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Rethinking Downstream Regulation: California's Opportunity to Engage Households in Reducing Greenhouse Gases

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Rethinking downstream regulation: California's opportunity to engage households in reducing greenhouse gases

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ABSTRACT

With the passage of the Global Warming Solutions Act of 2006 (AB32), California has begun an ambitious journey to reduce in-state GHG emissions to 1990 levels by 2020. Under the direction of executive order S-20-06, a mandated Market Advisory Committee (MAC) charged with studying market-based mechanisms to reduce GHG emissions, including cap and trade systems, has recommended taking an "upstream" approach to GHG emissions regulation, arguing that upstream regulation will reduce administrative costs because there are fewer agents. In this paper, we argue that, the total costs to society of a GHG cap and trade scheme can be minimized though downstream regulation, rather than the widely proposed upstream approach. We propose a household carbon trading system with four major components: a state allocation to households, household-to-household trading, households to utility company credit transfers, and utility companies to government credit transfers. The proposed system can also be considered more equitable than carbon taxes and upstream cap and trade systems to control GHG emissions from residential energy use and is consistent with AB32.

1. Introduction

To achieve sufficient near-term reductions in greenhouse gas (GHG) emissions, all aspects of the economy must become engaged (Pacala and Socolow, 2004; Romm et al., 1998), including the residential sector. This sector accounted for 21% of national CO_2 emissions in 2005, including those resulting from electrical generation (EIA, 2006a, Table 6), and constituted 13.5% of CO_2 emissions in California for 2004, the most recent year from which data are available (CEC, 2006 and EIA, 2006b). California's reduced reliance on coal for fuel and its per capita electricity consumption, which is the lowest in the US (CEC, 2007), all contribute to a lower proportion of total state emissions. However, by 2030 demand for power in California is expected to increase 52% as population rises to 50 million from 32 million in 2003 (Budhraja et al., 2003). Since the mix of fuels used to generate electricity dictates the carbon intensity of home electric usage, any changes to the mix will also affect household GHG emissions.

There are generally two regulatory options for GHG emissions control: command and control regulations or market-based measures. The former comprises, for example, emissions targets and technology mandates, while the latter includes measures such as emissions taxes and tradable allowance programs. Traditionally, the choice between the two has been posed as either an emissions tax or command and control regulation. Economists, led by Pigou (1920), argued for the use of taxes that would modify the price of emitting activities to include externalities associated with the resulting pollution, correcting an apparent market failure and resulting in the optimal level of production and consumption. Often regulators do not have the required information to set the tax rate at the optimal level, and have thus traditionally favored command and control approaches (Tietenberg, 2006). Additionally, taxes are considered politically difficult to implement, particularly in the United States where a general antipathy to increased government revenues exists.[1]

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[1] Contradictory findings exist about apparent current declines in anti-tax sympathies. A recent poll (Americans' Evaluations of Policies to Reduce Greenhouse Gas Emissions"—June, 2007) carried out in conjunction by researchers at the New Scientist Magazine, Stanford University and Resources for the Future, shows, in line with the American's historical opposition to energy taxes, that respondents rank taxation lower compared to other climate policies. However, surveys by the New York Times ("Americans Are Cautiously Open to Gas Tax Rise, Poll Shows" released on 02/28/2006), and the Massachusetts Institute of Technology (sequestration.mit.edu/research/survey2006.html) among others, reveal new support for energy prices increases, provided these would help in reducing climate change.

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Properly applied, the taxation rate would also have to be adjusted fairly frequently in order to promote increasing reductions in GHG emissions, with each adjustment subject to additional political pressure. A flat tax would also be regressive, but this could be mitigated by providing credits or refunds that could be returned to low-income households (Fleming, 1997). Command and control approaches also have drawbacks. They are often inefficient in the sense that they do not result in mitigation at the lowest societal cost, and inequitable since they treat everyone similarly and limit innovation by specifying what can and cannot be done (Stavins, 2003).

An alternative approach, but similar to command and control, is the promotion of household energy efficiency through various measures such as replacement subsidies and appliance efficiency standards. As a result of these measures, household energy efficiencies have improved, but are juxtapositioned against increasing demand for services from appliances; the number and size of appliances in use, along with increasingly larger homes, have more than erased historical efficiency gains (Moezzi and Diamond, 2005). There is also a paradox in that increased appliance efficiency reduces the usage cost, which may in turn increase its use, and therefore carbon emissions (Greening, Greene et al., 2000). Tradable emissions allowances appear to alleviate the concerns with both taxes and command and control regulation and are now receiving broad support for controlling GHG emissions.

Tradable allowances are based on the ideas of Coase (1960), who suggested that a better way to deal with actions that cause harmful effects on others would be to consider the rights to perform those actions as factors of production, clearly defining the respective property rights. Dales (1968) explicitly proposed a system of auctioned property rights for the use of natural resources as an alternative to effluent charges, and Montgomery (1972) provided the theoretical underpinnings of its economic-efficiency properties. For example, consider the US sulfur dioxide (SO_2) allowance trading system under which a coal-fired power plant must own or purchase allowances representing the right to pollute the air with a unit of SO_2 in order to produce electricity. By placing a cap on the number of allowances provided (or sold) to firms and reducing this cap over time, the government controls the aggregate amount of emissions and can gradually achieve reductions, allowing time for regulated entities to adapt, and for new technology to develop. Firms that value the allowances greatest, or those that have the highest emission reduction costs, can purchase additional allowances from firms that value the allowances less. Under this type of regulation the marginal cost of compliance can be minimized and equalized across firms without the regulator requiring detailed information since the market in allowances determines the price (Ellerman, 2000; Tietenberg, 2006). Cap and trade schemes are a unique incarnation of tradable allowances, combining an upper limit on total emissions with the ability to trade between emitters.

The US SO_2 trading program has been widely viewed a success, lending credence to cap and trade's current support (Ellerman, 2000). The European Union Emission Trading Scheme, Chicago Climate Exchange, and the New England Regional GHG Initiative all use cap and trade systems to reduce GHG emissions. With the passage of the Global Warming Solutions Act of 2006 (AB32), an ambitious bill seeking to reduce in-state GHG emissions to 1990 levels by 2020, California has also begun to seriously examine the implications of using a cap and trade system for mitigating GHG emissions.

Under the direction of Governor Schwarzenegger (executive order S-20-06), the Secretary for Environmental Protection created a Market Advisory Committee (MAC) charged with studying market-based mechanisms to reduce GHG emissions, including cap and trade systems. The MAC recently issued a final report outlining guidelines for designing a GHG cap and trade system for California with basic framework goals of supporting certain types of GHG reductions, and ensuring cost effectiveness, equity, and simplicity (MAC, 2007). Two options for implementing a cap and trade system in California, both covering 83% of the GHGs emitted in the State, were recommended. The first would initially cap GHG emissions from electricity generation and large industrial sources with the intention that the cap would be expanded over time to include petroleum refiners and natural gas distributors. The second option would cap GHGs from petroleum refining and both in-state and imported natural gas production.

These recommendations generally represent an "upstream" approach to GHG emissions regulation. The stream in this case is the chain of economic activity from production to consumption with upstream referring to activities closer to the point of production. The MAC argued that upstream regulation would reduce administrative costs because there are fewer agents, while regulating further downstream might increase liquidity in the permit market because there would be more entities that could be engaged in the trading with more cost-effective options to reduce emissions. Moving as far as possible downstream, to consider end users (individuals), with arguably the widest range of options available to reduce emissions, was not considered. This is not surprising, since the approach taken in the extant GHG cap and trade schemes has been to regulate upstream emitters: power plants, petroleum refiners. and other large industries (Ellerman, 2000; Tietenberg, 2006). In this sense, the MAC's recommendations follow a well-established pathway. Placing a cap on upstream energy generators or distributors will encourage the reduction of carbon intensity and a reduction in emissions. However, it is clear that in order to achieve the large, durable, and efficient reductions required to address climate change, the social barriers to downstream efficiency and conservation must be addressed (Fleming, 1997; Fawcett, 2005); ultimately, it is the actions of individuals that drive production and the associated GHG emissions.

In this paper, we outline a household GHG cap and trade (HHCT) system, which exploits the economic efficiency, environmental effectiveness, and equity benefits of a tradable permit system and downstream regulation at reasonable implementation costs. As designed, the system would also partially deal with ethical and equity concerns embedded in the traditional upstream regulation where freely distributed rights, and thus scarcity rents or windfall profits (Burtraw et al., 2002), are given over a global and inter-generational resource (Goodin, 1994; Azqueta and Delacamara, 2006). We address equity and environmental justice concerns by considering the distributional impacts of different permit allocation schemes on low-income and under represented groups. The temporal and geographic variability in the GHG intensity of California's energy supply also presents issues, and these are addressed in the system design.

2. Regulating downstream

From an economic perspective, an upstream cap can promote GHG emissions reductions through increased energy prices, which in turn reduce demand or increase the supply of less carbon-intensive fuels. However, the increases in energy prices required to affect consumer behavior are likely to be large and their impacts inequitable (Fleming, 1997). For example, a lower-income household will bear a greater financial burden as a proportion of total earnings than a higher-income household if energy prices increase (Fawcett, 2005). This would lead the former to consider reductions in consumption more readily than the latter household

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if no fiscal compensation scheme is in place. To mitigate these effects, the downstream end user who has direct control over their own actions can become the point of regulation (Roberts and Thumim, 2006).

There is also a strong argument supporting downstream regulation in order to increase economic efficiency, which involves the total costs imposed on society resulting from GHG abatement. Variability in behavior (i.e. consumption of goods and services) between similar households, with respect to household size, type, and location, can lead to very different carbon emissions (Baker, Hartzheim et al., 2007). Despite the fact that upstream cap and trade schemes are typically considered to result in the most efficient abatement of GHG emissions, in order to produce the most efficient reduction in GHG emissions there must also be significant demand side reactions, exploiting some other low-cost conservation paths to reduce energy use, which are not likely to be induced solely by price variations.

At the household level, consumers tend to be more likely to optimize when they know how much energy they are consuming and what options, along with associated costs, are available to them to reduce consumption. Darby (2006) found that providing direct energy consumption feedback with an in-house display resulted in reductions in household energy consumption between 5% and 15%. Indirect forms of feedback, such as detailed billing statements, resulted in up to a 10% reduction. Similar energy savings have been reported in appliance studies in which an energy reduction goal along with direct feedback produced energy savings of 21% over users having no goal (McCalley and Midden, 2002). Given these findings, it is unlikely that most households currently have the required information and knowledge to make decisions that might lead to sustainable demand reductions (McCalley and Midden, 2002; Darby, 2006).

The HHCT system proposed in this work would provide the necessary feedback and extends the scheme first articulated by Fleming (1997) and recently expanded upon by several researchers in the United Kingdom (see Fawcett, 2004; Starkey and Anderson, 2005; Roberts and Thumim, 2006). Fleming's (1997) system of "tradable quotas" with carbon allowances distributed to end users of energy includes free distribution to individuals and a tender (auction) process where business and government organizations must purchase quotas. The tradable quotas are used when purchasing energy in the form of electricity or transportation fuel where they are transferred upstream to energy service providers and ultimately to generators who must turn over the quotas to the regulator. Fleming (1997) argues that such a strong signal is required to promote behavioral change in order to take full advantage of end user efficiency and conservation. Though a carbon tax could accomplish this, he argues that the measures needed to address its regressive impacts would be more costly than administering a tradable quota program and that an equal distribution of quotas to individuals is more equitable than an equivalent tax.

Starkey and Anderson (2005) and Fawcett (2004) expanded the scope of Fleming's system by including air travel under schemes labeled as Domestic Tradable Quotas and Carbon Rationing, respectively. Fawcett (2004) only considers individual carbon allowances, while Starkey and Anderson (2005) consider all end users. When compared to the UK national identification card, an individual trading system is technologically feasible, but likely to exceed administrative costs that are realized with other methods to reduce emissions (Starkey and Anderson, 2005).

3. A California household GHG cap and trade system

In devising the HHCT system outlined below, we have kept within the ambitious nature of AB32 while envisioning a workable policy that could provide the required emissions reductions. The HHCT cap would be set on GHG emissions resulting from the production of electricity and supply of natural gas to the residential sector in California. Allowances would be distributed to households and used to pay a GHG charge imposed by the utility service provider to cover GHG emissions. At the end of a compliance period, the state would collect the permits from the utilities and determine compliance with the cap.

Under this system, the regulatory costs would not change from the proposed upstream cap and trade systems, including those proposed by the MAC. Utilities would, however, be tasked with enforcing the cap on households through GHG charges. This additional task could be integrated into existing billing systems and facilitated by existing customer service expertise. Distributing the permits downstream, to households, encourages efficient behavior by explicitly linking energy consumption with GHG emissions and providing a goal to keep emissions under available allowances, features not apparent in upstream systems. Allocating GHG permits to households also imparts a degree of fairness by providing all households with a stake in the future of the climate.

For our purposes the path of GHGs embodied in energy begins at the large power generators and natural gas suppliers (Fig. 1). Fossil fuels and other feedstocks are used by generators to produce electricity, which is then distributed to municipal utility service providers across the state who in turn provide residential electricity. Natural gas follows a similar path. The life cycle of carbon allowances within the proposed trading system begins with the setting of a yearly cap on carbon emissions derived from residential energy use and based on the emissions reduction targets specified by the California Air Resources Board (CARB) for AB32 compliance. Once the cap is set, CARB determines the number of allowances to allocate to each household (represented by utility account holders). The carbon allowances are then provided to utility service providers who place the allowances in each user's account.

The carbon allowances will be fully tradable between households. At the end of each month, households receive their regular utility bill informing them of how many carbon allowances they owe for that particular month. At the end of the year, the state (in California, CARB) collects the carbon allowances from the utility service providers and verifies that annual carbon emissions equals the amount of carbon allowances collected. If the amount of emissions and collected allowances do not balance, then appropriate actions and fines will be issued to the utility service provider. The process would continue the next year with a lower cap put in place by the state.

The proposed HHCT system has four major components that must work in concert for the larger system to be effective: state allocation to households, household-to-household trading, households to utility company credit transfers, and utility companies to government credit transfers. Each of these is discussed in more detail below.

4. State allocations to households

CARB will determine an allocation of GHG allowances to each household based on the AB32 goals, with households represented via their utility account. Allowances will be given to the utilities, as determined by their number of customers, and the type of utility service they provide (i.e. gas vs. electricity). Utilities then distribute the proper amount of allowances to user accounts as dictated by the allocations set by CARB. Since each household already has an account with a utility provider the existing infrastructure can easily be used to facilitate the HHCT system. The utility account would then double as a carbon allowance

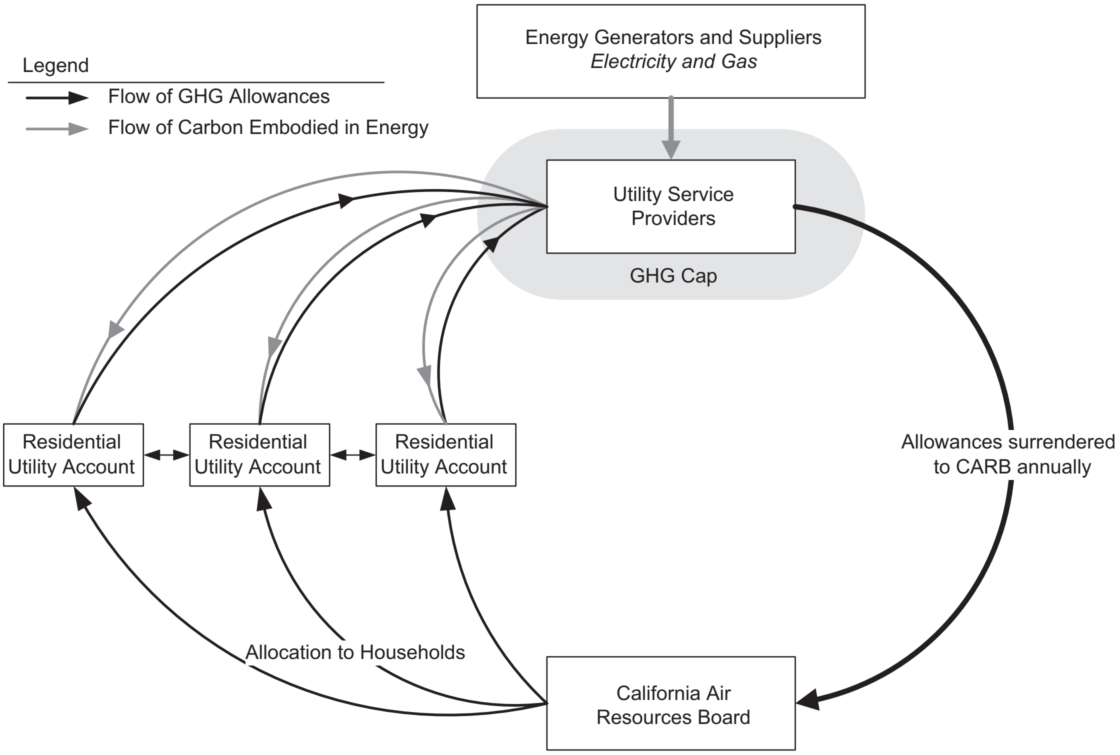

Fig. 1. Overview of California household GHG cap and trade scheme.

account. The owner of the account would have complete control over these allowances even though the account is set up through the utility.

Over time there will be a gradual reduction of the number of allowances that the state distributes. The goal would be to curb emissions to 1990 levels by 2020, as stated in AB32. Given a stable energy mix this would come about by a reduction of roughly 20% to the total initial allowance count. Reducing the allowances in the system will motivate households to find ways of reducing their electrical use or to trade with other households to obtain enough credits to cover their emissions.

4.1. *Household-to-household trading*

At the household level, we envision a system where households would be able to trade carbon allowances. Account holders who have available allowances from conservation or efficiency gains would be able to sell them, and likewise, account holders with energy expenditures in excess of allowances would be able to buy additional carbon allowances. At the end of the month end, unused allowances would carry over to the next.

Trading carbon allowances between households is a key component of the proposed system. Although no one is forced to sell allowances in a trading system, one would gain financially if they chose to do so. While it may be easier for wealthier households to buy additional allowances while continuing to emit at a higher rate, poorer households would have the ability to sell allowances, with a net change in assets.[2] According to economic theory, trading results in an overall cost reduction since the price of allowances determines which conservation and efficiency measures go forward, with only those less expensive than an additional allowance being undertaken (Tietenberg, 2006; Fawcett, 2004).

An additional benefit is that household-to-household trading is progressive, whereas a carbon tax is regressive. Under a HHCT scheme, lower-income households would receive a greater financial benefit than higher-income households since lower-income households would on average have excess allowances to sell. Tradable allowances have also been shown to have advantages over command and control strategies. For example, improved environmental performance and economic efficiency were observed from the US SO_2 program and the Lead Phasedown (Carlson et al., 2000; Ellerman et al., 2000; Stavins, 2003). With full control of allowances, and thus increased awareness of their own carbon emissions, households may be more proactive in conservation efforts. Starkey and Anderson (2005) suggest that, in addition to the benefit of lowered emissions, individuals may realize that their actions can make a difference in the greater effort to mitigate climate change impacts; this positive feedback has the potential to produce additional emission reductions.

4.2. *Households to utility company*

At the end of each billing period, households will be required to “pay for” their carbon emissions with their permits. This carbon billing system will operate simultaneously with the utility power and natural gas billing system as mentioned above. Utility customers will pay their bill with both dollars for the energy used and carbon allowances for GHG emissions. Linking the carbon billing system with the already developed utility billing systems will allow for a user friendly, familiar household billing system. A similar method was proposed for transportation fuel purchasing, citing that the transaction would be virtually indistinguishable from current purchasing methods involving debit cards (Fleming, 1997).

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[2] Higher-income households consume more energy but spend less to purchase it as a percentage of their income compared to lower-income households (see Table CE1-3e of the Residential Energy Consumption Survey 2001 at www.eia.doe.gov/emeu/recs/). The former would be more reluctant to change their energy-use patterns given the low cost associated with preserving them.

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A typical payment would begin when the customer receives their utility bill for the previous month's usage, clearly displaying both GHG emissions as well as their current balance of allowances. Balances will carry forward to the next month at no penalty. Customers who do not have adequate allowances to pay the bill have until the due date to purchase additional allowances from the market. Failure to pay the carbon balance will result in measures similar to those resulting from failure to pay for utility usage. Each utility provider would determine their own enforcement mechanisms that could involve late fees, fines to cover the utilities expense of purchasing allowances for the household, or eventual discontinuation of service. Additionally, current allowances may be used to cover past shortfalls but each kg of shortfall will be paid at a higher rate (e.g., 1.5 allowances instead of 1). Since penalizing customers for non-compliance comes under the jurisdiction of the utility companies, the need for CARB to regulate individual households is removed.

4.3. *Utility companies to government*

At the end of each year, utility companies submit permits to the governmental regulatory body, in this case CARB. The sum of the permits reported must equal the sum of all residential (or commercial if the system is expanded) GHG emissions generated by the utilities. Utility companies that fall short may either buy extra permits on the market if possible or pay a fine. If the companies properly set up their penalty system for non-compliance, this fine would be at least partially paid with the fines collected from households. Audits and fines would ensure the integrity of the system.

5. Discussion

There are a number of benefits and uncertainties associated with using a household cap and trade system. Here, we discuss the equity and effectiveness of the HHCT system, which in turn affects public acceptability and political feasibility—essential considerations in practical policy design. We also qualitatively compare the effectiveness of the HHCT system to other types of regulation. Finally, we elaborate on how the HHCT system can work in concert with other climate change policies that are expected to be part of California's plans to mitigate climate change impacts, and how it could evolve over time to become integrated with other cap and trade systems to increase economic efficiency (MAC, 2007).

To give context to our discussion, we have developed several scenarios using data from the 2001 Residential Energy Consumption Survey (RECS). The survey is periodically conducted by the US Energy Information Administration, with 2001 being the most recently available. The survey data are collected using in-house interviews and cover all aspects of household energy consumption and expenditure. It is a nationally representative area probability sample containing 4822 observations, with additional data for the four largest states, including 541 observations in California. The plots shown in the following discussion use sample weights provided with the RECS survey data to estimate the distribution of permits to different types of households.

For our analysis we assume an emissions cap that is 20% below the current levels of household GHG emissions resulting from electrical power and natural gas consumption. We chose this level because it represents a desired end result since California must lower future statewide GHG emissions by approximately 25% to comply with AB32 (AB32 Fact Sheet, 2006). It may be the case that other sectors could, at least initially, make larger reductions in GHG emissions for less cost, but a starting point of 20% is reasonable, given uncertainties and our purpose in showing the implications in terms of equity and effectiveness.

An important policy consideration is the initial allocation of allowances to households. There are several methods for initial permit allocation: auctioning and free allocation, which can then be made by historical use or some other metric. Auctioning of permits has some attractive attributes: providing a new stream of revenue which could be used to reduce other distorting taxes providing a so-called "double dividend" (Ellerman, 2000; Tietenberg, 2003); eliminating a disincentive to new entrants, a problem associated with historical allocations (Tietenberg, 2003); and preventing gaming of the system, which is possible with free allocation based on historical use (Tietenberg, 2003). However, in practice free allocation to historical users is more common because it is usually necessary to gain some support from those being regulated (Ellerman, 2000).

Under the HHCT system, we expect that allowances would be allocated for free, at least initially, since the public will likely be reluctant to pay for something they previously received at no cost. Thus, the initial allocation of allowances to households can potentially redistribute income, influencing policy equity. In the individual carbon permit systems proposed by Fleming (1997), Starkey and Anderson (2005), and Fawcett (2004), permits are allocated on an equal per capita basis. The rationale behind this approach is one of simplicity and an egalitarian sense of fairness. Permits could be allocated by historical energy use, for several reasons we view this as unfavorable. First, under the proposed HHCT system permits are allocated by historical use—to the housing sector, and then distributed equally to households. We find no reason to justify why one person should receive a larger allocation based on historical use as the basic needs for a person are essentially the same for everyone (an argument can be made for local climate which we address later). When considering firms as opposed to households, the "needs" of each could be quite different depending on what they produce; therefore, an allocation based on historical use may be more favorable. Additionally, allocations based on historical use may present equity issues for low-income households and could prove difficult to implement given the continuous turnover of the housing stock. Under our proposed HHCT system, equal per capita allocation is not possible since the regulator currently has no way of knowing how many individuals live in each household. Instead, we consider several alternative allocation schemes to approximate an equal per capita allocation.

The first, which we focus on and consider preferable, is an equal per household allocation. An equal per household scheme is simple since it requires no specific information about the household. The second and third schemes rely on a household weighting scheme by the number of bedrooms and the total square footage, respectively, which serve as proxies for the number of residents. In the final scenario, we consider an equal per capita distribution in order to compare the results of the proposed HHCT system with those of an individual cap and trade system.

5.1. *Equity*

We considered equity in four forms: vertical equity, which refers to the equal treatment of people in different groups; horizontal equity, which calls for the equal treatment of equals, that is two agents having the same preferences should be treated equally (Fleurbaey and Maniquet, 1997); distributional equity, the consequences across individuals and groups; and finally, using the

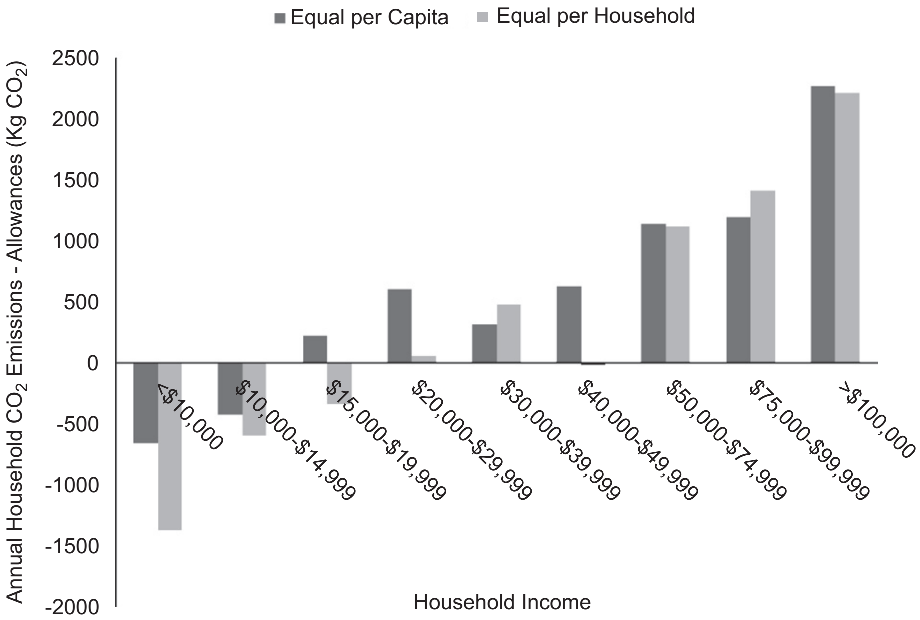

Fig. 2. Median household initial allowance balance by household income.

ethical and philosophical consideration of fairness, which here represents the fairness associated with carving up the rights to emit GHGs and distributing them to individuals. All four perspectives, while not exhaustive, are important because policies that appear equitable under one measure may not be under another. Similarly, addressing one type of equity may worsen another type (Litman, 2007).

First, consider the impacts of a HHCT system on different income groups under two types of allocation systems. In Fig. 2, the horizontal axis groups households by income level and the vertical axis indicates the range of values for the difference between annual household GHG emissions[3] and annual allowances. Positive *y*-axis values indicate additional allowances are needed and negative values indicate a surplus of allowances. When we consider the total allowance balance by income group for equal per household and per capita allocation schemes, we find that in both cases lower-income groups generally receive more than enough allowances to cover emissions, while higher-income groups would require additional allowances. In other words, both allocation strategies seem to be progressive with the equal per household case being the most progressive.

It is important to note that this allocation result is in the aggregate, and as both Fawcett (2005) and Starkey and Anderson (2005) point out, some low-income households will almost certainly be made worse off. Providing tax credits or subsidies to help pay for additional allowances or programs to improve the energy efficiency of low-income households can help to partially offset this impact. Another approach would be to over allocate to low-income individuals (or households in our case) (Fawcett, 2004). This would obviously alter the notion of equal rights to emit GHGs. It is also unclear that over allocation, which would add substantial complexity to the allocation scheme, provides any additional benefit over the ability of a tax credit or subsidy to help offset inequities. Financial resources required to fund these subsidies could be obtained within the system by applying a transaction fee per carbon allowance purchase, or directing to these purposes a fraction of the non-compliance penalties and fines collected.[4]

Given the inherent progressive nature of the equal per household allocation, major distributional issues do not arise. Assuming that the expected value of a carbon allowance is similar to the current trading price of allowances on the European Climate Exchange, presently at about $35 per tonne of carbon dioxide equivalent,[5] it is unlikely that the amount higher-income households would pay to acquire additional allowances constitutes a significant burden. For example, taking the European Climate Exchange price, approximately 25% of households making over $75,000 annually would need to purchase (or otherwise reduce energy consumption) around 1000 carbon allowances (for the purposes of our analysis, each taken as equal to 1 kg of CO_2), which would constitute less than 0.05% of their annual household income.

Allocation of allowances to households is potentially problematic because an equal number would be provided to each household irrespective of the number of occupants. For example, consider two similar households with a different number of occupants. On average, the household with more occupants will consume more total energy, but less on a per capita basis (Fawcett, 2005; O'Neill and Chen, 2002). Allocating allowances equally to every household will make larger households worse off even

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[3] GHG emissions estimates include household electric and gas consumption of CA households in the 2001 RECS survey. Average carbon emission factors were used to estimate CO_2 emissions from the 2001 RECS consumption data. For electric consumption a factor of 0.108 KgC/KWh was used and for gas consumption a factor of 0.0149 KgC/ft^3 was used. The conversion factor of 0.27 KgC/KgCO_2 was used to estimate the mass of CO_2 emissions. The average emission factor for electric consumption and the carbon conversion are from Marnay and Fisher et al. (2002). Estimating Carbon Dioxide Emissions Factors for the California Electric Power Sector. Berkeley, Ernest Orlando Lawrence Berkeley National Laboratory. The average emission factor for gas is from the US EPA and is available online at http://www.epa.gov/appdstar/pdf/brochure.pdf.

[4] If private firms are allowed to set up market places that charge transaction and member fees, resources could be collected from these businesses' income taxes.

[5] From www.ecxeurope.com the price of December 2008 permits was 23.35€ per tonne for October 2007. The 4-year second phase of the European Union Emission Trading Scheme starting in 2008 is expected to observe much higher levels of permit scarcity, hence driving up permit prices from their currently almost zero 2007 value.

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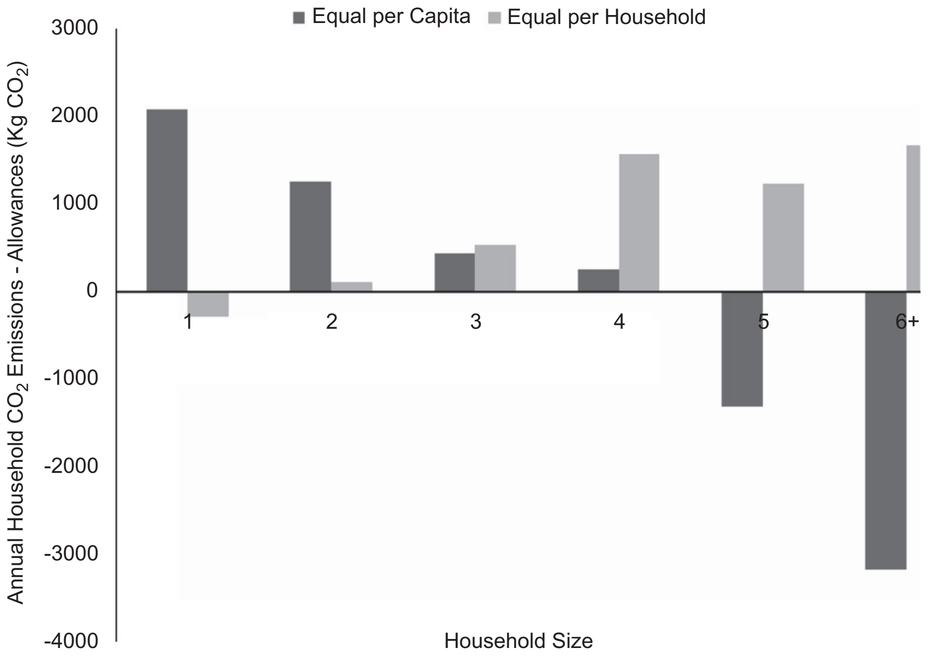

Fig. 3. Median household initial allowance balance by household size.

though they are responsible for fewer emissions on a per capita basis (Fig. 3). With an equal per capita allocation (Fig. 3) the opposite occurs—smaller households do not have enough allowances, while larger households have an excess.

Although an equal per capita allocation is attractive from an egalitarian point of view, this is not the only consideration in terms of fairness. Every household requires some baseline amount of energy independent of the number of residents. For example, base heating and cooling requirements are largely independent of the number of occupants. With this in mind, it can be argued that since households with fewer residents emit more carbon per capita, it is equitable that they must purchase extra permits in order to encourage a demand reduction. This of course assumes that individuals have the ability to choose their living situation, which may not be true. It is also unlikely that most people would form larger households in order to achieve economies of scale. Therefore, while larger households are less carbon intensive on a per capita basis, this does not suggest that it would be equitable to under allocate allowances to smaller households.

The impact of the allocation scheme on historically underrepresented groups is also an important consideration in policy analysis. An equal per household allocation treats each racial group approximately the same, while the equal per capita allocation places more burden on whites and blacks (Fig. 4).

In addition to race and income, we also considered equity from the perspective of residential location and climate zone. Urban residents, with greater numbers of multi-unit housing and generally smaller residences, will tend to have an excess or small shortage in the number of allowances, while suburban and rural residents may tend to have a larger shortage (Fig. 5). California has a wide variety of climate zones. Heating and cooling degree days provide a measure of how often and to what extent a location requires energy to maintain thermal comfort. Under the proposed HHCT system, most households are equitably allocated allowances (Figs. 6 and 7). However, households in climate zones, which are extremely hot or cold, may not have enough allowances to cover emissions. One solution to the extreme weather issue would be to subsidize energy efficiency measures such as increased insulation and modern heating and cooling systems in these regions.

The spatial distribution of households across the state and the energy mix changes that occur across seasons also introduce equity considerations. The GHG emission intensity of electricity is typically higher in the winter months when hydroelectric power generation is limited, and in Southern California where more coal-fired power plants are located and hydroelectric power generation is naturally limited. When considering the distribution of allowances to households across the state, the variation in carbon emission intensities is problematic. That is, households should be able to estimate a GHG budget so that they can make informed decisions to buy or sell allowances and to engage in behavioral changes. However, if the GHG intensity of electricity delivered to households varies from month to month, it will be difficult to budget allowances, and awareness of savings from conservation and energy efficiency investments is likely to diminish. One means of countering this problem is to distribute allowances to households on a monthly basis, where the number of allowances distributed varies each month in accordance with the expected GHG emission intensity of electricity. While this would help prevent households from unexpected shortfalls in allowances, it would not help with household budgeting.

While the seasonal variation of GHG intensity reduces the effectiveness and efficiency of the HHCT system, regional differences in GHG emission intensities negatively affect the equity of the policy (Figs. 6 and 7). Households generally have only one option for electrical power service unless they are willing to generate their own. Therefore, it would be inequitable to distribute household allowances equally across the state when GHG emission intensities are not similarly distributed. Under current conditions, allowances in Northern California would cover more electricity than an equivalent number of allowances in Southern California. However, in this case, the problem is not at the household level, it is associated with the power generators and suppliers. One possible solution would be to distribute allowances to households based on their electric power provider in a way that accounts for the differences in GHG emission intensities. While this would solve the equity problem, it would

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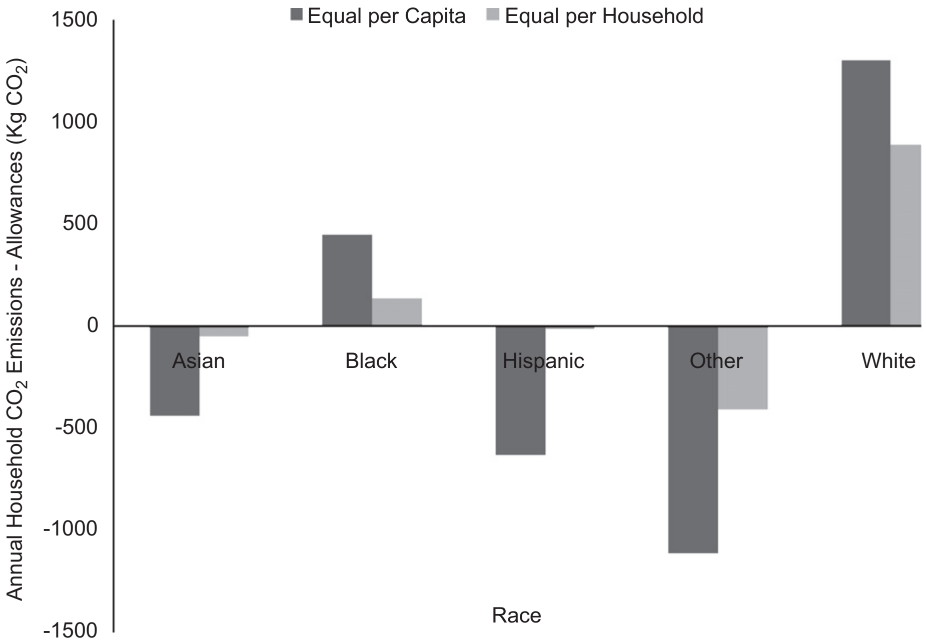

Fig. 4. Median household initial allowance balance by race.

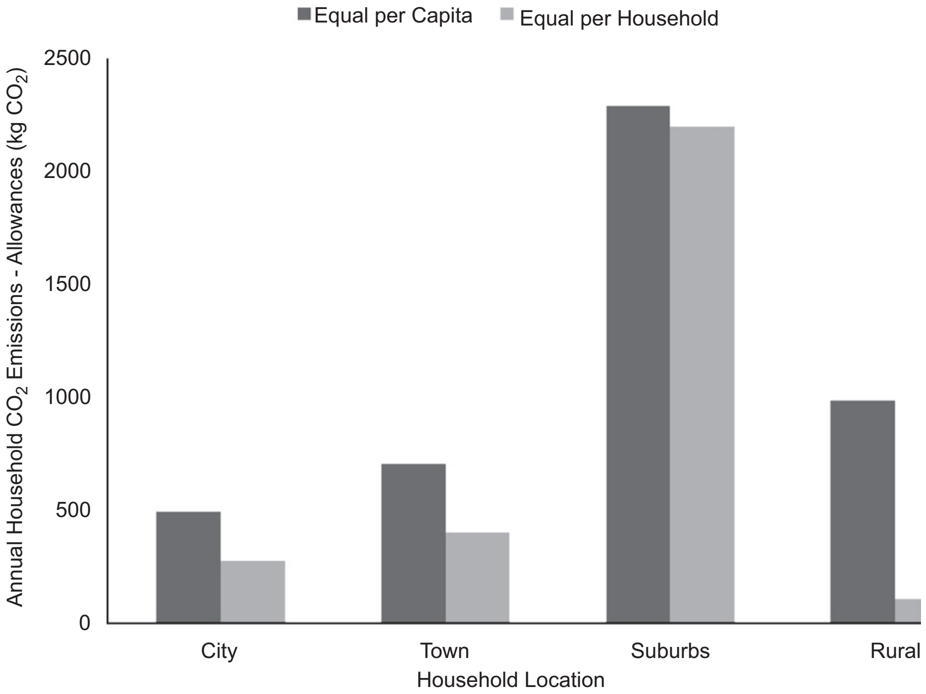

Fig. 5. Median household initial allowance balance by location.

do little to change the GHG emission intensity of the power supply. The customers of the least efficient utilities would have more allocations to turn over to the utility, providing little incentive for change.

A simple extension to the HHCT system, the use of utility-to-utility allowance trading, can solve both of the above problems (Fig. 8). To remove seasonal and regional variations, the rate (kgC/kWh) charged to households should be set to the annual average GHG emission intensity of power produced for residential consumption in California. Every household in California would then be charged the same GHG rate every month, with periodic changes as utilities alter fuel sources and decommission old and open new power generation facilities. Under this scenario, some utilities will have excess allowances, while others will experience a shortfall, as shown by the flow of permits from households to utilities. Utilities with excess allowances would be free to sell them to utilities with a shortfall. Not only does this address the efficiency and equity of the household cap and trade system at the household level, but it also reinforces the incentive for utilities to reduce their GHG emission intensity.

This analysis has shown that it is possible to establish a HHCT system that can be equitable. When this system is compared to an

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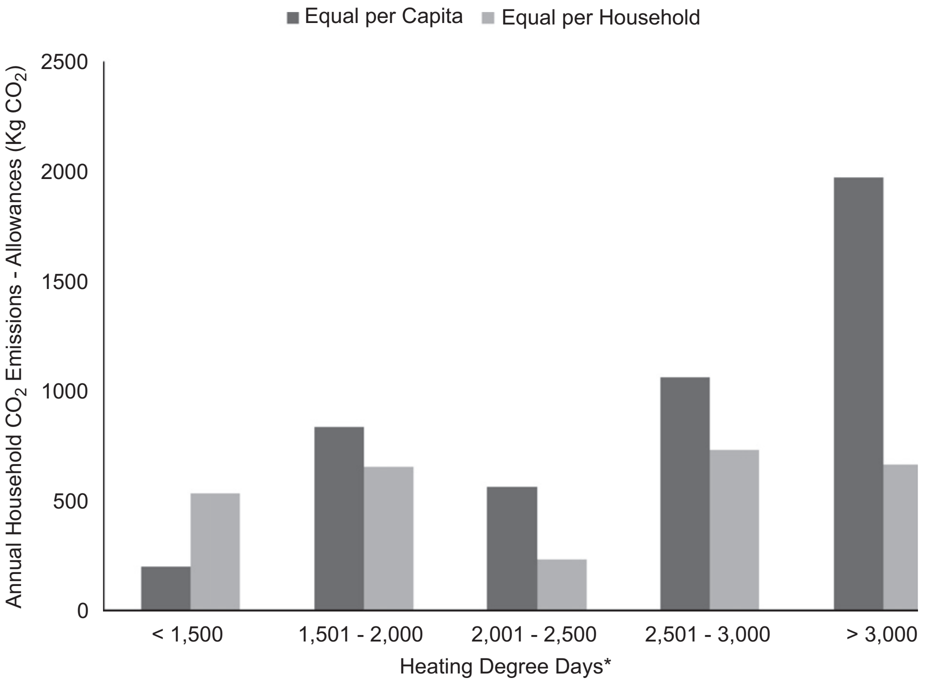

Fig. 6. Median household initial allowance balance by heating degree day. *A climate measure: the sum over all days of the amount by which the daily average temperature is above 65°.

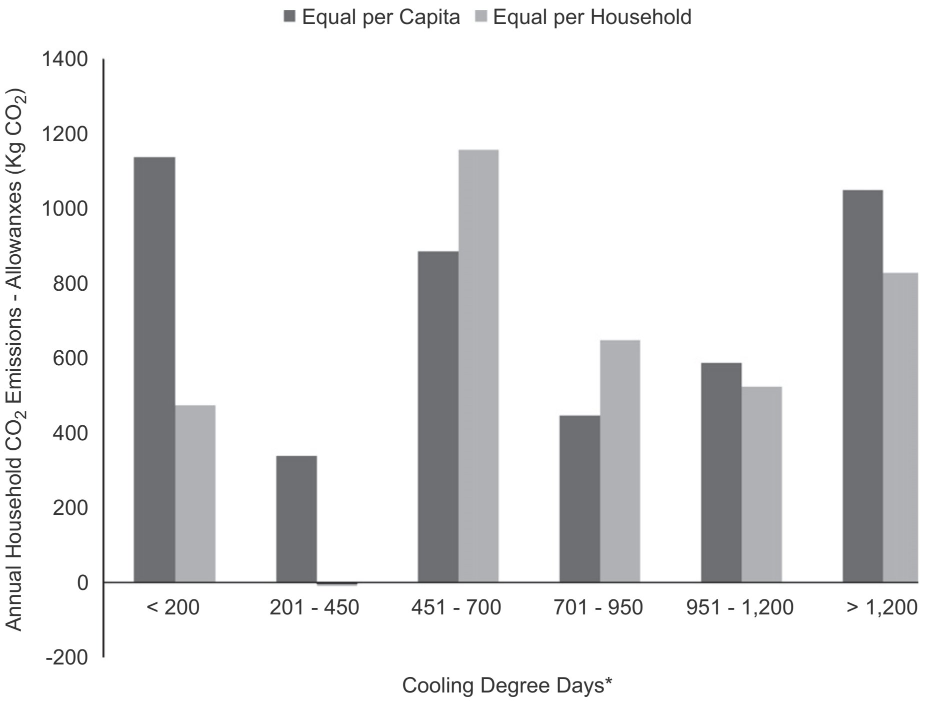

Fig. 7. Median household initial allowance balance by cooling degree days. *A climate measure: the sum over all days of the amount by which the daily average temperature is below 65°.

equal per capita allocation, which has been argued for by others on grounds of an egalitarian view of fairness and simplicity (Fawcett, 2004; Starkey and Anderson, 2005; Roberts and Thumim, 2006), the household cap and trade system appears more equitable by most measures, at least for California. In the aggregate, the system is more progressive as low-income households receive allowances in excess of their carbon emissions, while high-income households do not receive enough. However, the additional financial burden placed on these high-income households is likely to be small.

5.2. *Integration with a global carbon market and AB32*

AB32 mandates that GHG emissions in California be capped at 1990 levels by 2020. Other regions have adopted similar GHG

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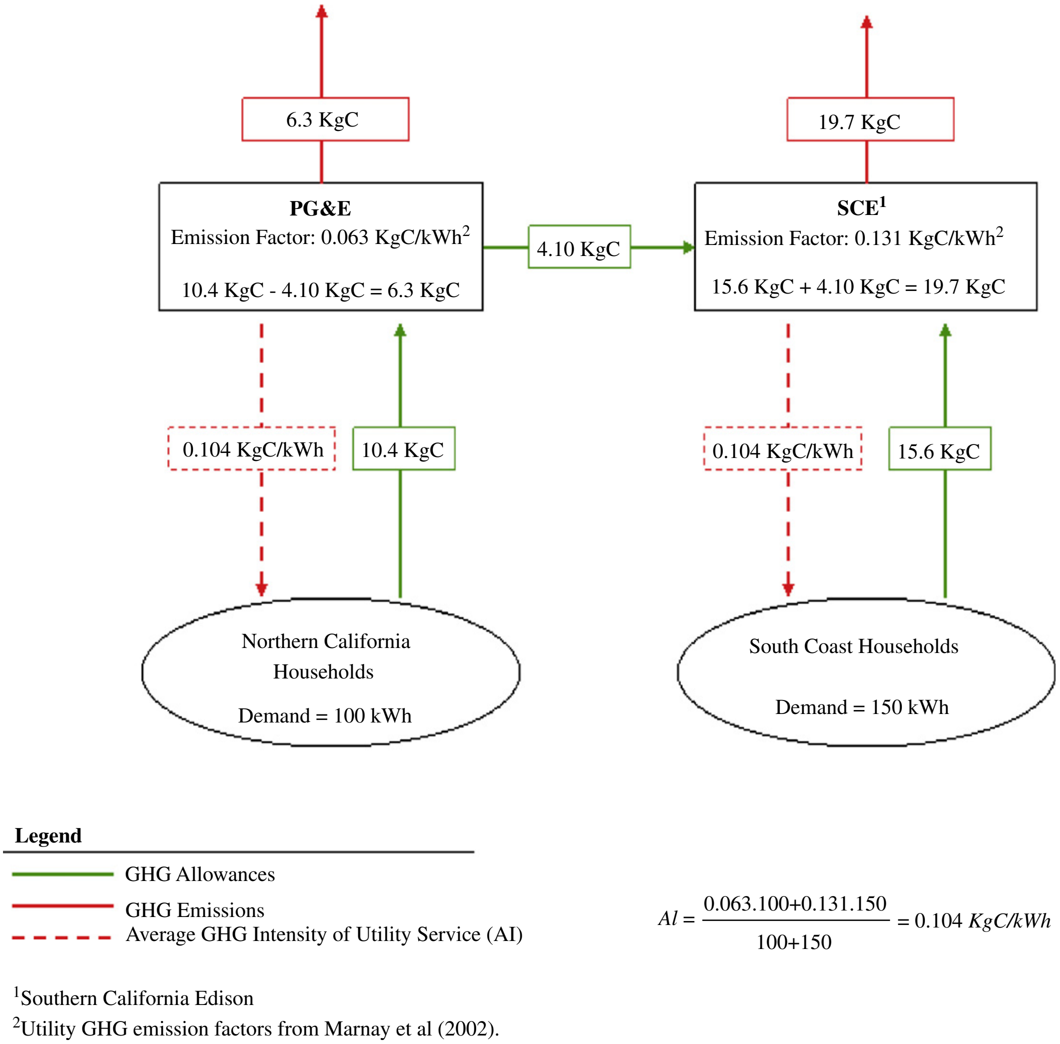

Fig. 8. GHG charging and utility–utility trading.

emission caps as well. There is potential to integrate each of these programs (as well as future programs) into a global carbon market, thus increasing the overall cost effectiveness and benefits to society. Before such integration is possible, however, consistency issues must be addressed.

While it does not necessarily matter which sectors are covered under a cap and trade system as long as the caps are enforced, or whether the regulations are upstream or downstream, some design features must be standardized to allow trading between different systems (Ellerman, 2000). The first is penalties. Each system must adopt the same penalties for non-compliance. Otherwise the lowest penalty dictates the penalty for the entire system since the allowances are tradable. Second, there must be agreement over the use of offsets. Again, if one system allows offsets, all systems will be able to take advantage of them. Third, there must be agreement over how to enforce the integrity of the system. Inadequate enforcement, particularly verification that firms selling allowances have actually reduced or accounted for emissions, reduces the integrity of the entire system. Fourth, caps must be below current emissions, otherwise the effect would be to flood the market with worthless permits. Considering these issues, there are no fundamental design features of the proposed HHCT system that would preclude its integration into a global carbon market.

AB32 has promulgated guidelines for designing regulations associated with achieving GHG emissions reductions (AB32 Fact Sheet, 2006). The HHCT system clearly satisfies the requirements. For example, it has been demonstrated within this study that downstream regulation has few barriers to implementation and can be both equitable and cost effective. It does not disproportionately impact low-income households and, in the aggregate, is generally a progressive policy. Entities that have voluntarily reduced their GHG emissions before the program is implemented would receive credit for these early actions by selling their excess permits to entities that have not taken early action. There is further evidence in this study that the proposed system can fit within all or some of these guidelines better than upstream cap and trade, taxes, and command and control because it can be more equitable, cost effective, and fair.

5.3. Costs

We argue that the proposed HHCT system could be more efficient then an upstream cap and trade system or a carbon tax, the net of transaction, regulatory, and abatement costs being lower. The billing system to households is already established and administered by utility service providers, with the household carbon allowance balance added to the original energy billing statement. Transaction costs are expected to be higher than an upstream approach, due to the greater number of trades to be

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facilitated; however, we believe that given the presence of a carbon market the cost of each transaction would be low. The higher transaction costs could be more than offset by relatively low abatement costs, which are not realized though upstream cap and trade or taxes. Regulatory costs are expected to be similar.

We also acknowledge that the proposed HHCT system could be less efficient than an upstream regulation or a carbon tax. Starkey and Anderson (2005) make a crude attempt to cost out their individual GHG cap and trade system by comparing it to a proposed national identification card in the United Kingdom and conclude that their approach is feasible by comparison since the national identification card has been adopted and is similar in administrative and technical complexity. Their analysis is limited since it does not compare the relative costs between their approach and relevant alternatives: upstream cap and trade and carbon taxes (Roberts and Thumim, 2006). Roberts and Thumim (2006) argue that all comparisons should be based on the marginal costs of abatement to society of each scheme, which includes the administrative costs plus the costs of abatement incurred by all segments of the economy, from end users to upstream suppliers. They suggest as a starting point for examining administrative costs to consider the costs of banking systems and store "club cards", which essentially perform the basic information technology tasks required of an individual GHG cap and trade scheme. We agree that a similar analysis of marginal abatement costs would be useful in determining the relative efficiency of the HHCT system; however, this was beyond the scope of our study.

5.4. *Challenges of downstream cap and trade*

Additional challenges and considerations include the political feasibility of the program and the public acceptability of HHCT. Will the public understand the program and take part in trading (Roberts and Thumim, 2006)? Very little research has been done in this area; however, as Roberts and Thumim (2006) point out, these issues could be among the most important considerations. The relative political feasibility of a program to reduce GHG emissions rests largely on the costs (efficiency), fairness, and distributional effects of the policy. We have suggested that a downstream HHCT system can be more efficient, fair, and progressive than other schemes, and thus perhaps more politically feasible. However, one issue that comes along with certainty in GHG reductions is uncertainty in GHG permit prices.

The public may find the uncertainty associated with GHG permit prices to be too large compared to other available alternatives, despite their limitations. For example, while carbon taxes have a certain defined marginal cost, the GHG reductions that may result are unknown (and uncertain). This implies that a periodic adjustment in tax rates is required to achieve the reductions over time, something that is generally not politically feasible. The risk associated with cap and trade programs can be reduced by adding some amount of certainty in the form of a safety valve, which would set an upper limit on permit prices (Tietenberg, 2003; Jacoby and Ellerman, 2004). Flexibility can also be provided by allowing banking of excess allocations and borrowing from future allocations (Leiby and Rubin, 2001; Tietenberg, 2003). This temporal flexibility can reduce the impact of price spikes from extreme weather and provide time to acquire technology or perform improvements to reduce energy consumption.

The HHCT system may also be feared as to complicated and burdensome: how will the trading be facilitated? While the logistics of the trading, information technology and accounting may be complex, the end user burdens can be minimized. Carbon trading is already available and could be used by firms, which would compete to facilitate allowance trading and banking. The basic mechanism of trading and banking could be similar to existing electronic bill pay systems and online banking. The Chicago Climate Exchange and a growing number of business enterprises offering voluntary carbon offsets in the US provide evidence that the market place is ready.

6. Summary and conclusions

There is now almost universal acknowledgment of the dangers posed by continuing to freely emit GHGs. Problems ranging from more frequent major storms to the erosion of coastal areas due to rising sea levels are predicted to occur within the next 50 years if measures are not taken to curtail emissions (IPCC, 2007). The US is responsible for over 23% of the world's energy-related CO_2 emissions and 7% of US total CO_2 emissions are produced within California (CEC, 2006; EPA, 2006). The California legislature recently passed AB32, mandating that GHG emissions be reduced to 1990 levels by the year 2020, while providing guidelines but requiring no specific implementation method. As part of AB32, the MAC recently released recommendations to CARB for complying with the bill, which is currently designed as an upstream cap and trade program. We argue that a downstream cap and trade program may achieve greater efficiency, and therefore provide greater benefits to California.

In our approach to downstream regulation, we implement a household GHG cap and trade strategy using existing household utility accounts. The small scope of our scheme, limited to household GHG emissions tied to electrical power usage and natural gas consumption, is intentional. Limiting the scope of the program does limit possible efficiency gains, but reduces the complexity, risk, and political opposition. The concept is a compromise that can produce efficient and effective GHG emission reductions, while providing a starting point from which the scope of the program could be increased as experience and acceptance is gained.

The HHCT system can also be considered more equitable than carbon taxes and upstream cap and trade systems to control GHG emissions from residential energy use. As previously discussed, a carbon tax would be regressive since everyone would face the same marginal cost even though low-income groups have less ability to pay the tax and fewer opportunities to improve efficiency. An upstream cap and trade system will equate the marginal cost of abatement across power generators or distributors, but the costs of abatement are likely to be passed on to consumers. These costs would essentially be a flat tax and thus regressive. In short, a household cap and trade system does not provide every individual with an equal right to emit GHGs, so it would not be considered strictly egalitarian. However, we have shown that the HHCT system may actually be more equitable by other measures.

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