Greenhouse Gas Implications in Large Scale Infrastructure Investments in Developing Countries: Examples from China and India

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I. Introduction

Meaningfully addressing global climate change concerns necessarily entails curbing the greenhouse gas (GHG) emissions of key developing economies. In 2002 China and India together accounted for roughly 18% of global CO_2 emissions, the leading human cause of climate change.[1] These countries' growth in GHG contribution outpaces that of the U.S. and the E.U., and by 2020 they will together account for one quarter world's CO_2 emissions (Appendix A, Figure 1).[2] Engaging China and India in climate change agreements is difficult because climate concerns understandably take a backseat to the priority these countries place on development. Traditional approaches to involving reluctant countries in international climate policy have proven incapable of enticing or coercing these countries' cooperation.[3]

Presently, the Kyoto Protocol's Clean Development Mechanism (CDM) is recognized as the principal international apparatus for engaging developing countries in GHG abatement. However, poor oversight and governance, as well as gaming have plagued the CDM, and we anticipate that the mechanism's ultimate impact on developing countries' baseline emissions will be modest (Appendix A, Figure 2).[4] Furthermore, those changes that the CDM exacts are marginal and do not create game-changing technology or infrastructure necessary to curb developing world emissions in the long run. For example, in practice, CDM projects have not adequately addressed developing countries' reliance on coal. And as of December 2005, less than a quarter of the CDM market was devoted to projects aimed at reducing CO_2 emissions (Appendix A, Figure 3).

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[1] Calculations based on data provided by EIA on July 2005 in report #: DOE/EIA-0484(2005) available at http://www.eia.doe.gov/oiaf/ieo/pdf/ieoreftab_10.pdf.
[2] *Ibid.*
[3] Developing countries will not enter into cap-and-trade systems (such as the Kyoto Protocol) unless they are afforded ample headroom within the system to accommodate their development. Such headroom corrupts a cap-and-trade system by undermining the system's market mechanism. See Victor, David G., Joshua C. House and Sarah Joy, 2005, "A Madisonian Approach to Climate Policy," *Science*, vol. 309, No. 5742, pp. 1820-1821.
[4] For example, as of February 17, 2006, emissions reductions attributable to the 100 largest CDM projects were 97.3 million tonnes of CO_2. For reference, to meet its obligations under the Kyoto Protocol, the EU would have to cut about 204 million tonnes of CO_2.

II. "Development First"

We assert that effectively engaging developing countries in climate change abatement regimes requires infrastructure investments that accommodate the high energy demands of economic growth and development. Espousing this theory of "development first,"[5] we formulate here two possible "deals" that could occur in China and India with assistance from the developed world. Both plans are built on the assumption that these countries will participate in a CO_2 abatement program only if the program assists (or at least accommodates) their unhindered procurement of the energy needed to foster economic and population growth.

III. China

As of 2004, China's total primary energy consumption was 1,386 million tonnes oil equivalent (Mtoe), representing growth of over 100% from 1990,[6] and is projected to reach 2,072 Mtoe by 2020.[7] By 2020, China is projected to account for 21% of the world's CO_2 emissions.[8] This increased contribution is largely attributable to China's population and economic growth, and its reliance on coal-fired electricity.

China is interested in alternatives to coal primarily to reduce urban air pollution rather than out of concern for global GHG emissions. To that end, the country is pursuing a diverse mix of gas supplies that includes domestic production, international pipelines, and imported liquefied natural gas. In addition to China's highly publicized bidding for equity stake in foreign oil and gas fields, the country completed in 2004 the East-West Pipeline to bring gas to coastal markets. The first of several planned LNG terminals is expected to come on-line in 2006.

Most of China's projected coal and gas consumption will be used in electricity generation. The projected generation capacity of coal and gas is provided below (Table 1).

Table 1: China Reference Scenario

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[5] See T. C. Heller, P. R. Shukla in *Beyond Kyoto: Advancing the International Effort Against Climate Change*, J. E. Aldy et al., Eds. (Pew Center on Global Climate Change, Arlington, VA, 2003). See also Bradley, Rob and Kevin A. Baumert, Eds. *Growing in the Greenhouse: Protecting the Climate by Putting Development First*. (World Resources Institute, Washington, D.C., 2005).

[6] BP Statistical Review of World Energy June 2005, on-line: http://www.bp.com/statisticalreview

[7] International Energy Agency. *World Energy Outlook 2004*.

[8] Calculations based on data provided by EIA on July 2005 in report #: DOE/EIA-0484(2005) available at http://www.eia.doe.gov/oiaf/ieo/pdf/ieoreftab_10.pdf.

	Installed Capacity (GW)[1]	
	2002	2020
Coal	247	560
Gas	8	67
Total Capacity[2]	360	855

[1] Source: World Energy Outlook 2004

[2] Total capacity includes coal, gas, oil, nuclear, hydro, and renewables.

We explore the carbon implications of a plausible scenario in which China replaces 50 GW of planned coal capacity with natural gas by 2020. Our scenario represents a 9% reduction of projected installed coal capacity in 2020.[9] As the calculations below indicate, such a switch could reduce annual CO_2 emissions in 2020 by 213 million tonnes.

In our scenario, subcritical coal plants are replaced with baseload combined cycle gas turbines (CCGT). We make the following assumptions about the load factor and carbon intensity of coal and CCGT plants in China (Table 2).

Table 2: China Gas Deal Load Factor and Carbon Intensity Assumptions

	Subcritical Coal	CCGT
Load Factors	0.85	0.90
Emissions rate (tonne CO_2/GWh)	920	350

The carbon implication of our proposed 50 GW substitution is calculated by holding total electricity production in 2020 constant and determining the amount of new gas necessary to meet this demand. Because of the higher load factor of CCGTs, 50 GW of coal capacity can be displaced with 47 GW of natural gas. Using the load factors and emissions rates above, we find a CO_2 savings of 213 million tonnes per year (Table 3):

Table 3: Emissions Reductions Implications of China Gas Deal

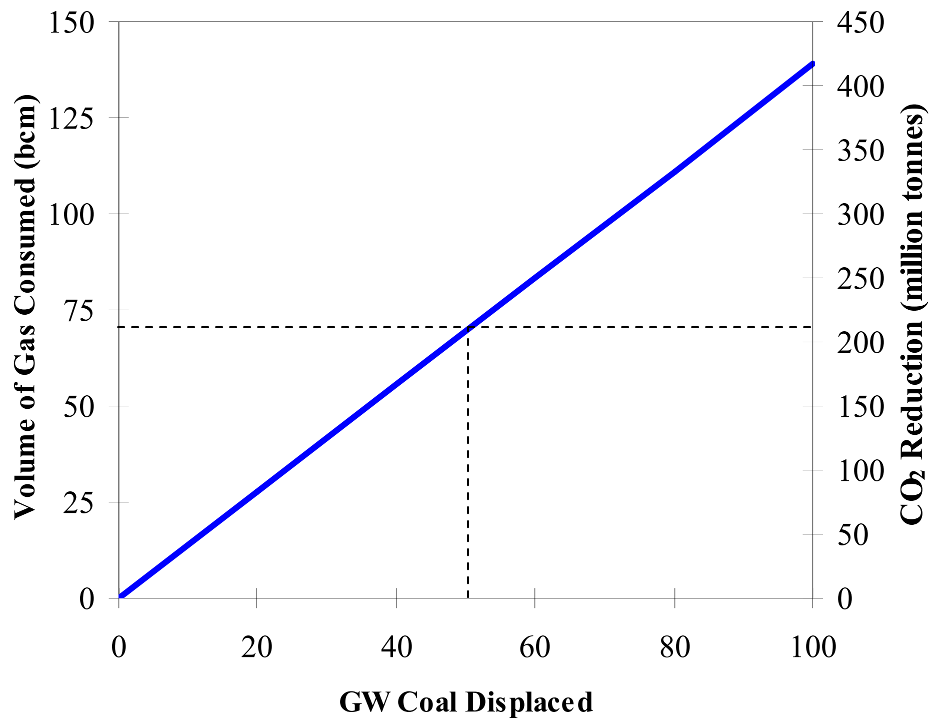
	Coal Scenario	Gas Scenario
Capacity (GW)	50	47
Total Generation (TWh)	372	372
CO_2 Emissions (million tonnes CO_2/year)	343	130

Assuming a reasonable CCGT heat rate of 7,000 Btu/kWh (49% efficient), we find China would need an additional 70 billion cubic meters (bcm) to fuel this new gas capacity.

[9] International Energy Agency. *World Energy Outlook 2004*.

The CO_2 and gas supply implications for replacing the range of 0 to 100 GW of coal capacity with natural gas is provided in Figure 1.

Figure 1: Implications of Coal Displacement in China in 2020



It is easy to construct a set of plausible storylines in which China could access additional new gas supplies with developed countries serving as a broker for such a deal. For example, our proposed 70 bcm of increased gas demand could be met by two large pipelines from Russia, or nine LNG terminals the size of the Guangzhou terminal expected to come online in 2006. With world gas consumption in 2020 projected to be 4,150 bcm, this incremental increase in gas consumption in China is not implausible.

IV. India

India's total primary energy consumption was 376 Mtoe in 2004[10] and is expected to reach 829 Mtoe by 2020.[11] As with China, coal dominates India's electricity landscape, accounting for about 60% of total installed capacity. Table 4 details India's projected capacity.

Table 4: India Reference Scenario

[10] BP Statistical Review of World Energy June 2005, on-line: http://www.bp.com/statisticalreview

[11] IEA. *World Energy Outlook 2004*.

	Installed Capacity (GW)[1]	
	2002	2020
Coal	69	127
Gas	13	45
Nuclear	3	9
Total Capacity[2]	116	252

[1] Source: World Energy Outlook 2004

[2] Total capacity includes coal, gas, oil, nuclear, hydro, and renewables.

We explore the carbon implications of the recent deal between India and the U.S. to share and implement nuclear energy technologies. While there are a range of assumptions of the amount of new capacity this technology transfer could provide by 2020, we analyze a middle-of-the-road estimate of 30 GW of new nuclear capacity. Under this scenario, nuclear would save 218 million tonnes of CO_2 if it displaced only coal capacity, and 83 million tonnes if it replaced exclusively gas. In practice, nuclear capacity would likely replace a mix of both coal and gas, and the emissions reduction would fall within this range.

We make the following assumptions about the load factor and carbon intensity of coal, gas, and nuclear plants in India (Table 5).

Table 5: India Nuclear Deal Load Factor and Carbon Intensity Assumptions

	Nuclear	Subcritical Coal	CCGT
Load Factors	0.90	0.85	0.90
Emissions rate (tonne CO_2/GWh)	0	920	350

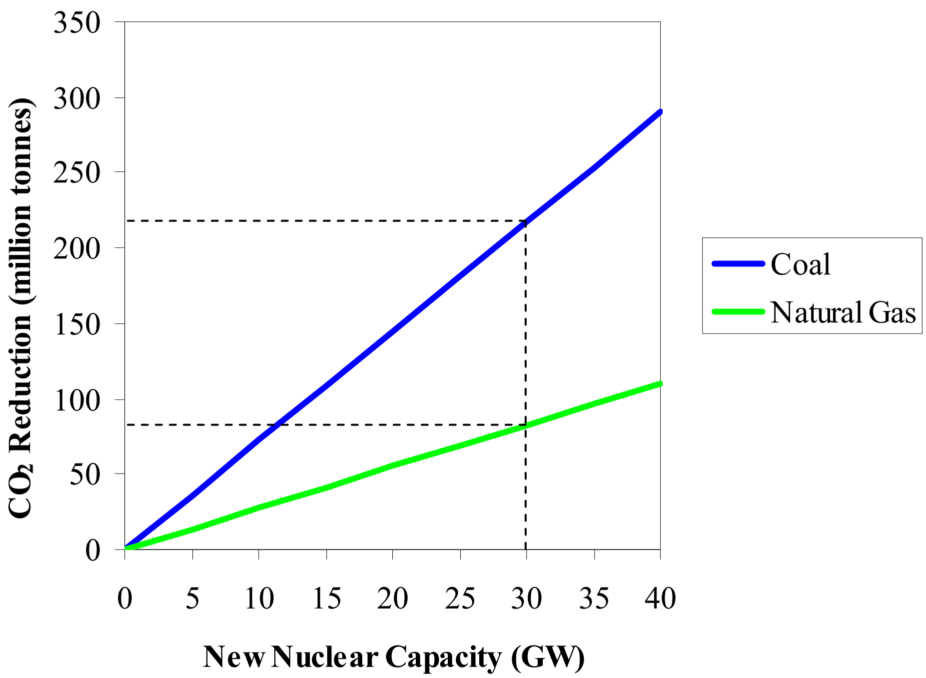
The carbon implications of new nuclear capacity are determined by calculating the annual energy produced by the nuclear plants and estimating the displaced CO_2 emissions from coal and natural gas. Note that 30 GW of nuclear capacity displaces 32 GW of coal capacity, owing to coal's lower load factor (Table 6).

Table 6: Emissions Reductions Implications of India Nuclear Deal

	Nuclear Replaces Coal	Nuclear Replaces Gas
Displaced Capacity (GW)	32	30
Total Generation (TWh)	237	237
CO_2 Emissions Reductions (million tonnes CO_2/year)	218	83

The CO_2 implications of replacing coal or gas with a range of installed nuclear capacities are provided in Figure 2. Assuming nuclear will displace a mixture of coal and gas, the carbon reductions for any given nuclear capacity will fall between these two lines.

Figure 2: Carbon Implications for Indian Nuclear Deal



V. Conclusion

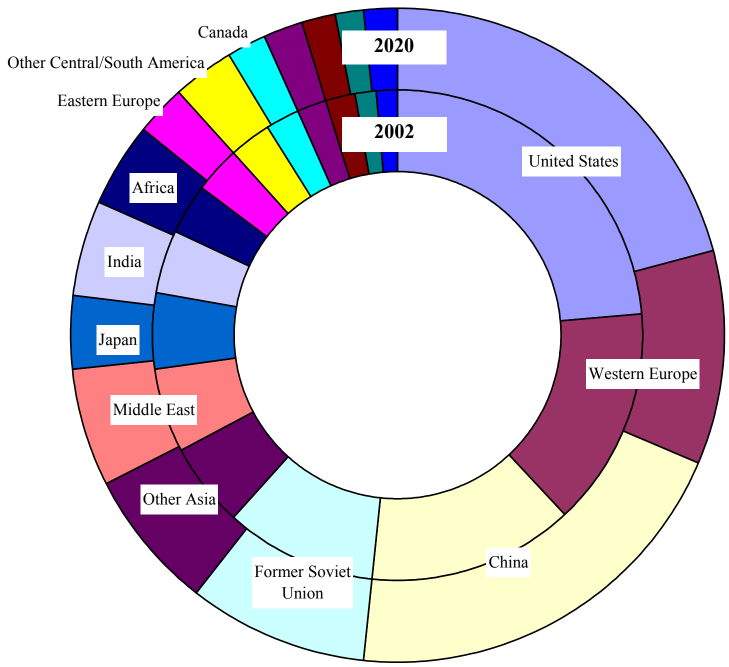
The deals modeled in this paper are meant to demonstrate that well-structured investments in energy infrastructure in developing countries have the potential to bring about massive reductions in CO_2 emissions (Appendix A, Figure 2). Such investment deals show promise not only because they represent viable means of carbon mitigation; we argue that, in helping these countries achieve their energy and development goals, these deals represent the only feasible way of engaging reluctant countries in emissions reductions.

Successful implementation of these energy infrastructure investments requires attention to three general areas. Firstly, targeted developing countries need flexible, but credible policy, that can adapt to these energy infrastructure changes. Second, the right actors, including private entities adept at managing technical and political risk, need to be involved in these infrastructure deals. Lastly, contextual changes in areas such as price formation and security concerns may be needed to accommodate newly established energy markets. Our institution, The Program on Energy and Sustainable Development, focuses on these issues in our other work and plans to examine them in the context of these deals.

The purpose of the analyses here is simply to provide a rough estimate of the magnitude of these deals' potential CO_2 savings. Our models' implications underscore the need for further and more sophisticated analysis.

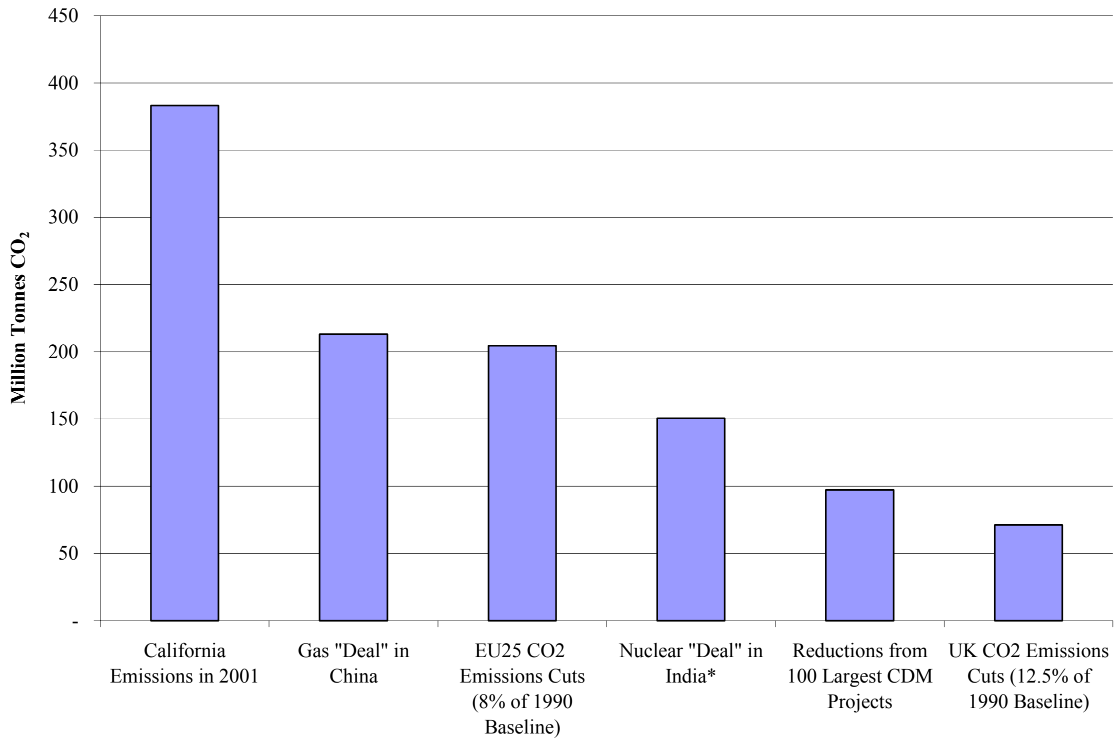
Appendix A

Figure 1: Global CO2 Emissions by Region (2002 and 2020)



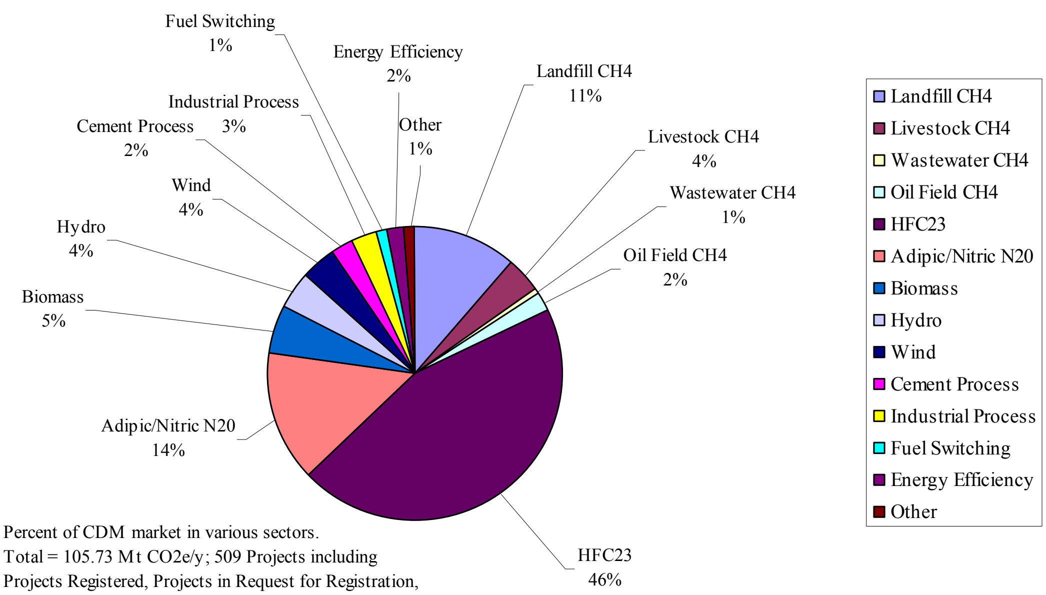
Source: EIA

Figure 2: CO2 Savings in Perspective



* Represents an average of the emissions reduction from displacing coal and gas.

Figure 3: CDM Market by Sector



Percent of CDM market in various sectors.
Total = 105.73 Mt CO2e/y; 509 Projects including Projects Registered, Projects in Request for Registration, Post-Validation, or Validation Stage by CDM Board as of 23.12.05