



ISSUE BRIEF 14

MANDATORY REGULATION OF NONTRADITIONAL GREENHOUSE GASES: POLICY OPTIONS FOR INDUSTRIAL PROCESS EMISSIONS AND NON-CO₂ GASES

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SUMMARY

Traditional economic theory suggests that the most efficient and least-cost approach for regulating greenhouse gas (GHG) emissions will be as broad as possible—covering as many emissions from as many sources as possible under a single pricing policy designed to elicit the cheapest abatement options. Applying this concept is relatively straightforward for the dominant GHG, carbon dioxide (CO₂). CO₂ emissions from the use of fossil fuels account for around 80 percent of U.S. GHG emissions¹ and are well-suited to regulation through either an emissions tax or cap-and-trade program.² A wide variety of other emissions sources and gases account for the other approximately 20 percent of U.S. GHG emissions.³ Some of the cheapest mitigation options are likely to involve these “non-traditional” GHGs,⁴ making it desirable to include them in a regulatory program. Given the diversity of activities and sources that give rise to these emissions, however, creative policy approaches may be needed to effectively tap associated abatement opportunities.

This issue brief surveys options for regulating

those non-traditional GHG emissions that lend themselves most readily to a mandatory approach, including methane emissions from coal mines, nitrous oxide and process CO₂ emissions from large stationary sources, and emissions of high global-warming potential (GWP) fluorinated gases. Together this group of emissions and sources accounted for about 5.5 percent of the overall U.S. GHG inventory in 2005. As discussed in more detail in Issue Brief #1, many other non-traditional GHG emissions originate from fugitive sources that would be difficult to include in a mandatory program. These emissions are likely best addressed through a project-based program to recognize offset activities as part of a broader tax or cap-and-trade program.⁵

Among the gases covered in this issue brief as potential candidates for inclusion in a mandatory program, some could be integrated relatively easily in a cap-and-trade (or tax) program; others could be included, but special considerations or provisions may need to apply; and others still may need to be addressed through sector-specific policies or through efficiency or technology standards.

- The fluorinated gases could be included in a mandatory program by regulating production sources rather than actual emissions, which are widely dispersed and difficult to measure. The number of entities

1 All emissions data in this issue brief are from 2005 and are taken from a report issued by the U.S. Environmental Protection Agency. U.S. EPA, 2007. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2005*, EPA 430-R-07-002, EPA: Washington, DC. Available at <http://epa.gov/climatechange/emissions/usinventoryreport.html> Accessed August 21, 2007. Fossil fuel combustion accounted for 79 percent of U.S. GHG emissions in 2005; the non-energy use of fossil fuels—as lubricants or feedstocks, for example—accounted for another 2 percent.

2 See Issue Brief #5 on taxes, trading schemes, and standards for further discussion of these regulatory approaches.

3 See Issue Brief #1 on U.S. GHG emissions for a detailed breakdown of these emissions.

4 For example, an EIA analysis from March 2006 that considered a range of cap-and-trade proposals found that with modest near-term GHG permit prices (\$8 to \$24 (2004 dollars) per metric ton of CO₂e in 2020), reductions in other GHGs (i.e., those besides energy-related CO₂) would account for 25–55 percent of total emissions reductions in 2020, despite composing only about 6 percent of regulated emissions in the reference scenario. (EIA, 2006. *Energy Market Impacts of Alternative Greenhouse Gas Intensity Reduction Goals*, SR/OAIF/2006-01, EIA: Washington, DC.)

5 Offset programs are discussed in Issue Brief #15. Such programs could be used to recognize GHG reductions that involve fugitive emissions, such as methane and nitrous oxide emissions from agricultural activities (over 7 percent of U.S. emissions) and from landfill and wastewater treatment (over 2 percent). (See Issue Brief #13 for further information on specific GHG-reduction opportunities in the agricultural sector.) Some non-traditional GHG emissions may be difficult to regulate under any policy, such as methane emitted during the transmission, storage, and distribution of natural gas (around 1 percent of U.S. GHG emissions) or nitrous oxide from mobile combustion (around 0.5 percent of U.S. GHG emissions).

engaged in producing or importing these gases, however, is comparatively small. Fluorinated gases could be included in an economy-wide tax or cap-and-trade program; alternatively, they could be addressed in a separate, stand-alone cap-and-trade (or price-based) program.

- Industrial process emissions from large stationary point sources—where measurement is straightforward—can generally be included in broad tax or cap-and-trade programs. This category of emissions includes process-related CO₂ emissions from industrial sources and nitrous oxide (N₂O) emissions from stationary combustion and nitric and adipic acid production.
- Methane (CH₄) emissions from underground coal mines could generally be included in broad tax or cap-and-trade programs, as methane is typically vented from underground mines at a limited number of defined points. By contrast, methane emissions from surface coal mines, which occur as the coal is exposed, and from abandoned mines are fugitive in nature and probably could not be included in a mandatory price-based program. These emissions would likely be best addressed through offset programs.

Remaining sections of this issue brief describe major sources of emissions in each of these categories and outline potential policy options for addressing them.

Fluorinated Gas Emissions

The fluorinated gases—also frequently called the high global-warming potential (GWP)⁶ gases—include three of the six traditional major GHGs: hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF₆).⁷ They currently account for around 2.2 percent of total U.S. GHG emissions. Their share of total U.S. emissions has grown over the last several years, a trend that is projected to continue in the near future.⁸ The vast majority of fluorinated-gas emissions originate from widely dispersed end-use activities—frequently

as fugitive emissions or leaks—rather than from large point sources. This implies that regulating the original production sources for these chemicals—a relatively small number of entities—is likely to be the only practical approach to including them in a mandatory policy.⁹

Among the fluorinated gases, HFCs are most commonly used as refrigerants—in mobile and stationary air conditioning or commercial refrigeration systems, for example. They are also used as fire suppressants and as blowing agents in foam production. The majority of emissions come from leaks in air conditioning and refrigeration units. PFCs are used in semiconductor production; they are also associated with aluminum production. SF₆ serves as an insulator and interrupter in equipment that transmits and distributes electricity, and it is also used in magnesium production. Most SF₆ emissions are fugitive releases, such as leaks from gas-insulated electrical substations through equipment seals or releases during servicing or disposal activities. As noted previously, the major proposals for addressing these fluorinated-gas emissions involve regulating production, either by including production sources in an economywide pricing policy, by establishing a separate cap-and-trade system for these emissions, or by utilizing a deposit-refund approach. Each of these options is discussed at greater length below.

Include fluorinated-gas production sources and imports in an economywide cap-and-trade (or tax) program

Many cap-and-trade proposals currently under discussion would include the high GWP gases from all production and import sources (including gases embedded in imported goods).¹⁰ Producers and importers would be required to submit allowances (on a CO₂-equivalent basis) for HFCs, PFCs, and SF₆. To provide incentives for recovering and recycling or destroying these gases, entities would be awarded allowances (or offset credits) for capturing and destroying existing stocks of these chemicals. This approach would have several benefits: it would make higher GWP products relatively more expensive¹¹ than alternatives with lower GWPs, driving the

6 Global warming potentials (GWPs) are factors that are used to calculate CO₂ equivalent units so as to facilitate comparisons between various GHGs based on the warming impact (radiative forcing) different gases have once in the atmosphere. The GWP of a gas depends on the strength of its warming effect and its lifetime in the atmosphere. HFCs and PFCs all have potent warming effects and many have long lifetimes, resulting in GWPs that range from more than 100 times that of CO₂ to more than 10,000 times greater over a 100-year period (with the most commonly used gases having GWPs ranging from 1,300 to 4,000). (IPCC/TEAP, 2005. *IPCC/TEAP Special Report: Safeguarding the Ozone Layer and the Climate System: Issues Related to Hydrofluorocarbons and Perfluorocarbons, Summary for Policymakers*, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.) SF₆ is the most potent GHG covered by the Kyoto Protocol, with a 100-year GWP of 23,900.

7 These are the six gases listed in the Kyoto Protocol.

8 Both recent emissions growth and future growth projections are driven primarily by the substitution of these gases into a variety of applications, rather than from increased demand for refrigeration and other end-use activities. Specifically, HFCs and PFCs are being used to replace ozone-depleting substances, such as CFCs, HCFCs, and halons, as these are phased out under the Montreal Protocol. For further information on projected emissions see U.S. EPA, 2006. *Global Anthropogenic Non-CO₂ Greenhouse Gas Emissions: 1990-2020*. USEPA: Washington, DC. Available at <http://www.epa.gov/nonco2/econ-inv/international.html> Accessed September 18, 2007.

9 The one notable exception involves emissions of HFC-23 from production point sources during the manufacture of HCFC-22; this source accounts for about 10 percent of fluorinated gas emissions in the U.S. These emissions would presumably be included in the regulatory program “at the smokestack” in the manner of traditional air pollutants.

10 Because emissions of high GWP gases are associated with their use (instead of production) it is vital to include all import sources, including the high GWP gases embedded in imported goods. Failure to include imports would create a large potential source of emissions leakage. For examples of current proposals see the Lieberman-McCain “Climate Stewardship and Innovation Act of 2007” (S. 280) or the Bingaman-Specter “Low Carbon Economy Act of 2007” (S. 1766). The Bingaman-Specter legislation explicitly includes the high GWP gases in imported products (e.g., window air conditioning units).

11 A simple calculation helps to provide a rough sense of the scale of the price incentive created by the inclusion of high GWP gases in a cap-and-trade program. Suppose the price for a metric ton of CO₂ emissions is \$10. (This would translate into approximately 10 cents per gallon of gasoline.) One of the most commonly used refrigerants, HFC-134a—which has a relatively low GWP (for a fluorinated gas) of 1300—would therefore have an extra price of \$13,000 per metric ton, or just under \$6 per pound. Assuming that a vehicle air-conditioning unit holds around 2 pounds of refrigerant, there would be around \$12 of value in completely capturing the evacuated refrigerant when the system was recharged. Incentives would be proportionally larger for higher GWP gases and higher CO₂ prices.

near-term adoption of more climate-friendly substitutes in applications where fluorinated gases are currently used. Industry would also face incentives to innovate in developing new chemicals that could perform the same functions with less warming impact. A price signal would also reward owners of more efficient equipment, such as air conditioners, and would encourage the adoption of increasingly efficient units. As already noted, incentives would also exist for the collection and recycling or destruction of existing stocks.¹² Both this approach and the next—creating a separate cap-and-trade system for only high GWP gases—have been suggested by a major producer of refrigerants as possible approaches for regulating this category of emissions.¹³

Because the fluorinated gases have such high GWPs, a potential downside to including them in an economywide approach is that relatively modest prices for CO₂ emissions could produce big changes in the cost of these chemicals.¹¹ In response, users might shift to alternative materials that generate other health or environmental risks (for example, the use of ammonia as a refrigerant).¹⁴ There is also concern that a particularly sudden increase in prices might unnecessarily burden both producers and end users. A more gradual change in price would give producers time to create lower-GWP alternatives and give consumers time to acquire new equipment that uses lower-GWP alternatives, uses existing gases more efficiently, or is less prone to leakage.¹⁵ Under a cap-and-trade system, allowance allocation could be used to ameliorate potential price shocks by awarding free allowances to the producers of fluorinated gases using an updating output-based approach, although this would tend to reduce overall program efficiency.¹⁶

Create a separate cap-and-trade program

Another possible approach would be to create a separate, stand-alone cap-and-trade program explicitly for the high GWP gases. This would work in a nearly identical fashion to the first approach, but it would offer the option of applying a different price to fluorinated-gas emissions (and thereby addressing the cost concerns noted above).¹⁷ The chief disadvantage of this approach is that it produces a less efficient (and hence more costly) policy overall. Two programs with separate prices imply that society is paying more to achieve reductions in one sector than in another sector, even when those reductions achieve the same environmental benefit. Other disadvantages are more political: once one sector receives a special carve-out, others may line up for theirs. If separate treatment of the fluorinated gases begins to undermine a unified, economywide approach, policy costs and efficiency losses would rise further. In addition, the potential for disruptive levels of price volatility rises under smaller, separate trading programs. Finally, all of these disadvantages also extend into the future: a lower near-term price for fluorinated-gas emissions—one designed to avoid hardship—would also lower the effective incentives for innovation to develop alternative chemicals. To help address some of these disadvantages while still attending to short-term price concerns, one might design a separate program for fluorinated gases such that it gradually converges to, and eventually links with, an economywide policy. In summary, the overall economic cost and political difficulties of a separate cap must be weighed against society's interest in tailoring regulation and managing price increases in this sector.

Use a deposit-refund approach

A third regulatory option would be to institute a deposit-refund program in which an up-front fee is charged for the production (or initial purchase) of fluorinated gases that is refunded when the gases are later captured and destroyed. This would be similar to a separate cap-and-trade program for only the high GWP gases, except that it fixes the price rather than the quantity of emissions allowed—indeed, it would be effectively identical to an emissions tax on these gases. By setting the fee and rebate amount, policymakers could make a direct decision about the level of cost that would be imposed on users of these gases. As with a separate cap-and-trade program, however, this approach would still have

12 This approach would also provide regulators with a potential avenue for addressing existing stocks of hydrochlorofluorocarbons (HCFCs), which currently exist in a kind of regulatory limbo between the Montreal and Kyoto Protocols. HCFCs are now being used as replacements for chlorofluorocarbons (CFCs) and other halons under the Montreal Protocol because they have less impact on stratospheric ozone. They are still ozone-depleting substances, however, and their production is being phased out under the Montreal Protocol. They are also—like other fluorinated gases—potent greenhouse gases, but because they were already regulated under the Montreal Protocol they were not included in the Kyoto Protocol. The former agreement, however, regulates the production of ozone depleting substances, whereas the Kyoto Protocol is focused on emissions of GHGs. This means that HCFCs produced legally under the Montreal Protocol are otherwise unregulated. While there is little HCFC production in the United States that results in emissions—the bulk of U.S. production is for chemical feedstocks to make materials such as Teflon(RT)—the United States does import HCFCs in ready-to-use equipment such as window air conditioning units. Further, there are existing stocks of HCFCs in older equipment. All major Congressional proposals for comprehensive mandatory climate legislation to this point have focused on the six Kyoto Protocol gases; none have included other gases (whether HCFCs or others). By allowing existing stocks of HCFCs to qualify for project-based credits—while leaving the Montreal Protocol to address HCFC production—regulators could provide incentives for collecting and destroying HCFC stocks, to the benefit of both the ozone layer and the climate.

13 Testimony of Mack McFarland, Committee on Oversight and Government Reform, U.S. House of Representatives, May 23, 2007.

14 Note that an economy-wide policy would capture all potential trade-offs in terms of climate benefit. For example, switching to refrigerants with lower GWPs would be beneficial, on the one hand, but could also reduce the efficiency of refrigerant-using equipment, such as air conditioners. The result could be an increase in energy use and CO₂ emissions that would offset some of the benefits from switching refrigerants. A broad cap-and-trade or tax policy with a single emissions price will efficiently balance these emissions trade-offs. Other non-climate externalities that might be associated with switching to lower-GWP products, however, will not be captured by a climate policy (economy-wide or otherwise); correcting these externalities requires other, appropriately targeted health, safety, or environmental regulations, or other policies.

15 The situation is analogous to having an initially modest CO₂ price that rises through time in order to avoid prematurely retiring existing capital while providing incentives for investment in less emitting technologies when it is replaced.

16 Updating, output-based allocations can reduce product prices because they reward producers with valuable emissions allowances for each additional unit of output. Producers thus face incentives to boost output, which lowers product prices. Updating, output-based allocations entail efficiency costs because, by

lowering output prices, they diminish incentives for end-use demand reductions. Potentially this allocation approach could be adopted initially to manage short-term price impacts and then be phased out over time in favor of allocation methodologies that do not entail similar efficiency losses. Policymakers will have to decide how to balance the trade-off between reducing sudden price impacts on fluorinated gases and sacrificing some program efficiency. See Issue Brief #6 for further discussion of these and other issues related to allowance allocation.

17 A similar cap-and-trade system is currently in place for manufacturers of ozone-depleting substances under Title VI of the Clean Air Act. See <http://www.epa.gov/Ozone/title6/phaseout/index.html> Accessed September 19, 2007.

the disadvantage that it forecloses the opportunity to make cost trade-offs with reductions in other sectors—with resulting efficiency losses for the overall policy and higher costs for society as a whole.

Nitrous Oxide and Process-related CO₂ Emissions From Large Stationary Sources

Several industrial processes emit non-traditional GHGs—particularly nitrous oxide and CO₂ process emissions—at large stationary sources. Process-related CO₂ emissions from industrial sources are separate from (and occur in addition to) the CO₂ emissions associated with fossil-fuel use. For example, cement production begins by heating limestone—calcium carbonate (CaCO₃)—to produce lime and CO₂ (the lime goes on to form the primary ingredient in cement). Iron is produced by reducing iron ore in a blast furnace with metallurgical coke, a process that emits CO₂. Other CO₂-emitting industrial processes include ammonia production, lime production (for uses besides cement), and the production of various metals, including aluminum, zinc, and lead.¹⁸ Industrial process-CO₂ emissions represent about 2 percent of total U.S. GHG emissions, with iron and steel production and cement manufacture accounting for the majority of these emissions.

Nitrous oxide (N₂O) emissions from stationary sources in the United States come primarily from the production of nitric and adipic acids and from combustion sources.¹⁹ Nitric acid production plants use either non-selective catalytic reduction or selective-catalytic reduction to control emissions of nitrogen oxides (NO_x), a criteria air pollutant regulated under the Clean Air Act. In addition to controlling NO_x emissions, non-selective catalytic reduction units are also effective at controlling nitrous oxide emissions but are used in only about 20 percent of plants because of their high energy costs.²⁰ The other significant stationary sources of nitrous oxide are adipic acid production facilities and large combustion point sources, primarily electric power generation units. Nitrous oxide emissions from adipic acid production can be controlled using conventional pollution control technology.²¹ Emissions from stationary combustion are influenced by air-

fuel mixtures, combustion temperatures, and the pollution control equipment employed. Altogether stationary sources of nitrous oxide emissions account for about 0.5 percent of total U.S. GHG emissions. Two primary options for regulating these emissions include covering them under a broad pricing program or mandating a particular control technology or performance standard. Each is discussed below.

Include industrial N₂O and process CO₂ emissions in an economywide cap-and-trade (or tax) program

Including nitrous oxide and process-CO₂ emissions from industrial sources in a cap-and-trade program should be straightforward given the relative ease of measuring emissions “at the smokestack.” This approach would allow producers to weigh the relative costs of emissions allowances against the costs of installing and operating new control technology or improving process efficiency to reduce emissions. The price signal generated by inclusion in a cap-and-trade system would also provide incentives for research into improved control devices—such as catalysts for N₂O—and alternative production processes that are less emissions-intensive.²² Many of these stationary-source emissions are covered in current GHG regulatory proposals. For example, almost all legislative proposals to date have covered the electric power sector (which includes stationary combustion sources of N₂O) and most economywide approaches include emissions from nitric and adipic acid production.

Use control technology mandates or efficiency and performance standards

In the case of many stationary sources—nitric and adipic acid production, for example—known technologies exist for controlling GHG emissions. Thus another regulatory option for these sources would be to simply mandate the use of certain control technologies. However, this approach would likely involve large capital expenses for some industries—for example, almost all nitric acid plants built since the late 1970s have been designed to operate with selective catalytic-reduction units because of lower operating costs and these plants would be forced to redesign their processes to operate with new emissions controls. Further, a technology mandate would not provide the same incentives for research and development to continue improving emissions performance. Some firms have called for performance or efficiency standards to be used to control process-CO₂ emissions rather than including these emissions in a cap-and-trade program, arguing this approach would provide a greater level of cost

18 U.S. EPA, 2007. Chapter 4, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2005*, EPA 430-R-07-002, EPA: Washington, DC.

19 The overwhelming source of U.S. anthropogenic N₂O emissions—more than three-fourths of the total—is agricultural soil management. The stationary sources discussed here account for about 8 percent of U.S. N₂O emissions.

20 U.S. Climate Change Technology Program, 2005. *Technology Options for the Near and Long Term*, Section 4.4.1. Available at <http://www.climatechange.gov/library/2005/tech-options/index.htm> Accessed August 21, 2007.

21 U.S. EPA, 2007. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2005*, Section 4.16, EPA 430-R-07-002, EPA: Washington, DC.

22 For example, one technology under development is a cokeless iron-making process. U.S. Climate Change Technology Program, 2005. *Technology Options for the Near and Long Term*, Section 1.4.3. Available at <http://www.climatechange.gov/library/2005/tech-options/index.htm> Accessed August 30, 2007.

certainty for affected firms.²³ While an appropriately designed efficiency or emissions performance standard might be more flexible and efficient than mandating the use of particular control technologies, it remains less efficient than inclusion in a broader market-based policy and still has drawbacks in terms of creating incentives for continuous improvement.

Methane Emissions From Coal Mines

Methane (CH₄) emissions from coal mines account for about 0.8 percent of U.S. GHG emissions. As coal is mined, methane trapped in coal seams or in surrounding strata is released. The majority of coal-mine methane emissions (over 60 percent) comes from underground mines, where greater geologic pressure creates and traps larger volumes of this gas. Methane emissions from surface mines are much smaller; they cannot be captured and escape as fugitive emissions into the atmosphere. Small amounts of fugitive emissions are also released from abandoned mines and during post-mining activities including coal processing, storage, and transport.

Methane in underground mines poses a hazard to mine workers, and so has to be extracted or ventilated for safety reasons. Methane is typically liberated from underground coal seams in one of three ways: pre-mine drainage wells, gob wells, or mine-ventilation air systems.²⁴ Pre-mine drainage wells are drilled months or years prior to mining and extract a highly-concentrated gas (typically over 95 percent methane) that can be sold for commercial distribution to natural gas pipelines or used onsite for heat or power. Most methane from pre-mine drainage wells is thus not emitted to atmosphere. Gob wells exhaust methane released in the fractured rubble zone, called the “gob” area, that forms as the coal seam is mined and the surrounding strata collapse. Because methane concentrations in the gob area are still relatively high (30–90 percent), it is sometimes used onsite or enriched for sale to pipelines, but is also frequently vented to the atmosphere. Finally, mine-ventilation air systems ensure that methane concentrations in the mine are at safe levels. The concentration of methane in ventilated air is too low—below 1 percent—to allow for economic recovery and use in most cases. Therefore, the gas is usually vented.²⁵ Options for taking advantage of GHG-abatement opportunities

associated with coal-mine methane emissions include directly including these emissions, where possible, under a broader cap-and-trade program; covering these emissions through an offsets program; and a combination of both. Each is discussed below.

Include coal-mine methane in an economywide cap-and-trade (or tax) program

Some proposals have called for coal-mine methane emissions to be directly included in a broader GHG cap-and-trade program. This would be relatively straightforward for emissions from underground mines, as these are captured by active degasification or ventilation systems that can be monitored with relative ease.²⁶ Inclusion in a broader pricing policy would create incentives for mine owners to recover and use captured methane, reinforcing an existing trend that has seen the amount of methane recovered and used by mines more than double since 1990 (as a result, total methane emissions from underground mines have declined over the last two decades).²⁷ This approach would be hard to apply, however, to the remaining 40 percent of coal-mine methane emissions from surface mines, abandoned mines, and post-mining activities, where monitoring emissions is far more difficult.

Include coal mine methane in an offset program

Given the difficulties of regulating coal-mine methane directly, it may be easier to include these emissions in a broader policy *indirectly*, via an offsets program. Mine operators (or other project developers) could conduct activities to reduce emissions that would let them earn emissions credits on a project basis. These activities would be voluntary and would occur in response to the financial incentives generated by the allowance market (under a cap-and-trade system) or by the potential for tax rebates (under an emissions tax system).

Adopt a hybrid approach

A third alternative is to adopt a hybrid approach, in which emissions from underground mines are directly included in the cap (meaning that mine owners would need to submit allowances for these emissions), while emissions from surface or abandoned mines, or from fugitive sources, would be addressed through an offsets program. Although technically feasible, adopting different modes of regulation for portions of the mining industry seems likely to be politically contentious.

23 For example, the cement industry in California is urging regulators to employ “Japan-style” energy efficiency requirements rather than including cement producers in a state-wide cap-and-trade program created to implement Assembly Bill 32. G. Hyatt, 2007. “Cement Makers Back Energy Efficient Rule Over Carbon Cap-And-Trade”, *Carbon Control News*, Vol. 1, No. 25, July 2, 2007.

24 Further information on methane from underground coal mines can be obtained from the U.S. EPA Coalbed Methane Outreach Program (<http://www.epa.gov/cmop/index.html>). Specific information on the types of wells used to extract methane came from U.S. EPA, 2005. *Identifying Opportunities for Methane Recovery at U.S. Coal Mines: Profiles of Selected Gassy Underground Coal Mines 1999-2003* EPA 430-K-04-003. EPA: Washington, DC.

25 U.S. Climate Change Technology Program, 2005. *Technology Options for the Near and Long Term*, Section 4.1.4. Available at <http://www.climatechange.gov/library/2005/tech-options/index.htm> Accessed August 21, 2007.

26 In some cases emissions are already monitored; for example, the Mine Safety and Health Administration maintains a database of methane emissions from ventilation air.

27 U.S. EPA, 2007. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2005*, Section 4.16, EPA 430-R-07-002, EPA: Washington, DC.