Natural Gas: Bridging Fuel or Roadblock to Clean Energy?

A Greenpeace Report

Published by Greenpeace, Inc.

1436 U St., N.W.
Washington, DC 20009

This publication is printed on non-chlorine bleached paper, which does not contribute chlorinated toxics to the environment. The cover is printed on recycled stock.

For copies of this report, please send $5.00 to:
Greenpeace
Atmosphere & Energy Campaign
1436 U St., N.W.
Washington, DC 20009

1/93/5M/1.13/5.00

Acknowledgments

Prepared for Greenpeace by Carol Alexander, January 1993

Many thanks to Art Dingle for his skillful editing. A large debt of gratitude is also owed to Tom Lent, who persevered through all the numerous revisions of this report and whose insight and editing suggestions were invaluable. Thanks also to many others for their contributions including, Jeremy Leggett, Ken Stump, Jan Sinclair, Andrew Kerr, Pamela Miller, Kelly Quirke, Dorothy Smith, Kevin Jardine, Steve Kretzmann, Jackie Christensen, Don Bain, Rob Watson, Chris Flavin, Stewart Boyle, Meg Duskin, and Meg Kimmel.

Table of Contents

List Of Figures

Boxes

Summary

Natural gas is gaining widespread support as a fuel for electricity generation and transportation. Its proponents describe it as a clean, plentiful fossil fuel that contributes minimally to global climate change. Some describe it as the "fuel of the future," while others advocate its use as a "bridging fuel" to an eventual future when efficiency and renewable systems will fill the energy needs of the world.

Most presentations of natural gas consist of variations on the benign "little blue flame" image seen in advertisements. *Natural Gas: Bridging Fuel or Road Block to Clean Energy?* provides a different perspective—an overview of the seldom-discussed problems created by natural gas use.

Natural Gas and Global Warming

The crisis of unprecedented rates of global climate change was brought to centerstage at the United Nations-sponsored Earth Summit in June 1992, where it became painfully clear that there is no easy fix to the problem of global warming. Our lovely blue-green world seemed very small indeed as international communication satellites beamed the news of its vulnerability to anyone who had their television or radio tuned to the Earth Summit coverage. Those who were not previously aware of the climate-altering consequences of human actions—notably, unleashing the carbon contained in fossil fuels—learned that continuing the status quo could catastrophically change our world within the space of a lifetime.

Because natural gas contains less carbon than any other conventional fossil fuel (one-half that of coal, one-third less than oil), some people advocate a switch from coal and oil to gas. But the presentation of natural gas as a "clean" fossil fuel sidesteps the fundamental issue that must be addressed: the need to discontinue all fossil fuel use, and soon, in favor of efficient, carbonless, renewable energy sources that are technologically available today.

Underlying discussions about natural gas as a preferred fuel—advocacy and skepticism alike—is an unassailable reality: 960 billion tons of carbon remain locked in the global natural gas reserve. If we unleash even one-third that amount of carbon (from any and all fossil fuels) we will push the temperature of the earth past the upper limit for "allowed" warming (2 degrees Celsius or 3.6 degrees Fahrenheit), beyond which await catastrophic changes.

Furthermore, natural gas itself is a potent global warming gas. Processed gas is 90 per-

cent methane, a global warming gas 20 times more powerful than carbon dioxide. Even minute amounts of leakage from the natural gas production and distribution system drives the earth's temperature further toward the red zone.

Natural Gas and Pollution

To describe natural gas as a clean-burning, non-polluting fuel is to either minimize or completely ignore its total fuel cycle impacts—beginning with the initial seismic surveys, drilling, production, processing, and distribution—all the way through to the final combustion process. Even a cursory look at these impacts dispels the notion that natural gas is a clean fuel.

The same drilling and production process that brings us oil brings us natural gas. That process creates huge volumes of toxic drilling wastes, destructive boom-bust economic cycles, physical disruption and pollution of marine and terrestrial habitat, fresh water contamination, wetlands destruction, preemption of land and fishing grounds, and so forth. More than 50 percent of domestic gas production is by the historic "Seven Sisters" of the petroleum industry with gas and oil frequently extracted from the same geologic formations by the same industry.

Transportation of natural gas is accomplished either by extensive pipeline systems or by hazardous cryogenic tankers. Pipelines create land-use conflict and often involve passage through land protected because of particular habitat, wildlife, or wilderness values.

Processing plants create toxic waste disposal problems, deplete fresh water, and generate hazardous substances such as hydrogen sulfide and radioactive sludge. Much of the remaining natural gas and oil lies in fragile offshore regions and the Arctic.

Natural Gas as a Transportation Fuel

Although natural gas is said to be a desirable alternative fuel for transportation, it emits quantities of nitrogen oxide (a precursor of acid precipitation, ground-level ozone, and urban smog) equal to or greater than gasoline in today's vehicles, with no dramatic improvements in sight. As a transportation fuel, it also produces global warming emissions nearly equivalent to gasoline.

Perhaps even more significant is the misconception that methane is a clean and safe transportation fuel perpetuates the growth in numbers of personal vehicles, thus undermining attempts to improve mass transit and to market clean, carbonless alternative fuels, such as solar hydrogen.

During the past year, the impetus to use methane in automobiles has gathered momentum from new federal and state regulations. Federal legislation and initiatives, federal agency rule-making, and state and regional laws and rules have been formulated to encourage the use of natural gas, to exempt it from certain emission control standards, and to facilitate placement of the distribution infrastructure. The American Gas Association and others predict there will be millions of methane-powered vehicles on the road by the turn of the century.

Natural Gas in Utilities

Those who advocate methane as a "bridging fuel" also recommend a "short-term" switch to natural gas from coal and oil in electricity-generating facilities. Much more than a short-term switch is under way as artificially cheap natural gas is chosen to fill new capacity for electricity generation, excluding conservation and renewables from competitive bidding processes and locking in natural gas as the preferred fuel for decades to come.

In the United States, renewable energy sources have represented only 12 percent of the total new electrical generating capacity selected in competitive bidding, while natural gas represents 54 percent. This preference for natural gas is largely a reflection of its low market cost, growing confidence in long-term supply, and the relatively low capital investment required for new gas combustion turbines. In the Pacific Northwest, for example, the low price of gas-fired electricity has had the effect of setting an unnaturally low ceiling of "cost-effectiveness" for energy efficiency and renewable energy developments.

If all costs imposed by the total fuel cycle of methane—including global warming impacts—were included in the market price, this takeover of competitive bidding could not happen.

Natural Gas and the Larger Fossil Fuel Industry

The exclusion of efficiency and renewables today presents a complex problem for tomorrow. New power systems coming online today to burn "clean" natural gas may well be burning gasified coal (or just about any low-grade carbon-based fuel) tomorrow when conventional gas reserves dwindle and prices rise.

The United States has the world's largest reserves of coal, a reality that is never far from the minds of long-term energy planners. National energy legislation and even the new Clinton administration have pledged to focus on "clean coal" technologies in order to utilize this resource. What are euphemistically called "clean-coal" processes, such as combined-cycle coal gasification systems and co-firing gas with coal, emit nearly the same quantity of carbon dioxide as conventional coal plants. Various sectors of the fossil fuel industry may publicly bicker, but it is fundamentally all one industry. Continued reliance on natural gas will likely ensure continued dependence on coal and oil as well.

Natural Gas Supply and Demand in a Biased Market

In the past, expansion of the energy market share for natural gas has been constrained by preoccupation with oil, but also by perceptions of an unreliable supply. This situation is changing rapidly with new federal rules to "unbundle" pipeline services and with generous government subsidies to encourage exploration and production. Additionally, ratification of the North American Free Trade Agreement (NAFTA) will create a borderless pool of natural gas. Free trade accords will alleviate any lingering buyer skepticism about long-term stable supply and will help stabilize the industry's market ideal—gradually rising price for a relatively plentiful product.

Although the reserves:production ratio for proven domestic natural gas reserves is only eight years, a large global estimated recoverable natural gas base awaits definition. The NAFTA will not only allow U.S. access to our neighbors' energy resources, but because the accord sanctions subsidies *only* for oil and gas, it will also keep the North American energy market heavily biased toward fossil fuels.

The mechanisms mentioned above to encourage use of methane as a transportation fuel also contribute to stable supply-demand balance. Pro-rationing manipulations (restraining production to effect a desired price level) from gas-producing states has also proven effective. Additionally, the petroleum industry has formed a number of powerful alliances within various sectors of the industry, with utility regulators and federal and state agencies, even

with some environmental organizations and representatives of the renewable energy industry. A stable natural gas market is assured by all these actions.

It is important to note that even with the addition of the natural gas reserves of Canada, Mexico, and, eventually, all of Latin America through free trade accords, more than two-thirds of the world's methane reserves lie in the Middle East, Eastern Europe, and the republics of the former Soviet Union. If gas continues to be the fuel of choice in the future, hazardous cryogenic tankers will ply the shipping lanes with hydrocarbons produced from politically unstable regions—an all-too-familiar pattern.

The Alternatives

Some of those who advocate natural gas as a bridging fuel do so reluctantly, suggesting that an abrupt switch to clean energy alternatives is simply not feasible and that a gradual weaning process must be undertaken to avoid economic chaos.

While it cannot be denied that drastic restructuring of the global energy infrastructure would invoke profound socio-economic restructuring as well, this need not be a negative impact over the long term. Measures that would most effectively reduce carbon dioxide emissions can also save energy and money, stimulate the economy, create jobs, and reduce pollution and urban smog.

The transition will be difficult, but not nearly as difficult as the catastrophic problems awaiting the next generation if we do not act quickly and decisively. It is better to take on these challenges now, before we have our hands full dealing with a world altered by sea level rise, regional droughts, lack of fresh water, loss of biodiversity, shifting agricultural patterns and loss of productivity, famine, intensified tropical storms, and forest death.

The means to more efficient energy use are at hand. Currently, the United States already lags far behind countries like Japan and Germany that use energy twice as efficiently. Even within a biased market, solar and wind systems are technologically available and nearly cost-competitive with subsidized fossil fuels and nuclear energy. In some cases, they are already cost-competitive. The barriers to their immediate implementation are political and are becoming more impenetrable with every passing moment of the natural gas greenwash.

Threshold Moments

If one asks: "Is natural gas less polluting, and less of a factor in climate change, than coal and oil?" the answer must be 'yes' if only the impacts of combustion are examined. The answer becomes a shaky 'maybe' when the *total* fuel cycle impacts are examined. If one frames the question: "Is natural gas less polluting and less of a contributor to global warming than conservation, efficiency, and renewable energy?" the answer is an unequivocal 'no.' If we fail to pose the correct question at this critical juncture, when energy choices made now will endure for decades, we will surely produce the wrong answer.

As the accolades for natural gas continue to pile up, as the infrastructure to produce and distribute gas grows more extensive, and as the marketplace grows more biased, the future becomes more certain for long-term expanded use of this fuel and its sister fossil fuels. Natural gas is excluding the entry of renewable energy and efficiency into the utility and transportation sectors.

The United States only has a few years to reverse this trend. Once the next round of competitive bidding for new electricity supply is completed and combustion turbines and combined cycle systems are in place, once Detroit has retooled for natural gas vehicles, and compressed natural gas refilling

stations are in every city, we will be stuck paying off that investment. We will not have another opportunity to implement clean energy again for decades.

Perpetuating fossil fuel dependence in the United States is not the only concern. In today's reign of free markets and free trade agreements, industrialized countries cannot make isolated energy choices. Accords such as the NAFTA and the Enterprise for the Americas Initiative will ensure that the Western Hemisphere must follow the lead of the world's most energy-hungry country down the fossil fuel dead-end street.

The Clinton/Gore administration has come to office at the precise moment when the country is at a crossroad of possible energy futures. The impetus to continue on the fossil fuel path is powerful, and President Clinton has already endorsed natural gas. But both leaders have demonstrated their commitment to change and to ensuring that the needs of all people are met—including the most basic need for a healthy world. Reversing their endorsement of natural gas is critical if they hope to remain consistent with that commitment.

Chapter One
Introduction

The United States faces difficult and challenging energy choices after a year of extraordinary political change. In June 1992, the United Nations Conference on Environment and Development (UNCED, the Earth Summit) helped focus world attention on the profound dilemma of global climate change as a consequence of human activity—notably, the use of fossil fuels. Months later, the American people voted out a President who shamed the country at the Earth Summit by actively impeding international attempts to address that dilemma.

As a consequence of these two events, there is now increased recognition of the problem of global warming in the public and political sectors, and an opportunity to address it in meaningful ways. Under the new direction of President Clinton and Vice President Gore, the United States can assume a role of leadership in global efforts to reduce the use of fuels that are poisoning the planet. The Clinton/Gore administration has the opportunity to atone for that appalling moment in history when the United States blockaded the first real international step toward responsible energy planning for all people.

However, an energy choice that has already won enthusiastic endorsement from the new administration is natural gas, another fossil fuel. Proponents of natural gas describe it as a clean, plentiful fossil fuel that contributes minimally to global climate change. Some describe it as the "fuel of the future," while others advocate its use as a "bridging fuel" to a future when energy efficiency and renewable systems will fill the energy needs of the world. Both these presentation exclude some hard realities. To describe natural gas as a clean-burning fuel is to either minimize or completely ignore its total fuel-cycle impacts—from the initial seismic surveys all the way through to the final combustion process.

Those who endorse natural gas as a bridging fuel claim that clean and efficient renewable energy systems are not widely marketable or politically palatable at this time and that forcing a rapid transition to clean energy now would create debilitating economic chaos. These arguments have some merit. It will be a formidable task to enforce immediate changes in a marketplace, infrastructure, and political climate geared toward production and distribution of fossil fuels. Yet this difficulty pales in

comparison to the social and economic upheaval awaiting us in a global climate abruptly altered by continued use of fossil fuels.

Some of the best minds in the world caution that a slim window of opportunity is available for preventative action to stave off planetary climate change. By shying away from bold action to change the patterns of energy use today, our descendents will be forced to deal with the consequences of global warming (sea level rise, failed agricultural production, regional drought, mass extinctions, famine), as well as the causes.

There is no easy fix for the problem of global warming. Abusive consumption of fossil fuels has brought us to this crisis; continued use of fossil fuels will not avert it. The presentation of natural gas as a clean fossil fuel sidesteps the fundamental issue that must be addressed: the need to discontinue all fossil fuel use in favor of efficient, carbonless, renewable energy sources.

Underlying all discussions about natural gas as a preferred fuel—advocacy and skepticism alike—is an unassailable reality: 960 billion tons of carbon remain locked in the global natural gas reserve. If we unleash even one-third of that amount of carbon (from any and all fossil fuels) we will push the temperature of the earth past the upper limit (2 degrees Celsius, 3.6 degrees Fahrenheit) for "allowed" warming, beyond which await catastrophic changes.[1]

If one asks: "Is natural gas less polluting, and less of a factor in climate change, than coal and oil?" the answer must be 'yes' if only the impacts of combustion are examined. The answer becomes a shaky 'maybe' when the *total* fuel cycle impacts are examined. If one frames the question: "Is natural gas less polluting and less of a contributor to global warming than conservation, efficiency, and renewable energy?" the answer is an unequivocal 'no.'

If we do not pose the correct question at this critical juncture—when energy choices made now will endure for decades—we will surely produce the wrong answer. Already, artificially "cheap" natural gas is pushing conservation and renewable energy systems out of competitive bidding for new energy supply choices in the United States, effectively locking those alternatives out of the energy mix for coming decades.

Most presentations of natural gas consist of one-sided variations on the theme of the benign "little blue flame" image we have seen in advertisements for years. Little information is publicly available about the problems created by natural gas use. This report is meant to provide at least an outline of the other side of the picture, an overview of the entire fuel cycle impacts of a fuel that is neither clean nor cheap.

Clean Energy Today or Global Disaster Tomorrow?

If the preponderance of the world's scientific community is correct, the atmosphere will warm at unprecedented rates—perhaps as much as three to eight degrees Fahrenheit by the year 2050. This human-caused warming of the earth over the next 50 years would equal all the warming that has occurred over the entire history of human civilization, beginning more than one hundred centuries ago.[2]

There are, simply speaking, two ways we can react to the crisis of global warming: we can stop it—or at least slow it—or we can try to adapt. What would adaptation involve? And what would it cost?

Economic analysts have just begun to calculate what it might cost to protect low-lying coastal regions from sea level rise that will accompany global warming, if it is even possible. What will it cost to dike the entire U.S. Atlantic seaboard, the countries of the Indian subcontinent, the Mediterranean? What will become of the peoples of the Pa-

BOX 1: A No-Regrets Policy for Carbon Dioxide Reduction

A news story quoted former U.S. Energy Secretary James Watkins as he cautioned coal, oil, and gas interests to maintain a united front against "leftist extremists" who were exaggerating warnings about global warming. "There is no scientific justification for a tax on carbon dioxide. None whatsoever. Clearly it will be destructive to the national economy," he said, rejecting claims by scientists that carbon dioxide emissions were contributing to global warming. "The Ice Age was coming in the 1970s. Every day we find out that what we found out yesterday was wrong," he said.[1]

As the rhetoric flies and the public wonders whom to believe, numerous recent studies have carefully concluded that reducing the cause of fossil fuel-generated global warming emissions would effect a "no regrets" policy. The general thesis of these studies is that even discounting the likelihood of unprecedented rates of global warming as a consequence of fossil fuel combustion, other documented negative impacts of fossil fuels make them environmentally *and* economically unsound investments.

The premise that saving energy saves money is not news. We would remind Admiral Watkins that some of what we found out yesterday is right: measures to increase energy efficiency introduced since the first oil crisis in 1973 are already saving the country $150 billion every year in avoided fuel costs,[2] yet the United States still uses energy only one-half as efficiently as Japan and Germany.

A reduction of fossil fuel-generated greenhouse gas emissions will also effect reduction of acid precipitation, urban smog, human health problems, destructive boom-bust development cycles, as well as conserve finite resources.

It is estimated that the United States alone spends $100 to $300 billion annually for lost jobs, tax credits, and health and environmental costs imposed by fossil fuel use,[3] exclusive of any estimation of the impacts of greenhouse gas emissions. In the United States, taxpayers subsidize the fossil fuel industries upward of $25 billion annually.[4] These costs are on top of an annual fuel bill of $450 billion.[5]

In his book, *The Greenhouse Gambit*, Douglas Cogan writes "As America's military actions in the Persian Gulf demonstrate, the U.S. government finds the money and muster to act when it perceives a threat to one of the nation's vital interests. If global warming were regarded in the same way, there is little doubt that the government would resolve to act once again."[6]

A genuine working definition of energy security must get beyond the dangerous preoccupation with ever-expanding supply—the Mad-Hatter notion that more must be better—to a definition that describes the need for enduring energy sources that meet the needs of all people, the use of which will not inflict irremedial harm. Finite, polluting fossil fuels that threaten to alter the global climate just do not fit the bill.

As Cogan and others point out, reduction of greenhouse gas emissions can provide a net benefit to society. Scientists from the National Academies of Science and Engineering, Harvard University, Carnegie Mellon University, Massachusetts Institute of Technology, Oak Ridge National Laboratory, University of California Berkeley, and General Motors Research Laboratories report that:

> "...a variety of measures are available to slow or reduce the growth in greenhouse gas emissions at low cost, perhaps even at a net cost savings. In most cases, such measures will bring ancillary benefits, such as a reduction in urban air pollution...many of these may be viewed as 'no regrets' options

that are worth pursuing independently of greenhouse concerns."[7]

This highly respected team of scientists found that measures to increase energy efficiency in buildings, transportation, and industry, combined with CFC-reducing measures, could reduce current U.S. carbon dioxide-equivalent emissions up to 40 percent (3,100 million tons per year), with energy cost savings that would exceed annual investment expenditures by $10 to $110 billion a year.[8]

Similarly, a U.S. EPA study found that a carbon tax providing investment tax credits would simultaneously reduce carbon dioxide emissions and boost the U.S. economy over the long run. Their study ran four separate models, three of which produced an overall rise in gross national product when revenues from a carbon tax were recycled into investment tax credits; the fourth model predicted no significant change in base-line gross national product.[9]

As another example, a Canadian study reported:

> Most of the measures that reduce emissions of carbon dioxide also save energy. In many of these cases, the value of the energy saved over the life of the measure exceeds the initial investment required; that is they produce a net benefit...Implementing the measures economically attractive to society yields a net benefit of $150 billion on the basis of energy savings alone.[10]

And a joint U.S./European study funded by the Dutch government reported that Western Europe could reduce carbon dioxide emissions 17 to 60 percent below current levels "while boosting economic growth, saving large sums of money, and enhancing international competitiveness."[11]

In the various discussions of using market mechanisms, including carbon taxes, to reduce global warming emissions, most analysts rightfully caution that care must be taken to direct some of the revenues to offset impacts on lower-income and rural communities.[12]

Notes

1. Anonymous. "U.S.Energy Sec'y says carbon tax bad for economy." Washington, DC: *Reuter* 11/19/92.

2 .Brower, M. "*Cool Energy: The Renewable Solution to Global Warming.*" Cambridge, MA: Union of Concerned Scientists, 1990, p. 13.

3 . Hubbard, Harold, M. "The Real Cost of Energy." *Scientific American* April 1991, p. 36.

4. Ibid.

5 . Cogan, Douglas. *"The Greenhouse Gambit."* Washington, DC: Investor Responsibility Research Center, 1992.

6 . Ibid.

7 . Rubun, Edward S., et al. "Realistic Mitigation Options for Global Warming." *Science* Vol. 257, 7/10/92, pp. 148-266.

8 . Ibid: Additionally, they defined other measures to reduce methane, nitrous oxide, and carbon dioxide that could reduce CO_2-equivalent emissions by an additional 10 percent (up to 800 million tons/year) at a direct cost of less than $1 billion a year.

9. Anonymous. "Carbon Tax With Investment Credits Could Stimulate Economy, EPA Report Says." *BNA Environmental Law Update* 3/27/92.

10. The DPA Group in Association with CH4 International Ltd., *Study On the Reduction of Energy: Related Greenhouse Gas Emissions.* Vol.1, Report and Appendix A, March 1989, p. 11.

11. Krause , Florentin. *The Cost of Cutting Carbon Emissions: A Case Study of Western Europe.* Vol. 2, El Cerrito, CA: International Project for Sustainable Energy Paths, , March 1992: concludes that EC-5 countries could reduce their $C0_2$ emissions by 58 percent from 1998 levels while paying 2 percent to 26 percent less for energy services in 2020 than they would under a "business as usual" scenario. And in the U.S., final energy use in 2020 could be cut by approximately 45 percent from the business as usual level, reducing $C0_2$ from 17 percent to 40 percent below 1985 levels. *Energy Report* 3/16/92, p. 197.

12. For example, Alliance to Save Energy, the Natural Resources Defense Council, et al. *America's Energy Choices: Investing in a Strong Economy And A Clean Environment.* Cambridge, MA: Union of Concerned Scientists, Cambridge, MA, 1991.

cific Islands whose countries will simply be gone with even a moderate rise in sea level?

And, as climates favorable for agricultural production migrate toward the poles, will we be able to relocate the agricultural infrastructure quickly enough to follow the shift?[3] If so, who will forge the international agreements necessary and who will fund the shift?

Global warming is predicted to increase the frequency and intensity of tropical storms. How will people of equatorial countries feed, house, and provide for themselves when catastrophic storms hit them with increasing regularity and ferocity, as the sea creeps ever higher up their shores? At this writing, three months after Hurricane Andrew swept through Florida, one of the wealthiest countries in the world has not been able to get the region back on its feet, and insurance companies have exhausted their resources in attempts to pay off claims.[4]

Even now, millions of people all over the world live in hunger and crushing poverty because there is no international accord on how to distribute food and other resources equitably. How will we achieve a distribution system in the face of global climate change accompanied by regional droughts, storms, dying crops, epidemics, sea level rise, and decimated forests?

How will we move fresh water to coastal regions that will have none after rising seas cause salt water to intrude into fresh water aquifers?

What will it take to build migration corridors to allow species to migrate to appropriate habitat as climate and patterns of vegetation change? Will we route these corridors through the miles of pavement and brick of urban centers? Around them?

What is biodiversity worth?

Taken together, all these questions add up to a powerful unknown: "What will it take to change the infrastructure of human civilization in the face of a global crisis?" It is a question no one can answer.

We do have an answer for the question, "What can we do to slow global warming?" The answer is a difficult one for a world that powered an industrial revolution with fossil fuels, a world where fossil fuel use is embedded in the very fabric of society. The answer is that we must discontinue consumption of fossil fuels—all fossil fuels—and turn to available renewable energy systems and energy efficiency before an irrevocable crisis is upon us.

The Greenwash

As the world comes to acknowledge the grave consequences of fossil fuel-generated global warming, the oil and gas industry, some energy policy makers, and even some environmental organizations, have begun to line up behind increased use of natural gas. Natural gas, the "cleanest" of the fossil fuels, averages a carbon content one-half that of coal and one-third less than oil, and is presented as a means to forestall global warming.

The international scientific community has calculated that reductions of 60 percent or more in carbon dioxide emissions, and similar drastic cuts in emissions of other greenhouse gases, are necessary to hold these gases at their current levels of atmospheric concentrations.[5] Although the means to achieve these reductions quickly are technologically proven (see Chapter 8: The Alternatives), some energy planners caution that we must begin a slow diversification from coal and oil by increasing the use of natural gas until efficient, renewable energy systems become more marketable and politically palatable. Other energy planners have no intention of abandoning coal and oil as primary fuels.

While it cannot be denied that drastic restructuring of the global energy infrastructure would invoke profound socioeconomic restructuring as well, this need not produce a negative impact over the long term. The

measures that would most effectively reduce carbon dioxide emissions can also save energy and money, stimulate the economy, create jobs, reduce pollution and urban smog (see Box 1: A No-Regrets Policy for Carbon Dioxide Reduction).

With the urgent need to end dependence on high-carbon fuels and nuclear energy sources, and with growing alarm at the rapidity of changes taking place in the planet's atmosphere, it is understandable that many hasten to find something to slow the impending global catastrophe. But a component of some carbon-emission reduction strategies is going awry: the recommendation for a "short-term" switch to natural gas from coal and oil.

As outlined in later sections, much more than a short-term switch is under way as artificially cheap natural gas is chosen to fill new capacity for electricity generation, excluding conservation and renewables from competitive bidding processes and locking in natural gas as the preferred fuel for decades to come. Similarly, new federal rules and legislation are ensuring that natural gas will be heavily favored in choices for alternative transportation fuels (see Chapter 2: Emissions Associated with Production and Consumption).

If the present market bias toward subsidized fossil fuels is not quickly corrected, non-carbon energy alternatives will be all dressed up with no place to go. They will be available for a corrected marketplace to choose from—as indeed they are now—but natural gas will have already filled the niche in electricity generation as well as a transportation fuel.

What many hopefully describe as the "bridging" fuel is quickly becoming a multilane, transcontinental freeway, cemented in place by an ever-growing, borderless production and distribution infrastructure to keep natural gas moving to market.

A study by the ICF Consulting Firm cautions that demand for natural gas could soar 500 percent by the year 2015 if the policy goal were to stabilize carbon dioxide emissions and the only other generating alternative was limited amounts of (relatively) high-cost renewables.[6] The ICF study comments that such demand for gas would eventually cause delivery prices to more than triple, adding as much as $90 billion to the country's annual fuel bill. That may or may not be the case, as it is likely that accords such as the North American Free Trade Agreement (NAFTA), along with other market mechanisms, will keep expanding supply in balance with demand, thus maintaining relatively modest natural gas prices for at least the next decade. The more important point is that if natural gas use soars 500 percent, or even 200 percent, the supposed desirability of a fuel that possesses one-half as much carbon as coal and one-third as much as oil becomes meaningless in the face of an acknowledged need to *reduce* net carbon emissions by 60 percent.

Difficult Choices

In countries such as those of Eastern Europe and the republics of the former Soviet Union, the immediate energy choices are painfully difficult. For example, if the governments of the former Soviet republics must make an immediate choice between decommissioning dangerous nuclear reactors or expansion of natural gas, we in the United States could not presume to counsel them against natural gas.[7] Natural gas seems far preferable to dirty coal technologies or hazardous nuclear reactors in that context.

By comparison, energy choices in the United States are relatively simple. Here, the potential for rapid implementation of renewable energy and efficiency improvements is great, despite market disincentives and frank political resistance from the Reagan and Bush administrations, and now, the natural gas greenwash.

Perhaps if it were true that natural gas could wean the industrialized world from oil and coal consumption, one might accept the trade-off that natural gas is indeed another finite fossil fuel that contributes significantly to global warming, acid precipitation, and urban smog. But natural gas will not simply replace coal and oil, nor will it merely serve as a temporary bridge to clean energy. On the contrary, energy policies now being forged in the industrialized world will ensure a perpetuation of all fossil fuels under the green wing of natural gas.

Before offering examples and documentation of these policies, it is first appropriate to examine the impacts from the entire fuel cycle, how its production and distribution affect local and regional environments and economies, what the experts predict in terms of short- and long-term demand, and what energy alternatives are available now.

Chapter Two

Emissions Associated with Production and Combustion

After decades of a biased energy marketplace that favors heavily subsidized fossil fuels and nuclear energy, attempts are now under way by some utilities, regional power planning councils, and others to include the "hidden" societal costs of fuels into the market cost in order to create a level playing field for all energy sources, including efficiency and renewables. However, even these progressive costing initiatives still only examine some of the emissions associated with fuel combustion, excluding pre-combustion impacts of the entire fuel cycle.

In the case of natural gas, pre-combustion impacts have not been examined nor quantified, and combustion emissions themselves have also not been thoroughly examined. Some of the emission reductions claimed possible by switching to natural gas turn out to be exaggerated in some cases, and not achievable with current technology in other cases.

Carbon Dioxide

Natural gas has a carbon content by weight, roughly one-half that of coal and one-third that of oil (see Fig. 1). Natural gas thus can be expected to produce less carbon dioxide (CO_2) when burned; the proportions are dependent on a number of variables, including the efficiency of the combustion system. As a rough average, oil combustion produces 40 percent more CO_2 than natural gas, and coal emissions of CO_2 are around 75 percent greater.[8]

On the face of it, it appears that switching to natural gas could significantly reduce global warming emissions on a comparative basis with other fossil fuels, but in real-world applications, natural gas is not living up to its promise.

Carbon Dioxide from the Transportation Sector

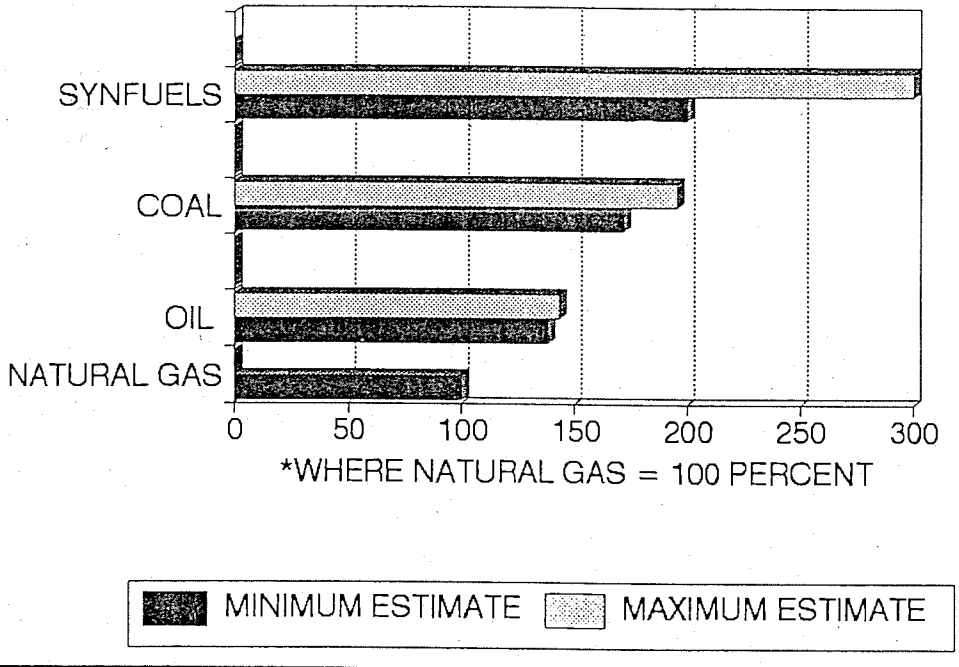
Because the United States transportation sector is responsible for 63 percent of annual oil consumption,[9] the Bush administration's National Energy Strategy (NES) pledged to replace gasoline with "alternative fuels," including natural gas, to lessen oil use and thereby reduce oil imports. The provisions of the National Energy Policy Act of 1992, the Clean Air Act Amendments of 1990, and other non-legislative federal rule-making will result in switching widespread from gasoline to natural gas as a transportation fuel.

An estimated 30,000 natural gas vehicles are now in use in the United States.[10] The American Gas Association estimates there will be four million by the year 2005,[11] including 2.5 million new compressed natural gas (CNG) vehicles by the year 2000 accounted for by the Clean Air Act Amendments alone.[12] (For reference, a CNG vehicle consumes about as much fuel in a year as a home heated with natural gas.[13])

This rapid growth rate is a concern because the comparative emission reductions possible with natural gas as an alternative fuel are still speculative. Mile for mile, most vehicles powered by CNG today emit 0 to 15 percent less CO_2 than gasoline-powered vehicles.[14] The U.S. EPA, in a 1990 test of CNG vehicles on the road, found that by factoring in tailpipe emissions of methane (without considering emissions from the production and distribution systems for

Figure 1

RELATIVE CARBON DIOXIDE EMISSIONS OF FOSSIL FUELS*



Source: World Resource Institute adaptation of data from Gordon J. MacDonald, editor. "The Long Term Impacts of Increasing Carbon Dioxide Levels." U.S. General Accounting Office, *Meeting the Energy Challenges of the 1990s: Experts Define the Key Policy Issues*, GAO/RCED-91-66. Presentation by James J. Mackenzie.

CNG), two of the three CNG vehicles tested had a greater global warming impact than their gasoline-powered counterparts.[15]

Other studies suggest that dedicated vehicles optimized for CNG use will offer an average 20 percent reduction of global warming emissions over gasoline-powered vehicles. However, the U.S. EPA has just drafted a revised estimate of the comparative global warming impacts of transportation fuels with the conclusion that even an optimized CNG vehicle produces global warming impacts nearly equivalent to gasoline-powered vehicles.[16]

Even if 20-percent reductions in global warming impacts are realized in the future, recall that we need to reduce carbon dioxide emissions by 60 to 80 percent just to stabilize global warming gas concentrations. The 20-percent reduction that might be realized by changing to natural gas falls far short, and the number of personal CNG-powered vehicles on the road continues to climb.

Industry analysts point out that "natural gas will realize its potential as a transportation fuel only when, and if, an infrastructure is built that will support refueling, manufacturing, maintaining, and reselling natural gas vehicles (NGVs). In the race for profits, the winners will target their receptive market segments and move quickly to put their technology's infrastructure in place."[17]

The National Energy Policy Act of 1992 offers tax deductions for purchasing alternatively fueled vehicles (up to $2,000 for light duty vehicles and progressively greater amounts for heavy duty vehicles), as well as deductions of up to $100,000 for the costs associated with equipment, storage, and dispensing of alternative fuels.[18]

Additionally, the U.S. EPA is writing a new standard for natural gas vehicle emissions because CNG vehicles are unable to meet the existing standard for total hydrocarbon emissions. (see following sections on Hydrocarbons).

Producers and distributors of CNG are hastening to capitalize on the opportunity provided by new national regulations for alternatively fueled vehicles. In recognition of the need to corner the alternative fuel market quickly, Mesa Inc., headed by Boone Pickens, has gone so far as to offer financing of public and private fleet conversions to CNG in return for gas purchase agreements in several states. Pickens calls his program "MESA Environmental—Clean Fleet," and predicts that 20 million vehicles in the United States will be fueled by CNG by the year 2000.[19]

"Miscellaneous" Carbon Dioxide Release

In addition to the combustion process, natural gas emits CO_2 into the atmosphere in ways that are neither well scrutinized nor quantified.

During extraction, other gases come out of the reservoir with the hydrocarbons. According to a California Energy Commission study of greenhouse gas emissions, when natural gas is extracted:

> ...often times, carbon dioxide is present in significant concentrations (as much as two-thirds). Since carbon dioxide is an unwanted product of gas extraction and not considered a pollutant, it is separated from the gas stream and vented into the atmosphere. Though data exists for flaring of natural gas at the well or processing plant, there was little information on direct venting of carbon dioxide.[20]

Accurate quantification of CO_2 loading from this source has not been attempted. Although it is unlikely that CO_2 would comprise anywhere near two-thirds of the production stream from gas production wells on an average,[21] even a fraction of that would be of concern. In the United States, natural gas wells were estimated to generate 91.3 billion cubic feet of CO_2 from direct flaring and venting in 1987.[22] This estimate does not include CO_2 flaring and venting from oil wells that produce associ-

ated gas and does not include CO_2 venting from processing facilities nor anywhere else "downstream" from the well. Considering the expansion of natural gas production endorsed by regional, national, and international energy policies, these previously ignored sources of global warming emissions warrant attention.

Carbon Dioxide Emissions from Utilities

The use of natural gas rather than oil or coal to generate electric power has greater promise for reducing CO_2 emissions produced during combustion. Each kilowatt-hour of coal-derived electricity puts more than two pounds of CO_2 into the air. By comparison, oil emits fewer than 1.75 pounds of CO_2 per kilowatt-hour and natural gas (burned in conventional gas turbine) emits about 1.33 pounds.[23]

Highly efficient, combined-cycle natural gas plants can do better at comparative CO_2 emission reductions. According to the executive officer of Enron, operator of the country's largest gas distribution system: "In comparing a new natural gas combined-cycle plant with a new technology coal plant, the natural gas plant emits 58 percent less CO_2."[24]

Chris Flavin of the Worldwatch Institute is even more optimistic, reporting that newly developed combined-cycle natural gas power plants emit up to 65 percent less CO_2 than conventional coal plants.[25]

However, the likelihood of simply shutting out coal in favor of natural gas-powered facilities is questionable and will be discussed in later sections. The fossil fuel industry and new national legislation and policy directives encourage power-generating systems that co-fire coal and natural gas. These policies also support technology that will utilize gasified coal in combined-cycle systems once easily produced natural gas reserves are depleted. (Co-firing is a process to combine natural gas and coal during combustion, generally with much greater proportions of coal to natural gas. Gasified coal produces nearly the same amount of CO_2 when combusted as does solid coal.)

For the immediate future, "cheap" natural gas will consistently exclude conservation and renewables from competitive bidding processes, thus capturing the market on new generating capacity for the next several decades and ensuring that carbon-less energy remains underutilized (see Box 4: Cornering the Utility Markets).

Hydrocarbons

Sales quality natural gas is about 90 percent methane, a hydrocarbon that is considered "nonreactive" and therefore assumed not to contribute to ozone formation (ozone is formed when hydrocarbons react with nitrogen oxides in the presence of sunlight; it is a global warming gas in its own right and is the principal ingredient of urban smog). Because natural gas-fueled vehicles emit fewer reactive hydrocarbons than gasoline vehicles, and because more than 50 percent of reactive hydrocarbon emissions in the United States are a consequence of the transportation sector, attention has centered on the potential for natural gas as a vehicle fuel to reduce urban smog.[26]

In 1991, the Gas Research Institute reported that:

> "...the EPA has now indicated that methane may be sufficiently reactive to require control...this is reflected in proposed limits on emissions of total hydrocarbons from motor vehicles, including NGVs (natural gas vehicles)."[27]

As it turns out, the U.S. EPA has just proposed a new rule that will specifically *exclude* methane emissions from regulation, by supplementing the current total hydrocarbon emission standard by one that will only regulate non-methane hydrocarbon emissions from CNG vehicles. Because of high methane emissions, natural gas-fueled vehicles are never able to meet the existing

hydrocarbon standard. According to the Federal Register Notice of the new rulemaking from the U.S. EPA:

> ...compared to current petroleum-fired vehicles, vehicles operating on natural gas have fairly high total HC [hydrocarbon] emissions which consist primarily of methane, but have non-methane HC levels comparable to or below those of gasoline-fueled vehicles...the high methane emissions would make it infeasible for current technology natural gas-fired vehicles to comply with the THC [total hydrocarbon] standards currently in place for other fuels...current exhaust catalyst technology is largely ineffective at oxidizing methane.[28]

The U.S. EPA explains that the catalyst technology that might eventually be able to oxidize methane is "early on its development," thus "the Agency [EPA] does not believe that the THC [total hydrocarbon] standards are feasible in the near term for natural gas-fueled vehicles."[29] The new rule excluding tailpipe methane emissions from regulation is said to reflect the mandate of Congress as exemplified in provisions of the Alternative Motor Fuels Act and The Clean Air Act Amendments:

> ...[it] reflects Congress' view that natural gas is a promising future transportation fuel in light of both environmental and national energy security. For these reasons, the Agency does not believe that natural gas-fueled vehicles should be excluded from the market while catalyst technology is being developed.[30]

Unfortunately, the proposed rule does not address the global warming impacts of unregulated methane emissions, although according to other U.S. EPA studies of CNG vehicles, they are significant.[31] With only 30,000 natural gas vehicles now on the road, it does not seem particularly alarming that natural gas vehicles cannot meet total hydrocarbon standards, but if projections are correct, in a decade when the number reaches millions, there will certainly be a concern.

According to a 1992 study by the Argonne National Laboratory and the International Institute of Applied Systems Analysis in Vienna, Austria, if greenhouse gas reductions are to be realized for natural gas as a vehicle fuel both in the short- and long-term, very strict regulation of tailpipe emissions will be necessary.[32] Yet the United States is preparing to abandon standards for methane tailpipe emissions because the technology is not available to reduce emissions to acceptable levels.

The methane problem aside, converting a gasoline-fueled vehicle to natural gas can reduce reactive hydrocarbon emissions by 40 to 60 percent.[33] That is a significant reduction, but, again, not nearly enough in the context of the swelling numbers of personal vehicles on the road. The efficacy of reducing reactive hydrocarbons by one-half is dubious in the face of the projected growth of vehicles on the road. In fact, the improvement in per vehicle emissions may encourage this growth to increase and, in the end, result in greater total emissions. Going one small step forward and one giant step backward is not progress.

Rather than rushing to subsidize natural gas as an "alternative" fuel, exempting it from federal standards of emission control and expanding the infrastructure for its distribution, the country could seize this opportunity to implement mass transit reform, innovative land-use planning, and genuine alternative fuels with zero hydrocarbon emissions.

Oxides of Nitrogen and Sulfur

There is no argument about the relative merits of fossil fuels in terms of sulfur emissions. Sulfur dioxide emissions (a precursor of acid precipitation) from natural gas com-

bustion are nearly zero, although removal of hydrogen sulfide from "sour" natural gas can be locally problematic.

It is much less clearcut when it comes to nitrogen oxide emissions. Because natural gas inherently contains less nitrogen than other fossil fuels, the potential for reduction of nitrogen oxide emissions during combustion is great. However, the combustion process for natural gas can produce greater quantities of nitrogen oxides than other fossil fuels unless special catalytic reducers or some other post-combustion treatment removes the oxides of nitrogen.

For now, there are technological hurdles to overcome in order to achieve the necessary catalyst efficiency for natural gas as a transportation fuel.

Nitrogen Oxide Emissions from theTransportation Sector

Most natural gas-fueled vehicles currently produce greater nitrogen oxide emissions than gasoline-powered vehicles.[34] Although automotive engineers believe they can eventually design fuel injection systems and optimize exhaust after-treatment specifically for natural gas that could "approach that of gasoline vehicle systems,"[35] there are some difficult technological tradeoffs to be considered.

Engineers report that typical catalyst efficiency for natural gas is about 15 percent in comparison with 80 percent for gasoline.[36] High compression engines would allow efficiency improvements of 15 to 20 percent, but higher compression ratios cause greater nitrogen oxide emissions.[37] According to the U.S. EPA, compressed natural gas (CNG) should be burned at high compression, with a lean air-to-fuel ratio to reduce carbon monoxide and non-methane hydrocarbons while achieving maximum efficiency, but the lean-burn increases nitrogen oxide emissions.[38]

The Worldwatch Institute and others report that the potential exists for specialized catalytic converters to reduce emissions of nitrogen oxides, as well as for efficient, high-compression engines that will burn less fuel and thus reduce carbon dioxide emissions.[39] The existing dilemma is summed up by a representative of Ford Motors, who candidly admitted:

> "...we are very concerned—even though natural gas has many attributes that make it a clean fuel—whether or not we are going to be able to meet the future [NOx] emission standards with this fuel."[40]

According to the U.S. EPA:

> Balancing the large carbon monoxide and NMHC [non-methane hydrocarbon] reductions possible with a dedicated CNG-fueled vehicle with the degree of NOx (nitrogen oxide) control necessary will be the most difficult technical area and is clearly one in which more research, development and demonstration is necessary.[41]

New federal legislation and public relations efforts to subsidize and portray natural gas as a clean-burning transportation fuel have bolted far ahead of the information base. The U.S. General Accounting Office reported to Congress in September 1992 that "Subsidies for alternative fuels would reduce gasoline consumption, but whether they would necessarily lead to cleaner air is uncertain. The combustion of some alternative fuels—for example, compressed natural gas and methanol—may reduce carbon monoxide and hydrocarbon emissions, but may not significantly reduce nitrogen oxide emissions."[42]

Nitrogen Oxide Emissions from Utilities

Natural gas does offer greater advantage over coal for nitrogen oxide emission reductions in electricity-generating facilities, but is certainly no panacea.

As with compressed natural gas in vehicles, the necessity of high-temperature combustion of natural gas in power plants requires catalytic treatment to significantly

reduce oxides of nitrogen. The Clean Air Act Amendments of 1990 require U.S. utilities to reduce nitrogen oxide emissions from 110 large Eastern generating stations by a modest two million tons. A 1991 National Academy of Science report concluded that much greater nitrogen oxide control will be required to reduce smog.[43]

The Clean Air Act Amendments require nitrogen oxide emission reductions of 40 to 50 percent, achievable with after-burners. But the National Academy of Sciences study calls this moderate restriction into question. Catalyst removers are available in Germany that reduce nitrogen oxide emissions from power plants by as much as 85 percent, but they are costly,[44] and many U.S. facilities will resist them unless strictly mandated.

Impacts of Nitrogen Oxide Emissions

The National Academy of Sciences study is one several recent assessments that express increasing concern for the impacts of nitrogen oxide emissions, which are three-pronged: nitrogen oxide is a precursor of acid precipitation; it is instrumental in the formation of tropospheric ozone, which is a potent greenhouse gas; and ozone is the precursor of smog.

The National Academy of Science study concludes that U.S. EPA's control strategies for reducing smog had focused too exclusively on reducing the hydrocarbon component of the ozone equation and too little on the nitrogen oxide side of the equation.[45] The U.S. EPA underestimated concentrations of volatile organic compounds in cities because they underestimated contributions from motor vehicle sources and had neglected important natural sources, such as trees. The National Academy of Science findings indicate that tighter controls of nitrogen oxides are clearly necessary to reduce urban smog.

Yet the transportation fuel now billed as an answer to urban pollution produces quantities of nitrogen oxide equal to or greater than gasoline. If natural gas can reduce air pollution and global warming gases as advocates claim, the temptation to endorse it would be compelling, but as a transportation fuel, at least, natural gas falls far short. A transportation fuel that produces greater nitrogen oxide emissions than gasoline, and global warming impacts equivalent to gasoline, cannot be called clean. Nor can it be called "cheap" in its ultimate cost to society and the environment.

Chapter Three

Let's Call It What It Is: Methane

A full-page advertisement run by the Enron Corporation depicts an artist's rendition of eagles soaring above a gas processing facility nestled in an otherwise pristine setting of forested mountains and sparkling rivers. "Isn't it wonderful natural gas is invisible so the rest of nature never will be? As an energy source, natural gas certainly lives up to its name," the advertisement reads.

Actually, processed "natural gas" is roughly 80 to 95 percent methane. Methane is a global warming gas more than 20 times as effective as CO_2 at trapping heat in the atmosphere over a 100-year period, and more than 60 times over a 20-year span.[46] The most recent assessment from the Intergovernmental Panel on Climate Change (IPCC) indicates that summing all direct and indirect methane effects, it may be almost 70 times more powerful a greenhouse gas than CO_2, molecule-for-molecule, over a 20-year time frame.[47]

Of the human-caused global warming gases, methane is second only to carbon dioxide in terms of its contribution to future climate change (see Box 2: Atmospheric Methane Concentrations). The IPCC calculates that methane will be responsible for 18 percent of future warming and CO_2 for 66 percent, although these numbers are constantly being revised.[48] Methane's atmospheric lifetime is about 11 years, while CO_2 molecules endure in the atmosphere for 120 years.[49] Although the shorter life span allows at least the possibility for more rapid reduction of methane concentrations than for CO_2, the potency of methane as a global warming gas in the short term is a concern because of the probability of global warming feedback mechanisms that might occur within decades. These mechanisms are "wild cards" in the predictive modeling science of climate change and could drastically increase the rate of global warming.

For example, as global temperatures rise, enormous quantities of methane trapped in frozen Arctic tundra could be released, causing yet greater warming and eventual release of submarine methane hydrates now trapped beneath Arctic permafrost. This would hasten warming and deplete the at-

mospheric hydroxyl reservoir (the hydroxyl radical is the atmosphere's "cleansing agent," oxidizing methane and carbon monoxide, nitrogen oxides, and other gases).[50] With the depletion of the hydroxyl reservoir, the ability of the atmosphere to rid itself of excess gases declines, thus accelerating the buildup of those gases and the global warming they create. (See Jeremy Leggett, ed. *Global Warming: The Greenpeace Report*. Amsterdam, The Netherlands: Greenpeace International, 1990, for a complete description of this and other feedback mechanisms).

Methane Emissions from the Natural Gas System

Because natural gas combustion emits less CO_2 than either coal or oil, its advocates argue that it can mitigate global warming if used as a replacement fuel for transportation and electrical generation. But the lack of hard data on methane emissions makes a cogent decision on the relative merits of natural gas impossible, even discounting the other global warming and polluting impacts of the entire fuel cycle.

Anthropogenic methane loading is difficult to quantify, and estimation of fugitive emissions from the natural gas system are particularly nebulous. The U.S. EPA has completed a draft report on anthropogenic methane emissions.[51] The study examines U.S. emissions, but also offers a range of global estimates of 200 to 550 teragrams (one teragram [Tg] equals a million metric tons) of methane emissions a year from all anthropogenic sources.[52]

U.S. EPA estimates of emissions from the global natural gas system in the draft report are somewhat contradictory. Estimates cited in the text for natural gas system leakage only are also given for oil and gas together in tables listing all sources and sinks. The tables (based on IPCC data) give a range of estimates for both oil and gas system leakage of 30 to 70 Tg (for comparison, the table lists global emissions from coal mining at 25 to 50 Tg a year). The text states (also citing the IPCC):

> Some authors have suggested that approximately 2 to 4 percent of the total global natural gas production may be emitted. At this rate, total global emissions are estimated at about 30 to 70 Tg per year.[53]

A mean 3 percent estimate globally would be consistent with other studies; however, all researchers consistently underscore the uncertainties of estimates and inadequate data. Most studies suggest that 3 percent methane leakage from the natural gas system is a conservative global estimate.[54] Many researchers also agree that if methane leakage from the natural gas system is even a seemingly low 3 percent worldwide, there will be no net benefit in terms of global warming to be gained by changing from oil to natural gas.[55]

The other area of agreement is that the highest levels of emissions come from the former Soviet republics and Eastern Europe and the lowest levels from North America. Estimates for the former range to greater than 10 percent and for the latter from 3 percent to less than 1 percent.

Methane Leakage in the U.S. Natural Gas System

The draft U.S. EPA report on methane emissions concludes that methane emissions from the U.S. natural gas system accounted for 2.2 to 4.3 Tg per year, with a central estimate of 3, equating to 11 percent of anthropogenic methane emissions nationwide, and less than 1 percent of total marketed gas in 1990. This estimate excludes combustion-related emissions associated with customer gas use.[56] The total also ex-

cludes venting and flaring emissions at the wellhead, "...because preliminary analyses indicate that a large majority of emissions from wellhead venting and flaring originate from oil wells that do not market gas."[57]

The authors acknowledged the lack of information available for analysis: "...very little emissions data have been developed for most of the emission sources in the natural gas system."

Although the U.S. EPA study is the most comprehensive attempt thus far to quantify natural gas system methane leakage in the United States, the conclusions are constrained by the paucity of information available at the outset of the investigation. Most of their conclusions are extrapolated from a very limited data set provided by several industry studies.[58] The estimates are also limited because they do not include all possible sources, such as abandoned well leakage, or venting and flaring from active wells.

Other studies concluded in the recent past also reflect the uncertainties:

- The American Gas Association (AGA) reported in 1989 that total system emissions were only 0.3 percent. (They did not estimate emissions from production and processing.)
- A 1989 study by Dean Abrahamson from the University of Minnesota produced an estimate of 2.8 percent for the total system.
- A 1990 report to the U.S. Department of Energy by D. Barns and J. Edmonds suggested a 2 percent total.
- Last, a 1992 Radian Corporation report estimated the total emissions at 1.11 percent.[59]

Interestingly, while the Radian study finds the greatest sources of emissions are the production and processing sectors of the natural gas system rather than the transmission, storage, and distribution of gas, the U.S. Department of Energy and Abrahamson studies conclude just the opposite: that most emissions result from transmission, storage, and distribution processes.[60]

Uncertainties of Future Methane Emissions

Oil and gas industry representatives are quick to assure their critics that methane emissions from production and distribution can be adequately controlled in the United States and, with introduction of new materials and technology, the global rate can be reduced as well—even in Eastern Europe and the former Soviet republics, where leakage is thought to be greatest.

Let us say, for the sake of discussion, that industry assertions are true: that leakage from new natural gas distribution systems can be held to 1 percent with new technology and materials, even in the former republics of the Soviet Union. Unfortunately, this does not address the problem of existing infrastructure. There are approximately one million kilometers of natural gas pipeline in place,[61] and much of it is old and corroding. The difficulty and expense of incorporating new materials and technologies into existing pipeline and distribution systems would be enormous. There are also thousands of abandoned wells that may or may not be leaking.

In the final analysis, attempts to capture the methane emissions would probably be cost-effective, since the emissions are a salable commodity. However, the time required to realize the savings to industry is discouraging. In the United Kingdom, where there has been a comparatively significant debate about methane leakage and efforts undertaken to repair and replace leaking mains, it is estimated that the present program for replacing pre-1969 gas piping will take 45 years for mains and 15 years for services at current rates.[62] In the former Soviet republics, the geographic spread of the system alone will make repairs and rebuilding much more time consuming and costly. Several decades is a long time to allow continued emissions of this powerful global warming gas.

Even if regulatory agencies are willing to mandate this time and expense and industry is willing to undertake them, there would remain the need for monitoring to ensure compliance at a time when many countries, including the United States, are encouraging federal deregulation of energy industries and industry self-monitoring programs.

Some of the supposed benefits of switching to natural gas are based on assumptions and conclusions that have not yet been supported with a sound information base (as with CNG as a transportation fuel). Seldom questioned in the midst of this speculation is what even a 1 percent methane leakage rate will mean for global warming if natural gas use is increased two- or threefold (as some predict), and if other mechanisms, such as melting tundra and release of methane hydrates, simultaneously and abruptly load methane into the atmosphere.

The 1992 draft U.S. EPA report does attempt to address future emissions, stating that although "changes in future methane emissions will be determined by the changes in the size of the gas system which in turn will be determined by the changes in future consumption of natural gas and the productivity of the system," natural gas system emissions might not necessarily increase proportionately: "The use of improved alternative practices will reduce

BOX 2: Atmospheric Methane Concentrations

Atmospheric methane concentrations have more than doubled in the past two centuries and continue to climb. More than 70 percent of the total emissions are a consequence of human activities.[1] Atmospheric methane concentrations have increased at twice the rate of CO_2.[2]

However, a team of National Oceanic and Atmospheric Administration (NOAA) scientists reported in 1992 that, although methane continues to accumulate in the atmosphere, the rate of accumulation slowed between 1983 and 1990.[3] The NOAA study found that in the early 1980s, methane levels were climbing at 13.3 parts/billion per year, but by 1990, the rate of increase had dropped to 9.5 parts/billion per year. They predicted that if this deceleration continues, "global methane concentrations will reach a maximum around the year 2006."

The report suggests that several human activities could be responsible for the change—a decreasing world cattle population since 1975, a slowdown in global rice production, and changes in oil industry practices since the late 1970s that reduce methane loss during extraction. Since methane persists in the atmosphere for 10 to 11 years, any or all of these factors could be responsible.[4]

The NOAA team stated: "Our results hint that changes in methane emissions in the latitude band 30 to 90 degrees North may be of particular significance to this trend...Although it is not possible to determine from this study which particular sources have slowed their increase, the rapidity of the deceleration suggests that direct human actions may be responsible. The component of the global methane source that is most amenable to rapid reduction by human intervention is that associated with fossil-fuel extraction."

Although not mentioned by the NOAA team, another trend occurring during the period in question was a temporary reduction in natural gas and oil use in the northern latitudes. There was a fall in U.S. natural gas use by 16 percent from the early 1970s to 1990.[5] Global natural gas

methane emissions per unit of the natural gas delivered by the system."[63]

It is to be hoped that this will be the case, but what seems lacking so far is an immediate financial incentive or some regulatory mechanism. The U.S. EPA forecast is also incomplete in that it discounts future methane emissions from natural gas-powered vehicles and the associated distribution and refueling system, which could be substantial.

and oil production also declined slightly in the years 1980 through 1983.[6]

Other explanations have been offered. Ronald G. Prinn, Director of the Center for Global Change Science at the Massachusetts Institute of Technology, suggests that increased concentrations of hydroxyl radical (the hydroxyl radical is the atmosphere's "cleansing agent," oxidizing methane and carbon monoxide, nitrogen oxides and other gases) is slowing the rate of growth of methane concentrations. The greater concentration of hydroxyl radical is accounted for, he says, by replacement of natural forests with cultivated areas, which have greater nitrogen oxide emissions, leading to greater production of the hydroxyl radical. Burning of biomass in the tropics, and urbanization and its attendant pollution also increase levels of hydroxyl radical over the tropics.[7]

Whatever the cause for the apparent slowdown of the rate of methane buildup in the atmosphere, it is good news for now, but we should not be lulled into unconcern about the global warming potential of future anthropogenic methane emissions. The only certainty in the infant science of long-term climate change modeling and the complex interactions of sources, sinks, and feedback mechanisms, is its uncertainty.

Notes

1. Hogan, Kathleen, et al. U.S. Environmental Protection Agency Global Change Division, *Anthropogenic Methane Emissions in the United States: Estimates for 1990: Report to Congress*, Review Draft. October 1992, p. ES-1.

2. California Energy Commission. *1988 Inventory Of California Greenhouse Gas Emissions*, Final Staff Report, October 1990, p. 2.

3. Steele, L.P. et al., "Slowing Down of the Global Accumulation of Atmospheric Methane During the 1980's." *Nature* July 12, 1992, pp. 313-316.

4. *Science News* 7/25/92, p. 55.

5. DOE/EIA. *Natural Gas Strategic Plan And Multi-year Program Crosscut Plan FY 1993-1998.* April 1992, DOE/FE-0251P.

6. American Petroleum Institute. *Basic Petroleum Data Book.* Washington, DC, 1991.

7. From a report of the "Atmospheric Methane Conference." in Huntington Beach, CA in "Role of Methane in GLobal Warming Continues to Perplex Scientists." *Chemical And Engineering News* 2/10/92, pp. 26-28.