Scope of a Greenhouse Gas Cap-and-Trade Program

This brief describes issues involved in choosing the set of greenhouse gases (GHGs), emission sources, and sectors of the economy included in a cap-and-trade program. Trade-offs between three primary criteria determine whether a source should be included in a cap-and-trade program: broader coverage, measurability of emissions, and ease of administration. Policymakers also face choices in determining which entity in each sector must hold allowances at the conclusion of each compliance period (the point of regulation)—either upstream, where the carbon dioxide or GHGs first enter the economy, or downstream at the location where GHGs are emitted, or somewhere in between. The choice of upstream or downstream depends partly on measurability and concerns about administration, and could have important impacts on the economic incentives for emission reductions. Additional choices include whether to regulate small sources, to expand program scope over time by "phasing in" additional sectors or GHGs, and whether to pursue complementary policies that can provide additional emission reduction opportunities. Special considerations are also important in defining the scope for each sector of the economy. The power sector requires special treatment to ensure proper incentives for carbon capture and storage and to avoid double-counting emissions from natural gas use. The transportation sector may be difficult to regulate downstream, but fuels can be included upstream and complementary policies play a particularly important role in this sector. High global warming potential gases are generally easier to include upstream, but adjustments may be necessary depending on the category of industrial use. Residential and commercial use of natural gas can be covered upstream or through those delivering natural gas, or can be addressed through efficiency standards.

As the United States moves toward mandatory reductions in greenhouse gas (GHG) emissions, market-based mechanisms—such as a cap-and-trade program—offer the opportunity to minimize the cost of such reductions.

A critical element of a cap-and-trade program is its scope, meaning the set of gases, emission sources, sectors of the economy, and regulated entities that comprise the program.

This Congressional Policy Brief discusses key policy issues associated with defining the scope of a cap-and-trade program. The Brief first sets the context of the discussion with a quick review of the sectors and gases that comprise the inventory of U.S. GHG emissions. Next, the Brief presents three criteria that can be used to assess the pros and cons of including a particular category of emissions within the scope of the program. Finally, the choices open to policymakers —with respect both to the broad features of the national program and the approach for specific sectors—are reviewed.

Context

U.S. Emission Sources

As policymakers consider the scope of a cap-and-trade program, it is important to recognize that carbon dioxide (CO_2) emissions from fossil fuel combustion in two sectors—electric power and transportation—make up the majority of U.S. GHG emissions (59.8 percent in 2006). As Table 1 shows, however, emissions from other sectors and of other gases are important, too.

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Significant additional CO_2 emissions come from the industrial sector (in the form of emissions from both on-site fossil fuel combustion and production processes) and the residential and commercial sectors (primarily from use of natural gas and oil for space and water heating). For methane (CH_4), significant emissions originate in the industrial sector (including natural gas and petroleum systems and coal mining), the agricultural sector (mostly from enteric fermentation and manure management), and the commercial sector (primarily from landfills and wastewater treatment).

The agricultural sector is the dominant source of nitrous oxide (N_2O) emissions, mostly from fertilizer application and other cropping practices. Finally, there is a set of fluorinated industrial chemicals—perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), and sulfur hexafluoride (SF_6)—that, on a per-unit basis, have a high global warming potential (GWP). These high-GWP gases emanate from all sectors other than agriculture.

Existing and Proposed Programs

Both the European Union Emissions Trading Scheme (EU ETS) and the Regional Greenhouse Gas Initiative (RGGI) have chosen to cover only CO_2, in part because it was possible to estimate emissions based on existing fuel data and monitor future emissions using continuous emissions monitors. The EU regulates electric utilities and certain industrial processes, and will be phasing in additional sectors over time starting with the airline industry. RGGI starts as an electric power generation program in January of 2009. Most of the bills introduced in the 110th Congress, however, cover not just CO_2 but also the other GHGs, including CH_4, N_2O, and the high-GWP gases, and multiple sectors (see Table 2).

Table 1 *2006 U.S. Greenhouse Gas Emissions by Sector and Gas (Tg CO_2-equivalent,[1] Percent of Total)*

Sector	Greenhouse Gas				
	CO_2	CH_4	N_2O	High-GWP Gases	All GHGs
Electric Power	**2353.4** (33.4%)	**0.7** (0.0%)	**10.5** (0.1%)	**13.2** (0.2%)	**2377.8** (33.7%)
Transportation	**1865.9** (26.5%)	**2.1** (0.0%)	**32.0** (0.5%)	**69.5** (1.0%)	**1969.5** (27.9%)
Industrial	**1084.6** (15.4%)	**227.1** (3.2%)	**29.9** (0.4%)	**30.0** (0.4%)	**1371.5** (19.4%)
Agriculture	**51.6** (0.7%)	**199.1** (2.8%)	**282.9** (4.0%)	**0** (0.0%)	**533.6** (7.6%)
Commercial	**210.1** (3.0%)	**152.0** (2.2%)	**10.2** (0.1%)	**22.4** (0.3%)	**394.6** (5.6%)
Residential	**326.5** (4.6%)	**3.1** (0.0%)	**2.3** (0.0%)	**12.9** (0.2%)	**344.8** (4.9%)
U.S. Territories	Detailed data not available				**62.4** (0.9%)
All Sectors	**5983.1** (84.8%)	**555.3** (7.9%)	**367.9** (5.2%)	**147.8** (2.1%)	**7054.2** (100.0%)

Source: U.S. EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006*, April 2008

Criteria

The GHG inventory in Table 1 defines the maximum scope of a cap-and-trade program. The practical reality, however, is that it may not be feasible or desirable to include all GHG sources in a cap-and-trade program. Deciding which sources to include in a program while keeping transaction costs reasonable and maintaining program integrity entails making trade-offs among three criteria: breadth of coverage, measurability of emissions, and program administrative feasibility.

Table 2 *The Scope of Cap-and-Trade Proposals in the 110th Congress*

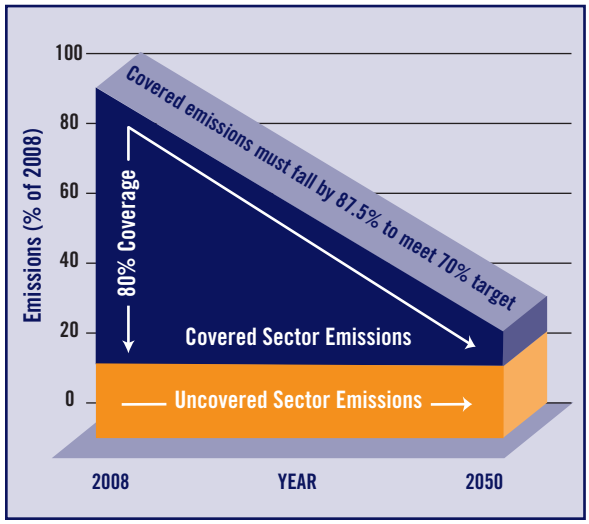
Bill	Scope of Coverage
Boxer-Lieberman-Warner S. 3036 – June 2008 Lieberman-Warner Climate Security Act of 2008 Substitute amendment to S. 2191 considered by full Senate	**6 GHGs—CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6** Economy-wide, "hybrid" – upstream for transport fuels and natural gas; downstream for large coal users and GHG manufacturers; separate HFC cap
Bingaman-Specter S. 1766 – July 2007 Low Carbon Economy Act	**6 GHGs—CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6** Economy-wide, "hybrid" – upstream for natural gas and petroleum; downstream for coal
Alexander-Lieberman S. 1168 – April 2007 Clean Air/Climate Change Act of 2007	**4 Pollutant—CO_2, SO_2, NO_X, and Mercury** Electric utilities only, coverage downstream, cap-and-trade for CO_2, SO_2, and NO_X combined with performance standards
Kerry-Snowe S. 485 – February 2007 Global Warming Reduction Act	**6 GHGs—CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6** Economy-wide, point of regulation not specified
Sanders-Boxer S. 309 – January 2007 Global Warming Pollution Reduction Act	**6 GHGs—CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6** Economy-wide, point of regulation not specified
McCain-Lieberman S. 280 – January 2007 Climate Stewardship and Innovation Act	**6 GHGs—CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6** Economy-wide, "hybrid" – upstream for transportation sector; downstream for electric utilities and large sources
Markey H.R. 6186 – June 2008 Investing in Climate Action and Protection Act	**7 GHGs—CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, and NF_3** Economy-wide, "hybrid", upstream for transport fuels, downstream for electric utilities and large sources, natural gas at LDCs
Waxman H.R. 1590 – March 2007 Safe Climate Act of 2007	**6 GHGs—CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6** Economy-wide, point of regulation not specified
Olver-Gilchrest H.R. 620 – January 2007 Climate Stewardship Act	**6 GHGs—CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6** Economy-wide, "hybrid" – upstream for transportation sector; downstream for electric utilities and large sources

Breadth of Coverage

Broadening a cap-and-trade program to cover as many emission sources as possible has several advantages. Maximum coverage is important because exempting sectors makes the program less effective and more expensive for meeting a given environmental objective. For instance, even if emissions in uncovered sectors or of uncovered gases remain stable, an overall emissions target forces larger reductions on covered sources as illustrated by Figure 1. The broader the coverage, the more likely it is that total emissions will be controlled.

There are also sound economic arguments for broad coverage. First, there are thousands of opportunities for emission reductions across the economy and wide variation in the cost effectiveness of those potential reductions (i.e., the cost to reduce one ton of GHG emissions). Because the allowance trading provisions of a cap-and-trade program ensure that the most cost-effective reductions occur first—thereby minimizing the aggregate national cost of attaining any particular emission target—it is important that as many sources be included in the program as possible. For example, including non-CO_2 gases allows for reductions in those with higher warming potentials, which can have lower costs and be more easily captured in the near term (e.g., methane) as well as providing benefits over the long-term.[2]

Figure 1 *Reduction Required with 70% Economy-Wide Target and 80% Coverage with Stable Emissions in Uncovered Sectors*



Including additional sectors in a cap-and-trade program can also reduce costs by stimulating the search for new cost-effective emission reduction strategies that may have gone unrealized in the absence of a cap on those sectors.[3]

Another advantage of a broad program is that it can limit the potential for "leakage" from capped sources to uncapped sources.[4] For example, if power sector generators are included in a program, but on-site industrial generation of electricity is excluded, incentives may be created to shift power generation (and the associated emissions) to the unregulated source. Considerations of equity and a desire to fairly share the economic impact of emission reductions across the economy suggest a broader program may be preferred to a narrower one. As noted above, given an economy-wide emissions target, any sectoral exemptions from a cap would require a more stringent reduction from capped sectors unless complementary policies ensure that exempt sectors carry their "fair share" of the emission reduction burden.

On the other hand, there are arguments for crafting a smaller cap-and-trade program. A program could start in a single sector, such as electric power, that easily meets the measurability and administrative feasibility criteria with data

that are already collected, a well-developed regulatory structure, and sectoral experience with emissions trading. A program of more limited scope would be easier to craft and thus may be able to start sooner, building capacity for and experience with GHG cap and trade. Additional emission sources could be phased in later or addressed through complementary measures such as efficiency standards.[5]

Measurability

The environmental integrity of a cap-and-trade program depends on its ability to ensure that emissions are actually limited to levels that are commensurate with the aggregate national reduction timetable. Accurate monitoring of emissions is also needed to ensure that the allowances surrendered at the end of a compliance period by a regulated entity correspond to actual emissions and that any allowances that have been traded are in fact surplus to those emissions. Some sources are better suited than others to accurate measurement. Stack emissions of CO_2 at power plants are already reported and can typically be measured directly with existing equipment and verified against fuel input and plant efficiency data. Even in cases where emissions cannot be directly measured, it may be possible to include an emission source in a cap-and-trade program by using a proxy that allows emissions to be reliably inferred from verifiable data.[6]

Some emissions, however, may prove to be very difficult to measure accurately. It may be infeasible or prohibitively expensive to monitor emissions directly, and there may be no reliable protocol for using proxies to estimate emissions, either because emissions per unit of activity vary widely across sources or because relevant inputs cannot be reliably tracked. Examples include methane emissions from surface coal mining, methane emissions from manure management, and nitrous oxide emissions from agricultural soils.[7] Inclusion of hard-to-measure emission sources in a cap-and-trade program may also lead to undetected noncompliance that undermines the integrity of the program.[8]

Administrative Feasibility

Coverage of individual sources that are small or diffuse can be difficult because the administrative costs (per ton of GHG) for emissions tracking, allowance trading, and compliance monitoring would be prohibitively high. For example, while it might be possible to measure the emissions from the transportation sector at the level of the vehicle, it would not be feasible to administer emissions trading with such a system. Emissions from small or diffuse sources could fall within the scope of a cap-and-trade system if they are regulated elsewhere in the product or fuel cycle (see "Choice of the Point of Regulation" on p. 6), or they can link up to the system through mechanisms such as offsets. If the measurement of these small sources is difficult or impossible, emission reductions may be encouraged through complementary measures such as standards. Ultimately, policymakers must determine whether administrative costs outweigh the benefits of including small sources within the cap or, as described below, whether other approaches to such sources may be preferable.

Given these three criteria, policymakers face many choices in setting the scope of a cap-and-trade program. One of the most important is the point of regulation, discussed in the following section.

Choice of the Point of Regulation

Policymakers determine the point of regulation for each sector in a cap-and-trade program by identifying which entities must hold allowances sufficient to cover emissions at the conclusion of a compliance period. These regulated entities could be the direct emitters or could be other entities.

Experts in the field often describe the point of regulation options for a particular sector or emission source as *upstream* or *downstream*. "Upstream" refers to points of regulation closer to where carbon first enters the economy, such as the mine, well, or port of entry, or to the point of manufacture of products such as high-GWP gases. "Downstream" refers to locations where GHGs are emitted, such as stack emissions from a power

Box 1 *Natural Gas in Cap and Trade*

The production, transportation, and consumption of natural gas accounts for 18% of total U.S. GHG emissions.[9] Including natural gas within the scope of a cap-and-trade program presents unique challenges including:

- End-users include both large and small users: large industrial facilities (5.3% of total U.S. GHG emissions from natural gas combustion), large electricity generators (4.4%), and smaller residential sector users (3.6%) and commercial sector users (2.3%). In contrast, emissions from coal originate almost entirely from large sources, while those from petroleum products originate almost entirely from small sources.
- The natural gas sector generates fugitive emissions of methane throughout the supply chain which are difficult to measure and monitor (about 2% of U.S. emissions).
- Natural gas changes hands multiple times between production and end-user through a number of different types of entities and pipelines making monitoring difficult. Point of regulation can thus have a large impact on emissions coverage and the number of entities and facilities facing compliance (see Table B1).
- Economic regulation can affect the extent of cost pass-through.
- Some industrial end users incorporate the carbon from natural gas into manufactured products rather than emitting it in the form of CO_2 from combustion.

One approach to natural gas emissions that addresses the large number of users in the residential and commercial sector is to require gas producers, processors, transporters, or distributors to submit allowances to cover the carbon content of the natural gas they move through the economy.

Table B1 *Natural Gas Sector Coverage*[10]

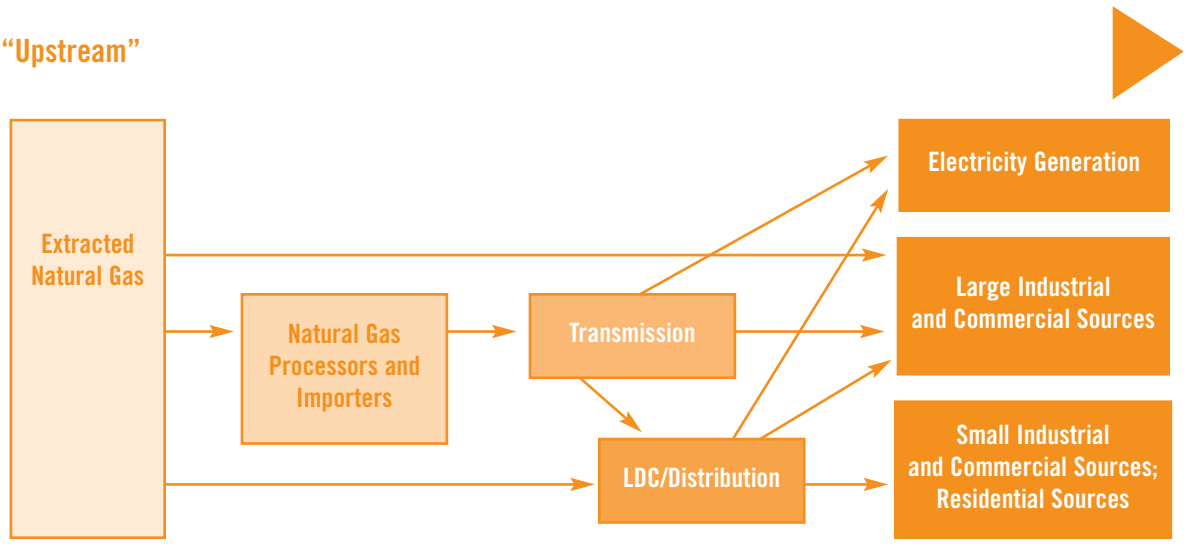
Point-of-Regulation Option	CO_2 from Gas Combustion $MMTCO_2e$ (%)	Non-Energy CO_2 $MMTCO_2e$ (%)	Total CO_2 Coverage $MMTCO_2e$ (%)	Entities	Facilities
Upstream on Producers & Importers	**1,111** (96%)	**0** (0%)	**1,111** (94%)	825	700,500
Upstream on Processors & Importers	**821** (71%)	**0** (0%)	**821** (70%)	572	365
Upstream on Pipelines	**1,020** (88%)	**0** (0%)	**1,020** (87%)	132	27,750
Downstream on Large Sources	**622** (54%)	**21** (100%)	**643** (55%)	5,382	8,250
Downstream on Large Sources & LDCs	**1,115** (97%)	**21** (100%)	**1,136** (97%)	5,532	8,400

plant, process emissions from a manufacturing facility, or tailpipe emissions from a car (see Figure B1 for an example of upstream and downstream for natural gas).

If the regulated entity is not the direct emitter (i.e., if regulation is upstream), then protocols for quantifying emissions based on proxy measures must be specified since actual emissions data would not be directly available. Proxy measures can also be necessary for downstream systems if the measurement of individual sources of emissions is impossible or prohibitively expensive. If the point of regulation is a power plant, for example, emissions can be directly measured; if, however, the point of regulation is the fossil fuel supplier, then the carbon content of the fuel (along with appropriate calculations) would have to be used as a proxy for emissions.

However, a difficulty arises if policymakers simultaneously impose a downstream compliance obligation on emissions from entire sectors (e.g., electric power generators and large industrial sources) regardless of fuel type (rather than, for example, regulating downstream for coal, upstream for petroleum, and upstream or midstream for natural gas). In this case, there are two alternatives. First, large stationary sources that are regulated downstream (power generators and industry) and that use natural gas rather than other fuels can be exempted from submitting allowances for their natural gas use. Otherwise, the only feasible alternative for addressing the remaining natural gas emissions is to put the compliance obligation on the companies that control the distribution of processed natural gas, called local distribution companies. Doing so would make it possible to distinguish gas bound for residential and commercial uses (for which the distributors would be required to hold allowances) from gas destined for power plants and large industrial sources (where allowances would be required of the emitter, not the gas distributor). If this "split system" is not pursued, then policymakers could designate gas producers, processors, pipelines, or distributors as regulated entities. Doing so, however, would require addressing a number of legal, regulatory, and administrative considerations.

Figure B1 *Point of Regulation for Natural Gas*



Proxy measures are most feasible in a commercial transaction where market forces motivate accurate recordkeeping and where there is a clear relationship between the proxy and eventual GHG emissions. The quantities, for example, of coal shipped, natural gas imported, gasoline distributed, or high-GWP gas manufactured and distributed, are likely to be tracked by both parties to the transaction. If sound methodologies also exist to allow the GHG emissions associated with such proxies to be reliably computed, then it may be possible to regulate such sources in a cap-and-trade program either upstream or downstream. However, proxy measurements do not always correlate directly with GHG emissions, for example in cases when fuels (such as natural gas) or manufactured high-GWP gases (such as PFCs) that are used by some industries wholly or partially as feedstocks are embedded into products rather than burned or emitted. In these cases, upstream regulation would be complicated, requiring exemptions or crediting for non-emission uses.

Most previous cap-and-trade programs have covered large-source downstream entities, including the U.S. Acid Rain Program, the EU ETS, the South Coast Air Quality Management District's RECLAIM program, and RGGI. Upstream cap-and-trade programs have typically been used in the United States when manufactured products (rather than emissions) are the object of regulation. For example, U.S. obligations under the Montreal Protocol have been implemented with tradable production allowances leading to a complete phase-out of the manufacture of ozone-depleting substances.

It is important to note that economists generally agree that the point of regulation is not the most important determinant of where in the economy the cost of compliance is ultimately incurred. Depending on supply and demand and regulatory conditions, allowance and emission reduction costs may be passed through to customers in the form of higher prices or to suppliers in the form of reduced demand for fuels and other production inputs, or may be absorbed by the firm and reflected as lower profits with implications for workers and shareholders.

There is not a consensus as to whether upstream or downstream coverage provides more powerful incentives.

When it comes to the question of whether upstream or downstream coverage creates more powerful incentives for emission reductions, there is not a consensus among experts. A downstream program puts the compliance obligation (and hence costs) directly on entities that can reduce GHG emissions by, for example, improving process efficiency, changing processes, or substituting material and fuel inputs. The same emissions reduction behaviors could be induced under an upstream approach solely by the price signal that comes from fossil fuel suppliers passing on the compliance costs through an increase in the product price. To the extent that suppliers cannot pass on the full compliance costs, there will be less incentive for downstream reductions. An argument can also be made that a price signal does not induce behavioral changes to the same extent as the direct obligation to surrender allowances, although there is not broad consensus on this point.

Downstream entities may be more inclined to change behaviors or technologies that result in emissions if they were directly covered by

the program. For example, downstream coverage would incentivize continued research and development of new technologies that reduce GHGs at the point of emission such as carbon capture and storage (CCS), whereas an upstream system would require crediting to provide these incentives. Otherwise, a coal-fired power plant would not have an incentive to invest in technologies like CCS, because it would not realize any benefit to reducing its emissions. On the other hand, a downstream system will generally involve a larger number of regulated entities than an upstream system and could thus entail higher administrative costs.

Upstream and downstream coverage can be combined across sectors in a hybrid approach, although care must be taken to ensure that no sources are covered twice or inadvertently excluded. For example, the Boxer-Lieberman-Warner bill (S. 3036) in the 110th Congress took a hybrid approach, regulating upstream for transportation fuels and natural gas, but downstream for large coal users and GHG manufacturers. Many other proposed bills also took hybrid approaches across sectors (see Table 2). The coverage of natural gas in these hybrid systems can be particularly complicated, and is discussed in Box 1.

Additional Policy Options

Expanding Program Coverage over Time

As noted above, there are benefits to implementing as broad a program as possible. Policymakers may find, however, that action could more easily be taken in some sectors than in others or that phasing in certain sectors of a program over time is preferable. For example, conventional air pollutant emissions from large electric generation plants are already regulated under federal law and these firms have substantial experience with the existing acid rain program. Accordingly, it may be feasible to launch a cap-and-trade program in the power sector and then extend it to other sectors as measurement protocols are finalized, regulated entities identified, relevant data compiled, and appropriate administrative structures put in place.[11] This approach is similar to that taken in the RGGI program and may be more attractive at the federal level in light of recent court cases requiring EPA to revisit regulations for conventional air pollutants from these sources under the Clean Air Act.[12]

Policymakers may also wish to consider that if certain sectors, sources, or gases are excluded from a national cap-and-trade program, it may be possible to tailor other policies to address their emissions (see "Emissions of High-GWP Gases" on p. 13 for an example).

Complementary Policies

Additional standards or practices may be beneficial to encourage reduction of emissions that are not easily covered by cap and trade, as supplements to cap and trade in sectors that are within the cap, and to address other market failures economy-wide. For example, emissions from some small, diffuse sources such as landfills and wastewater treatment systems would be difficult to include in a cap but could be reduced using complementary policies such as design standards, or allowed to join the program as offsets.

While policies complementary to a cap-and-trade program are the subject of separate Pew Center Congressional Policy Briefs, it is important to note one important linkage between the scope of a trading program and implementation of

policies that try to address emissions in a covered sector as a supplement to the cap. A cap-and-trade program is intended to correct one market problem (i.e., the release of damaging GHGs), while complementary policies can be economically efficient when they aim to correct other market problems, such as the lack of readily available data to inform consumers' purchases of energy efficient technologies or limits on the ability of an innovator to fully capture the rewards of its investment in emission reduction technologies.[13]

A size-based threshold may be most appropriate for sectors where there are a few big sources and many small sources.

Many complementary policies reduce the GHG intensity of a particular activity (e.g., lowering emissions per vehicle mile traveled) but may not show a price signal that reduces the overall level of that activity (e.g., total miles driven). A cap-and-trade program thus may provide an incentive that would not otherwise exist to reduce the level of the activity itself. In this example, the two policies work in tandem to achieve the desired environmental result.

Treatment of Small Sources

If many facilities in a sector emit little or no GHGs, policymakers may be concerned about the trade-off between environmental protection and administrative costs. In such cases, it may not be necessary to exclude the sector in its entirety from a cap-and-trade program. Instead, it may be preferable to set a size threshold, above which compliance is required. Doing so has the benefit of limiting administrative costs while still addressing the largest sources in a sector.[14] Size thresholds could be based on the quantity of emissions, the production capacity of the plant, or a combination of the two. In addition, the threshold could be set at different levels for different sectors.

For example, the EU ETS has proposed to make changes in coverage of small installations for its third phase (2013-2020) by allowing member states to remove installations from the trading scheme ("opt out") if they meet certain size thresholds and emissions limits, and if measures are put in place that will achieve an equivalent contribution to overall emission reductions. The change will affect roughly 4,200 installations that account collectively for around 0.7 percent of total ETS emissions.[15]

A size-based threshold may be most appropriate for sectors where there are a few big sources and many small sources, and the big sources account for a large percentage of the sector's total emissions. When it comes to CO_2 emissions from fossil fuel combustion in the manufacturing sector, for example, only 7,800 facilities out of the nation's 363,000 facilities (or 2 percent of the total) have annual emissions over 10,000 metric tons CO_2, despite being responsible for 80 percent of total emissions. And 47,000 facilities (or 13 percent of facilities) emit over 1,000 metric tons CO_2 per year, but generate over 95 percent of the total emissions.[16]

An alternative to using a size standard to screen out small emission sources is to set a point of regulation upstream of the emitting industry. For example, it may be feasible to impose a cap-and-trade requirement on gasoline and diesel fuel suppliers even though it is infeasible to directly include all of America's cars and trucks

in a trading program. Doing so may bring all of the emissions of these small sources into the program without creating a large administrative burden. More detail on this approach is provided below on a sector-by-sector basis.

Treatment of Imports

While a cap-and-trade program can effectively address the vast majority of GHG emissions associated with U.S.-made goods, additional policies may be required to deal with imported goods and raw materials. At a minimum, if an upstream program is adopted for fossil fuels or high-GWP gases, then importers of such materials should be required to hold an appropriate number of allowances; otherwise, a competitive imbalance would occur between foreign and domestic producers.

Policies to address the import of other goods, the manufacture of which created overseas GHG emissions, would be more complex. Under a cap-and-trade program, domestic producers of GHG-intensive products facing significant competition from firms in countries without comparable GHG controls could be at a competitive disadvantage. In turn, production of these goods could "leak" from within the scope of the cap to outside the scope. That is, manufacturing and the associated jobs and emissions could migrate overseas to places with no price (or a lower price) on emissions.[17]

A separate Pew Center policy brief evaluates which sub-sectors are vulnerable to trade impacts and considers strengths and weaknesses of various approaches to addressing potential leakage. Ultimately, the solution for addressing leakage concerns is an international agreement that imposes meaningful controls—within a reasonable period of time—on GHG emissions in all countries, thereby ensuring that climate policy does not distort the competitive balance between the U.S. and its trading partners.

Sector-Specific Choices

While breadth of coverage is helpful, other criteria such as measurability and administrative feasibility suggest that a cap-and-trade system may not be appropriate for every source of GHG emissions. The following section assesses the suitability of various sectors and sources for inclusion in a cap-and-trade program.

It is important to note that if specific sectors are excluded from a national cap-and-trade program, policymakers will need to determine whether other policy tools should be used to limit emissions from those sectors or whether deeper cuts need to be made inside the cap-and-trade program to reflect the exclusion of those sectors.

Emissions from Electric Power

The electricity sector produces 34 percent of U.S. GHG emissions, almost entirely as CO_2 emissions from combustion of fossil fuels. The sector could be addressed under either an upstream or downstream program. An upstream system would be based on the carbon content of fossil fuels used to generate electricity. Fuel providers (i.e., coal and natural gas suppliers) would be required to hold allowances equivalent to the eventual emissions at the point of combustion. In this case, entities in the electricity sector would not have compliance responsibility and a price signal would be passed from fuel providers to power generators. Unlike many efficiency measures, methods of capturing emissions do not involve a reduction in fuel use. Therefore, as discussed above, a price signal alone provides no incentive to develop CCS. To correct

for this, a system could be developed to issue credits for sequestered emissions. That is, sequestration could be treated as a "negative emission," with downstream generators granted credits to compensate for the embedded cost of emissions credits in the fuel price.

A downstream, generator-based system would require power plants to hold allowances equal to their emissions. To accommodate potential use of CCS, allowances might be required only for net emissions, calculated by subtracting sequestered emissions from total emissions. A generator-based system would resemble the current Acid Rain Program and leverage existing experience in the industry. A downstream system for the electric sector along with an upstream system for one type of fuel supplier (like natural gas) would require an exemption either for suppliers to electric generators or for generators using that fuel, to avoid double counting.

Several legislative vehicles in the 110th Congress took the approach of covering emissions from electricity generation based on the fuel rather than treating the sector separately, with coal users covered downstream (including electric power generators), petroleum covered upstream, and natural gas covered either upstream or midstream (see Box 1).

Emissions from Transportation

The transportation sector is the second largest source of GHG emissions, primarily in the form of CO_2, along with small amounts of N_2O and high-GWP gases as well (see below for discussion). With over 240,000,000 cars, trucks, and buses on the road, a downstream cap-and-trade program covering individual sources is not an option.[18] Because virtually the entire carbon content of a gallon of gasoline is released as CO_2 during combustion, it is possible to treat gasoline consumption as a proxy for emissions and thus regulate automotive emissions upstream. A fuel-based program would require that allowances equal to the carbon content of fuel sold be held by refineries, fuel distributors, or some other entity in the distribution chain for transportation fuels. Under this system, allowance holders would have few options for reducing the carbon content of fuels, so the allowance price of carbon would then be seen by consumers in the price of fuel. While higher prices would discourage driving and hence GHG emissions, it's not clear that the modest price increases that may result from cap and trade in the near term would change vehicle choice or driving behavior significantly. However, recent increases in fuel prices have caused some consumer switching towards more efficient vehicles and public transportation, indicating that a price signal over the long term could have an impact through improved total fleet efficiency and reduced vehicle miles traveled.[19]

Because of the relatively weak sensitivity of transportation emissions to a modest price signal, non-price policies can become an important supplement, or even an alternative, to including fuel suppliers within the cap. For example, federal fuel efficiency standards for automakers were recently substantially revised for the first time in decades[20] and have reduced projected emissions from the sector.[21] EPA is also considering tailpipe standards for automobiles.[22] Some reductions in GHGs could also be achieved by requiring fuels to meet a low carbon fuel standard (LCFS) which specifies a target life-cycle emissions level. Another option, a renewable fuel standard (RFS), specifies a target for the percentage of renewable fuels (ethanol or biodiesel) blended into the fuel

stream; however this target does not always generate lower GHG emissions. With any of these complementary policy options, care needs to be taken to assure that they work with the cap-and-trade system in a way that considers and integrates the multiple regulatory requirements faced by the sector.

Emissions of High-GWP Gases

The high-GWP gases (i.e., HFCs, PFCs, and SF_6) are a small, but important, source of GHG emissions in all sectors of the economy other than agriculture. These gases are manufactured for use in numerous applications, and emissions are widely dispersed across many sectors, processes, and uses. Including these gases in a downstream cap-and-trade program, however, could be problematic owing to the difficulty of measuring emissions and the potential costs of program administration.

An alternative would be an upstream program aimed at the manufacturers of these gases. Such manufacturers (as well as any importers) would be required to hold allowances based on the quantity of each high-GWP gas shipped to customers. Because some end-uses of these gases offer the opportunity for recapture and destruction rather than emission (e.g., PFCs in electronics manufacturing), a system for creating appropriate credits would be needed.

Because of the high global warming potential of these chemicals as compared to CO_2, some argue that there exists the risk of a significant price shock for these chemicals if they are included in a single cap-and-trade system. The GWP of HFCs, for example, ranges from 140 up to 11,700.[23] One proposed alternative would be to institute a second cap-and-trade program—limited to all or a subset of the high-GWP gases— that could be structured to limit excessively high allowance costs. Another alternative would be to regulate these gases using more conventional Clean Air Act regulatory approaches.[24] Both of these alternatives, however, would increase economy-wide costs and run the risk of reducing program integrity, and have implications for broad coverage, measurability, and administrative feasibility.

Although industry accounts for almost 19 percent of all U.S. GHG emissions, it is a heterogeneous sector.

Emissions from Industry

Although industry accounts for almost 19 percent of all U.S. GHG emissions, it is a heterogeneous sector. It includes GHG-intensive operations like cement manufacturing and coke production, as well as sectors with little or no direct emissions, such as apparel, furniture, and leather production. Direct industrial emissions can include both energy-related on-site combustion of fossil fuels and emissions generated from industrial processes such as the calcination of limestone to form clinker (the primary ingredient in cement).[25] While the measurement protocol would differ from process to process, most of the major industrial emission sources could be covered in a downstream cap-and-trade program.

An issue could arise in an upstream program if fossil fuels used by industry as feedstocks do not result in GHG emissions but are instead chemically incorporated into the product (e.g., in the manufacture of some plastics). In such situations, credits could be granted in an amount equal to the upstream allowances that were applied to the fossil fuels used as production inputs. Avoiding this complication is one of the advantages of downstream coverage.

Residential & Commercial Emissions

In addition to electricity consumption and use of high-GWP gases (both generally covered elsewhere if within the cap), the residential and commercial sectors have significant direct GHG emissions primarily from natural gas (and some propane and fuel oil) used in equipment such as boilers, space and water heaters, and kitchen appliances. Given that there are tens of millions of residences in the U.S., a downstream residential-sector program is not feasible. In the commercial sector, there are 4.6 million buildings, only 6,000 of which emit more than 1,000 CO_2-equivalent tons per year (primarily very large universities and hospitals that run large boilers for central heat).[26, 27] The vast majority of the commercial sector is therefore also not suitable for inclusion in a downstream cap-and-trade system. Several options exist for covering natural gas either midstream or upstream (see Box 1).

The residential and commercial sectors have significant direct GHG emissions primarily from natural gas (and some propane and fuel oil) used in equipment such as boilers, space and water heaters, and kitchen appliances.

With an upstream coverage of natural gas and some pass-through of price to residential and commercial sources, incentives could be created to shift from natural gas to other fuels such as propane or home heating oil if they are not also covered. These incentives could be avoided by ensuring that all potential fuel sources for the highly-distributed use in residential and commercial sectors are subject to similar controls.[28]

Alternatively, policymakers could exclude residential and commercial uses of natural gas from the cap-and-trade program and instead address these sectors with other policy tools. One option is to change utility rate regulations to decouple sales from profits for natural gas distributors and instead reward them based on efficiency improvements (which would lower GHG emissions), even as less gas is sold to residential and commercial customers. Another option is to intensify energy efficiency efforts such as model building codes, appliance standards, and market transformation programs like ENERGY STAR®. It is worth noting, however, that exempting residential and commercial natural gas use from coverage while simultaneously covering emissions from electricity generation would confer an advantage on natural gas over electricity. Given the long-standing competition between natural gas and electricity in residential and commercial markets, and the uneven regional distribution of electricity and natural gas use for space conditioning, this approach would likely meet significant political resistance and could result in shifts towards higher natural gas usage, resulting in increased emissions that could undermine the cap.

Agricultural Emissions

Most emissions from agriculture are non-CO_2 gases, coming primarily from enteric fermentation (livestock methane), manure management, fertilizer application, and cropping practices. While the relatively small CO_2 emissions would be captured under an upstream system on fuels, most of the sector's emissions would not be covered. For the most part, the agricultural sector is not a viable candidate for inclusion in a cap-and-trade program for reasons of measurability and administrative feasibility

(as well as political viability). While numerous emission reduction opportunities exist, the uniform national monitoring and verification of agricultural GHG emissions would be difficult.[29]

Project-specific verification of agricultural emission reductions is likely to be feasible in some circumstances, thereby facilitating the creation of "offsets" which can be traded (with some limitations) and used by an emitter to meet its compliance obligation (see separate Pew Center Offsets Brief). In addition, policy tools other than cap and trade, such as incentives for use of best management practices, may be valuable in the agricultural sector.[30]

Other Emission Sources

Important sources of GHG emissions not discussed above include: non-combustion emissions from natural gas and petroleum production and exploration and leakage from distribution systems; coal mining; landfills; and wastewater treatment systems. Fugitive emissions from natural gas and petroleum production and distribution systems and from surface coal mining are very difficult to monitor and measure, thereby making it difficult to include such emissions in a national cap-and-trade program. Accordingly, other policy tools would be needed to limit emissions from such sources.

Because of its hazardous nature, methane from underground mines is typically managed carefully and vented. It may be possible to monitor emissions from these systems and include them within the scope of a cap-and-trade program.

When it comes to emissions from landfills and wastewater treatment systems, variability in source characteristics can make it difficult to create a uniform protocol for monitoring and measuring emissions.[31] If such a uniform protocol can be designed, these sources can be included in the cap-and-trade program. Alternatively, if reductions from such sources can be validated, it may be feasible to include them as offsets.

Key Design Questions

As policymakers specify the scope of a cap-and-trade program to address U.S. GHG emissions, several important questions must be addressed:

- What sectors, sources, and gases are covered by the program?
- Does the program maximize cost-effectiveness by covering as many emission sources as possible, given other constraints?
- Can emissions from sources included in the program be accurately measured or reliably estimated using proxies?
- Have administrative burdens been balanced against the environmental benefit of including additional sources and sectors in the program?
- For each covered sector, source, and gas, is the point of regulation upstream, downstream, or a hybrid approach?
- Has an appropriate strategy been developed to minimize the cost of addressing emissions from small sources?
- How will the program encourage emission reductions outside the capped sectors?

End Notes

[1] CO_2-equivalent is a metric used to compare quantities of greenhouse gases on a similar basis, obtained by multiplying the amount of a gas times its global warming potential relative to CO_2.

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[5] Nordhaus, Robert, and Kyle Danish, *Designing a Mandatory Greenhouse Gas Reduction Program for the U.S.*, Pew Center on Global Climate Change, May 2003.

[6] Market Advisory Committee to the California Air Resources Board, *Recommendations for Designing a Greenhouse Gas Cap-and-Trade System for California*, June 30, 2007.

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[9] U.S. EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*, April 2007.

[10] From Bluestein, Joel, *Coverage of Natural Gas Emissions and Flows Under a Greenhouse Gas Cap-and-Trade Program*, ICF International for the Pew Center on Global Climate Change, forthcoming.

[11] See Western Climate Initiative, *Draft Program Scope Recommendations*, March 3, 2008, pages 11-13, for a discussion of the issues associated with phasing.

[12] An example is the recent decision by the U.S. Court of Appeals for the District of Columbia vacating in its entirety the Clean Air Interstate Rule promulgated by EPA in 2005 to establish a cap-and-trade system for SO_2 and NO_X in a set of upwind states to meet air quality standards in the Clean Air Act.

[13] Goulder, Lawrence, and William Pizer, *The Economics of Climate Change*, Resources for the Future, June 2006.

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[15] European Council, *Questions and Answers on the Commission's proposal to revise the EU Emissions Trading System*, MEMO/08/35, January 23, 2008, found at http://ec.europa.eu/environment/climat/climate_action.htm.

[16] West, Tristram, and Naomi Pena, 2003. *Determining Thresholds for Mandatory Reporting of Greenhouse Gas Emissions*, Environmental Science and Technology 37(7):1057.

[17] Committee on Energy and Commerce, U.S. House of Representatives, *Climate Change Legislation Design White Paper: Competitiveness Concerns/Engaging Developing Countries*, October 2007.

[18] 2008 U.S. Statistical Abstract, Table 1064.

[19] "Driving Less, Americans Finally React to Sting of Gas Prices, Study Says." *New York Times*, June 19, 2008.

[20] Recent changes were included in the Energy Independence and Security Act of 2007, signed into law in December of 2007 (Pub.L. 110-140). The original EPCA set car standards out to 1985, after which they were weakened by NHSTA then increased in 1990 back to the 1985 standard (27.5 mpg) and held at that level until now. See http://www.nhtsa.dot.gov/CARS/rules/ CAFE/overview.htm.

[21] U.S. Energy Information Administration. AEO 2008. Found at http://www.eia.doe.gov/oiaf/aeo/pdf/0383(2008).pdf.

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