A New Climate Change Solution?

Incentivizing Air Capture Through Emissions Offsets and Greenhouse Gas Property

Derek Lemoine

Submission to the Science, Technology, and Engineering Policy (STEP) 2007 White Paper Competition

Executive Summary

Policy proposals for global climate change have focused on greenhouse gas (GHG) emissions reductions, but because climate change is driven by accumulated atmospheric stocks of GHGs, policies should include incentives to reduce these stocks. One feasible stock-reducing technology is air capture of carbon dioxide (CO_2), which can take CO_2 from the atmosphere and permanently sequester it underground. Development and deployment of this technology will require long-term incentives that are not found in current climate change proposals. A first step at providing such incentives is to include air capture as an offset for emissions under cap-and-trade programs. A more comprehensive proposal is to shift the focus of climate change policy from emissions to stocks by developing a GHG property and tax regime. We should include long-term incentives for air capture in federal climate change policy, and we should bring the idea of a GHG property regime into the policy discourse.

Climate Change Background

Global climate change is increasingly important and increasingly visible. Scientists have recorded higher average surface temperatures, increased glacier loss, reductions in Arctic sea ice, rising sea levels, changes in oceanic acidity, shifts in the ranges and behaviors of animal and plant species, and, perhaps, increased incidence of extreme weather events (*The Economist* 2006; IPCC 2007). The more scientists learn about feedback loops such as methane release from the warming tundra and the self-lubricating march of Greenland glaciers to the sea, the more they increase their estimates of possible warming. Further warming will change weather patterns, temperatures, and sea levels and will challenge ecosystems and societies.

As greenhouse gases (GHGs) accumulate in the atmosphere, they absorb radiation reflected from the earth towards the sun and re-emit it back towards the earth. The earth and the atmosphere thereby absorb more solar radiation and their temperatures rise accordingly. Carbon dioxide (CO_2) is the most important GHG because it is long-lived, it is steadily increasing in atmospheric concentration, and it is a byproduct of nearly all combustion processes.[1] Because a large proportion of anthropogenic climate change may be traced to the combustion of fossil fuels and the subsequent release of CO_2 (IPCC 2001: 37, 204), climate change policies typically focus upon reducing CO_2 emissions from the energy sector.

Yet in focusing upon emissions reductions, most policies fail to provide incentives to develop technologies to reduce atmospheric stocks of GHGs. Unlike urban smog or acid rain, climate change is not driven by any year's emissions but by accumulated historical emissions. Yet neither cap-and-trade programs nor carbon taxes provide an incentive to cut into past emissions. I will describe a new technology that could reduce atmospheric CO_2 stocks, and I will present two options for spurring such stock-reducing technologies within a broader climate change policy framework.

---

[1] A molecule of emitted CO_2 may hang around for a long time: the atmospheric lifetime of CO_2, or the time it takes for altered CO_2 concentrations to return to equilibrium, is somewhere between 5 and 200 years (IPCC 2001: 38). Parts per million by volume (ppm_v) is the number of moles of a gas per million moles of air. In 2005, atmospheric CO_2 concentrations were 379.1 ppm_v, an increase of 35% from the relatively constant pre-industrial level of 280 ppm_v, and they have increased at an average rate of 1.9 ppm_v per year over the last ten years (WMO 2006).

Air Capture of Carbon Dioxide

There are two main ways of quickly reducing the stock of CO_2: biological sequestration and air capture.[2] Biological sequestration involves cultivating organisms that take in CO_2 via photosynthesis. This often means planting forests, but it also includes proposals to scatter iron on the ocean surface to promote the growth of phytoplankton that would lock up their embodied carbon as they die and fall to the seafloor. The potential of biological sequestration may be limited, however. First, its potential may be constrained by the available land area, by the availability of non-CO_2 nutrients, by the rate of sequestration, or by secondary effects. Second, and more troublingly, the CO_2 sequestration may not be permanent. If a sequestration forest is eventually cut and burned, its CO_2 would end up right back in the atmosphere. Biological sequestration generally suffers from an inability to secure large quantities of carbon for long periods.

Air capture of CO_2 is a more permanent sequestration option. Air capture would likely take one of two forms: it would either capture the CO_2 created by burning biomass for energy, or it would use a sorbent such as calcium hydroxide or sodium hydroxide to form a solution with CO_2 from the air. In this latter formulation, the CO_2 would then be separated from the sorbent and the sorbent would be recycled to capture more CO_2.[3] In either case, the captured CO_2 may be sent to some economic use (if such is found) or sequestered in old petroleum formations, in saline aquifers, or along the seafloor. Sequestration is often proposed for CO_2 captured from power plant emissions (known as carbon capture and storage, or CCS), but air capture technology would take the molecules straight from the air, thus avoiding the need for power plant retrofits, enabling capture at the sequestration site, and permitting the abatement of historic emissions and of emissions from sectors other than electricity.

[2] Of course, eliminating all CO_2 emissions would also reduce atmospheric stocks, but these reductions would take some time.

[3] No CO_2 air capture facilities have been built, but many of the individual steps are already widely used for other purposes. Indeed, some gases are already commercially produced by capture from the air.

Estimates of the economic and energy costs of air capture suggest that it could be a useful technology, and both costs may fall with economic incentives and effort. Azar et al. (2006) calculate that biomass-based air capture could cost $300 per ton of carbon (tC) without accounting for the value of the electricity produced. Keith et al. (2006) estimate that biomass-based air capture facilities could operate for under $200/tC and that chemically-based air capture facilities could operate for under $500/tC with a minimum energy requirement of 1.6 GJ/tC for capture (or 4 GJ/tC for capture and sequestration). Baciocchi et al. (2006) describe a process that would use at least 44-62 GJ/tC for capture and compression, and Nikulshina et al. (2006) propose processes that use concentrated solar power in amounts of 208-250 GJ/tC for capture.[4] For comparison, CCS currently costs about $200-$250/tC (Anderson and Newell 2004), and coal contains about 40 GJ/tC and natural gas contains about 70 GJ/tC (Keith et al. 2006). These energy costs indicate that chemically-based air capture may require low-carbon energy sources.

Apart from Richard Branson's recently announced prize for the air capture of CO_2 (Kanter 2007), there has been little public discussion of this technology. This is partly because there is no economic incentive to develop it, partly because there are cheaper initial opportunities in climate change abatement, and partly because scientists and environmental groups have been reluctant to discuss such options for fear of diminishing the drive to reduce GHG emissions (e.g., Parson 2006). An important component of a policy solution to climate change would be to provide incentives for the development and adoption of this game-changing technology without compromising emissions reductions. While prizes and government-funded research may push initial development, further refinement and actual adoption may require long-term incentives to assure profitable use.

The First Step: Air Capture as an Offset for Emissions

Cap-and-trade programs, which limit the total number of GHG emissions allowances granted per year, are moving forward in the European Union, in California, and in several northeastern states, and talk of a federal climate change solution in the U.S. generally focuses upon a national cap-and-trade system. One of the more contentious

[4] I have converted the reported results to the common units of gigajoules per ton of carbon.

issues in their design is the inclusion of offsets, which are credits for emissions reductions that take place outside of the cap. Commonly mentioned offsets include biological sequestration, especially in forestry and agriculture, and emissions reduction projects in developing countries. Offsets are contentious because the actual reductions in GHG stocks or emissions can be hard to measure and verify. However, GHG stock reductions from air capture would be much clearer, and so they should be explicitly allowed as offsets. This would provide a clear incentive to develop and deploy air capture technology since doing so would create a stream of emissions credits that could be sold in cap-and-trade regions.

A New Policy Basis: Greenhouse Gas Property

My larger proposal would shift the focus of climate change policy from emissions to stocks by creating a private property regime and tax system for GHGs. Commonly proposed cap-and-trade programs and carbon taxes focus only upon the release of CO_2 to the atmosphere, but a property regime would make atmospheric stocks the unit of taxation and, by extension, the focus of cost minimization through emissions reductions and sequestration. This could provide a clear long-term incentive for air capture technology while placing climate change policy on firmer economic footing.

When a company burns coal to make electricity, we say that it owns the coal inputs, and our concept of property is fluid enough to flow through thermodynamic transformations to say that the company also owns the electricity output. We do not, however, say that the company owns the gas molecules it releases to the atmosphere. Because these gas molecules have no productive value, the company does not claim them as its property, and nobody forces the company to recognize them as its property. If we consistently apply our ideas of private property to the bad outcomes as well as to the good, then the GHGs released from the coal's combustion are owned by some agent that is responsible for the effects of its property. Because carbon is conserved, we can think of agents as owning carbon property in fossil fuels that becomes GHG property upon combustion.

We should initially assign the property so as to minimize transaction costs and make ownership comport with control. Combusting fossil fuels releases carbon that would otherwise have remained locked in the coal, gas, or oil. Moving down the fossil fuel product chain involves more parties and uses: oil extractors beget refiners and diverse refined products, which beget an array of intermediate companies and products, which finally beget consumers and end uses. Because extractors are situated at the simplest level of the fossil fuel product chain, and because they are directly responsible for liberating the carbon from its geological sequestration, it makes sense from an efficiency perspective initially to assign carbon property to them.[5] Of course, the carbon and GHG property could be bought and sold like any other property. If the carbon property is transferred by contract along with the original product, we would expect the product to be discounted because the buyer would assume the property liability. And since fossil fuels that are not combusted would not produce GHG property, owners of carbon property might offer rebates to encourage such alternate use.

The key part of my policy solution is to tax GHG property annually so that property owners would have to bear a cost as long as their property resides in the atmosphere. This would provide a direct incentive to reduce emissions now, and it would also provide a direct incentive to reduce atmospheric stocks in the future since removing CO_2 from the atmosphere would avoid future tax payments.[6] If such removal benefits from economies of scale, companies could arise that specialize in abating GHG property: they would accumulate property from owners for a fee and profit by removing it from the atmosphere at less cost. Air capture could then be used not just to offset contemporary emissions but to offset any emissions produced between the establishment of the property scheme and the development of economical large-scale air capture technology.

---

[5] On a sub-global level, we would assign carbon property to extractors and importers.

[6] Taxation could also directly internalize the option value from climatic irreversibility: if the taxing agency can credibly commit to adjust the tax rate periodically in response to new information about climate change, the uncertainty about future tax rates and the partial irreversibility of emissions would create an option value to waiting to emit because companies could learn more about the trend of future tax rates. In my ongoing Master's Project work, I calculate the option value for different property tax structures, I examine how the tax-setting institution could be designed so that its commitment to properly change the tax rate would be credible, and I assess how such a property scheme could form the basis of a more effective international climate change treaty.

This property proposal does have difficulties. First, it is quite different from commonly advanced climate change policies and so may be difficult to implement. We may need to look to hazardous waste policies for an appropriate model, though our experiences with GHG registries should prove helpful. Second, the scheme as I have laid it out focuses on energy sector CO_2 emissions, but there are other anthropogenic sources of CO_2 and there are other GHGs. These other sources and gases may require their own policies that are tailored to their physical, economic, and technological specifics. Finally, the government would not have precise control over actual emissions. It would in effect cede such control to the market in exchange for increased efficiency and better stock-reducing incentives, but the loss of such control may preclude reliance upon emissions targets in future international treaties. A GHG property regime may itself provide new options for an international treaty, however, and if the property regime extends a cap-and-trade program by allowing tradable permit costs to count towards future tax payments, then the government could get the stock-reducing advantages while retaining fine control over annual aggregate emissions.

Conclusion

We should add air capture offsets and a GHG property regime to the quickening climate change policy discourse because they provide the long-term signals needed to spur stock-reducing technologies. The property proposal is unique in that it offers clear long-term economic incentives to develop and deploy means of reducing problematic atmospheric concentrations while also emphasizing near-term reductions in emissions. We should ensure that any federal cap-and-trade program includes air capture as an offset, and we should debate the merits and demerits of adopting a GHG property regime as our long-term climate change solution.

References

Anderson, S. and R. Newell. 2004. "Prospects for carbon capture and storage technologies." *Annual Review of Environment and Resources* 29:109-42. doi: 10.1146/annurev.energy.29.082703.145619

Azar, C., K. Lindgren, E. Larson, and K. Möllersten. 2006. "Carbon capture and storage from fossil fuels and biomass—Costs and potential role in stabilizing the atmosphere." *Climatic Change* 74:47-79. doi: 10.1007/s10584-005-3484-7

Baciocchi R., G. Storti, and M. Mazzotti. 2006. "Process design and energy requirements for the capture of carbon dioxide from air." *Chemical Engineering and Processing* 45:1047-1058. doi: 10.1016/j.cep.2006.03.015

Intergovernmental Panel on Climate Change. 2001. *Climate Change 2001: The Scientific Basis*. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change [J.T. Houghton, Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, and C.A. Johnson (eds.)]. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press. 881 pp. Available at: http://www.grida.no/climate/ipcc_tar/wg1/index.htm.

Intergovernmental Panel on Climate Change. 2007. *Climate Change 2007: The Physical Science Basis. Summary for Policymakers*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. 18 pp. Available at: http://www.ipcc.ch/SPM2feb07.pdf

Kanter, J. 2007 Feb 10. "$25 million to encourage cleaner air." *The New York Times*, late ed (east coast): C.3.

Keith, D.W., M. Ha-Duong, and J.K. Stolaroff. 2006. "Climate strategy with CO_2 capture from the air." *Climatic Change* 74:17-45. doi: 10.1007/s10584-005-9026-x

Nikulshina, V., D. Hirsch, M. Mazzotti, and A. Steinfeld. 2006. "CO_2 capture from air and co-production of H_2 via the $Ca(OH)_2$-$CaCO_3$ cycle using concentrated solar power—Thermodynamic analysis." *Energy* 31:1715-1725. doi: 10.1016/j.energy.2005.09.014

Parson, E.A. 2006. "Reflections on air capture: The political economy of active intervention in the global environment." *Climatic Change* 74:5-15. doi: 10.1007/s10584-005-9032-z

The Economist. 2006 Sept 9. "The heat is on: A survey of climate change." 16 pp.

World Meteorological Organization. 2006 Nov 1. "WMO Greenhouse Gas Bulletin: The state of greenhouse gases in the atmosphere using global observations through 2005." Available at: http://www.wmo.int/web/arep/gaw/ghg/ghg-bulletin-en-11-06.pdf.

Proposal for Travel Grant

Federal climate change legislation seems imminent. Because the legislation is still in development, however, this is the perfect opportunity to translate academic work into real world impacts. I propose to travel to Washington, D.C. to meet with key members of Congress and their staffs as a step in injecting the offset and property ideas into the policy discourse. Legislators may be particularly drawn to new ways of approaching the problem of climate change if doing so allows them to realign entrenched positions.

I aim to meet with Rep. Edward Markey (D-Mass.) because he has been nominated as the chair of Speaker Nancy Pelosi's (D-Calif.) Select Committee on Energy Independence and Global Warming. Speaker Pelosi wants to have climate change legislation by July 4, and she has tasked this committee with holding hearings and recommending legislation. Because it is the direct creation of the Speaker, the committee's recommendations could carry great weight, and it may have the purview to consider creative new policy ideas for tackling global climate change. I also aim to meet with the staff of prominent climate change advocates, especially those such as Sen. John McCain (R-Ariz.) and Sen. Barack Obama (D-Ill.) who are looking to gain attention in the presidential race. Finally, I could use UC-Berkeley connections to gain an audience with the staff of Sen. Barbara Boxer (D-Calif.), who has been considering climate change legislation in her role as Chairwoman of the Senate Environment and Public Works Committee.