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Renewable Energy under the Kyoto Protocol: The Case for Mixing Instruments

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This paper argues that effective climate policy may require a mixture of policy mechanisms to encourage technological development necessary to facilitate an eventual fossil fuel phase out. This idea contrasts with the view that broad global environmental benefit trading[1] offers a climate change panacea. The trading as panacea view suggests that the *Kyoto Protocol*'s trading mechanisms assure adequate attention to renewable energy and that neither trading design nor technology policy measures are important as long as a broad and wide carbon market exists. This paper explains why this view is mistaken and puts forward the idea of taxing fossil fuels in order to pay for the introduction of more renewable energy, the use of other targeted programs to encourage renewable energy, and trading design principles to encourage technological progress.

This paper begins with an explanation of why renewable energy is important to efforts to address global climate change. The paper's second part presents data showing that global environmental benefit trading has not encouraged renewable energy as well as more targeted programs. This part of the paper also briefly presents some of the theoretical reasons to expect global trading to perform suboptimally in encouraging renewable energy.

The paper's final part discusses policy implications. It argues that the proper goal of policy should be to move toward an eventual phase-out of fossil fuels, rather than maximizing short-term cost minimization. It suggests a mix of policy tools and emissions trading design principles that can help move us toward this goal.

1. Renewable Energy's Importance in Addressing Global Climate Change

Practically all climate change experts recognize that meaningfully addressing climate change will require fundamental changes in the production and use of energy. Predictions of the amount of carbon reductions needed to avoid dangerous climate change tend to coalesce at around a 50 per cent global reduction by 2050, followed by even more drastic cuts.[2] Because developed countries like Canada have better technological capabilities than developing countries and bear historical responsibility for most of the problem, developed countries will need to produce substantially more than a 50 per cent reduction in national carbon emissions to make a worldwide cut of that magnitude possible. Since carbon dioxide, a product of fossil fuel combustion, accounts for about 80 per cent of the global warming potential of world greenhouse gas emissions, the overwhelming majority of these cuts must come from drastic reductions in the amount of fossil fuel burned.[3] Achieving anything less than this creates a high probability of very serious consequences, such as melting polar ice caps, the inundation of much of Bangladesh, and widespread drought in Africa.[4] Seen in this light, a successful climate change program will deliver large short-term reductions in a manner that sets the stage for making more serious cuts in the future.

The economics of energy suggest that strategies employed now to reduce carbon emissions must contribute to lowering the price and increasing the utility of renewable energy in order to make more drastic future cuts feasible. Economists frequently use top-down approaches to modelling the costs of addressing climate change, relying on basic macroeconomic data about the effects of previous rises in energy costs.[5] This approach, which implicitly assumes that our technological capabilities today resemble those of the 1970s, sometimes generates numbers so high that they raise serious questions about whether the world's governments would ever agree to make the reductions needed to avoid dangerous climate change.[6] Yet, some bottom-up models, which consider current technologies available to reduce greenhouse gas emissions,[7] predict that the drastic cuts scientists call for can be achieved at zero net cost, meaning no more cost than continuing with business as usual would generate.[8] They arrive at this conclusion by assuming that the continued refinement of existing technologies will generate cost savings in energy technology comparable to what we have seen in the past, especially for renewable energy.[9] This suggests that policies must support the deployment of renewable energy in the near term in order to make avoiding dangerous climate change feasible. Deployment of renewables creates 'learning by doing,' which will enable renewable energy providers to improve the utility and lower the cost of their products.[10]

Renewable energy has enormous advantages over competing forms of energy, when viewed from a long-term perspective. Some forms of renewable energy, such as solar, have zero fuel costs.[11] This implies that even with large initial capital investment, if the technology is durable, then the non-discounted long-term costs should be low. And renewable energy offers zero direct carbon emissions while simultaneously delivering significant reductions in particulate and ground-level ozone, which constitute serious health hazards in Canada and in many other places around the world. Furthermore, a transition to renewable energy promises to ameliorate acid rain and the ecological damage associated with burning fossil fuels. Thus, renewable energy would be worthwhile, even if it costs a lot more than 'end-of-the-pipe' approaches to greenhouse gas reductions because it simultaneously offers a host of incidental environmental benefits.

The history of renewable energy suggests that its employment will cost much less in the future than it does today, if appropriate policies support its development. We have seen large decreases in the cost of all forms of renewable energy as manufacturers learn how to more efficiently deploy renewable energy with increased production opportunities.[12] Indeed, wind power has become competitive with fossil fuels as a source of peak generating power. Generally, progress has been most dramatic in countries and regions with supportive policies.[13] It is reasonable to assume that with appropriate policies, costs can continue to fall.

By contrast, continued reliance on fossil fuels presents grave risks to the economy and our security, not just to the environment. Since fossil fuels are finite resources, their price will eventually rise and then they will run out. If we fail to implement policies that will stimulate development, refinement, and deployment of alternative technologies, these price increases and shortages will likely prove very disruptive.

To put it another way, we will stop using oil and coal as energy sources sooner or later, because they will cease to exist. The only question is whether we switch to alternatives before or after we commit the atmosphere to very dangerous global warming.

It would seem prudent to begin the switch as soon as possible in light of the long residence times of greenhouse gases. Once emitted, these gases remain in the atmosphere trapping heat for a century or more, so that we cannot subsequently adjust to failures to make sufficiently ambitious cuts early on.

In emphasizing renewable energy's importance, I do not mean to deny the relevance of other technological options. Indeed, cogent analysis of how to avoid dangerous climate changes envisions a mixture of technologies and strategies, as renewables may not solve the climate change problem alone.[14] Improved energy efficiency is an important part of making renewables, which are difficult to introduce at a large scale, more viable. But many other technological options have significant drawbacks that make renewable energy relatively attractive. Nuclear power poses the risk of accidents and creates security and waste disposal issues. Carbon sequestration may have potential, at least for addressing part of the problem, but it leaves many environmental problems associated with burning coal unaddressed and may not provide a long-term solution to climate change.[15] Advances in renewable energy then are important to our future and sustainable development, even though they are not the sole means we have of addressing climate change.

2. Trading, Targeted Incentives, and Renewable Energy

The literature on trading suggests that it encourages innovation, which might lead one to suspect that the trading of carbon credits will stimulate large increases in the production of renewable energy. So far, trading does not seem to have done so. China and India add significant amounts of coal powered-generating capacity to their power grids every year.[16] One might object that this does not represent a failure of trading, but rather the lack of caps on those countries. But that is precisely the point. Cap-and-trade programs' environmental improvements come from the caps, not from the trading. The trading simply provides a means of lowering the cost of meeting the environmentally valuable carbon reductions required by setting strict caps. Cap-and-trade programs must demand large carbon reductions from very significant sectors of the economy in order to provide a meaningful impetus for carbon reduction.

At first glance, the Clean Development Mechanism (CDM), the *Kyoto Protocol*'s trading program allowing developing countries to provide emission reduction credits to offset emissions in the developed world, seems to provide a countervailing force. The majority of CDM projects involve renewable energy. But a more careful analysis makes the countervailing force vanish. One should evaluate CDM distribution by carbon credits, because this gives a picture of how much of the greenhouse gas reductions being provided come from renewable energy. An evaluation of the distribution of carbon credits reveals that renewable energy has provided approximately 17 per cent of the total credits, and energy efficiency, which is vital to renewable energy's long-term prospects, constitutes a paltry 10 per cent.[17] End-of-the-pipe control, as figure 12.1 shows, generates the lion's share of the credits.

[Figure 12.1 to go about here, top of page]

The main reason that trading encourages end-of-the-pipe controls is that the market favours the cheapest means of meeting greenhouse gas reductions. End-of-the-pipe projects controlling emissions of potent greenhouse gases, such as HFC 23, cost less than most renewable energy projects on a dollar per carbon dioxide equivalent basis.[18] The data available so far reflect only the experience with the reductions encouraged by Phase I of the European Union's emissions trading scheme (ETS) and the newly proposed stricter targets in Phase II. The limits imposed on pollution sources create demand for credits, making the ETS the primary driver of private sector purchases. One would expect the role of renewable energy to increase somewhat as targets become stricter, as they will in phase two of this two-part scheme.

However, competition among CDM projects will tend to encourage the cheapest emissions reductions. This means that the market does not systematically account for renewable energy's long-term and non-carbon advantages, that is, its capacity to contribute to long-term technological advances and its ability to limit conventional air pollution. Emissions trading markets are better vehicles for seizing low hanging fruit than for planting new fruit trees. Trading's maximization of short-term cost effectiveness conflicts with the goal of maximizing technological progress, collateral benefits from carbon motivated technological changes, and even long-term cost effectiveness.[19]

While the suggestion that trading does not optimally encourage valuable innovation may appear novel, it enjoys increasing support in the economics literature.[20] Furthermore, the most careful students of the acid rain trading program's technological impact have concluded that it encouraged innovation less effectively than the traditional performance standards that preceded it.[21]

By contrast with trading, more targeted energy policies have increased deployment of renewable energy significantly, creating a huge increase in wind generating capacity and more modest increases in deployment of other alternative energy sources.[22] Fiscal incentives have played a key role in encouraging these advances, but some quantity mechanisms have also played an important role. The most successful fiscal incentive appears to be the 'feed-in tariff,' which is widely used in Europe.[23] Countries employing feed-in tariffs require electricity producers to pay a fixed above-market price for all alternative energy produced. Countries experiencing the greatest growth in wind power have employed this system.[24] Many regions of the world employ renewable portfolio standards to encourage renewable energy, rather than feed-in tariffs. These programs require the purchase of a fixed quantity of renewable energy. Recently, these programs have taken the form of 'renewable certificate' programs, which allow trades of certificates representing renewable energy generation. While these limited trading programs offer some advantages in tracking compliance with renewable portfolio standards, it is not clear that the extra flexibility they provide is vital to achieving program goals.[25] Targeted measures aimed at supporting renewable energy, unlike broad global trading, have played a major role in encouraging the increases in production and decreases in price that we have seen in the renewable energy sector.

Trading programs and targeted incentives for renewables clash philosophically. A philosophy of market liberalism undergirds trading programs. Devotees of these programs want to limit governments' role to goal setting and leave technological choices to the free market.[26] By contrast, renewable programs stem from government decisions to favour a particular class of technologies. Governments around the world have decided that sustainable development goals – including energy security, long-term economic development, protection of the health of current generations from routine air pollution, and the creation of local employment – all favour renewable energy. From the standpoint of market liberalism such decisions smack of unjustified interference in the free market of emissions trading. One frequently hears the mantra, 'Let the market decide.' This slogan seems to reflect the notion that the only legitimate goal involved in choosing future energy technology is the short-term reduction of carbon at the lowest possible cost.

The analysis offered above, however, suggests that the market, even markets that have internalized some environmental costs associated with current carbon dioxide emissions, do not offer proper incentives for the long-term changes needed to address global warming and the economic well-being of future generations. Economists recognize that markets tend to under-invest in technological innovation. Those who advance technological development create positive economic spillovers – that is, benefits that do not generate revenues for the firm bearing the cost of technological development.[27] For example, an advance in the design of photovoltaic cells that may make them cheaper or more useful in cloudy climates may gain some additional revenue for the person making the advance. But if another firm looks at the design of these cells and uses the information gleaned from this examination to further advance the state of the art, the second firm, not the first, may gather the revenue. The contribution of the first firm's technology to the second technological advance constitutes a positive spillover from the first firm's investment. Companies can be reluctant to make investments that will substantially benefit competing firms. Furthermore, investments in new technologies are inherently risky and their benefits are difficult to predict.[28] This can make firms, especially firms that control lucrative conventional technologies, reluctant to invest in innovation, which is a major driver of economic prosperity. The collateral benefits of reduced conventional air pollution also constitute a positive spillover that carbon markets do not encourage firms to internalize. This means that even with optimal carbon targets, an emissions trading program does not provide optimal incentives for broadly rational technological choices unless supplemented with some corrective mechanism. This suggests that governments should supplement carbon markets with more targeted measures aimed at advancing technology.

3. A Mix of Policies

Instrument selection reflects implicit normative choices. For the most part, writers assume that the norm of minimizing the short-term cost of meeting a given carbon reduction goal should govern instrument selection, and therefore use a short efficiency criterion to guide instrument choice. In the climate change context, however, society should instead choose a goal of pushing the price differential between renewables and fossil fuels to a tipping point where renewable energy becomes the more economic option. This goal commends itself because of the significant costs associated with failing to avoid dangerous climate change.[29] If one wants to avoid those costs, then maximizing long-term technological change is more important than minimizing short-term costs. While we can expect some movement in this direction to occur through scarcity-induced increases in fossil fuel prices, this price-induced change will not move the world toward the drastic cuts we need to meaningfully address global warming in a timely manner. The question is: What can be done to make this change happen?

3.1. New Economic Incentive Programs

The goal of encouraging a shift from fossil fuels to renewables suggests that we should tax fossil fuels to fund renewable energy. Mikael Skou Andersen has pointed out that systems that employ this kind of approach, employing a negative economic incentive to fund a positive economic incentive, can effectively encourage innovation.[30] This approach sends a signal that private actors should invest in alternatives to fossil fuels, instead of building new coal-fired plants with years of useful life ahead of them that pump large amounts of carbon into the atmosphere.

This proposal also helps rectify the problem of fossil fuel subsidies artificially delaying the introduction of renewable energy by making fossil fuels too cheap relative to renewable energy.[31] Of course, that observation leads to the question, why not simply abolish fossil fuel subsidies? Abolishing fossil fuel subsidies would be a good idea, although we probably need to increase positive incentives for renewable energy as well.[32] But eliminating long established subsidies from tax codes and government budgets may prove even more politically difficult than enacting a bold new program to shift the incentives in the right direction.

China provides an example of deliberate government use of tax incentives to meet sustainable development goals. China has taxed CDM projects differentially, imposing high taxes on projects generating carbon credits through end-of-the-pipe controls of industrial gases while imposing low taxes on renewable energy.[33] Furthermore, China has announced an intention to fund renewable energy.[34] It is at least possible that some of the funds for the renewables will come from taxes on less desirable CDM projects. China, then, has created incentives that favour renewable energy, which makes sense for the climate and economic development. It would be even better policy to tax the generation of carbon, rather than carbon reductions, to fund renewable energy.

An Environmental Competition Statute, which also funds positive economic incentives with negative economic incentives, has the potential to avoid many of the governmental weaknesses that tend to interfere with the achievement of ambitious goals, like those needed to address global warming. Such a statute would simply authorize any entity lowering its carbon dioxide emissions to recoup the costs incurred in reducing its carbon output from a competitor of its choosing that has higher emissions, along with a pre-set premium.[35] It allows the capacity of the most environmentally progressive entities in an industry to establish benchmarks that other companies must adhere to if they wish to avoid paying competitors. It thus encourages a race to maximize environmental performance, comparable to the race to improve product quality that can occur because of market share concerns in highly competitive markets.

This approach helps avoid a problem with emissions trading and pollution taxes; namely, their dependence on tough government decision-making. Trading can only work when government officials set ambitious caps. Similarly, pollution taxes only provide significant reduction incentives if officials set reasonably high tax rates. The Environmental Competition Statute allows the capabilities of the most environmentally capable companies to drive programmatic achievements, relying on the government only to set up a law requiring these sorts of payments and establishing the profit margin that companies besting their competitors will be awarded through the premium. In this approach the limited bravery of government officials in setting caps or tax rates does not limit the programs' achievements.

3.2. Sectoral Programs

Countries can expand and strengthen the sectoral programs that have proven more successful than trading in stimulating renewables, such as renewable portfolio standards and feed-in tariffs. These programs can include demand-side management programs for electric utilities and energy efficiency standards for appliances and vehicles.[36]

3.3. Trading Design

While an environmental benefit trading program offers a suboptimal tool for stimulating relatively expensive renewable energy, renewable energy can play a role in such programs. A country can maximize that role by attending to the following design principles if it employs environmental benefit or emissions trading.

STRICT CAPS

Ambitious caps requiring large emission reductions will raise the cost of compliance sufficiently to make some renewable energy viable. While those purchasing credits will still prefer to avoid relatively expensive renewables in favour of lower cost conventional options, they may find some purchase of renewable credits unavoidable if they must purchase large volumes of credits in order to comply. And, of course, strict caps ameliorate climate change more effectively than lax caps, simply because they lower the amount of carbon warming the earth.

LIMITED OFFSETS

A country that wishes to make sure that its credit purchases make a long-term contribution to sustainable development can limit the classes of projects eligible for offset credits and the amount of offsets that are allowed. Indeed, a country could accept only renewable energy projects as offsets, thereby ruling out projects that contribute little to the long-term process of technological development to facilitate fossil fuel replacement.[37] The Regional Greenhouse Gas Initiative, a program to limit utility emissions in the northeastern states, provides quantitative and qualitative limits on offsets in order to protect the program's environmental integrity.[38]

LIMITED BREADTH

Large linked markets will tend to maximize cost savings, thereby dropping the cost of credits.[39] These cost drops reduce incentives for expensive innovation. This point is consistent with economic models of taxes, which link higher tax rates to greater innovation rates. Narrower programs stimulate valuable high-cost innovation better than broad ones, by limiting the availability of cheap conventional credits.

INPUT ALLOWANCES

A program limiting the total amount of fossil fuel consumed through tradable allowances in dirty inputs (such as coal and oil) will better encourage innovation than a broad program focused on end-of-the pipe allowances.[40] It will also prove much easier to monitor and enforce. Such a program can reach the transport sector, which has been left out of caps enacted so far, thereby allowing for a comprehensive economy-wide cap. Some of the bills pending in the United States Congress use a variant on this idea to create an economy-wide cap.[41]

4. Conclusion

A tension exists between maximizing short-term cost effectiveness and maximizing long-term investments needed to address global warming. We can creatively employ a mixture of policy tools to maximize incentives to shift away from fossil fuels to cleaner approaches.

Notes

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[1] I use the term 'environmental benefit' trading, rather than emissions trading, because the climate change regime leaves open the possibility of offsetting emissions with carbon sequestration credits, rather than reducing emissions. See D.M. Driesen, 'Free Lunch or a Cheap Fix? The Emissions Trading Idea and the Climate Change Convention' (1998) 26:1 B.C. Envtl. Aff. L. Rev. at 32–3 [Driesen, 'Free Lunch'], (describing how the concept of emissions trading became broadened to go beyond trading of emission reductions). This means that the term 'emissions trading' does not accurately describe the Kyoto trading system, at least when sequestration credits are used, since more than just emissions can be traded.

[2] See A. Dessler and E. Parson, *Science and Politics of Global Climate Change: A Guide to the Debate* (Cambridge: Cambridge University Press, 2006) at 155–8 (suggesting that avoiding a 3°C temperature rise may require a 40 per cent cut in global carbon dioxide emissions from 2010 levels by 2050 and more than a 60 per cent cut by 2100); J.E. Hansen, 'A Slippery Slope: How Much Global Warming Constitutes "Dangerous Anthropogenic Interference"?' (2005) 68 Climate Change 269 at 277. (stating that a 2°C temperature rise 'almost surely takes us well into the realm of dangerous' climate change); M. Meinshausen, 'What Does a 2°C Target Mean for Greenhouse Gas Concentrations? A Brief Analysis Based on Multi-Gas Emission Pathways and Several Climate Sensitivity Uncertainty Estimates' in H.J. Schnellnhuber et al., eds., *Avoiding Dangerous Climate Change* (New York: Cambridge University Press, 2006) 265 at 269–70 (estimating that limiting a temperature rise to less than 2°C likely requires a 55 per cent reduction below 1990 emission levels by 2050).

[3] See R.A. Posner, *Catastrophe: Risk and Response* (New York: Oxford University Press, 2004) at 15 (describing global warming as largely a product of fossil fuel combustion).

[4] See R.L. Glicksman, 'Global Climate Change and the Risks to Coastal Areas from Hurricanes and Rising Seas: The Costs of Doing Nothing' (2006) 52 Loyola L. Rev. 1127 at 1135–42 (reviewing the science on ice melting and sea level rise); J.E. Hansen, 'Global

Warming: Is There Still Time to Avoid Disastrous Human-Made Climate Change? I.e. Have We Passed a Tipping Point?' (Discussion at the National Academy of Sciences, Washington, DC, 23 April 2006) at 26–9, online, http://www.columbia.edu /~jeh1/nas_24april2006.pdf (providing maps of areas that would probably be under water if temperature increased by 3°C); see also James E. Neumann et al., 'Sea-Level Rise & Global Climate Change: A Review of Impacts to U.S. Coasts' (Paper prepared for the Pew Center on Global Climate Change, Arlington, February 2000) at 12, online, http://www.pewclimate.org/global-warming-in-depth/all_reports/sea_level_rise/index.cfm (providing maps of areas likely to experience flooding under three different scenarios).

[5] R. Repetto and D. Austin, *The Costs of Climate Protection: A Guide for the Perplexed* 6 (Washington, DC: The World Resources Institute, 1997). See also T. Barker et al., *Climate Change 2007: Mitigation of Climate Change, Summary for Policymakers* (Working Group III Contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report, 2007) 10. T. Barker et al., Working Group II Contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report, *Climate Change 2007: Mitigation of Climate Change, Summary for Policymakers* (2007) 10.

[6] See R.J. Sutherland, '"No Cost" Efforts to Reduce Carbon Emissions in the U.S.: An Economic Perspective' (2000) 21:3 Energy J. 89 at 90–1 (comparing 'mainstream economic analysis' with an 'energy conservation paradigm'); but see T. Barker and P. Ekins, 'The Costs of Kyoto for the U.S. Economy'(2004) 25:3 Energy J. 53 at 53–4 (finding that some top-down models predict high costs, but that the view that addressing climate change will be very costly is 'not well founded').

[7] Repetto and Austin, *supra* note 5 at 6. See also Barker et al., *supra* note 5 at 10; R.N. Stavins, J. Jaffe, and T. Schatzki, 'Too Good to Be True? An Examination of Three Economic Assessments of California Climate Change Policy' (Washington, DC: AEI-Brookings Joint Centre for Regulatory Studies, January 2007), online, http://ssrn.com/abstract-973836.

[8] Sutherland, *supra* note 6 at 91.

[9] Ibid.

[10] See A.B. Jaffe et al., 'Technological Change and the Environment,' in K.G. Mäler and J.R. Vincent, eds., *Handbook of Environmental Economics*, vol. 1 (North Holland, 2003) 461 at 493 (discussing price drops due to learning by doing); Sabine Messner, 'Endogenized Technological Learning in an Energy Systems Model' (1997) 7 J. Evolutionary Econ. 291 at 293 (characterizing 'learning by doing' as 'among the best empirically corroborated phenomena characterizing technological change in industry'); L. Argote and D. Epple, 'Learning Curves in Manufacturing' (1990) 247 Science 920 (reporting learning curve effects documented in building *inter alia*, ships, aircrafts, petroleum products, oil refineries, and trucks).

[11] M. Ilkan, E. Erdil, and F. Egelioglu, 'Renewable Energy Resources as an Alternative to Modify the Load Curve in Northern Cyprus' (2005) 30 Energy 555 at 565 ('similar to other renewable energy systems, Photovoltaic and [wind-electric conversion] systems are characterized by high capital, low operation and maintenance cost, and zero fuel cost').

[12] J. Greenblatt et al., 'Baseload Wind Energy: Modeling Competition between Gas Turbines and Compressed Air Energy Storage for Supplemental Generation' (2007) 35 Energy Pol'y 1474 at 1474 (attributing a 30 per cent annual increase in installed wind capacity to a 'twofold drop in capital costs between 1992 and 2001' and 'government initiatives'); Commission of the European Communities, *The Share of Renewable Energy in the EU: Evaluation of the Effect of Legislative Instruments and Other Community Policies on the Development of the Contribution of Renewable Energy Resources in the EU and Proposals for Concrete Actions* 2004 (SEC) 547 at 19 [hereinafter 2004 Commission Energy Evaluation] (finding that wind costs have fallen by 50 per cent over the last 15 years); L. Barreto and S. Kypreos, 'Emissions Trading and Technology Deployment in an Energy-Systems 'Bottom-up' Model with Technology Learning' (2004) 158 Eur. J. Operational Res. 243 at 246–8 (estimating an 80 per cent progress ratio for solar photovoltaics, representing the rate of cost decline per doubling of production).

[13] See F.C. Menz and S. Vachon, 'The Effectiveness of Different Policy Regimes for Promoting Wind Power: Experiences from the States' (2006) 34 Energy Pol'y 1786 at 1794 (finding that renewable portfolio standards have stimulated increased production of wind power); 2004 Commission Energy Evaluation, *supra* note 12 at 19 (finding that

wind power grew by 23 per cent in 2003, exceeding EU wind target). See also A. Ford et al., 'Stimulating Price Patterns for Tradable Green Certificates to Promote Electricity Generation from Wind' (2007) 35 Energy Pol'y 91 at 92 n. 4 (explaining that the Texas renewable portfolio standard produced the 'Texas Wind Rush,' the installation of 10 new wind projects in 2001 producing 930 megawatts of power); N.H. van der Linden et al., *Review of International Experience With Renewable Energy Obligations Support Mechanisms* (Netherlands: ECN Policy Studies, 2005) at 35, online, http://eetd.lbl.gov/ea/ems/reports/57666.pdf (suggesting that a number of policy instruments have contributed to increased renewable energy production in Sweden and that investment in wind power has slowed as the governmental support for land-based wind power is phased out); J.W. Moeller, 'Of Credits and Quotas: Federal Tax Incentives for Renewable Resources, State Renewable Portfolio Standards, and the Evolution of Proposals for a Federal Renewable Portfolio Standard' (2004) 15 Fordham Envtl. L.J. 69 at 73–7 (explaining that a federal requirement that electric utilities purchase power from renewable energy sources played a 'significant, though not precisely quantifiable, role' in expanding renewable power generation).

[14] See S. Pacala and R. Socolow, 'Stabilization Wedges over the Next Fifty Years With Current Technologies' (2004) 305 Science 968. This analysis bases its estimate of renewable energy's contribution to limiting climate change on existing technologies. While innovation should enable the role to grow, this analysis suggests that the growth would have to be truly enormous to make it the sole solution to climate change.

[15] See Working Group III, Intergovernmental Panel on Climate Change, *Special Report on Carbon Dioxide Capture and Storage* (New York: Cambridge University Press, 2005) at 24, 60–6 (noting that the potential for carbon capture corresponds to only 9–12 per cent of 2020 global carbon dioxide emissions and 21–45 per cent of 2050 emissions, that 38 per cent of carbon dioxide emissions are from dispersed sources that are generally not considered suitable for carbon capture technologies, that other environmental costs and risks may arise from the storage of carbon dioxide such as impacts on marine ecosystems due to the slow seepage of carbon dioxide into the water, and that the amount of carbon that remains in storage once deposited varies with the type of storage system).

[16] See K. Bradsher, 'China to Pass U.S. in 2009 in Emissions,' *The New York Times* (7 November 2006) C1 (discussing new coal-fired power plants in China, India, Germany, and Britain).

[17] See J. Fenhann, UNEP Risoe CDM/JI Pipeline Analysis and Database, CDM Pipeline Overview (July 2007), online, http://cdmpipeline.org/publications/CDMpipeline.xls; see also Capacity Development for the CDM, Guidance to the CDM/JI Pipeline 1 (2006), online, http://cdmpipeline.org/publications/GuidanceCDMpipeline.pdf (explaining that data comes from UNFCC homepage located at http://cdm.unfccc.int/index.html, including Project Design Documents also available there). Joergen Fenhann, UNEP Risoe CDM/JI Pipeline Analysis and Database, *CDM Pipeline Overview* (July 2007) online, http://cdmpipeline.org/publications/GuidanceCDMpipeline.pdf.

[18] See K. Capoor and P. Ambrosi, *State of the Carbon Market, 2006* (Washington, DC: The World Bank and IETA, 2006), online, http://carbonfinance.org/docs/StateoftheCarbonMarket2006.pdf (characterizing HFC projects as the 'lowest-cost options' and therefore becoming the 'first asset class to be systematically tapped globally'); X. Zhao and A. Michaelowa, 'CDM Potential for Rural Transition in China Case Study: Options in Yinzhou District, Zhejiang Province' (2006) 34 Energy Pol'y 1867 at 1876 (finding the initial cost of solar installation high, even though over the long-term it is cost competitive).

[19] I have discussed the tension between maximizing short-term cost effectiveness and encouraging innovation before. For a detailed discussion of the theory underlying this tension, see D.M. Driesen, 'Design, Trading, and Innovation,' in J. Freeman and C. Kolstad, eds., *Moving to Markets in Environmental Protection: Lessons after 20 Years of Experience* (Oxford: Oxford University Press, 2007); D.M. Driesen, 'Does Emissions Trading Encourage Innovation?'(2003) 33 Envt'l L. Rep. (Envtl. L. Inst.) 10094.; Driesen, 'Free Lunch,' *supra* note 1; D.M. Driesen, 'Is Emissions Trading an Economic Incentive Program? Replacing the Command and Control/Economic Incentive Dichotomy' (1998) 55 Wash. & Lee L. Rev. 289.

[20] See J.F. Bruneau, 'A Note on Permits, Standards, and Technological Innovation' (2004) 48 J. Envtl. Econ. & Mgmt. 1192; J.-P. Montero, 'Permits, Standards, and

Technology Innovation' (2002) 44 J. Envtl. Econ. & Mgmt. 23; J.-P. Montero, 'Market Structure and Environmental Innovation' (2002) 5 J. Applied Econ. 293 (trading, taxes, or traditional regulation can best encourage research and development when firms' products are strategic substitutes); D.A. Malueg, 'Emissions Credit Trading and the Incentive to Adopt New Pollution Abatement Technology' (1987) 16 J. Envtl. Econ. & Mgmt. 52 (pointing out that firms purchasing credits under trading face lesser incentives to innovate than they would under a traditional performance standard); W.A. Magat, 'Pollution Control and Technological Advance: A Dynamic Model of the Firm' (1978) 5 J. Envtl. Econ. & Mgmt. 95.

[21] M.R. Taylor, E.L. Rubin, and D.A. Hounshell, 'Regulation as the Mother of Innovation: The Case of SO2 Control' (2005) 27 Law & Pol'y 348 at 370 (finding that 'command and control' regulation created more innovation than the trading program and did not change the type of innovation found); D. Popp, 'Pollution Control Innovations and the Clean Air Act of 1990' (2003) 22 J. Pol'y Analysis & Mgmt. 641 (finding more innovation under 'command and control' but a different type of innovation under trading).

[22] See, e.g., van der Linden, *supra* note 13 at 38 (suggesting that a number of policy instruments have contributed to increased renewable energy production in Sweden); Moeller, *supra* note 13 at 73–7 (explaining that a federal requirement that electric utilities purchase power from renewable energy sources played a 'significant role' in expanding renewable power generation); cf. I. Choi, 'Global Climate Change and the Use of Economic Approaches: The Ideal Design Features of Domestic Greenhouse Gas Emissions Trading and an Analysis of the European Union's CO_2 Emissions Trading Directive and the Climate Stewardship Act' (2005) 45 Nat. Resources J. 865 at 891 n. 86 (claiming that the acid rain program has discouraged the use of renewable energy, in spite of the establishment of reserve allowances to provide incentives to use it).

[23] See M. Mendonça, *Feed-in Tariffs: Accelerating the Deployment of Renewable Energy* (London: Earthscan Publications Ltd., 2007) at 19 (claiming that numerous empirical studies have documented the superiority of feed-in tariffs as an instrument and listing countries using them).

[24] M. Ringel, ‘Fostering the Use of Renewable Energies in the European Union: The Race between Feed-in Tariffs and Green Certificates’ (2006) 31 Renewable Energy 1 at 10.

[25] See O. Langniss and R. Wiser, ‘The Renewables Portfolio Standard in Texas: An Early Assessment’ (2003) 31 Energy Pol’y 527 at 532 (stating that ‘certificate trading may not be essential for the effective design of a state RPS, and little trading has yet taken place in the Texas market’).

[26] See B. Hansjürgens, ed., *Emissions Trading for Climate Policy: U.S. and European Perspectives* (Cambridge: Cambridge University Press, 2005) at 3 (stating that once government allocates allowances its ‘action is limited to supervising the market, monitoring, and applying sanctions in the case of non-compliance’).

[27] See B. Frischman and M.A. Lemley, ‘Spillovers’ (2007) 107 Colum. L. Rev. 257 at 258–61.

[28] Posner, *supra* note 3 at 123 (commenting that uncertainty lies at the ‘core’ of technological innovation, because ‘scientific progress is unpredictable’).

[29] See N. Stern, *The Economics of Climate Change: The Stern Review* (Cambridge: Cambridge University Press, 2007) at xvi–xvii (finding that the costs of climate change are very high and justify strong measures to address climate change). Cf. F. Ackerman, ‘Debating Climate Economics: The Stern Review vs. Its Critics’ (2007) online, http://www.ase.tufts.edu/gdae/Pubs/rp/SternDebateReport.pdf (reviewing various criticisms of the Stern Review and offering some of his own).

[30] M.S. Andersen, *Governance by Green Taxes: Making Pollution Prevention Pay* (Manchester: Manchester University Press, 1994) at 206–10 (‘In general, earmarked taxes represent a second-best solution to user payment and must be regarded as especially appropriate for the production of environmental goods, such as environmental protection.’).

[31] *See* M.L. Hymel, ‘The United States Experience with Energy-Based Tax Incentives: The Evidence Supporting Tax Incentives for Renewable Energy’ (2006) 38 Loy. U. Chi. L. J. 43 at 73 (finding that the United States has invested three times as much money in fossil fuels as in renewables).

[32] Ibid. at 80 (concluding '[the United States needs] to formulate a strategy to eliminate fossil fuel subsidies in favor of alternatives'); A.D. Owen, 'Environmental Externalities, Market Distortions, and the Economics of Renewable Energy Technologies' (2004) 25:3 Energy J. 127 at 155 (concluding that the removal of indirect and direct subsidies for power generation and the appropriate pricing of fossil fuels are essential policies for stimulating development of alternative energy technologies).

[33] China's Office of National Coordination Committee on Climate Change, *Measures for Operation and Management of Clean Development Mechanism Projects in China* (2005) art. 24, online, http://cdm.ccchina.gov.cn/english/ then follow 'Measures for Operation and Management of Clean Development Mechanism Projects in China' hyperlink under 'Domestic Policy & Regulation' (providing that the Chinese government will take 65 per cent of the certified emissions reductions from HFC and PFC projects but only 2 per cent of the certified emissions reductions from renewable energy projects).

[34] See BBC News, 'China Accelerates Construction of Renewable Energy Projects' (31 July 2006) (reporting that the Chinese government will 'set up special fund to support renewable energy projects, giving assistance to their research and development as well as favorable tax policies to relevant enterprises'); see also 'China Sets Up Special Fund for Renewable Energy,' *People's Daily Online* (14 June 2006), online, http://english.people.com.cn/200606/14/eng20060614_273831.html.

[35] See D.M. Driesen, *The Economic Dynamics of Environmental Law* (Cambridge, MA: MIT Press, 2003) at 151–61.

[36] See J.C. Dernbach et al., 'Stabilizing and then Reducing U.S. Energy Consumption: Legal and Policy Tools for Efficiency and Conservation' (2007) 37 Envt'l L. Rep. (Envt'l L. Inst.) 10003 (providing a review of policy tools useful for energy conservation); J.N. Swisher and M.C. McAlpin, 'Environmental Impact of Electricity Deregulation' (2006) 31 Energy 1067 at 1071, 1073, and 1077–8 (linking demand-side management to increased energy efficiency); R.C. Cavanagh, 'Least Cost Planning Alternatives for Electric Utilities and Their Regulators' (1986) 10 Harv. Envtl. L. Rev. 229 (explaining least cost planning and the rationale for it); R.C. Cavanagh, 'Responsible Power Marketing in an Increasingly Competitive Era' (1988) 5 Yale J. Reg. 331 at 337 (defining

least cost planning as a model demanding choice of energy conservation when demand reduction proves cheaper than increasing supply to correct imbalances of supply and demand).

[37] Cf. Driesen, 'Free Lunch,' *supra* note 1 at 79–81 (defending a focus on credits reflecting 'advanced technology').

[38] See D.M. Driesen, 'The Changing Climate for United States Law' (2007) 1 Carbon & Climate L. Rev. 33 at 40 (describing the limits); see also C. Streck and T.B. Chagas, 'The Future of CDM in a Post-Kyoto World' (2007) 1 Carbon & Climate L. Rev. 53 at 58–9 (discussing environmental integrity problems in the offsets offered for credit through the Clean Development Mechanism); CDM Watch, 'The World Bank and the Carbon Market: Rhetoric and Reality' (2007) 16, online, http://www.cdmwatch.org/files/World%20Bank20paper20final.pdf; S. Greiner and A. Michaelowa, 'Defining Investment Additionality for CDM Projects-Practical Approaches' (2003) 31 Energy Pol'y 1007 at 1007 (linking the lack of targets for reductions in developing countries to potential problems with CDM's integrity).

[39] See M.A. Mehling, 'Bridging the Transatlantic Divide: Legal Aspects of a Link Between Carbon Markets in Europe and the United States' (2007) 7 Sustainable Dev't L. & Pol'y 46 at 46 (associating linking of emissions trading markets with 'increased liquidity' and therefore 'reduced compliance costs'); J.B. Wiener, 'Global Environmental Regulation: Instrument Choice in Legal Context' (1999) 108 Yale L.J. 677 at 748 (explaining that widening participation in emissions trading to include developing countries reduces abatement costs).

[40] See D.M. Driesen and A. Sinden, 'The Missing Instrument: Dirty Input Limits' (forthcoming 2008); R.R. Nordhaus and K.W. Danish, 'Assessing the Options for Designing a Mandatory U.S. Greenhouse Gas Reduction Program' (2005) 32 Bost. Coll Envt'l Aff. L. Rev. 97 at 129–33 (discussing the model of an 'upstream' cap and trade program).

[41] See Driesen and Sinden, *supra* note 40; see, e.g., Climate Stewardship Act of 2007, S. 280, 110th Cong., §§3(5), 121(a)(3).(b), 124(a) (1st Sess. 2007) (requiring refiners and importers to hold allowances representing the fossil fuel content of the fuel they supply).