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Working Paper Series:

The Global Energy Market:
Comprehensive Strategies to Meet
Geopolitical and Financial Risks

Climate Policy and Energy Security: Two Sides of the Same Coin?

Peter R. Hartley and Kenneth B. Medlock III

THE JAMES A. BAKER III INSTITUTE FOR PUBLIC POLICY
RICE UNIVERSITY

THE GLOBAL ENERGY MARKET: COMPREHENSIVE STRATEGIES TO MEET GEOPOLITICAL AND FINANCIAL RISKS

THE G8, ENERGY SECURITY, AND GLOBAL CLIMATE ISSUES

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STUDY AUTHORS

JOE BARNES
DANIEL BRUMBERG
MATTHEW E. CHEN
DAVID BRYAN COOK
MAHMOUD EL-GAMAL
MALCOLM GILLIS
JORGE GONZALEZ GOMEZ
PETER R. HARTLEY
DONALD HERTZMARK
AMY MYERS JAFFE
YOON JUNG KIM
NEAL LANE
DONGCHAO LI
DAVID R. MARES
KIRSTIN MATTHEWS
KENNETH B. MEDLOCK III
RONALD SOLIGO
LAUREN SMULCER
RICHARD STOLL
XIAOJIE XU

About the Global Energy Market Study

The Global Energy Market: Comprehensive Strategies to Meet Geopolitical and Financial Risks—The G8, Energy Security, and Global Climate Issues examines a variety of scenarios for the future of global energy markets. Some of these scenarios evaluate factors that could trigger a regional or worldwide energy crisis. The study assesses the geopolitical risks currently facing international energy markets and the global financial system. It also investigates the consequences that such risks could pose to energy security, pricing, and supply, as well as to the transparent and smooth operation of the global market for oil and natural gas trade and investment. By analyzing these threats in depth, the study identifies a series of policy frameworks that can be used to fortify the current market system and ensure that it can respond flexibly to the array of threats that might be encountered in the coming years. The study also looks at the impact of emerging climate policy on the future of world energy markets.

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The **Baker Institute Energy Forum** is a multifaceted center that promotes original, forward-looking discussion and research on the energy-related challenges facing our society in the 21st century. The mission of the Energy Forum is to promote the development of informed and realistic public policy choices in the energy area by educating policymakers and the public about important trends—both regional and global—that shape the nature of global energy markets and influence the quantity and security of vital supplies needed to fuel world economic growth and prosperity.

The forum is one of several major foreign policy programs at the James A. Baker III Institute for Public Policy of Rice University. The mission of the Baker Institute is to help bridge the gap between the theory and practice of public policy by drawing together experts from academia, government, the media, business, and nongovernmental organizations. By involving both policymakers and scholars, the institute seeks to improve the debate on selected public policy issues and make a difference in the formulation, implementation, and evaluation of public policy.

The James A. Baker III Institute for Public Policy
Rice University – MS 40
P.O. Box 1892
Houston, TX 77251-1892 USA

http://www.bakerinstitute.org
bipp@rice.edu

ABOUT THE
INSTITUTE OF ENERGY ECONOMICS, JAPAN

The Institute of Energy Economics, Japan (IEEJ), was established in June 1966 and specializes in research activities in the area of energy from the viewpoint of Japan's national economy in a bid to contribute to sound development of Japanese energy supply and consumption industries and to the improvement of domestic welfare by objectively analyzing energy problems and providing basic data, information and the reports necessary for policy formulation. With the diversification of social needs during the three and a half decades of its operation, IEEJ has expanded its scope of research activities to include such topics as environmental problems and international cooperation closely related to energy. The Energy Data and Modeling Center (EDMC), which merged with the IEEJ in July 1999, was established in October 1984 as an IEEJ-affiliated organization to carry out such tasks as the development of energy data bases, the building of various energy models and the econometric analyses of energy.

The Institute of Energy Economics, Japan
Inui Building
Kachidoki 10th, 11th, and 16th Floor
13-1, Kachidoki 1-chome
Chuo-ku, Tokyo 104-0054 Japan

http://eneken.ieej.or.jp/en/

About the Authors

Peter R. Hartley, Ph.D.
Baker Institute Rice Scholar, James A. Baker III Institute for Public Policy
George and Cynthia Mitchell Chair and Professor of Economics,
Rice University

Peter R. Hartley is the George and Cynthia Mitchell chair and a professor of economics at Rice University. He is also a Rice scholar of energy economics for the James A. Baker III Institute for Public Policy. Hartley has worked for more than 25 years on energy economics issues, focusing originally on electricity, but including also work on natural gas, oil, coal, nuclear and renewables. He wrote on reform of the electricity supply industry in Australia throughout the 1980s and early 1990s and advised the government of Victoria when it completed the acclaimed privatization and reform of the electricity industry in that state in 1989. Apart from energy and environmental economics, Hartley has published research on theoretical and applied issues in money and banking, business cycles and international finance. In 1974, he completed an honors degree at the Australian National University, majoring in mathematics. He worked for the Priorities Review Staff, and later the Economic Division, of the Prime Minister¹s Department in the Australian government while completing a master's degree in economics at the Australian National University in 1977. Hartley obtained a Ph.D. in economics at the University of Chicago in 1980. He came to Rice as an Associate Professor of Economics in 1986 after serving as an Assistant Professor of Economics at Princeton University from 1980-86.

Kenneth B. Medlock III, Ph.D.
Fellow in Energy Studies, James A. Baker III Institute for Public Policy
Adjunct Assistant Professor of Economics, Rice University

Kenneth B. Medlock III is currently research fellow in energy studies at the James A. Baker III Institute for Public Policy and adjunct assistant professor in the department of economics at Rice University. He is a principal in the development of the Rice World Natural Gas Trade Model, which is aimed at assessing the future of liquefied natural gas (LNG) trade. Medlock's research covers a wide range of topics in energy economics, such as domestic and international natural gas markets, choice in electricity generation capacity and the importance of diversification, gasoline markets, emerging technologies in the transportation sector, modeling national oil company behavior, economic development and energy demand, forecasting energy demand, and energy use and the environment. His research has been published in numerous academic journals, book chapters and industry periodicals. For the department of economics, Medlock teaches courses in energy economics.

Climate Policy and Energy Security:

Two Sides of the Same Coin?

PETER R. HARTLEY, BAKER INSTITUTE RICE SCHOLAR

KENNETH B. MEDLOCK III, FELLOW IN ENERGY STUDIES, BAKER INSTITUTE

I. Introduction

At the height of controversy in the European Union (E.U.) over former U.K. Prime Minister Blair's support for President Bush's policy on Iraq, Blair responded that his "special relationship" with the United States would enable him to influence other policies that Europe cared about. Foremost among those was the difference between the United States and the European Union over climate change policy, and especially the U.S. refusal to ratify the Kyoto Protocol. Prime Minister Blair apparently decided that a potentially fruitful approach in speaking to President Bush about the climate change issue would be to link it to the security issues that motivated the Bush Administration's policy on Iraq and the Middle East more generally. In a speech in the United States on October 20, 2006, Prime Minister Blair asserted that, "We must treat energy security and climate security as two sides of the same coin." This argument has been repeated by a number of leaders of E.U. countries, and is frequently used by leaders in the United States as a rationalization for various policies.

The claim that policies may be able to address both climate change and energy security at the same time is plausible. On one side of the coin, climate policy is aimed at limiting or reducing human impacts on climate. Theoretical models of the global climate system, known as global climate models (GCM), have suggested that the observed increases in average global temperatures in the final quarter of the twentieth century were linked to anthropogenic CO_2 emissions arising predominantly from the burning of fossil fuels. Furthermore, these same computer models, combined with scenarios about likely future fossil fuel use in the absence of policy adjustments, predict that future increases in atmospheric concentrations of CO_2 could produce potentially detrimental changes in climate. Policy measures to reduce this perceived threat by reducing the consumption of fossil fuels are what Prime Minister Blair had in mind when he referred to the need to ensure "climate security."

On the other side of the coin, energy security policy typically aims to reduce the vulnerability of the economy to disruptions in energy supplies and accompanying severe price volatility. Since Hamilton (1983) pointed out that every recession except one since the end of World War II has been preceded by an increase in the price of oil, many economists have presented empirical evidence that energy price shocks reduce the rate of economic growth and either cause, or are a catalyst for, recessions.

Energy-importing countries face additional energy security concerns centering on international relations or national security, instead of the domestic economy. For example, the Organization of the Petroleum Exporting Countries (OPEC) oil embargo of 1973 demonstrated to the United States that dependence on Middle East oil could be used as a lever to try to influence U.S. foreign policy. Similarly, in Japan, a paucity of domestic energy resources has long been seen as a strategic weakness that could affect Japan in times of actual and potential international conflict. These types of concerns often motivate countries to adopt policies aimed at limiting dependence on foreign energy resources. Japan, for example, adopted a very aggressive policy of diversifying its energy portfolio away from crude oil toward nuclear and natural gas following the oil shocks of the 1970s. Among the countries of Western Europe, France, with its limited endowment of domestic energy resources, has pursued nuclear power as a way of limiting dependence on foreign energy sources.

Energy security concerns extend beyond crude oil markets. For example, recent disputes between Gazprom and Former Soviet Union (FSU) transit countries, particularly Ukraine, over gas pricing and debt payments highlighted the vulnerability of the European Union due to its strong reliance upon Russian natural gas supplies. It can be argued that Gazprom's disputes with these countries are the result of a desire to move to market-based pricing for all Gazprom gas supplies.[1] However, Gazprom chose to cut supplies at times and for reasons that appeared to be political rather than economic. Regardless of Gazprom's motives, the use of supply restrictions as a negotiating tool during winter months when demand is highest substantially raised energy security concerns among the countries of Western Europe.

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[1] The most pressing need for reform is within Russia itself, but there is little chance that the Russian public could be convinced of the need for higher natural gas prices while people in neighboring countries are supplied at subsidized prices.

Given the negative macroeconomic consequences of reductions in available supplies or increases in price, a reduction in dependence on imported fuel supplies would enhance energy security. This can be achieved in many ways, one of which is through the use of alternative, or renewable, energy sources. If reductions in the fossil-fuel share in primary energy supply reduce the emission of CO_2, such an outcome would also benefit "climate security." In that sense, policies that are likely to achieve both goals are "two sides of the same coin."

Although the argument, as outlined above, has some merit, we shall demonstrate that restrictions on fossil fuel use could actually reduce energy security and possibly national security, especially in the short run. We shall further argue that restricting fossil fuel use may not be an efficient response to the threat of climate change even if it had no negative consequences for energy security. Our discussion will examine the issue from the U.S. perspective, but many of our remarks will also be relevant for all energy-importing countries.

II. POLICIES TO PROMOTE ENERGY SECURITY

Before we ask whether climate policy and energy security policy are indeed complementary, we need to examine the basis for such policies. We begin with policies aimed at enhancing energy security. Specifically, we need to ask why markets might not appropriately account for the risks associated with different sources of primary energy supply. One answer is that various kinds of externalities (apart from the environmental ones) may be associated with the use of energy from different sources.

In the wake of the U.S.-led invasion of Iraq, many commentators have suggested that the action was motivated, at least in part, by the desire to secure oil supplies from the Middle East. It has also been suggested that animosity toward the United States from the "Arab street" is the result of years of U.S. policy aimed at ensuring the flow of oil exports from the Middle East, with little regard to other issues affecting the region.[2] To the extent that these claims have merit, any policy in the Middle East that involves military presence or action carries a cost. Reducing consumption of oil may be a feasible alternative to such military (and other) expenditure aimed at maintaining Middle East oil supplies. In fact, because energy, the Middle East, and the U.S. military are often intertwined in foreign policy discussions, the concept of energy security becomes a part of the U.S. national security debate.[3]

For example, in the introductory chapter of their volume of essays exploring the topic of energy security, Kalicki and Goldwyn (2005) define energy security for the United States as "assurance of the ability to access the energy resources required for the continued development of national power." A related consideration is that dependence on foreign energy suppliers could compromise the ability of the U.S. armed forces to maintain operations in time of sustained conflict. The Defense Energy Support Center reports annual sales of between 130 and 144 million barrels of oil products to the U.S.

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[2] In fact, it has been claimed that U.S. policy and consequent regional animosity was an underlying cause of the attacks of September 11, 2001.
[3] The following discussion of national security issues is based on Jaffe and Soligo (2008).

armed services for fiscal years 2002 through 2006, making the U.S. armed services the largest consumer of oil products in the world.

Other commentators, such as former CIA director Woolsey (2002) and Wirth, Gray and Podesta (2003), have argued that the large purchases of Middle Eastern oil by consuming countries has directly or indirectly financed groups hostile to U.S. interests and led to a constraint on criticism of some of the region's regimes. Similarly, a recent Task Force report by The Council on Foreign Relations (Deutch et al., 2006) noted in the overview summary that oil revenues allowed governments to pursue strategic and political objectives that conflicted with the perceived interest of the U.S. and its allies. For example, although the animosity between the U.S. and Iran has other, deeper roots, the fact that Iran is an important oil exporter and is geographically located near the nexus of much of the world's oil supply adds a complication to negotiations regarding Iranian nuclear ambitions. In the Western Hemisphere, Venezuelan leader Hugo Chavez has also used oil revenues to finance activities inimical to U.S. interests. The fact that his domestic policies have compromised investment needed to maintain Venezuelan oil production also is troublesome for the United States, particularly given the large share of Venezuelan oil in U.S. imports.

The economic dimension of energy security can be defined as reducing the vulnerability of the overall economy to a reduction or cut-off of oil supplies or to sudden large increases in prices of specific energy commodities such as oil and natural gas. In fact, Bohi and Toman (1996) defined energy security as "the concept of maintaining stable supply of energy at a reasonable price in order to avoid the macroeconomic dislocations associated with unexpected disruptions in supply or increases in price." The OPEC oil embargo of 1973 brought to the fore concerns not only about national security but also about economic security. OPEC's restriction of global oil supply in response to the West's policies regarding Israel affected economic stability by contributing to higher inflation and lower economic growth throughout the developed world for at least a decade.

Historically, there is a very strong negative correlation between oil prices and macroeconomic output in oil-importing countries (see Hamilton (1983), Mork et al. (1994) and Federer (1996), to name a few). Figure 1 illustrates the correlation for the United States from 1949 through 2007. The gap between actual GDP and potential GDP, where potential GDP is an estimate of the U.S. Federal Reserve and represents where the economy would be if all factors of production were at full employment, tends to become negative when oil prices increase.

In fact, the negative relationship extends beyond just oil prices because, in general, energy commodity prices are linked to each other through various fundamental market forces (see, for example, Hartley, Medlock and Rosthal (2008)). Energy importing countries in the European Union, United States and Japan have all experienced negative macroeconomic consequences from price increases caused by events such as the OPEC oil embargo (1973-1974), the Iran-Iraq War (1980), and the Iraqi invasion of Kuwait (1990).

Figure 1. U.S. GDP, Oil Prices, and Catalyst Events (1949-2007)

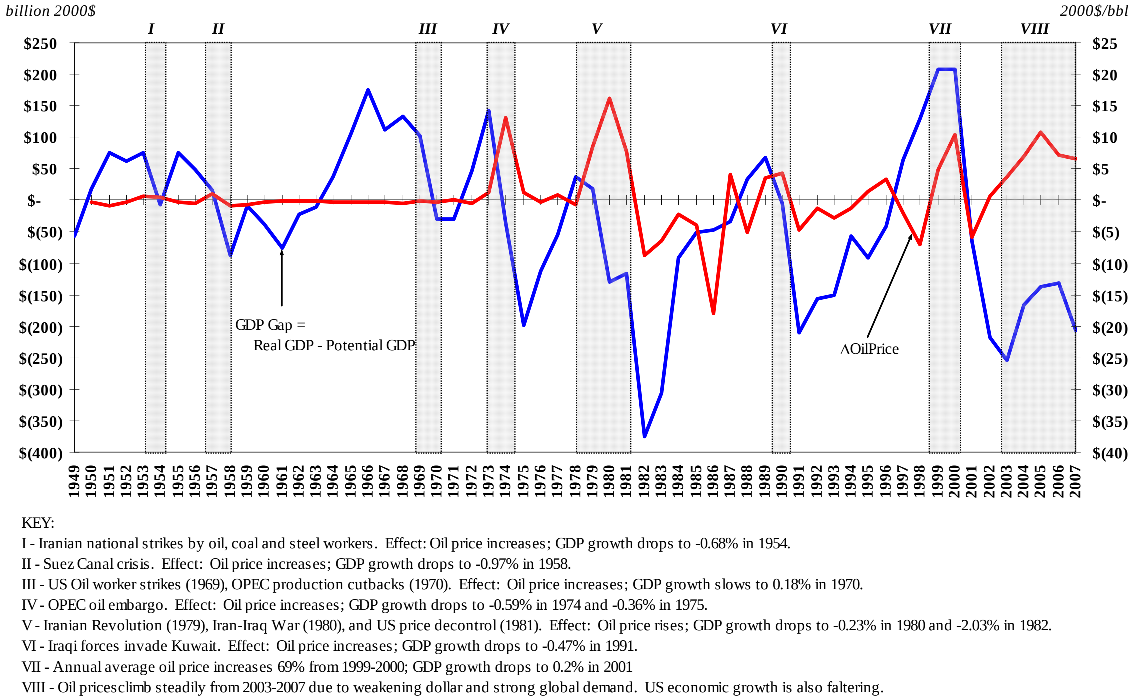

Figure Data from the U.S. Federal Reserve Database and the U.S. Energy Information Administration.

It should be noted that the existence of a causal relationship between oil prices and GDP is an open debate in the economic literature. At issue is the channel through which energy prices affect GDP. While some maintain that the negative macroeconomic consequences follow just from energy price increases, others have claimed that the response of monetary policy or other investment-related and sector-specific effects cause the negative consequences. The Appendix outlines various channels through which energy prices have been proposed to influence macroeconomic performance. In general, however, rising energy prices influence consumers to reduce discretionary spending and firms to alter the utilization of energy-using capital stocks. This rational cost-minimizing behavior on the part of households and firms has negative consequences for the economy as a whole, and is often referred to as an aggregate demand externality.

Encouraging the *diversification* of energy supplies is one very important way governments have limited the negative macroeconomic effects of events that cause the price of any single energy commodity to rise. A portfolio of energy inputs that has a more stable composite price is likely to lead to greater macroeconomic stability, all else being equal. Thus, if oil prices increase unexpectedly without similar increases in other energy commodity prices, the negative macroeconomic impacts will be larger as the share of oil in total primary energy increases (see Medlock and Hartley (2003)).

There is also some evidence that declining energy intensity has moderated the negative effects of rising energy prices by reducing the cost increases resulting from energy price increases. Reductions in energy intensity have in turn resulted from a shift to less energy intensive activities and improvements in energy efficiency in many industries. These types of adjustments offer alternative means of improving energy security.

Commodity storage is another tool at the disposal of policy-makers to enhance energy security. In the United States, the purpose of the Strategic Petroleum Reserve (SPR) is to provide insurance against short-term disruptions of supply such as an embargo on exports, war or weather events. The Energy Policy Act of 2005 directed the Secretary of Energy to fill the SPR to its authorized capacity of one billion barrels. As of January 28, 2008 the inventory was slightly above 689 million barrels.

In the longer term, a nation can reduce its vulnerability to energy market shocks by seeking a diverse selection of energy suppliers. (Note this is distinctly different from the goal of diversifying the total energy supply portfolio discussed above.) However, this is likely to have only limited effectiveness for any one country since any change in supply or demand in a global market for a fungible energy commodity such as oil will tend to affect prices everywhere and then only to a relatively minor extent. The United States is the major exception in this regard in that it is a relatively large consumer in the world oil market. For example, data from the EIA (2008) indicates that the United States accounted for about 24.5 percent of all crude oil consumption in 2006. Moreover, the U.S. imports about 60 percent of its annual demand, so a substantial reduction in U.S. crude oil imports could reduce oil prices.

An *increase* in the *elasticity* of demand for oil imports into the United States also could reduce oil prices. The reason is that there is strong evidence that Saudi Arabia in particular, but also OPEC more generally, operates as a monopolist equating marginal revenue to the marginal costs of production.[4] An increase in the elasticity of demand for OPEC exports would then reduce the difference between the demand and marginal revenue curves and thus lower the profit-maximizing price. The elasticity of demand for imports can be raised by increasing either the domestic demand or supply elasticities through an increase in the substitutability between energy sources.

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[4] See for example, Gately (2004) or Gao, Hartley and Sickles (2008), Soligo and Jaffe (2000) point out that Saudi Arabia has been practicing price discrimination against customers in the Far East in favor of customers in United States and Europe, which is consistent with a profit maximization motive.

III. CLIMATE POLICY AND FOSSIL FUELS

For the purposes of this discussion, we shall take it as given that continuing anthropogenic CO_2 emissions will cause climate to change in ways that have significant detrimental impacts. It need not follow, however, that limiting CO_2 emissions is the best policy response. We shall classify actions regarding climate change into the following four categories:

1. Reducing the emissions of greenhouse gases, particularly CO_2
2. Increased sequestration of greenhouse gases, particularly CO_2
3. Limiting the potential harmful consequences of climate change
4. Improved remediation of damages resulting from climate change

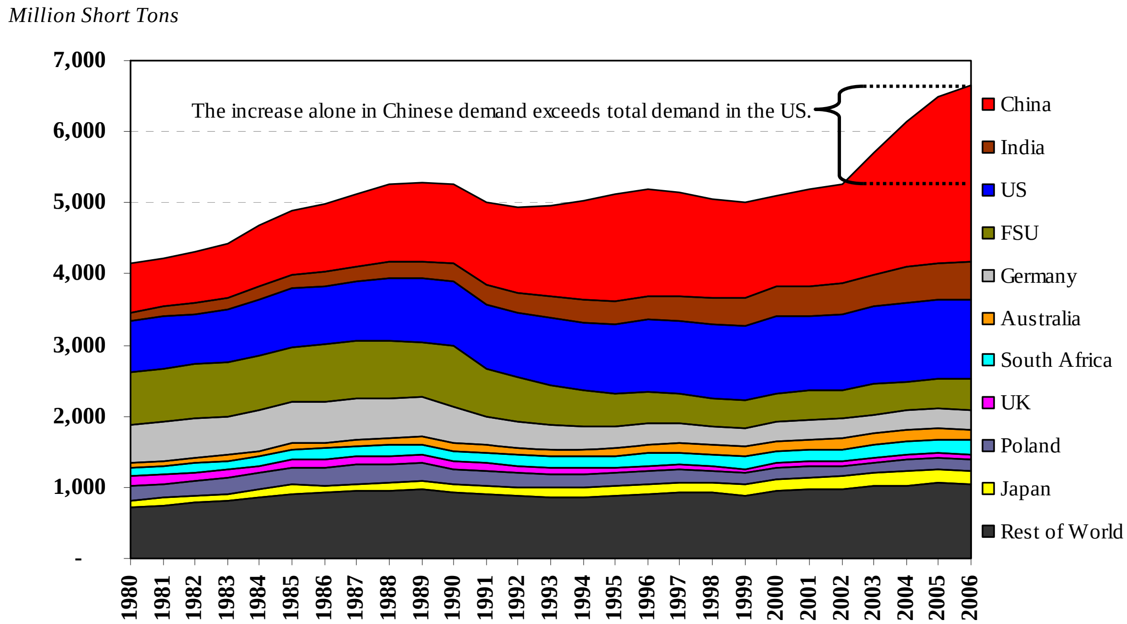
In the next four sub-sections, we shall consider some issues regarding policies in each of these categories.

Reducing Emissions of CO_2

When considering the effectiveness of measures to reduce the emission of CO_2 in the United States, or even the developed world as a whole, one needs to take account of the likelihood of "carbon leakage." Policies aimed at raising the cost of burning fossil fuels in only some economies will encourage relocation of fossil fuel intensive industries to regions where such policies are not in force. Less developed countries such as China and India remain most focused on raising standards of living through economic development. For those countries, growth in the availability of low-cost energy inputs is more critical than it is for the West. Accordingly, less-developed countries are likely to be very reluctant to adopt any policies that result in CO_2 rationing.

To highlight the point that developing countries will tend to use the lowest cost energy resources first, consider Figure 2, which graphs global coal use from 1980 through 2006. In 2006, the United States, China, and India accounted for 16.7 percent, 37.3 percent, and 8.1 percent of coal use, respectively, and of the remaining 37.9 percent, Japan, Germany and Russia accounted for one-third, or about 12 percent of the world total. It is no coincidence that with respect to global coal reserves the United States, Russia, China and India rank first, second, third and fourth respectively. Australia ranks just behind these countries in total coal reserves, and exports large amounts of coal to fuel Japanese, and increasingly Chinese, consumption. Most striking from the figure is the growth in Chinese coal demand in the past several years. In fact, the increase alone from 2001 to 2006 tops 1.1 billion short tons and is higher than total U.S. consumption in 2006. This trend is indicative of a preference ordering that places economic development higher than concern about CO_2 emissions or even local pollutants such as particulates or oxides of sulfur and nitrogen.

Figure 2. Global Coal Use (1980-2006)



Source: Energy Information Administration

Even if the coal-intensive developing countries such as China and India could be encouraged to reduce CO_2 emissions, it is unlikely that the major oil and gas producing countries of the Middle East would adopt these same policies. Already we are seeing a tendency for oil refining, petrochemicals and aluminum refining to relocate to these regions, and controls on CO_2 emissions in the rest of the world will tend to accelerate the trend. Given that CO_2 is a global concern, this can be particularly problematic. If locating in these regions had been cost-minimizing absent the CO_2 constraints, then it would have likely been done. Effectively, comparative advantages in production will be altered due to CO_2 emission constraints, resulting in a less efficient outcome. Thus, carbon leakage may actually increase CO_2 emissions due to less efficient production methods being used and/or the fact that bulk products rather than intermediate energy inputs must be transported to economies around the world.

Another issue is whether the concentration of CO_2 in the atmosphere could be limited to levels that current GCMs predict as being safe for avoiding harmful climate change while the world remains dependent upon fossil fuels for the majority of primary energy supply. Current policy proposals, embodied in agreements such as the Kyoto Protocol, aim to raise the price or limit the consumption of fossil fuels via a tax or quantity constraint. To date, these policies do not appear to have limited CO_2 emissions in many of the ratifying countries in Western Europe. Indeed, over the period 2000–2004, annual emissions of CO_2 in the United States increased 1.4 percent while in the 15 core economies of the European Union, they rose 2.3 percent even though the United States experienced higher economic and population growth over that period.

More importantly, however, the constraints embodied in the Kyoto Protocol are miniscule compared to what would be needed to stop the accumulation of CO_2 in the atmosphere. There is no known way of achieving the latter goal without raising the cost of energy high enough to stop economic growth. However, it is not realistic to expect democracies to countenance long periods of reduced economic growth rates, as economic prosperity is a critical element of political support in most democracies. From the time economic theory showed that government monetary and fiscal policy could influence business cycles and economic growth rates, voters have held governments and politicians responsible for economic downturns, even when forces beyond the control of the existing government were the primary cause of those downturns.

Our current political economy suggests that the development of new energy technologies capable of displacing fossil fuels is the only feasible long-term solution to controlling the accumulation of CO_2 in the atmosphere.[5] Ultimately, depletion of fossil fuels will raise their prices and force a transition to alternative energy sources. However, the amount of easily accessible low-cost fossil fuel is sufficiently large that a depletion-driven substitution to non-carbon fuels is likely many years away. In addition, some currently viable alternative energy sources carry other costs that must be managed. The experience of France in particular shows that nuclear fission could replace a substantial amount of fossil fuel in the generation of electricity, but the problems of waste disposal and controlling nuclear proliferation suggest that there is also a limit to that energy source.

In our view, solar is the only alternative energy source that currently appears feasible for sustaining economic growth for a very long time while limiting CO_2 accumulation in the atmosphere as well as other major environmental externalities. Solar is, in fact, the ultimate backstop energy resource. It is available in abundant quantities at relatively stable cost. The principal limiting factor involves the deployment of capital necessary to harvest solar energy. Given the large solar resources in the southwestern United States and Mexico, solar energy would also have few, if any, energy security implications for North America. However, to make solar competitive with fossil fuels for

[5] Since the oceans and the biosphere sequester an amount of CO_2 that increases somewhat as its concentration in the atmosphere rises, a ceiling on the concentration in the atmosphere above pre-industrial levels is compatible with a continuing low level of emissions from anthropogenic sources.

supplying most of our primary energy, further improvements are needed in the efficiency of solar plants, electricity storage, HVDC transmission and electric automotive technologies (see, for example, Zweibel et al. (2007)).

Increasing Sequestration of CO_2

Developing cost effective ways to sequester CO_2 would allow fossil fuels to continue to be used while limiting the accumulation of CO_2 in the atmosphere. The U.S. Department of Energy reports that CO_2 is already being used to aid in the recovery of up to 4 percent of total U.S. oil production, and notes that it can also be used to aid in the recovery of natural gas.[6] In addition, since oil and natural gas reservoirs and coal and saline formations have retained methane and other hydrocarbons for eons, there is every reason to believe these same formations can successfully sequester CO_2. A number of projects are underway in the Department of Energy and the U.S. Geological Survey to further assess the opportunities and costs of CO_2 sequestration in various geologic formations.

The National Energy Technology Laboratory (NETL), part of the Department of Energy, recently released an atlas of potential CO_2 sequestration sites in the United States and Canada. They identify stationary sources of emissions (more than 85 percent of

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[6] Conoco-Phillips has patented a process to sequester CO_2 while extracting methane from methane hydrates. It remains to be seen, however, whether it can be developed commercially. According to an article in *The Canadian Press* on April 16, 2008 Canadian and Japanese researchers working in the Mackenzie Delta achieved a sustained flow of methane from hydrates "for six days at a rate lower than conventional gas but about equivalent to a coal-bed methane well" using modified conventional technologies according to Scott Dallimore, the Geological Survey of Canada researcher in charge of the drilling program.

which are power plants and another 4 percent of which are refineries or chemical plants) are most suitable for sequestration initiatives. In 2004, 4365 assessed stationary sources produced around 3.8 billion metric tons of CO_2, which was almost 54 percent of U.S. CO_2 emissions in that year. NETL determined that oil and gas reservoirs in the United States and Canada could sequester around 82 billion metric tons of CO_2. The estimates for potential sequestration in coal seams not suitable for mining range from 156 to 183 billion metric tons of CO_2. The estimated sequestration range for deep saline reservoirs is 919 to 3378 billion metric tons of CO_2. Many of these potential reservoirs are also well situated beneath industrial areas of the Midwest, New Jersey, Delaware, Florida, Central and Southern California and along the Gulf Coast.

It is possible that the marginal costs of sequestration (especially for enhanced oil and gas recovery) could be lower than the costs of reducing emissions from burning fossil fuels. Furthermore, sequestration could be consistent with enhanced recovery of domestic oil and natural gas resources. In either of these cases, U.S. domestic energy security could be compatible with a climate change policy that encourages sequestration.

Limiting Potential Harmful Consequences of Climate Change

Controlling emissions and increasing sequestration each attempt to reduce the anthropogenic element of climate change by controlling the build-up of CO_2 in the atmosphere. Another approach to dealing with climate change involves taking steps to limit the damages that could occur as climate change progresses. Thus, if we accept that climate will continue to change, efforts could focus on limiting the harmful consequences and accentuating any future beneficial effects rather than limiting or sequestering emissions today. Any number of measures can be taken to reduce the likelihood of large damages from climate change. For example:

- dykes can be built to protect vulnerable coastlines;
- building wind-variance codes can be altered to limit damage from high winds;
- improved evacuation plans and procedures can be developed to more quickly get people out of harm's way;
- new, more resilient agricultural crops or techniques can be developed;
- governments can cease the subsidization of activities that increase the harm from climate change, such as those that encourage development in vulnerable areas; and
- people could be compensated to move from areas susceptible to flooding.

Of course, the costs of each of these measures, and any other for that matter, would need careful scrutiny before being implemented. If any of these measures could prove to be cheaper than limiting or sequestering CO_2 emissions, then they should be considered in place of the alternative.

Improving Remediation of Damages

Another policy response that involves accepting that the global climate will continue to change focuses on better recovery from any damaging climatic events that occur. Unlike the measures in the previous section, these policies do not attempt to take precautions to limit damages before an event occurs. Rather, they assist with recovery after a damaging event in order to make it less costly to the people who have been affected. Examples of improved remediation of damages could include:

- developing better procedures and planning to move human and material resources into place so they can be more effectively deployed after a disaster;
- improving cooperation and planning and sharing resources, between disaster relief teams from different areas; and
- developing a better civil reconstruction capability.

An important thing to note about these measures is that they yield benefits in many situations apart from extreme weather events including, for example, earthquakes, tsunamis, fires, industrial and transportation accidents, and terrorist attacks.

Other Considerations Relevant to Designing an Optimal Climate Change Policy

The fact that climate change can result from many anthropogenic and natural influences bears critically on the expected benefits of measures aimed specifically at dealing with climate change. Anthropogenic influences aside from the emission of greenhouse gases, such as land-use changes, the establishment of large-scale irrigation, and the enhancement of urban heat islands, have all been shown to have significant effects on local climates.

Most importantly, there is evidence in the geologic record that climates continually change as a result of natural forces. For example, the periods known as the Little Ice Age, Medieval Warm Period and Roman Warm Period are well documented and appear to be of natural origin. Scientific evidence also attests to what used to be known as the Holocene Optimum as a period of warmer than current temperatures around 7,000 years before the present. Going further back in time, the ice ages (the most recent one ending about 11,000 years ago) are also of natural origin. On a shorter time scale other natural climate phenomena, such as fluctuations connected with the major ocean basins – the El Niño-La Niña Southern Oscillation, the Pacific Decadal Oscillation and the Atlantic Multi-decadal Oscillation – have been occurring for eons and appear to have dramatic effects on the frequency and severity of droughts, floods and violent storms (including hurricanes and tornadoes) at the decadal scale.

The fact that climate change can result from many sources is important because the larger the proportion of climate change due to factors other than the accumulation of CO_2, the stronger the argument for using measures that mitigate or remediate damages. Such measures will help protect against climate change regardless of its source, while limiting CO_2 emissions or increasing CO_2 sequestration addresses only one source of climate change.

Another factor that differentiates CO_2 from air pollutants such as particulates or oxides of sulfur and nitrogen is that CO_2 is not directly hazardous. Rather, the potential harm associated with CO_2 is associated with its gradual accumulation in the atmosphere over time.[7] By contrast, pollutants such as particulates or oxides of sulfur and nitrogen are directly hazardous to human health or assist in the formation in ozone, which is also hazardous to human health. In order to control the potential damage associated with such pollutants, they need to be controlled with immediacy and local to their sources.

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[7] In technical terms, the negative externality is associated with the *stock* of CO_2 while for particulates or oxides of sulfur and nitrogen, the negative externality is associated with the *flow*.

Since the harm from CO_2 arises from a gradual accumulation, the long-term potentially harmful consequences will be the same under many different alternative paths of accumulation over time. For example, assume that very harmful consequences are projected to occur only when CO_2 concentrations in the atmosphere exceed 500 parts per million (ppm) by volume. In this case, it makes little difference to the discounted costs if the build-up occurs at the rate of 2 ppm per year for 50 years followed by 1 ppm for 15 years, or the build up occurs evenly at around 1.77 ppm per year over the same 65 year period. Since potential climate change is associated only with the accumulated stock of CO_2, reducing accumulation by a greater amount in the future and a lesser amount today is a close substitute for reducing the accumulation by a larger amount immediately and a smaller amount in the future. In fact, when one considers the costs of reducing CO_2 accumulations, there are important reasons to plan for gradual reductions in the near term with more aggressive reductions in the future.

One potentially very large cost that would result from extreme near-term controls on CO_2 emissions is that a substantial amount of electricity generating capacity would be made obsolete and would need to be replaced. A much less costly path would involve committing to emission controls on future plants, so new capacity produces less CO_2, but allow existing plants to continue to generate electricity until they have reached their useful economic life.

The fact that more aggressive future control can substitute for more aggressive near-term control has another implication. As long as there is uncertainty about the costs or benefits of control, there may be an option value to delaying a particular course of action. For example, it may make sense to invest heavily in resolving the uncertainties in climate science rather than spending those same resources on controlling emissions today. If the new information reveals that the problem is less serious than we thought, we can save on incurring costs of control. On the other hand, if the new information reveals the problem is more serious, stronger controls can be put in place to achieve the same long term level of CO_2 accumulation.

Similarly, if there is uncertainty about future cost reductions for various alternative energy technologies, there is a benefit to waiting to see how those different technologies develop. If technologies develop such that non-fossil fuel energy sources become economically competitive in a short amount of time, then CO_2 emissions will be reduced without further policy interventions. Not waiting runs the risk of wasting resources on an inferior alternative technology.

A powerful counter-argument to there being an option value to delaying is that there could be learning-by-doing. For example, the most effective way of reducing the costs of using alternative energy technologies in, say, power generation or industry may be to build commercial scale plants. As experience is gained, the costs are likely to fall. This favors immediate action to promote investment in alternative energy technologies.

IV. ARE CLIMATE CHANGE AND ENERGY SECURITY POLICIES COMPLEMENTARY?

There are clearly several policies that can serve both the climate change and energy security policy goals. The most obvious would be policies that increase the use of non-fossil sources of energy, such as nuclear, wind, solar, hydroelectric and geothermal power for generating electricity and biofuels, hydrogen and electricity for transportation.

While some of these options could both increase energy security and reduce CO_2 emissions, they may be relatively expensive, be associated with other undesirable externalities, or compromise other policy goals. For example, the policy of encouraging the use of corn as a feedstock to grow ethanol production for use as a transport fuel has raised the cost of not only corn, but also beef, milk and other agricultural products. This, in turn, has significant consequences for many important issues ranging from domestic inflation to the cost of international food assistance for developing countries. Moreover, it may actually provide an additional link through which high energy prices can affect the economy, especially as food prices become more closely linked to crude oil prices. Ethanol from corn is not the only example of a non-fossil energy source receiving negative backlash. There is considerable controversy over the effects on communities and river-based ecosystems of very large hydroelectric projects, such as the Three Gorges Dam in China, while proposed wind farms have been rejected on the grounds that they would spoil attractive landscapes or interfere with wildlife, especially birds.

Perhaps the clearest example of a policy that could serve to both enhance energy security and lower CO_2 emissions is an increase in energy efficiency. Energy is a *derived* demand. We demand energy commodities for the services they facilitate. If consumers can, at a reasonable cost, achieve a given amount of energy service, such as transportation or space heating/cooling, using less primary energy input then they will do so. Thus, by reducing the demand for energy below what it would otherwise be, increased energy efficiency may reduce the vulnerability of the economy to energy market shocks. To the extent that the reduced energy consumption results in lower use of fossil fuels, it also helps reduce CO_2 emissions below what they otherwise would have been. In this way, energy efficiency acts as a *virtual* source of supply.

Improvements in energy efficiency generally occur over time as firms and consumers seek to lower their user cost of energy-using capital equipment. However, there are factors that can delay such improvements. For example, it is generally true that replacing older, obsolete capital equipment with newer vintages can increase energy efficiency. But, if maintenance costs for the old equipment are low, it may still be expensive to replace the older capital despite the energy cost savings.

The building and insulation codes for commercial and residential structures also have bearing on energy use. New structures often are more energy-efficient than older ones. In this case, however, new structures are not needed to benefit from improvements in energy efficiency because buildings can be retrofitted with newer insulation, double-paned windows, and other items that raise energy efficiency. As an example, Wal-Mart has instituted a very aggressive program to raise the energy efficiency of its stores. They claim that their daylight/dimming system used in their U.S. stores has savings of about 250 million kilowatt-hours (kWh) a year. They also use high-efficiency heating and cooling units and have found that they can significantly reduce energy use by controlling the units centrally from Bentonville, Arkansas. They report that the complete set of energy-efficiency measures that they have adopted reduces the electricity consumption in their California stores by about 4.5 million kWh per month.

Current and expected future energy prices play a critical role. If the price of energy is high and is expected to remain so, then investments in energy efficiency are more likely to be cost-effective. In particular, only when prices are expected to remain high will firms and households, in general, find it worthwhile to invest in new capital with higher levels of energy efficiency.

Policy also can foster increased energy efficiency. In general, there are many ways of increasing energy efficiency in addition to installing new capital, including altering procedures and processes, changing fuels, or adopting new technologies. As a result, the most effective way of achieving efficiency improvements is to raise the price of energy to provide incentives for firms and consumers to find the best ways to respond. The alternative of direct quantitative controls, for example mandating particular pieces of equipment, typically will achieve lower gains for the same cost. This is a general conclusion from the environmental economics literature, which has long demonstrated that direct regulatory controls of environmental externalities are much more costly than more market-based mechanisms (see, for example, Atkinson and Lewis (1974), Seskin et al. (1983), Kolstad (1986), Magat et al. (1986), Oates et al. (1989), Jaffe and Stavins (1995), and Viscusi (1996)).

While some policies can enhance energy security while reducing CO_2 emissions, and thus appear as “two sides of the same coin,” there are other policies that have conflicting implications for these two goals. In particular, limiting diversity of fossil fuel sources of supply will compromise energy security goals, and limiting especially the use of coal and unconventional oil supplies will have strong negative implications for the energy security of the United States and Canada. Such policies also would make the world as a whole more dependent upon an unstable Middle East and an increasingly unpredictable Russia for an even greater proportion of its crude oil and natural gas supplies.

The Canadian province of Alberta has recently become a major producer of unconventional oil from bituminous sands in the Athabasca region of Alberta (popularly called the Athabasca tar sands). Heat and water are needed to upgrade the bitumen in these sands to synthetic crude that is suitable for transport and refining. Currently, natural gas provides much of the energy for this process, although plans to consider using nuclear energy have been announced. Since the bitumen contains hydrocarbon chains with a higher ratio of carbon to hydrogen than conventional crude, using it to produce gasoline and other oil products inevitably involves the joint production of larger amounts of CO_2 than normally associated with the use of conventional crude oils. Hence, exploitation of this resource is not consistent with the goals of climate change policy. From the perspective of energy security, however, this resource represents a large supply of oil in a country with a stable political and economic system, making it of considerable value.[8] When it comes to the Athabasca tar sands, climate change policy and energy security are most definitely *not* "two sides of the same coin."[9]

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[8] For example, the International Energy Agency World Energy Outlook for 2006 projects non-conventional oil production, mainly from Canadian tar sands which is expected to reach 9 million barrels per day, to contribute almost 8percent of global oil supplies by 2030.

[9] The conflict between these objectives has become evident in a proposal to repeal section 526 of the "Energy Independence and Security Act of 2007." This provision prevents U.S. Federal agencies from procuring "alternative or synthetic fuel, including a fuel produced from unconventional petroleum sources, for any mobility-related use … unless the contract specifies that the life cycle greenhouse gas emissions associated with the production and combustion of the fuel …[are]…less than or equal to such emissions from the equivalent conventional fuel produced from conventional petroleum sources." Since the section

While the Athabasca tar sands are of particular interest from the perspective of enhancing U.S. and Canadian energy security, they, as well as other similar types of unconventional oil resources, could also provide price stability in the global oil market. Figure 3 provides 2005 estimates of bituminous oil resources from various countries and regions, as reported by the World Energy Council (WEC). These figures do not include resources in Venezuela, which that country categorizes as "extra heavy oil." The WEC also reports that the total world resources of bituminous oil in place amounts to 3.27 trillion barrels, which is considerably larger than the 1.22 trillion barrels of proved recoverable reserves of conventional crude oil and natural gas liquids (NGL) reported by WEC member countries.[10]

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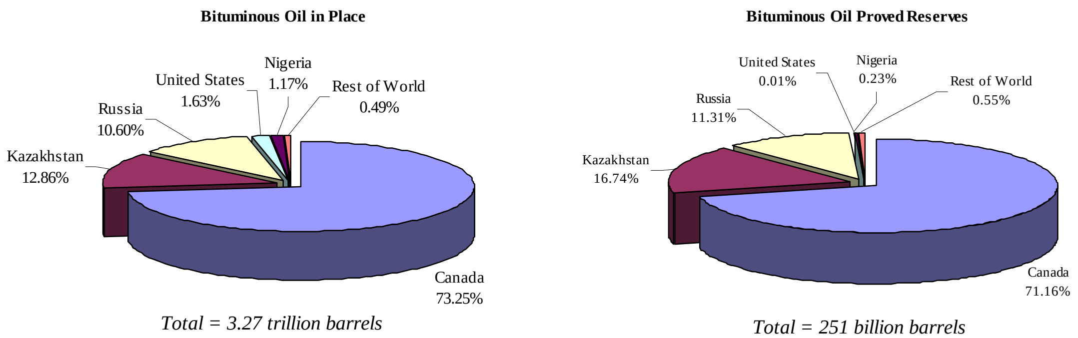
does not define "conventional" sources or "lifecycle greenhouse gas emissions" it is unclear how it might be interpreted or implemented in regulations. House Oversight Committee chairman Waxman and ranking member Davis recently asked the Department of Defense how it intends to comply with section 526 with regard to coal to liquid fuel or fuels from tar sands. In their letter, Waxman and Davis noted the complications arising from the fact that refiners use inputs from a variety of sources. Questions have also been raised about whether section 526 violates the WTO government procurement agreement or other WTO rules, while the Canadian government has already warned that it may challenge the provision if it discriminates against fuels derived from Canadian tar sands. On April 29, 2008 Senator Pete Domenici, ranking member of the Senate Energy and Natural Resources Committee, asked leaders of the Senate Armed Services committee to repeal section 526 on the grounds that it "will make it more difficult and expensive for the US military to obtain fuel."

[10] The WEC warns that the reported reserves represent only a sample of all potential reserves in the world. They also compile data on crude oil and natural gas liquids resources in place, but far fewer member countries report these so we have used the reserves figures.

Figure 3. Distribution of Estimated Resources and Reserves of Bituminous Oil 2005

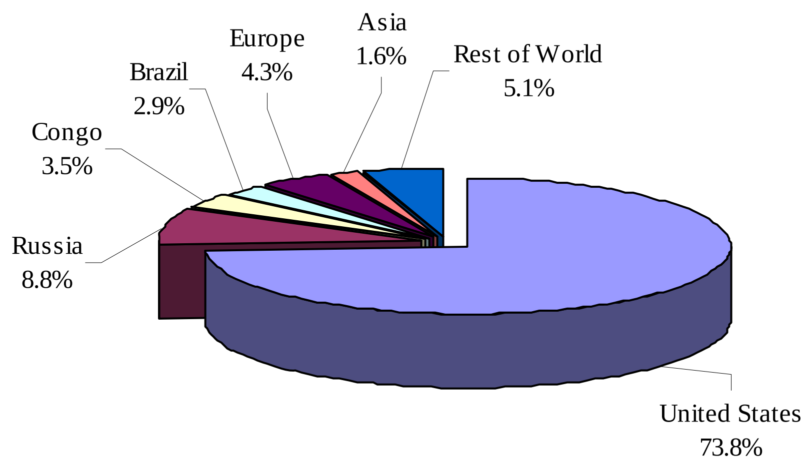


Source: World Energy Council

The potential misalignment of global climate change policy and energy security policy for North America does not end with the bituminous oil reserves of Canada. The WEC also reports estimates of shale oil resources in member countries, which are summarized in Figure 4.

Again, the estimated shale oil resources are very large relative to the estimated recoverable reserves of conventional crude oil and NGL. Furthermore, almost three-quarters of these resources are found in the United States alone. Therefore, shale oil could be a critical source of supply to enhancing energy security of the United States and the western world more generally. If the United States produced more oil from shale resources and Canada produced more oil from bitumen, North American demands on conventional oil resources would decrease substantially. This is quite substantial for global crude oil market since the United States alone consumes almost 25 percent of the world's petroleum. Allowing more of those resources to be consumed by the rest of the world could have a significant dampening effect on price. In turn, this could provide stability in energy markets since a larger proportion of the world oil market will be supplied by stable developed economies.

Figure 4. Distribution of Estimated Resources of Shale Oil 2005



Total = 2.83 trillion barrels

Source: World Energy Council

On the other hand, as with bituminous sands, exploiting shale oil would result in greater emissions of CO_2. Requiring CO_2 sequestration, however, would likely make exploiting shale oil uneconomic, even at oil prices of $100 per barrel. As with the bituminous oil in Canada, energy security and climate change policy are not "two sides of the same coin" with regard to the exploitation of the vast amount of shale oil in the Unites States. The International Energy Agency projects that unconventional oil could represent as much as 9 million barrels per day (b/d) of the incremental 30 million b/d to 40 million b/d of new oil supply that will be needed to meet demand by 2030. Canadian tar sands production could reach as high as 4 million b/d to 5 million b/d while upgraded heavy oil could represent an additional 2 million b/d and coal to liquids and oil shale could provide an additional 1 million b/d to 2 million b/d. If this supply were to be curbed to meet carbon reduction goals, dependence on Middle East oil supply would be substantially higher in the coming decades.

Policies affecting the use of coal offer yet another area where the goals of energy security and climate policy conflict, especially for a country such as the United States. North America is projected to become a large importer of natural gas in coming decades. The advent of combined cycle gas turbines has made natural gas a much more competitive fuel for generating electricity. This, coupled with the environmental advantages of burning natural gas relative to coal and oil, has stimulated demand for gas around the world, not just in North America. As demand has grown, the major producing basins in the mature markets in United States and Canada are at or nearing decline, implying that production will not be able to keep up with expanding demand. This has prompted a great deal of investment in developing LNG import capacity into North America.

As the demand for LNG imports into North America increases, similar issues that affect energy security via the oil market could begin to arise with natural gas. Most of remaining proved and potential reserves of natural gas are estimated to be in the Middle East and Russia. Thus, importing countries will become increasingly reliant upon the suppliers from the same regions of the world for both natural gas and conventional oil.

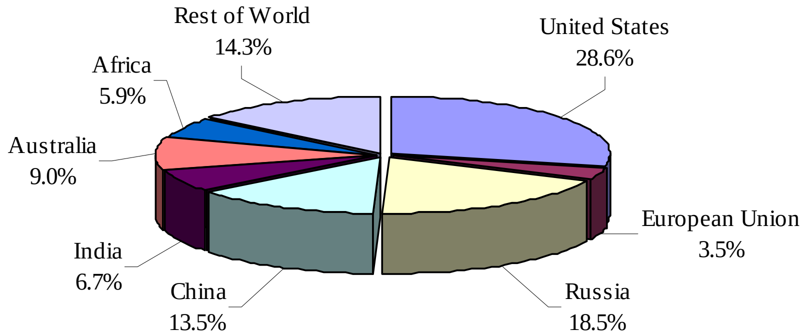
In the United States, coal is used to generate around about 50 percent of total U.S. electricity supply, with natural gas and nuclear each providing about 20 percent.

Hydroelectricity supplies another 7 percent, oil products just under 2 percent and other sources, including renewables, provide slightly over 2 percent. Perhaps more significantly, the reference case for the Energy Information Administration's 2008 Annual Energy Outlook projects that coal-fired generating capacity (new plants less retirements) will grow at an annual rate of around 1.29 percent from 2008-2030 compared to 0.68 percent for nuclear power, 0.89 percent for natural gas combined cycle and 1.51 percent for all renewable sources. Furthermore, since coal is a baseload source of power generation and natural gas plants are typically further up the supply stack (so they are generally operated for fewer hours/day), the coal input measured in terms of energy content is expected to increase at an even faster rate relative to natural gas. Any policy that limits the use of coal, which is more carbon intensive fuel than natural gas, will tend to increase reliance on natural gas.[11] This could have negative consequences for energy security.

Figure 5 reports WEC estimates of proved recoverable reserves of coal in selected countries or regions in 2005. In those regions of the world where coal is abundant, it can be used in a cost-effective manner to produce both natural gas and liquid fuels. Indeed, before the widespread use of natural gas, many cities relied on coal gasification to provide reticulated gas supply. In addition, gasified coal can also be used in the Fischer-Tropsch process to produce a very clean liquid transportation diesel fuel.

[11] Natural gas is the likely primary alternative, with wind and other renewables filling a niche, because gas facilities are relatively easy to site and construct, can be operational rather quickly (24-30 months in most cases), are very reliable and highly efficient.

Figure 5. Distribution of Estimated Proved Recoverable Reserves of Coal 2005



Total = 847.5 billion tons

Source: World Energy Council

It is quite clear that, for the United States in particular, barring the use of coal substantially diminishes energy security relative to the case where coal can continue to be used to provide the bulk of the U.S. electricity supply. On the other hand, coal produces more CO_2 per unit of electricity supplied than any other fossil fuel, so barring its use is consistent with the goals of climate change policy. In this case, therefore, energy security and global warming policy once again most definitely are not "two sides of the same coin."

V. SCENARIO ANALYSIS

To investigate the implications of reducing the use of coal to generate electricity in the United States, we used the Rice World Gas Trade Model (RWGTM). The RWGTM is a dynamic spatial general equilibrium model based on the software platform *Market Builder* from Altos Management Partners, a flexible modeling system widely used in industry. The model calculates prices to balance supply and demand at each location in each period such that all spatial and temporal arbitrage opportunities are eliminated. The model thus seeks equilibrium in which sources of supply, demand sinks, and the transportation links connecting them, are developed over time to maximize the net present value of investments in new supply and transportation while simultaneously accounting for the impact of these new developments on current and future prices. Output from the model includes regional natural gas prices, pipeline and LNG capacity additions and flows, growth in natural gas reserves from existing fields and undiscovered deposits, and regional production and demand.

The resource data underlying the model is based on proved reserves obtained from the *Oil and Gas Journal* and an assessment produced by the U.S. Geological Survey (USGS). The costs of exploiting resources globally are based on National Petroleum Council (NPC) estimates of North American development costs for fields with similar geologic characteristics.

The supply data is combined with economic models of the demand for natural gas based on the assumption that there are five major determinants for natural gas demand: (i) population, (ii) economic development, (iii) resource endowments and other country specific attributes, (iv) the relative price of different primary fuels and (v) technological developments in alternative energy sources.

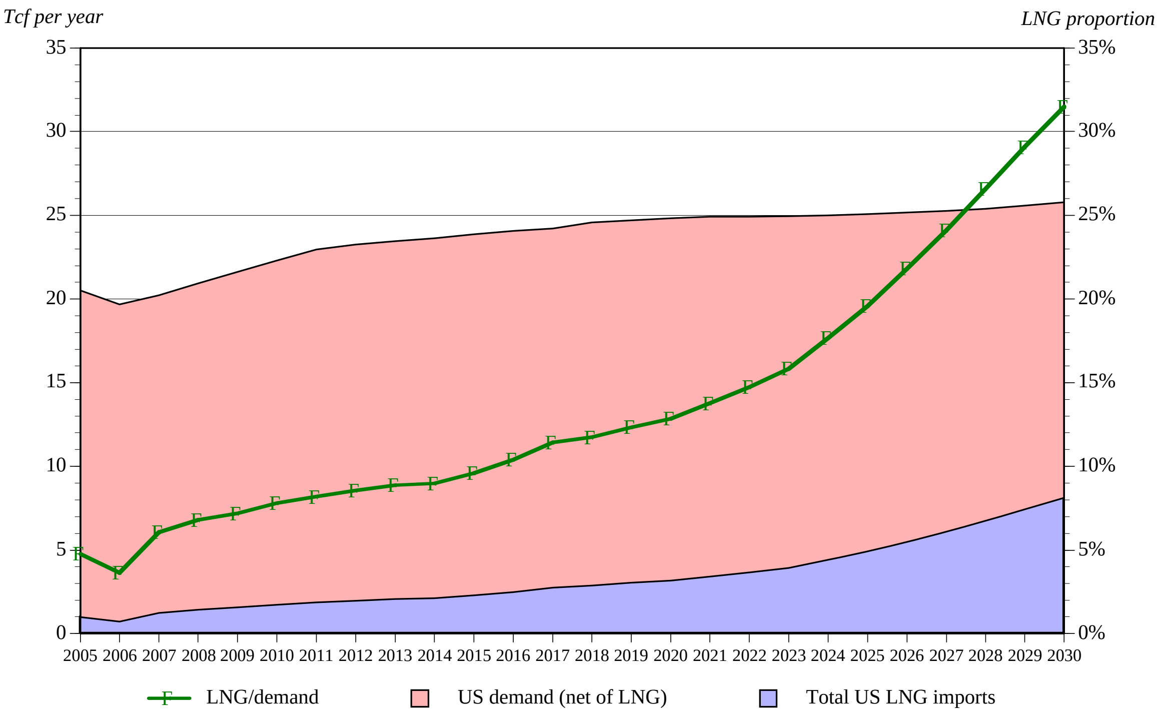
The costs of constructing new pipelines and LNG facilities were estimated using data on previous and potential projects available from the EIA, IEA and various industry reports. Variable costs and transportation rates are either taken from a variety of industry sources where available or estimated based on rate of return considerations otherwise.

The data used in estimating demand were obtained from the U.S. Energy Information Administration (EIA), the International Energy Agency (IEA), the World Bank, and the Organization for Economic Cooperation and Development (OECD). The extent of regional detail in the model varies based primarily on data availability and the potential influence of particular countries on the global natural gas market. For example, large consuming and producing countries, such as China, the United States, India, Russia, and Japan, to name a few, have extensive sub-regional detail in order to understand the effect that existing or developing intra-country capacity constraints could have on current or likely future patterns of natural gas trade. In sum, there exist over 280 demand regions and more than 180 supply regions.

Projected demand in the RWGTM Reference Case for natural gas in the U.S. power industry is based in part on the EIA Annual Energy Outlook reference case projections of additions to natural gas fired generating capacity. We then examined an alternative scenario, a Coal-Constrained Case, where all new coal-fired capacity included in the EIA reference case was replaced by natural gas. In both the Reference Case and the Coal-Constrained Case, the projections are only partly based on the EIA projections because we allow for coal-fired plants *with* CO_2 sequestration (which are more expensive than conventional coal) to begin to displace natural gas plants as the price of natural gas rises. The cost of coal-fired plants with sequestration is based on the estimate of costs provided by the Office of Fossil Energy in the U.S. Department of Energy.

Figure 6 graphs predicted total U.S. demand for natural gas from 2005-2030. Also illustrated is the component of that demand that is met by imports of LNG directly into the United States and indirectly via imports into Canada and Mexico that are subsequently shipped by pipeline to the United States. The line overlay in Figure 6 presents LNG imports as a percentage of the overall demand.

Figure 6. U.S. Demand for Natural Gas in the RWGTM Reference Case

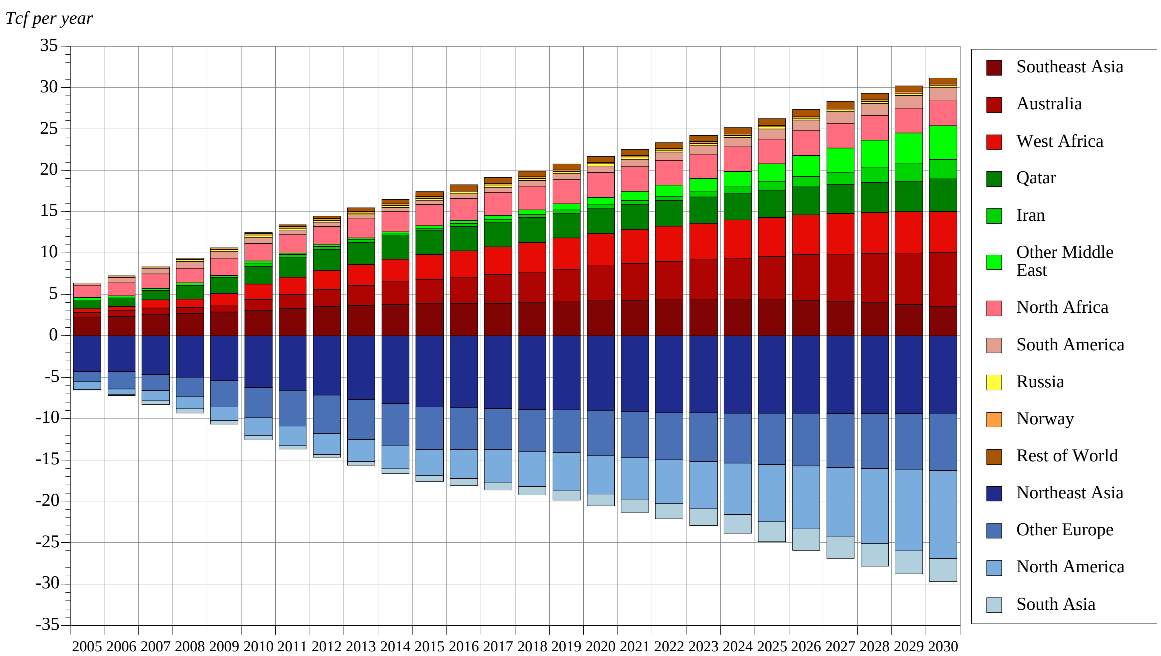


Source: Calculations based on the Rice World Gas Trade Model

While the projected growth in the total demand for natural gas is relatively steady, imports from overseas expand rather dramatically after 2020. This occurs because domestic sources of natural gas begin to be much more expensive to exploit relative to the cost of imported natural gas beyond that date. By 2030, the model indicates that over 30 percent of U.S. demand for natural gas will be met by LNG imports.

While the flow of LNG from specific suppliers is likely to fluctuate from one year to the next depending on factors such as different weather patterns that impact the demand in one place but not another, it is possible to assess how vulnerable the world market for LNG may become to supply disruptions by looking at the various sources of LNG supply.

Figure 7. Forecast Trade in Liquefied Natural Gas under the EIA Reference Case



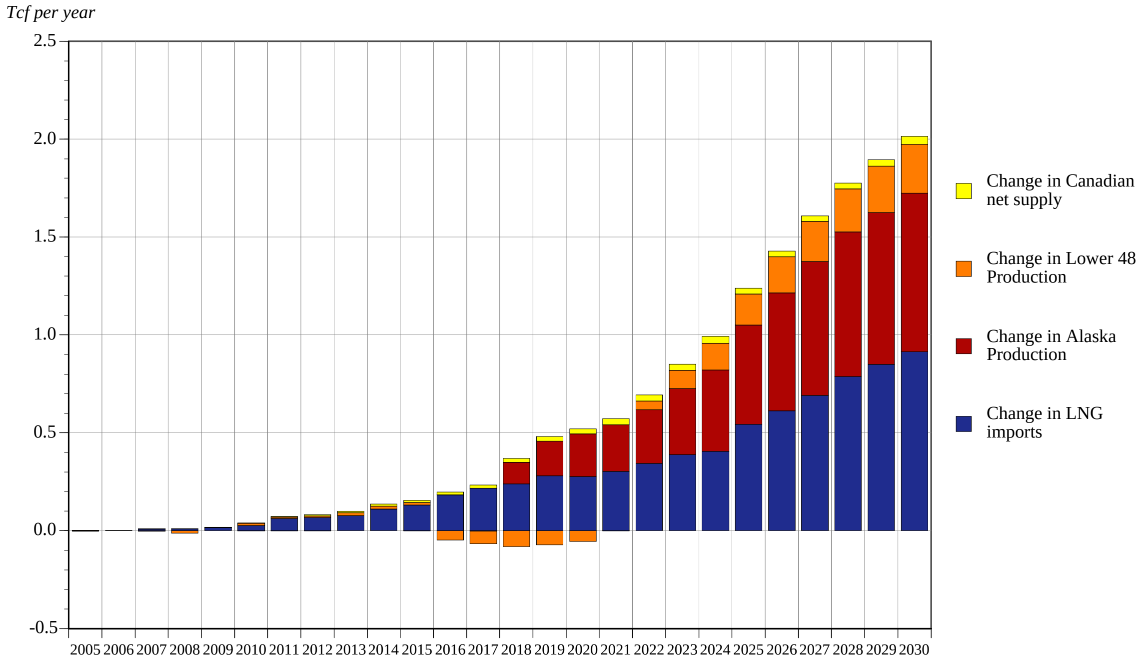
Source: Calculations based on the Rice World Gas Trade Model

Figure 7 graphs the Reference Case projections for trade in LNG separated on the supply side (top half of the graph) into a few major exporting countries with the remaining sources aggregated into regions. The lower half of the figure also shows how imports are likely to split across regions.

Given that the world has previously experienced a serious disruption of oil supply from the Middle East, of particular interest from the perspective of energy security is the share of Middle East exports in the world LNG market. This is indicated in Figure 4 by the areas depicted in various shades of green. Beyond 2020, when the United States is projected to become a major importer of LNG, the share of Middle East exporters in the world LNG market rises dramatically. Iran and Qatar are projected to become the two largest suppliers of LNG from the Middle East, although a range of other smaller suppliers also contribute a substantial share of world LNG exports beyond 2020.

In order to understand the possible energy security implications of limiting the use of coal for generating electricity in the United States, we ran a Coal-Constrained Case in which we assumed that the projected net increase in coal-fired generating capacity in the EIA reference case was instead supplied by additional NGCC plants. This case is then compared to the Reference Case to assess the impacts. It is important to point out that this will likely understate the consequences for natural gas demand of prohibiting the construction of new coal fired generating plants because natural gas plants are currently predominantly used to supply power in the middle of the supply stack. Coal plants, by contrast, supply baseload power. If more natural gas plants were to supplant coal plants, more of them would be operated as base load plants, and hence they would be used for more hours of each day than the typical NGCC plant is operated today. Our econometrically estimated relationships between plant capacities and fuel consumption represent the way plants currently are operated, not the way they would be operated if natural gas were used to supply more baseload power.

Figure 8. Changes in Natural Gas Supply to the United States with Coal Use Constrained



Source: Calculations based on the Rice World Gas Trade Model

Figure 8 shows that if the net addition of conventional coal capacity is instead replaced by natural gas combined cycle, the share of LNG imports in U.S. natural gas supply will rise. When one examines the data underlying Figure 5, it turns out that Venezuela is the most significant source of increased LNG imports for the United States. Given the troubled relations between the United States and Venezuela in the past, this raises an obvious energy security issue. The other major source of increased supply is Alaska. If, however, the Alaskan pipeline is not constructed for environmental reasons, this gas, too, would be replaced by increased LNG imports.

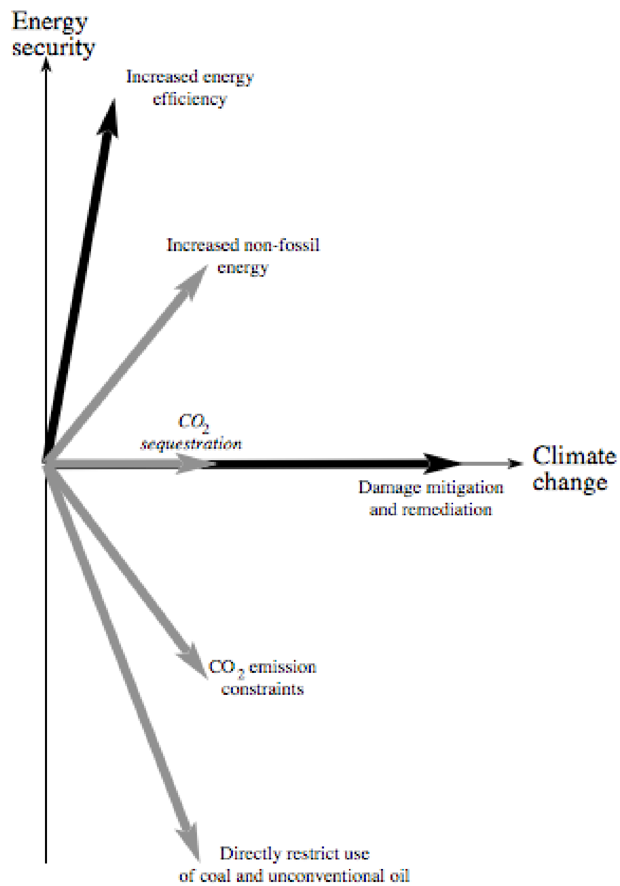
VI. INSTRUMENTS AND TARGETS

We can summarize the preceding discussion with the simple vector diagram depicted in Figure 6. On the horizontal axis, we place the policy target of reducing the harmful effects of climate change, while on the vertical axis we place the policy goal of enhancing energy security. We can then plot some of the key policy instruments to see how they are likely to affect both goals.

The policy vectors drawn in gray all have an uncertain effect on the negative consequences associated with climate change because they all address climate change *indirectly* via their effect on CO_2 emissions. To begin, the effect of changes in U.S. policy alone will depend greatly on whether other countries match those policies. If they do not, there is likely to be substantial "carbon leakage," which, as noted above, could actually be counter-productive from the perspective of controlling global emissions of CO_2. In addition, since climate change can be attributed to factors other than CO_2 accumulations, such as natural forces or anthropogenic factors other than CO_2 emissions, the extent to which changing the concentration of CO_2 in the atmosphere alone can alter climate change is uncertain.

From the perspective of Figure 9, a policy of encouraging greater energy efficiency stands out as contributing positively to both goals. Another policy where the conflict is minimal is encouraging the increased use of non-fossil energy sources.

Figure 9. Policy Instruments and Targets



In the longer term, finding a cost-effective, environmentally benign and secure alternative to fossil fuel is essential. It is the only way of coping with the accumulation of CO_2 that is consistent with sustainable economic development. As noted above, we will eventually proceed down this path as supplies of fossil fuel dwindle. However, encouraging faster development of these alternative technologies in a cost-effective manner so the transition occurs more rapidly can contribute to both increased energy security and reduce the risk of serious climate change.

Energy Taxes

The favored climate change policy instrument at the moment involves taxing or directly limiting emissions of CO_2. There is a large literature on the relative merits of taxing emissions of CO_2 versus directly limiting them through a "cap and trade" scheme that places a quantitative limit on emissions but allows the emission permits to be traded. With no uncertainty over abatement costs or the marginal damage from emissions, an emission tax or marketable permit system should work equally well in limiting emissions. In a more realistic setting, however, the efficiency of the two instruments is likely to differ. The classic article in this literature, Weitzman (1974), argues that if the marginal costs of abatement rise faster than the marginal damages of emissions, then emission fees are likely to be more efficient than permits, and vice versa. This result has remained largely intact in the subsequent decades of research with more complicated models.[12] Nordhaus (2005) observes that its application to the control of CO_2 emissions gives a strong presumption in favor of emission taxes rather than permits. The reason is that, as noted earlier, the presumed damages from CO_2 emissions are related to the stock of CO_2 in the atmosphere whereas the costs of control are related to current emissions. Since (as argued above) future controls are a close substitute for current controls, marginal damages from emissions in any single year will not change that much. On the other hand,

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[12] The main modification has been research showing that under various circumstances hybrid price and quantity regulations are likely to be more efficient than the "pure" version of either type of control (see, for example, Roberts and Spence (1976), Kwerel (1977), Dasgupta et al (1980), Spulber (1988) and Bulckaen (1997)).

the marginal costs of emissions control are likely to increase much more rapidly since progressive reductions in emissions will be much more expensive to obtain.[13]

Hassett and Metcalf (2007) also observe that, while a permit system could raise revenue by auctioning the permits off, in practice existing sources have been issued permits without charge. The resulting forgone revenue is likely to exacerbate the efficiency costs of the system. It also encourages wasteful rent-seeking behavior as firms lobby to be given a larger permit allocation. A related point is that permit systems for CO_2 emissions are likely to have extremely high administrative costs in practice as detailed studies are undertaken to assess the “lifecycle emissions” of different processes before permits are issued or emissions are checked against permit levels.

We do not dwell on the differences between CO_2 taxes and emission permits, however, since we believe that either of these policies is inferior to a third alternative. To make the distinction between CO_2 taxes or permits and this third alternative clearer, it is simpler to focus on CO_2 taxes, although the same arguments can be made about a permit scheme. A tax on CO_2 emissions can be viewed as a tax on *energy* combined with a *rebate* for energy production that increases the less CO_2 emissions the energy source produces. Thus, natural gas would get a larger implicit rebate than coal, and wind power would get a larger rebate than both natural gas and coal. The tax on CO_2 emissions would

[13] This result perhaps is a major part of the explanation for the very strong preference among economists who have examined the question for CO_2 emission taxes rather than permits while at the same time environmental economists on the whole have a very favorable view of the SO_2 emissions trading scheme in the United States.

thus tend to reduce CO_2 output in two ways. First, by raising the overall price of energy, it would tend to encourage increased energy efficiency and thus reduce energy use. Second, it would tend to alter the energy mix away from fossil fuels that produce more CO_2 emissions.

An alternative policy that also tends to encourage energy efficiency and stimulate the development of non-fossil fuel energy sources would be to raise the tax on energy consumption, no matter what the fuel source, and then target the revenue toward research into selected non-fossil sources of energy. In particular, the implicit rebates to less CO_2 intensive forms of energy under the CO_2 tax could instead be targeted more purposefully wherever the policy maker desired.[14]

Under both the CO_2 emissions tax and our proposed alternative policy, the tax on energy use would encourage conservation and increased energy efficiency. The implicit rebates under the CO_2 emissions tax, however, would encourage low CO_2 emitting energy sources that are *close to commercial viability today*, while more explicit subsidies to research and development could be targeted at basic research into technologies that are not as close to commercial viability today yet hold greater long term promise for displacing massive amounts of fossil fuel. Thus, although the two policies are similar, they differ in three important respects.

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[14] While a CO_2 emissions tax also would raise revenue that could be used to subsidize fundamental research into promising non-fossil sources of energy, the embedded rebates for low CO_2 emitting sources of energy imply that, for the same tax rate on energy use, the emissions tax would raise much less revenue.

Until competitive non-fossil sources of energy are developed, an energy consumption tax would not be biased against more CO_2-intensive fossil fuels and therefore would be less adverse to energy security. In particular, the combined energy tax and subsidy policy would not encourage imported LNG at the expense of coal, or imported Middle East oil at the expense of Canadian bituminous sands. It would, however, also produce more CO_2 emissions in the short run than the alternative policies that specifically target the use of CO_2-intensive fossil fuels. If the "short run" is not very long, perhaps because the subsidies result in rapid development of economically competitive alternative energy sources, the difference in CO_2 emissions in the long run along the two policy paths will not be great. A related issue involves the fact that the combined energy tax and subsidy policy could be altered to more closely mimic the CO_2 tax if additional information shows that more aggressive action with regard to CO_2 may be warranted.

The second major difference between the two policies is that they most likely would favor different non-fossil energy sources. We have already argued that a constraint on CO_2 emissions, such those present in either a cap-and-trade program or a tax on CO_2 emissions, would tend to favor natural gas in the short run. Such a constraint would also tend to favor those non-fossil fuel sources that are currently the most competitive, such as ethanol fuel and wind power. However, these are not necessarily the technologies that have the best long-term prospects for providing the large amounts of primary energy needed to meet growing demand while simultaneously displacing the largest volume of fossil fuels and reducing carbon emissions to the greatest extent. By contrast, research subsidies financed by an energy tax could be directed toward the non-fossil sources, such as large-scale solar electricity generation, that have the greatest chance of permanently eliminating fossil fuels as an energy source. In addition, subsidies could be directed at *basic* research that might be more important at this stage than the more applied research that would be encouraged by direct constraints on CO_2 emissions.

The third major difference between the two policies is that the policies that directly target CO_2 that have been implemented to date do not actually involve a tax. Rather, they have involved direct limitations on CO_2 emissions or some allocation of marketable emission permits to firms for use in a cap-and-trade program.[15] Hence, while the direct energy tax and subsidy policy could set aside some revenue for mitigation and remediation strategies, the cap-and-trade program without an auction of the permits would not provide any funds to support such policies. Even if the permits were auctioned, or a CO_2 emissions tax were levied, less revenue would be raised than under the equivalent energy tax because the less CO_2-intensive energy sources are taxed at a much lower rate. A tax on all energy usage, not just energy sources by virtue of their carbon-intensity, would raise the maximum amount of money that could then be used for a mix of mitigation and remediation strategies or to develop alternative energy sources. As we noted above, the additional mitigation and remediation strategies that could be financed

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[15] Some other policies, such as the proposed penalty on oil derived from Canadian tar sands, are effectively a variant on a CO_2 emission permit scheme. They are actually inferior to a tradable permit scheme, however, in so far as they mandate a particular mix of crude oil input into the refining process regardless of whether or not that is the least cost way of reducing CO_2 emissions.

under the proposed energy tax have the advantage of protecting against the adverse effects of climate change *regardless of the source* as well as other natural and man-made disasters, such as earthquakes and terrorist attacks.

Finally, many policies designed to limit CO_2 emissions through either cap-and-trade or taxation do not provide full credits for sequestration activities, or impose taxes or require permits for land clearing. Counter-productive results could emerge, depending on the system design. For example, if incentives for increased biofuels production are strong compared to the penalties (if there are any) for deforestation, forests could be cleared to provide land for growing biofuels. Energy taxes, however, do not require authorities to adjudicate these issues by assessing the extent to which different technologies have life-cycle consequences for net additions to CO_2.

VII. CONCLUDING REMARKS

Concerns about climate change arising from anthropogenic CO_2 emissions do not necessarily imply that restricting such emissions is the optimal policy response. Rather, policy could be aimed at mitigating the likelihood of large damage associated with climate change whatever its source. Another alternative is to invest in measures that could improve recovery after climate disasters. This would have the additional benefit of assisting with recovery from non-climate related disasters such as earthquakes or terrorist attacks.

Even if restricting CO_2 emissions is part of the optimal response, policies to address climate change and energy security are not necessarily "two sides of the same coin." In fact, the goals are as likely to conflict as coincide, with some measures furthering one goal while having little effect, or even negative effect, on the remaining goal. For example, the International Energy Agency World Energy Outlook, 2006 projects that, under its reference scenario, production from unconventional oil will reach around 9 million barrels per day, or around 8 percent of world oil output, by 2030. Given the huge resources, however, it has the potential to contribute even more. Their reference case projections also have the Middle East OPEC countries supplying over 34 percent of oil in 2030 compared with a little over 27 percent in 2005.

The goals are more complementary with regard to encouraging energy efficiency and the development of large-scale non-fossil energy sources. We argue that a tax on energy use would be more effective at accomplishing the intended goal while bearing less cost. A tax encourages energy efficiency, and the revenue could be used to mitigate and remediate any harmful effects of climate change and subsidize basic R&D into alternative energy and sequestration technologies. This would make more sense for a country such as the United States than constraining the use of coal and unconventional oil, at least in the short-term. In developing effective policies to limit greenhouse gases, policy makers must pay attention to the energy security consequences of the energy sources that their policies favor. No matter how important climate change is as a goal, it is not the only policy goal, and climate policy needs to take other consequences of affecting energy markets into account.

APPENDIX.

The energy economics literature has investigated the negative correlation between energy prices and macroeconomic performance and proposed many "channels" through which energy prices could influence an economy. These are summarized as follows:

1. **Real Balances Channel:** Increases in the price of oil (energy) lead to inflation, which lowers the real value of nominal wealth (money and bonds) thereby reducing consumption of all goods and services.
2. **Monetary Policy Channel:** Counter-inflationary monetary policy responses to the inflationary pressures generated by oil (energy) price increases reduce investment and net exports, and consumption to a lesser extent.
3. **International Transfers Channel:** Oil (energy) price increases result in income transfers from oil (energy) importing countries to oil (energy) exporting countries. This, in turn, causes rational agents in the oil (energy) importing countries to reduce consumption thereby depressing output.
4. **International Financial Instability:** Large changes in oil (energy) prices lead to large monetary flows between oil (energy) importing and exporting nations. This can in turn lead to large changes in exchange rates, interest rates and the pattern of investment flows that produce correlated negative shocks to financial markets (see, for example, El Gamal (2008)).
5. **Complements Channel:** If oil (energy) and capital are complements in production, oil (energy) price increases will reduce capital utilization and suppress output.

6. **Sectoral Shocks Channel:** If it is costly to shift specialized labor and capital between sectors, then oil (energy) price increases can decrease output by decreasing factor employment. If training costs are high and the shock is expected to be temporary, specialized labor will wait until conditions improve rather than seek employment in another sector.
7. **Uncertainty Channel:** In the face of high uncertainty about price it is optimal for firms to postpone irreversible investment expenditures. Investments are irreversible when they are firm or industry specific. Firm specific examples include advertising and marketing expenditures, which are largely unrecoverable. An industry specific example is the construction of a steel plant. If the steel industry is reasonably competitive, bad times for one manufacturer will be bad for another, making the probability of resale low.

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