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Legal Disputes Related to Climate Change Will Continue for a Century

Richard J. Pierce Jr
George Washington University Law School, rpierce@law.gwu.edu

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Richard J. Pierce, Jr[1]

I am confident that my current students will be working on legal issues related to climate change when they retire fifty years from now.

I. Introduction to the Problem

The average global temperature is already certain to increase by 2 degrees Fahrenheit.[2] It will increase by far more, with other major attendant changes in climate, unless we reduce global emissions of greenhouse gases (ghgs) by at least 50% by 2050.[3] The effects of failure to accomplish that daunting task will be catastrophic. They include the deaths of millions and the displacement of scores of millions.[4] The worst effects will be experienced in places like central India and central Africa, which will suffer extreme desertification, and in many island states, coastal Indonesia and large portions of Bangladesh, which will be underwater.[5] The US will suffer some significant adverse effects, however, including desertification of much of the southwest, submersion of significant parts of Florida and Louisiana, increases in the incidence and severity of storms of various types,[6] and a 13 degree increase in the average summer temperature in Washington, DC.[7]

The task of effectively mitigating climate change is somewhere between extremely difficult and impossible. The main problem is CO2 emissions. CO2 is by far the most abundant ghg, and it is the inevitable byproduct of combustion of hydrocarbons.[8]

While the US is the second largest source of CO2, neither the US nor the developed world have accounted for any significant increase in emissions in several years.[9] Even if the developed world were to take no steps to reduce CO2 emissions, the developed world is unlikely to increase emissions of ghgs by any significant amount at any time in the future because of the steady improvements in energy efficiency that always occur over time. The increases in CO2 emissions over the last few years

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[1] Lyle T. Alverson Professor of Law. This essay was originally presented as the Harold Leventhal Lecture to the D.C. Bar on August 22, 2012. I am grateful to Bill Funk and Rob Glicksman for comments on an earlier version of this manuscript.
[2] EPA website, Climate Change Basics (2012)
[3] Id.
[4] Intergovernmental Panel on Climate Change, Fourth Assessment Report: Climate Change 2007 [hereinafter IPCC 2007].
[5] IPCC 2007: Africa, Asia, Small Islands.
[6] IPCC 2007: North America.
[7] UK Met Office, Climate: Observations, Projections and Impacts: United States of America (2011).
[8] EPA website, The Main Greenhouse Gases (2012).
[9] European Commission, Long-Term Trends in Global CO2 Emissions: 2011 Report.

and in the future will occur almost exclusively in the developing world, with China alone accounting for a majority of the increase.[10]

This trend is easy to explain. The citizens of the developing world want the kind of goods and services that we have long taken for granted, e.g., cars and air conditioning. As they are increasingly able to indulge those preferences, they will increase their per capita emissions of CO2.

Reducing CO2 emissions in the developed world by 50% would not be nearly enough to accomplish the goal of reducing *global* emissions by 50%. The developed world must reduce its emissions by far more than 50% to offset the inevitable increases in emissions in the developing world. That task is made more difficult by the basic laws of supply and demand. Most hydrocarbons are sold on global markets. To the extent that the developed world is successful in reducing CO2 emissions through some means, e.g., a carbon tax or subsidies for carbon-free sources of energy, the attendant reduction in the quantity of hydrocarbons demanded will decrease the global price of hydrocarbons. That, in turn, will increase consumption of hydrocarbons in the developing world unless developing countries also adopt means of reducing consumption of hydrocarbons—a step they have not been willing to take to date. The resulting increase in consumption of hydrocarbons in developing countries has the potential to offset 29-70% of the reductions in hydrocarbon consumption in the developed world.[11] **Thus, countries in the developed world need to reduce CO2 emissions by far more than 50% even if countries in the developing world can be persuaded to take steps that will reduce the otherwise dramatic rate of their increases in CO2 emissions.**

While the broad outlines of the relationship between CO2 emissions and climate change are well known, there is at least one major source of uncertainty. We do not have a good understanding of the shape of the dose-response curve that describes the relationship. Thus, for instance, some climate scientists believe that there is a "tipping point" at which a given concentration of CO2 in the upper atmosphere will have irreversible catastrophic effects on climate.[12] **Others believe that the dose-response curve is roughly linear, thereby creating a situation in which each increment of CO2 will have a roughly proportionate adverse effect on climate.**[13]

That difference could be important for policy making purposes. If the relationship is characterized by a "tipping point," and we conclude that we cannot avoid exceeding that point, we should simply accept the inevitable changes in climate and put all of our scarce resources into devising and implementing methods of adapting to the changes in climate. If the dose-response curve is linear, we should devote significant resources to reducing global emissions of CO2 whether or not we believe that we can

[10] Id.
[11] Steven Stoft, Global Energy Policy Center, Renewable Fuel and the Global Rebound Effect 2 (2010).
[12] See, e.g., James Hansen, Storms of My Grandchildren (2009).
[13] See, e.g., OECD, Climate Change Mitigation (2008). Of course, the curve may well be linear after we reach a tipping point.

avoid a particular concentration of CO2 in the atmosphere. In that situation, we should act on the basis of a belief that every incremental reduction is important.

The Supreme Court majority in Massachusetts v. EPA[14] implicitly embraced the assumption that there is a linear dose-response relationship between ghg emissions and climate change. EPA argued that it was not required to regulate emissions of CO2 from new cars in part because any such effort was unlikely to have any meaningful beneficial effect on climate change. Total emissions of CO2 from US autos account for only 4% of global emissions of ghgs. Moreover, even a large reduction in emissions from new cars sold in the US would have little effect on climate change, given the large offsetting increases in CO2 emissions in developing countries. The majority rejected EPA's argument on the basis that regulating CO2 emissions from new cars in the US would make a "meaningful contribution" to climate change mitigation.[15]

I will indulge the assumption that the dose-response curve is linear in the balance of this lecture, but it is merely an assumption. I do not have enough relevant expertise to participate in the debate between the proponents of the "tipping point" theory and those who believe instead that the relationship between ghg emissions and climate change is linear.

II. Impediments to Climate Change Mitigation

The main impediments to effective climate change mitigation are economic and political. Hydrocarbons are much less expensive than carbon-free alternative sources of energy. I will focus primarily on the electricity sector, which accounts for nearly half of CO2 emissions,[16] but the economic and political impediments are similar in the transportation and industrial sectors.[17]

The most recent estimates of the cost of generating electricity from various sources in the US are: coal and gas, 4-5 cents per kwh; wind, 7-8 cents per kwh; nuclear, 9-10 cents per kwh, and solar, 18-22 cents.[18] The cost differences between hydrocarbons and carbon-free sources are less in Europe and Asia because coal and gas are more expensive in Europe and Asia than they are in north america. [19]

Those are estimates of generating costs only, however. Supplying electricity from wind and solar to consumers is more costly than supplying electricity from gas or coal for two reasons that are independent of generating costs. First, the unit cost of transmission is higher, partly because those sources tend to be long distances from

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[14] 549 U.S. 497 (2007).
[15] Id. at 525-26.
[16] International Energy Agency (IEA), CO2 Emissions Data Base (2009).
[17] See Arnold Reitze, Controlling Greenhouse Gases from Highway Vehicles, 31 Utah Env. L. Rev. 308 (2011).
[18] Energy Intelligence, New Energy (June 7, 2012).
[19] Id.

major markets and partly because they are much lower load factor sources.[20] Second, both wind and solar are intermittent sources. To compare the cost of intermittent sources with the cost of dispatchable sources like coal, gas, and nuclear, you must either add the cost of some combination of supplemental dispatchable sources and storage or discount the value of each unit of intermittent energy to reflect its lower value.[21] Either adjustment adds significantly to the effective unit cost of supplying electricity generated by wind or solar to consumers. To illustrate the effect of those adjustments, consider that the unit cost of the Cape Wind project proposed to be constructed off of Cape Cod will be 80-85 cents per kwh after adjusting for the lower value of the intermittent supply.[22]

A similar adjustment must be made to reflect the lower value of the intermittent supplies of electricity available from solar sources, but the adjustment is lower because the correlation between periods of high electricity demand and periods of sunshine is better than the correlation between periods of high demand and periods of wind velocity in the range that allows windmills to operate.[23] When unit generating costs are adjusted to reflect differential transmission costs and intermittency, solar and wind are 3 to 15 times more expensive than coal or gas in the US.[24]

The political impediments to effective climate change mitigation are primarily derivative of the economic impediments. Four other factors add to the political impediments, however.[25] First, because CO2 remains in the atmosphere for many decades after it is emitted, the cost of implementing mitigation measures must be incurred many decades before the benefits will be experienced. Second, the benefits will appear in a form that many people either do not understand or do not accept. They will take the form of a negative—catastrophic climate effects that will be avoided. Third, the benefits will be enjoyed disproportionately by citizens of highly vulnerable developing countries like India and Bangladesh, while the costs will be incurred disproportionately by citizens of less vulnerable developed countries like the US and Germany. Indeed, many people in countries like Canada and Norway may experience net benefits as a result of climate change. Fourth, most of the projects that must be completed as part of the mitigation effort require regulatory approvals that can take a decade or more to obtain. Thus, for instance, Cape Wind, the first offshore wind farm proposed in North America, has been the subject of a complicated and contentious regulatory approval process for over a decade.[26]

[20] Roger Bezdek & Robert Wendling, Not-So-Green Superhighway, 34 Pub. Util. Fort. 35 (Feb. 2012).
[21] Paul Joskow, Comparing the Costs of Intermittent and Dispatchable Electricity Generating Technologies, 101 Am Econ. Rev. 238 (2011).
[22] Richard Pierce, Natural Gas: A Long Bridge to a Promising Destination, 32 Utah Env. L. Rev. ___, ____(2012).
[23] Joskow, supra. note 21.
[24] Bezdek & Wendling, supra. note 20.
[25] See generally Cass Sunstein and Adrian Vermeule, Climate Change Justice, 96 Geo. L. J. 1565 (2008).
[26] See Minerals Management Service, Efforts to Reach a Decision on the Cape Wind Energy Project (2010). See also Town of Barnstable v. FAA, 659 F.3d 28 (D.C. Cir. 2011).

III. Potential Methods of Mitigating Climate Change

A. A Carbon Tax

There is a broad consensus among economists that a carbon tax would be the most efficient and effective means of mitigating climate change.[27] A carbon tax of $50-200 dollars per ton of carbon emitted would provide a powerful incentive to engage in research and development in the dozens of areas in which there is clear potential to reduce CO2 emissions.[28] They include wind, solar, biomass, geothermal, hydro, nuclear, carbon capture and sequestration, storage, and the most promising, increased energy efficiency. It is impossible to predict which of the tens of thousands of r&d efforts will yield technological developments that will reduce CO2 emissions significantly, but it is easy to be confident that some combination would be effective both in reducing total consumption of electricity from all sources and in bridging the much smaller gap that would then exist between the cost of using sources that emit CO2 and the cost of using carbon-free or low carbon sources.

A cap and trade system of the type the US House of Representatives enacted in 2008 and the EU implemented in 1997 is functionally equivalent to a carbon tax in most respects if the cap is low enough to be effective. The cap in the version enacted by the House would not have been effective for many decades, if ever,[29] and even the lower cap in the EU version was far too high to be effective. The EU version of cap and trade has produced a carbon price of $8 per ton in 2012.[30] To be effective, a cap and trade system would need to yield a carbon price of $50-200 per ton.

There is an obvious impediment to a carbon tax that is high enough to be effective or to a carbon cap that is low enough to be effective—public aversion to taxes. The US now has one political party that opposes all taxes and another that wants to tax only millionaires, billionaires, and big oil companies. A carbon tax would be paid by everyone.

B. Litigation

The US could make use of the mechanism we rely on to further many other purposes—litigation. Thus, for instance, citizens that are, or will be, injured by climate change could sue sources of CO2. The Supreme Court unanimously rejected that mechanism in its 2011 opinion in American Electric Power Co. v.

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[27] E.g., Robert Stavins & S.M. Olmstead, Three Key Elements of a Post-2012 Climate Policy Architecture, 6 Rev. Env. Econ. & Pol. 1 (2012); William Nordhaus, After Kyoto: Alternative Measures to Control Global Warming, 96 Am. Econ. Rev. 31 (2006).

[28] Mark Lee & Amanda Card, A Green Industrial Revolution, Canadian Centre for Policy Alternatives (2012); Charles Komanoff, A Question of Balance: Finding the Optimal Carbon Tax Rate Carbon Tax Center (2008); Ekundayo Shittu & Erin Baker, Profit-Maximizing Investment in Energy Technology Under Carbon Tax Uncertainty, International Energy Agency Working Paper (2008).

[29] David Schoenbrod & Richard Stewart, The Cap and Trade Bait and Switch, Wall Street Journal (Aug. 24, 2009).

[30] Thomson Reuters, Point Carbon (June 2012).

Connecticut.[31] The Court held that the Clean Air Act displaces the power of courts to consider actions filed by states and environmental organizations to force sources of CO2 to decrease their emissions. In the Court's words:

> **It is altogether fitting that Congress designated an expert agency, here, EPA, as best suited to serve as primary regulator of greenhouse gas emissions. The expert agency is surely better equipped to do the job than individual district judges, issuing ad hoc, case-by-case injunctions. Federal judges lack the scientific, economic, and technological resources an agency can utilize for this purpose.[32]**

C. EPA Regulation Under the Clean Air Act

By contrast, a majority of Justices held that EPA is required to regulate ghgs as pollutants under the Clean Air Act (CAA) in the Court's 2007 opinion in Massachusetts v. EPA.[33] The CAA is a poor fit for the problem, however. Most pollutants can be regulated effectively by imposing emission limits that allow an activity to continue at the somewhat higher cost needed to accommodate installation of pollution control devices of some type. The most important ghg, CO2, is an inevitable byproduct of combustion of hydrocarbons. Thus, emission limits on CO2 can be attained in most circumstances only by ceasing or reducing the activity that yields the emissions.

EPA has taken two actions so far that have some potential to reduce CO2 emissions. First, EPA issued a rule jointly with the National Highway Traffic Safety Administration in which it required all auto manufacturers to attain new higher average fleet mileage requirements in the future.[34] Second, EPA has proposed a rule that would impose limits on CO2 emissions from new generating plants that are so low that they would constitute a de facto prohibition on construction of new coal-fired generating plants.[35]

It is not clear that either of those rules will have significant effects on CO2 emissions, however. As discussed in section IIIE, mandatory efficiency rules usually have limited beneficial effects, and, as discussed in section IIIG, it is unlikely that any new coal-fired generating plants will be constructed in the US even if EPA does not issue its proposed new rule that would limit CO2 emissions from new generating plants. Even if EPA rules issued under the CAA have some beneficial effect on CO2 emissions, their effects will fall far short of the reductions in emissions needed to avoid major changes in climate.

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[31] 131 S.Ct. 2527 (2011). See also Coalition for Responsible Regulation v. EPA, ___F3d ____(D.C. 2012) (upholding EPA greenhouse gas rules).
[32] 131 S.Ct. at 2539-40.
[33] 549 U.S. 497.
[34] 75 Fed. Reg. 25324 (May 7, 2010).
[35] 77 Fed. Reg. 22392 (Apr. 13, 2012).

D. Smart Meters and Realtime Pricing

Both the cost and the value of electricity vary greatly from time to time. Even within a 24-hour period, the cost of receiving a unit of electricity can vary by a factor of twenty.[36] This enormous variation is a function of several factors, including the inability to store electricity at a reasonable cost, large temporal variations in quantity of electricity demanded, transmission capacity constraints, and variations in the unit cost of the generating stations that are in use.

Traditional methods of billing consumers disguise the large temporal variation in the costs of making electricity available.[37] State regulators have long required electric utilities to bill on an average cost basis. As a result, consumers confront the same unit cost for each unit they consume notwithstanding the large variations in the cost of the units. Studies have shown that a shift to realtime pricing, i.e., a system of pricing in which consumers confront the constantly changing cost of electricity, would reduce the total cost of providing electricity by as much as 12 per cent.[38] Such a pricing system would induce consumers to change the temporal pattern of their electricity consumption to reduce their costs. Thus, for instance, most people would choose to operate their clothes driers and automatic dishwashers when they can purchase electricity for 5 cents rather than 50 cents.

One of the variables that determines the cost of electricity is the mix of generating units that are used to supply electricity at various times. During periods of high demand, utilities must operate their peaking units. Peaking units typically have low capital costs and high operating costs. The high operating costs of peaking units are largely a function of their lower level of efficiency, i.e., they generate less electricity per unit of input. The unit of input is almost always a hydrocarbon. Thus, a change from average cost pricing to realtime pricing would reduce CO2 emissions by reducing the quantity of hydrocarbons required to meet the total electricity needs of the nation.

The federal government has engaged in aggressive attempts to encourage utilities and state regulators to implement realtime pricing by, inter alia, providing federal funds to purchase the smart meters required to implement realtime pricing. So far, those efforts have achieved little success. Even in jurisdictions in which consumers have federally-funded smart meters, state regulators have been extremely reluctant to switch to a system of realtime pricing.[39] The primary opposition comes from advocates for senior citizens who fear that their constituents will pay higher electricity bills under realtime pricing because they can not or will not change their temporal patterns of consumption and from privacy advocates who fear that

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[36] Alfred Kahn, The Economics of Regulation 89-91 (1970).
[37] Richard Pierce, A Primer on Demand Response, G.W. J. En. & Env. 102 (Winter 2012).
[38] Adrian Booth, Mike Greene & Humayun Tai, U.S. Smart Grid Value at Stake: The $130 Billion Question, McKinsey on Smart Grid (2010).
[39] Ashley Brown & Raya Salter, Can Smart Grid Technology Fix the Disconnect Between Wholesale and Retail Pricing? Elec. J. Jan./Feb. 2011at 8-9; Steven Andersen, Saving the Smart Grid, Pub. Util. Fort. Jan. 2011 at 33.

realtime pricing will provide utilities and regulators with data about the temporal patterns of consumption of individual consumers that they will use to harm consumers. Unless advocates for senior citizens and for privacy can be persuaded to drop their opposition to realtime pricing, that potential method of mitigating climate change will remain unavailable.

E. Mandatory Efficiency Requirements

For decades, the US has relied to a considerable extent on mandatory efficiency standards to induce manufacturers, and derivatively consumers, to reduce their consumption of hydrocarbons. Thus, for instance, the federal government has mandated a series of constantly increasing average fleet mileage rules applicable to auto makers and constantly increasing efficiency criteria applicable to refrigerator makers. Efficiency standards have some potential to be of assistance in mitigating global warming, but their beneficial effects are overstated by a significant amount because of our failure to take into account three phenomena that have effects on all such measures.[40]

First, we usually assume that efficiency would not improve in the absence of the mandatory standards. Thus, for instance, we attribute all increases in the gas mileage of cars to mandatory standards. That assumption is unsupportable. Even without mandatory standards, manufacturers are driven by market forces to improve the efficiency of the products they make. Only some unknown fraction of the efficiency improvements are attributable to government mandates. Second, manufacturers always game mandates in ways that reduce their efficacy. Thus, for instance, the aggressive average fleet mileage rules issued in the 1980s induced auto makers to cease making station wagons that qualified as cars and to substitute lower mileage sport utility vehicles that were considered trucks.[41] Third, any resulting improvements in efficiency are offset to some extent by increased rates of utilization. Thus, the large improvement in the efficiency of refrigerators has dramatically increased the use of refrigerators by, inter alia, creating a situation in which most hotel rooms have refrigerators.[42]

F. Subsidies and Mandates

Both the US and the EU have relied heavily on a combination of subsidies for carbon-free sources and mandates to utilities to use carbon-free resources to generate a specified proportion of their total electricity supply.[43] Mandates are

[40] Ted Gayer & Kip Viscusi, Overriding Consumer Preferences with Energy Regulations, Vanderbilt Law and Economics Research Paper No. 12-24 (2012).
[41] Michael Lynch, CAFE Standard Insanity, Center for Individual Freedom (2005).
[42] Edward Comer, The Future of Energy Law: Electricity, 31 Utah Env. L. Rev. 429, 434 (2011).
[43] Subsidies for renewable fuels exist at every level of government; the federal government alone spends $24 billion a year on subsidies for renewables. See Steve Hargreaves, Energy Subsidies Total $24 billion, most to renewables, CNN Money (March 7, 2012). Most states mandate that electric utilities provide specified percentages of their total supply from renewables. See Lincoln Davies, Power Forward: The Argument for a National RPS, 42 Conn. L. Rev. 1339 (2010).

functionally indistinguishable from subsidies. They are simply subsidies that are paid involuntarily by consumers rather than by taxpayers. Use of subsidies for carbon-free fuels is an expensive and ineffective means of mitigating climate change.

Since the Europeans have been far more aggressive than the US in subsidizing carbon-free sources of electricity, we can learn a lot from their experience. Germany, Spain, and Portugal embarked on similar ambitious subsidy programs in 1997. Spain and Portugal have cut back on their efforts many times since 2008 to reduce their adverse fiscal effects.[44] Spain and Portugal lead the world in the proportion of their electricity supply that is generated by wind. The resulting electricity has little value, however, because it is available primarily at times of low demand. As Paul Joskow demonstrated in his paper in the May 2011 issue of American Economic Review, a unit of wind power is worth about one-quarter as much as a unit of power from a dispatchable hydrocarbon source because of the intermittent nature of wind power and its tendency to be available when demand for electricity is low.

Germany has reduced the magnitude and scope of its subsidies for solar energy as it has been forced to confront the high cost and limited efficacy of those subsidies. Germany has spent $130 billion on solar subsidies.[45] Those subsidies have created a situation in which Germany now has more installed solar capacity than the rest of the world combined.[46] Solar power accounts for only 3% of the total electricity supply in Germany, however.[47] Like wind power, solar power is an intermittent low load factor source. Germany's solar subsidies have cost it over $1000 per ton of CO2 not emitted[48]—at least five times the cost of using a carbon tax to reduce emissions. Europe's extravagant efforts to decrease ghg emissions have had no apparent effect. Emission in the EU and in the US decreased by about the same amount—seven per cent—between 2007 and 2010.[49]

Recent studies predict similar results for other subsidy-based mitigation strategies. Thus, for instance, the Fraser Institute estimates that Ontario consumers will pay an average of $285 per year for its solar subsidies, with solar ultimately accounting for only 3% of the total electricity supply in Ontario.[50] RWE estimates that Prime Minister Cameron's plan to rely on subsidies for nuclear energy to mitigate climate change in the UK will cost every household in the UK $12000.[51]

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[44] See, e.g., Spain Ejects Clean Power Industry with Europe Precedent, Business Week (May 29, 2012); Portugal Extends Wind Tariff Cuts to Existing Projects, Windpower Monthly (May 18, 2012); Germany Cuts Subsidies to Floundering Solar Industry, The New American (Mar. 22, 2012).
[45] Bjorn Lomberg, Goodnight Sunshine, Slate (Mar. 22, 2012).
[46] Id.
[47] Reuters, German Solar Output Up 60 pct in 2011(Dec. 29, 2011).
[48] Lomberg, supra. note 45.
[49] Compare EPA, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010, p. ES-4 (2012), with European Environment Agency, Why Did Greenhouse Gas Emissions Increase in the EU in 2010?, p. 3 2012).
[50] Fraser Institute, Ontario's Feed-in Tariff Jacks up Electric Bills with Little Evidence of Creating "Green Jobs" or Reducing Carbon Emissions (May 20, 2011).
[51] Stephen Castle, Britain Charts Way to Wider Nuclear Investment, New York Times (May 22, 2012).

G. Switching from Coal to Gas

Coal is now, and has long been, the dominant source of electricity throughout the world.[52] Replacing coal with natural gas as a generating fuel would reduce CO2 emissions from electricity generation by about 50%.[53] A new application of two old technologies—horizontal drilling and hydraulic fracturing—has had remarkable effects on the supply of natural gas in the US.[54] "Fracking" has created a situation in which the US is now the Saudi Arabia of gas.[55] The International Energy Agency predicts that the US will become the world's top gas producer by 2017.[56] The US has already eliminated completely its reliance on foreign sources of gas and is about to become a major gas exporter.[57] Gas reserves in the US are now sufficient to supply 100% of US demand for over a century: US gas reserves increased by the largest amount in history in 2010.[58] The price of gas in the US is now a small fraction of the price of oil and about equal to the price of coal.

In just the past three years, the US has already replaced over ten per cent of the coal it uses to generate electricity with gas.[59] Given the new economic relationship between coal and gas, all new fossil fuel generating plants constructed in the US are likely to be built to operate on gas rather than coal.[60] Thus, as generating plants are replaced over time, the US is likely to eliminate completely its reliance on coal as a generating fuel.

Fracking has the potential to yield similar effects in other regions of the world. Geologists have identified scores of basins all over the world that contain gas-rich shale that can support production of large quantities of gas through use of fracking.[61] Over time, fracking has the potential to increase dramatically the quantity of gas available in Europe and Asia, with a corresponding decrease in the price of gas to the point at which its price approximates the price of coal.[62] The International Energy Agency (IEA) predicts that global demand for gas will increase by over 50% by 2035 and that gas will overtake coal as the dominant source of global electricity generation by 2035.[63] Over time, the gusher of new gas supplies will reduce emissions of CO2 from the transportation sector as well as the

[52] Energy Information Administration, Annual Energy Outlook 2012; International Energy Agency, Electricity Information 2011.
[53] International Energy Agency, CO2 Emissions Data Base (2009).
[54] Pierce, supra. note 22.
[55] Whitehouse.gov, Remarks of the President (Jan. 26, 2012).
[56] International Energy Agency, Gas Medium-Term Market Report (2012).
[57] Energy Information Administration, Medium-Term Gas Market Report 2012.
[58] Whitehouse.gov, State of the Union Address (Jan. 25, 2012); EIA, U.S. Proved Reserves Increased Sharply in 2010 (2012).
[59] Energy Information Administration, Electric Power Monthly April 2012.
[60] Energy Information Administration, supra. note 57.
[61] Energy Information Administration, World Shale Gas Resources (Apr. 2011).
[62] Kenneth Medlock, Impact of Shale Gas Development on Global Markets, Natural Gas & Electricity 22 (2011).
[63] International Energy Agency, Golden Rules for a Golden Age of Gas (2012).

electricity sector through a combination of direct substitution of natural gas for gasoline and indirect substitution through cars that operate on electricity generated with gas.[64]

All we need to do to realize this rosy future is to implement what IEA calls the "Golden Rules" of regulation.[65] IEA has identified a series of critical rules that governments must apply to fracking to allow it to realize its potential with acceptable environmental consequences. IEA estimates that implementation of the of the regulatory rules it considers important will add no more than 7% to the unit cost of gas produced through fracking.[66] Such an increase in cost would still render gas the cheapest source of electricity generation for the foreseeable future.[67] Replacement of coal with gas can not alone achieve the daunting goal of decreasing global CO2 emissions by 50% by 2050, but it will get us a long way toward that goal.[68]

H. Reducing Black Carbon and Methane Emissions

While CO2 is the most abundant ghg, it is not the most powerful. Black carbon and methane are many times more powerful ghgs measured on a per unit emitted basis.[69] The UN estimates that reducing black carbon and methane emissions can yield far greater mitigation benefits than reducing CO2 emissions over the next thirty years.[70] The UN has identified 16 ways in which we can reduce black carbon and methane emissions significantly on a cost-effective basis, e.g., by improving the filters on diesel engines, implementing "green completions" of natural gas wells, and reducing open burning on agricultural land.[71] Each of the methods identified in the UN report would actually yield net economic benefits in forms such as more efficient performance of diesel engines and increased volumes of methane that can be sold by producers.[72] Moreover, implementation of the black carbon and methane mitigation methods urged by the UN would simultaneously save 2.5 million lives per year and increase crop production by 32 million tons per year.[73]

Like replacing coal with gas, reducing black carbon and methane emissions would not be enough alone to avoid the catastrophic effects of climate change. Black carbon and methane are powerful but relatively short-lived ghgs.[74] As a result, the beneficial effects of reducing emissions of black carbon and methane dissipate over

[64] Whitehouse.gov, supra. note 55.
[65] International Energy Agency, supra. note 63.
[66] Id.
[67] Id.
[68] Pierce, supra. note 22.
[69] UN, Integrated Assessment of Black Carbon and Tropospheric Ozone (2011).
[70] Id.
[71] Id.
[72] Id.
[73] Id.
[74] Id.

time. Reducing black carbon and methane emissions can buy us many decades of time in which to implement effective means of reducing CO2 emissions, however.

I. A Carbon Tax Revisited

I hope that the foregoing review of the difficulty and cost of attempting to mitigate climate change through other means will help to persuade you that a carbon tax of $50-200 per ton is by far the most effective and least expensive method of mitigation. There is broad agreement that technological improvements have the potential to render effective mitigation a goal that is attainable in a timely and cost-effective manner. There is massive disagreement, however, with respect to the critical question of which of the scores of technological frontiers are most likely to yield developments that will provide opportunities to implement cost-effective means of reducing emissions. The candidates include solar, wind, nuclear, conservation, biomass, geothermal, electricity storage, and carbon capture and sequestration. Moreover, each of those broad categories can be divided into countless subcategories. Thus, for instance, there are many promising forms of solar energy and many promising methods of storing electricity economically.

Choosing among the many candidates for major breakthroughs in cost-effective mitigation is a fool's errand. No one can be confident that solar or nuclear will provide better results than wind or carbon capture and storage ten, twenty, or fifty years from now. Implementation of a substantial carbon tax avoids the need to engage in such a hopeless guessing game by providing the same powerful incentive for research and development along each of those promising margins, while simultaneously encouraging implementation of the most cost-effective means of reducing emissions.

Economic conditions are all wrong for implementation of any new tax at present. Once the US and global economies are performing well, and the US is willing and able to confront the need for new revenues to reduce the present unsustainable level of annual budget deficit, we should choose a carbon tax to further simultaneously both our fiscal policy goals and our climate change mitigation goals. If the US leads the rest of the world in implementing the IEA's "Golden Rules" for regulating gas production and the UN's 16 methods of reducing emissions of black carbon and methane, we can buy the time required to create the combination of political and economic conditions that are conducive to adoption of an effective carbon tax. Once the US adopts a substantial carbon tax, it will have the credibility to lead the rest of the world in a new more effective round of negotiations to agree on an effective global mitigation effort.

IV. Adaptation

Even if we achieve considerable success in our efforts to mitigate climate change, some uncertain amount of change is inevitable. My colleague, Rob Glicksman, has begun the crucial process of identifying the hundreds of steps we must take to adapt

to climate change.[75] Many of those steps will involve major changes in the legal environment.

In his initial assessment of the need to adapt existing legal institutions to the changing climate, Glicksman explains why climate change will "fundamentally rearrange US ecosystems."[76] He then explores the many ways in which that fundamental rearrangement will complicate existing relationships among legal institutions and require a fundamental rethinking of the ways in which the US allocates responsibility for management of natural resources.

Conclusion

I will end where I began. I am confident that my current students will be working on legal issues related to climate change when they retire fifty years from now. I hope that many of them will work on identifying and implementing effective means of mitigating climate change. Even if they are successful in those efforts, however, the climate will change significantly in ways to which the legal system must adapt. Whatever path we take to address climate change, there is no doubt that climate change will be a dominant factor in the world of law for the foreseeable future. Every lawyer in the country will encounter climate change and its legal implications in myriad contexts for at least a century.

Some of the legal disputes of the future will look a lot like recent disputes with respect to the arguable need for actions by legislatures, regulators, and courts concerning proposed renewable fuel projects, nuclear powerplants, transmission lines, fracking operations, efficiency standards, etc. We are already beginning to see new types of disputes, however. Thus, for instance, we are beginning to see disputes about whether zoning boards should authorize construction of long-lived structures on tracts of land that are likely to be completely submerged in a few decades. As deserts and oceans expand dramatically to take increasingly large areas of land that humans and animals have long used for various purposes, we will see hundreds of new disputes with respect to competing uses of increasingly scarce land. Moreover, as hundreds of millions of people in Africa, Asia and small Island States discover that their land has either become submerged or been rendered worthless by desertification, the US will confront major new foreign relations challenges. DOD and CIA consider climate change a major source of future global conflicts.

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[75] Alejandro Carmacho & Robert Glicksman, A Multi-Dimensional Framework for Reallocating Government Authority in Response to Regulatory Stress: The Climate Change Adaptation Example (forthcoming).
[76] Id. at ___.