Should California Include Motor Vehicle Fuel Emissions in a Greenhouse Gas Cap-and-Trade Program?

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Abstract

California should include vehicle fuels as part of a greenhouse gas reduction cap-and-trade program. Numerous political, administrative and economic reasons that suggest otherwise are considered. They include compliance and enforcement concerns, other regulatory programs for transportation, belief that gains from inclusion would be small, jurisdictional linkage issues, and both political skepticism and agency inexperience with market-based regulation. However, consideration of most of these strongly favors inclusion. Inclusion also creates an important competition between the electricity sector and other vehicle fuels to shrink emissions over time as they vie to see which can most successfully replace ordinary gasoline and diesel.

Key words: climate change, cap-and-trade program, environmental regulation, emissions trading, transportation, electricity, greenhouse gases, carbon emissions markets

I. Introduction: AB32 and Climate Change

California passed landmark legislation in Sept. 2006, entitled the Global Warming Solutions Act of 2006 and known popularly by its legislative identification as AB32. AB32 requires that California reduce its carbon (and other greenhouse gas) emissions by 2020 to the 1990 level. Governor Schwarzenegger also issued Executive Order S-3-05 in June 2005 that mandates further reductions by 2050 to only 20 percent of the 1990 level. The California Air Resources Board (CARB) is responsible for developing and implementing the regulations to achieve the AB32 reductions.

It is (1) to develop by January 1, 2009 a "scoping plan" that lays out the mix of measures that it intends to adopt to achieve the 2020 target, and (2) to adopt by January 1, 2011 regulations to implement the measures identified in the plan. The legislation directs CARB to consider "…direct emission reduction measures, alternative compliance mechanisms, market-based compliance mechanisms, and potential monetary and nonmonetary incentives…" in formulating the regulations. It further directs CARB to choose regulatory methods that achieve "…maximum feasible and cost-effective reductions…." This paper focuses primarily on one aspect of this task: consideration of whether emissions from motor vehicle fuel use should be included in any cap-and-trade program that CARB may put into place.

It is helpful to clarify in the beginning the magnitude of the tasks ahead. AB32 applies to six greenhouse gases (GHGs), although I am going to focus on the method of regulating carbon (meaning carbon dioxide or CO_2 unless stated otherwise) emissions. [1] In 1990, California emitted 344.9 million metric tons (mmts) of CO_2, meaning that is the allowed amount for 2020 (and 69.0 mmts the allowed amount for the 2050 goal).[2] By 2004, California was emitting 403.7 mmts (an increase of 17% over 1990 levels). Between 2004 and 2012 when the main AB32 regulations are scheduled to go into effect, emissions will still be increasing although perhaps the rate of increase will slow somewhat.[3] The California Energy Commission suggests that if "business as usual" were to prevail, California's 2020 emissions would be about 24-28% higher than 1990.[4] So we know the regulatory system between 2012 and 2020 will have to achieve an absolute reduction of more than 17 %, probably close to 25%, and that this is just the beginning of much steeper reductions to be achieved from 2020-2050.

It is also helpful to clarify the sources of CO_2 emissions in California. As of 2004, by far the biggest source is the transportation sector with 188 mmts, or 46.6% of total CO_2 emissions. The next largest sector is electricity (including imports), accounting for another 115.9 mmts, or 28.7%. Thus it seems inconceivable for California to achieve its goals without a regulatory system that from 2012 to 2020 will achieve quite substantial absolute reductions in CO_2 emissions from both of these key sectors, especially transportation. It is with this task in mind that we now turn to consideration of the regulatory methods to be used.

Politically in California the potential use of any market-based regulatory instruments can cause intense political controversy and debate, and this political volatility will undoubtedly affect the nature of the overall program put into place. An issue of contention in the state budget for fiscal 2007-08 illustrates this. The budget contains funding for 123 additional positions in CARB to develop and implement the regulatory program. Given the scale and complexity of the new responsibilities that AB32 gives to CARB, there was little political disagreement about the size of this increase. However, the Governor's budget proposal specified that 25 of these 123 positions be for people designated to develop proposals for the market-based regulations that are expected to be some part of the overall program. It should also be noted that the staff of CARB (as of the summer of 2007) was essentially devoid of economists, as its pre-AB32 responsibilities emphasized engineering and legal knowledge and skills necessary for setting technical standards. Nevertheless, the state legislature, responding to a deep mistrust of markets among a number of important interests, modified the Governor's proposal to reduce the number of new personnel designated to work on market-based instruments from 25 to 2.[5]

II. Why Not Include Vehicle Fuels?

A. The Simple Pro-Inclusion Argument

If you simply asked most economists, they would say that of course motor vehicle fuels should be a part of any carbon cap-and-trade program. Economists think automatically that all CO_2 emissions from economic activity should be priced, no matter what their source. Furthermore any reductions should be achieved at the least possible total cost, which means that the marginal cost of reducing emissions from one source must be equal to the marginal cost at any other source. One way to achieve this is to make all emitters, no matter what the source, face a common price per unit of emissions. When all emitters of CO_2 face the same allowance price for their emissions, each will reduce until its marginal cost equals that allowance price and thus all the marginal costs will be the same. In fact, the economists are likely to divert this question into another one: why not have a carbon tax instead of a cap-and-trade program? Many distinguished economists hold this position, including at least three former members of the President's Council of Economic Advisors.[6]

As meritorious as the tax idea may be, it is not on the current policy-making agenda in California nor, to my knowledge, is it receiving serious consideration in other state or federal legislative proposals.[7] Politically, the cap-and-trade program is the market-based regulatory instrument of choice. This is true as well in most other countries that have enacted climate change programs. The most important example of this is the European Union's cap-and-trade program, which covers largely the power and heating industry and some other large industrial users of fossil fuels (representing about 45% of the total CO_2 emissions of the participating countries). There are a few exceptions, e.g. Sweden has a carbon tax.[8] But in states like California, any new taxes require approval by a two-thirds vote of the legislature, which essentially scotches the idea politically. Therefore, I do not consider further the use of a general carbon tax as a possible instrument for California.[9]

Putting aside the idea that there would be general support from within the economics community for inclusion of motor vehicle fuels, there is actual support from a very important source: the state's Market Advisory Committee (MAC), which issued its final report on June 29th of this year. This Committee was a non-partisan group of experts appointed by The Secretary of the California Environmental Protection Agency to advise the state on the design of market-based regulatory mechanisms to achieve the AB32 emission reduction goals. The Committee was chaired by Winston Hickox, former Secretary of Cal EPA during the Davis administration (when AB1493, the greenhouse gas reduction legislation for motor vehicle manufacturers, was passed) and before that Environmental Advisor to Gov. Jerry Brown. Its Vice-Chair was environmental economist Larry Goulder of Stanford University, and it had 12 other expert members including those from environmental advocacy groups, think tanks, and groups with expertise in different aspects of operating environmental markets. It was by no means a given that this group would recommend a broad cap-and-trade program, but it did. In terms of the scope it said: "The Committee prefers to include the transport sector[10]" and "The program should eventually include all major greenhouse gas-emitting sectors of the economy in the cap-and-trade program.[11]"

Despite MAC's support for the inclusion of the transportation sector, it was tepid about exactly when. MAC considered 4 alternative program scopes: (1) all major stationary sources, primarily electricity generators and large industrial plants that comprise 39% of the state's GHG emissions; (2) Program 1 plus CO_2 emissions from the transportation sector, comprising 72% of CA GHG emissions; (3) Program 2 plus CO_2

emissions from fossil fuel combustion of residential, commercial, and small industrial sources, comprising 83% of the state's GHG emissions; and (4) same coverage as Program 3 but with compliance for fossil fuels upstream at the source of the fuel (e.g. natural gas at either the pipeline entry to CA or its recovery in CA minus exports). It concluded: "…the sense of the Committee is to prefer a cap-and-trade program design in which (1) the program initially covers first sellers of electricity and large industrial emitters, and (2) the transportation and buildings sectors are added in subsequent phases as soon as CARB determines that emissions in those sectors can be monitored, and that the administrative costs of extending coverage to those sectors are not prohibitive.[12]" Thus while MAC clearly supports the inclusion of transportation fuel use, its language does gives CARB some support for delaying serious consideration of this while other pieces of the regulatory plan are first put into place.

To this point, I have suggested that simple efficiency reasoning as well as the broad-based major advisory committee to the state suggest that carbon emissions from motor vehicle fuels (as well as all other sources of carbon emissions) be included within the cap-and-trade program. So what are the objections?

One simplification that I will make throughout the paper perhaps should be the source of an objection, although it is a near-universal simplification made by analysts in this area. The economic principle is to put a price on the harmful activity: the emission of a GHG into the atmosphere, with special focus here on carbon emissions from motor vehicles. The simplification is to measure California in-state motor vehicle carbon emissions by the amount and type of fuel consumed in California.[13] That is, technically there is virtually perfect correlation between California fuel consumption and in-state emissions because there seem to be no feasible ways to reduce the emissions given the fuel consumption. Perhaps someone will invent a carbon-to-harmless-something conversion or carbon-capture-and-sequestration (CCS) system for motor vehicles, but I am going to assume that fuel consumption completely determines emissions.

The validity of this assumption is necessary at a broad level to make a "comprehensive fuels" approach sensible as an alternative. It also allows inclusion of motor vehicle fuels through regulation at an upstream point like refinery production rather than the downstream point where the emission actually occurs. The main known exception to this assumption is with CCS for coal-fired electric plants. If someone invents a way to convert automatically your auto's carbon emissions into diamonds that get deposited into your auto's trunk, that would be another exception. The more that technologies develop that remove the assumed deterministic relationship between fuel use and carbon emissions, the more imperfect would be any regulatory approach like “comprehensive fuels” that relies upon such an assumption. Indeed, the possible problem is somewhat deeper to the extent that the regulatory system influences the course of technology. That is, it is possible for example that a “comprehensive fuels” regulatory system would discourage efforts to find useful conversion and/or sequestration technologies.

Putting aside the concern that perfect motor fuel measurement might not be satisfactory as a method of measuring emissions from motor vehicles, what other objections are there to inclusion of motor vehicle carbon emissions within a cap-and-trade program?

B. The Anti-Inclusion Arguments

A definition of a cap-and-trade market that is largely restricted to the electricity sector is plausible because of bureaucratic routines and interagency cooperation. It is a definition that fits comfortably within the regulated sector that the California Public Utilities Commission (CPUC) routinely handles. The CPUC, working in collaboration with ARB, is taking the lead on developing an AB32 regulatory plan for the electricity and natural gas sectors, and has been holding extensive hearings with full stakeholder participation. However, the outcome of the hearings will be a recommendation to CARB which has final jurisdiction over the matter. In my judgment, it would be quite unusual for the framework that comes out of the CPUC proceeding to be rejected by ARB. However the transportation sector does not have an equivalent quasi-judicial regulatory environment within which all stakeholders can semi-collaboratively participate in the details of generating, analyzing, and discussing alternative regulatory ideas and articulating positions before an administrative law judge on these ideas. So unless CARB itself puts substantial effort into considering sectors like transportation that are outside of electricity for a cap-and-trade program, it is unlikely to happen.

To the above bureaucratic reasoning that could explain the exclusion of motor vehicle fuels, let us consider whether there are public interest reasons that also might favor exclusion. In a world of imperfect information and substantial transaction costs that create barriers to efficient trading, there are many possible public interest reasons not to include emissions from the transportation sector. Here are seven:

1. It cannot reasonably be administered. There is no reliable way to track fuel consumption in order to make sure the appropriate number of allowances is surrendered.

2. It cannot reasonably be enforced. Californians (especially big rigs with large capacity fuel tanks) will fill up their gas tanks in bordering states and Mexico, and fuel will surreptitiously be trucked in and consumed illegally and without environmental compliance.

. 3. Such regulation would be excessive, as California already has two other important regulations to discourage motor vehicle GHG emissions. One is AB1493 that mandates an increasingly cleaner new car fleet beginning in 2009 (although its implementation depends on receiving a federal waiver as well as a favorable outcome from pending legal challenges). The other is the low carbon-fuel standard that has already been adopted by CARB as one of its early actions under AB32.

4. It is duplicative and/or in conflict with federal laws and regulations. It can be argued, for example, that it violates the dormant Commerce Clause because much vehicle usage is interstate economic activity, or it violates exclusive federal jurisdiction over mobile sources legislated in the Clean Air Act.

5. The transaction costs of inclusion are greater than the reduction in emission costs from inclusion because of (a) low fuel price elasticity of demand; and (b) little room for mutually profitable trading across the fuel and stationary sectors.

6. Transportation is different because it involves a host of other externalities (other pollutants, congestion, safety issues) that make separate transportation regulation more efficient than piecemeal participation in multiple regulatory systems.

7. Including motor vehicle fuels creates linkage problems with cap-and-trade programs from other jurisdictions that do not include them.

C. What are the alternatives to inclusion?

In an important sense, any merits to the above anti-inclusion arguments are not necessarily determinative. This is because they do not ask “Compared to what?” Some of the arguments may suggest that doing nothing further is preferred. However, given that motor vehicle emissions are 46.6% of all CO_2 emissions in California, it is unrealistic to expect the reduction goals of AB32 to be achieved without substantial absolute reductions in motor vehicle emissions. Further direct technical and performance regulations will be considered, and more forceful adoption of them is much more likely if motor vehicle fuels are not included in the cap-and-trade program. For example, CARB is already considering a required accelerated deployment of hybrid technology for passenger vehicles. Another possibility, with very attractive economic characteristics although poor political prospects, is to consider an increase in the existing state gasoline and diesel fuel taxes.

The balance of this paper considers in more depth the arguments and alternatives that have been introduced here.

III. Analysis: Administration and Compliance Issues

One of the possible objections to inclusion of motor vehicle fuels is a compliance issue. If an entity could consume motor vehicle fuel without California allowance regulators knowing about it, then the system would not work. If it were easy for some entity to produce its own gasoline without detection, for example, this might be away around the allowance system. Or if it were easy to buy gasoline from an out-of-state source, then this would be another way around the system.

However, all California motor vehicle fuels have long been subject to an $.18 per gallon state fuel tax, as well as county sales taxes and non-carbon CARB emission standards. Thus there are multiple, pre-existing regulatory reasons why the California system already tracks motor vehicle fuel consumption with a very high degree of precision. I would administer allowances to exactly the same entities that are already required to report gallons sold and pay the state gasoline and diesel taxes to the Board of Equalization. The pre-existing structure for tax compliance is not perfect; it is possible for a small number of motor vehicle fuel consumers who live in border areas like Lake Tahoe to purchase gasoline across the border if it is to their advantage. However, this is a pretty small problem in the scheme of things, and as long as neighboring states will agree to prevent an explosion of new fueling stations by these border areas, there is no reason to think that it will become significant.[14]

In fact, it is interesting to compare electricity and motor vehicle fuels in this regard. It is far easier for California electricity consumers to minimize their allowance requirements with no actual emission reductions than it is for California motor vehicle fuel consumers to do the same. All electricity in the state's grid is part of a homogeneous common pool and the source of the particular electrons that any consumer receives cannot be known. We may know that 5% of the power in the grid is Bonneville hydropower, and another 5% from the Four Corners coal-fired plant[15], but physically we cannot determine which consumers receive the hydro-generated power and which receive the coal-generated power. Sometimes there are bilateral contracts that may be used to establish this, but even here the power supplier may have recontracted with another generator to actually provide the power. And when power is bought on the spot market rather than through bilateral contract, this is simply a common pool purchase that cannot be attributed by the buyer to a particular source.

Perhaps most disturbingly, Bushnell (2007) has shown that there is enough clean power in the western states so that merely by contract reshuffling California can meet its emission goals on paper without any change whatsoever in the generators actually making the power (and the emissions). That is, California can arrange to no longer purchase from Four Corners and instead up its purchases from cleaner sources, while consumers in unregulated areas will find themselves with power from Four Corners (such that over both areas total consumption and each plant's generation and emissions remains constant). The only cost of doing this is the contract renegotiations, far less than the cost of actually reducing carbon emissions. Indeed, it would be very surprising if California importers, faced with a higher cost of coal-based import contracts (more allowances needed) compared to cleaner sources, did not do exactly this.

My point is not that cap-and-trade cannot work with electricity; it will require additional regulation initially and hopefully the broader western region cap-and-trade program that is under development will solve for the longer term the contract reshuffling issue (if all areas have similar emission reduction goals, nothing is gained from contract reshuffling).[16] My point is that, with motor vehicle fuels, there is no common pool and no analogue to contract reshuffling. So if what one is interested in is a cap-and-trade system in which you can be assured that real emission reductions are being made and are being reliably measured, the motor vehicle fuels part will be the easier one to do.[17]

In fact, there is one further issue about compliance that should be addressed. One of the reasons, perhaps the main reason, why cap-and-trade programs are considered favorably for the electricity sector is because of the success of previous environmental cap-and-trade programs with the same sector. The U.S. Acid Rain Program is the prime example of this. However, it should not be overlooked that the first very successful pollution trading program in the United States did not involve the electricity sector but the refineries: the lead trading program of 1982-1987, during which motor vehicle fuel makers were required to phase out the lead from their products. Fuel makers that had more lead in their products than called for by the phase-out schedule were allowed to buy credits from fuel makers that had less lead than required by that schedule. This program was characterized by very active trading among the nation's refineries, with more than half of them participating in the market and trading rights representing more than 20% of the total allowed amount of lead.[18]

The administrative requirements for this program were simple. Each quarter the refineries reported the amount of fuel produced and its lead usage, the volume of trades in lead rights and with whom, and (when banking was allowed in 1985-1987) beginning and closing balances of banked rights including any purchases or sales of them. It was easy for EPA to keep track of each refinery's after-trading compliance level, and enforcement was no different than in the earlier years when no trading was allowed but lead was still being gradually reduced.

IV. Analysis: Robustness of the Cap-and-Trade Market

A. The Electricity Sector Primarily. Some arguments for fuel exclusion depend on the assumption that a primarily electric utility cap-and-trade market would be robustly competitive by itself. But this is not obvious for several reasons. One is that a method originally recommended by the California Public Utilities Commission makes the load-serving entities in the state responsible for compliance, of which there are relatively few.

Consideration of this idea arose in an attempt to make all California electricity consumption subject to the cap including that imported from neighboring, unregulated states (as specified by AB32). It avoids direct regulation of out-of-state sellers that would likely violate the Federal Power Act (and perhaps the dormant Commerce Clause) which gives the federal government exclusive jurisdiction over interstate electricity sales. However, the state's two largest investor-owned utilities each provide 30% of all state electricity consumption to end-users, and any electricity-sector allowance market with LSEs as the trading entities will be highly concentrated.[19] While it is true that these entities are regulated and that obviates some of the concerns associated with the possible exercise of market power, it is also true that such concentrated markets are unlikely to spark the kind of vigorous entrepreneurial competition that is necessary to achieve significant emissions reductions at the least cost. The LSEs in it do not even compete with one another, as there is essentially no competition at the retail level in California.[20] It is not clear to what extent these local monopolies might be motivated to produce at least cost. That is, even putting concentration aside, it is not clear how vigorously these entities would seek to minimize environmental compliance costs.[21]

However, two other possibilities are a generator-based approach, or a slightly broader approach to include imports known as the "first-seller" or "first-deliverer" method and originally recommended by the State's Market Advisory Committee.[22] There are many more generating entities in the state than there are LSEs, and many of these generators are independently owned and face stiff competition for their sales—they cannot afford to be several dollars per megawatt-hour above close competitors either for long-run or short-run contracts.[23] Previous reports have considered only the number of generators rather than the concentration of ownership of them.[24] It is the ownership concentration that matters to the competitiveness of the market. Most of the larger fossil-fueled generation facilities in the state are owned by a relatively small number of independent (nonutility) entities.

We examine this in more depth below, and find that problems of possible market concentration are (a) unlikely if all allowances are initially sold at auction by the state, but (b) possible if allowances are freely distributed based on historical emissions (and not required to be immediately sold at auction). The method of allowance distribution determines which entities will be buyers and which will be sellers. Both the demand side and the supply side must be competitive (or behave competitively) for the market to be efficient. Under the auction sale method, all generators will be on the buying side of the market (with the state either as sole supplier or requiring that all freely distributed allowances be put up for sale at the auction, in which case the generators have to buy back the ones that they want to use). However with free historically-based distribution and no required auction, some generators will be buyers while others will be sellers. They will have to sort themselves out in whatever forms of allowance markets arise (e.g. exchange trading, use of third-party brokers). It is possible that only a few owners will dominate one side of this market, even if the other side is competitive.

In order to analyze market robustness, I construct a dataset from several independent sources that allows calculation for the year 2004 of each firm's or public agency's carbon emissions and (under various assumptions to be explained) its share of the overall cap-and-trade market. The data comes from the California Energy Commission (CEC), the U.S. Energy Information Administration (EIA), and the California Board of Equalization. As I mentioned earlier, according to the 2004 California Greenhouse Gas Inventory maintained by the CEC, there were a total of 403.7 mmts of CO_2 (including electricity imports) of which the electric power sector contributed 115.9 (28.7%) and transportation 188.0 (46.6%). According to the inventory, in-state electric generators contributed 55.1 mmts, and 60.8 mmts were from imports. In the dataset from the EIA of California generators that emit at least 10,000 tons of $C0_2e$, there are 245 plants with 54.89 mmts in total (99.6% of the total inventory).[25]

It was not hard to convert the in-state data from the larger number of plants to the smaller number of owners (the 245 plants are owned by 119 firms or public agencies). However, there is no method for reliably identifying the source of all imported electricity and therefore the emitted carbon associated with it; the estimates for 2004 range from a low of 47.0 mmts to a high of 60.8 mmts. I use the higher figure in my calculations; it comes from the CEC which devotes a substantial effort to the methods used for calculating this. California has virtually no coal-fired in-state electricity plants, but it does rely upon several large out-of-state coal plants for some of its electricity. That is why a relatively small amount of imported electricity (26.9%) is associated with a rather large portion (52.5%) of the total CO_2 emissions from this sector.[26]

If all allowances were auctioned, then the market would appear to be unconcentrated. A standard measure of concentration, the Hirschmann-Herfindahl Index (HHI), is only at the 500 level when including in-state sources and known "first-deliverers" of import sources. As a benchmark, the U.S. Justice Department (DOJ) considers a market unconcentrated for any HHI below 1,000, moderately concentrated if between 1000 and 1800, and concentrated if above 1800 (and often will challenge proposed mergers of firms in such an industry). The above calculation does leave out the 33% of carbon from unknown imported sources in the electricity inventory; however, it does not change much if one assumes that most of this goes to the major first-deliverers.[27]

However, a quite different picture is possible if there is no auction and the allowances are initially distributed by some formula, often historical emissions, to those participating in the cap-and-trade program. In this case, for the market to do its work, there must be extensive trading among the firms in order to equalize their marginal costs of abatement. This is unlike using the auction, which approximates equalized marginal costs from the start and in which after-auction trading occurs primarily to take account of unexpected changes in circumstances.[28] Some of the firms will be allowance buyers while others will be allowance sellers. Buyers will be those who receive an initial distribution quantity that is less than their quantity at equilibrium; sellers will be those who receive more than their quantity at equilibrium. There will be two sides to the market, demanders and suppliers, and both must be competitive for the market to function properly.

Two factors determine which sources will be buyers and which will be sellers: the specific formula used for the initial distribution, and the marginal cost curve for abatement of each source. At this point, very little is known about the shape of the marginal cost curve for abating emissions from each source. Without this information, it is not really possible to make accurate prediction of which sources will be buyers and which sellers.

However, suppose we assume for purposes of this exercise that the coal-fired plants, responsible for over half of the carbon emissions from the electricity sector, have the highest marginal cost of reducing emissions. This may be plausible in that much of these emissions are from plants treated as baseload for which substitution is difficult.[29] More energy-efficient coal-burning technologies like supercritical and ultra-supercritical plants seem to require completely new facilities rather than retrofits. Similarly carbon capture and sequestration (CCS) also requires location at a proper geologic site, rather than a modification to any existing plant. Out of several reports reviewed, none suggested these would be viable at carbon prices below $30 per ton of CO_2e.[30] On the other hand, many more of the natural gas burning plants are non-baseload plants for which it is easier to ramp them up or down as demanded. The use of these may be much more substitutable for wind-generation facilities that are only available at given times, or more responsive to energy-efficiency strategies that focus on peak-period demands like air-conditioning use.

If we also assume that allowances will be distributed for free based largely on historical emissions (as they are in the U.S. Acid Rain Program) that include both in-state generators and first-deliverers of imports, then the two assumptions together imply that the first-deliverers of coal-fired sources will be the allowance buyers in this market. That is, for any total allowance amount that is less than the historical emissions baseline, the first-deliverers of coal-fired sources will find that it is cheaper to operate normally and buy additional allowances from the gas-fired sources that can reduce emissions more cheaply. The question becomes: how concentrated is ownership within the group of allowance buyers?

To suggest an answer to this, I make additional assumptions in order to calculate an HHI for the group of first-deliverers from the coal-fired imported sources.[31] This calculation requires an estimate of the number of allowances bought by each buyer in the market. To generate this, I assume a cap equal to 90% of the 2004 baseline data, force all reductions to come from the non-coal fossil-fueled plants, and assume that these reductions are, for net buyers only, proportional to the historical level of their non-coal emissions. The latter assumption is to take account of the fact that some first-deliverers of coal-fired electricity also bear responsibility for emission due to non-coal sources. Since these sources are cut back by more than the initial allocation for them, they essentially generate internal allowance transfers that reduce the need to purchase allowances to cover the coal emissions.

The result of this exercise is to predict that allowances for 3,297,874 tons will change hands, with the number of buyers in the market equal to 16 (out of 125 participants in the allowance system).[32] The HHI on the buying side is 2229, concentrated by DOJ standards. The largest buyer is Southern California Edison, which buys 41 percent of the allowances, and the second largest buyer is the Los Angeles Dept. of Water and Power, which buys 16 percent of the allowances. The top 8 buyers, shown in Table 1, buy 94 percent of all allowances.[33] These top 8 include the state's three major investor-owned regulated utilities and five public entities. Of course the specific results depend on specific assumptions like attributing responsibility for emissions from imports from unknown sources. However, if reducing emissions from coal does turn out to be more expensive to reduce than from alternative sources, it is hard to imagine an outcome in which the southern California retailers that make significant use of coal resources would not turn out to be the major allowance buyers.

While the group in Table 1 is not a group that triggers thoughts of substantial exercise of monopsony power, it is also not a group that triggers thoughts of robust, creative, market dynamism to reduce the burden of buying emission allowances.[34] Perhaps expressed differently, all of these entities are retail providers of electricity that have largely captive audiences. They do not compete with one another. They face some oversight pressure to produce at least cost, but this stops well short of the threat in truly competitive markets that the firm can lose its entire customer base to lower-cost competitors.

Insert Table 1 about here

The above scenario ignores the contract reshuffling problem described earlier. A quite different and very undesirable scenario is that the first-deliverers responsible for the historic coal emissions receive the same allowances as above but do not need them at all—they manage through legal contract reshuffling to import only clean power once the allowance system goes into effect. In this case, in which there are no real emission reductions, these concentrated first-deliverers become the allowance sellers as well, and the allowance buyers are the unconcentrated in-state gas-fired plants that will generate and emit at their usual levels. The competitive allowance price should be near zero, as there will be more allowances than emissions from business-as-usual in-state generation[35]. The concentration of the first-deliverers may allow them to charge above competitive levels for these allowances. However, the more important point is to avoid this second scenario altogether.

The second scenario arises because the baseline used to determine the total number of allowances includes the substantial historical emissions from imported electricity, while those who would be legally responsible for it in the future have found a way out of this responsibility. Is it possible to avoid this problem by not counting the imported emissions in the baseline used to determine aggregate allowances? To the extent that contract reshuffling is not possible or is preventable, then one must include the carbon emissions baseline from the sources that continue to be counted in California emissions (otherwise the cap level would be far too low).[36] One possible solution would be to use an "updating" method for the import baseline on the grounds that it is primarily accounting for contract reshuffling (and not real emissions reductions).[37] That is, each year one should remove from the baseline emissions those from imported sources that have been "contract reshuffled" away. This would be administratively equivalent to removing from the California baseline and the yearly emission count any imported emissions from a neighboring state that has adopted similar emission reduction goals and regulations and thus already counted them (otherwise the emissions would be double-counted). This updating solution should prevent the second scenario, but still would do little to promote vigorous competition in the electricity-only cap-and-trade market.

B. <u>The Electricity Sector Plus the Transportation Sector</u>.

I mentioned previously that the State Board of Equalization collects $.18 per gallon fuel tax on each gallon of gasoline and diesel fuel that is sold in the state of California. According to its records for 2004, there were exactly 47 taxpaying entities for the 15,941,732,912 gallons of gasoline sold. The seven largest of these held 89% of the market (largely the major oil companies), with the remaining 11% contributed by the 40 smaller entities (smaller refineries, blenders and importers). It would make a great deal of sense, if motor vehicle fuels are part of a cap-and-trade system, to make this precise set of gasoline taxpaying entities responsible for holding the required number of allowances—they already report the exact number of gallons sold in the state.[38]

The distribution by auction method of allowance allocation was not concentrated for electricity under the first-deliverer approach. Adding allowances for motor vehicle fuel would expand the number of market participants from 125 to 172, expand the amount of capped emissions from 116 mmts to 279 mmts, and the market would remain unconcentrated with an HHI of 602.[39] To the extent that the additional firms bring differing possibilities for ways to reduce carbon emissions (on both the demand and supply sides), they bring opportunities to lower the cost for all and to increase the dynamism of the market as well.

It is much more difficult to make an estimate of the degree to which adding in motor vehicle fuels would reduce concentration if allowances are distributed freely based on historical emissions. To the extent that the national lead-trading experience is a guide, the motor fuel refineries as a group likely have very diverse technologies. But this task of reducing carbon may be as much a matter of cleverness in reducing demand as it of technology to change the supply. That is, one could imagine the major oil companies competing this way: “Buy a new car designed to use our biofuel, and we will give you a credit card for our stations with up to X gallons of our biofuel free in the first year.” The company would not only spur demand for greener vehicles, but it would ensure a market for its new biofuel (lowering its need for allowances), and it knows that it will retain most customers even after the free gallon period.

Facing this, perhaps the most exciting prospect is to induce the electric utilities to compete by making their own offers for some free electricity for customers that purchase plug-in hybrids. That is the kind of competition, electricity versus biofuel, that a well-working, dynamic market should stimulate. It is not just the ability to compete, but the shrinking carbon cap over time that all but guarantees a large market for one or more of the cleaner alternatives. If ordinary gasoline and diesel will be reduced to about 20% of their current sales by 2050, what will take their place? Who will win the 80% percent of the market that used to be conventional fuels, valued at about $45 billion per year in California? For the electricity sector to be able to compete fairly for this, it is critical that it learns how to compete. The California electricity retailers, as monopolies with largely captive customers and roughly $31 billion in annual sales, have had only the most limited experience in competing.[40] Furthermore, their night rates (when most plug-in hybrids will be recharged and when there is substantial excess capacity for charging them) must be reduced to be close to the social marginal costs.[41]

Because so little is known about what trading opportunities will be attractive to each of the 47 motor fuel allowance holders in our example, it is perhaps not useful to speculate about how they might be distributed as allowance buyers and sellers. However, it is difficult to imagine a scenario in which the resulting market did not become substantially less concentrated as a result of their inclusion. Recall that the only concentration with the electricity sector was on the buying side. It is hard to imagine that many of the motor fuel sellers will not also be buyers, absent success at marketing an alternative, cleaner fuel. Thus these participants will help to deconcentrate the buying side. Some of the others will find success in marketing a biofuel and become important sellers of allowances. However, this side of the market is unconcentrated on the electricity side, and even large success by only a few of the motor fuel majors will still leave the market unconcentrated.

It is useful to digress for a moment and comment on market robustness over time. For the type of competition envisioned above to do its job, both in terms of stimulating both clever marketing plans and the technology with which to implement them, the allowance schedule must be known with a high degree of confidence for many years in advance. Simply having a market with many participants is not enough to induce long-range strategic planning and investing by those participants. There must also be confidence that the basic parameters under which the market will operate over time are known. If one looks at the national SO_2 market as an example, Cramton and Kerr (2002) mention that these allowances are issued 30 years in advance.

The California carbon cap-and-trade context is not exactly like SO_2; there is more uncertainty about what is appropriate for the very long-run and somewhat more adaptability is needed. For example, announcing a firm schedule of the allowance caps from 2012-2020, with a tentative schedule for 2021-2030 that will be made firm by 2017 along with an announcement at that time of the tentative schedule for 2031-2040, would provide the basic confidence necessary. It would also provide the flexibility to make adjustments to this path as our knowledge improves—again, announced long in advance and not affecting the stability of the market for its next few years. Success depends not only on participants having a clear idea of the long-run schedule, but also on how significantly the cap is going to decline over the years. The long-run decline in the cap is what determines long-run allowance price expectations (high for a substantially declining cap absent significant technological progress) that in turn triggers the substantial private research and development efforts that will help to make the best technological progress in achieving the reduction goals (and to lower allowance prices from what would occur without the technological progress).

In sum, if all allowances must initially be bought at auction, then market concentration is not itself a reason for including motor vehicle fuels in the cap-and-trade market. However, if allowances are going to be distributed for free based on a formula that is roughly proportional to historical emissions, then it could easily turn out that the market might have some undesirable concentration on the buying side (the coal-fired sources). In this case, that concentration is highly unlikely to persist in an expanded market that includes the motor vehicle fuels—there will be additional allowance buyers from the latter group, both large and small, who have not been successful in marketing a cleaner fuel and will deconcentrate the buying side of the market. Furthermore, when one considers robustness or the degree of competition as opposed to concentration per se, the allowance market will be substantially, perhaps critically, more dynamic and competitive with motor vehicle fuels included under either allowance distribution method.

V. Analysis: Large or Small Gains from Inclusion?

One of the arguments raised against inclusion of motor vehicle fuels in a cap-and-trade program is that the efficiency gains are so small relative to the extra administrative and compliance costs that it is not worth it. I have already argued in the compliance section that the extra administrative costs are essentially negligible because the allowance system can piggyback on the administrative structure already in place for collecting the state fuel tax, and that the enforcement costs are also essentially negligible because the state already enforces compliance with its unique pollution standards for motor vehicle fuels. But what about the size of any efficiency gains? If the expected carbon price increase is relatively small in absolute size, and the price elasticity of carbon for transportation use is almost perfectly inelastic, then the behavioral response will be negligible and likewise for any efficiency gains.

To understand this issue, it is critically important to recognize that there are three important areas of potential responsiveness to a carbon price that will affect emissions from motor vehicle usage: (1) the response of vehicle manufacturers in making more carbon-efficient vehicles (e.g. plug-in hybrids, fuel-cell vehicles, flex-fuel vehicles, more fuel-efficient conventional vehicles); (2) the response of fuel manufacturers and distributors in making more carbon-efficient fuels competitively available (e.g. biofuels, hydrogen, natural gas, electricity), and (3) the response of vehicle drivers in choosing more carbon-efficient alternatives (e.g. buying more carbon-efficient vehicles, using more carbon-efficient fuels, and reducing carbon-emitting vehicle usage—the latter by choices such as more use of alternative transits like buses, rails, bicycles, and walking, more use of carpooling or fewer discretionary shopping or leisure miles by vehicle, and better choice of live-work arrangements). Note that the magnitude of (3) is heavily conditioned by the responses to (1) and (2).

It is of course very difficult to know just what allowance prices to expect. We observe that in the European Union Emission Trading Scheme (EU ETS), allowance prices for its Phase II regime are in the €25 range, or about $40 per metric ton. To the extent that the California system might be linked with EU ETS, that will cause prices to be similar between the two systems. My expectations are that allowance prices in California are likely to be in the $20-$40 range during most of the 2012-2020 period, as California eases in a new regulatory system, ensures its integrity, and then links first with its immediate neighbors (the WCI). While we hope for increasing world harmonization as we approach the end of this period, the initial California reductions should be expected to come from the least costly methods of reducing carbon emissions. How might this affect gasoline prices? A rough rule-of-thumb based on the carbon content of a standard gallon of gasoline is that its allowance value is 1/100 of a ton: if we use $30 per ton as a reasonable illustrative example of an allowance price, then this implies a price increase for gasoline of about $.30 per gallon. Furthermore, since gasoline prices are currently about $4.00 per gallon, we are illustrating a 7.5% price increase.

While we would like to know about the carbon price elasticity in transportation (and elsewhere), the absence of carbon prices means that it has not been studied yet. What do we know about the price elasticity of demand for gasoline? Some focus erroneously on the short-run price elasticity, as does the first volume of the Low Carbon Fuel Standard report: "The price signal associated with a $25 per tonne of CO_2 would also be too small to induce significant reductions in transportation demand, either for passengers or freight. Consumers appear to be very insensitive to changes in gasoline prices, at least in the short term, with price elasticity of demand of less than -0.1…"[42] Of course what matters is the long-run price elasticity, as we will be striving to reduce GHG emissions for at least several lifetimes.

The price elasticity of gasoline, both short-run and long-run, is one of the most studied empirical issues in economics. There have been literally hundreds of econometric studies done on a diversity of data from different countries and different time periods using a diversity of methodologies. There have been numerous review articles appearing periodically to summarize the available literature, and meta-analyses of the individual studies. In Graham and Glaister (2002), a review of all of these led them to this conclusion: "the overwhelming evidence from our survey suggests that long-run price elasticities will typically tend to fall in the -0.6 to -0.8 range."[43] In other words, a 7.5% price increase by itself will cause behavior to change enough to yield approximately a 5% reduction of gasoline demanded in the long-run. Since that is also a 5% reduction in carbon dioxide emissions from the biggest single source in California, it is nothing to be slighted. Note that the long-run gasoline price elasticity includes the net effects of all three types of price responsiveness that we identified above (manufacturers, fuel makers and distributors, and vehicle users), independently from any non-price regulation like CAFE standards.

However, the difference between carbon price elasticity and gasoline price elasticity becomes very important here. Focus on the gasoline price elasticity understates, perhaps very greatly, the potential importance of behavioral change. In all past studies of gasoline, there has been no alternative less-carbon intensive fuel that could be substituted for gasoline (nor has there been proper incentive to introduce such a fuel, or to produce vehicles that use it). One either drives or uses the very imperfect substitutes of alternative transit modes. There is really no comparison between a situation in which one either buys gasoline or doesn't drive, and a situation in which one either buys gasoline or ethanol or any other carbon-saving fuel for a vehicle or doesn't drive. In the latter case, from the consumer’s point of view, gasoline and a carbon-saving fuel may be near-perfect substitutes and then the price-elasticity of gasoline becomes almost perfectly elastic, not inelastic. I am not suggesting that we are living right now in this world with good alternative fuels available. But I am suggesting that the price-inelasticity of gasoline, particularly the long-run elasticity, will change dramatically as alternative fuels and alternative vehicles like hybrids become more widely available. Estimates of responses to gasoline prices that are higher due to its carbon content and that rely upon existing studies when no cleaner alternatives were available are underestimating the degree to which consumers will reduce gasoline usage.[44]

There is an additional key factor (other than demand responsiveness) in determining the size of gains from including motor vehicle fuels in a cap-and-trade program that also encompasses the electricity sector. The more differently shaped are the marginal cost curves of emissions reductions for the two sectors, the greater the efficiency gains.

Of course, this brings us back to the problem that as of yet we have very little knowledge about the shape of either of these curves. However, the fragmented evidence that we do have suggests that they are of very different shapes, with the marginal cost of reducing carbon emissions from motor vehicle fuel much flatter than the marginal cost of reducing carbon emissions from electricity usage. It is generally recognized that because so many diverse technologies are and can be used to generate electricity, the marginal cost of reducing emissions across them varies enormously. It may be relatively easy to find a way of substituting for the carbon emissions caused by relatively dirty peaker plants that are only used during heavy peak periods; this could include either cleaner peaker technology or simply better pricing of peak-period services (including those for demand-management programs like interruptible rates). However, as we discussed earlier, there may be few or no inexpensive ways to reduce emissions from large, coal-fired baseload plants.

On the other hand, there is some evidence that the marginal cost curve of reducing vehicle fuel emissions is relatively flat over abroad range. One reason for this is the nature of energy-efficiency improvements in motor vehicles, a major source of reducing fuel emissions by reducing the fuel needed to travel a given distance. The extensive economic-engineering analysis that CARB did in considering how to implement AB1493 (GHG reductions for automobiles, to be discussed shortly) concluded that it is essentially costless to reduce emissions by improving light-duty vehicle efficiency: the extra capital costs incurred to make the vehicle more energy-efficient are slightly more than offset by the lowered present value of operating costs—and this analysis, while challenged by the automobile manufacturers, was done when gasoline was valued at only $1.74 per gallon.[45] By requiring that the new fleets introduced each year meet these standards, each year a greater proportion of the vehicle stock is greener and the carbon emissions reductions get achieved at a relatively constant marginal cost—near-zero if the estimates are correct.

Even if the CARB estimates turn out to be underestimates, this would not affect the basic flatness of the marginal cost curve but rather its level. It would still be true that at some point the flat curve from motor vehicle emissions would intersect the rising curve from the electricity sector (see Figure 1). Before the intersection point, the electricity sector would be doing the emissions reductions (it can accomplish them more cheaply). To the right of the intersection point, further emissions reductions should come from reductions in the transportation sector's emissions. That is, those still emitting in the electricity sector would find that they can buy allowances more cheaply than further reducing their own emissions.

Figure 1 about here

These pieces of evidence are consistent with a detailed empirical study done by Fowlie, Knittel and Wolfram (2006) that asks the same question for nitrogen oxide. They find that these cost curves look precisely the way I've suggested the carbon reduction costs curves may look: flat for motor vehicle fuel emissions, and rising fairly sharply for electricity plants (in their case coal-plants with a variety of retrofit options). While the cost curves for carbon reduction may not turn out to look like those for reducing nitrogen oxide, it is striking how similar the results of this careful study are to the fragmentary reasoning above. Interestingly, this study finds very substantial efficiency losses caused by regulating separately mobile and stationary sources of NOx, of magnitude equal to 28% of the cost of the regulatory programs. These losses occur because electricity is made to cut back emissions to a point where its marginal costs are substantially greater than the marginal cost of further reductions from motor vehicles. Under a cap-and-trade program that included both sectors, marginal costs would be equalized and efficiency losses like these would not arise.

In sum, there are likely to be large and significant gains from including motor vehicle fuels in the cap-and-trade program. This occurs for two reasons. First, consumers are going to be more responsive to higher gasoline prices (because of its carbon content) in the future than they have in the past because of the presence of alternative fuels, vehicles that use them, and more fuel-efficient vehicles. Second, because the marginal cost curves of reducing emissions are likely to have such different shapes in the electricity and transportation sectors, there will be large gains from a cap-and-trade system that provides market incentives to equalize marginal costs across them through allowance trading.

VI. Analysis: Interaction with Other California Regulation (AB1493 and the Low Carbon Fuel Standard)

A. AB1493

In 2002, California passed AB1493 that requires CARB to develop regulations that will achieve "…the maximum feasible reduction of greenhouse gases emitted by passenger vehicles and light-duty trucks and any other vehicles determined by the state board to be vehicles whose primary use is noncommercial personal transportation in the state." The legislation specifies that these regulations are to go into effect for the 2009 model year, although as mentioned earlier this depends both on obtaining a waiver from the United States EPA (denied in December 2007 and on appeal) and on the outcome of a law suit challenging the legislation by the automobile manufacturers.

CARB has developed regulations in accordance with this legislation that establish a "…a CO_2-equivalent fleet average emission requirement…" for passenger cars and light-duty trucks.[46] CARB estimates that its requirements will mean that the fleets of 2016 emit about 30% less carbon than the fleets of 2002.[47] CARB also estimates that this will be achieved at no net cost to consumers, as the increased vehicle purchase cost will be more than offset by reduced operating costs. While this may seem surprising, it is quite consistent with the conclusions from a National Research Council study in 2002 that the marginal redesign costs are likely less than the value of fuel savings for increases in fuel efficiency up to 50% above the standards then in effect.

According to CARB, these motor vehicle standards are expected to reduce climate change emissions in 2020 by approximately 30 mmts, about an 18% reduction from passenger cars. This would certainly be a significant reduction, even if it is somewhat short of the more than 20% percent statewide reduction from 1990 levels mandated by this time. However, it is unrealistic to count on this magnitude of reduction for two reasons: (1) California's appeal of the EPA waiver denial may be denied, or the automobile manufacturers' lawsuit against the program may prevail; or (2) delay in resolving the waiver issue or the lawsuit, even if both are resolved successfully from

California’s point of view, can significantly delay implementation of the program. The new standards are supposed to be in effect for the 2009 model year, and it is not possible to resolve the issues quickly enough for this to occur.

In denying the waiver request, EPA Administrator Stephen Johnson noted the recent decision to increase federal fuel efficiency (CAFE) standards to 35mpg by 2020. The fuel economy gains from this program will partially offset the losses from not having AB1493 in effect as scheduled. However, because the federal program does not target GHG emissions per se, and because its increased fuel efficiency standards will be phased in more slowly than those proposed in AB1493, CARB estimates that in 2020 the GHG reductions from the new federal standards will be 41% less than those that would have been achieved by AB1493.[48]

Would it be problematic both to have the AB1493 standards and to include motor vehicle fuels in a cap-and-trade program? Note that the AB1493 standards do nothing to discourage driving itself. In fact they (and the higher CAFE standards) should be expected to cause an increase in driving, because they have reduced the marginal operating costs. In the transportation economics literature, this is referred to as the “rebound” effect. According to estimates by Small and Van Dender (2007), the size of the long-run rebound effect is between 10% and 20% (again, as with price elasticity, it is the long-run effect that matters in this context). This is consistent with earlier studies of the same phenomena.[49] That is, a technological gain in fuel economy of 10% will be offset down to 8-9% due to the rebound effect of increased driving. However, including motor vehicle fuel use in the cap-and-trade program would discourage driving with carbon-emitting fuel because it increases the marginal cost of doing so.

One might think that, if motor vehicle fuels are included in the cap-and-trade program, there is no need for automobile emission standards like those of AB1493. In fact, there is an important rationale for these standards from behavioral economics, in addition to having a cap-and-trade program for carbon-emitting vehicle fuels. That rationale is the “sticker shock” effect, which has been found to be an important barrier to the purchase of many energy-efficient appliances. That is, the consumer has the choice of “losing” some money up front (the higher purchase price of a more energy-efficient appliance) in return for gaining reduced energy bills in the future. In many behavioral economic studies, consumers have been observed to give much higher weight to the present as opposed to the future, as well as undue loss aversion even with the prospect of substantial gains.[50] Perhaps the most well-known example from energy is the energy-efficient refrigerator, which is indistinguishable from an ordinary refrigerator except for its higher purchase cost and lower electricity usage while running. Many consumers turn down the opportunity to earn 20-25% rates of return on this small investment in energy-efficiency in order to keep their funds in savings accounts paying 5% or less. Brown (2003) cites a number of studies that support this type of finding, although none apply specifically to motor vehicles (which suggests a good area for further study). Nevertheless, a policy that increases the number and variety of new vehicles with energy-efficient features that more than repay themselves is likely welfare-improving.

B. Low Carbon Fuel Standard

This is a performance standard that makes the carbon intensity of CA fuels decrease over time. It has been adopted as an early discrete action by CARB with a goal of a 10% reduction in carbon intensity by 2020. CARB plans to adopt specific regulations by the end of 2008, with implementation effective in 2010. Note the intensity goal says nothing about the absolute amount of carbon being emitted. This goal could be satisfied with an increase in the absolute amount of petroleum being burned, as long as enough cleaner stuff like biofuel is also being burned (which further adds to GHG emissions). Indeed, according to the report recommending the LCFS, the standard with no other requirements would be expected to achieve its 10% intensity reduction goal by 2020 but with a 13% *increase* in carbon emissions from motor vehicles relative to 2007.[51] Clearly additional policies will be needed if California is to achieve its AB32 reduction goal.

The LCFS is much like the renewable portfolio standard in the electricity sector. That too requires no absolute decrease in fossil-fuel fired electricity. On September 12, 2002, Governor Gray Davis signed a bill (SB 1078) requiring California to generate 20 percent of its electricity from renewable energy no later than 2017. The PUC accelerated the goal, requiring the utilities to obtain 20 percent of their power from renewable sources by 2010 (SB 107 codified this goal in state law). Currently, the Commission is considering ways to achieve 33 percent renewable energy by 2020. All of these goals can, in principle, be satisfied with an increase in fossil-fueled electricity, as long as there is enough renewable-fueled electricity to go along with it.

One big difference between the LCFS and the renewable electricity standard is the role of consumers. When consumers receive electricity, there is no way to identify the source that made it—it is a homogeneous product blended with all generation sources from the moment it hits the grid. It is the utility retailers—usually the local utility—that are responsible for assembling and complying with the renewable portfolio standard. Wherever they get the electricity from, it gets delivered to their consumers. But for transportation fuel, consumers must choose at the pump (or perhaps electric socket!) what type of fuel to purchase, and they are constrained by the type of vehicle that they are driving. The fuel suppliers—largely the refineries with some fuel importers—are responsible for compliance with the LCFS, even though they have no direct control over what fuel consumers purchase or what vehicles they are driving. It may be possible for the standard to be satisfied as a technical matter, even if some unpopular fuel products will sit in storage tanks unbought by any actual fuel consumer.

One might wonder what purpose this type of standard achieves, since it does not require any absolute reduction. In this regard it is somewhat like the renewable portfolio standard in electricity, which has the purpose of stimulating diversity in the electricity supply above and beyond what arises in the market. The justification for this is to account for unpriced negative externalities associated with heavy fossil-fuel dependence, including not only pollution but the dependence on an import supply that is unreliable due, for example, to political actions beyond our control. Of course, to the extent that these negative externalities do become priced (like some pollutants through programs like cap-and-trade), that reduces the need for this type of policy. Interestingly for fuels, the argument is sometimes made that there is an additional barrier to proper market functioning: network externalities, in that the attractiveness of a new fuel depends heavily on the extent to which the existing infrastructure makes it easy to refuel. There can be circumstances in which a new fuel would largely displace an existing one, but it never gets started because it is understood that early-arriving new fueling facilities will lose money unless and until some critical mass of them is reached.[52] The LCFS does not address this directly, but its implicit subsidy for new, less carbon-intensive fuels to some extent may encourage the infrastructure development (and if so, that is an important attraction).[53]

The LCFS works by attributing an LCFS rating to each fuel distributor. For any single fuel distributor, its LCFS credit (or deficit) is determined by its sales of each fuel type (converted into megajoules of energy supplied) times that fuel's average fuel carbon intensity (AFCI), compared to the state standard AFCI for that year. For example, California gasoline is rated at 92 grams of CO_2e per megajoule (92gCO_2e/MJ), whereas average California electricity is rated at only 27gCO_2e/MJ. The state standard of 83gCO_2e/MJ as the 2020 target could be met if 14% of vehicle fuel in 2020 comes from electricity and the other 86% is conventional gasoline (.14*27 + .86*92 = 83). Distributors with an average AFCI below the 83 standard may bank or sell their extra credits, while those above the standard must purchase sufficient credits from distributors that have them in order to be in compliance. The credit (or deficit if negative) in our example is (83 – distributor's AFCI)* distributor's MJs.

A real challenge for the LCFS is whether it can be implemented in a way that does not inefficiently bias it in favor of biofuels and against non-liquid fuel alternatives. To implement it, CARB must know how much fuel of each type (in terms of its carbon intensity) each fuel distributor puts into vehicles. The most promising realistic alternative to gasoline is electricity.[54] It is already gaining ground through the hybrids that can draw power either from an electric motor or the internal combustion engine, and it is not hard to imagine these evolving to plug-in hybrids (reducing further the amount of gasoline used). Hydrogen is another non-liquid fuel that may become important, as could natural gas or propane. However, it is not at all clear that regulators can know, for example, how much electricity is actually being used instead of gasoline, which makes an unbiased implementation of the LCFS difficult.

Let us be sure this difficulty with the LCFS is clear. The LCFS distinguishes between electricity that is generated by the vehicle (as current hybrids do) and electricity that is received through a plug into the vehicle. The vehicle-generated electricity, no matter what portion of power it may provide compared to a conventional nonhybrid vehicle, does not enter the LCFS at all. If every car on the road was a Prius or Prius-like, with all the fuel still ordinary gasoline, there would be no LCFS progress toward a greener fuel-mix. The fact that we would have reduced gasoline consumption and carbon emissions by more than 50% would be seen as irrelevant to the LCFS. Technological progress in hybridization that could allow this percentage to rise even higher, say to 70 or 80%, is of no interest to the LCFS and would not be stimulated by it.

On the other hand, the LCFS considers plug-in electricity as taking the place of gasoline. The report on LCFS to the state suggests the installation of special car electricity meters (e.g. in the garage) so that regulators can know how much plug-in electricity is being used to power vehicles.[55] Added up across vehicle users and using an estimate of the average amount of power-to-the-wheel that this electricity provides and the average amount of carbon emitted to generate it, the knowledge of the quantity of metered electricity along with similar knowledge of the amount of gasoline consumed (and its average power-to-the-wheel and carbon emissions) allows calculation of the LCFS. Since a joule delivered to the vehicle wheel from plug-in electricity results in fewer emissions than a joule from gasoline, the LCFS will be lower than if gasoline alone was used.

The above reasoning seems both impractical as well as somewhat torturous in terms of the basis for estimating the LCFS. The impracticality is that there is no other reason apart from enforcing the LCFS why one would need these special electricity meters. Indeed, part of the beauty of the plug-in hybrid idea is that many consumers would need nothing at all: most garages already have electricity, and think of all those gas stations and trips to them that would no longer be needed. Electric meters are somewhat expensive, on the order of about $100 each to install, without consideration of any extra meter-reading costs. And of course if consumers for some reason decided they prefer a different plug (on the regular meter), there is little to stop them from using it. If both motor vehicle fuels and electricity are included under a cap-and-trade program, no special meters would be required, and increased hybridization and reduced driving would all be encouraged on the same basis as cleaner fuel (i.e. carbon emissions avoided). Furthermore those consumers using especially clean electricity would be rewarded for it, while those using electricity with above average emissions would have to pay for it (unlike the LCFS that will attribute the statewide average electricity emissions to all).

It is always possible that, through the encouragement of the LCFS, there will be a major fuel breakthrough that will make the reduction task much easier than it would be otherwise. But it is also clear that we cannot bank upon this happening. Given the mandate of AB32 to substantially reduce the absolute amount of GHGs emitted by California, regulation in addition to the LCFS is needed for vehicle fuels. The MAC report is certainly right on this aspect.

VII. Analysis: Linkage Problems with Other Jurisdictions

One vital aspect of the global warming problem is that no single country, let alone state within a country, is capable of solving the problem on its own. California's efforts will accomplish nothing at all if most other jurisdictions in the world do not undertake similar efforts. Much of the world—those signing the Kyoto Protocol, the European Union with its Emission Trading System (EU ETS), the northeastern states participating in the regional Greenhouse Gas Initiative (RGGI), the western states and Canadian provinces that are forming the Western Climate Initiative (WCI), the midwestern states and provinces that are similarly forming the Midwest Greenhouse Gas Reduction Accord (MGGRA) and others—seems to recognize this, and they are building collaborative efforts that hopefully will evolve into an effective global system. For purposes of this paper, I only consider whether the inclusion of motor vehicle fuels in California's cap-and-trade system will hinder or cause important impediments to linking the separate systems.

One important aspect of this to consider is how California's system will mesh with a United States national system, if there is to be one. This is different from voluntary linkages between two or more sovereign countries (or states as in the WCI), in that the

US has the power to override a California system. A national system would likely supersede California's system, except if California prefers a more stringent system (and even if so, under some circumstances a US EPA waiver might also be required).[56] The more similar are the two systems, the less likely are future disputes over California's system. While we do not know what the future will bring, the bill receiving the most congressional attention at this time, Lieberman-Warner (S. 2191), would cap transport emissions at the refinery level analogously to the method considered here for California. If a bill like this is passed nationally, there would be no linkage issue caused by the inclusion of motor vehicle fuels in the California system. Indeed, California's possible exclusion of motor vehicle fuels might cause it linkage problems in this case. Along the same lines for voluntary linkage, the WCI recently issued its draft plan stating "Most partners have a strong interest in including transportation fuels in the cap-and-trade program."[57]

Of course, there are other U.S. bills that have been introduced, like Feinstein-Carper (S. 317) that are limited to the electricity sector. There are potential voluntary linkage partners like RGGI which is also limited to the electricity sector. For reasons we have already discussed, it is unrealistic to imagine that the alternative to inclusion of vehicle fuels in a cap-and-trade program is no regulation; it would be different forms of regulation. In the EU ETS, for example, vehicle fuels are not included in the trading sector but gasoline costs about $9 per gallon (compared to $4 in the U.S.) because it is subject to stiff taxes. If a small portion of the roughly $6 per gallon tax common in Europe can be considered to account for the GHG externality, then it is a carbon-tax equivalent to an allowance requirement. Efficient emissions reductions within and across the jurisdiction would occur if the carbon tax portion of the overall fuel tax is kept at parity with the allowance price (e.g. $40/ton allowances imply approximately a $.40 per gallon carbon component of the fuel tax). Inefficiency would arise if the tax rate and allowance prices are not harmonized in this way (because the marginal cost of reducing emissions would not be equalized across the sectors).

It is thus difficult to generalize about the efficiency effects of linking one jurisdiction which has motor vehicle fuels in its cap-and-trade program with another jurisdiction that regulates them differently without knowing the specific circumstances. However the general trading advantage applies. Linking the two jurisdictions reduces the cost to each of achieving its target reductions. It may not be the minimum possible cost, but it is lower than if no trading was allowed between allowance-holding vehicle fuel distributors and allowance holders in the linked jurisdiction. Because any trading is voluntary, it only occurs when it makes both trading parties better off. Whether the motor vehicle fuel distributors responsible for allowances buy from or sell to parties in the other jurisdiction, it only occurs when it lowers the cost of compliance for both and in the aggregate.[58]

In the analyses of linkage that have been done largely in setting up EU ETS, the general finding to date has been that there are little to no administrative, enforcement, efficiency or effectiveness problems caused by linkage across the different national jurisdictions.[59] The important aspects for successful linkage that these studies identify are reliable enforcement, common methods for measuring tradable emissions, and common allowance units and trading periods.

If California includes motor vehicle fuels in its cap-and-trade program, to the extent that it links with other jurisdictions it will meet its goals at lower cost than if these fuels were excluded from it. The inclusion of motor vehicle fuels is unlikely to cause problems with a future US national system, although the exclusion of them would be problematic (likely to lead to federal preemption) if the national system includes them. Similarly, inclusion is unlikely to cause problems in terms of voluntary linkages with other jurisdictions.

VIII. Summary and Conclusions

I have considered whether or not California should include motor vehicle fuels in any cap-and-trade system that it sets up to help achieve the GHG reductions mandated by its AB32 legislation. I take as a given that the large stationary sources, primarily the electricity sector, will be included. While first-best economic principles suggest that the program be as inclusive as possible of all sources of carbon emissions, there are a variety of reasons for opposing this broad solution. I mention, although do not focus upon, both some political resistance as well as agency inexperience with broad market-based regulatory programs. Both of these as barriers can be overcome should the public interest rationale for inclusion be sufficiently strong.

I consider administrative and compliance concerns about the inclusion of motor vehicle fuels. On these grounds, it is actually easier to encompass motor vehicle fuels in a cap-and-trade program than it is to encompass electricity. California's Board of Equalization already tracks exactly how many gallons of gasoline, diesel, and other fuels subject to various taxes are sold in California. There are only 47 payers of the state gasoline tax, and my proposal is to make fuel taxpayers responsible for allowances for motor vehicle fuel emissions. Furthermore, both CARB and the Highway Patrol already ensure compliance with California's existing pollution standards for these fuels, so there is little concern that illegal markets for non-allowance gasoline would arise. On the electricity side, it is probably impossible for California alone to prevent the contract reshuffling that will make its imports look clean while the same coal-fired sources continue to operate as usual.

In terms of the robustness of any cap-and-trade program, I argue that for any definition of participants the market will be more competitive if allowances are initially distributed by auction than if distributed freely by formula like those based on historical emissions. This is because auction distribution places all participants on the buying side of the market, while the free formula distribution divides the same participants into allowance buyers, sellers, and nontraders—and the buying and selling sides must each be robust for the market to operate well. I show empirically that an auction market even restricted to the electricity sector will be unconcentrated by normal economic standards (HHI of 500), and it remains unconcentrated with motor vehicle fuels included.

On the other hand, it is quite possible that formula distribution to the electricity sector alone might be more concentrated than is desirable. If the coal-fired sources remain in the market and are the most expensive to reduce, an illustrative calculation shows possible concentration on the buying side (HHI of 2229), although there is considerable uncertainty about this. It is highly likely that inclusion of motor vehicle fuels would deconcentrate this market, although again there is considerable uncertainty because allowance buying or selling behavior depends as much upon success or failure in marketing alternative cleaner fuels as it does on the technology to produce them. Perhaps most importantly, robustness depends not just on the degree of concentration but on the strength of competition. Under either allowance distribution method, the inclusion of motor vehicle fuel emissions stimulates a critically important competition across the electricity and transportation sectors as they each vie to gain market shares as alternative fuel providers.

Other objections to the inclusion of motor vehicle fuels have suggested that the efficiency gains are not worth the incremental transaction costs. I find that these arguments are erroneous. They are based largely on a picture of demand for carbon in vehicle fuels as nearly perfectly inelastic. We have practically no knowledge of carbon price elasticity because carbon has not been priced before. We do have knowledge about gasoline price elasticity, which is of some relevance but has no bearing on the incentive to reformulate a less carbon-intensive form of it. Existing studies of the long-run price elasticity of gasoline find this to be in the -.6 to -.8 range, nothing to write off as irrelevant in terms of emission reductions. But all of these studies measure the elasticity when there are practically no substitutes for gasoline, and pricing carbon emissions greatly increases the incentives to introduce cleaner fuels that are close substitutes for conventional gasoline. In a climate conscious world with alternative fuels including biofuels and electricity as well as an increasingly hybridized, fuel-efficient choice of vehicles, one is not stuck with high gasoline consumption. In this context, the availability of many more substitutes will make the price elasticity of gasoline far more elastic than it has been in the past.

An additional factor that works to make sizable gains from trade possible is the very different marginal cost structure for reducing emissions from electricity as opposed to from driving. While these cost structures are as yet largely unknown, the available fragmentary evidence suggests that the marginal cost curve for abating carbon emissions will be rising fairly sharply in electricity while relatively flat for those caused by driving; these different shapes create the potential for substantial gains from trading allowances across the sectors.

Another objection to including motor vehicle fuel in the cap-and-trade program is that the GHG reductions from the transportation sector are already addressed by other regulatory programs. In particular, California has separate and earlier legislation known as AB1493 to reduce emissions from light-duty vehicles, and CARB has adopted as one of its early actions under AB32 a Low Carbon Fuel Standard. Neither of these requires that absolute emissions be reduced. The LCFS may be very useful in stimulating the introduction of some cleaner alternative fuels like biofuels. But it is expected by its authors to result in an increase in carbon emissions by 2020 from 2007 of 13%. AB1493 would be an important program that helps to induce more efficient vehicles, but it is stalled by the denial of a federal EPA waiver and still under legal challenge. It may never go into effect and even if it does, its delayed implementation means it cannot achieve the reductions intended from it by 2020. Neither of these programs can be counted upon to achieve either the 2020 or the 2050 goal, and neither of them address the market failure that the cap-and-trade program does: carbon emissions are a negative externality that must be internalized so that carbon emitters face the social cost of their emissions.

While interjurisdictional issues involving the linkage of different systems raise many issues, I only consider whether the inclusion of motor vehicle fuels in California's cap-and-trade programs itself causes any such issues. In general, inclusion causes no harm and in fact lowers the cost of California reliably achieving its emission reduction goals. In terms of possible federal preemption of California's system, it is the exclusion of motor vehicle fuels that would cause problems if the national system included them, as is proposed in several bills like Lieberman-Warner (S. 2191).

Perhaps the greatest race of the 21st century, if we run it, will be the race to see who provides the best energy alternatives to those that cause harmful GHG emissions today. In the transportation sector, will we see hydrogen-run cars, or bio-diesel fueled cars, or electric cars like plug-in hybrids? Perhaps we will see a mixture of them, or perhaps there will be something quite different. Over time there may be more vehicles (e.g. if they are zero-emission types) or there may be fewer (e.g. if they are cleaner but still cause significant emissions, and consumers economize on their use). In California, motor vehicle fuel sales are in the range of $60 billion annually, and at least $40 billion of that will be up for grabs to whichever purveyors of cleaner transportation convince the public to go with them. Including motor vehicle fuels in California's cap-and-trade program will set up this competition in an unbiased way in which the public is assured that we will meet our critical climate change emission reduction goals, and do so in a way that minimizes costs to them and lets them decide the technologies to use.

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Notes

[1] The six regulated gases are carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexaflouride. In 2004, the total emissions of these gases in terms of CO_2 equivalents (CO_2e) were approximately 479.3 mmts (including those from imported electricity), of which CO_2 comprises 84%. Equivalent in this context is in terms of global warming potential as defined by the Intergovernmental Panel on Climate Change. As a regulatory matter, it may be possible to allow trade-offs among the gases in which an emitter of one can achieve compliance by reducing or paying for the reduction of another. However, each of these gases has its own distinct regulatory concerns. For example, hot spots are not a concern with CO_2, but may be for one or more of the others.

[2] All figures in this paragraph are taken from the California Energy Commission's Greenhouse Gas Inventory 1990-2004 as revised in January 2007, by adding its figures for net CO_2 emissions in state with its estimates of the CO_2 emitted from imported electricity (AB32 specifies that the latter is to be included in measuring the state's GHG emissions).

[3] CARB has adopted several "early actions" that will go into effect by 2010 and will reduce emissions in several areas from what they would be otherwise. These range from simple requirements like mandating tire air pressure checks whenever a vehicle is serviced to more complex initiatives like the adoption of a low-carbon fuel standard that we discuss later in this article.

[4] The lower bound is from p. 8 of "Inventory of Greenhouse Gas Emissions and Sinks: 1990 to 2002 Update", California Energy Commission Publication CEC-600-2005-025, June 2005. The upper bound is from the California Climate Change Portal website at http://www.climatechange.ca.gov/.

[5]The outcome might be described as an uneasy truce, in which the new staff are simply designated to carry out the language of the AB32 legislation. This does not prevent the staff from working on market-based regulatory rules, but it does hamper the ability of the agency to recruit many personnel with strong economic skills.

[6] William Nordhaus, member during the Carter administration, advocates the tax-based approach as does Joseph Stiglitz, member and chair during the Clinton administration, and N. Gregory Mankiw, chair during the George W. Bush administration. See Nordhaus [2007] for a detailed exposition; Stiglitz [2006] expresses this view thinking primarily of achieving global cooperation and Mankiw echoes this argument in a New York Times editorial on Sept. 16, 2007 (p. 6, Sunday Business section).

[7] Representative John Dingell of Michigan announced that he is developing a carbon tax proposal. However, political cognoscenti consider this dead-in-the-water legislatively, and many think Dingell's motives are to use the (expected) failure as proof that the American people do not want significant climate change legislation (thus protecting the automotive industry in his state). See for example the news story "'Faux' Gas Tax Tests Resolve on Global Warming" in The Chrisitian Science Monitor, July 13, 2007.

[8] Norway, Sweden, Finland, Denmark and the Netherlands have adopted carbon taxes. As a generalization, these taxes have not been implemented as economists might hope. They have been characterized by important exemptions and special lower rates for particular industries that have resulted in more modest effects than would a more uniform, comprehensive tax on carbon emissions. This suggests that policy designers able to consider a carbon tax should take careful account of the likely effect of political forces on the implemented version of what they design, and be sure to compare this “likely implemented” version with alternative approaches. For an analysis of the actual carbon tax in Norway, see Bruvoll and Larsen (2002).

[9] The arguments for the superiority of a tax approach as opposed to a cap-and-trade approach depend to some extent on one’s views of how the public sectors will operate each program. A cap-and-trade program that auctions permits is nearly identical to the tax approach. The pro-tax arguments may underestimate the difficulty of harmonizing the tax rate across different jurisdictions; this is just as difficult as agreeing upon quantity shares for the cap-and-trade, and tax rates might be even harder to adapt appropriately to changing knowledge or circumstances than quantity limits.

[10] P. 35, MAC (2007)

[11] P. iv of the Executive Summary.

[12] Pp. 38-39 MAC (2007).

[13] A different issue is that many imported products cause GHG emissions outside of California in their production and transportation to California. Furniture, for example, may be assembled in North Carolina in an energy-using factory that imports its wood inputs from Brazil and trucks the finished furniture to California for sale. The question arises as to whether or not California regulators should be responsible for the non-California emissions of these products (called “life-cycle” emissions accounting), or if their responsibility is limited to in-jurisdiction emissions. Any regulatory system that divides responsibility among jurisdictions so that each emission is assigned to one and only one jurisdiction would be comprehensive, but it may not be very efficient. Suppose California decided to use life-cycle emissions accounting and to regulate the imported furniture. It would be easy for the North Carolina firm to use (or claim to use) low-emission recycled wood in furniture destined for California and the higher emission Brazilian wood in furniture destined for unregulated areas (with no actual change in its overall use of wood or in GHG emissions). The system of counting and regulating only in-jurisdiction emissions is usually preferable on efficiency grounds because the regulators have no authority to regulate out-of-jurisdiction behavior and because it is difficult for regulators to know and to verify out-of-jurisdiction emission changes. For GHG emissions, this requires that all jurisdictions regulate the GHG emissions that occur within it (which they are not yet all doing). This is the objective of efforts like the Kyoto Protocol. In such a global system, California regulators would not be responsible for the non-California emissions caused by the imported furniture, but California consumers would still face the cost of those emissions (and thus have

incentive to avoid them) because the external regulatory costs become embedded in the price of the furniture.

California emissions as defined by AB32 mean emissions that occur within the state except for those out-of-state emissions caused by importing electricity. This system of primarily in-jurisdiction accounting and regulating is largely forward-looking, on the assumption that other jurisdictions will eventually create analogous regulatory systems. However, in the short-run it may be sensible for one jurisdiction to take into account unregulated out-of-jurisdiction emissions (requiring that such numbers be continually revised as other jurisdictions begin to regulate). CARB correctly counts only in-state emissions from motor vehicle fuels in its GHG inventory and in its future targets. This does not mean that it wants to encourage consumers to switch away from gasoline to, say, corn-based ethanol that has even higher life-cycle emissions but low in-state emissions (if grown primarily in unregulated jurisdictions). Thus its proposed Low Carbon Fuel Standard (LCFS), discussed later in the text, uses life-cycle emissions in rating each fuel. Life-cycle emissions accounting is also required by the federal biofuel mandate of the Energy Independence and Security Act of 2007 (in which out-of-country emissions in growing and transporting the biofuel are counted in establishing its rating). Both of these would be problematic if they are not continually revised to remove previously-counted emissions from external jurisdictions that have become regulated and reduced them. In establishing allowance values for new biofuels under a cap-and-trade program, the desired future linkage with other jurisdictions makes it important for the jurisdictions to have common measures of verifiable emissions and allowance values. This reinforces the case for using in-jurisdiction accounting for cap-and-trade, relying upon other rules in the short-run like the LCFS to discourage shifting to fuels (and other products) with high non-California emissions.

[14] An alternative cruder approach that relies upon a fixed relationship between technology and emissions is to make the vehicle manufacturers responsible for the vehicle emissions, using the expected lifetime fuel consumption of each vehicle based on standardized assumptions like a 150,000 mile useful life before the vehicle is scrapped. This does not really change manufacturer incentives, as vehicle drivers would enjoy essentially the same savings from more efficient vehicles (and thus have the same willingness to pay for them) whether fuel distributors or vehicle manufacturers are responsible for the allowances. There may be important behavioral effects not predicted by simply looking at the price incentives. For example, perhaps vehicle manufacturers that are also subject to CAFE requirements would be more likely to calculate (and equate) the marginal cost of abatement from compliance with both the cap-and-trade and CAFE regulations (although the economic incentive to do this is actually the same with fuel suppliers responsible for the allowances). Even if true, one would think there would be offsetting (and perhaps stronger) behavioral effects as fuel suppliers would then think less hard about introducing greener fuel choices. More importantly here, the assumption that the vehicle determines the emissions is far less true than measuring emissions based upon actual fuel consumption. This is particularly true for flex-fuel vehicles, especially the

plug-in hybrid, in which the consumer's fuel choice (and therefore emissions) will be dictated by relative fuel prices (that may shift unexpectedly) over the vehicle's lifetime. Furthermore, a vehicle may not be in California for some portion of its life, and there would be compliance and enforcement complications in addition to the actual emissions uncertainty (for example, registering the vehicle in another state to avoid California's allowance requirement, but driving it in California). In short, compliance and enforcement is easier and more reliable with fuel suppliers responsible for allowances rather than automobile manufacturers.

[15] Even these statements are subject to error whenever transmission lines to the grid carry power from multiple generators, as they often do.

[16] As of October 2008, the Western Climate Initiative (WCI) had as members Arizona, British Columbia, California, Manitoba, Montana, New Mexico, Ontario, Oregon, Quebec, Utah, and Washington. These 11 states and provinces have adopted a goal of achieving approximately a 15% reduction in GHG emissions from the 2005 level within the region, and are developing a regional cap-and-trade program and other actions to achieve it. Of the 6 major coal plants that are imported sources of California's electricity (see n. 26), only Reid Gardner in Nevada is not regulated under this plan. Nevada is an official "observer" of the WCI and may still join.

[17] While there are not comparable compliance concerns, the issue of regulating emissions from new biofuels that may be imported from unregulated areas raises a related issue discussed in n. 13. There we discussed the general impracticality of trying to regulate out-of-jurisdiction emissions. Part of the electricity problem is because AB32 specifies that emissions from imported electricity be counted by California regulators.

[18] For more information about the lead trading program, see Hahn and Hester (1989).

[19] According to the California Energy Commission, 264,740 Gigawatt-hours of electricity were consumed in 2003, of which PG&E provided 30% and SCE provided 31%. See the web page http://www.energy.ca.gov/electricity/electricity_consumption_utility.html.

[20] Retail competition was planned as a feature of the state's restructured electricity system implemented in April 1998, although it never got off the ground and any potential progress was halted by the electricity crisis of 2001-02. The CPUC suspended the right of customers to "direct access" (choosing a non-utility energy service provider) on Sept. 20, 2001. Additionally, the state legislature passed AB1X in 2001 which prevents the resumption of direct access until expiration (in 2013) of the last long-term electricity contract signed by the Department of Water Resources in order to end the crisis. For additional information, see Blumstein, Friedman and Green (2002) and Friedman (2009).

[21] With real competition, any single entity is motivated to produce at least cost for fear that otherwise it will lose customers to lower-priced competitors. Absent real competition, the only other pressure on the retail utility (or public enterprise) is the threat that its regulator (or overseer) will not find its allowance expenses

to be just and prudent. This is a difficult task for the regulator, and one might expect to see such findings only in flagrant cases. Nevertheless, many of the much larger number of utilities that participate in the (highly unconcentrated) national Acid Rain allowance program do appear to trade allowances actively and lower their costs to some extent.

[22] See the Final Report, Market Advisory Committee, “Recommendations for Designing a Greenhouse Gas Cap-and-Trade System for California,” June 29, 2007, available at http://www.climatechange.ca.gov/documents/2007-06-29_MAC_FINAL_REPORT.PDF. In 2008 the CPUC recommended an almost-identical approach that it termed “first-deliverer” rather than “first-seller”; the difference is to strengthen California’s legal claim that it is not regulating interstate wholesale electricity sales. The difference does not otherwise bear on the analysis in this paper. The first-deliverer is “the entity that owns the electricity as it is delivered to the grid in California.” See Decision 08-03-018, California Public Utilities Commission, March 13, 2008. Henceforth we use the term “first-deliverer.”

[23] The nature of competition in electricity generation is complicated because electricity is nonstorable and must be generated as needed, and because the demands for electricity vary widely over hours of the day as well as with seasonal conditions. This leads to a set of diverse generation facilities from baseload plants that run essentially all the time to peaker plants that are only in use for the small number of hours during a year when system capacity is strained. There are times (and contracts to govern) when particular plants “must run” to keep the overall system in balance. Nevertheless, at most times there is choice about which plants will be doing the generating, and none of them want to be at a competitive disadvantage during the bidding for these services.

[24] For example, A 2006 report by California’s Climate Action Team “Cap and Trade Program Design Options,” indicates (p. 20) that there are approximately 313 in-state fossil-fueled electricity generators of at least 25MW that could be included in a cap and trade program. This number seems inconsistent with the CEC 2005 Power Plant Database, which lists only 185 generators of this size. The database lists 965 generators within the state, including those owned by public entities, private entities, and co-generators. The fossil-fuel generators consist of 17 that are coal-fired and 374 that are oil-fired or gas-fired. However, most of these are quite small, and the number that have online MW of 25 or more is 185: 9 coal-fired and 176 oil- or gas- fired. The MAC report states (p. 29) that there are approximately 450 facilities in its Program (1) coverage, which includes electricity generators that emit 10,000 metric tons of CO2e annually as well as facilities of energy-intensive industries like refineries and cement.

[25] The EIA electric plant dataset lists 463 sources of GHG emissions from 328 individual plants. There are 83 plants that have emissions but are below the 10,000 ton amount per year. Existing state reports suggest that some sources are too small for inclusion in a cap-and-trade program on administrative grounds, and recommend cutoffs at either 10k or 25k. This cutoff choice makes little difference in this case: at 25k, there are 221 plants that emit 54.6 mmts (99.1% of the total inventory).

[26] Major out-of-state coal-fired plants include Intermountain (UT), Four Corners (NM), Navajo (AZ), San Juan (NM), Reid Gardner (NV) and Boardman (OR). According to the CEC, imports in 2004 represented 22.9% of total gigawatt hours used in California, whereas imports represented 52.5% of carbon emissions. This can be slightly confusing as the CEC counts Intermountain (and Mohave in Nevada which we excluded since it ceased operations at the end of 2005) as an in-state facility in the gigawatt-hours calculation (on the grounds that it is within CA "control areas") but not the CO_2 calculation. Putting its electricity into the import category makes imports represent 26.9% of California electricity.

[27] There are 38 mmts of carbon listed in the inventory as from imported electricity from unknown sources. For our purposes, we accept the measure and consider who are the likely first-deliverers of this electricity and thus would be responsible for the necessary allowances. In general, first-deliverers will be retailers or marketers that are entities different from the in-state generators, and thus will tend to deconcentrate the market unless one or two entities are responsible for all of the unknown imports. The latter is not really plausible. These imports are primarily the residual short-run purchases that retailers need to meet their demands after accounting for their longer-run sources of supply, such as spot market purchases. Perhaps the most plausible assumption is that over a period like one year each retailer will be a first-deliver for an amount approximately proportionate to its total sales. In this case the electricity is widely dispersed among many first-deliverers, and the HHI will go down from the 500 level.

To determine if the market might be concentrated we do not assume wide dispersion but choose assumptions that we think lead to the most concentrated ownership plausible. There are only 5 retailers in the state that provide more than 2% each of statewide electricity sales: PG&E, SCE, Sempra (SDG&E), SMUD, and LADWP. In 2005, these 5 retailers provided 86.45% of statewide electricity. We attribute all of the unknown imports to these entities. While this may at first sound like an extreme assumption, it only differs from the "all retailers" assumption by attributing the 13.55% of unknown imports that would go to many small retailers to the five major ones. Furthermore, we make use of the fact that the portions coming from the Pacific Northwest (serving primarily PG&E and SMUD) and that from the Desert Southwest (serving primarily SCE, Sempra, and LADWP) are known (7 and 31 mmts respectively). We attribute emissions only among the major first-deliverers in each area, based upon their relative sizes by electricity sales. The upshot of this, however, is that the HHI remains at an unconcentrated level of 885.

Essentially any plausible assumption about how these emissions are distributed among first-deliverers yields a result of low concentration. The only way to change this picture is with implausible assumptions. For example, if all 38 mmts were attributed to just one of the larger first-delivers, like LADWP, the HHI would rise to 1975. But if the 38 mmts are split evenly between only two major first deliverers, like SCE and LADWP (still an implausible degree of concentration), the HHI drops to 1240.

[28] Sometimes authors will emphasize a distributional difference between auctions and free permits based on historical emissions. This is not necessarily so. One can require that all allowances be auctioned while still

granting rights to initial ownership of them based on historical allocation (i.e. the auction revenues are distributed to the sources based on their shares of the baseline historical emissions).

[29] I am referring to actual substitution that reduces the coal-fired emissions, and not contract reshuffling which merely re-labels who is responsible for them. To the extent that California demand for such sources occurs as needed as opposed to by long-term contract, this would make them marginal and subject to substitution.

[30] For example, see MIT (2007) which finds that CCS starts to become economic at about $30/ton of CO_2. See also the report by McKinsey & Company (2007), which estimates that U.S. GHG emissions can be reduced in half by 2030 with measures costing no more than $50/ton, and includes some CCS becoming economic at $30/ton (see Exhibit B, p. xiii). Nevertheless, because there is great uncertainty about just what technologies might become viable with particular generating plants, the assumption may turn out to be false. For example, there is a retrofit technology under development known as algal scrubbing, in which the CO_2 being emitted from smokestacks is used to grow algae which absorb the carbon and are then themselves harvested to produce clean biofuels (see, for example, the website of GreenFuel Technologies Corporation). This technology can, in principle, be installed at both coal-fired and gas-fired generating plants, and perhaps it will be equally or even more efficient at the coal-fired plants.

[31] For purposes of this calculation, I use the same assumption as in note 27 and attribute all emissions from unknown imported sources to the major first-deliverers.

[32] The above assumptions are described mathematically in a brief appendix. This scenario has 3% of allowances being traded. As a benchmark, Schmalensee et al. (1998) report (p. 61) that traded or transferred allowances grew to 10-13% of the capped SO2 emissions in the US Acid Rain Program from 1995-7, although the proportion was substantially lower in its earlier years.

[33] Granting for purposes of the exercise the assumption that “coal-fired emissions are most expensive to reduce,” the figure for the top 8 is more reliable than that for any individual owner because of the uncertainty in attributing responsibility for emissions from the “unknown” imports.

[34] It is interesting that contract reshuffling could lead to the exact opposite result described here. To the extent that first-deliverers of these coal-fired imports are able to sell their purchase obligations to unregulated, out-of-state utilities and substitute electricity from cleaner sources, they will have reduced need for allowances (even though there may be no change in real emissions, only what is counted as California emissions). If these first-deliverers do this enough, they will become the allowance sellers rather than the buyers and it is the selling side that would be moderately concentrated.

[35] Some allowance recipients may choose to save allowances for future use. This depends on both the future allowance schedule as well as any expected future changes in the treatment of contract-reshuffled sources.

[36] Contract reshuffling may be prevented by existing contract clauses that do not allow for resale, or by the lack of adequate transmission lines to send the power to unregulated, non-California users.

[37] The general problem with the updating method is that it reduces the incentives of sources to vigorously reduce emissions. That is why this suggestion only applies to contract reshuffled imports.

[38] The analogous information for sales of diesel fuel collected by the same agency are not made public, so for purposes of this section I have assumed that the distribution of diesel sales is identical to that of gasoline. This probably overstates somewhat the degree of concentration, as diesel has more taxpaying entities. According to the 2004-05 Annual Report of the State Board of Equalization, 128 diesel fuel suppliers paid more than 86% of the 2004-05 diesel fuel tax. We do know that diesel emissions are approximately 20% of vehicle fuel emissions in the state GHG inventory (total 2004 emissions from gasoline are 130.94 mmts, whereas 32.16 mmts are from transportation "petroleum distillate" which is basically diesel).

[39] Crampton and Kerr (2002) consider the possibility of market power in a U.S. national system in which all carbon allowances are auctioned. In their "upstream" model, just over 1700 entities participate including 175 refineries, 550 coal preparation plants, 250 natural gas pipeline companies and 725 natural gas processing plants. The largest single entity in this model is the coal producer Peabody Holdings, which only has 5.6% of the market, with Chevron second biggest at only 2.3%.

[40] Examples of the limited competition they have faced involve their large industrial customers. These customers compare their costs of purchasing electricity from the utility with the net cost of making it themselves by constructing their own co-generation facilities. They also were able, under the state's brief deregulated regime, to bypass the utility and to arrange for electricity by "direct access" to a generator or another wholesaler. Direct access was suspended during the state's electricity crisis of 2001-02, and has not yet been reinstated.

[41] In California, the CPUC has already ordered utilities to replace the older, conventional residential meters with new smart meters capable of assessing real-time prices. This is currently being implemented. However, there are no real-time rate structures yet in place for most residential and commercial customers. Some of these customers may have non-varying time-of-use (TOU) rate schedules that distinguish off-peak (night) rates from other times, although most do not even have this. Even for those with TOU rates, the off-peak rates increase with the customer's quantity consumed and may far exceed marginal social costs. For example, PG&E residential customers in Tier 5 of TOU Schedule E-7 pay in excess of $.30/kwh for off-peak electricity, even though the average rate (for both peak and off-peak) is only $.16/kwh. This is no way to attract plug-in hybrid customers. Because of excess capacity at night, these rates should be substantially below average electricity rates. Of course these rates will need to reflect the marginal carbon allowance costs as well. In advanced applications, the electricity grid may even be able to generate some power during peak periods by buying it from hybrids not in use then.

[42] P.24, LCFS I (2007).

[43] P. 22, Graham and Glaister (2002). Some less comprehensive sources suggest a slightly lower elasticity. An earlier 1996 review cited by USCBO (2008) and focusing on the U.S. concluded that a reasonable estimate of long-run gasoline price elasticity is .4, which is also consistent with the recent estimate of Small and Van Dender (2007).

[44] Some of the analyses of proposed federal legislation to reduce GHG emissions generate low estimates of expected reductions from the transportation sector for precisely this reason. For example, EPA (2007) bases its analysis of expected reductions from S.280 (Lieberman-McCain) on a computable general equilibrium model and cautions it does not model new developments in transportation technologies (neither fuels nor vehicles).

[45] See the Air Resources Board "Economic Impacts of the Climate Change Emissions Regulations," a Technical Support Document for the Final Staff Report, August 6, 2004.

[46] There are actually two fleets in the CARB regulatory definitions: one for passenger cars and light duty trucks considered Type 1, and another for Type 2 light duty trucks.

[47] Note this is not an estimate of carbon reduction for all cars and light-duty trucks on the road, but just the new 2016 fleet compared to the 2002 fleet when it was new.

[48] See the CARB mobile sources web page for links to its technical studies, http://www.arb.ca.gov/cc/ccms/ccms.htm.

[49] Some of these are cited and discussed briefly in Portney et al (2003).

[50] See, for example, O'Donoghue and Rabin (1999) and Tversky and Kahneman (1991).

[51] See Box 1 on p. 31 of "A Low-Carbon Fuel Standard for California, Part 1: Technical Analysis," August 1, 2007, available at http://www.energy.ca.gov/low_carbon_fuel_standard/UC-1000-2007-002-PT1.PDF. The report suggests that without the standard, the 13% increase in emissions would be a 25% increase.

[52] The argument is identical to that used with respect to the 1980s competition between Beta and VHS video recording tapes: many thought Beta was a superior tape, but VHS was entrenched first in all of the rental stores (like gasoline in gas stations) and discouraged consumers from buying Beta recording and playing equipment. Hydrogen-fueled cars might have a problem similar to Beta tapes, if new hydrogen-fueling facilities are necessary for it to be successful. Electricity may not raise this issue at all; indeed, to the extent that refueling can occur with little or no modification to the garages already in residences, it has the enormous advantage of freeing up many of the resources (e.g. land, storage tanks, pumps and metering devices) that we now devote to making safe gasoline stations.

[53] An excellent paper by Holland, Knittel and Hughes (2007) demonstrates that the LCFS is equivalent to a set of relative fuel prices that are inefficient. Efficient prices would discourage all fuel-burning that emits GHGs in proportion to the amount emitted. The LCFS however encourages rather than discourages the burning of fuels with below-average emissions. This problem would be mitigated by including motor

vehicle fuels in a cap-and-trade program. We note that the same logic applies to the renewable portfolio standard in electricity, a sector in which there appears to be consensus about applying both policies.

[54] Fossil-fueled electricity generation and gasoline both cause carbon emissions, but electricity when used to power vehicles is relatively efficient and produces fewer emissions per MJ. While average electricity in California is rated at only 27 gCO_2e/MJ, even electricity coming exclusively from existing coal-fired plants would be rated at 60-65gCO_2e/MJ, compared to 92 for gasoline.

[55] California IOUs have experimental rates and meters for a few low-emission vehicles that are holdovers from a 1990s-era policy that tried (unsuccessfully) to promote them. Future need for special vehicle meters is obviated (apart from the LCFS) by the smart meters being installed throughout the state referenced earlier in note 41. An alternative way for the LCFS to measure electricity input into vehicles would be by undertaking small random samples of electricity-using vehicle owners periodically, and using this as the default value applied to the number of registered vehicles in the electricity distributor's service area.

[56] The Clean Air Act specifies that a waiver is required for state regulation of mobile sources as a substitute for federal regulation. Mobile source regulation has been interpreted to mean motor vehicle regulation like California's AB1493, but not fuel regulation.

[57] See p. 8 of its "Draft Design Recommendations on Elements of the Cap-and-Trade Program," May 16, 2008, available at http://www.westernclimateinitiative.org/ewebeditpro/items/O104F17390.PDF.

[58] This does not mean that all parties in each jurisdiction are better off. Suppose the electricity scenario we described earlier is true: coal-fired plants are more expensive to reduce than gas-fired ones, so that in a cap-and-trade system limited to electricity the gas-fired plant owners are allowance sellers. It is possible that when this system links with one that includes vehicle fuel distributors in its allowance system, these distributors can reduce emissions more cheaply than the gas-fired plants and partially displace them as the allowance sellers. Total costs of achieving the combined jurisdictional emission reductions will go down, and most consumers in both jurisdictions will typically benefit from this, but those heavily dependent on the gas-fired plants may be worse off. There is nothing in this example that is special to cap-and-trade; it applies to all economic trading.

[59] See for example Haites and Mullins (2001), Bode (2005), and Sterk (2006).

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Appendix: The Mathematics of the Allowance Example

Let X_i^B = Baseline emissions from coal, source *i*
Let Y_i^B = Baseline emissions from noncoal, source *i*

Let X_i^C = Equilibrium emissions under a cap from coal, source *i*

Let Y_i^C = Equilibrium emissions under a cap from noncoal, source *i*

(1) Allowance distribution to source *i*: $.9(X_i^B + Y_i^B)$

(2) Number of bought allowances by source *i*: $X_i^C + Y_i^C - .9(X_i^B + Y_i^B)$

(3) No emission reductions from coal: $X_i^C = X_i^B$

(4) Cap at 90% Baseline: $\sum X_i^C + \sum Y_i^C = .9(\sum X_i^B + \sum Y_i^B)$

Using (3) to substitute in (4) and dividing by *n* to describe the average:

(4a) $\overline{Y}^C = .9\overline{Y}^B - .1\overline{X}^B$

Since some sources with coal emissions also have (usually minor) noncoal emissions, we have to know the size of the noncoal emissions cutback in order to predict the number of allowances bought to cover the coal sources. A simple assumption consistent with (4a), applied only to the small number of entities with emissions from coal-fired and at least one other noncoal source, is that the non-coal emissions level is reduced proportionately:

(5) $Y_i^C = Y_i^B(.9 - .1(\overline{X}^B / \overline{Y}^B))$

In our sample, n =139, $\sum X_i^B = 61.291$, $\sum Y_i^B = 54.87$, and thus (5) reduces to:

(5a) $Y_i^C = .688Y_i^B$

And thus (3) and (5a) allow (2) for coal sources to be simplified to:

(2a) Number of bought allowances by source *i*: $.1X_i^B - .212Y_i^B$

Equation (2a) is used on our baseline data to generate the buying distribution described in the text.

Table 1: Allowance Buyers are Concentrated when Emissions from Coal are Most Expensive to Reduce, Allowances are Distributed Freely Based on Historical 2004 Emissions, and the Cap is at 90% of the 2004 Emissions Level

Name	**Allowances Bought**	**Market Share (%)**
Southern California Edison	1,354,000	41
LA Dept. of Water & Power	533,000	16
Sempra (SDG&E)	359,000	11
Southern CA Public Power	304,000	9
City of Anaheim	168,000	5
Pacific Gas & Electric	154,000	5
CA Dept. of Water & Power	125,000	4
City of Riverside	97,000	3
Top 8 Buyers	3,094,000	94
Whole market	3,297,874	100

Figure 1: Efficient emissions reductions across the transportation sector and the electricity sector depend on the shape of their marginal cost curves for emissions reductions. For a cap that requires reductions of Q_c, the efficient allocation is achieved at the allowance price of P_c with the electricity sector providing Q_e emissions and the transportation sector $Q_c – Q_e$. If the same cap is achieved only through the electricity sector, the efficiency cost is shown by the shaded area.