NATURAL GAS AND EFFICIENT TECHNOLOGIES A RESPONSE TO GLOBAL WARMING

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INTRODUCTION

Global Warming has become an environmental problem caused by the use of fossil energy. The emission of the radiative gas CO_2 from a particular country is intimately connected with the size of its population, its efficiency of utilization of fossil energy and the carbon content of the fuel. This paper deals with CO_2 mitigation technologies including the reuse of emitted CO_2 and indicates a direction for CO_2 emissions reduction for the U.S. economy.

The average CO_2 emissions for the three fossil fuels are as follows: Coal - 215 LbsCO_2/MMBTU (HHV = 11,000 BTU/Lb and C content of 76%); Oil - 160 Lbs CO_2/MMBTU (HHV = 6 MMBTU/Bbl) and Gas = 115 Lb CO_2/MMBTU (HHV = 1 M BTU/cu. ft.). Table 1 shows the U.S. fossil energy consumption and CO_2 emission, the total world consumption and emission and the principal energy supply service. In the U.S., most of the coal is used for generation of electrical power, in large central power stations. Oil is mainly used for production of transportation fuel (gasoline and diesel) with some limited electrical power production and gas is mainly used for industrial and domestic heating. However, there is also lately a growing consumption of natural gas for electrical power production.

Substituting Natural Gas for Coal for Electrical Power Production

If all the current electrical power production in the U.S. is generated by natural gas in combined cycle power plants, two benefits of CO_2 emission are achieved. First, the efficiency of electrical power production is increased from the current average coal-fired plant efficiency of 34% to over 55% for a modern natural gas fired turbine combined cycle plant and secondly the CO_2 emission per unit of energy from the fuel is reduced by 47% compared to the coal-fired plant. Applying this to the U.S. consumption, and assuming that natural gas usage remains the same a 22% reduction in the total CO_2 emission can be realized.

Substituting Natural Gas for Oil for Automotive Transportation

Compressed natural gas (CNG) vehicles are already on the market and if natural gas is substituted for oil in the transportation sector a 13% reduction in CO_2 emissions can be realized in the U.S. Thus, the substitution of natural gas for Coal and Oil in the electrical power and transportation sectors adds up to a 35% overall reduction in CO_2 emissions.

The Carnol System for Preserving the Coal Industry for Electrical Power Production and Reducing Oil Consumption by Substituting Methanol in the Transportation Sector

The Carnol System consists of generating hydrogen by the thermal decomposition of methane and reacting the hydrogen produced with CO_2 recovered from coal-fired central power stations to produce methanol as a liquid transportation fuel. Figure 1 illustrates the Carnol System which has the following advantages: 1. The Carnol System preserves the coal industry for electrical power production. 2. The Carnol System produces a liquid fuel for the transportation sector which fits in well with the current liquid fuel infrastructure. 3. The Carnol System reduces consumption of the dwindling domestic supplies of fuel oil in the U.S.

In the Carnol System, the carbon from the coal is used twice, once for production of electricity and a second time for production of liquid fuel for fueling the transportation sector, in automobile vehicles. The reduction in CO_2 emissions results from two aspects. The elemental carbon produced from the thermal decomposition of the methane is not used as fuel. It is either sequestered or sold

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as a materials commodity. In this respect, thermal decomposition of methane (TDM) has an advantage over the conventional steam reforming of methane (SRM) for hydrogen production reduced. In the TDM process, carbon is produced as a solid which is much easier to sequester than CO_2 as a gas. Furthermore, the energy in the carbon sequestered is still available for possible future retrieval and use. The carbon can also be used as a materials commodity, for example, as a soil conditioner. Table 2 gives the estimate of CO_2 emissions using the Carnol System applied to the U.S. 1995 consumption and indicates a 45% overall CO_2 emissions reduction. The methanol in this case is used in conventional internal combustion engines (IC) which is 30% more efficient than gasoline driven IC engines. The natural gas requirement would have to increase to 62 Quad which is three times the current consumption of natural gas for heating purposes. The rise in natural gas requirement is because only about 58% of the natural gas energy is used for hydrogen for methanol. Methanol production and that carbon produced is sequestered unburned to the extent of 0.58 GT. This can be considerably reduced by going to fuel cell vehicles.

Carnol System with Methanol Fuel Cells for the Transportation Sector and Substituting Natural Gas with Combined Cycle Power for Coal Fired Central Station Power

In the not too distant future, fuel cells will be developed for automotive vehicles. This will improve the efficiency of automotive engines by at least 2.5 times compared to current gasoline driven internal combustion engines. Direct liquid methanol fuel cells are under development. If we use coal or oil for central power stations, there will be too much CO_2 generated for liquid fuel methanol by the Carnol Process for the transportation sector using fuel cells. Therefore, it is much more energy balanced if we use natural gas for power because it generates the least amount of CO_2 per unit of energy. In this scenario, the natural gas in a combined cycle plant displaces coal for power production and displaces oil for methanol by the Carnol Process for transportation. The results are shown in Table 3. Thus, by applying natural gas for electrical power production, liquid fuels production for fuel cell driven automotive engines and for heating purposes an overall CO_2 emissions reductions of over 60% can be achieved. This degree of CO_2 emission reduction could stabilize the CO_2 concentration and prevent the doubling of the CO_2 in the atmosphere expected by the middle of the next century if business is conducted as usual. The 0.32 GT of carbon required to be sequestered is about 3 times less than the amount of coal mined in the U.S. currently. If a market can be found for this elemental carbon, such as a soil conditioner, the cost of methanol production can be significantly decreased.

Natural Gas Supply and Utilization

The all natural gas energy system of Table 3 requires a three-fold annual consumption in natural gas. Recent reports indicate that the current estimated reserve of conventional natural gas is of the same order of magnitude as the current estimated oil reserves which might last only for another 80 years or so. However, unconventional resources, especially methane hydrates and coal bedded methane indicate an enormous resource which is estimated to be more than twice as large as all the fossil fuel resources currently estimated in the earth. If this is so, then we can begin to think of utilizing natural gas for reducing CO_2 emissions in all sectors of the economy. It appears that even today that deep mined coal in several parts of the world, especially in England, Germany, and the U.S., has become too expensive; and, as a result, many of these mines have been closed. Most economical coal used today comes from surface mined coal. Furthermore, the contaminants in coal, sulfur, nitrogen and ash in addition to the high CO_2 emission mitigate against its use. Rail transportation of coal also becomes a problem compared to pipeline delivery of natural gas. When natural gas becomes available, even at a somewhat higher cost, it can displace coal and even oil for power production and transportation. Long term supply of economical natural gas is the main concern for increased utilization of natural gas.

Economics of Natural Gas Displacing Coal and Oil

The current unit cost for fossil fuel in the U.S. is for coal $1.00/MMBTU, oil $3.00/MMBTU and for gas $2.00/MMBTU. For the total consumption of 76 Quad in 1995, the primary fossil fuel energy bill was $167 billion. Applying this to the all natural gas scenario of Table 3, we come up with a natural gas fuel bill for the required 49 quads of $98 billion. So there is a resulting 41% savings in the current fossil fuel bill. The cost of natural gas could go up to $3.50/MMBTU without the fuel bill exceeding the current energy bill. In order to achieve these results, capital investment in the replacement new technologies must be made. Only incremental replacement cost need be considered, since capital investment will be needed, in any case, to replace old equipment under business as usual conditions. Table 4 indicates the incremental capital replacement cost to achieve the all natural gas economy based on the following data.

a) Replacement of coal fired plants including scrubbers, etc., runs about \$2000/kw(ϵ); for the more efficient natural gas combined cycle plants runs about \$1000/KW(ϵ); thus, there is a \$1000/Kw(ϵ) capital cost savings and when applied to an installed capacity of 400,000 MW(ϵ), the savings amounts to \$400 billion.

b) For replacing oil refineries with Carnol Methanol plants which require CO_2 removal and recovery from the natural gas power plants, it is estimated that the current unit cost is \$100,000 per daily ton of methanol. The total incremental cost to supply the total 14 quads of methanol for fuel cell vehicles is then \$220 Billion. No credit was taken for the replacement of oil refineries, over time, so that this incremental capital cost is probably high.

c) New pipelines will have to be built to transport the natural gas and new methods of extracting natural gas eventually from deep sea wells containing methane hydrates. Assuming \$1 million per mile for these new gas supply facilities and a rough estimate of 200,000 miles needed gives a capital cost of roughly \$200 billion. It is also assumed that the liquid methanol pipeline and tanker distribution will be about equal to the current liquid gasoline distribution for the transportation sector.

d) In terms of replacing the current existing more than 100 million gasoline driven IC engine vehicles with fuel cell vehicles, it eventually should not cost much more than the present average cost of \$15,000 to \$20,000 per vehicle. And, so the incremental cost should be negligible and may even show a savings because of the more efficient fuel cell vehicle than the IC engine vehicle.

Table 4 indicates that the incremental savings due to the new technologies in the one electrical power sector just about balances the incremental cost in the other three sectors. Thus, the new total incremental capital replacement cost is negligible compared to the capital cost requirement for continuing with the business as usual current power technology structures.

Conclusions

The ability of achieving a 60% reduction in the U.S. CO_2 emissions by natural gas fuel substitution with improved technologies is based on the following assumptions and developments:

1. that there are vast reserves of natural gas that can be recovered from both conventional and non-conventional natural gas resources especially from methane hydrates and coal bedded methane at costs which are not more than about double current gas productions cost.
2. that an efficient Carnol process for methanol production based on thermal decomposition of methane can be developed.
3. that an efficient direct methanol fuel cell vehicle can be developed.

The benefits in terms of mitigating global warming provides a strong incentive for working on and achieving the required development goals. The all natural gas economy with efficient technologies for CO_2 global warming mitigation avoids alternatives of (1) sequestering CO in the ocean or underground, (2) switching to nuclear power, and (3) relying solely on solar and biomass energy.

FIG. 1

INTEGRATED SYSTEM FOR CO_2 EMISSION REDUCTION

CARNOL PROCESS

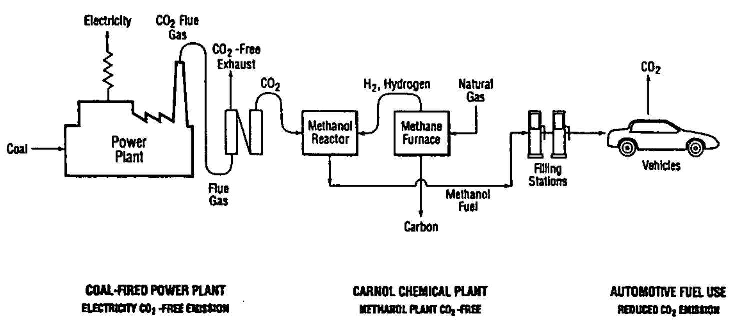

Table 1
Total Fossil Fuel Energy Consumption and CO_2 Emission for the U.S. in 1995[3]

Fuel Type	Quantity	Energy Consumption Quads 10^{15} Q BTU	Principal Energy Service	CO_2 Emission	
				GT(CO_2)	%
Coal	0.9×10^9 tons	20	electricity	2.15	35%
Oil	5.8×10^9 bbls	35	Auto transport	2.80	45%
Gas	21.0 TCF	21	heating	1.21	20%
U.S. Total World Total		76 330		6.16 (1.68 GT(C)) 22.7 (6.2 GT(C))	

TCF = Trillion (10^{12}) cubic feet
GT = Giga (10^9) tons
Q = Quads (10^{15}) BTU

Table 2
Carnol Methanol Substitution for Oil in the Conventional Auto Transportation Sector Produced from Natural Gas and CO_2 from Coal-fired Power Plants

Fuel Type	Natural Gas Consumed Quads	Energy Consumed Quads	Energy Service	CO_2 Emissions GT(CO_2)
Coal[a]	--	20	Electricity	0.22
Methanol[b] substitutes for gasoline	41	24	Auto Transport	1.96
Gas	21	21	Heating	1.21
Total	62	65		3.39
Reduction from current CO_2 emission				2.77
% CO_2 Emission Reduction from 1995 level				45.0%
Elemental carbon sequestered				0.58 GT (C)

Table 3
Natural Gas substituted for Coal Fired Power Production, Carnol Process for Methanol Production, Substituting for Oil in Fuel Cell Vehicles for the Transportation Sector

Fuel Type	Natural Gas Consumption Quads	Energy Consumption Quads	Energy Service	CO_2 Emission GT (CO_2)
Natural gas for coal[a]	14	14	Electricity	0.08
Methanol for oil	24	14	Auto Transport Fuel Cells	1.12
Gas	21	21	Heating	1.21
Total	59	49		2.41
Reduction from Current CO_2 Emissions				3.75
% CO_2 Emission Reduction from 1995 level				61%
Elemental carbon sequestered				0.34 GT (C)

a) Natural gas for combined cycle power plant is 55% efficient and 90% of CO_2 emissions is recovered for Carnol plant.

Table 4
Capital Investment Required to Replace Present Power Structure

Present Power Structure (and capacity)	Replacement Structure (and capacity)	Incremental Unit Capital Cost	Incremental Replacement Capital Cost $\$10^9$ ($ Billions)
Coal fired electrical[a] power 400,000 MWe	Natural gas fired combined cycle electrical power	− $1000/kw (savings)[a]	− $400
Oil refineries[b] 35 Quads	Carnol methanol plants 14 Quads	$\$10^5$/T/D Methanol[b]	+ $200
Wells and pipelines[c]	additional pipeline and new methane hydrate wells	$\$10^6$/mile[c] 200,000 miles of gas lines	+ $200
Automotive IC vehicles 100×10^6	Fuel cell vehicles	0[d]	~ 0
Net total incremental replacement cost			~ 0