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TRANSPORTATION AND GREENHOUSE GAS EMISSIONS TRADING

FINAL TECHNICAL REPORT

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Table of Contents

Transportation and Greenhouse Gas Emissions Trading

Executive Summary

The paper examines four alternative approaches to carbon emissions trading for transportation emissions in the United States: upstream trading, vehicle maker-based trading, an upstream/vehicle maker hybrid, and upstream trading combined with vehicle maker carbon efficiency standards. To put consideration of emissions trading in a broader context, we begin with a discussion of the range of options available to reduce emissions from on-road transportation sources. While emissions trading does not guarantee reductions specifically from transportation sources, if designed correctly it is superior to other policy approaches because it both provides greater certainty that overall emissions goals will be met and results in cost-effective achievement of these goals.

The first trading design option considered, an upstream approach, would require fuel producers to hold allowances for the carbon contained in the fuels they sell. Petroleum refineries would be the point of regulation of transportation fuels in this system. The upstream approach would achieve broad coverage while imposing minimal administrative burden. Broad coverage is important because it both provides greater certainty that environmental goals will be met and results in greater economic efficiency.

The paper then considers two types of programs that would make vehicle manufacturers responsible for emissions from vehicles. Under the "on-road fleet" approach, vehicle manufacturers would be responsible for emissions from all vehicles on the road, whereas in the "new vehicles" approach, manufacturers would be responsible for the lifetime emissions of vehicles at the time of sale. While both methods provide a feasible approach to integrating vehicle manufacturers into the trading system, both have significant drawbacks. In particular, the on-road fleet method would hold vehicle makers accountable for actions they cannot control and could have a distortionary impact on new vehicle prices, while the new vehicles approach would not capture emissions from vehicles sold prior to program inception and therefore would place a burden on other sectors of the economy. Further, unlike an upstream system, neither program would address emissions from heavy-duty vehicles, aviation, marine and off-road sources.

The paper then examines the merits of a hybrid system in which responsibility for transportation sector emissions is split between vehicle makers and fuel producers. Under this approach, both sectors would be required to hold allowances for their portion of transportation sector emissions. The purpose of this dual approach would be to try to catalyze greater abatement activity by sending a fuel price signal and by providing incentives for improving vehicle technology. Drawbacks associated with a hybrid approach include the administrative and political complexities associated with regulating two different sectors and the potential for fraud by energy users created by a hybrid system. This potential results from the fact that a hybrid system would create a differential between light duty vehicle fuel prices and the prices of other fuels. It is

unlikely that the potential technical benefits of a hybrid system would justify the additional complexities introduced.

The paper then notes that many land use and infrastructure policies, which significantly affect VMT growth, are unlikely to be reached effectively by a trading system. We recommend that this market failure be addressed by establishing a mechanism to fund land use planning activities and alternative modes of transportation that help reduce VMT and transportation sector GHG emissions in the long-term. We conclude that setting aside emissions allowances for such activities would complicate the GHG emissions trading system. We recommend instead that a small portion of revenues from a carbon allowance auction be earmarked for land use planning and alternative transportation mode activities that reduce GHG emissions. We believe that this additional program could help change the long-term trajectory of transportation sector greenhouse gas emissions.

An important consideration in designing a national GHG control program is whether or not it is necessary to ensure that emission reductions take place within the transportation sector. The primary reasons for targeting reductions within the transportation sector include potential long-term cost savings for GHG abatement, and complementary social, economic and environmental benefits. None of the cap-and-trade options discussed would do so, because all fully integrate the transportation sector into a broader national cap-and-trade program. This integrated approach leads to a least-cost national GHG abatement strategy, but it does not guarantee transportation sector emission reduction activity.

We do not reach a conclusion on whether it is necessary to establish programs that specifically target transportation sector reductions, with the exception of the land use-infrastructure program just mentioned. However, if policy makers believe that specific transportation sector emissions reductions are warranted, then we would recommend combining an upstream trading system with vehicle carbon efficiency standards. Such standards should be designed with an "escape valve" that allows vehicle manufacturers to pay a cash penalty equal to the price of carbon allowances in lieu of meeting their efficiency requirements. This mechanism would ensure that the regulatory cost placed on vehicle manufacturers does not exceed that imposed on sectors participating in the carbon trading system and that an economically efficient strategy is pursued.

1 Controlling Transportation Sector Emissions

The transportation sector accounted for 26 percent of the United States' greenhouse gas (GHG) emissions in 1997. Emissions of CO_2 constitute 95 percent of total sectoral GHG emissions, and the sector is responsible for almost one-third of the nation's CO_2 emissions. Between 1990 and 1997 the sector's emissions increased at about the same rate as total U.S. GHG emissions (1.5 percent per year).[1] In the future, however, the rate of increase in CO_2 emissions from the transportation sector is projected to outstrip the rate of increase of CO_2 emissions for the nation as a whole: transportation sector CO_2 emissions are projected to grow at a rate of 2.1 percent annually from 1997 to 2010, whereas national CO_2 emissions from energy use are expected to grow at an annual rate of 1.5 percent.[2] The projected increase in transportation sector GHG emissions is driven by continued growth in vehicle miles traveled[3] with vehicle efficiency remaining relatively constant.[4] As shown in Table 1, more than three-quarters of transportation sector CO_2 emissions occur as a result of on-road vehicle use.

Table 1. 1997 CO_2 Emissions from the Transportation Sector[6]

Mode	% of Total US CO_2 Emissions	% of CO_2 Transportation Emissions
On-road Vehicles	23	78
Aviation	3	11
Marine	1	3
Other	2	8
Total	**30**	**100**

Clearly, U.S. climate policy must address the rapid growth in greenhouse gas emissions from the transportation sector. A comprehensive emissions trading approach that included transportation sources would encourage those reductions in transportation emissions that are cost-effective relative to reductions in other sectors and other countries. However, including transportation sources in a carbon reduction strategy will be complex, even if we put aside the historical political difficulties in addressing environmental issues in this sector. To begin to examine how to include transportation sources in emissions trading, we focus here on one group of sources: light duty vehicles (passenger cars, vans, pickups and sport utility vehicles). These account for the majority

[1] USEPA. 1999. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1997.* April 1999.
[2] USDOE. 1998. *Annual Energy Outlook 1999.* EIA.
[3] From 1990 to 1997, automobile VMT grew at about 1% per year (Oak Ridge National Laboratory, *Transportation Energy Data Book*, Edition 19, September 1999). From 1997 to 2010, VMT from light duty vehicles is expected to grow at 1.7% per year (USDOE 1998).
[4] DOE actually projects a 1% decrease in on-road light duty vehicle efficiency over this time frame (USDOE 1998). This is apparently due to a projected increase in the use of light trucks and SUVs.
[5] From 1997 to 2010, aviation emissions are expected to grow at about 3% per year versus 2% per year for on-road vehicles (USDOE 1998).
[6] USEPA. 1999. Note: Excludes bunker fuels.

(60 percent) of CO_2 emissions from the sector. Issues related to including the remaining portion of emissions (40 percent) in emissions trading are discussed briefly in Section 7.2.

Challenges in addressing transportation GHG emissions

Vehicle carbon emissions are determined by three key variables: distance traveled, fuel efficiency, and fuel carbon content (Equation 1). Fuel carbon content is a good proxy for emissions because the carbon in fossil fuels is almost completely combusted to CO_2,[7]

Equation 1. Vehicle Carbon Emissions

Vehicle Carbon Emissions =

Vehicle Miles Traveled (VMT) ÷ *Vehicle Efficiency (mpg)* × *Fuel Carbon Content (lb. C/gal)*

A primary challenge in addressing emissions from this sector is the fact that a wide range of factors influences these variables both directly and indirectly. These factors include: fuel prices, vehicle prices, income levels, parking costs, vehicle stock turnover, consumer preferences, available technologies, land use patterns, and the availability of and attitudes toward different transportation modes (transit, biking, walking, car pooling, teleworking).

For example, vehicle manufacturers respond to consumer demand, but at the same time make important decisions about where to focus R&D and which technical options to introduce to the market. Consumer choice and travel behavior is critical to the types of vehicles that are on the road, how much they are used and how well they are maintained. Consumers' preferences, however, are shaped by the options presented to them. For example, dense, mixed-use development is more conducive to walking, biking and use of transit. Similarly, commuters living in communities with well-designed HOV lanes may be more inclined to travel by carpool or vanpool if they offer real time savings. Therefore, local, regional and state governments, land owners and private developers can have a crucial impact on long-term travel behavior through land use planning, zoning, development patterns, and other policies. Some of these direct and indirect influences on transportation sector greenhouse gas emissions are presented in Table 2.

Table 2. Direct and Indirect Influences on Transportation Sector GHG Emissions

Entity/Factor	Vehicle Miles Traveled	Vehicle Efficiency	Fuel Carbon Content
Consumers	Travel Decisions	Consumer Preferences, Vehicle Maintenance	Consumer Preferences
Vehicle Manufacturers	(*indirect influence*: vehicle efficiency impact on driving costs)	Vehicle Technology	Vehicle Technology
Fuel Producers	Fuel Price	NA	Product Mix
Land Use & Transportation Infrastructure	Available Travel Options	NA	NA

[7] A percent or so is contained in ash or particulates, or incompletely combusted to form CO.

Given the range of factors that impact emissions from this sector, achieving emissions reductions from transportation sources may require multiple policy approaches. Below, we review a number of policy options for reducing transportation sector emissions. Whereas these approaches seek, but do not guarantee, reductions from transportation sources, incorporating transportation sources into a national emissions trading program would guarantee lower emissions, but not necessarily from transportation sources. Some of these policy options may be appropriate to begin to change the emissions trend in the transportation sector. Many of these could be implemented in tandem with a national emissions trading program. Some would require careful coordination with emissions trading to avoid reducing the efficiency of trading.

1.1 Non-Market Approaches in the Transportation Sector

There are many non-market approaches to reducing transportation sector emissions, many of which have been implemented to address air pollution, traffic congestion, and other local and regional concerns. This paper does not attempt a comprehensive description of these, but lays out some key options to indicate the range of possibilities.

- **Vehicle Efficiency Standards.** The Corporate Average Fuel Economy (CAFE) program mandates a fuel efficiency standard for the average of all cars and light vehicles sold in each year. Strengthening the CAFE standards would either reduce or slow the growth of GHG emissions (depending on changes in vehicle miles traveled).
- **Sales Quotas.** Some states have set quotas for low- and zero-emission vehicle sales to control local air pollution. For example, starting in 2003 California will supplement stringent fleet average emissions requirements with a requirement that ten percent of manufacturers' light-duty vehicle fleets be zero-emissions vehicles (ZEVs.)[8] Rules such as these are designed to provide an incentive for manufacturers to develop and commercialize new vehicle technology. Other states have the right to opt into California standards under the 1990 Clean Air Act Amendments – New York and Massachusetts have each elected to do this.
- **Land Use/Transportation Planning.** Consumers may drive less if they have access to high quality public transportation, and a safe and convenient infrastructure for walking and biking. Development patterns in which goods and services can be purchased within easy walking distance of home, work, or transit stops are key to creating viable alternatives to the automobile for non-work trips. A well-designed HOV network can allow carpools and vanpools to move through rush-hour traffic more quickly than single occupancy vehicles.

  Planning activities and land use regulations at all levels, from local to federal, have major long-term impacts on the transportation sector. Zoning affects development patterns, which in turn affect the amount of automobile travel in an area. Parking requirements are another land use tool that can affect the transportation emissions in

[8] "Staff Report: Low-Emission and Zero-Emission Vehicle Program Review." California Air Resources Board, Division of Mobile Sources. Sacramento, November 1996. Website of the California Air Resources Board, August 9, 1999.

an area. Ongoing research is investigating the impacts of "smart growth" development patterns (higher density, mixed-use, multi-modal) on transportation emissions.

- **Research and Development.** Basic research and development must be funded to bring new vehicle technologies to fruition. For example, fuel cell and battery technology are required to improve the performance of electric and hybrid vehicles.

1.2 Market Mechanisms in the Transportation Sector

There are several possible market-based mechanisms that could be used in the transportation sector, including:

- **Emissions Trading.** In an emissions cap-and-trade system, an emissions cap is determined for the sectors included in the trading system, and allowances are allocated to regulated entities. These entities must hold allowances for their emissions; to achieve compliance they may both reduce emissions themselves and purchase allowances from other entities. In this paper we examine four different emissions trading program designs.

- **Standards Trading.** Under this approach performance standards are determined for regulated entities.. Entities that achieve better performance can trade to entities that fail to meet the standards. For example, vehicle manufacturers could be required to meet a standard similar to existing CAFE requirements. If a manufacturer were to achieve better efficiency, then it could sell the improvements beyond their carbon efficiency requirement to other manufacturers.

- **Fees, Rebates, and Tax Credits.** These and other similar market mechanisms could be used in addition to or instead of emissions trading. One example is the federal gas guzzler-gas tax policy, which requires manufacturers to pay a tax on vehicles that do not meet a set fuel efficiency standard. Other proposals include VMT penalties on rental cars and pay-at-the pump car insurance.

- **Taxes.** Gasoline taxes , taxes based on vehicle efficiency, and VMT taxes are other market-based approaches. Gasoline taxes historically have faced strong political opposition.

- **Road Pricing.** Road pricing can mean road tolls or tolls for single-occupancy vehicles that use designated high-occupancy lanes. Road pricing can be used to reduce the number of single-occupant vehicle trips, thereby reducing GHG emissions.

- **Parking Pricing or Restrictions.** The availability of free or inexpensive parking makes driving more affordable. Urban or regional parking limits or parking "cash out" policies (which provide cash in lieu of free parking to employees) can encourage drivers to consider alternative transportation options.

Benefits of Emissions Trading: Certainty, Flexibility and Cost-effectiveness

We believe that an emissions cap-and-trade system offers several advantages over other approaches for controlling transportation sector GHG emissions. First, by establishing a national cap related to the emissions target for the country, the cap-and-trade approach ensures that the target is met. In contrast, many other approaches (e.g., per-unit-output emissions standards) cannot guarantee that environmental goals will be met, because unanticipated events, such as increases in vehicle miles traveled, will increase emissions even if all firms are in compliance with applicable standards. Further, a number of the approaches do not lend themselves to quantification of emissions impacts. Second, trading systems give regulated entities maximum flexibility in internal business decisions. In particular, some entities can avoid implementing excessively costly reduction options by purchasing extra allowances, whereas other entities can receive a revenue stream from "over-compliance" by selling allowances they no longer need. This provides a direct incentive for regulated entities to seek out innovative compliance methods that are more cost-effective than "one-size-fits-all" regulation. Emissions trading provides certainty that environmental goals will be met and provides incentives for innovation that lead to a least cost solution.[9]

2 Cap-and-Trade Approaches

There are five basic steps in the design and implementation of any cap-and-trade system.

(1) **Set the cap**. First, the government sets the "cap," which is the total emissions that may be generated in a given year (or other time period) by the emissions sources covered by the trading system. This cap then represents the total number of emissions allowances distributed. Each regulated source must hold allowances to cover all of its carbon emissions.

(2) **Select the point of regulation.** Second, the point of regulation must be determined. The point of regulation defines which entities are responsible for holding allowances. It also defines the point at which emissions must be measured or estimated, and the number and types of entities that must be tracked in the administration of the trading system. As such, selecting the point of regulation will affect to a significant degree the feasibility and effectiveness of the system. As discussed later in this section, potential points of regulation for fossil fuel-related emissions may be found throughout the fossil fuel life cycle, from the point of fuel extraction (upstream) to the actual point of combustion (downstream). Petroleum refiners are further "upstream" than vehicle operators.

(3) **Distribute allowances**. Third, allowances must be distributed among the regulated entities. Allowances can be "grandfathered", or distributed gratis, based on criteria such as historic or current emissions or fuel use, or auctioned in an open market. A previous paper in CCAP's Airlie series explores the relative merits of allowance

[9] The relative value of trading over direct regulation depends to a large degree on the variability in emissions control costs for different entities. If there is a large difference, then trading is more likely to achieve significant cost savings.

auctioning and grandfathering.[10] Any of the different distribution mechanisms could be used for each of the trading system designs discussed below.

(4) **Report actual emissions.** Fourth, in each year (or other time period), actual emissions must be reported for each regulated entity. Emissions can be determined by direct measurement of emissions sources, or indirect estimation based on other activity data and supporting assumptions (e.g., emissions factors). The feasibility, accuracy, and cost of different calculation approaches will vary by point of regulation.

(5) **"True-up": reconcile actual emissions with allowances**. Fifth, at the end of the period reported emissions must be compared to allowances held. Entities with more allowances than emissions would be able to sell their excess to other regulated entities or possibly bank them for future use.[11] Entities with fewer allowances than emissions would be in non-compliance. They would need to purchase additional allowances to make up their shortfall and/or pay fines or other enforcement penalties.

Selecting a Point of Regulation: Upstream, Downstream, or Both

Selecting the point of regulation is a key design consideration, and the transportation sector offers many potential points of regulation to provide incentives for emission reductions. One obvious point of regulation would be somewhere along the fuel supply chain. Requiring allowances to be held for the carbon contained in transportation-related fuels at any point along the supply chain – fuel extraction, processing, transport and distribution, retail sale – would account for eventual emissions of CO_2. Regulation at the point of combustion, the very end of this chain is also (theoretically) an option. Each point presents different hurdles in estimating emissions and administering the program.

Other points of regulation exist where considerable influence on transportation emissions could be exerted. First, regulation of vehicle design offers an opportunity to affect the purchasing options and decisions of vehicle end users and could make more efficient designs available and/or increase the cost of less efficient vehicles. Second, transportation infrastructure and land use planning could be included in a trading system, to provide incentives for long term development that facilitates the implementation of low-emission transportation options such as transit and walking.

This paper addresses four potential points of regulation, based on the implications of previous papers in this series.[12] Section 3 looks at the upstream end of the chain of fuel supply, focusing on petroleum refiners. Section 4 considers options that regulate at the point of vehicle sale. Section 5 examines ways to take advantage of the benefits of both of these two options at the same time by establishing a hybrid system. Section 6 explores another option in which an upstream trading system is combined with carbon efficiency

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[10] Cramton, P. and S. Kerr. CCAP. 1998a. *Tradable Carbon Allowance Auctions: How And Why To Auction*. March 1998.

[11] Note that we do not mean to imply here that trading may take place only during the true-up period; entities would be able to trade at any time during the compliance period.

[12] Hargrave, T. CCAP. 1998b. *U.S. Carbon Emissions Trading: Description of an Upstream Approach*. March 1998; Festa, D. CCAP. 1998c. *U.S. Carbon Emissions Trading: Some Options that Include Downstream Sources*. April 1998.

(CAFE-like) regulations. Following the model established in the other Airlie Carbon Trading Papers, we detail how each approach could be implemented and then evaluate the approaches. Our primary interest here is to develop trading approaches that would allow transportation sources to trade with other sectors.

3 Upstream Systems

In an upstream emissions cap-and-trade system, fuel producers, processors, or carriers of fuel would be required to hold allowances for the potential GHG emissions of their fuels. An upstream approach covers emissions from all sectors of the economy that use fossil fuels, including those from the transportation sector.[13] Based on prior CCAP analysis, the following points of regulation are recommended for transportation-related fuels: petroleum refiners; oil importers; and natural gas processing plants and pipelines.[14] These points of regulation would allow for full coverage of all transportation-related fossil fuels, while regulating the smallest possible number of facilities. Roughly 1,250 facilities would be included: 175 refiners, 200 importers, and 875 gas processors and pipeline companies.[15] This is in contrast to hundreds of thousands of oil and gas wells, and tens of thousands of business entities, engaged in either the extraction or distribution of transportation-related fuels.[16]

By requiring allowances to be held for the carbon content of transportation fuels, the price of fuel would go up in proportion to the carbon content.[17] Thus, natural gas or renewable fuel sources would become proportionally less expensive than petroleum fuels such as gasoline and diesel. The immediate increase in vehicle operating costs would provide a direct incentive for operators to switch to lower carbon fuels, reduce vehicle use and maintain vehicles in good condition, thereby reducing emissions. In addition, the increase in lifetime operating costs would provide an indirect incentive to alter vehicle-purchasing decisions in favor of more carbon efficient vehicles.

An upstream system provides a relatively simple and highly accurate method for estimating the number of emissions allowances that must be held at the point of regulation. In general, these methods are compatible with and as accurate as national inventory methods. Thus, emissions can be calculated by combining data on the volume of crude oil (or refined oil products) and natural gas with emissions factors representing their carbon content.[18]

[13] In this case, emissions from all transportation subsectors are covered, not just on-road vehicles.
[14] CCAP 1998b. Note that emissions from many other sectors are included here too. The entire upstream system would also regulate coal preparation plants and mines; only trivial amounts of coal are used in the transportation sector.
[15] CCAP 1998b.
[16] In addition, regulating downstream from refineries would not capture the energy used in the processing of fuels. Although not conventionally considered in transportation sector emissions, these emissions are significant (CCAP, 1998b).
[17] Note that there is little that refiners can do to reduce the carbon content of a given product. Their only option is to pass on as much of the cost of allowances as they can to consumers.
[18] CCAP (1998b) finds that it would be easier to regulate refinery inputs of crude than the more numerous refinery outputs.

Data on the volume of crude oil used by refiners and natural gas leaving gas processing plants would be relatively easy to monitor. In fact, these entities already track the volumes of these substances, as they are their primary products. For the trading system, the incremental cost would be that of reporting data (for the regulated facilities) and verifying the validity of reported data (for the government).

The carbon content of fossil fuels is also easily measurable. Processed natural gas is a very homogeneous product, so a single factor could be used with a high degree of accuracy to estimate the carbon contained in all natural gas. Crude oil is a more complicated and heterogeneous product, and actual carbon content may vary by a few percent. This is a fairly small variability, however, so a single factor could still be used. For more certainty, although at higher cost, factors could be developed for different grades of crude or measured for individual deliveries of crude. It also would be straightforward to impute refinery emissions by combined refined product sales data with emissions factors for those products.[19]

Conclusions on an Upstream Trading System

An upstream system would provide complete coverage of the transportation sector and therefore is an effective, efficient approach. In addition, it would minimize the number of regulated entities while ensuring simple and accurate emissions measurement. Further, the system is compatible with the application of an upstream system to other emissions sectors. There are some drawbacks to an upstream system. In particular, there is an unresolved question regarding the relative effectiveness of price signals on the level of technical innovation that is stimulated and therefore the total national cost of compliance. Some analysts argue that fuel price signals may result in higher mitigation costs than would measures targeting vehicle efficiency (Sections 4 - 6).[20] Others comment that fuel price signals are less effective without viable alternatives to driving alone such as walking, transit, and car pooling (Section 8).

In addition, a number of difficult accounting issues must be worked out. These include:

- Accounting for non-fuel use of fossil fuels. Some products produced by refineries are not combusted and do not necessarily result in carbon dioxide emissions. Examples include asphalt, which locks up carbon for very long periods of time, and natural gas liquids such as ethane and propane that are used as petrochemical feedstocks. Refiners should not be required to turn in allowances for products that do not result in emissions; the refiners themselves, however, often are unable to know whether the carbon embodied in the products will be returned to the atmosphere. Therefore making the appropriate accounting adjustments is difficult.
- The double counting of both natural gas liquids and intermediate refinery products. These products are traded among fuel producers, so it is possible that they will be double-counted if the accounting system is not set up carefully.

These issues are discussed in further detail in the earlier Airlie paper on upstream trading.

[19] Again see CCAP 1998b.
[20] This point was made regularly by some participants at GHG Emissions Trading Braintrust meetings.

4 Downstream Systems

Downstream emissions trading systems focus on or close to the point of emissions. For the transportation sector, a *pure* downstream system would hold owners and operators of vehicles directly responsible for their emissions. Proponents of downstream systems argue that making vehicle operators directly responsible for emissions from their automobile use would provide a more effective incentive for emissions-reducing activities than would an increase in fuel price, which would be comparatively indirect.

Regulating the emissions from individual vehicles would be technically and administratively difficult to achieve. First, the technical ability to measure or estimate each and every vehicle's emissions directly, accurately and at reasonable cost does not yet exist. Second, that there are millions of vehicles on the road and elsewhere in the sector appears to pose a huge administrative and data handling burden. Moreover, the transaction costs of individual vehicle owners participating in the allowance distribution process and the trading market would be immense. In addition, it is not difficult to imagine this type of program being seen as regulating the amount people can drive (individual emission budgets) and penalizing (through the need to purchase allowances) those who drive more. A pure downstream program likely would face major political opposition.

Retail fuel outlets (e.g., at the gas pump) represent another point of regulation for the transportation sector in a carbon emissions cap-and-trade program. This approach, which moves one step upstream from vehicle operators, in practice would be very similar to an upstream system: The incentive to reduce emissions would be provided by a price signal. Requiring retail fuel outlets to hold allowances to cover the emissions from the fuel sold would involve a much greater number of entities than the upstream approach. It is estimated that there are currently about 181,000 gasoline stations in the US.[21] While regulating this number of entities would be feasible, it is not clear why doing so would be preferred to regulating at the refinery.

4.1 Vehicle Manufacturers as a Point of Regulation

An alternative downstream approach would make vehicle manufacturers the point of regulation.[22] In a downstream system focusing on vehicle manufacturers, manufacturers would be required to hold allowances based on the "imputed emissions" of their vehicles. Imputed emissions are the estimated emissions generated by the vehicles sold by each manufacturer, which would be derived from measured data or estimates of vehicle use and characteristics. Imputed emissions are a substitute for direct emissions measurement.

[21] "1999 Industry Report", *Journal of Petroleum Marketing*, Volume 12, no. 7, mid-June 1999.

[22] From this point forward, "downstream" refers to a system in which vehicle manufacturers are responsible for turning in emissions allowances – not a pure downstream system in which individual vehicle owners would bear this responsibility.

Vehicle manufacturers are an interesting choice for the point of regulation because they do not really lie on the chain of fuel supply mentioned above. Nevertheless, there are two main reasons why they are a good point of regulation. First, manufacturers are a critical player in the transportation sector because they determine what types of vehicles are manufactured. They can therefore affect both vehicle efficiency and the ability of vehicles to use low carbon fuels – two of the three key variables affecting vehicle carbon emissions (Equation 1). The number of vehicle miles traveled is the only factor they do not influence (Table 2). Even though vehicle makers base production decisions on consumer demand, it is nevertheless true that they control research and development budgets and ultimately decide on the vehicle options that are introduced into the market. Making vehicle manufacturers responsible for emissions addresses this issue.[23]

In the short-term, vehicle manufacturers are somewhat removed from fuel price signals since they do not pay the actual fuel costs for the vehicles they produce. Delegating responsibility for vehicle emissions to manufacturers may encourage greater vehicle efficiency improvements than would result from a fuel price increase because manufacturers would experience a direct signal. If long-term emissions caps were specified at the outset of a GHG trading system, then there should be little difference in vehicle efficiency improvements between upstream and downstream approaches.[24]

The second advantage of requiring allowances of vehicle manufacturers is that there are relatively few vehicle manufacturers. There are roughly 50 major manufacturers of on-road vehicles.[25] This would reduce the administrative burden on the trading system and reduce transaction costs for those seeking to make trades. Moreover, these entities are familiar with regulations controlling their vehicles' aggregate characteristics.

The cost of allowances would presumably be passed to consumers at the point of sale. Vehicle manufacturers could choose to attach most of the costs to their inefficient vehicles (such as SUVs) to encourage sales of more efficient vehicles. The incentive would be "front-loaded" for consumers, which is quite different from and may be more effective than the ongoing cost of the fuel price incentive provided by upstream approaches. If costs of more efficient vehicles were significantly increased, however, this would tend to discourage new car purchases and slow the turnover to a more efficient fleet.

Calculating "Imputed" Emissions

A critical question for this approach is whether imputed emissions of vehicles can be estimated accurately with data that are or could be available. If not, then the environmental effectiveness of the trading program could be undermined. The basic formula for calculating imputed emissions is presented below (Equation 2).

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[23] Table 2 also illustrates why it makes sense to implement policies for transportation planning and land use in addition to an emissions trading system. A trading system will not directly impact planning activities, and a system targeting manufacturers will not adequately address travel behavior.

[24] This discussion raises the concern that it may be economically inefficient to target specific technology improvements. It also points to the broader issue of whether it matters where in the economy emissions reductions occur, which we treat in Section 9.

[25] CCAP, 1998c.

Equation 2. Imputed Vehicle Carbon Emissions

$$\text{Imputed Vehicle Carbon Emissions} = \textit{Number of Vehicles Sold} \times \textit{Distance Traveled} \div \textit{Vehicle Efficiency} \times \textit{Fuel Carbon Content}$$

In this equation, the *number of vehicles* refers to vehicles of a given type, for which the other parameters of the equation can be obtained with sufficient accuracy. For example, these could be the number of cars of a certain model year. Thus, for example, total imputed emissions for a given manufacturer would be estimated by summing the imputed emissions for each year a given model was sold. *Distance traveled* is an estimate of the typical (annual) miles traveled for each category of vehicle. For example, light-duty trucks tend to be driven more than passenger cars, so distance traveled would be different for these two categories. The typical unit for distance traveled is vehicle miles traveled (VMT). *Vehicle efficiency* is a measure of fuel use per distance traveled, and is typically measured in miles per gallon. The *carbon content of fuel* would then be measured as the amount of carbon in one gallon (or Btu) of fuel. Because the emissions equation includes parameters for both fuel efficiency and carbon content, technologies that increase efficiency or use low- and zero-carbon fuels will be rewarded directly by reducing the allowance burden of those manufacturers that introduce such technologies.

Imputed emissions estimates will be less accurate than estimates based on direct measurement of fuel volumes, the approach discussed for the upstream system. This is because inaccuracies will be introduced by making general assumptions about the use patterns and efficiency characteristics of broad categories of vehicle types.

Ascertaining Sectoral Emissions

One way to eliminate this relative inaccuracy would be to estimate total emissions for the transport sector based on total sectoral fuel use, and then use the imputed emissions calculated for vehicle manufacturers to allocate responsibility for total sectoral emissions among the manufacturers. Because the number of allowances required of the transport sector would be based on more accurate total sectoral fuel use data, overall environmental goals are more likely to be met.

There are two potential drawbacks of this approach. First, it requires two sets of emissions estimates—total sectoral emissions as calculated from refinery fuel sales data and imputed emissions for each of the manufacturers. However, national level emissions estimates involving the collection of refinery level data will most likely be conducted in any case. Second, it introduces the problem of needing to distinguish light-duty vehicle fuels from other fuels at the refinery. This is because the vehicle manufacturers should be made responsible for only those refinery products used in light-duty vehicles. Making this distinction would be very difficult because gasoline and diesel can of course be in used in many types of equipment other than light-duty vehicles.

4.2 Two Approaches to Including Vehicle Manufacturers in Trading

There are two basic approaches to including vehicle manufacturers in the trading system. Under the first, which we have named the "on-road fleet" approach, vehicle manufacturers would be required to hold allowances to cover the current period emissions of all vehicles on the road.[26] The cost of these allowances most likely would be passed through to new vehicle buyers, although they also might be passed to employees and or shareholders. Under the second approach, which we have termed the "new vehicles" approach, vehicle manufacturers would have to hold allowances for the projected lifetime emissions of all new vehicles sold in the current period. These approaches differ in a number of important ways, including:

- the treatment of vehicles on the road at the time of program inception;
- the impact on new vehicle prices;
- the accuracy of emissions estimates, and whether vehicle manufacturers or others bear the cost if the lifetime emissions of a vehicle differ from initial projections; and
- the compatibility of the accounting methodology with that of the larger trading system.

Treatment of Existing Vehicles

The new vehicles method effectively grandfathers-in existing vehicles while the on-road fleet approach makes manufacturers responsible for emissions of vehicles sold prior to the start of the program. This difference in treatment raises a difficult equity issue of who should bear responsibility for emissions from existing vehicles.

An important argument against the on-road fleet approach, which would make the vehicle manufacturers liable for emissions from existing vehicles, is that it would penalize the manufacturers for equipment-purchasing decisions made by consumers before the start of the program. One could argue that the transportation sector is no different than other sectors in this regard, and in fact may be less burdened than sectors with longer lasting capital equipment. Roughly 50 percent of the vehicle fleet turns over every 5 years,[27] so the allowances required for existing cars will decrease very rapidly.[28] Power generators, on the other hand, if they were regulated, would be responsible for emissions from existing equipment for decades.

While the argument in favor of making vehicle manufacturers responsible for emissions from existing vehicles has some merit, it ignores a crucial difference between vehicle manufacturers and other sectors, which is that vehicle manufacturers do not control the use of the emissions-producing equipment. A power generator, in contrast, can make operating decisions that affect emissions (e.g., efficiency improvements, fuel switching).

The problem with the new vehicles approach, on the other hand, is that if the US is to meet its overall emissions target then someone must bear the costs of reducing emissions from existing vehicles. If the vehicle manufacturers do not, then the burden will be

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[26] This approach also is discussed in CCAP 1998c.
[27] *Alternative Design for a Domestic System to Control Greenhouse Gas Emissions*, John Holmes, Heinz Center, 1998. Draft Paper.
[28] Note that it is the oldest and most-polluting cars that will tend to be retired first from the population of existing cars.

placed on other sectors. While this burden will decline to zero over time as existing cars are retired, the burden passed to other sectors would be considerable in the initial years of a GHG control program.

Impact on New Vehicle Prices

Another difference between the two approaches, closely related to the first one, is the impact on new vehicle prices – and the incentive to retire old vehicles. Manufacturers are most likely to recover the cost of allowances by increasing the price of new vehicles. Under the new vehicles approach, only the cost of allowances for new vehicles will be passed through. Under the on-road fleet approach, however, the cost of allowances for both new and existing vehicles will be passed on in the form of new vehicle price increases. The price of new vehicles therefore would be artificially increased, creating an incentive to keep older, probably higher-emitting, vehicles on the road. Keeping these vehicles on the road would not cause the country to miss its target (because the existing vehicles would still be covered under the cap) but it would put pressure on allowance prices.

It is important to note that the new vehicles approach also would lead to distortionary pressures: the responsibility for existing vehicle emissions would be passed on to other sectors, introducing distortions there. It is impossible to predict the emissions impacts of these distortions without knowing where the additional burden would be placed.

There are several ways to address the distortion introduced by the on-road fleet approach. One option, discussed further below in the section on hybrid systems, would be to incorporate a fuel price component into the GHG control program. This would impact existing as well as new vehicles. It also should be noted that the problem of price distortion would decrease over time as the vehicle fleet turns over, because the distortion is a "one time" hit associated with vehicles sold before the start of the program.

Accuracy of Emissions Estimates

Because vehicle makers will pass the cost of allowances to consumers, under both trading approaches manufacturers will have to estimate the lifetime emissions associated with new vehicles. Under the new vehicles approach, this projection would be based on estimates of lifetime VMT and the expected carbon content of fuel. Manufacturers would then surrender allowances equal to estimated emissions; as such, they would not be liable for differences between the projected lifetime emissions at the time of sale and actual lifetime emissions. This removes the risk of their needing additional allowances if emissions are higher than projected as a result of increased vehicle use or maintenance decisions beyond their control. Compliance with national emissions targets requires reconciling the difference between required allowances and actual emissions, however, so the costs of "extra" reductions will have to be transferred to other sectors.

In the on-road fleet approach, in contrast, the manufacturer would make a projection of future emissions not for regulatory purposes but instead to estimate the future GHG allowance costs that they should build into new vehicle prices. If actual future emissions were greater than the company's initial estimate, then the manufacturer itself would have to purchase additional allowances. The likelihood that the manufacturers will precisely forecast future emissions is remote, especially because vehicle usage is difficult to predict.

Two factors may reduce the level of this risk. First, the potential estimation error is as likely to favor vehicle manufacturers as it is to hurt them, especially because experience to date with cap-and-trade programs suggests that companies plan compliance conservatively. In addition, any losses from the cost of allowances may still be passed on to new vehicle purchasers.

Compatibility of Emissions Accounting with Broader Trading System Accounting

The on-road fleet approach makes manufacturers responsible for emissions in the current year only; therefore it fits neatly into national emissions inventorying and into the broader cap-and-trade program. On the other hand, the new vehicles approach assigns responsibility for the lifetime emissions of vehicles sold, and thus introduces a discrepancy between vehicle manufacturer emissions accounting and broader system accounting. Some of the allowances that vehicle makers would be responsible for surrendering would relate to emissions in the current period while others would relate to future periods. This discrepancy could impact the ability of the nation to meet its target: if manufacturers were to sell allowances related to emissions reductions in future periods, then buyers would be able to increase emissions in the current period even though emission reductions did not take place until a later period. National emissions thus would rise in the current period.

This problem of trading allowances across periods could be addressed by vintaging allowances for the transportation sector. Under this procedure, each allowance distributed to vehicle manufacturers would be designated as "belonging to" a particular compliance period and would not be tradeable prior to the beginning of that compliance period. The use of vintaging would make the new vehicles approach more like the on-road fleet approach, the (major) difference being that manufacturers would not be responsible for emissions from vehicles sold prior to the start of the program.

Conclusions on Vehicle Manufacturers as the Point of Regulation

While both the on-road fleet approach and the new vehicles approach appear to offer a feasible approach to integrating vehicle manufacturers into the trading system, both are saddled with significant problems. The on-road fleet method holds vehicle makers accountable for past decisions and actions they cannot control and could have a distortionary impact on new vehicle prices. The new vehicles approach fails to capture emissions from vehicles sold prior to program inception and therefore places a burden on other sectors of the economy. Further, because the new vehicles approach relies on spot projections of lifetime vehicle emissions, it introduces the likelihood of discrepancies between imputed and actual emissions, and the potential for failure in meeting national emissions reduction goals.

5 Hybrid: Integrating Upstream and Downstream Systems

The upstream and downstream systems described above provide different incentives to reduce emissions to manufacturers and vehicle end users. There is considerable debate among analysts regarding the effectiveness of the different incentive structures. Theoretically, the two systems could be combined in a hybrid system that would establish two points of regulation in the transportation sector: upstream, at the refinery level; and downstream, at the vehicle manufacturer level. In this hybrid approach, refiners would be required to hold allowances for transportation fuel sales and vehicle manufacturers would be held responsible for the "imputed emissions" of the vehicles they sell.

The hybrid system would provide a different incentive structure than the upstream or downstream approaches. A hybrid upstream/downstream system would provide incentives for reduced transportation fuel consumption through a fuel price increase, and incentives to vehicle manufacturers to increase the carbon efficiency of the vehicles they sell. These complementary signals would be reinforced by increased consumer demand for high efficiency vehicles in response to the higher fuel prices.

A hybrid program may have several advantages over a pure upstream or downstream system. First, spreading allowance costs between fuel refiners and vehicle manufacturers would moderate fuel price increases and thus may reduce the political problem of high fuel costs likely under a pure upstream system. Second, a more comprehensive set of emission reduction activities may occur, because direct incentives are established for more than one type of entity. Third, any "rebound" effect (the extent to which greater fuel efficiency leads to increased VMT) resulting from vehicle efficiency improvements may be tempered by the increase in fuel price.

5.1 Implementing a hybrid program

Developing a hybrid program would involve three basic steps: determining total sector emissions, dividing responsibility for sectoral emissions between the fuel producers and vehicle manufacturers, and distributing allowances to the regulated entities. From this point on, a hybrid would follow the steps outlined earlier for any trading system – the emissions from each source would need to be estimated and reconciled with the allowances each source held at the end of the period.

(1) **Total allowances required by the transportation sector would be determined based on sector fuel consumption (fuel consumed × emissions per unit of fuel).** This approach is more accurate than a calculation of imputed emissions based on vehicle use and thus would ensure that emissions and required allowances for this sector have been accurately determined. In addition, this approach would be compatible with the fuels-based measurement used in other sectors and thus would facilitate equitable treatment across economic sectors.

(2) **Responsibility for holding allowances is assigned to the upstream and downstream components of the hybrid system.**[29] Responsibility could be split 50:50, with the fuel refiners and vehicle manufacturers each required to hold allowances for half of total sectoral emissions. However, other distribution ratios are also possible.

(3) **Responsibility for holding allowances would be assigned to entities within each of the two sectors.** For the refiners, responsibility for the subsector's emissions could be based on each refiner's own outputs. These data will have been gathered to estimate total sector emissions, so there would be no additional measurement or reporting burden, and entity-level estimates would be fully compatible with the sector-level estimate. As an example, a refiner produced five percent of all tagged outputs, would be responsible for five percent of the refining subsector emissions, or 2.5 percent of total transportation related emissions (assuming a 50:50 split between refiners and manufacturers).

Manufacturers' allowance responsibilities would be determined based on the calculation of imputed emissions. Imputed emissions would be calculated for each manufacturer and for the subsector. The ratio of each manufacturer's imputed emissions to imputed sectoral emissions would be applied to the actual total sectoral emissions.

5.2 Challenges to a Hybrid System

Diluted Price Signal

The most difficult question posed by a hybrid system is whether the reinforcing effects of simultaneous upstream and downstream signals make up for the fact that both signals will be diluted. After a review of the literature we conclude that there is no clear analytical answer to this question.

Allocating Responsibility for Emissions between Refiners and Vehicle Manufacturers

The 50:50 split of responsibility referred to above is arbitrary, although it does have the appeal of simplicity and apparent fairness. To some extent, this decision would be a political one. However, the split would determine the magnitudes of the different incentives created, and thus have technical implications for the results of the program. The technical circumstances are not static, so the optimal allocation may change over time.

One approach to dividing the responsibility would be to favor the point of regulation that would create the strongest signals for emissions reducing activities. This raises the difficult question of whether an upstream or a downstream signal would encourage greater and more cost-effective technical innovation. While there is a conflicting

[29] For now we address light-duty vehicles only. As such, the total allowances would only include fuels tagged for light-duty vehicle use (e.g., exclude aviation fuels). The system could be expanded to include other transportation subsectors. See Section 7.2 for more on this.

empirical information and significant debate about likely responses by the two sectors to carbon controls, no technical consensus exists.

Another approach would base the allocation of responsibility on the influence fuel producers and vehicle manufacturers have had on emissions since the start of the emissions control program.[30] As noted, current emissions are a function of the efficiency of the vehicle fleet, the carbon content of fuels and the miles traveled. Faced with carbon regulation, fuel producers can send price signals that will affect the use of all vehicles on the road, potentially producing immediate emissions reductions. Vehicle manufacturers, on the other hand, faced with emissions responsibility, could change their vehicle designs and price new vehicles to favor more efficient models. Clearly, fuel producers can affect emissions more immediately than can vehicle manufacturers. Applying this consideration leads to a phase-in of responsibility for vehicle manufacturers that would approximate the turnover of the vehicle fleet. This reflects the fact that, over time, more and more of the existing cars will have been sold since the start of the emissions control program.

A phased-in hybrid approach would be advantageous in allowing the burden for existing vehicle emissions to remain within the transportation sector, rather than being transferred to other sectors. This can be achieved by making fuel producers responsible for the majority of emissions in the first budget period and then over time decreasing their share by the same amount as the manufacturers' share is increased. For example, if the manufacturers' share increases from zero to 50 percent over ten years, the fuel producers share would decrease from 100 to 50 percent over the same time frame. This ensures full coverage of transportation-related emissions within the transportation sector.[31]

Tagging Transportation Fuels and Incentives for Fraud

The hybrid system introduces the need to identify those refinery outputs that will be used in light-duty vehicles, so that total sectoral emissions may be estimated. The hybrid system also would introduce an incentive to use light duty vehicle fuels for other purposes, making effective tagging of light duty vehicle fuel important to ensuring compliance. Developing and enforcing such a tagging system would add to the administrative burdens of a hybrid trading system.

To understand how the incentive for fraud occurs, consider the situation in which all sectors are covered by a comprehensive upstream system except for the hybrid system for light duty vehicles. In this situation, all other sectors pass through to consumers the full cost of emissions allowances in the form of fuel price increases. However, because vehicle manufacturers will take some of the responsibility for light duty vehicle emissions, the increase in light duty vehicle fuel price necessary to cover refiners' allowances will be lower than for other fuels. To the extent that some fuels can be used

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[30] In this approach, vehicle manufacturers would be responsible for the emissions of vehicles sold since the start of the trading program.

[31] Phasing down fuel suppliers allowance responsibility could lead to a relative decline in fuel price from the first budget period to the second, potentially causing an increase in transportation fuel demand. Alternatively, it could provide windfall profits to fuel suppliers.

for both light duty vehicle and non-light duty vehicle applications, there is the potential for fraudulent use of the relatively cheaper light duty vehicle fuels for other purposes. An effective tagging system for dual-application refinery outputs is therefore critical for the effectiveness of the system.

The incentive for fraud will also occur if other sectors are regulated with a downstream approach. For example, consider the case where electric power generators monitor their emissions directly. Their fuel is not regulated upstream, because the emissions associated with its use are regulated at the stack. In contrast, the hybrid regulation of the transportation sector places some of the cost of emission reductions on the price of transportation fuels. Thus, the price charged by producers for natural gas for use in vehicles will be higher than that for natural gas intended for use in power plants or homes. There will be an incentive for natural gas vehicle operators to fuel their vehicles with "non-transportation" natural gas. Similar incentives will exist in any case where fuels can be used for transportation and non-transportation uses.

The physical tagging of fuels is already used in some cases to identify fuels for tax purposes. For example, diesel fuel and home heating oil are essentially the same but are differentiated for tax purposes by a colored additive. Similar approaches would have to be implemented for all fuels with dual uses. In particular, natural gas appears to be technically challenging because tagging is not yet in place for other purposes and because of its diverse uses. Natural gas, for example, may be sold to end users such as industrial facilities which themselves use the fuel for more than one application.

Cross Fuel Differences

In a hybrid trading system, oil refiners would have to hold fewer allowances per ton of carbon than coal and gas producers, due the dominance of oil in the transportation sector and the fact vehicle manufacturers would bear partial responsibility for the sectors emissions. This complexity could reduce the transparency of the trading system and might introduce market distortions. It could also diminish the incentive for refiners to produce low carbon fuels and pursue internal GHG emissions abatement measures.

Strategic Considerations

In a hybrid trading system, fuel suppliers would benefit from efficiency improvements on the part of vehicle manufacturers. Similarly, vehicle manufacturers would need to surrender fewer allowances as a result of increases in fuel price or decreases in the carbon content of transportation fuels. This situation raises the possibility for symbiotic coordination on fuel and vehicle production, or on the other hand, strategic behavior in which one sub-sector delays action to benefit from the other sub-sectors activities. The extent to which this problem occurred would relate back to the method used for allocating emissions responsibility. If the method were designed to recognize and reward GHG emissions reduction activities, then the possibility of gaming would be reduced.

5.3 Conclusions on a Hybrid Trading System

The hybrid system might be more effective than a pure upstream or downstream system at reducing emissions in the transportation sector because it would provide multiple, reinforcing incentives. The hybrid system is unique in that it both directly targets fuel price and provides incentives for improving vehicle technology. By spreading the burden of holding allowances among more entities, it may also be more fair and moderate the cost borne by any particular entity. A phased approach to allocating responsibility among fuel producers and vehicle manufacturers also provides a mechanism for removing the responsibility of manufacturers for the existing fleet of vehicles, while maintaining full emissions coverage in the transportation sector.

These advantages must be carefully weighed against the challenges to a hybrid system. The impact of diluting incentives by splitting allowance responsibility across sub-sectors is of serious concern, though difficult to quantify. The hybrid approach also introduces additional complexity to the trading system: more entities are included; two different measurement approaches must be implemented at the same time, and integrated; a formula must be developed for allocating emissions responsibility between the two sectors; and tagging of fuels is required. Cross fuel differences could further complicate a hybrid trading system.

The hybrid approach is aimed at combining the benefits of the upstream and downstream systems in a synergistic way. It appears to fail to achieve this goal, however, because some of the disadvantages of upstream and downstream approaches remain and additional complexities are introduced.

6 Upstream Trading plus Carbon Efficiency Standards

Combining an upstream trading system with carbon efficiency standards may further the goal of complementing a fuel price signal with downstream incentives for producing more efficient vehicles and avoid many of the problems inherent in the other techniques described above. The Corporate Average Fuel Economy (CAFE) standards now in place require vehicle manufacturers to reach specific efficiency levels, but are not derived on the basis of cost-benefit analysis. Therefore, vehicle manufacturers might be forced to make efficiency improvements that are more expensive on a per-ton-of-carbon basis than emissions reductions in other sectors of the economy. One way to address this potential inequity and economic inefficiency is to *allow vehicle manufacturers to purchase emissions allowances or pay a cash penalty equal to the market price of carbon if they fall short of meeting their CAFE or similar requirements.*

Under this approach, the upstream trading system would function as described in Section 3. To coordinate CAFE standards with a trading system it would be necessary to calculate annual emissions associated with average fuel economy levels by assuming typical annual VMT. If a vehicle manufacturer failed to reach the standards, it would be able to buy allowances to come into compliance, or, as discussed below, it might also pay a financial penalty. For example, assume that the CAFE standard was set at 40 miles per gallon (mpg), but a vehicle manufacturer was only able to achieve an average 37-mpg on its annual sales of one million cars. If we assume that annual average VMT is 10,000 miles, then the company would need to be about 200,000 tons of CO_2 allowances, as calculated below. Note that a vehicle manufacturer would not be able to sell allowances if it achieved greater average fuel economy than required by CAFE, because they would not receive any allowances as part of an initial allocation.

Expected annual emissions =

(1,000,000 cars) × (10,000 miles) ÷ (40 miles/gal) × (0.01 tons CO_2/gal)* = **2,500,000 tons CO_2**

Actual annual emissions =

(1,000,000 cars) × (10,000 miles) ÷ (37 miles/gal) × (0.01 tons CO_2/gal)* ≈ **2,700,000 tons CO_2**

Therefore need to buy 200,000 tons CO_2 of allowances to comply with CAFE.

* Note: The actual carbon content of gasoline is 0.0098 tons CO_2/gallon.

In implementing this approach, it would be useful to cast the vehicle standards as "Corporate Average Carbon Economy" (CACE) to emphasize GHG emission reduction goals. This would encourage the production of vehicles that use low-carbon fuels as well as efficiency improvements. The ensuing discussion could apply to a Corporate Average Carbon Economy system as well as CAFE.

There are three main options for implementing the CACE component of an "upstream plus efficiency standards" system:

(1) **Purchase Carbon Allowances at Market Price.** As presented in the example above, vehicle manufacturers could buy allowances from the GHG emissions market to cover any shortfall in meeting their CACE requirements. This would occur when it was more expensive to meet CACE standards than to purchase carbon allowances on the open market.

A potential drawback to this approach is that the increased demand for allowances (from vehicle manufacturers) would increase the market price for carbon by pulling allowances out of the trading system, making compliance more expensive for other sectors. The magnitude of this effect would obviously depend on how many allowances vehicle manufacturers actually needed to buy. It is unclear what the impact of increased allowance prices would be on energy demand; perhaps this secondary impact would have an equilibrating effect.

(2) **Pay Penalty at Market Price Without Purchasing Carbon Allowances.** To address the concern about tightening the allowance market, the penalty for failing to meet CACE standards could be set based on the market price of carbon. This would ensure that vehicle manufacturers face the same per-ton-of-carbon costs as entities in other sectors of the economy, without the risk of increasing the burden on other sectors. There is no environmental risk even if all vehicle manufacturers chose to pay the penalty instead of meeting CACE standards, because total GHG emissions still would be capped in the upstream system.

(3) **Tradable CACE.** A third approach would be to allow vehicle manufacturers to trade with each other to meet CACE standards. If a vehicle manufacturer "over-complied" with CACE, it could sell CACE allowances – which would not be tradeable in the cap-and-trade system – to vehicle manufacturers that could not meet the standard. Such an approach could be independent of or combined with options (1) or (2) above. Enhancing tradable CACE with the ability to purchase allowances from the GHG emissions market would provide vehicle manufacturers with maximum flexibility in meeting the standard. Combining tradable CACE with a compliance penalty based on the market price of carbon would preserve flexibility without tightening the emissions market, while at the same time providing vehicle makers with an incentive to surpass the CACE standard. (Fully integrating a tradable CACE system into the emissions trading system is equivalent to the "new vehicle" downstream approach of Section 4.)

Under scenarios (1) and (2), there is no incentive for vehicle manufacturers to exceed CACE standards. In a tradable CACE system, individual vehicle manufacturers might go beyond CACE, but the sector as whole is unlikely to over-comply because there is no mechanism for selling the overage to other sectors. A hybrid upstream/downstream in which carbon allowances were actually allocated to vehicle manufacturers *would* allow for trading with other sectors, but as noted earlier, introduces significant complexities. It would be useful to explore mechanisms for rewarding over-compliance with CACE without resorting to a complicated hybrid approach. One idea would be to simply pay manufacturers the market price of allowances for each ton of carbon by which they surpass the CACE requirement.

7 Cross-Cutting Implementation Issues

This section covers a number of important issues that would need to be addressed by any of the systems described above. For each issue, we define the general concern and then discuss both the impacts on each of the systems and potential mitigation approaches.

7.1 Increasing Use of New Fuel Types

Current emissions from the transportation sector are almost entirely the result of combusting petroleum-derived fuels. As the carbon content of fuel begins to affect the price of fuels, the market share of natural gas and renewable fuels will increase.

In an upstream approach, a system could be established to certify the carbon content of biofuels.[32] Increased use of natural gas should not introduce new requirements because this fuel already would be covered in an upstream system. In a vehicle-maker based system, the introduction of biofuels and vehicles to use them will create more categories of vehicles and fuels that must be differentiated in imputed emissions calculations. Electric vehicles pose no special challenges, as their electricity-related emissions already would be covered whether an upstream or downstream system is in place. In an upstream

[32] This idea is discussed in a companion paper in the Airlie series: Kline, David, Tim Hargrave and Christine Vanderlan. 1998d. *The Treatment of Biomass Fuels in Carbon Emissions Trading Systems.* March 1998.

system the producer of the fuel used to generate electricity would be regulated while in a downstream system the power generator itself would be regulated.

7.2 Expanding the System Beyond Light-Duty Vehicles

This paper focuses on light-duty vehicles (passenger cars, vans, pickups, and SUVs) for reasons of simplicity, but light-duty vehicles account for only 61 percent of transportation greenhouse gas emissions. Expanding coverage to all on-road vehicles (including motorcycles, trucks, and buses) would bring 77 percent of transportation sector GHG emissions into the trading system. A pure upstream system would include transportation emissions from all modes: on-road, non-road, aviation, and marine.

There are several reasons to attempt to expand coverage of a downstream or hybrid program to the entire transportation sector. First, full coverage is a goal of any program because it provides greater certainty that environmental goals will be met, reduces costs by bringing more low-cost mitigation opportunities into the trading system and ensures that all emitters face the same marginal cost. If emitters that are not regulated do not reduce emissions, then additional emission reductions will be required from those emitters that are regulated. Moreover, incomplete coverage introduces the potential for leakage, whereby emission reductions by regulated sources are offset by increased emissions in uncovered subsectors. For example, if only passenger cars were included in the program, motorcycle use may increase relative to passenger cars, thereby offsetting the reductions achieved by the decline in passenger car VMT.

Non-road vehicles (construction equipment, agricultural machines, recreational boats and other sources) account for about four percent of transportation sector GHG emissions. Excluding non-road vehicles would introduce an additional administrative burden, as fuels that have both on-road and off-road applications would need to be tagged based on their intended use. Consider a downstream system that only addresses manufacturers of on-road vehicles. Gasoline for use in cars, for example, would need to be distinguished from gasoline for use in recreational boating and a host of other small-engine applications.

Bringing manufacturers of engines for airplanes, boats, construction equipment, recreational equipment, etc., into a downstream system would add to system complexity. A key challenge would be in generating reasonable assumptions for imputed emissions calculations, such as distance traveled for boats and operating hours for construction equipment.

7.3 Non-dedicated Alternative Fuel Vehicles

Vehicles that can run on either alternative fuels, conventional fuels or both are known as non-dedicated vehicles. These vehicles introduce a unique issue in the calculation of imputed emissions outlined for the downstream trading approaches.[33] To most accurately impute emissions, it would be necessary to know the relative use of possible fuels to determine the fuel carbon content for the imputed emissions calculation. The on-road

[33] Flex-fuel vehicles would not affect emissions calculations in an upstream system.

fleet approach would require a calculation of the relative use of each fuel each year. In the new vehicles approach, lifetime relative fuel use would need to be projected at the point of sale. However, it is unlikely that either emissions or fuel use by non-dedicated vehicles could be directly monitored. Barring data from direct measurement, a ratio of traditional versus alternative fuel use would need to be projected for non-dedicated vehicles.

In estimating the net amount of alternative fuel used by non-dedicated vehicles, the Energy Information Administration divides VMT by "adjusted consumption proportions of alternative versus traditional fuels." These proportions are affected by the availability of alternative fuel and the fuel choices made by vehicle operators.[34]

There are three different types of non-dedicated vehicles, each of which has a different potential for consumption of alternative fuels. Flexible-fuel vehicles can operate wholly on alternative fuels or traditional fuels or on a combination of alternative fuel and traditional fuels. Dual-fuel vehicles combust alternative fuel and conventional fuel simultaneously. Bi-fuel vehicles, however, operate on either an alternative or conventional fuel at any one time. Thus, bi-fuel vehicles could be run solely on alternative fuel, whereas dual-fuel vehicles cannot, which means that the two vehicle types could have significantly different emissions impacts. It may be desirable to develop different ratios for flex-, dual- and bi- fuel vehicles to reflect this.[35]

8 Land Use Planning and Alternative Transportation Modes

As noted in Section 1, land use patterns and infrastructure decisions impact transportation sector emissions over the long-term. If automobile-oriented land use patterns continue, VMT and transportation GHG emissions will continue to rise. Upstream price signals will be less effective without viable alternatives to driving alone (transit, walking, HOV, etc.). Similarly, VMT growth will offset GHG emissions reductions from vehicle efficiency improvements. Upstream and downstream trading systems fail to encourage significant changes in land use patterns and transportation infrastructure. There are four principal key reasons for this market failure.

(1) **Short-Term Focus of Trading System.** Relatively permanent carbon controls are not now under discussion. Current proposals for GHG emissions control programs focus on short time frames and do not adequately produce a signal for long-term measures. Altering land use patterns and transportation infrastructure can take long periods of time, even when there is significant political will behind the decisions. In fact, such changes require long-term planning.

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[34] Energy Information Administration, *Alternatives to Traditional Transportation Fuels*, 1996. EIA also reduces the VMT estimate for alternative fuel vehicles to reflect the fact that they are driven less than conventional vehicles.

[35] In practice, it is unlikely that bi-fuel vehicles would be run solely on alternative fuels in the near-term due to the limited refueling infrastructure. Perhaps initially, bi- and dual- fuel vehicles could be treated the same in the trading program. This would inevitably introduce an error into the calculations for these cars. It also would make it difficult to provide an incentive for drivers to use the lower-carbon fuel.

(2) **Multiple Parities in Land Use Planning.** The diverse parties most able to influence land use patterns and transportation infrastructure (local and regional governments, state DOTs, private land owners, developers, etc.) are not part of proposed upstream or downstream trading systems – and it is probably impractical to try and include them.

(3) **Uncertain Impacts of Land Use Projects.** It is difficult to quantify the impacts of many measures that can reduce VMT, such as: dense mixed use design, good transit service, walkable communities, bike lanes, HOV lanes, parking restrictions, etc. Policies and measures aimed at reducing VMT depend on many economic and political factors, including the plans of private developers, further increasing the uncertainty of their impacts.

(4) **Externalities Associated with Current Transportation Infrastructure.** Current land use patterns and the existing transportation infrastructure facilitate negative environmental, economic, and social impacts that are not captured in the economics of a GHG trading system. The most direct impact is that motor vehicle use causes air pollution and the associated environmental and health impacts. Even with the dramatic improvements in criteria pollutant emissions control technology over the past 30 years, VMT growth is soon expected to reverse this progress. Further, automobile-oriented development increasingly consumes agriculture land and open space, with the resultant loss and fragmentation of habitat. As more and more land is paved for roads and parking lots, runoff of oil, gasoline and other chemicals increases, polluting aquifers and aquatic ecosystems.

There are also detrimental economic impacts of automobile-oriented land use patterns. First, taxpayers increasingly are called upon to fund new infrastructure in new and growing suburbs while infrastructure in the urban core and first-ring suburbs is increasingly abandoned. Second, time spent commuting could be put to more productive uses or spent in leisure activities. Third, employers in sprawling regions with long commute times may find it harder to attract quality employees. Social impacts of current land use patterns include the stress of long commutes and community fragmentation.

Communities around the country are pursuing long-term "smart growth" efforts to try to rein in suburban sprawl and its associated environmental, economic and social impacts. An emissions trading system, however, provides only limited incentives to undertake such measures, based on the factors discussed above. To the extent that these smart growth measures otherwise would represent part of a national least-cost GHG mitigation compliance strategy, the failure to implement them will result in higher societal costs for meeting GHG targets. Therefore infrastructure- and land use-related measures may be needed to supplement the trading system. We now examine two such measures.

8.1 Allowance Set-Aside for Land Use Planning and Alternative Modes

One approach to incorporating land use and transportation planning policies and measures into a GHG trading system would be to set aside a limited pool of allowances to be awarded to select transportation-related projects that reduce GHG emissions. Entities responsible for those projects that produce emissions reductions that can be quantified with some certainty could receive emissions allowances based on their impacts. Given the uncertainty of quantifying impacts for the class of measures under discussion, it may be necessary to develop methodologies to discount the number of allowances awarded. It will also be important to reconcile long-term impacts with short-term GHG control program compliance periods.

Large-scale projects probably lend themselves better to such quantification. For example, consider an "in-fill" project in which a large, centrally located brownfield is redeveloped. The project would put many thousands of new employees and residents in close proximity to a transit hub and basic retail services, and is likely to have noticeable short-term VMT impacts that could be estimated via transportation demand models. The U.S. EPA is now developing quantification tools for such projects and looking at generating SIP credits for air quality improvements. The impacts of smaller-scale projects, such as improved sidewalks or bike-racks on buses, would be more difficult to quantify.

Once project GHG emissions impacts are determined, it would be necessary to come to agreement as to which party or parties would actually receive the allowances. For example, the in-fill project from above could involve the transit agency, local government, the metropolitan planning organization, the state environment and transportation departments, the U.S. EPA, commercial real-estate developers, private land owners, local NGOs, etc. Needless to say, this could result in some fairly complex negotiations. Perhaps loose coalitions could agree to put any revenues from allowance sales back into the project and focus their negotiations on which project elements to support with the revenues from allowance sales.

Because the GHG emissions impacts of land use and transportation projects often are difficult to quantify and most projects will have multiple participants, an allowance set-aside could add layers of complexity to a GHG emissions trading system (e.g., the development of quantification methodologies). In addition, setting the precedent for one set-aside could pave the way for many other set-asides to address other market failures. This could quickly hinder the efficiency and transparency of a trading system.

8.2 Recycle Auction Revenues for Land Use Planning and Alternative Modes

Revenues on the order of tens or even hundreds of billions of dollars per year would be generated if GHG emission allowances were auctioned (depending on allowance cost assumptions). A significant portion of this amount probably would be directed to tax relief. However, a small portion of these revenues could be dedicated to fund cost-effective policies and measures aimed at reducing long-term VMT, including land use planning and public transportation.[36] Even a small percentage of total auction revenues would make an important contribution to efforts aimed at slowing VMT growth.

[36] Other portions of these revenues would probably be targeted at other policies that address market failures such as the need for long-term R&D on energy efficiency and renewables.

It would be extremely difficult (and probably misleading) to rank-order land use planning and alternative transportation measures on a dollar-per-ton-carbon basis. Instead, it would probably be useful to develop an inter-disciplinary expert body to develop evaluation criteria, review projects and determine which ones to fund. While this approach does not guarantee GHG reductions, we see it as an important complement to a trading system that may help change the trajectory of transportation sector GHG emissions.[37]

9 Does It Matter Where Emissions Reductions Occur?

An important issue that has arisen in several places in this paper is whether or not it is necessary to ensure that GHG emissions reductions are achieved *within* the transportation sector. From a strictly climate change perspective it does not matter, because one ton of CO_2 from a car is equivalent to a ton of CO_2 from a power plant or other source. There are two reasons, however, why we might want to consider specifically reducing GHG emissions from the transportation sector: projected long-term growth in transportation GHG emissions, and the negative externalities associated with transportation sector GHG emissions and in particular VMT growth.

In 1990, the Intergovernmental Panel on Climate Change (IPCC) concluded that an immediate 60 percent reduction in CO_2 emissions would be required to stabilize atmospheric CO_2 concentrations at 1990 levels.[38] While few policy proposals advocate this level of reduction in the short-term, the IPCC study provides a sobering sense of the magnitude of the climate change problem. Emissions reductions of that level will likely require GHG reductions from every sector of the economy. From a purely mathematical standpoint, then, it will be necessary to reduce emissions from all sectors, including transportation, which already accounts for a significant portion of emissions and is growing faster (from an emissions perspective) than other parts of the economy.

An important question for policy makers (though one that is beyond the scope of this paper) is whether it is necessary to implement vehicle-, land use- and infrastructure-related policies now to minimize long-run GHG abatement costs. On the one hand if we do not start to lay the groundwork for reducing VMT now, it may be even more difficult and expensive to reduce transportation sector GHG emissions in the future. On the other hand we may not have enough information to reach such a conclusion due to uncertainty in long-term abatement costs. Clearly, further analysis of long-term cost minimization across all sectors is called for.

A second argument in favor of implementing policies that ensure transportation-related GHG emissions (as noted in Section 8) is that transportation-related GHG abatement measures, especially those related to VMT reduction, provide a wide range of ancillary benefits. Cap-and-trade systems do not guarantee that these measures would be adopted,

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[37] It might be most constructive to use these revenues to fund innovative pilot projects with potential for nationwide replication.

[38] *Climate Change, The IPCC Scientific Assessment.* J.T. Houghton, G.J. Jenkins, J.J. Ephraums, editors. Cambridge University Press, Cambridge UK, 1990.

however, as they direct capital to the least-cost reductions available in the economy, in whichever sectors they may be. If the trading system directs capital to other sectors and not to transportation, then the multiple benefits associated with transportation-related efforts would not occur. The ancillary benefits of transportation-related GHG emissions reduction activities, and in particular the broad-ranging benefits of reducing VMT provide a strong argument in favor of developing transportation-specific policies.

It is important to note, however, that there are also multiple environmental and economic benefits associated with GHG emissions abatement measures in other sectors of the economy. For example fuel switching from coal to gas reduces SO_2, NO_x, and mercury emissions along with CO_2. Green technologies such as high efficiency fuel cells or wind turbines could represent economic growth opportunities in certain regions of the country.

The consideration of "multiple benefits" is an acknowledgement of the fact that our society has concerns other than reducing GHG emissions. Therefore it is necessary to consider how GHG emissions reductions in all sectors contribute to or hinder other societal goals. While as a practical matter it is impossible to optimize all social goals simultaneously, it is important to examine how a GHG trading system contributes to the achievement of other goals. It is important to avoid conflicting signals and to pursue complementary policies. A multiple benefits analysis across all sectors of the economy would be serve to flesh out these issues. While it is not possible to quantify all impacts (e.g., "quality of life"), such an analysis would be very informative.

10 Conclusions

We conclude that an upstream system would ensure complete regulatory coverage of transportation sector emissions in an efficient and feasible manner, and as such represents a key component of a national least-cost GHG emissions abatement strategy. The broad coverage provided by an upstream system recommends this approach over vehicle-maker based approaches, which would not cover emissions from heavy-duty vehicles and the aviation, marine and off-road sub-sectors. The "on-road fleet" approach unfairly and inefficiently burdens vehicle manufacturers with responsibility for emissions that they cannot control. A "new vehicles" approach would exclude emissions from vehicles on the road prior to program inception. The hybrid approach faces significant technical and political complications, and it is not clear that the approach would actually change behavior among vehicle makers and users, which is its main purpose.

We also note that a trading system would fail to encourage many land use and infrastructure measures that affect VMT growth and GHG emissions. We recommend that this market failure be addressed by complementing the trading system with a program specifically targeting land use- and infrastructure-related activities.

A key issue that must be addressed in designing a national GHG control strategy is whether or not it is necessary to guarantee GHG reductions from the transport sector. Neither an upstream system nor a downstream approach would do so, since both would direct capital to the least-cost abatement opportunities wherever they were found. We review two reasons why it may be desirable to force transportation sector reductions:

first, that the long-term response to climate change will require reductions in all sectors; and second, the many ancillary benefits associated with transportation-related, and especially VMT-related, emissions reduction activities.

If policy makers find it desirable to establish transportation-specific policies, we recommend (in addition to the land use policies mentioned above), that they combine an upstream trading system with a carbon efficiency standard similar to the current CAFE standard. Under this approach a fuel price signal would be complemented by incentives for manufacturers to produce more carbon efficient vehicles. To prevent vehicle manufacturers from being forced to pay more than other sectors for reducing GHG emissions, we recommend that the vehicle makers be allowed to pay a cash penalty equal to the market price of allowances in lieu of meeting carbon efficiency requirements.