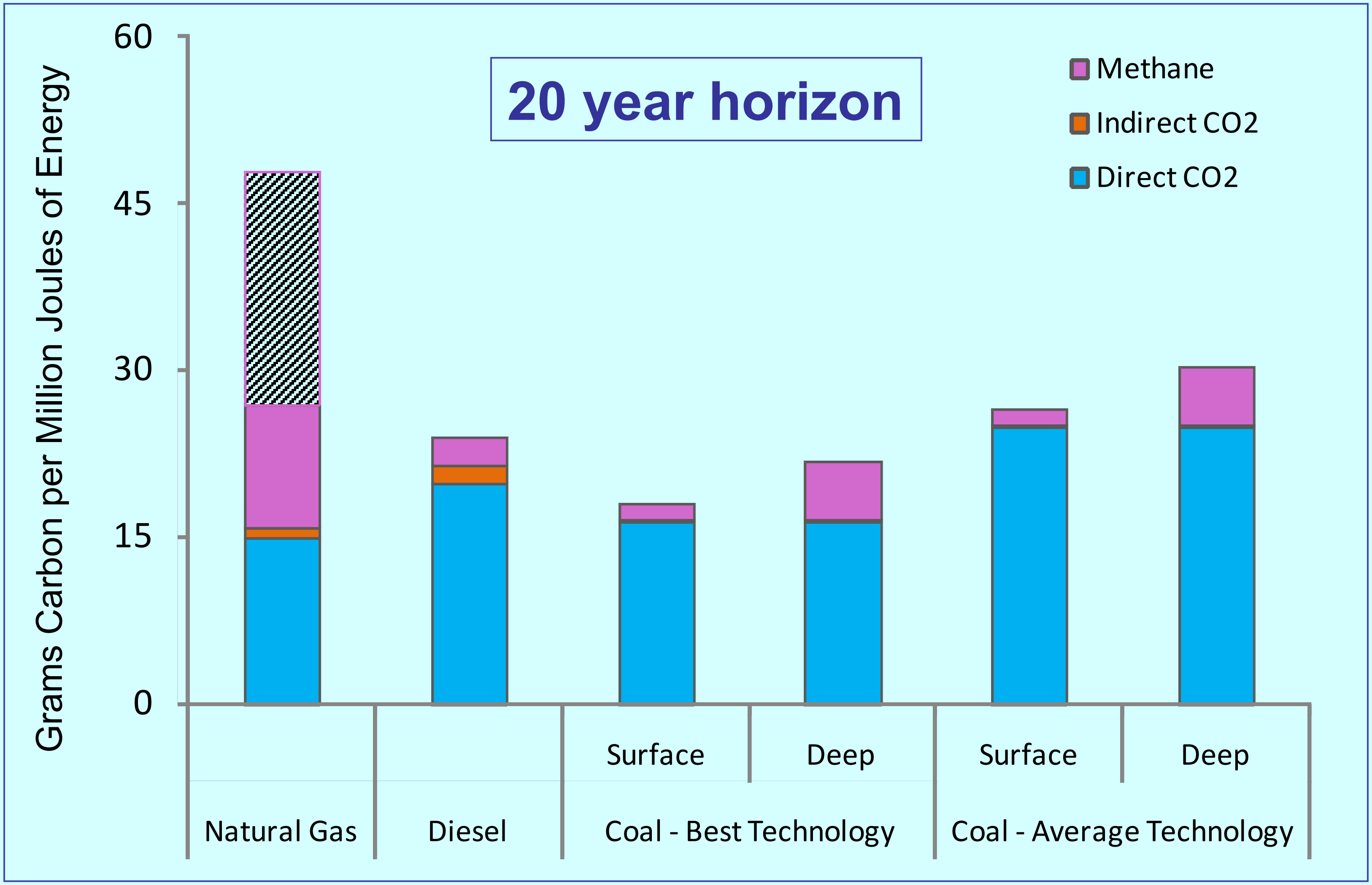
Contamination of groundwater aquifers, with subsequent emission to air = ??

Processing of gas = 0% to 0.19%

Transport and distribution through pipelines = 1.4% to 4.9%

TOTAL = 1.9% TO 5.6% (or more….)

Greenhouse Gas Emissions, including Indirect Emissions
(global warming value including indirect effects in equivalents of carbon dioxide)



(Howarth, Santoro, & Ingraffea)

Total GHG footprints for natural gas, diesel fuel, and coal
(g C MJ-1 CO2 equivalents)

	20-year time horizon	100-year time horizon
Natural gas – low methane emission rate	27	19.5
Natural gas – high methane emission rate	48	26.0
Surface-mined coal, of highest quality and burned with greatest efficiency	18.1	17.2
Surface-mined coal of average quality burned with average efficiency	26.6	25.7
Deep-mined coal, of highest quality and burned with greatest efficiency	22.0	18.7
Deep-mined coal, of average quality burned with average efficiency	30.5	27.2

I am not advocating mountain-top removal for coal……

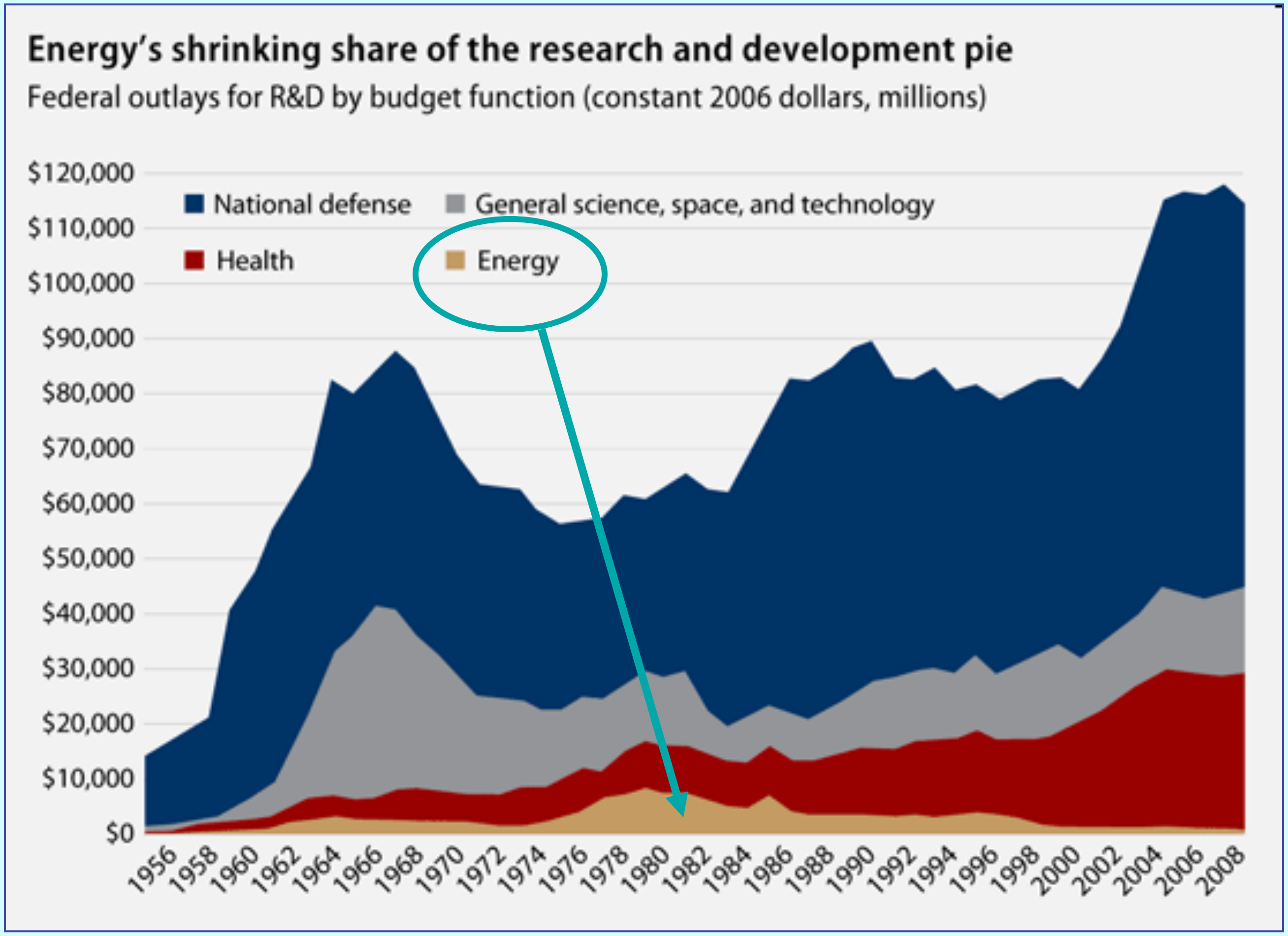
Mountain-top hydrofracking in Pennsylvania…

Plenty of considerations beyond greenhouse gases make fossil fuels problematic….

Other air pollutants (mercury, benzene, etc.).

Water pollutants…

US gave up on energy research at least 10 years ago…. Never got serious on research for green alternatives.



Jacobson and Delucchi 2009

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