

***“COMBINED ISSUES OF CLIMATE POLICY
AND ENERGY POLICY:
REDUCING GREENHOUSE GAS EMISSIONS
WHILE MEETING INCREASING GLOBAL
ENERGY DEMAND”***

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GLOBAL ENERGY DEMAND**

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INTRODUCTION

Climate change is not just a complex problem but a complex of problems. Nearly everyone appreciates the need to stabilize atmospheric concentration levels of greenhouse gases (GHGs) to avoid substantial socio-economic and ecological harm.¹ But that is not the only issue. Climate change is equally a problem of energy supply. A myopic focus on reducing greenhouse gas emissions could have devastating socio-economic consequences, particularly for developing countries that are most at risk from either climate change or disruptions to energy supplies that are necessary for development. Thus, the real issue is *how* to mitigate climate change while ensuring adequate global energy supplies.

This paper addresses issues at the intersection of climate policy and energy policy. In the first place, climate change is a problem directly related to energy use, particularly the burning of fossil fuels that release carbon dioxide into the atmosphere. But energy demand has been increasing throughout the world (although not during the recent global economic downturn), and is expected to continue increasing at least through 2030. The key question, as already noted, is how to meet growing energy demand while avoiding severe economic and ecological disruptions from climate change. To date, most of the suggested answers to this question have been so

¹ A disclaimer: As a nonscientist, the author lacks the expertise to independently assess the work of the Intergovernmental Panel on Climate Change and thousands of independent scientists working on climate-related issues. Therefore, like the vast majority of social scientists who have studied the issue, this author treats the scientific basis of anthropogenic climate change as well-settled.

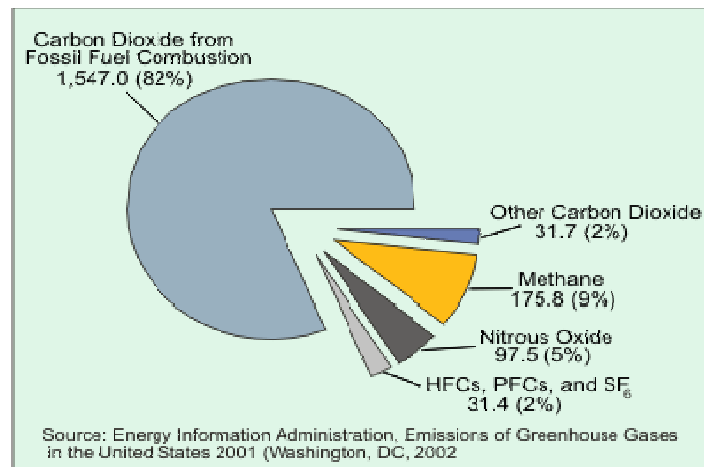
simplistic as to be virtually useless. Given the relative costs of energy supply from various sources under current and projected technologies, there is virtually no chance of any kind of major move away from coal, oil and natural gas over the next 20 years (at least). As a consequence, any climate change policy inevitably will focus on mitigating emissions from carbon-based sources of energy for which domestic and global demand is increasing. Thus, if we conceive of climate change as a battle, it is a battle that will be fought uphill, at least for the next couple of decades.

Part I of this paper examines the climate change/fossil fuel nexus. Part II examines prospective policies for dealing realistically with the combined problem of stabilizing the global climate stabilization while supplying growing global energy demand. Part III concludes with a measure of cautious optimism about prospects for accomplishing that goal.

I. CLIMATE CHANGE AND ENERGY

A. Fossil Fuel Emissions from Power Plants and Cars

Climate change is foremost about emissions of carbon dioxide from electric power plants and cars. The chart below shows that, in the US, carbon dioxide is far and away the most prominent (although not the most powerful on a per unit basis) GHG, and fossil fuel combustion is the most prominent source of carbon dioxide emissions.



Recently, the US Environmental Protection Agency prepared an inventory of GHG emissions by economic sector (see below).² The top two sectors, responsible for more than 50% of total US emissions, were the electric power industry and transportation – or, simply put, coal and oil.

Table ES-7: U.S. Greenhouse Gas Emissions Allocated to Economic Sectors (Tg CO₂ Eq.)

Implied Sectors	1990	1995	2000	2001	2002	2003	2004	2005
Electric Power Industry	1,859.7	1,989.5	2,329.9	2,292.0	2,300.7	2,330.2	2,363.4	2,429.8
Transportation	1,523.0	1,677.2	1,903.2	1,876.4	1,931.2	1,928.2	1,982.6	2,008.9
Industry	1,470.9	1,478.4	1,443.3	1,395.4	1,380.0	1,371.8	1,403.3	1,352.8
Agriculture	585.3	589.2	614.4	618.4	602.6	575.7	567.0	595.4
Commercial	417.8	420.5	415.5	406.6	413.7	433.5	432.6	431.4
Residential	351.3	375.1	393.6	383.6	382.7	404.8	391.6	380.7
U.S. Territories	34.1	41.1	47.3	54.5	53.6	60.0	63.2	61.5
Total Emissions	6,242.0	6,571.0	7,147.2	7,027.0	7,064.6	7,104.2	7,203.7	7,260.4
Land Use, Land-Use Change, and Forestry (Sinks)	(712.8)	(828.8)	(756.7)	(767.5)	(811.9)	(811.9)	(824.8)	(828.5)
Net Emissions (Sources and Sinks)	5,529.2	5,742.2	6,390.5	6,259.5	6,252.7	6,292.3	6,378.9	6,431.9

Note: Totals may not sum due to independent rounding. Emissions include CO₂, CH₄, N₂O, HFCs, PFCs, and SF₆.

In many other countries, too, GHG emissions are heavily dominated by carbon dioxide from the combustion of fossil fuels to produce electricity and power automobiles. Globally, carbon dioxide comprises 77 percent of total GHG emissions based on global warming potential.³ However, fossil fuel-based carbon dioxide emissions comprise a much larger percentage of total GHG emissions in developed countries than in developing countries, as the table below indicates.

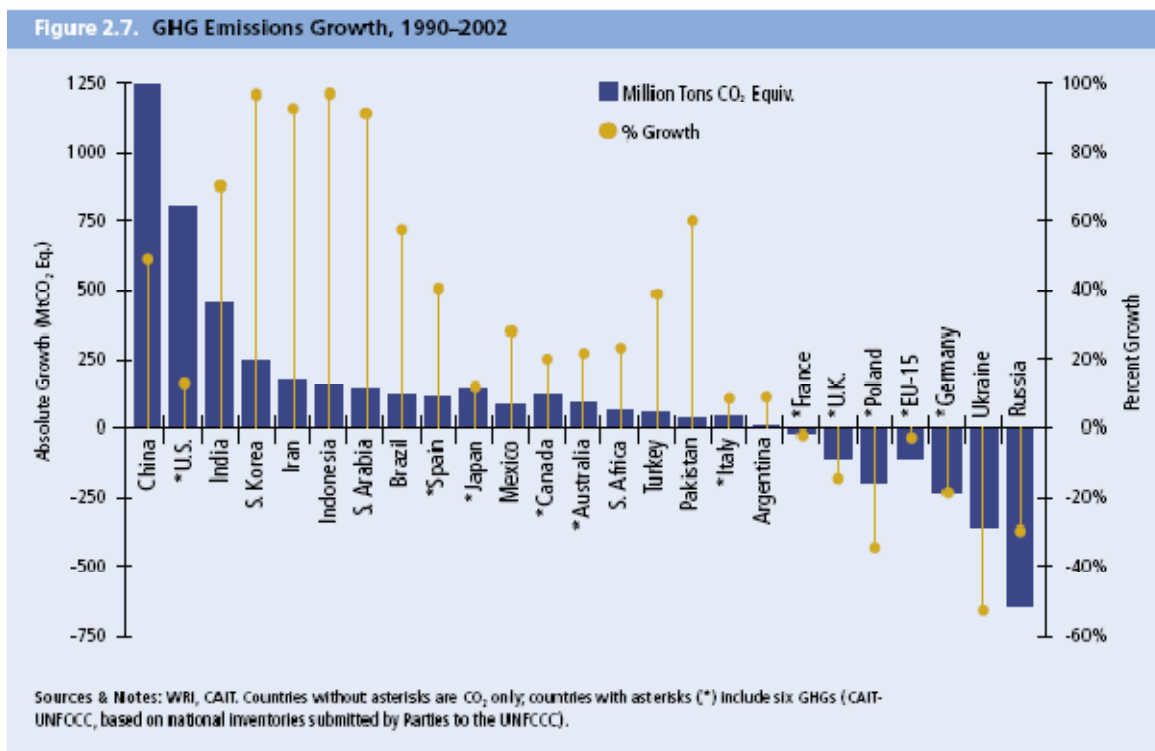
Carbon dioxide emissions from fossil fuels as a percentage of total GHG emissions	
Developed countries	81%
Developing countries	41%
Least developed countries	5%

Source: BAUMERT, HERZOG, and PERSHING, supra note 3, at Fig. 2.6.

² US EPA, Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2005 (April 2007) .

³ Kevin A. Baumert, Timothy Herzog, Jonathan Pershing, *Navigating by the Numbers: Greenhouse Gas Data and International Climate Policy* (Washington, DC: World Resources Institute, 2005), p.6.

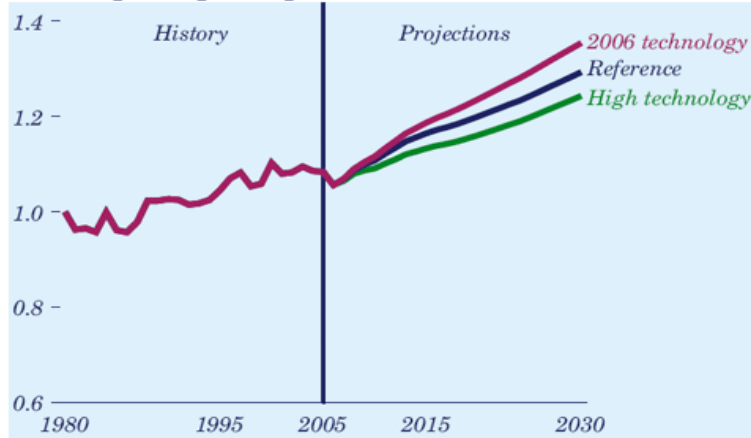
However, the rate of growth in carbon dioxide emissions from energy-related combustion has been growing fastest in developing countries. The chart below indicates that, in percentage terms, the rate of growth in carbon dioxide emissions is highest in countries including China, South Korea, India, Indonesia, Saudi Arabia, and Iran. Nominally, growth in carbon dioxide emissions has been strong in the US, but in percentage terms the rate of growth has been relatively low. In other developed countries, including the EU as a whole, the rate of growth has been flat or slightly negative.



Source: BAUMERT, HERZOG, AND PERSHING, *supra* note 3, at 15, Figure 2.7.

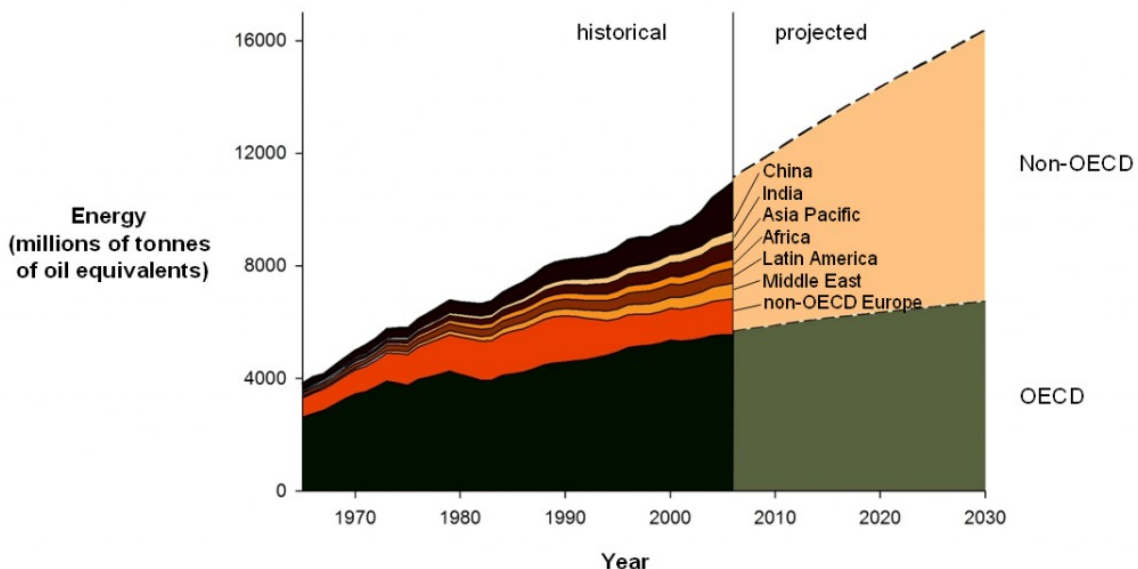
Demand for energy is widely expected to continue rising for at least the next two decades. As the chart below indicates, the US Energy Information Administration expects that domestic energy demand will increase to at least 2025, even if an unusually high rate of technological improvement improves energy efficiency.

Figure 40. Commercial delivered energy consumption per capita, 1980-2030 (index, 1980 = 1)

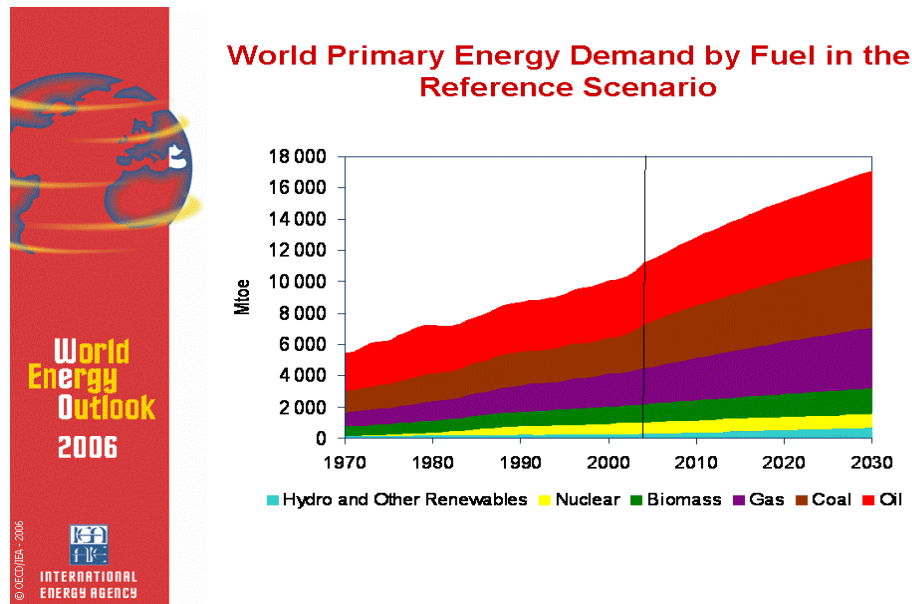


Energy demand is expected to increase most, however, not in the US and other developed countries but in the developing world, where increasing energy production and consumption are crucial factors in economic development, which itself is vital for building capacity to adapt to climate change. The projections in the figure below show that energy consumption is expected to grow fastest in non-OECD countries over the next two decades.

**World Energy Consumption:
Contribution of Non-OECD Countries and Regions**



That increasing demand will be met primarily by fossil fuels, according to the International Energy Agency (IEA). The figure below shows the IEA projections for global energy demand to 2030, broken down by fuel source.



The IEA projects that renewable energy sources and nuclear power will still supply only a tiny fraction of total energy demand in 2030. Coal, gas, and oil will continue to be the fuel sources of choice. This is not good news from a climate-change perspective. Nevertheless, while extreme technological optimists, apparently including President Obama,⁴ might take issue with the suppositions behind the IEA's projections, there is little reason to believe that the IEA's projections are unrealistic.

B. The False (Near-term) Promise of Renewables

President Obama has argued for a combined energy and climate-change policy that would substantially reduce GHG emissions while providing abundant and cheap energy, *and* creating

⁴ See *infra*

millions of “green jobs” (however those might be defined).⁵ The president is quite right to link energy and climate policies, but according to the best information available from the sober analysts of the Energy Information Administration and the International Energy Agency, any near-term hopes for substantially reducing GHG emissions while meeting increasing energy demand with low-cost “green” fuels is either disingenuous or panglossian. Even if fossil fuel prices increase substantially in the near term and stay high, alternative energy sources will not become economically competitive and, therefore, are not expected to play a major role in energy supply between now and 2030.

Lately, much attention, as well as billions of dollars in government subsidies, has focused on the potential of biofuels, such as ethanol, to replace fossil fuels. That attention is largely misplaced from both economic and environmental perspectives. Corn-based ethanol, for example, is not a low-carbon substitute for gasoline because, given currently technologies, it takes more fossil fuels to create a gallon of ethanol than the ethanol generates. To be precise, ethanol from corn requires 29% more energy from fossil fuels to produce than the final product contains.⁶ ‘Ethanol contains about 76,000 British Thermal Units (BTUs) of energy per gallon, but producing that ethanol from corn takes about 98,000 BTUs. By comparison, a gallon of gasoline contains about 116,000 BTUs per gallon. But making that gallon of gas — from drilling the well, to transportation, through refining — requires around 22,000 BTUs.’⁷ Because corn-based ethanol requires so much more energy than gasoline to produce, it is also much more expensive to produce. In fact, ethanol would not be available in the market today without massive government subsidies. One recent study puts the total 2006 subsidy for ethanol production in the US at \$5.1 to \$6.7 billion.⁸ That comes to \$1.05 to \$1.38 per gallon of ethanol produced in 2006.⁹ Moreover, because ethanol production requires so much more energy to produce than gasoline, its production results in greater carbon dioxide emissions. In other words, ethanol is worse than gasoline for climate change.

⁵ See <<http://my.barackobama.com/page/content/newenergy>>.

⁶ See ‘Ethanol and Biodiesel from Crops Not Worth the Energy’ (6 July 2005) *Sci Daily*, available at <<http://www.sciencedaily.com/releases/2005/07/050705231841.htm>>.

⁷ Robert Bryce, ‘Corn Dog: The Ethanol Subsidy Is Worse Than You Can Imagine’ (19 July 2005) *Slate*, available at: <<http://slate.com/id/2122961/>>.

⁸ See Doug Koplow, *Biofuels: At What Cost? Government support for ethanol and biodiesel in the United States* (Geneva: Global Subsidies Initiative of the Institute for Sustainable Development, 2006) p 51, Table 5.1, available at <http://www.globalsubsidies.org/IMG/pdf/biofuels_subsidies_us.pdf>.

⁹ *Ibid* at 52, Table 5.2.

In Brazil, ethanol is produced from sugarcane, which is a far more energy-efficient source than corn. Sugarcane-based ethanol produces 8 times more energy than is required to produce it (a better output-to-input ratio even than gasoline). It is also much cheaper to produce than corn-based ethanol.¹⁰ The United States does not, however, import large quantities of sugarcane-based ethanol because the government has imposed high import tariffs which make Brazilian sugarcane-based ethanol more expensive than home-grown corn-based ethanol.¹¹ This trade barrier indicates that ethanol policy in the US is driven not by a desire to reduce dependence on fossil-fuels but to subsidize farmers. Even if the trade barrier did not exist, however, sugarcane-based ethanol could not presently satisfy more than a small fraction of energy demand in the US, let alone global energy demand. According to the Sierra Club, an area the size of Wisconsin – about 41 million acres – would have to be planted with sugarcane to replace just 5% of US gasoline consumption.¹² The prospects for replacing gasoline consumption with corn-based ethanol are even worse. ‘For corn ethanol to completely displace gasoline consumption in this country, we would need to appropriate all U.S. cropland, turn it completely over to corn-ethanol production, and then find 20 percent more land for cultivation on top of that.’¹³

Even assuming counterfactually that alternative fuels could be produced in sufficient quantities to replace fossil fuels, the costs of production and consumption, including infrastructure changes, would in all likelihood greatly exceed the costs of producing and using coal, oil, and natural gas. The bottom line is that substitute technologies are currently far more expensive than fossil fuels and are likely to remain so for some time to come.¹⁴ Increasing fossil fuel taxes would help to close the gap and increase incentives for innovation, but in the absence of some unanticipated technological breakthrough it will likely be decades (at least) before the

¹⁰ See Emma Marris, ‘Sugar cane and ethanol: Drink the best and drive the rest’ (7 Dec 2006) 444 *Nature* 670, available at <<http://www.nature.com/nature/journal/v444/n7120/full/44670a.html>>.

¹¹ See Colin A. Carter and Henry I. Miller, ‘Why Ethanol Backfires’ (17 May 2007) *Los Angeles Times*, available at <<http://www.latimes.com/news/opinion/la-oe-miller17may17,0,7603395.story?coll=la-opinion-righttrail>>.

¹² See <<http://sierraclub.org/sierra/200709/biofuelschart.pdf>>.

¹³ Jerry Taylor and Peter van Doren, ‘Ethanol Makes Gasoline Costlier, Dirtier’ (27 Jan 2007), *Chicago Sun Times*, available at <http://www.cato.org/pub_display.php?pub_id=7308>.

¹⁴ See, e.g., Jeffrey Chow, Raymond J. Kopp, and Paul R. Portney, ‘Energy Resources and Global Development’ (23 Nov 2003) 302 *Sci* 1528, 1531 (‘With energy choices driven by relative prices, fossil fuels will dominate energy use for many years to come.’); Vijay Vaitheeswaran, *Power to the People: How the Coming Energy Revolution Will Transform an Industry, Change Our Lives, and Maybe Even Save the Planet* (New York: Farrar, Straus, & Giroux, 2003), p 6 (‘there is no immediate solution, because there is no practical alternative to oil-fired transport’).

global economy can be weaned from fossil fuels without significantly reducing *net* social welfare, especially in developing countries, where energy demand is rising fastest.¹⁵

Just recently, Kevin Parker, the global head of asset management for the Deutsche Bank Group, captured the false promise of bio-fuels succinctly, when he said, “‘It’s become clear ..., in the work that we’ve done, that converting photosynthesis into transport fuel is very inefficient. There’s no sense of rolling back the clock on that one. The world has moved on.’”¹⁶ Put differently, while climate policy and energy policy must be constructed together, they should not be conflated with farm policy.

Compared to biofuels, alternative sources such as wind, solar, and hydrogen fuel cells may hold greater long-run potential to replace a substantial percentage of fossil fuels, but no one believes they are likely to make much of a dent in the next couple of decades. According to the IEA’s projections, (see the graph above on page 6), renewables are not expected to make more than a tiny contribution to the overall energy mix in 2030. Of course, unexpected technological advances are possible, but we should not bank on them.

II. TOWARDS MORE EFFECTIVE POLICIES TO DEAL WITH THE COMBINED PROBLEMS OF CLIMATE STABILIZATION AND INCREASING ENERGY DEMAND

To restate the fundamental problem: the international community needs to increase global energy supplies over the next 20-30 years to meet increasing global demand, while at the same time significantly curtailing carbon emissions. On the realistic assumption that global energy supply during that period will continue to be dominated by fossil fuels, the prospect for accomplishing both feats seems bleak. However much the international community may be committed to reducing greenhouse gas emissions – and so far the evidence indicates that the largest emitters are not all that committed – it would be unrealistic to suppose that countries would be willing to forego energy-dependent economic growth to do so. Moreover, there is little

¹⁵ International Energy Agency, *World Energy Outlook 2006* (Paris: International Energy Agency, 2006), p 1.

¹⁶ *Quoted in* Steven Mufson and Juliet Eilperin, *EPA Proposes Changes to Biofuel Regulations*, Washington Post, May 6, 2009 < <http://www.washingtonpost.com/wp-dyn/content/article/2009/05/05/AR2009050503731.html?hpid=moreheadlines>>.

reason to suppose that foregone economic growth would be less harmful than moderate climate change, at least for developing countries (and possibly for developed countries as well).

The situation is not altogether hopeless, however. There certainly are steps that can, and should, be taken now to cost-effectively mitigate carbon emissions while meeting growing global energy demand. I do not pretend to offer a fully fledged policy combining climate stabilization and energy supply. I can, however, offer some suggestions for moving those policies in the right direction. If this seems an unduly modest goal, all I can say is that getting the direction of policy right is underrated and, so far, unachieved.

A. Raise Prices of Carbon-based Fuels, and Keep Them High

There is one, and possibly only one, policy that would serve to (a) reduce carbon emissions, (b) promote the innovation of cleaner alternative fuel sources, and (c) ensure adequate energy supplies to meet demand, all at the same time: the price of fossil fuels must rise to better reflect the social costs of energy consumption. The US missed a valuable opportunity to establish a price-floor for gasoline, after prices rose above \$4 per gallon in 2006.¹⁷ At that price, quantity demanded fell, incentives for conservation increased, and fuel-related emissions declined.¹⁸ Since prices have fallen back to \$2 per gallon and below, those trends have reversed.¹⁹ A tax-based price floor would have prevented that reversal or at least muted the effect of falling prices. Moreover, instituting permanently higher fossil-fuel prices would create market incentives for the technological development of lower-priced alternative energy resources, without the need for direct subsidization by the government. Instead of politicians and bureaucrats picking which alternatives to subsidize – something they tend to do very badly²⁰ – a tax on fossil fuels would

¹⁷ See, e.g., Jonathan Lemire and Rich Shapiro, 'Gulp! Try \$4.50!! Brooklyn gas station floors it, *New York Daily News*, Apr. 19. 2006.

¹⁸ See, e.g., Paul Krugman, 'Prices and gasoline demand,' *New York Times*, May 9, 2008 (asserting that the price elasticity of demand for gasoline is approximately -0.7, meaning that a 10% increase in gas prices results in a 7% reduction in quantity demanded); Barbara Hagenbaugh, 'High prices cut gasoline demand; prices could drop,' *USA Today*, Feb. 8. 2008 (noting that US drivers pumped 1% fewer gallons of gas on average during the first four weeks of 2008, compared to the first four weeks of 2007).

¹⁹ See, e.g., Moming Zhou, 'U.S. gasoline demand rises on cheaper prices,' *Wall Street Journal MarketWatch*, Mar. 13, 2009.

²⁰ See, e.g., Peter Z. Grossman, 'The Political Logic of Failed Energy Programs (Draft 2009) <http://www.indiana.edu/~workshop/colloquia/materials/papers/grossman_paper2.pdf>; Peter Z. Grossman, 'The

provide an equal-opportunity incentive for *all* energy entrepreneurs. The government has a legitimate role to play in funding basic energy research – indeed, that would be one useful purpose for fossil-fuel tax revenues – but the government should refrain from “picking winners,” as it has done in the past with synfuels, solar water heaters, and corn-based ethanol, to name just a few.²¹

It is highly unlikely that the government will only tax carbon inputs or emissions; it is likely to regulate them as well. But substantial regulations of carbon emissions would also have the effect of raising energy prices for consumers.²² This is not the place for an extensive discussion of whether a tax- or quantity-based approach to raising fossil fuel prices is preferable. Suffice it to note that various economists and policy analysts have stated a preference each approach.²³ The theory of path dependency and a cursory examination of legislation currently before the US Congress, would suggest that a cap-and-trade regulatory approach to climate change is far more likely than a tax-based approach.²⁴ However, there are ways that tax-like mechanisms might be made part of a cap-and-trade regulatory regime. For example, emissions allowances could be auctioned rather than allocated for free, as most economists currently advocate.²⁵ Moreover, the trading regime might, and probably should, come with a pre-set price

History of U.S. Alternative Energy Development Programs: A Study of Government Failure (Draft 2009)
<http://www.law.northwestern.edu/searlecenter/papers/Grossman_Alternative_Energy.pdf>.

²¹ See *id.*

²² As Martin Weitzman pointed out in his classic 1974 article, ‘Prices vs. Quantities,’ every regulation that effectively constrains supply relative to demand constitutes an implicit tax at a certain price. Martin Weitzman, ‘Prices vs. Quantities,’ 41 *Rev. Econ. Stud.* 477 (1974).

²³ Among economists, policy analysts, and legal scholars preferring a tax-based approach are: William Nordhaus, ‘After Kyoto: Alternative Mechanisms to Control Global Warming,’ *Foreign Policy in Focus Discussion Paper* (Mar. 27, 2006) <<http://www.fpif.org/pdf/papers/0603afterkyoto.pdf>>; Michael Waggoner, ‘Why and how to tax carbon,’ 20 *Colo. J. Int’l Envtl. L. & Pol’y* 1-34 (2008); Richard N. Cooper, ‘Alternatives to Kyoto : the case for a carbon tax,’ in J.E. Aldy and R.N. Stavins (eds), *Architectures for Agreement : Addressing Global Climate Change in the Post-Kyoto World* (Cambridge : Cambridge University Press, 2007), p. 105 ; and N. Gregory Mankiw, ‘One Answer to Global Warming : A New Tax,’ *New York Times*, Sept. 16, 2007. Others who prefer quantity-based regulations in the form of cap-and-trade approach include: Richard B. Stewart and Jonathan B. Weiner, *Reconstructing Climate Policy: Beyond Kyoto* (Washington, DC : AEI Press, 2003) ; Tom Tietenberg, ‘The Tradable-permits Approach to Protecting the Commons : Lessons for Climate Change,’ in D. Helm (ed.), *Climate-change Policy* (Oxford : Oxford University Press, 2005), p. 167 ; Robert Stavins, ‘A U.S. Cap-and-Trade System to Address Global Climate Change,’ *Brookings Institution Hamilton Project Discussion Paper 2007-13* (Oct. 2007) <http://www.brookings.edu/~media/Files/rc/papers/2007/10climate_stavins/10_climate_stavins.pdf>.

²⁴ At US insistence, the parties to the Kyoto Protocol adopted cap-and-trade as the preferred approach. Even the European Union, which opposed cap-and-trade at Kyoto, has since create the world’s most extensive cap-and-trade system for carbon dioxide emissions. Most current legislative proposals before the US Congress to deal with the climate change problem are cap-and-trade bills.

²⁵ See, e.g., Written Testimony of Dallas Burtraw, Senior Fellow, Resources for the Future, Washington, D.C., Prepared for the US House of Representatives Select Committee on Energy Independence and Global Warming,

floor ensure continued emissions reductions during economic downturns. Such a price floor would have precisely the same effect as a tax.

B. To Mitigate Climate Change, Start with the (Still Plentiful) Low-hanging Fruit

In theory, energy conservation should yield only slight reductions in emissions because competitive markets tend to root out waste. In reality, evidence exists that industries could realize significant savings on resource inputs, emissions, and costs by instituting policies to reduce waste from pipelines and production streams. Early efforts by a few companies to minimize carbon-related waste have yielded some surprisingly good results. In the 1990s, for example, British Petroleum instituted a company policy that was designed to reduce its total carbon dioxide emissions by 10% from 1990 levels by 2010. Simply by improving operational efficiency, for example by plugging leaks in pipelines, it met the target 9 years ahead of schedule, and in so doing provided a *net benefit* to shareholders of \$650 million.²⁶ In a five year period, from 1999-2003, Kodak managed to decrease emissions and save \$10 million in costs through simple waste reduction efforts. And BASF instituted process changes that reduced GHG emissions by 38% between 1990 and 2002. Those process changes also reduced annual operating costs, at one plant by an estimated €500 million.²⁷

It might be that before their post-Kyoto waste reduction efforts and process changes BP, Kodak, and BASF were operated inefficiently. Assuming the steps they took truly were economically efficient, those steps probably should have been taken anyway, regardless of the climate change issue. Other companies, meanwhile, might have little or nothing to gain economically from proactive measures to reduce GHG emissions. At the very least, however, the experiences of BP, Kodak and BASF indicate the extent to which deliberate policies to reduce waste and improve dynamic efficiency in production *can* reduce emissions in relatively short periods of time and at reasonable (even negative) net cost.

'Cap, Auction, and Trade: Auctions and Revenue Recycling Under Carbon Cap and Trade,' Jan. 23, 2008 <<http://globalwarming.house.gov/tools/assets/files/0326.pdf>> (asserting that '[t]he vast majority of public finance economists would recommend an auction as the most efficient way to allocate emission allowances').

²⁶ Lord Browne, "Beyond Kyoto," *Foreign Affairs* (July/August 2004).

²⁷ Nicholas Stern, *The Economics of Climate Change: The Stern Review* 307 (Cambridge: Cambridge University Press, 2007).

Interestingly, a tension exists between energy conservation/emissions reduction efforts, however inexpensive, and a government policy designed to keep fossil fuel prices high, e.g., through taxation. Assuming energy demand is reasonably price elastic, conservation efforts would tend to depress energy prices by reducing quantity demanded, thereby undermining the effects of tax prices and other measures that would raise energy prices. It is therefore conceivable (though perhaps unlikely) that conservation measures might forestall post-carbon technological innovations. Nevertheless, from the perspective of climate policy, conservation remains desirable because it can cost-effectively reduce emissions per unit of activity (*i.e.*, per mile traveled or per unit of energy produced), as the case studies discussed above indicate.

It is inconceivable, however, that emissions reductions will only come from voluntary conservation efforts (which former Vice President Cheney equated with “personal virtue”²⁸). Within the next 12 months, Congress is likely to enact some sort of regulatory regime. Given the information provided in first figure from Section I of this paper, any serious policy for substantially reducing GHG emissions will have to focus on carbon dioxide emissions from coal-fired power plants. Any regulatory regime that does not do so will not accomplish much. Regulations imposed on power plants are extremely likely to require reductions in carbon emissions well beyond what might be privately efficient for regulated plants. In other words, they will be expensive. From the perspective of the last subsection (on raising the price of carbon-based resources), this is a good thing, unless prices rise too high, resulting in social costs that might equal or exceed the social costs of whatever amount of climate change the regulations are designed to avert.

This raises the question of how rapid and deep GHG emissions reductions should be. Economists who focus on the mean expected damages of the probability density functions in Integrated Assessment Models of climate change, including William Nordhaus and Thomas Schelling, argue that required reductions should be modest and implemented gradually.²⁹ Other economists (and some legal scholars) who look beyond the mean to incorporate low-probability, high-magnitude climate events that could disrupt future growth in the rate of consumption,

²⁸ See, e.g., Richard Benedetto, “Cheney’s energy plan focuses on production,” USA TODAY, May 1, 2001.

²⁹ See William Nordhaus, *The Challenge of Global Warming: Economic Models and Environmental Policy* (2007), p. 22; Thomas C. Schelling, ‘Climate Change: The Uncertainties, the Certainties, and What They Imply About Action,’ 4 *The Economists’ Voice* (July 2007), p. 4 < http://www.bepress.com/cgi/viewcontent.cgi?context=ev&article=1276&date=&mt=MTI0MjA1Mzg2Mg==&access_ok_form=Continue >.

including Nicholas Stern, Martin Weitzman, Kenneth Arrow, and Richard Posner, believe that GHG emissions reductions should be greater and more rapid.³⁰ Importantly, no economist who has seriously studied the issue believes that business-as-usual is an appropriate policy.

It should go without saying that emissions reductions, no matter how dramatic, from a single country will not successfully mitigate the climate change problem, if other countries do not reduce their own emissions or, worse, actually increase their emissions, as developing countries are expected to do over the next 20 years. Climate change thus presents a profound collective action problem, which the international community has barely made a dent in resolving.³¹ For this reason, if for no other, it seems sensible for the US to follow a policy of gradually ramping up (increasingly expensive) emissions reductions. Even assuming Stern and others are right about the risks of potential climate catastrophes, those catastrophes cannot be resolved by any country acting alone, *unless* by some form of effective and cost-effective geo-engineering, as the following subsection discusses.

C. Successful Geo-engineering Could Make a Near-term Switch to Alternative Energy Sources Unnecessary

The term “geo-engineering” refers to deliberate, large-scale efforts to counter-act the effects of increasing concentrations of carbon dioxide in the atmosphere. For example, intentionally emitting sulfur aerosols into the upper atmosphere (as volcanoes occasionally do, but in regular, systematic way) would reflect more sunlight away from the earth, reducing the amount of solar heating. It is at least conceivable that emissions of sulfur aerosols could be tailored precisely to offset an undesirable unit of marginal heating from increasing GHG concentrations.³² Another suggestion has been to seed the oceans with iron to promote plankton blooms, which might absorb more carbon dioxide from the atmosphere (and provide more food

³⁰ See Stern, *supra* note 27; Martin Weitzman, ‘On Modeling and Interpreting the Economics of Catastrophic Climate Change,’ (Draft July 7, 2008) <<http://www.nber.org/~confer/2008/si2008/EEE/weitzman.pdf>>; Kenneth J. Arrow, ‘Global Climate Change: A Challenge to Policy,’ 4 *The Economists’ Voice* (July 2007); Richard A. Posner, *Catastrophe: Risk and Response* (Oxford: Oxford University Press, 2004), p. 163.

³¹ See, e.g., Scott Barrett, *Why Cooperate?* (2007); Daniel H. Cole, “Climate Change and Collective Action,” 61 *CURRENT LEGAL PROB.* 229 (3008)

³² On the possible use of sulfur aerosols to mitigate global climate change, see, e.g., Schelling, *supra* note 29, at 3.

for whales at the same time).³³ Neither of these (or other) geo-engineering “solutions” is perfect or certain to be effective.³⁴ For instance, it is unclear how much sulfur would have to be inserted into the upper atmosphere to counter-act an estimated amount of warming. In addition, sulfur aerosols would have to be injected fairly often because they do not survive in the atmosphere for nearly as long as carbon dioxide and other GHGs. However, such issues could be resolved through testing, *e.g.*, demonstration projects, which is not presently occurring. This is unfortunate, given that some geo-engineering solutions may be significantly less difficult and costly to implement than regulations to substantially reduce GHG emissions.³⁵ If feasible, a geo-engineering solution would obviate the need for near-term emissions reductions *and* near- to mid-term substitution of alternative energy sources for fossil fuels.

Even if a geo-engineering solution is demonstrated to work, however, various issues would need to be resolved, including international legal issues relating to the right of one country to intentionally geo-engineer the atmosphere. Moreover, geo-engineering would reduce the incentives for entrepreneurs to find substitute energy sources, and could create perverse incentives for countries to emit more GHGs, which might undermine the geo-engineering solution, leaving the international community in a worse position than before the geo-engineering was implemented. Thus, geo-engineering should not be viewed as a long-term sufficient solution. At best, it would be a short-term fix, as governments and markets sought more sustainable approaches to combined energy and climate policies.

CONCLUSION

The problem of climate change – and possibly the greatest challenge of the twenty-first century – is not only about reducing GHG emissions to control climate change; it is about doing that *while* meeting increasing global demand for energy. Any climate policy that ignores this

³³ On the possible use of ocean plankton blooms to absorb carbon dioxide, *see, e.g.*, Martin LaMonica, ‘Seeding the ocean to capture carbon,’ CNET News, May 10, 2007 <http://news.cnet.com/Seeding-the-ocean-to-capture-carbon/2100-11395_3-6182861.html>.

³⁴ *See, e.g.*, ‘Scripps Research Gives Tiny Phytoplankton A Large Role In Earth's Climate System,’ *ScienceDaily* (Nov. 7, 2002) <<http://www.sciencedaily.com/releases/2002/11/021107074203.htm>> (noting that absorption of atmospheric carbon by plankton blooms could increase ocean heating).

³⁵ *See, e.g.*, Thomas C. Schelling, ‘The economic diplomacy of geoengineering,’ 33 *Climatic Change* 1573 (July 1996).

vital connection to energy policy is unlikely to be enacted; or if it is enacted, it is likely to be ignored (much like the Kyoto Protocol). Climate change is, for the most part, a problem of the energy and transportation industries, but any solution to it must recognize that people will continue to demand energy for their homes, businesses, and automobiles. Thus, energy policy and climate policy must be combined (but divorced from farm policy).