City carbon budgets: A proposal to align incentives for climate-friendly communities

By: Deborah Salon[a], Daniel Sperling[a], Alan Meier[a], Sinnott Murphy[a], Roger Gorham[b], and James Barrett[a]

[a] Institute of Transportation Studies, University of California, Davis; [b] The World Bank

ABSTRACT

Local governments can have a large effect on carbon emissions through land use zoning, building codes, transport infrastructure investments, and support for transportation alternatives. This paper proposes a climate policy instrument - city carbon budgets - that provides a durable framework for local governments to reduce greenhouse gas emissions. Local governments would be assigned an emissions "budget", and would be required to keep annual local transport and buildings emissions within this budget. This policy framework could be implemented and managed by a higher-level government, or might be used in awarding funds to developing country cities from international climate funds. The state of California has enacted a version of this policy. In this paper, we identify and evaluate options for creating an effective and acceptable institutional structure, allocating emission targets to localities, measuring emissions, providing flexibility and incentives to local governments, and assuring compliance. We also discuss the likely costs of such a policy.

KEYWORDS: greenhouse gas; energy efficiency; local government

1. INTRODUCTION

Most of the policy dialogue regarding climate change mitigation has focused on development and commercialization of energy production and end use technologies, national policies such as carbon cap and trade, and international targets. However, carbon emissions from the individual-level activities of passenger transport and energy use in residential buildings account for a huge proportion of total carbon emissions—approximately 40 percent in the case of the United States (Brown et. al. 2008). Absent an enormous leap forward in low-carbon energy technologies, meeting the challenge presented by climate change will require that individuals, households, and communities all become part of the process.

Local governments can strongly influence greenhouse gas emissions[1], particularly those related to the day-to-day activities of households. City planning and zoning ordinances influence the amount of travel that occurs, the modes used, the energy efficiency of buildings, and the energy embodied in building materials and used in construction. Recognizing this influence, many cities have developed climate action plans, containing a mix of mostly voluntary greenhouse gas emissions reduction proposals. These efforts could be enhanced and magnified substantially by coordinating these local-level efforts and making them mandatory for localities.

In this paper, we explore a climate policy instrument that would target behavioral change, focus on local governments, and require that real emissions reduction be achieved - city carbon budgets. While the details of such a policy instrument could vary across political regions, the present paper is meant to make the overall case for the approach and provide a solid starting point for discussion.

[1] Throughout this paper, we refer to greenhouse gas emissions and carbon emissions interchangeably. The reason for this is that most of the greenhouse gas emissions from the sectors we focus on here are in the form of carbon dioxide. We expect that local-level climate policy would, however, be written using the language of “carbon-equivalents” to include all of the greenhouse gases.

The city carbon budgets approach would make local governments accountable for greenhouse gas emissions that are under their control - either directly through city operations or indirectly through land use and other locally-held powers. Under city carbon budgets, local governments would be assigned an annual emissions "budget" and would be required to keep local transport and buildings emissions within this budget. This mandatory-but-flexible policy framework would empower localities to take responsibility for their future emissions patterns, while ensuring that reductions are made in a manner most appropriate to local circumstances.

2. EMISSIONS REDUCTION POTENTIAL: WHAT MIGHT A CITY CARBON BUDGETS APPROACH ACHIEVE?

The city carbon budgets approach would provide a framework for local governments to target the greenhouse gas emissions from day-to-day patterns of behavior. Before embarking on a detailed discussion of policy design, this section provides a review of the actions local governments could take to reduce emissions and the likely emissions impact of such actions.

The level of carbon emissions per person varies dramatically by region and even by neighborhood. For example, researchers estimated that per capita greenhouse gas emissions of urban neighborhoods in Adelaide, Australia were approximately two-thirds of those from suburban neighborhoods (Perkins and Hamnett, 2002). In Toronto, Ontario, one study estimated that per capita greenhouse gas emissions from transport activity were twice as high in suburban as in urban districts (VandeWeghe and Kennedy, 2007), and a second found that total lifecycle emissions of greenhouse gases differed by a factor of 2.5 (Norman, MacLean, and Kennedy, 2006). In the United States, another study found that per capita emissions in older, denser cities in the northeast are significantly lower than per capita emissions in northeastern suburbs (Glaeser and Kahn 2008).

Although these greenhouse gas emission differences across existing development patterns are impressive, the real policy question is left unanswered: What would be the impact of *changes* in existing neighborhoods on greenhouse gas emissions? Unfortunately, we will not know the answer to this question until something like a city carbon budgets policy is in place and we can measure the success of communities that are actively trying to reduce their climate impact.

2.1 Policies and potential for reducing greenhouse gas emissions from transport

Greenhouse gas emissions from transport are influenced by vehicle technology, vehicle use (which we will refer to as vehicle kilometers traveled, VKT), and the carbon content of fuels. Cities can reduce VKT by reducing the need for travel, making alternatives to the private car both more available and more attractive, and making cars less attractive for everyday trips.

Using their land use power, local governments could restructure zoning ordinances to stipulate off-street parking maximums rather than minimums, density minimums rather than maximums, reduced building setbacks, and relaxed building envelopes to more efficiently use space. Cost savings from reduced parking requirements in housing developments could make downtown projects more profitable for developers. Mixed-use zoning could be introduced or expanded, allowing shops, offices, and homes to be located in close proximity. Transit-oriented development can have an impact as well. These tools can be used to encourage mixed-use, dense, and transit-, bike-, and pedestrian-friendly urban environments that naturally lower VKT and reduce greenhouse gas emissions.

In the transportation planning arena, cities could implement parking and road pricing, develop bicycle and pedestrian infrastructure, and enhance transit, ridesharing, and carsharing programs. All of these strategies will encourage residents to utilize alternatives to the single-occupant vehicle for their daily travel needs. Revenues generated from pricing policies could be used to increase funding for public transit, carsharing, and other paratransit services.

The scope for local policies that affect vehicle technologies and fuels is limited outside of fleet-based operations. There are, however, creative ways that cities could impact the vehicle choices of their residents. Prime parking spots could be provided only for small, fuel efficient vehicles, or parking could be priced by vehicle size. Road prices could be raised for large SUVs, as was recently done in London. Local governments could also mount social marketing campaigns in support of climate-friendly vehicles.

How much could these policies reduce emissions? Focusing on the vehicle travel component, there are two relevant types of research that address the scope for greenhouse gas emissions reduction. The first uses statistical methods and existing data to predict the effect of changes in the land use-transport system on people's choices of how much to travel and which modes to use. These studies generally isolate the effect of a single factor – *e.g.* density, transit availability, or road pricing – rather than estimating the effect of policy and investment packages. The second takes direction from some of these results, using them to simulate multiple coordinated policies and investments and to estimate the resulting effect on choices.

To date, empirical research has not demonstrated a definitive relationship between urban form and travel. Although directionally-consistent relationships have been identified, the overwhelming finding can be summed up with “it depends” (Badoe and Miller 2000, Crane 2000, Handy 2005, TRB 2009, Cambridge Systematics, 2009). Badoe and Miller (2000) highlight the point that land use near employment centers is consistently found to be a significant indicator of transit use, walking, and ridesharing. A second consistent finding in the literature is that higher residential density discourages car ownership, and thereby reduces vehicle travel. Looking at the effect of transit, Handy (2005) finds that light rail can lead to higher densities. The evidence of the magnitude of all of these effects, however, is both extremely varied and at least partially dependent on the existence of coordinated policies and investments to support alternatives to car travel.

Empirical evidence consistently shows that raising the price of driving reduces VKT. Looking first at one of the few real-world urban examples of road pricing, London's congestion pricing scheme is estimated to have reduced VKT by 1.7 percent and fuel use by 2.8 percent when charging £5 per day for driving downtown (Transport for London 2007).[2] International estimates of the long-run elasticity of VKT with respect to fuel prices have a mean of approximately -0.30, meaning that a 10 percent increase in the cost of fuel should decrease VKT by approximately 3 percent (Graham and Glaister 2004, Goodwin, Dargay, and Hanly 2004). There is some recent evidence that the fuel price effect on travel may be shrinking over time, and that this effect might be especially small in the U.S. (Small and Van Dender 2007, and Hughes et. al. 2008).

There is a small-but-growing literature on the effect of 'soft' transport policy measures on VKT, including measures such as personal travel plans and public education campaigns. These measures are based on the premise that given better information about travel options - plus a bit of peer pressure, in some cases - many people will voluntarily make travel choices that are more environmentally sustainable. Moser and Bamberg's (2008) meta-analysis of 44 existing studies

[2] Fuel use is reduced more than VKT because vehicle fuel economy increases with the reduction in traffic congestion.

reports that in the U.K., the potential for car use reduction from workplace travel plans is substantial. These planning programs increase the fraction of employees using an alternative commute mode by an average of 12 percentage points. Taylor (2007) reviews the impact of soft transport policy measures in Australia. These programs achieved remarkable reductions in car use among participants – approximately a 10 percent reduction in vehicle trips – and these reductions in car use appeared to be sustainable.

One major shortcoming of all of this research looking at the effect of single policy changes or infrastructure investments on travel is that it does not take account of the synergies between strategies and feedback effects that occur in the real world. Urban simulation studies fill this gap. Johnston (2006) summarizes the main findings of recent studies that employ urban simulation techniques in an attempt to predict the effects on VKT of multiple coordinated policies and investments. These studies do not include 'soft' transport policy measures, but do include – to various degrees – all of the other measures discussed above. Johnston finds that when combined with pricing policies and transit investments, land use change can be an important part of an effective package to reduce auto dependence. Johnston's review of simulation studies indicates that reductions ranging from approximately 10 percent to more than 20 percent in VKT are achievable within 20 years.

2.2 Policies and potential for reducing greenhouse gas emissions from buildings

Through local policies and programs, cities and communities can influence both the technical efficiency of buildings and the energy-use behaviors of their inhabitants. On the technical side, strictly enforcing building codes for new construction and supplementing them with local incentives to encourage use of technologies such as solar electricity generation are two examples with large energy-saving potential.

Policies to accelerate energy efficiency-improving retrofits of existing buildings can have a sizeable impact on emissions as well, and cities can influence energy use through education and encouragement of energy-saving habits.

Overall evaluations of the energy conservation potential in buildings have found that the cost-effective potential savings is between 20 and 30 percent (Meier, Wright, and Rosenfeld 1983, Rufo and Coito 2002, McKinsey & Company 2007). Specific projects have demonstrated the possibility of far greater energy savings, especially for new construction. For instance, in Europe, the Passivhaus concept has been demonstrated to reduce space heating energy needs to below 20 percent of current levels, even in cold climates (Hastings 2004). A stricter building code in the Pacific Northwest led to a 40 percent reduction in space heating energy needs compared to homes built to normal practice (Meier and Nordman 1988). Also in the Pacific Northwest, the Energy Edge program demonstrated energy savings of 30-50 percent in commercial buildings (Piette et al. 1995).

Even among existing buildings located in the same community, built the same time, or equipped with the same appliances, the cumulative impact of hundreds of behavioral and operational decisions strongly affects a building's energy consumption (Diamond 1987). For instance, Kempton (1988) found that per-capita hot water use varied widely in a single Michigan community; the highest consumption was three times larger than the lowest. The electricity use of a home computer may vary by a factor of five depending on the user's selection of power management features.

These operational decisions are not fixed and can be revised through education, changing economic conditions, or new technologies. The challenge for local governments is to devise policies that will induce these behavioral changes.

There is some precedent for this – at least in periods of energy shortage. During electricity shortages in Brazil and California, consumers (mostly in buildings) cut their electricity use 20 and 12 percent, respectively (International Energy Agency 2005). Cities, such as Phoenix, have achieved reductions in electricity consumption of almost 15 percent in only a few days. A recent electricity crisis in Juneau, Alaska prompted an almost immediate 30 percent reduction in electricity demand (Yardley 2008). Most of these savings were achieved by switching off lights and computers, replacing incandescent with fluorescent bulbs, adjusting thermostat settings, and simply being more vigilant about energy use.

3. CITY CARBON BUDGETS: THE POLICY FRAMEWORK

All of the potential measures discussed above are already available for deployment and implementation by local governments. However, if some individual municipalities aggressively adopt these measures, but others do not, then those that do may be at a competitive disadvantage for development and tax resources. A city carbon budgets program would solve this problem by creating a common set of requirements and incentives, and helping to coordinate local-level emissions reduction efforts.

In this section, we describe how a city carbon budgets program could work and identify and evaluate options for implementing such a program. These implementation options include creating an effective and acceptable institutional structure, allocating emission targets to localities, measuring emissions, providing flexibility and incentives to local governments, and assuring compliance. We also discuss options for the timing of implementation and how city carbon budgets could complement other emissions reduction policies such as emissions trading between power producers.

In each of these policy design areas, there are certain aspects of this framework that we view to be necessary design features for the framework to function properly, and other aspects that are decisions to be made politically. We endeavor to make this distinction clear throughout this section.

Two aspects of a city carbon budgets program that are political decisions deserve mention here, however. These are the choices of how much of the total emissions reduction responsibility should be placed on localities and the severity and form of penalties for noncompliance with the program. Because we believe these to be largely political decisions, this paper does not address either of them in detail. We do note that most local governments, in rich and poor countries alike, have very limited resources. As a result, any use of financial penalties will face fierce opposition from local governments. A more politically plausible approach is to depend on incentives—financial rewards—to assure compliance.

It is also worth noting that local governments should be pursuing both emissions mitigation policies *and* climate adaptation policies. Significant climate change is virtually guaranteed to happen, and communities will have to adapt by moving or protecting infrastructure and buildings that are at sea level, adjusting to changing water supply conditions, protecting against wildfire encroachment, and making other accommodations (see the 2009 CNRA report for an example set of adaptation strategies). The city carbon budgets framework aims to address and coordinate only local-level emissions reduction policies, but the various institutional structures put in place to address mitigation could be extended to address adaptation. However, we do not address this extension of carbon budgets policies to climate adaptation in this paper.

3.1 Institutional structure

In our proposed city carbon budgets policy framework, local governments would be the point of regulation for local-level greenhouse gas emission reduction. They would have the responsibility to decide which set of greenhouse gas emission-reducing strategies to pursue, and to implement those strategies (as indicated in Figure 1). Our rationale for this is simple – almost all local governments worldwide have the authority to make the changes in land use policy that will be necessary to facilitate climate-friendly development.

Though chief responsibility would rest with the local government, all levels of government would have important roles under city carbon budgets. Figure 1 illustrates one possible distribution of responsibility among government bodies. Higher level state or national governments could serve important functions both in formulating the policy and providing informational, technical, and financial support (see Parshall et al. 2009). Where they exist, regional governments could support coordination between localities – especially in the areas of road infrastructure and public transit – as well as provide technical assistance, especially in modeling of transport policy outcomes and impacts. We propose that local governments have the ultimate responsibility of selecting and implementing actions.

Methodological consistency in both budget-setting and emissions measurement across localities is crucial to ensure the effectiveness of city carbon budgets. To foster this, standardized methodologies must be created to measure all emissions included in the budget, assign mobile emissions to localities, and collect any additional necessary data. The state or nation would be logical entities to take on the responsibility of devising such methods and also compiling the local-level emissions inventories. This would realize economies of scale in compilation of the

Figure 1: Sample division of responsibility for city carbon budgets program

State/Nation	Region	Locality
• set rules regarding city carbon budget allocation, emissions measurement and assignment to localities, flexibility mechanisms, incentive programs, and enforcement mechanisms • provide financial assistance to localities (and perhaps regional governments also) • collect data and calculate local emissions inventories using simple, standardized methodologies • set up information clearinghouse for local planners • provide guidance on how to adapt transport models to run greenhouse gas scenarios	• manage city carbon fund for the region, reviewing locality applications for funding • adapt transport models to run greenhouse gas scenarios and provide the results to localities • help localities to coordinate strategies, perhaps through a formal regional planning process	• based on information from regional, state, and national government, develop a package of local initiatives to meet greenhouse gas emissions reduction target • if additional funding is required, apply to regional government • coordinate with neighboring localities with help from the region • implement the plan

inventories, and it would also take the emissions counting burden off the localities. It should also be the responsibility of the state or nation to provide an information clearinghouse to help communities to share their experiences and identify climate strategies that are best for their local contexts. In California, the Air Resources Board has already created a website that begins to accomplish this (CoolCalifornia.org, 2009).

Because most local governments have limited analytical capacity, assistance in modeling transport energy use and greenhouse gas emissions is also critical. In larger metropolitan areas, centralized transportation planning or coordinating agencies, where they exist, are well-positioned to provide this service. They could provide direct technical support to municipalities and other units of local government, reconcile the roles of entities such as transit agencies that cut across city boundaries, and manage the allocation of incentive funds from state, provincial, or national governments.

3.2 Budget allocation and equity

Allocation of carbon budgets to localities has direct equity implications, and is therefore critical to the political feasibility of the policy. The budget allocation method should satisfy two key criteria. First, there must be a clear, predetermined schedule for what the carbon budgets will be in the future. Many emissions reduction strategies that will need to be employed to meet future budgets will have medium- to long-term payoffs. Thus, it is imperative that local policymakers know their current and future emissions reduction responsibility, and have a guarantee that it will not be changed. Second, the carbon budget should be specified such that it does not discourage city population or economic growth. Per capita carbon budgets meet this criterion.

We consider four potential budget allocation methods:

- Allowance allocation via auction,
- Uniform allowance allocation on a per capita basis,
- Using current per capita emissions as a starting point and transitioning gradually to a uniform allowance allocation on a per capita basis, and
- Using current per capita emissions as a starting point and reducing allowance allocation by the same percent for all localities.

The remainder of this section discusses each of them in turn.

Allowance auctioning. In cap-and-trade policy regimes, auctions are often promoted as economically efficient mechanisms to allocate responsibility for reducing emissions (Burtraw et. al. 2001). However, devolution of a portion of emissions reduction responsibility to lower levels of government is fundamentally different from allocation of emissions reduction responsibility to polluters. Local governments are not the main polluters and they are not – by and large – profiting from presiding over districts with high greenhouse gas emissions. For these reasons, we reject this approach.

Uniform allocation on a per capita basis, with a predetermined schedule for reducing the allocation over time. At first glance, this approach seems both fair and simple – every person is allowed the same emissions level. The problem with this scheme stems from the fact that communities today (and the individuals that comprise them) have made many long-term decisions under a paradigm in which energy was cheap and greenhouse gas emissions were costless. While some have chosen to live climate-friendly lifestyles (largely motivated by non-climate reasons), many have chosen to live in homes designed without energy efficiency in mind, located in areas accessible only by car, and have purchased vehicles with low fuel economy. As a result, current emissions per capita across communities vary widely, and therefore their emissions reduction responsibility under a single per capita target would also vary widely. This is both politically unworkable and economically inefficient. The inefficiency results from the likelihood that to comply with such a policy, some areas will need to provide incentives for sprawling residential developments to rapidly become more climate-friendly. While this will reduce emissions, loss of sunk costs from these developments could be reduced by a strategy of more gradual change.

Baseline per capita allowance allocation with convergence toward uniform *per capita budget.* This method begins with carbon budgets based on current emissions in each locality. Over time, the budgets are adjusted to arrive at a single per capita emission level across localities, which could then be lowered over time according to a predetermined schedule. In terms of political feasibility and economic efficiency, this option would clearly be an improvement over simply starting with a single per capita target because the initial allocation would take explicit account of existing conditions. However, this plan would still result in some communities having little or no requirement for emission reduction, while others would have much larger requirements. Therefore, we are concerned that this plan may not be politically acceptable.

Baseline per capita allocation with equal percentage reduction. This method entails setting carbon budgets equal to current emissions for each locality, and reducing them by a given percent each year according to a predetermined schedule. This allocation scheme has the benefit of not penalizing localities for decisions made in the past, and it arguably distributes the emissions reduction responsibility in an equitable manner across localities. Under this approach, all localities would have emissions reduction responsibility, but localities with larger initial emissions would be responsible for larger absolute reductions per capita.

The third and the fourth methods of allocation appear to be the most equitable. Critically, because they are both based on per capita emissions reduction targets, they achieve the environmental goal of emissions reduction by all localities without penalizing population and economic growth.[3] The most politically acceptable method must, of course, be resolved through the political negotiation

[3] An important point to note here is that even if per capita emissions drop, total emissions for a particular locality may rise due to population growth, and that *this outcome would not represent a policy failure*. In fact, more people living in a locality that has low emissions per capita is likely to mean lower emissions overall - which is the important environment-related outcome.

process.

3.3 Emissions coverage, measurement, and assignment to localities

Central to the success of the city carbon budgets framework will be an accurate inventory of emissions for each city or county, compiled according to a regular schedule (e.g. annually). These inventories will be used to measure emissions reduction progress, and would form the basis for determining compliance with the program; it is crucial that they are accurate.

Designing an inventory system that is simple and inexpensive enough to be carried out on a regular basis, yet precise enough to quantify incremental changes, will be challenging. The first decision, then, is which emissions to include in the inventory. In this paper we propose that the budgets are based on transport and building sector emissions. These categories represent the majority of greenhouse gas emissions generated within city limits, and, as previously mentioned, are the categories of emissions over which cities have the greatest influence. While there are other local sources of emissions or areas where emissions could be reduced (e.g. waste management or water systems), these do not generally comprise the bulk of the emissions.

Whichever emissions are covered and whatever method is used to measure them, that method should be simple, standardized, accurate, and equitable. The remainder of this section identifies and evaluates the options for creating such an inventory for emissions from the buildings and transport sectors.

3.3.1 Measuring building emissions

Tracking total energy use and the associated emissions from buildings is straightforward. Electricity, natural gas, and home heating oil provision are consolidated industries, and usually only a handful of these companies operate in a city or county. Thus building energy use data is tracked centrally, and those central data are easy to transform into a greenhouse gas emissions inventory from end-uses in the buildings sector. An open question, however, is the rate at which electricity consumption is converted into carbon emissions. Reasonable arguments exist for using either regional or national average conversion factors (Energy Information Administration 2000) because electricity can be generated considerable distances from the point of use.

Because newly-constructed buildings are generally more energy-efficient than older buildings, there is a potential equity differential between localities experiencing fast growth and those that are stable or declining. If total building emissions per capita is the metric used to determine compliance with city carbon budgets, fast growing cities might be able to meet their buildings sector budget without taking local action. This would happen if there is enough new construction (with associated mandated efficiency levels) so that on a per capita basis, average emissions would come down even without local action.

If this effect is large and thus threatens the political viability of the policy, one possible solution is to add an adjustment for new construction to the formula for allocating the buildings portion of the emission budgets. This adjustment would reduce/increase the emission budgets for cities with higher-/lower-than-average proportions of buildings constructed since the first year of the carbon budgets program, ensuring that all localities will have similar incentives to take local action to reduce building energy use. Depending on data availability, the adjustment could be according to percent of total floor area that is new or percent of total structures that are new.

3.3.2 Measuring base transport emissions and assigning them to localities

On-road vehicles move freely between localities, emitting greenhouse gases as they go. The best method of assigning these emissions to localities and measuring them is not immediately obvious but should be based upon some measurement of distance traveled (VKT) by vehicles in that region. The ideal assignment methodology should:

- enable precise local travel measurement,
- maximize options for local government action to reduce the assigned distance traveled, and
- avoid encouraging local policy that might actually increase distance traveled at a regional level.

The ideal measurement method would achieve accuracy that is sufficient to allow measurement of incremental changes in distance traveled over time.

Table 1 identifies five options for VKT assignment to localities along with the associated likely methodology for measuring/estimating those VKT. None of them fully satisfies all of the above criteria. We favor option 5 because, in our estimation, it strikes the best compromise between them. The remainder of this section will describe each option in turn, and discuss its relative merits and drawbacks according to the criteria listed above.

Table 1: VKT Assignment Options and Implied Measurement Methodologies

	VKT Assignment Method	**VKT Measurement Method**
1	VKT within locality	Loop detector data, model
2	VKT by refueling in locality	Fuel sales, average fuel economy
3	VKT by vehicle home locality	Odometer readings
4	½ VKT by vehicle origins in locality, ½ VKT by vehicle destinations in locality	Travel survey, model
5	**VKT by vehicle home locality, Adjustment for new nonresidential development**	**Odometer readings, survey of visitors to new nonresidential developments**

The first option assigns VKT to localities according to where vehicles actually travel. For trips that span multiple localities, the appropriate fractions of each trip are assigned to each locality. This option satisfies none of our three criteria. VKT would be estimated via loop detectors in conjunction with travel demand models, and incremental changes will not be detectable. Substantial VKT would be assigned to traversed localities that are neither the origin nor the destination of the trip, reducing local government options for emissions reduction. One policy option that would be available, however, is localized road pricing that would drive cars off of one locality's roadways and over to those of neighboring localities, likely increasing regional VKT as a result.

The second option assigns VKT according to where vehicles are refueled. This option satisfies the precise measurement criterion – fuel sales are precisely measured – but fails to satisfy our other two criteria. Particularly for localities that have major highways, a substantial portion of local refueling is for thru-traffic, and local government options for action are limited. To reduce fuel sales, a locality could tax fuel so that motorists refuel elsewhere, possibly increasing regional VKT as a result.

The third option assigns VKT according to where vehicles are garaged. The measurement methodology would be odometer readings – a precise method that can detect incremental changes. This provides strong incentives for smart land use and alternative transportation infrastructure near home locations. The incentive for action at employment and retail locations is weaker, however, because some portion of the VKT generated for those trips is assigned to other localities. This option would not encourage the perverse outcome of rewarding local policies that increase regional VKT.

The fourth option assigns VKT by splitting it between vehicle origin localities and vehicle destination localities, a trip-end approach identified in the literature by Millard-Ball (2008) and Ganson (2008). While it incentivizes local policy options to reduce VKT, it requires network based travel demand models to estimate VKT, and these estimates would not be precise enough to measure incremental changes.

The last option in Table 1 assigns VKT by home locality, as in option 3, but also includes an adjustment for new nonresidential development. We favor this VKT assignment method because it achieves measurement precision and enables local climate-friendly policymaking.

In the first year, VKT would be assigned according to vehicle home locality and measured using odometer readings. In subsequent years, localities with new nonresidential development would be required to collect data to estimate the net VKT generated by the development as well as the home localities of the vehicles responsible for these VKT. If the development changes the total VKT that originate outside its boundaries, an emission budget adjustment is applied. For example, say City A grants a development permit to a large big-box retailer, that then attracts shoppers from City B. Without an adjustment, City A would get developer fees and tax revenues from the development, while City B would be penalized under its carbon budget for additional VKT. With an adjustment, City A would compensate City B with emission allowances for the estimated additional VKT associated with the development. If the development actually *reduced* VKT outside its locality boundaries, the reverse emission budget adjustment would be made. This could happen if, for instance, the shoppers from City B previously traveled farther for their shopping.

3.3.3 Other emissions

Local governments control policy levers that affect greenhouse gas emissions outside of these base emissions categories. A mechanism could be included in a city carbon budgets policy, therefore, that allows localities to adjust their base emissions if they have reduced emissions in another area. Examples of such actions include reducing emissions from local government operations, promoting transportation technologies above and beyond the state or national requirements, or promoting lower carbon footprint (embodied emissions) building materials. For these “extra-base” activities, the burden would be on the locality to measure the actual reduction in emissions, using an approved measurement methodology.

3.4 Banking, borrowing, and trading of emission allowances

Many land use initiatives will not yield emission reductions immediately, but should be strongly encouraged due to their potential to yield large reductions in the medium- and long-term. Because of this fact, it is important that localities have some level of temporal flexibility as to when they reduce emissions.

One provision that would create this temporal flexibility is banking and borrowing of emission allowances. An emissions allowance is an authorization to emit a certain amount of a pollutant, in this case greenhouse gases. Within the city carbon budgets framework, each locality would be given emissions allowances equal to its budget for each year. With allowance banking, a locality could save part of its allocated emissions budget for use at a later time. Specifically, if a locality emits fewer greenhouse gases than it is allowed in one period, it can “bank” the difference, allowing higher emissions in future periods than would otherwise be allowed. Allowance borrowing is the reverse concept – if a locality’s emissions are greater than its budget in one period, it could “borrow” allowances from a future period’s budget to make up the difference. Allowance banking could be unlimited. However, there should be limits on allowance borrowing, since budgets are likely to be designed to fall over time and a large allowance “debt” would become difficult to pay back.

Market mechanisms could also be used to provide localities with spatial flexibility in meeting targets, meaning that some localities could exceed their emissions reduction requirements and others could fall short of meeting them. One means of providing spatial flexibility is the buying and selling of emission allowances. Theoretically, this sort of emissions trading would give communities a choice between reducing emissions within their community and buying emission allowances from a community whose greenhouse gas emissions are lower than its budget. Localities that are able to reduce emissions cheaply could sell allowances to cities and counties that find reductions more difficult, creating a revenue stream. In a well-defined market, allowance trading would lead to reductions in the marginal cost of compliance across localities.

There are at least two practical issues unique to city carbon budgets that make emissions trading problematic. The first is an equity issue – some communities would find it difficult to raise funds to purchase allowances. This could result in some communities adopting policies that lead to local emission reductions and other communities simply paying their way out, or even rejecting the policy entirely. The second is a timing issue. Although many land use policies have the potential to lead to large emission reductions, the full effect occurs years after the policy is implemented. It is important to not create an incentive that gives localities an “out” in the form of buying emission allowances to meet their short-term obligations, instead of starting the process of transitioning to climate-friendly land use policies.

To the extent that trading is included in a city carbon budgets policy, it should not be a replacement for long-term planning for carbon reduction. Eventually, trading could be allowed across cities and counties. However, the local policies that this framework encourages are meant to complement rather than substitute for other emissions reduction strategies (Section 3.7 elaborates on this point). For this reason, we do not envision that this city carbon budgets allowance market could be integrated into larger carbon markets that include activities such as power generation.

3.5 Carrots and sticks

In this section, we address compliance issues. Incentives to encourage compliance – "carrots" – are absolutely essential to a successful city carbon policy program, while penalties to punish noncompliance – "sticks" – should also be considered. It is essential that the program include new sources of revenue for local governments to craft and implement policies that reduce greenhouse gas emissions and that all levels of government begin the program as partners.

City carbon budgets programs must be *funded* mandates. Most local governments struggle to provide even basic public services: education, streets, and water and sanitation. For good reason, they resist taking on additional responsibilities without additional funding streams. Along with the responsibility to reduce greenhouse gas emissions, cities should receive a new source of funding specifically for this purpose.

Whatever the financial mechanisms chosen to support city carbon budgets, it is imperative that local governments be in support of the program from the start. Absent an enormous leap forward in low-carbon energy technology, reducing greenhouse gas emissions from the transport and buildings sectors is likely to be extremely challenging. It will require nothing short of a permanent shift in the way millions of people make both their medium- and long-term investments in both housing and vehicles, as well as their daily travel and energy use decisions. Therefore, we strongly believe that for city carbon budgets to be successful, all levels of government need to be partners rather than regulator and regulatee.

To foster this partnership, the use of "carrot"-style mechanisms to encourage and reward compliance should be emphasized far more than the threat of "stick"-style mechanisms to punish noncompliance. Punishing noncompliance will not achieve environmental goals – it is likely only to lead to animosity between local and higher-level governments, making the environmental goals even more difficult to achieve. That being said, having no punishment for grossly noncompliant localities makes the program effectively voluntary, and this is also unacceptable.

While we suggest focusing on rewards and incentives, an important question is where this funding might come from. One possibility is that a carbon trust fund could be created from a portion of the funds that may come from auctioning of greenhouse gas emissions allowances under an industry cap-and-trade program. These funds could then be used to finance some or all of the costs of local investments such as road pricing programs (in which case they could be paid back with the collected fees), climate retrofits for existing buildings, and transit, pedestrian, and bicycle infrastructure.

Another financial mechanism that could be used to encourage compliance is allocation of state and national transportation funds. All local governments might receive some base amount using current formulas, but those that perform better could be awarded additional funds for infrastructure and activities that lead to reduced emissions. There is substantial room for further creativity in devising mechanisms for funding a city carbon budgets policy to encourage compliance.

Because we expect diversity in local initiatives to reduce greenhouse gas emissions, we also expect that localities will not need the same level of financial assistance under city carbon budgets. Therefore, we suggest that the regional government maintain some control over the distribution of these funds to help insure that they go where they will have the greatest emissions impact (as in Figure 1).

If localities fail to meet their target budgets in the first years of the program, but are clearly experimenting with local initiatives that aim to reduce greenhouse gas emissions, then penalties are not in order. As experience accumulates with city carbon budgets, we will gain a better understanding of which types of initiatives are likely to be successful in which types of communities, and how much they cost to implement. Along with this knowledge comes greater local responsibility. If localities continue to miss their targets under this *funded* mandate after it is clear what they need to do to achieve them, then penalties should begin to apply. These could take the form of either withheld transportation funds or direct fines.

3.6 Timing

Implementation of a city carbon budgets program could occur in three stages. The first stage would be voluntary adoption by localities of non-binding carbon budgets. Local governments could receive technical assistance from the state or nation, but would not be eligible for financial implementation assistance because these budgets would be non-binding. The second stage would be voluntary adoption of a legally-binding budget. Local governments could receive both technical and financial assistance, both to support compliance with the budgets and to encourage adoption of budgets. The third stage would be the full policy framework: mandatory adoption of budgets by all local governments, with accompanying technical and financial assistance from the state or nation.

An attractive aspect of this policy framework is that, if implemented smartly, these stages of local greenhouse gas emissions responsibility could easily be phased in over time. The key to smart implementation is consistent standards for carbon budget determination, assignment of emissions responsibility to localities, and emissions measurement.

3.7 Integration of city carbon budgets with other climate policies

There are a number of other policies that are being considered to reduce greenhouse gas emissions at other levels of government and in other sectors of the economy. These include cap-and-trade systems for power generation and industrial sources of emissions, tailpipe greenhouse gas emission standards for vehicles, low carbon fuel standards for fuels, and direct carbon taxes. The city carbon budgets framework would complement, rather than substitute these other policy initiatives. The city carbon budgets framework mandates that localities implement policies to reduce greenhouse gas emissions. Most of the actions available to accomplish this at the local level are through demand reduction - either reduction in demand for energy through increased building efficiency or through reduced need for energy-intensive services such as motorized travel.

For example, one of the arguments against cap-and-trade systems for greenhouse gases or a carbon tax is that these policies will raise the price of energy such that households and businesses will experience economic hardship. This argument is most compelling where energy prices have historically been low, resulting in individuals making long-term decisions that depend on low energy costs. A policy built on the city carbon budgets framework would mandate that local governments help change these built environment and lifestyle trajectories in the near-term. Importantly, though, these changes would not occur because of acute economic hardship, but rather through government-supported changes in the lifestyle options to live well without producing high levels of greenhouse gases. This would reduce demand for high-emitting activities, making individuals less financially vulnerable to a carbon price, and potentially paving the way for broad political acceptance of cap-and-trade or carbon tax policies.

3.8. Carbon Budgets in California and Elsewhere

Enacted in 2008, California’s Senate Bill 375 (SB 375) is similar to the carbon budget approach proposed in this paper. The law imposes greenhouse gas emissions targets on regional governments, focusing on emissions from vehicle travel. It requires regions to prepare Sustainable Community Strategies as part of their transportation planning, identifying a set of actions at the regional level that would bring transportation greenhouse gas emissions down to target levels. Unlike the city carbon budgets framework described here, SB 375 does not target building emissions.

SB 375 has attracted much attention. In fact, it served as the model for the “transportation efficiency” provisions written into the Waxman-Markey climate bill adopted in mid 2009 by the US House of Representatives. A bill that has been recently introduced in the U.S. Senate - The Clean Energy Jobs and American Power Act - includes similar language.

At the same time, there has been substantial skepticism regarding its likely effectiveness, for good reason. This skepticism stems chiefly from the facts that (1) SB 375 requires only that a plan be devised to reduce emissions, with no requirement (or even strong incentive) to implement this plan, and (2) SB 375 focuses on regional governmental bodies which do not have the power to regulate land use (but do prioritize transportation funding for local governments). The weakness of the SB 375 law reflects the substantial political challenges involved in legislating VKT reductions.

Notwithstanding these reservations, the passage of SB 375 indicates a sense that the state has gone too far in embracing cars and car dependency and that it is time to change direction. The law puts in place a process to reduce VKT, sprawl, and greenhouse gas emissions, creating the foundation for subsequent laws and programs that will provide stronger incentives for action. Thus, SB 375 may be an important precursor to the development of a full city carbon budget framework.

The concept of city carbon budgets also shows promise in developing countries, as a mechanism for allowing those cities access to the large climate investment funds being created by affluent countries under the auspices of the UN Conference of Parties (at Copenhagen in 2010 and later).

4. COSTS AND CO-BENEFITS OF CITY CARBON BUDGETS

There would be three categories of costs associated with a city carbon budgets program - institutional costs, implementation costs, and societal costs and co-benefits.

Institutional costs are those of running the program, and can be divided into start-up program costs and ongoing costs of emissions monitoring. The start-up costs of city carbon budgets are likely to include development of institutional capacity for the program at all levels of government, development of standardized emissions assignment, measurement, and data collection methodologies, and a large-scale public education campaign regarding the new program. The ongoing costs are likely to include emissions monitoring costs and the cost of staffing the program at all levels of government. It makes sense for the bulk of the start-up costs to be borne by the nation or state. To ensure standardization, the nation or state could also assume responsibility for the base emissions monitoring of VKT and natural gas and electricity use. The cost of measuring emission adjustments in localities with new nonresidential development could be passed on to the developers. Measurement of the emission reductions from local initiatives that do not affect transport or buildings emissions could be the responsibility of the locality.

Implementation costs are the financial outlays necessary for local emissions reduction initiatives. The magnitude of such costs for a city carbon budgets-style program will depend on the particular strategies that localities use to meet their emissions reduction responsibilities. Many of the most likely local actions are either free to implement or pay for themselves over time in energy savings. Examples of such actions include climate-friendly changes to zoning codes, certain building energy retrofits, and conversion of regular lanes to high occupancy vehicle use. Other local actions – such as installing bicycle and pedestrian infrastructure – do have significant costs. However, because we see plentiful options for inexpensive action, we would not expect a locality to opt for an expensive strategy unless it brought substantial co-benefits to the community.

Even among strategies that pay for themselves over time through energy savings, some will require upfront investments that can be difficult for individual households and small businesses to afford. This is especially a problem for efficiency-enhancing building retrofit strategies. There are, however, creative ways that local governments can help. For instance, some local governments have already begun offering loans to homeowners and small businesses to help with these costs; California State Assembly Bill 811 specifically authorizes cities to enact such policies, and the US Congress is considering a related measure in the 2009 Clean

Energy Jobs and American Power Act dubbed the Retrofit for Energy and Environmental Performance (REEP) program.

Many other local initiatives to reduce greenhouse gas emissions do not have direct costs, but instead require political will for implementation. Part of the reason that greenhouse gas emissions from the transport and buildings sectors remain high is that two powerful forces at work at the local level often run counter to the goals of climate policy, favoring sprawled development over compact development. The first is local taxation practices. Cities seek to maximize the taxes and fees that they collect, and they tend to collect more property and sales taxes from large commercial facilities than from housing or mixed-use style development. Second, because greenfield development is often less risky for developers due to a lower likelihood of neighbor objections and lower land costs, developers apply strong pressure to cities and counties to approve and support such development. A city carbon budgets policy could provide a countervailing force, pushing for densification, mixed-use, and infill development.

In addition, some members of the community may perceive that their choice of lifestyle is being constrained, and this perception of constrained choices could be viewed as a societal cost of the program. Indeed, choices and behavior will be affected. Under city carbon budgets, single-occupant vehicle use is likely to become more expensive, while alternatives to the single-occupant vehicle for daily travel will become more abundant and convenient. Permits to develop new, residential-only neighborhoods that are not accessible by transit would likely become difficult to obtain, while permits to develop mixed neighborhoods with better transit access will become easier and less expensive to obtain.

To evaluate the full social cost of the policy, the costs described above need to be compared with the benefits - both climate protection benefits and non-climate co-benefits. These co-benefits are substantial. The most obvious of them is the reduced fuel needs for buildings and vehicles, leading to substantial cost savings, and, in a broader sense, increased energy security and lower energy prices.

By reducing VKT, cities will also be reducing three major externalities of our current transport system: local air pollution, traffic congestion, and road noise. Significant reductions in these externalities would be an extremely large co-benefit of city carbon budgets through reduced incidence of respiratory disease and reduced and/or more reliable travel times. To fully realize these co-benefits, it will be important for cities to provide enhanced transit, bicycle, pedestrian, and rideshare infrastructure to encourage mode shifting and carpooling.

To the extent that local strategies include provision of transit service as well as bicycle and pedestrian infrastructure, those who cannot drive cars will see enormous improvements in both their mobility options and their safety while traveling. This group includes children, the elderly, and the poor who cannot afford vehicle ownership.

In addition, we expect that the actions taken by cities and counties to reduce both VKT and the energy used in buildings will result in more compact, mixed-use, and transit-oriented development. This style of development will reduce the pressure to convert land to urban and suburban developments from their natural state or agriculture, preserving farmland and other open space important as wetland and other natural habitat. It will also slow the extension of suburban land development into forests, leading to lower fire-related risk, an especially important benefit in the western United States, where wildfires are common and highly destructive.

These co-benefits, together with technical and financial assistance for city carbon budgets from the nation or state, make it possible that communities will experience net *improvements* in their daily lives as a result of the policy. The extent of city carbon budgets co-benefits is somewhat dependent on the level of flexibility that local governments have within the program, as well as the extent of national and state support for local activities.

5. CONCLUSION

City carbon budgets is a policy framework that would guide efforts by local communities to minimize greenhouse gas emissions, aligning local powers and prerogatives regarding land use, zoning, transport programs and investments, and building codes with efforts at the state and national levels.

Despite this promising outlook, implementation of a city carbon budgets-style policy will require time and considerable effort. It will require accompanying investments in data collection and tool development. Critically, it will require all levels of government to work together to craft the policy details. Political forces will push back. Key to successful implementation will be the creation of incentives, such as revamped transport funding formulas based on attaining greenhouse gas targets. .

A city carbon budgets policy would send a strong signal that reducing greenhouse gas emissions is important and must be a factor in all local actions. It would empower local governments to take responsibility for their impact on climate change. Different localities will make different policy and investment choices to reach climate goals. This diversity in local solutions is both expected and encouraged, as it should stem from real differences between communities in the costs and emissions benefits of different strategies. It is difficult to imagine a serious effort to reduce local greenhouse gas emissions without a city carbon budgets policy or something similar.

REFERENCES

Badoe, D.A. and E.J. Miller. 2000. Transportation-land use interaction: Empirical findings in North America, and their implications for modeling. *Transportation Research Part D*. 5: 235-263.

Brown, M.A., F. Southworth, and A. Sarzynski. 2008. Shrinking the carbon footprint of metropolitan America. Report of the Metropolitan Policy Program at the Brookings Institution. Available at www.blueprintprosperity.org.

Burtraw, D., K. Palmer, R. Bharvirkar, and A. Paul. 2001. The effect of allowance allocation on the cost of carbon emission trading. Resources for the Future Discussion Paper 01-30. Available at www.rff.org.

California Natural Resources Agency (CNRA). 2009. 2009 Climate Change Adaptation Strategy: Discussion Draft. Available at www.climatechange.ca.gov/adaptation.

Cambridge Systematics 2009. *Moving Cooler: An Analysis of Transportation strategies for Reducing Greenhouse Gas Emissions.* Washington: Urban Land Institute.

CoolCalifornia.org. 2009. Local government toolkit website. www.coolcalifornia.org/local-government. Accessed November 2009.

Crane, R. 2000. The influence of urban form on travel: An interpretive review. *Journal of Planning Literature*. 15(1): 3-23.

Diamond, R. 1987. Energy use among the low-income elderly: A closer look. In *Energy Efficiency: Perspectives on Individual Behavior*, edited by W. Kempton and M. Neiman. Washington, D.C.: American Council for an Energy-Efficient Economy.

Energy Information Administration. 2000. *Carbon Dioxide Emissions from the Generation of Electric Power in the United States*. Washington, D.C.: U.S. Department of Energy.

Ganson, C. *forthcoming* 2008. The transportation greenhouse gas inventory: A first step toward city-driven emissions rationalization. University of California Transportation Center Research Report.

Glaeser, E.L. and M. Kahn. The Greenness of Cities. Policy brief of Rappaport Institute / Taubman Center. Cambridge: Harvard University Kennedy School of Government, March 2008.

Goodwin, P, J. Dargay and M. Hanly. 2004. Elasticities of road traffic and fuel consumption with respect to price and income: A review. *Transport Reviews*. 24(3): 275-292.

Graham, D.J. and S. Glaister. 2004. Road traffic demand elasticity estimates: A review. *Transport Reviews*, 24(3): 261-274.

Handy, S. 2005. Smart growth and the transportation-land use connection: What does the research tell us? *International Regional Science Review*. 28(2): 146-167.

Hughes, J., C. Knittel, and D. Sperling. 2008. Evidence of a shift in the short-run price elasticity of gasoline demand. *Energy Journal*. 29(1): 113-134.

International Energy Agency. 2005. *Saving Electricity in a Hurry*. Paris:

International Energy Agency.

Johnston, R.A. 2006. *Review of U.S. and European regional modeling studies of policies intended to reduce motorized travel, fuel use, and emissions*. Victoria, B.C.: Victoria Transport Policy Institute. Available from http://www.vtpi.org/johnston.pdf

Kates, R. W., M. W. Mayfield, R. D. Torrie, and B. Witcher. 1998. Methods for estimating greenhouse gases from local places. *Local Environment*, 3(3): 279-297.

Kempton, W. 1988. Residential hot water: A behaviorally-driven system. *Energy*. 13(1): 107-114.

McKinsey & Company. 2007. *Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost?* New York: The Conference Board.

Meier, A.K., and B. Nordman. 1988. A Thermal Analysis of the Model Conservation Standards for New Homes in the Pacific Northwest USA. *Energy*. 13(11): 833-844.

Meier, A.K., J. Wright, and A.H. Rosenfeld. 1983. *Supplying Energy Through Greater Efficiency*. Berkeley, CA: University of California Press.

Millard-Ball, A. 2008. The municipal mobility manager: A new transportation funding stream from carbon trading? Paper presented at the 2008 Transportation Research Board Annual Meeting.

Moser, G. and S. Bamberg. 2008. The effectiveness of soft transport policy measures: A critical assessment and meta-analysis of empirical evidence. *Journal of Environmental Psychology*, 28: 10-26.

Norman J., H.L. Maclean, and C.A. Kennedy. 2006. Comparing high and low residential density: Life-cycle analysis of energy use and greenhouse gas emissions. *Journal of Urban Planning and Development.* 132(1): 10-21.

Parshall, L., K. Gurney, S. Hammer, D. Mendoza, Y. Zhou, and S. Geethakumar. 2009. Modeling energy consumption and CO_2 emissions at the urban scale: Methodological challenges and insights from the United States. *Energy Policy.* doi:10.1016/j.enpol.2009.07.006.

Perkins, A. and S. Hamnett. 2005. “The significance of urban form in creating more greenhouse-friendly cities.” Presented at the International Conference of the Asian Planning Schools Association.

Piette, M., B. Nordman, O. de Buen, and R. Diamond. 1995. Findings from a low-energy, new commercial-buildings research and demonstration project. *Energy*. 20(6): 471-482.

Rufo, M., and F. Coito. 2002. *California’s Secret Energy Surplus: The Potential for Energy Efficiency*. Oakland, CA: Xenergy, Inc.

Salon, D., D. Sperling, A. Meier, S. Murphy, R. Gorham, and J. Barrett. 2008. “City carbon budgets: Aligning incentives for climate-friendly communities.” Institute of Transportation Studies, University of California, Davis, Research Report UCD-ITS-RR-08-17.

Small, K. and K. Van Dender. 2007. Fuel efficiency and motor vehicle travel: The declining rebound effect. *Energy Journal*. 28(1): 25-51.

Sperling, D. and D. Gordon. 2009. *Two Billion Cars: Driving Toward Sustainability.*

Oxford University Press.

Taylor, M. 2007. Voluntary travel behavior change programs in Australia: The carrot rather than the stick in travel demand management. *International Journal of Sustainable Transportation*. 1(3): 173-192.

Transport for London. 2007. *Central London Congestion Charging Scheme: ex-post evaluation of the quantified effects of the original scheme*. Available from http://www.tfl.gov.uk.

Transportation Research Board (TRB) Committee for the Study of the Relationships Among Development Patterns, Vehicle Miles Traveled, and Energy Consumption. 2009. *Special Report 298: Driving and the Built Environment: Effects of Compact Development on Motorized Travel, Energy Use, and CO2 Emissions*. Washington DC: National Academy of Sciences

VandeWeghe, J.R. and C. Kennedy. 2007. A spatial analysis of residential greenhouse gas emissions in the Toronto census metropolitan area. *Journal of Industrial Ecology*. 11(2): 133-144.

Yardley, W. 2008. A city cooler and dimmer, and, oh, proving a point. *The New York Times*, May 14.