TRAVEL CHOICES AND THEIR RELATIVE CONTRIBUTIONS TO CLIMATE CHANGE: WHAT BEHAVIORAL SHIFTS WILL BUY US, AND OPPORTUNITIES FOR HOUSEHOLD-LEVEL CAPS

Kara M. Kockelman
(corresponding author)
Associate Professor and William J. Murray Jr. Fellow
Department of Civil, Architectural and Environmental Engineering
The University of Texas at Austin
6.9 E. Cockrell Jr. Hall
Austin, TX 78712
kkockelm@mail.utexas.edu

Melissa R. Thompson
Undergraduate Research Assistant
Department of Civil, Architectural and Environmental Engineering
The University of Texas at Austin
6.9 E. Cockrell Jr. Hall
Austin, TX 78712
thomp652@gmail.com

Charlotte A. Whitehead
Undergraduate Research Assistant
Department of Civil, Architectural and Environmental Engineering
The University of Texas at Austin
6.9 E. Cockrell Jr. Hall
Austin, TX 78712
charlotteaw@mail.utexas.edu

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ABSTRACT

This paper relates the Kyoto Protocol objectives to American households and individuals. The sources of the average household carbon footprint are analyzed, and behavioral changes resulting in reduced emissions are demonstrated. Also, two policies that could be used to meet these objectives, carbon taxing and downstream carbon capping, are compared. It is determined that meeting the Kyoto objectives would require a CO2 emissions reduction of approximately 730 lbs per month per person. For the average U.S. household, a savings of nearly 2,000 lbs of CO2 per month can be obtained by employing such measures as switching from a sports utility vehicle (SUV) to a crossover utility vehicle (CUV) hybrid, switching from central AC to a window AC unit (space cooling) during hot months, and turning down the thermostat while away during the day (space heating) during cold months. Additional savings can be obtained from other

behavioral changes, such as reducing vehicle miles traveled, reducing home floor area, and replacing old appliances with energy efficient products, among many other possibilities.

MOTIVATION

Climate change has emerged as one of our planet's top issues, and is increasingly a part of the U.S.'s political and economic agenda. While estimates of the magnitude of this problem vary, many nations around the world agree that greenhouse gas (GHG[1]) emissions need to be reduced – and sooner is better (IPCC 2007). In order to stabilize the concentration of GHGs in the atmosphere, the United Nations Framework Convention on Climate Change (UNFCCC), many European countries, and the state of California believe that a reduction of 80% by 2050 is necessary to prevent the most catastrophic consequences of global warming (Step It Up 2007). Policy makers and researchers across the globe have suggested and are now implementing many strategies aimed at lowering emissions. Methods include carbon taxation and trading, with caps or taxes on upstream GHG sources, like oil refineries, electricity generators, and industrial plants. In theory, the effects of such schemes will be felt at the household level by way of higher prices.

The United States is lagging many nations on this issue[2]. With the exception of the U.S. and Australia, every developed country in the world has ratified the Kyoto Protocol (as described below). Moreover, the United Kingdom implemented the first economy-wide emissions trading scheme (ETS) in the world, in April 2002. The purpose of the voluntary scheme was to learn valuable lessons about emissions trading, and apply these lessons to the European Union ETS. By December 2006, when the scheme was scheduled to end, the UK ETS had achieved an emissions reduction of over 7.1 billion tons of CO2e (DEFRA, 2007). The United States implemented the Acid Rain Program in 1995, with the goal of cutting SO2 emissions, a contributor to the formation of acid rain, to 50% of their year-1980 levels (EPA Acid Rain Program 2007). This program reduced emissions by utilizing a cap and trade scheme and setting two progressively tighter caps for 2000 and 2010. Thus far, the program has been successful and suggests that the U.S. is probably capable of implementing a successful carbon cap and trade scheme, though sources of CO2 are far more abundant than sources of SO2.

This paper seeks to examine the strengths and limitations of various "downstream" GHG emissions reduction policies (namely person-level quotas), estimate per-capita emissions reductions necessary to meet Kyoto objectives, and demonstrate the potential household emissions savings of various behavioral changes.

POLICY BACKGROUND

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[1] GHGs are found naturally in the atmosphere contributing to the greenhouse affect. Human activities, like the burning of fossil fuels, are increasing the amounts of these GHGs, thus increasing the greenhouse affect and contributing to global warming. GHGs include carbon dioxide, methane, nitrous oxide, ozone, and many other gases.

[2] The current U.S. administration has developed some policies around making the U.S. more energy efficient, per dollar of gross national product (GNP), rather than focusing on reducing total GHG emissions. Federal funding is available for climate change research, credits are available to companies voluntarily reducing their emissions, and tax incentives are available to those wishing to invest in hybrid vehicles or renewable energy (Bush, 2002).

An amendment to the international treaty on climate change, the Kyoto Protocol was created in 1997 and became active in 2005 (UNFCCC, 2007). Aimed at reducing emissions of greenhouse gases, the policy separates countries into Annex I (developed) and non-Annex I (developing) categories. Annex I countries are required to reduce their GHG emissions to the level assigned to them by 2008-2012 (assuming they accept the reduction requirement). Non-Annex I countries are not subject to emissions reduction requirements, but are required to contribute to research, education, and technological advances related to climate change prevention (UNFCCC, 2007). Annex I countries can modify their emissions requirements by (1) trading tons of carbon dioxide equivalents ($CO2_e$) with another country, investing in projects that reduce $CO2_e$ emissions or enhance carbon sequestration in another Annex I country (referred to as "joint implementation"), or non-Annex I country (called the "Clean Development Mechanism").

As an Annex I country, the US would have been required to reduce its $CO2_e$ emissions to 7% below its 1990 level. In 2005, U.S. emissions were 7260 teragrams (Tg) CO2 equivalents (approximately 8.1 billion tons), whereas the Kyoto Protocol would require a maximum of 5805 Tg CO2 eq (approximately 6.4 billion tons) by 2012 (EPA, 2007). While the nation originally signed the Protocol, it withdrew in March 2001, shortly after George W. Bush became president[3].

In February of 2002 the Bush Administration announced goals for reducing $CO2_e$ emissions under the Clear Skies and Global Climate Change Initiatives. These include cutting GHG emissions intensity (tons of $CO2_e$ per dollar of GDP) by 18% over ten years (by 2012) and achieving emissions targets comparable to the Kyoto Protocol using market-based approaches. Since the plan focuses on reducing GHG intensity (rather than total emissions), total emissions could still increase. The U.S. Department of State (2007) has projected that by 2012, despite an estimated reduction in GHG intensity of 18.6%, total emissions will increase by 11% to 7,709 Tg $CO2_e$.

In addition to some steps toward a federal policy, several U.S. states and cities (Martinez, 2007; MEPA, 2007; Clark, 2007) have adopted aggressive policies to reduce GHG emissions. According to the Pew Center on Global Climate Change, 30 of 50 states have at least one policy aimed at reducing GHGs, with many of these states having multiple policies (Pew 2007).

All of these policies set goals to reduce GHG levels, including carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6). CO2 makes up the majority of U.S. GHG emissions (84% in 2005, by heat-trapping potential), nearly all coming from fossil fuel combustion (80% of GHG emissions, as measured in terms of heat trapping potential) (EPA 2007). CH4 makes up 7% of all U.S. GHGs, with landfills (1.8% of GHGs), enteric fermentation (1.5%), and natural gas systems (1.5%) serving as the nation's top three methane contributors (EPA 2007). N2O contributes another 7% of all GHGs, with agricultural soil management serving as the top source (5%) (EPA 2007). HFCs, PFCs, and SF6 account for only 2% of all GHGs (EPA 2007), largely due to the replacement of other, ozone-depleting substances. Because CO2 makes up such a large portion

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[3] The Kyoto Protocol expires in 2012, and Kyoto2 (2007) is the intended continuation framework. In addition to setting new targets, the Kyoto2 attempts to address various issues with current GHG regulations, like $CO2_e$ accounting and needs of the poor.

of all U.S. GHGs, and an even larger portion of household emissions, and because many reports on GHG emissions provide only CO2 numbers, this paper emphasizes CO2 values and reductions, rather than $CO2_e$.

THE ROLE OF PERSONAL TRANSPORT

Responsible for 12% of the world's CO2 emissions and 19% of US emissions (Wadud et al., 2007), personal transportation is a sector that warrants much attention. Recent research shows that technological improvements in U.S. vehicles over the next 20 years will not meet Kyoto objectives (Friedman, 2007). If every U.S. household switched to a Toyota Prius (and maintained present driving distances), a 1.1 billion ton savings in CO2 emissions would be expected. Similarly, if every household switched to solar-powered personal vehicles, a savings of 2.0 billion tons could be achieved. However, those sorts of shifts are hardly likely by 2012 (to meet a Kyoto target reduction of 1.6 billion tons) – or even in the next two or three decades. In addition, the target reductions will stiffen over time. Experts are now seeking a 50 to 80 percent reduction in total GHG emissions, in order to stabilize climate. As populations grow, the per-capita reductions needs appear even more dramatic. A thoughtful discussion of behavior-oriented mechanisms, rather than just new technologies, is clearly needed.

CARBON TAXES VS. CAP AND TRADE POLICIES

The marginal costs of GHG sequestration, avoidance, or removal are highly varied, and the cost of global warming is difficult to anticipate. Nevertheless, these will determine nations' emissions targets and thereby the local and global levels of carbon tax. Presently, experts (e.g., Nordhaus, 2007; Metcalf, 2007, and Parry et al., 2002) expect emissions removal or avoidance costs to vary between $10 and $80 per ton of $CO2_e$. This translates to just $0.13 to $1.04 per gallon of gasoline, quite a bit less than price shifts the world has seen in recent years (Bomberg and Kockelman 2007).

As is evident from recent past experiences in the U.S. (Krauss, 2007), higher fuel prices have meant relatively little in terms of Americans travel patterns. As Small (2006) and other experts note (Small et al., 2006; Hughes et al., 2006), fuel is a relatively small part of vehicle ownership and use, and not such a great part of one's annual expenditures (e.g., a household's 15,000 miles per year at 20 miles/gallon and $3/gallon is just $2,250, or 5% of the average US household's income; Census, 2007). Moreover, U.S. land use and transit provision patterns offer relatively few easy substitutes to driving one's car. Even a $1 increase in U.S. gas prices (implying a tax that is roughly *twice* what experts are suggesting for carbon trading purposes) raises this expenditure estimate to just $3,000/year. Recent fuel-price elasticity estimates suggest a $1 tax would result in near- and long-term VMT reductions of just 2.7% and 9.8% respectively, and gas-purchase reductions of 3% and 11% (Hughes 2006, Small 2006) (short- and long-term). The level of gas tax increases needed to achieve current Kyoto targets in the travel sector (500 million ton CO2e reduction needed in U.S., using 2005 data) are on the order of $4 per gallon; these kinds of numbers may quickly demobilize already burdened low-income groups (Lazarus, 2007).

Most energy economists agree that Americans make decisions in a progressive way, adopting low impact, short term strategies (car pooling, traveling during off-peak hours) first before making more dramatic changes (job or house location, hybrid vehicle purchase) (Mohktarian, 1997). However, Small and Van Dender (2006) note that “response to fuel prices has become increasingly dominated by changes in fuel efficiency rather than changes in travel”. Interestingly enough, the car serves as a status symbol for drivers of all types, including Prius owners. Perhaps as much as they choose the car for its environmental impact (or lack thereof), a survey of Prius owners showed that a significant number chose the model because they wanted the car to “make a statement” about them (Maynard et al., 2007). With personal vehicles so deeply imbedded in American culture and consumer attitudes controlling manufacturer’s decisions, more fuel efficient vehicles may be the best way to curb increasing CO2 emissions. In any event, policy makers may have better luck with taxation or cap-and-trade policies.

Taxation is commonly evaluated as a potential policy for impacting the demand of nearly any good. As such, it is rather well understood. Trading schemes, such as permits, are a far more innovative and complex solution that economists and policy makers are debating for reducing GHG emissions. Such permits are typically distributed by grandfathering and/or auction (EPA Acid Rain Program, 2007; DEFRA, 2007). Under a simple grandfathering approach, each producer within the region receives equal emissions allowances, and then trade to match needs, producing a market for emissions that new producers later can buy into (based on market-determined prices). Alternatively, auctioning directly determines producer allowances, with funds going to the auctioneer (rather than to grandfathered producers who do not need all their allowances). Essentially, both such mechanisms can be envisioned for a supplier-wide or consumer–wide application in the U.S. with GHGs. Several critical decisions emerge. These include (1) definition of participants (major energy suppliers and/or final consumers of goods and services, households or individuals, children or adults only), (2) definition of included activities (e.g., personal and freight transport, vehicle fuel and farming inputs), and (3) the system for administering carbon use and transactions (e.g., centralized or distributed, governmental or privately managed).

While governmental institutions could cap producers/providers of energy, such caps will effectively filter down as taxes, and thus be largely “lost” on end users (as described in more detail below). And wealth would likely accrue to a few large entities (e.g., petroleum mining companies). So capping consumption by end users, thereby making carbon allowances far more obvious to individual consumers, is an attractive option. As Raux (2005) notes, very little research has been done to determine the public’s response to a system of tradable carbon permits[4]. Raux hypothesizes that such a system could be seen as an alternative to yet another tax, and thus more acceptable to the public. Moreover, since it would apply at the level of individuals (not just businesses), it may receive more private sector support. Since U.S. vehicle-fuel prices (and income taxes) are much lower than those in Europe (Lieberman, 2007), the reaction to permits may differ. It is important to note that such a permit system would still be more effective than even a downstream tax, since the price of individually traded permits would be determined

[4] Kockelman et al. (2006) surveyed Texans and Gulipalli et al. (2005) surveyed tolling experts about their responses to a policy of credit-based congestion pricing, whereby drivers pay variable tolls to avoid congestion and then receive uniform/flat monthly travel budgets for use of the priced roadway system. The concept is complex, yet attractive to many, due to drivers’ strong desire to end unnecessary, recurring travel delays.

by the market (Feldstein, 2006), while gasoline would continue to reflect the world price of oil. If the goal of a gas tax is for consumers to feel a sting at the pump, applying this tax at the drilling or refining stages would not fully produce the intended effect (Raux, 2005).

The price elasticity of gasoline could well be the greatest indicator of what sort of policy would be most effective. Fuel elasticties decline with income and rise with real fuel price. Between 1975 and 1980, short run fuel elasticties were estimated to be -0.21 to -0.34. From 2001 to 2006, the range dropped considerably to -0.034 to -0.077 (Hughes, 2006). The short-term income elasticties do not differ significantly between these two periods, so one may conclude that Americans are becoming less sensitive to price. Additionally, long run elasticties for the periods 1966-2001 and 1997-2001 were .43 and .33, respectively (Small, 2006). This inelasticity in price asserts that the greatest and most likely impacts in energy policy will come from changes in fuel efficiency, either through more fuel efficient vehicles or vehicle technology, as Americans are less likely to reduce consumption when gas prices soar due to upstream emissions policies. There is also evidence of a declining rebound effect, in which improvements in fuel efficiency provide an incentive to drive, so the increase in VMT (and thus CO2 emissions) resulting from improved fuel standards would not offset the benefits of a more fuel efficient fleet. For the period 1966-2001, Small et al. (2006) found this rebound to be 22.2%. For 1997-2001, this value fell to 10.7%.

As noted, taxation generally is simpler than cap and trade systems. For example, fuel taxes already exist at the gas pump, and can be raised to reflect carbon contributions (recognizing that 25 lbs of CO2 are released [from well to wheel, recognizing all upstream contributions] per gallon of standard gasoline, on average (EPA 2006). Fees could be added to airline ticket prices (based on expected aircraft fuel consumption per passenger) and utility bills (based on feedstock contributions to CO2). In theory, if one charges a tax equal to the marginal, external cost of the produced GHG, well-functioning markets should equilibrate to a social-welfare-maximizing state of (carbon) use and production (Varian, 1992; Pigou, 1954). Unfortunately, it is quite difficult to quantify the cost of global warming, and producers and consumers do not have perfect information, nor do they precisely maximize profits and personal utility/welfare. Moreover, related market imperfections do exist, and may impact the behaviors[5].

Finally, as Fleming (2006) argues, such taxes may do very little to reduce carbon emissions in wealthy countries where income effects of such price increases will be negligible; the level of tax needed to rein in consumption by wealthier households could devastate those of lower income. A focus on actual quotas is simpler in certain ways (by focusing on carbon targets, rather than trying to set the right price, for example), and far more obvious to producers and consumers. However, the devil lies in the details of administering such a system. For example, regulation will require a great deal of reporting if quotas are applied across all final consumers, rather than big upstream producers (where cap and trade policies are expected to capture only 40 to 50% of U.S. carbon production, according to Northrop and Sassoon (2007). While taxation is arguably more predictable and less difficult to regulate, there are strengths of cap and trade polices that deserve close attention. They may very well deliver much stiffer reductions in $CO2_e$ emissions

[5] These include related, unpriced externalities, such as transport-produced noise, noxious emissions, congestion and safety externalities (see, e.g., Lemp and Kockelman 2007). Underpricing or lack of pricing on these in many nations means motorized travel is still “over-consumed”.

in the U.S. at far lower personal and private cost than equivalent taxes – particularly in systems where permits are distributed equally to all households. When cap and trade is done upstream, an effective gas tax (determined by the market) essentially gets factored into prices, serving as an effective tax. In contrast, consumer-level capping (with some form of trading) would be economically progressive and thus more beneficial to lower income groups. These arguments alone should probably decide the policy here (Raux, 2005; Fleming, 2006).

Of course, our GHG emissions come from far more than the transport sector. And deep cuts in energy consumption may be more readily made in other forms of consumption, such as one's food purchase decisions, home size, design and temperature settings. The following sections describe the many elements of one's carbon "footprint", and suggest where serious cuts in average American consumption patterns can be made, to try and achieve Kyoto targets at the level of individuals, as though under a cap-and-trade policy.

THE SOURCES OF OUR CARBON FOOTPRINTS

The terms "carbon footprint" (as in tons per person) and "carbon offsets" (as in positive, negative and neutral) have been popularized lately (see, e.g., Ross, 2007; Baschuk, 2007; *The Economist*, 2007). For example, if a person drives everywhere, shifting to transit and walking will still leave his/her travel patterns "carbon positive". One might offset these by sequestering carbon emissions elsewhere, via the planting of numerous trees in the Amazon, for example (Gore, 2006).

Tallying carbon emissions in the transport sector is reasonably straightforward. Vehicle fuel is the main source of such GHG emissions, and is measured through gasoline (and diesel) sales. However, each gallon of gasoline entails wasted crude oil, refining, and transport, raising the final $CO2_e$ tally by roughly 25 percent (25 lbs of CO2 per gallon of gasoline, rather than 20 lbs) (EPA 2006). Moreover, the energy embodied in a vehicle's production contributes roughly 10 to 15% of a vehicle's lifetime carbon emissions (Carnegie, 1998). So maintaining (and using) one's vehicle longer (or ensuring others use it for a long time) may be quite helpful in reducing one's long-term contributions – it will depend on the fuel economy of new vehicle options. The CTA (2001) estimates that the median lifetime (or "scrappage age") of 1990 passenger vehicles is 16 years, and given how rapidly we hope (and expect) new fuel use technologies to come online in the coming years, it may be optimal to retire certain gas guzzlers earlier, or at least stop driving them long distances. Obviously, energy is a key input to the production of most products (e.g., paper, clothing, homes, furniture, and electronics). A policy of simply re-using existing items may go a long way to meeting GHG reduction targets – it really depends on the rate of energy-use improvements and continuing-use levels of older technologies.

According to the Energy Information Administration (EIA, 2007), U.S. CO_2 emissions per capita (average carbon footprint) were 20 metric tons[6] (about 22 tons) in 2004, or 25% above our Kyoto target, as described earlier. These emissions come from various end-use sectors, including

[6] A metric ton (also known as a "tonne") is equal to 1.1023 short tons. A short ton, commonly referred to as simply a "ton," is equal to 2000 pounds.

transport (33%), industrial (28%), residential (21%), and commercial users (17%) (EPA, 2007)[7]. When electricity generation is extracted from each end use and given its own category, the emissions can be counted somewhat differently – as emerging from electricity generation (42%), transportation (33%), industrial sources (15%), residential users (6%), and commercial users (4%) (EPA, 2007).

In looking at these distributions, it is clear that the majority (75%) of CO2 emissions come from users of transport and electricity. It makes good sense that policies to reduce CO2 emissions would emphasize these two sectors. Improvements can be made at both the upstream and downstream ends. For example, more fuel-efficient vehicles can be produced, public transportation could be improved, and neighborhoods could be made more pedestrian friendly and offer more shopping. On the downstream end, of course, people also have to be willing to buy such cars and/or reduce their driving, and thereby lower their fuel demands. Similarly, improvements could be made in electricity generation (e.g., through new windmill technologies) and energy use by various products (like computers, lighting, and air-conditioning units). Of course, these advances in electricity generation efficiency could cause the price of electricity to drop, encouraging an increase in electricity use, negating any emissions reductions achieved initially. However, the demand for electricity is relatively inelastic (e.g., short run at -0.2 and long run at -0.32[8]), so one would still expect some reductions in carbon emissions (Bernstein, 2006).

Witty (2006) found that a majority of Americans, 68%, do not perceive global warming to be a serious threat. This belief implies that many will not be willing to make voluntary lifestyle changes for the purpose of global warming prevention. Directed policies are needed. The Kyoto Protocol is suggesting that the United States reduce its $CO2_e$ emissions by 7% below the nation's 1990 emissions levels, or 20% below its 2005 emissions[9]. This means a reduction to 4.8 billion tons of CO2 per year (EPA, 2007). Based on the current U.S. average of 22 tons of CO2 per person per year, and a population of 302,300,000 (Census, 2007), this implies a reduction of approximately 4.4 tons per person in the year 2007 – or 730 lbs per person per month.

Table 1 compares the amount of CO2 emitted for a variety of passenger vehicle choices. Emissions are calculated given vehicle type and a range of vehicle miles traveled (VMT) per month. It should be noted that the average VMT per month (per passenger vehicle) is just over 1,100 (NHTS 2001), and the average fuel economy is 21 MPG (EPA 2006), making for a rough CO_2 emissions average of 1,360 pounds per month per vehicle. A household could save a few hundred pounds of CO2 emissions per month by switching from an SUV to a CUV hybrid, switching from a large or mid-sized car to a mid-sized hybrid, or by reducing its monthly VMT by roughly 200 to 300 miles (6 to 10 miles a day).

TABLE 1 HERE

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[7] CO2 emissions due to electricity generation have been distributed to each end use in this portrayal of emissions sources.

[8] Short-run elastticies in fuel demand are lower largely because the vehicle fleet and home and activity locations are rather fixed in the short run. Price sensitivity comes from households shifting to more fuel-efficient vehicles already owned, taking shorter trips (particularly for vacation and other personal reasons), carpooling, and other behaviors (see, e.g., Bomberg and Kockelman 2007).

[9] 1990 CO2 emissions were 5.2 billion tons, and 2005 CO2 emissions were 6.3 billion tons.

Of course, our automobiles (and motorcycles) are not the only source of personal-travel emissions. Air travel was responsible for 9% of all U.S. GHG emissions in 2003, with commercial air travel contributing 72% of that share (EPA 2006). And the contributions from aviation are rising. On average, 0.6 lbs of CO2 is emitted per passenger mile flown on commercial jets (Houldson, 2007) – rather than 1.3 lbs of CO2 per vehicle-mile traveled on the road (assuming a fuel economy of 20 mpg). Table 2 compares emissions per mile from on-road vehicles and commercial aircraft. On average, air travel presently tends to be more efficient than driving solo, but this result depends on aircraft occupancy, trip length, and vehicle fuel economy (which varies greatly by make and model). Both travel modes emit roughly the same amount (per person-mile) when considering a two-person trip. For trips of three or more persons, the personal vehicle should be more efficient.

TABLE 2 HERE

Of course, goods movement is another source of transport emissions. For example, LaBelle (2005) estimates the average distance traveled by the average food item in the U.S. (from farm to table) to lie between 1,500 and 2,500 miles. The average fuel economy of a truck carrying foodstuffs is 5.85 mpg (BTS 2003); assuming a payload of 2.5 tons, the average pound of food consumed in the U.S. may generate 1.71 pounds of fuel-related CO2 emissions from truck transport alone. Purchases of local produce and other products could bring this number down substantially, along with more efficient forms of transport (e.g., rail rather than truck). Of course, buying used items – instead of new items – offers similar benefits from transport emissions, as well as significant savings in other forms of embodied energy (by avoiding new production). A well-known, web-based program for re-sale of used goods is www.craigslist.org, offering free access to information on a variety of personal items for sale and now available in 450 cities worldwide. Freecycle.org also operates in nearly all major U.S. regions, alerting individuals to others' unneeded, and free, items.

In addition to transport and other forms of embodied energy, households use electricity regularly, to power a variety of gadgets. Figure 1 illustrates how much electricity is used by a subset of key household items and appliances relative to others. While switching to low wattage light bulbs will certainly help households reduce $CO2_e$ emissions, shifts in heating, cooling and several other choices have a much greater savings potential and should be considered first.

FIGURE 1 HERE

Space heating and cooling together account for about 26% of electricity use (EIA 2001). Other heavy uses are refrigeration, water heating, and lighting. Table 3 describes potential CO2 emissions savings per month for changes in usage levels (shown in italics) relative to standard choices and use levels. As indicated, heating and cooling are likely to have the most emissions reduction potential for most households. For example, a household residing in a warmer area of the U.S. may well save over 1,000 pounds of CO2 emissions per month by switching from central air conditioning to a window air conditioning unit, and by using a "smart thermostat" to turn off the heater while away (or simply being diligent with manual thermostat control).

TABLE 3 HERE

As is evident in Tables 1, 2, and 3, a CO2 emissions reduction goal of 730 lbs per month per person could be accomplished rather readily by reducing household VMT and air travel, using a more fuel-efficient vehicle, adopting several of Table 3's electricity savings suggestions, or some combination of these tactics. For example, a household that switches from an SUV to a CUV hybrid, switches frsom central AC to a window AC unit, and keeps the heating and cooling systems off while away from home can expect to save nearly 2,000 pounds of CO2 per month.

Another aspect of household GHG emissions is the structure of the housing unit itself. In general, as a housing unit gets bigger, energy use, as well as CO2 emissions, increases fairly steadily – but average energy needs (per square foot) fall. For example, heating and cooling of a 1,500 sf one-story single family detached home in Austin, Texas is estimated to produce 11,361 lb CO2 yearly (LBL 2007)[10]. Adding 1,000 sf adds roughly 2,500 lbs of CO2 per year. A 1,500 sf two-story home emits nearly the same amount as the one-story home (LBL 2007). Clearly, there is a great deal to consider when studying methods of carbon reduction at the household level. Of course, all of us rely on energy expenditures away from our homes and vehicles, most days – in our workplaces, classrooms, restaurants, fitness clubs, shopping centers and entertainment venues and elsewhere. Some accounting for these forms of carbon production will need to be addressed as well, perhaps most readily through commercial use energy taxes.

IMPLEMENTATION OF CARBON CAPPING AT THE HOUSEHOLD LEVEL

Capping policies typically are designed to allow trading (i.e., "cap and trade") among capped entities, or households and other end users of energy in the case of GHG emissions (Fleming 2006). The trading process effectively sets a price for GHG emissions. Another revenue-neutral scheme is assigning benefits and penalties via, for example, income tax deductions (for those households who go under-budget) and penalties (for those who exceed their allowances). In the case of household end users, this would occur every April, when filing personal-income tax reports[11].

Whichever approach is used, those who exceed their cap would pay out of pocket – or solicit (and/or purchase) carbon credits from others. If some carbon trading is permitted among households, everyone would have an opportunity to go under-budget and make money off those who exceed their caps. In addition, households and/or individuals should be permitted to carry-over carbon credits from one year to the next, which may be very helpful when expecting new demands on the household's energy allotment[12]. The second approach (with tax filings) is probably most similar to and consistent with our current system of income tax reporting. It also

[10] Hypothetical housing units compared were based on the default values given for an Austin, TX home, holding all variables constant except for square footage and number of stories.

[11] For example, one might be required to file odometer readings (via transponder-type devices and on-board units or an annual inspection), air travel receipts and an annual utility statement with one's income tax forms every year, or quarter. And caps (or energy taxes) on health clubs, child care centers, industry/offices, dormitory residents, and others would help ensure families do not spend all their energy elsewhere (because those service providers and employers will be tracking their clients and workers, and charging/assessing penalties, where feasible).

[12] Such situations may include a new child (if quotas are not on a per-head basis), a family trip abroad, the addition of new appliances or the expansion of one's home, and the intended use of a less fuel-efficient vehicle.

permits some “certainty” in the pricing of excess carbon emissions over the course of a year, while avoiding several, non-trivial implementation costs associated with carrying a carbon “credit card” around or always designating a carbon “credit account”, to keep track of household member purchases.

Of course, such regulation is administratively burdensome (particularly when compared to a taxation policy). The costs of such implementation need to be ascertained before presuming that the social welfare effects make the capping policy a clear winner (over taxation).

CONCLUSIONS

While carbon taxation or capping and trading among upstream providers of energy in the U.S. and abroad offers simpler implementation opportunities than capping emissions across final consumers, its effectiveness is highly questionable when considering current energy-use elasticities, particularly in a country as wealthy as the U.S. Carbon cap-and-trade schemes are more complex, requiring more active regulation and possibly requiring several more years to fully implement. However, a policy that motivates thoughtful and significant behavioral change at the level of individuals is necessary to obtain desired GHG emissions reductions while buffering low-income households from myriad price effects.

The emissions reduction goal of Kyoto for the United States is 7% below 1990 emissions, or 20% below 2005 U.S. emissions by 2012. For U.S. households, this translates to an estimated reduction of 730 lbs of CO_2 per month per person. Many European nations are taking the Kyoto Protocol and the issue of climate change very seriously, along with several U.S. states. This paper highlights a variety of reasonable carbon-reducing behaviors. If these and other potential behavioral adjustments can be illuminated for household members, encouraging near-term and meaningful changes in behavior, the planet’s quest for reductions in GHGs should be attainable. Of course, the 80% reduction believed to be required for climate stabilization will demand that households reduce CO2 emissions by far more than 730 lbs per month per person in decades to come, which may not be attainable without future technological breakthroughs or serious behavioral (and economic) consequences.

This research suggests that Kyoto targets can be met by U.S. households, without forcing location changes or dramatic reductions in travel and home sizes. For example, a household can save a few hundred pounds of CO_2 emissions per month by switching from an SUV to a CUV hybrid or reducing their monthly VMT in the SUV by 200-300 miles. In addition, thousands of pounds of CO_2 typically can be saved by shifting to lower wattage appliances and moderate adjustments in home temperature settings, home size, or other lifestyle choices. A combination of these techniques will add up to 730 pounds of CO_2 per person.

Finally, it should be mentioned that a household cap and trade policy that regulates personal transportation and household utilities use (two sectors where carbon emissions are relatively easy to track) does not account for all sources of U.S. GHG emissions. To rein in the other roughly 60% of such emissions (EPA 2007), it will be necessary to either cap or tax commercial and industrial users of energy, causing price increases for the consumer in sectors other than transport and electricity. Nevertheless, a formal recognition of one’s impacts on others, both locally and globally, is the appropriate policy perspective to take, helping ensure that consumers and producers make the right, long-run decisions.

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Table 1. Expected Monthly CO2 Emissions by Vehicle Type and Miles Driven

Vehicle Characteristics			Pounds of CO2/month given VMT/month		
Vehicle Class	**Make/Model**	**Combined MPG**	**800 VMT (9600 mi/yr)**	**1,000 VMT (12,000 mi/yr)**	**1,200 VMT (14,400 mi/yr)**
Midsize Hybrid	Toyota Prius Hybrid	46	435	543	652
Compact Hybrid	Honda Civic Hybrid	42	476	595	714
Compact	Toyota Corolla	29	690	862	1034
CUV Hybrid	Ford Escape Hybrid	27	741	926	1111
Mid Sized	Toyota Camry	24	833	1042	1250
Luxury Car	BMW 3-series	22	909	1136	1364
Large Car	Buick LeSabre[1]	21	952	1190	1429
CUV	Ford Escape	20	1000	1250	1500
Minivan	Dodge Caravan	20	1000	1250	1500
SUV	Ford Explorer	16	1250	1563	1875
Pickup Truck	Ford F-150	16	1250	1563	1875
Cargo Van	Ford Econoline[2]	15	1333	1667	2000

Notes: Vehicles were chosen based on highest sellers in 2003 (Lemp and Kockelman 2007). Fuel economy comes from www.fueleconomy.gov and assumes 2007 model year (except large car class, which uses 2005) and automatic transmission.

Table 2. Average CO2 Emissions in Group Travel: Driving vs. Flying

# Passengers in Travel Party	Car Travel (lbs CO2 per party-mile)	Aircraft (lbs CO2 per party-mile)
1 Person	1.2	0.6
2 People	1.2	1.2
3 People	1.2	1.8
4 People	1.2	2.4
5 People	1.2	3.0

Notes: Chosen car is assumed to average 21 miles per gallon. Aircraft emissions are for an average commercial flight and can change according to aircraft model, occupancy, and trip length.

Table 3. Opportunities for $CO2_e$ Savings Based on Changes in Electricity Use Patterns

Type of Electricity Use	Wattage (kW)	Usage (hrs/day)	Usage (kWh/ month)	Potential Savings (kWh/ month)	CO2e Savings (pounds/ month)
Heating					
central heat (5000 W system)	5	24	3600	0	0
central heat w/smart thermostat	5	16	2400	1200	1609
space heater (two 1500-W heaters)	3	16	1440	2160	2897
Cooling					
central AC	3.5	12	1260	0	0
window AC	0.9	12	324	936	1255
fan	0.095	12	34	1226	1644
Clothes Dryer					
electric dryer	5	1	150	0	0
clothesline	0	NA	0	150	201
Clothes Washer					
hot water	5	0.86	129	0	0
warm water	2.5	0.86	65	65	86
cold water	0	0.86	0	129	173
Light bulbs					
Incandescent (60 W)	0.06	5.5	10	0	0
Fluorescent (15 W)	0.015	5.5	2	7	10
Television (19 inch display)					
25 hrs/week	0.9	3.6	97	0	0
0 hrs/week	0.9	0	0	97	130
Computer Mode					
full power all day (100 W)	0.16	24	115	0	0
sleep mode part of day (17 hrs at 5 W)	0.01	17	5	76	103
Refrigerator					
non energy efficient (900 kWh/yr top-freezer)	0.1	24	72	0	0
energy efficient (450 kWh/yr)	0.05	24	36	36	48
Computer Monitor					
CRT (120 watt)	0.12	7	25	0	0
LCD (40 watt)	0.04	7	8	17	23

Note: Wattages and usage amounts come from http://michaelbluejay.com/electricity/. Average pounds of CO_2 per kWh in 1999 was 1.341 (EIA, 2000). Clothes dryer assumes 5 kW electric dryer, 8 loads a week, and 45 min. per load. Washer assumes electric water heater, 8 loads per week.

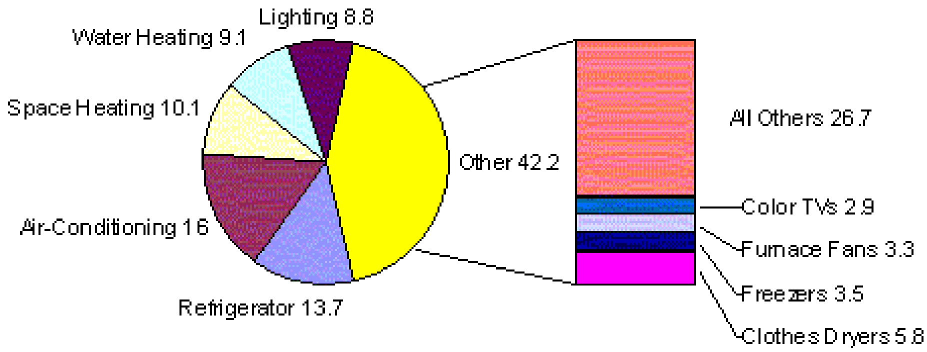

Figure 1. Household Electricity Consumption (EIA, 2001; Figure 1)