

Why Natural Gas Warms the Earth More but Causes Less Health Damage Than Coal, so is not a Bridge Fuel nor a Benefit to Climate

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Natural gas is not a recommended option for providing new sources of electric power for the world or U.S. for two reasons. First, it results in much more air pollution, climate degradation, and land devastation than do wind, water, or solar (WWS) technologies, thus it represent an opportunity cost. Second, even though it improves air quality versus coal, it causes faster global warming than coal, so neither coal nor gas is beneficial to society, and neither is recommended. Because WWS technologies can be combined to match the preponderance of power demand reliably, there is no need for natural gas to supply peaking power in the future and no need for new natural gas during the transition. These results follow from scientific analyses.

Natural gas is not recommended versus WWS technologies for several reasons. The mining, transport, and use of even conventional natural gas for electric power results in at least 60-80 times more carbon-equivalent emissions and air pollution mortality per unit electric power generated than does wind energy over a 100-year time frame. Over the 10-30 year time frame, natural gas is an even greater warming agent relative to all WWS technologies and a danger to the Arctic sea ice due to its methane leakage and black carbon-flaring emissions, as discussed shortly. Natural mining and use also produce carbon monoxide, ammonia, nitrogen oxides, and organic gases. Natural gas mining degrades land, roads, and highways and produces water pollution. Based on criteria described in Jacobson (2009), natural gas is not a recommended energy source for a clean and sustainable future in comparison with WWS resources. Since WWS resources are sufficiently available to power the world for all purposes multiple times over (Jacobson and Delucchi) and can be combined to meet electric power demand for nearly all hours of a year (Hart and Jacobson, 2011), and since several methods exist to allow WWS to meet the remaining demand (Delucchi and Jacobson, 2011), natural gas is not necessary for a sustainable future. On the other hand, WWS resources can power the world for all purposes while eliminating global warming and 2.5-3 million annual air pollution deaths.

The main argument for increasing the use of natural gas has been that it is a “bridge fuel” between coal and renewable energy because of the belief that natural gas causes less global warming per unit electric power generated than coal. Although natural gas emits less carbon dioxide per unit electric power than coal; natural gas emits more methane and less sulfur dioxide per unit energy. Both factors enhance its overall global warming relative to coal, particularly when the relevant time scale and up-to-date global warming potentials are used.

Several studies have shown that, without considering coal sulfur dioxide emissions, natural gas may result in similar or greater carbon-equivalent-emissions than coal on the 20-year time scale and, depending on the methane leakage rate, the 100-year time scale (Howarth et al. 2011, 2012a,b; Wigley 2011; Myhrvold and Caldeira, 2012). The most efficient use of natural gas is for electricity, since the efficiency of electricity generation with natural gas is greater than with coal. Yet even with optimistic assumptions, Myhrvold and Caldeira (2012) found that the rapid conversion of coal to natural gas electricity plants would “do little to diminish the climate impacts” of fossil fuels over the first half of the 21st Century. Recent estimates of methane radiative forcing (Shindell et al. 2009) and leakage (Howarth et al. 2012b; Pétron et al., 2012) suggest a higher greenhouse-gas footprint of the natural gas systems than assumed in Myhrvold and Caldeira (2012). Moreover, conventional natural gas resources are becoming increasingly depleted and replaced by unconventional gas such as from shale formations, which have larger methane emissions, thus a larger greenhouse gas footprint than do conventional sources (Howarth et al. 2011, 2012b; Hughes 2011).

Currently, most natural gas in the U.S. and many places in the world is not used to generate electricity but rather for domestic and commercial heating and for industrial process energy. For these uses, natural gas offers no efficiency advantage over oil or coal, and has a larger greenhouse gas footprint than these other fossil fuels, particularly over the next several decades, even while neglecting the climate impact of sulfur dioxide emissions (Howarth et al. 2011, 2012a,b). The reason is that natural gas systems emit more methane per unit energy produced than do other fossil fuels (Howarth et al. 2011), and methane has a global warming potential that is 79-105 times greater than carbon dioxide over an integrated 20-year period after emission and 26-41 times greater over a century period (Shindell et al. 2009). As discussed below, the 20-year time frame is critical.

When used as a transportation fuel, the methane plus carbon dioxide footprint of natural gas exceeds that of oil, since the efficiency of natural gas is less than that of oil as a transportation fuel (Alvarez et al. 2012). When methane emissions due to venting of fuel tanks and losses during refueling are accounted for, the warming potential of natural gas over oil rises more.

When sulfur dioxide emissions from coal are considered, the greater air-pollution health effects of coal become apparent, but so do the greater global warming impacts of natural gas versus coal, indicating that both fuels are problematic. This is discussed next.

Table 1 indicates that natural gas production and use in the U.S. emit more carbon monoxide (CO), volatile organic carbon (VOC), methane (CH₄), and ammonia (NH₃) than coal production and use, whereas coal emits more nitrogen oxides (NO_x), sulfur dioxide (SO₂), and particulate matter smaller than 2.5- and 10-mm in diameter (PM_{2.5}, PM₁₀). Thus, both fuels result in significant air pollution, although the higher SO₂ and NO_x emissions from coal results in overall greater air pollution from coal exceeding than natural gas.

Table 1. 2008 U.S. national emissions from natural gas and coal (metric tonnes/yr). Red indicates higher all-use emissions between coal and natural gas (NG).

	Coal all uses	NG all uses	NG mining & production	NG public electricity	NG Industrial boilers	NG non-boiler industrial/chemical	NG commercial/institutional	NG residential	NG CNG
CO	6.8x10 ⁵	9.0x10 ⁵	1.2x10 ⁵	8.0x10 ⁴	3.9x10 ⁵	4.0x10 ⁴	9.0x10 ⁴	8.0x10 ⁴	1.0x10 ⁵
VOC	4.0x10 ⁴	1.13x10 ⁶	8.7x10 ⁵	3.0x10 ⁴	1.8x10 ⁵	1.0x10 ⁴	3.0x10 ⁴	1.3x10 ⁴	0
CH ₄	5.0x10 ³	3.1x10 ⁵	1.1x10 ⁵	2.3x10 ⁴	1.3x10 ⁵	8.0x10 ³	2.4x10 ⁴	1.3x10 ⁴	0
NH ₃	1.1x10 ⁴	5.4x10 ⁴	0	1.0x10 ⁴	6.0x10 ³	1.0x10 ³	1.0x10 ³	3.5x10 ⁴	1.0x10 ³
NO _x	2.8x10 ⁶	1.54x10 ⁶	2.3x10 ⁵	1.6x10 ⁵	7.3x10 ⁵	6.0x10 ⁴	1.3x10 ⁵	2.1x10 ⁵	2.0x10 ⁴
SO ₂	7.6x10 ⁶	1.23x10 ⁵	5.1x10 ⁴	1.3x10 ⁴	3.4x10 ⁴	2.3x10 ⁴	1.0x10 ³	1.0x10 ³	0
PM _{2.5}	2.9x10 ⁵	6.1x10 ⁴	2.0x10 ³	1.7x10 ⁴	2.5x10 ⁴	8.0x10 ³	5.0x10 ³	4.0x10 ³	0
PM ₁₀	4.2x10 ⁵	7.1x10 ⁴	2.0x10 ³	2.0x10 ⁴	3.0x10 ⁴	1.0x10 ⁴	5.0x10 ³	4.0x10 ³	0

Source: U.S. EPA (2011). VOCs includes methane

Most SO₂ and NO_x from coal convert to sulfate and nitrate aerosol particles, respectively. Natural gas also emits significant NO_x, but not much sulfur dioxide (Table 1). Sulfate and nitrate aerosol particles cause direct air pollution health damage, but they are usually “cooling particles” with respect to climate because they reflect sunlight and increase cloud reflectivity. Thus, although the increase in sulfate aerosol from coal increases coal’s air-pollution mortality relative to natural gas, it also decreases coal’s warming relative to natural gas because sulfate offsets a significant portion of coal’s CO₂-based global warming over a 100-year time frame (Streets et al., 2001; Carmichael et al., 2002).

Coal also emits soot particles containing black carbon, but pulverized coal used in developed countries results in little soot. In countries that do not use pulverized coal, the black carbon emissions contribute further to coal’s warming. However, emissions from those same plants also contain more sulfur oxides, which counteract much of the BC impacts from those plants.

Using conservative assumptions about sulfate cooling, Wigley (2011) found that electricity production from natural gas causes more warming than coal over 50 to 150 years when coal sulfur dioxide is accounted for. The low estimate of 50 y was derived from an unrealistic assumption of zero leaked methane emissions.

A transition to natural gas is problematic and WWS is needed immediately because the Arctic sea ice will likely disappear in 10-30 years unless global warming is abated. Reducing sea ice uncovers the low-albedo Arctic Ocean below, accelerating global warming in a positive feedback loop (Hansen and Nazarenko, 2004; Jacobson, 2004; 2010; Flanner et al., 2007; 2011; McConnell et al., 2007; Quinn et al., 2008). Above a certain temperature, a tipping point is expected to occur, accelerating the loss to complete elimination (Winton, 2006). Once the ice is gone, regenerating it may be difficult because the Arctic Ocean will reach a new stable equilibrium (Winton, 2006). Arctic sea ice area and extent have been diminishing since the 1950s (Vinnikov et al., 1999) due to increasing air and ocean water temperatures. Sea ice levels in September 2012 reached

their lowest levels recorded in the satellite age, thus the ice may disappear much faster than previous estimates.

The only potential method of saving the Arctic sea ice may be to eliminate emissions of short-lived global warming agents, including methane (from natural gas leakage and many other sources) and particulate black carbon (from natural gas flaring and other sources). The 21-country Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants recognized the importance of reducing methane and BC emissions for this purpose (UNEP, 2012). Black carbon controls for this reason have also been recognized by the European Parliament (Resolution B7-0474/2011, September 14, 2011). Jacobson (2010) and Shindell et al. (2012) quantified the potential benefit of reducing black carbon and methane, respectively, on Arctic ice.

Instead of reducing these problems, natural gas mining, flaring, transport, and production increase methane and black carbon, posing a danger to the Arctic sea ice on the time scale of 10-30 years. Methane emissions from natural gas also contribute to the global buildup of tropospheric ozone resulting in additional respiratory illness and mortality.

In sum, natural gas does not appear to be a near-term “low” greenhouse-gas alternative to coal although it reduces traditional air pollution relative to coal. A danger in expanding rather than contracting the use of natural gas is that it will speed the elimination of the Arctic. Transitioning to WWS will slow that destruction and reduce mortality on a large scale.

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