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Aligning incentives for climate-friendly communities

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Deborah Salon, Daniel Sperling, Alan Meier,
Sinnott Murphy, Roger Gorham, James Barrett

Institute of Transportation Studies ◇ University of California, Davis

One Shields Avenue ◇ Davis, California 95616

PHONE: (530) 752-6548 ◇ FAX: (530) 752-6572

WEB: http://its.ucdavis.edu/

City carbon budgets: Aligning incentives for climate-friendly communities

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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. Recognizing this, many cities have developed climate action plans, containing a disparate mix of mostly voluntary greenhouse gas emissions reduction proposals. This paper describes an integrated climate policy instrument for local governments: city carbon budgets. 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. Our recommended policy structure is based on the principles of effectiveness, equity, efficiency, administrative ease, and political acceptability.

1. INTRODUCTION

Most of the dialogue regarding climate change has taken place at the national and international levels. However, carbon emissions from the individual-level activities of passenger transport and energy use in residential buildings accounted for approximately 40 percent of all US carbon emissions in 2005 (Brown et. al. 2008). Absent an enormous leap forward in low-carbon energy technology, meeting the challenge presented by climate change will require that individuals, households, and communities all become part of the process. As Kates et. al. (1998) write, "Global agreements and national regulations and incentives may be needed to encourage or require [greenhouse gas emissions] abatement, but abatement actually occurs at the local level when people and their organizations modify their behavior, change their activities, and employ different technologies."

In this paper, we identify a climate policy instrument that targets behavioral change and focuses on local governments: city carbon budgets. This approach would make local governments accountable for greenhouse gas emissions that are under their direct or indirect control. It would empower them to take responsibility for their future emissions patterns, while ensuring that reductions are made in a manner most appropriate to local circumstances.

Local governments can and do have a big effect on greenhouse gas emissions[1], and are particularly influential in determining the emissions that are locked into 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.

[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.

Realizing that they can and should be part of the solution, many cities have adopted climate action plans. But these plans are mostly premised on voluntary actions, rarely containing firm requirements or even substantive incentives. Higher authorities are reluctant to intervene because they do not want to infringe on land use powers and other prerogatives of local governments.

City carbon budgets provides a critical mechanism to harmonize local-level policies that affect transport and buildings energy use with larger-scale greenhouse gas emissions reduction goals. The aim is to empower local governments to devise effective initiative packages to reduce greenhouse gas emissions in their communities by providing both technical and financial help, and demanding environmental results.

This paper lays out the basic logic of a city carbon budgets program. We begin in Section 2 with a description of the city carbon budgets concept, discussing the logistical and technical details that would need to be worked out in order for the program to be both technically successful and also meet with public acceptance. Section 3 provides a discussion of what local governments can do and how effective these strategies might be, and identifies both costs and non-climate co-benefits that are likely to be associated with a city carbon budgets policy. Section 4 concludes the paper.

2. POLICY DESIGN OF CITY CARBON BUDGETS

The city carbon budgets concept aligns local powers and prerogatives regarding land use, zoning, transport programs and investments, and building codes with efforts at the state and national levels to reduce greenhouse gas emissions. The policy would assign responsibility to localities for reducing the emissions from local transport and buildings energy use. Cities and counties in a carbon budgets program would be responsible for reducing their per capita carbon footprint by a predetermined percent over a given time period. In return for taking on this responsibility, local governments would receive both financial and technical assistance.

Assigning responsibility to local governments to reach climate goals – instead of mandating that they adopt specific policies – would encourage solutions that are tailored to the communities where they will be implemented. Different localities will make different local 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. Because of this programmatic flexibility, it is likely that many of the resulting local initiatives will not only reduce greenhouse gas emissions, but will also make these communities more attractive places to live and work.[2]

[2] Some readers may be skeptical of this claim, arguing that cities would already be implementing any initiatives that make their communities "more attractive places to live and work". There are two reasons why this is not necessarily true. First, city carbon budgets will provide additional funding to local governments. Second, if city carbon budgets were implemented across an entire state or nation, it would change the way that cities compete for tax-generating development. A community that emphasizes environmentally-friendly planning today risks losing that competition for tax-generating development to neighboring communities that allow development that is harmful to the environment. Under a broad city carbon budgets policy, this tension between city competition for development and environmental protection would disappear – *all* of the communities in the area would be emphasizing environmentally-friendly planning.

2.1 Point of regulation and institutional structure

A city carbon budgets policy would devolve some responsibility for greenhouse gas emissions reduction from the state or nation to the local government (i.e. the city or county). We suggest that local governments are a logical choice for regulating emissions because they control physical development patterns, and physical development patterns have a large effect on greenhouse gas emissions from both the transport and buildings sectors. Higher-level governments clearly have an important role in setting performance standards for fuels, vehicles, and buildings, but they are in no position to micromanage development at the community level.

Though the chief responsibility rests with the local government, all levels of government have important roles in the city carbon budgets concept. Figure 1 illustrates the distribution of responsibility that we envision. In short, the role of the state or nation would be to create the policy and provide both informational and financial support. The role of regional government would be to support coordination between localities – especially in the areas of road infrastructure and public transit – and to provide technical assistance, especially in modeling of transport policy scenarios. Local governments would have the ultimate responsibility of deciding which strategies to pursue, and then implementing them.

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

Methodological consistency across localities is crucial to ensure the effectiveness of city carbon budgets. To foster this, the state or nation should create standardized methodologies to measure all emissions included in the budget, assign mobile emissions to localities, and collect any necessary data. The state or nation might actually take on the responsibility of compiling the local-level emissions inventories. This would realize economies of scale in compilation of the 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.

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, metropolitan planning organizations (MPOs) are in a good position to provide this assistance. They could provide direct technical support to cities and counties, reconcile the roles of entities such as transit agencies that cut across city boundaries, and manage the allocation of incentive funds from the state or national government.

We propose that local governments be the point of regulation for local-level greenhouse gas emission reduction. They should 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 – local governments of cities and counties have the authority to make the changes in land use policy that will be necessary to provide incentives for climate-friendly development.

There is, however, another possible set of entities that could be the point of regulation for a city carbon budgets policy – the regional governments. Land use planning for emissions reduction should be harmonized across regions, and the regions have the technical capacity for the land use and emissions modeling needed to devise the best emissions reduction strategies. However, the political reality in most areas is that regional governing bodies do not have regulatory authority over land use. It is the local governments that hold this power, and there are good reasons for them to retain this power. Thus, we believe that local authorities provide the optimal point of regulation. In metropolitan regions, however, regional planning processes should inform local climate actions and facilitate integration of regional-level plans. In areas with strong regional governance, these regional bodies could also determine the city carbon budget allocation within the region.

2.2 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. After considering several allocation options, we conclude that the most equitable and politically feasible allocation option is to take current carbon emissions as the starting point, and to require per capita emission reductions by a given percent each year according to a predetermined schedule.

Whatever the chosen allocation method, two aspects of budget allocation are crucial. 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 in such a way 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.

The first of these is allowance auctioning. Auctions are often promoted as economically efficient mechanisms to allocate responsibility for reducing emissions in seemingly similar situations (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. And thus, we reject this approach.

A second option is to allocate the same per capita emission level to all local governments in the state, reducing the level over time according to a predetermined schedule. At first glance, this seems fair – 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 (until recently) and greenhouse gas emissions were costless. They have chosen to live in homes designed without energy efficiency in mind, located in areas accessible only by car, and 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.

A third approach would be a phased approach that begins with carbon budgets based on current emissions in each locality and arrives 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 other communities would have much larger requirements. Therefore, we are not convinced that this plan is politically acceptable.

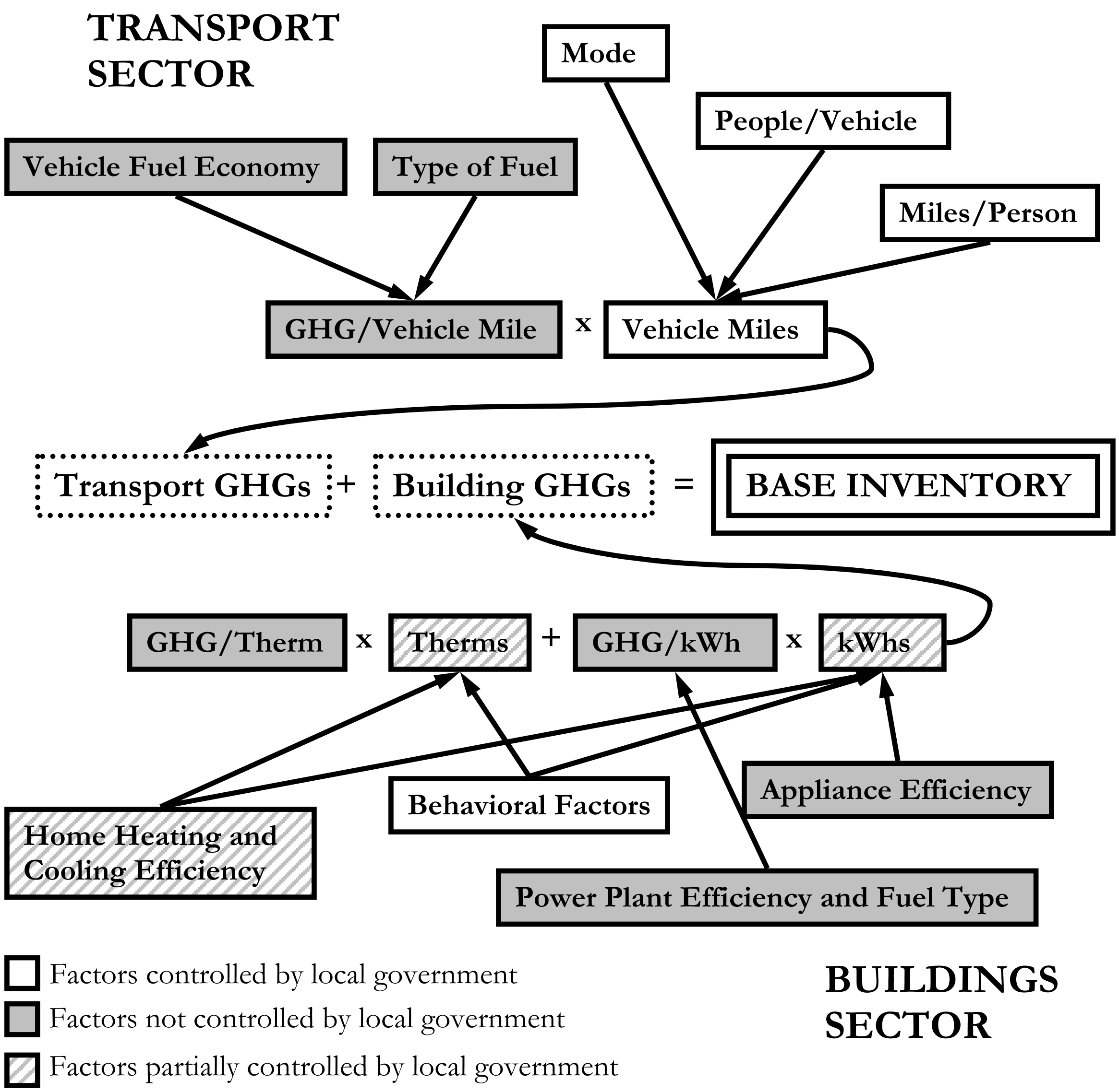
A fourth allocation method, which we suggest, is to begin with carbon budgets equal to current emissions for each locality, and to reduce these per capita budgets by a given percent each year according to a predetermined schedule. This allocation scheme has the benefit of not penalizing localities for decisions made in the past, and it arguably distributes the emissions reduction responsibility most equitably across localities. Under this approach, all localities will have emissions reduction responsibility, but localities with larger initial emissions will be responsible for larger absolute reductions per capita.

We find this fourth method most equitable and politically feasible. Because it is based on per capita emissions reduction targets, it encourages steady improvement by all localities without penalizing population and economic growth.

2.3 Emissions measurement and assignment to localities

Central to the success of the city carbon budgets program is an accurate inventory of base emissions for each city or county, compiled annually by the state or nation. These inventories

Figure 2: Factors that affect the base emissions inventory under city carbon budgets



will be used to measure emissions reduction progress in both the transport and buildings sectors. They will be the basis for determining compliance with the program, so it is crucial that they are accurate. This section identifies and evaluates the options for creating such an inventory for emissions from the buildings and transport sectors.

The main challenge is to devise a simple methodology to measure local greenhouse gas emissions with enough precision that incremental changes can be quantified. We suggest a particular emissions measurement methodology here, but a city carbon budgets policy could be based on alternate methods for compiling local emissions inventories. Whatever method is used, it should be simple, standardized, accurate, and equitable.

Figure 2 illustrates the composition of our suggested base emissions inventory for local governments. The top half of the diagram shows the factors that determine greenhouse gas emissions from the passenger transport sector, and the bottom half shows factors for the buildings sector. Factors in shaded boxes are those over which local governments have little influence. Partially shaded boxes denote factors over which local governments have partial control. Unshaded boxes indicate areas that local governments can influence through policies and investments.

Figure 3: Suggested relationship between base inventory and the city carbon budget

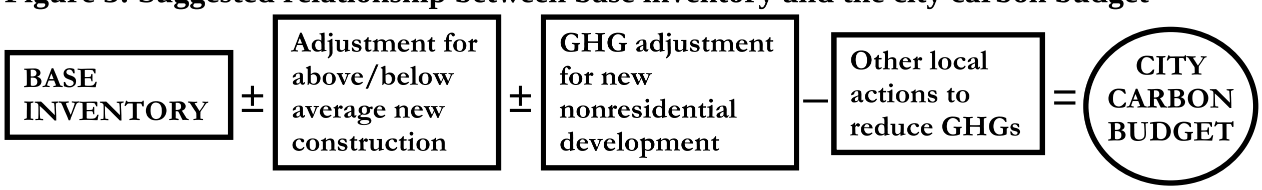


Figure 3 shows the relationship between the base emissions inventory and the city carbon budget. Adjustments for transport sector emissions, buildings sector emissions, and for actions that reduce greenhouse gas emissions outside of the transport and buildings base inventory are applied to the base inventory to arrive at the final budget. These adjustments aim to improve the inter-locality equity of the program, and will be described in more detail in the next sections of this paper.

2.3.1 Measuring building emissions

Measuring 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. This means that although the individual energy use in homes and offices is dispersed, it is tracked centrally, and those central data are easy to transform into a greenhouse gas emissions inventory from end-uses in the buildings sector. To convert kilowatt-hours to greenhouse gas emissions, we suggest using existing data on average regional emissions rates for electricity generation (Energy Information Administration 2000).

The challenge for incorporating emissions from building energy use into a city carbon budgets policy is in devising a way to use these measurements of total building emissions to regulate only the portion of building emissions that local governments can influence. Unfortunately, there is no way to accurately separate building energy use into parts that can and cannot be influenced by local action. This presents a potential inter-locality equity problem – the portion of building emissions not under local control is in flux as well, and is not changing at the same rate for all localities.

Differences between localities in this background rate of change of building emissions are strongly linked to new building construction. Most technical features related to the energy efficiency of new construction are determined by regulations and codes established at the state or national level. The energy efficiency of new appliances is also regulated by national standards and is not under the control of localities. This creates the equity problem between localities. 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 action. This would happen if there is enough new construction (with associated mandated efficiency levels) that on a per capita basis, average emissions would come down even without local action.

If this effect is large, one possible solution is to add an adjustment for new construction to the formula for allocating the buildings portion of the emission budgets, as indicated in Figure 3. 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, insuring that all localities will have similar incentives to take 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. More work is needed to ascertain the likely magnitude of the new construction problem.

2.3.2 Measuring base transport emissions and assigning them to localities

In contrast to the buildings sector, it is not hard to separate transport greenhouse gas emissions into parts that can and cannot easily be influenced by local governments. Mode choice, distance traveled, and vehicle occupancy rates are all clearly under the influence of local government policy. The availability and adoption of energy-efficient vehicle technologies and low-carbon fuels are less so. However, the fact that vehicles are mobile creates a need for an emissions assignment methodology that was not necessary in the buildings sector. This section focuses on the challenge of measuring vehicle miles traveled (VMT) and assigning them to localities. Because emission rates per mile are not largely under local control, we propose using a standardized average emission factor to convert these VMT into the transport portion of the base emissions inventory.

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. The ideal VMT assignment methodology should:

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

Table 1 identifies six options for VMT assignment to localities along with the associated likely methodology for measuring/estimating those VMT. None of them fully satisfies all of the above criteria. We favor option 6 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 three criteria listed above.

The first option assigns VMT 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. VMT would be estimated via loop detectors in conjunction with travel demand models, and incremental changes will not be detectable. Substantial VMT 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 VMT as a result.

Table 1: VMT Assignment Options and Implied Measurement Methodologies

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

The second option assigns VMT 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 VMT as a result.

The third option assigns VMT 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 VMT generated for those trips is assigned to other localities. This option would not encourage local policies that increase regional VMT.

The fourth option assigns VMT by splitting it between the home and work localities of vehicles. We include this option because it would encourage both home- and workplace-based policies to reduce VMT. There are two problems with this approach, however. First, work trips account for a relatively small percentage of total vehicle mileage. Second, extensive new data collection would be necessary to ascertain employment locations.

The fifth option assigns VMT by splitting it between vehicle origin localities and vehicle destination localities. This trip-end approach has been identified in the literature by Millard-Ball (2008) and Ganson (2008), and is attractive from the standpoint of maximizing local policy options to reduce VMT. The problem is that trip-end assignment implies that VMT measurement must be done using travel models. With current modeling capabilities, it is not possible to estimate VMT with enough precision that incremental changes are likely to be detectable.

The last option in Table 1 is to assign VMT by home locality, and to include an adjustment for new nonresidential development. We favor this VMT assignment method because it achieves measurement precision and enables local climate-friendly policymaking. Here, we describe the method in greater detail.

In the first year of the program, VMT would be assigned according to vehicle home locality and measured using odometer readings. The problem with simply continuing this is that it could lead to negative spillovers between localities in the following way. Imagine that City A and City B are neighbors and City A grants a development permit to a large big box retailer. Residents of City B may now drive more miles because they are shopping at the big box retailer across the border in City A. City A gets the developer fees and the tax revenue, and City B gets penalized for extra VMT.

This is clearly unfair, and this is where the “adjustment for new nonresidential development” comes in. Under this VMT assignment plan, localities with new nonresidential development (City A) would be required to collect data to estimate the net VMT generated by the development as well as the home localities of these VMT. If the development changes total VMT that originate outside its boundaries, an emission budget adjustment is done. If, as in our scenario, City A’s development increases City B’s VMT, then City A will compensate City B with emission allowances for the difference. If the development reduces VMT outside its locality boundaries (as would happen if the shoppers from City B used to travel twice as far as City A for their shopping), the reverse emission budget adjustment is made.

2.3.3 Other emissions

Local governments control policy levers that affect greenhouse gas emissions outside of these base emissions categories. A mechanism should 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 local promotion of technologies above and beyond the state or national requirements or of 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.

2.4 Banking, borrowing, and trading of emission allowances

Market mechanisms can and should be used to provide localities with temporal flexibility in responding to targets. This is important because 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.

One provision that would create this temporal flexibility is banking and borrowing of emission allowances. With allowance banking, a locality could save part of its allocated emissions budget for some later time. Specifically, if a locality emits fewer greenhouse gases than it is allowed in one period, then it can “bank” the difference, allowing higher emissions in future periods. 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 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, 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 below 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. However, there are significant problems associated with trading, particularly in the context of city carbon budgets.

In practice, markets require sufficient buyers, sellers, and information to function properly. A lack of buyers or sellers can result in liquidity constraints, while incomplete information can result in price swings as information is revealed. None of the conditions for a mature market currently exist in the context of city carbon budgets, making it less likely that allowance trading would substantially and equitably reduce costs.

Perhaps more importantly, 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. As such, a full trading system is not appropriate at the onset of this policy.

While we do not recommend that emissions trading be part of the carbon budgets program from the outset, we do support trading as the program matures. At some point, trading could be allowed across cities and counties within the state or country. After the kinks are worked out of trading protocols and practices, this local government market could be integrated into larger carbon markets that include other activities.

2.5 Carrots and sticks

It is essential that any city carbon budgets program be a *funded* mandate. 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. They have limited financial and technical resources, and cannot afford any new initiatives that might be costly. 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, state and local governments need to be partners rather than act as the regulator and the regulated.

To foster this partnership, the use of "carrot"-style mechanisms to support 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.

We suggest focusing on rewards and incentives, especially initially. The question, though, 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 to encourage compliance is allocation of state and national transportation funds according to emission reductions by local governments. All local governments might receive some base amount using current formulas, but those that perform better would be awarded additional funds for infrastructure and activities that lead to reduced emissions.

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 targets 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 both 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 be begin to apply. These could take the form of either withheld transportation funds or direct fines.

2.6 Timing

Although we present city carbon budgets as a full transfer of greenhouse gas emissions responsibility from the state or nation to the localities, the concept would not have to be implemented in its fullest form all at once. There are three possible stages of emissions responsibility that could be taken on by local governments. The first stage would be voluntary adoption by localities of non-binding carbon budgets. In this case, local governments would 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 would receive both technical and financial assistance, both to support compliance with the budgets and to encourage adoption of budgets. The third stage would be mandatory adoption of budgets by all cities and counties, with accompanying technical and financial assistance from the state or nation.

An attractive aspect of this policy concept 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. EMISSIONS REDUCTION POTENTIAL, COSTS, AND CO-BENEFITS OF CITY CARBON BUDGETS

The potential for greenhouse gas emissions reduction through reducing vehicle miles traveled and buildings energy use is substantial. However, the potential magnitude of emission reductions from a particular action is highly context-specific. This is one of the reasons that action decisions should be made at the local level – where the context is best understood.

It is clear that per capita emissions vary dramatically with neighborhood type. 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 metropolitan Toronto, Ontario, one study found that per capita greenhouse gas emissions from transport activity were estimated to be 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). For sake of comparison, the difference in greenhouse gas emissions between a sport utility vehicle and the average passenger car in the United States is on the order of only 25 percent.

Although these greenhouse gas emission differences across existing development patterns are impressive, the real policy question is left unanswered: What would be the impact be 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. The following two sections review the related literature that estimates the impact of individual, local-level policies and investments on transport and building energy use. Sections 3.3 and 3.4 discuss the costs and potential co-benefits of the policy.

3.1 Policies and potential for reducing greenhouse gas emissions from transport

Greenhouse gas emissions from transport are influenced by vehicle technology, vehicle miles traveled, and the carbon content of fuels. Cities have a clear role in land use and transportation planning to reduce the need for travel, to make alternatives to the private car both more available and more attractive, and to make cars less attractive for everyday trips. Here, we identify possibilities for city actions, and summarize results from the literature as to their effectiveness in reducing transport greenhouse gas emissions.

On the land use side, 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 vehicle miles traveled 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 as a source of funding for public transit or carsharing.

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. Public education about choosing a climate-friendly vehicle is always an option as well.

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 on existing data to predict what the effect of a change in the land use-transport system might be on people's choices of how much to travel and which modes to use. These studies generally isolate a single factor – density or transit 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.

The unsatisfying main finding of the reviews of the empirical literature on the relationship between urban form and travel is that “it depends” (Badoe and Miller 2000, Crane 2000, Handy 2005). 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 estimates consistently show that raising the price of driving reduces vehicle miles traveled. Looking first at one of the few real-world urban examples of road pricing, London’s congestion pricing scheme is estimated to have reduced vehicle miles traveled by 1.7 percent and fuel use by 2.8 percent when charging £5 per day for driving downtown (Transport for London 2007).[3] Estimates of the long-run elasticity of vehicle miles traveled 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 vehicle miles traveled by approximately 3 percent (Graham and Glaister 2004, Goodwin, Dargay, and Hanly 2004). There is some recent evidence that the fuel price effect on

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

travel could be smaller in the U.S., however (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 VMT, including measures such as personal travel plans and public education campaigns. Moser and Bamberg's (2008) review 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 12 percentage points. Public education campaigns are found to reduce car use by 5 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 VMT 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 vehicle miles traveled are achievable within 20 years.

3.2 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 and supplementing them with local incentives to encourage use of technologies such as solar are two examples with large energy-saving potential. Policies to accelerate 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.

How big could the impact of such policies be? 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 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 current energy crisis in Juneau, Alaska has resulted in nearly 50 percent lower electricity use (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.

3.3 How much will this cost?

Costs are highly uncertain and sensitive to the magnitude of the emissions reduction target. Because city carbon budgets aim at local policy changes as opposed to adoption of specific technologies, it is difficult to provide accurate cost estimates. In this section, we outline categories of potential costs to this program and discuss who might pay them.

There are three main categories of costs associated with city carbon budgets: institutional costs, implementation costs, and societal costs and co-benefits. Institutional costs are those of running the program. Implementation costs are the financial outlays necessary for local emissions reduction initiatives. Societal costs are any reduction in quality of life that results from city carbon budgets.

Institutional costs 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 the levels of the nation, state, region, and locality, 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 insure standardization, the nation or state could also assume responsibility for the base emissions monitoring of vehicle miles traveled and natural gas and electricity use. The cost of measuring the 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 the base emissions should be the responsibility of the locality.

The magnitude of the implementation costs for a city carbon budgets program will fully 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 they pay for themselves in energy savings. Examples of such actions include climate-friendly changes to zoning codes, certain building energy retrofits, and conversion of regular lane-miles to HOV-only. Other local actions – such as installing bicycle and pedestrian infrastructure – do have substantial 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.

Many of the local initiatives to reduce greenhouse gas emissions do not have direct costs of implementation, 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 are at work at the local level that often run counter to the goals of climate policy, favoring sprawled development over compact development. One 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, low density development is often easier for developers – there is less likelihood of neighbor objections and land costs are lower – developers apply strong pressure to cities and counties to approve and support such development. A city carbon budgets policy would 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 mixed neighborhoods with better transit access will become easier and less expensive.

3.4 Co-benefits of city carbon budgets

The motivation for the city carbon budgets concept is the need to reduce greenhouse gas emissions, but substantial non-climate benefits could result from actions taken under such a policy. These co-benefits include reduced vehicle travel, more livable communities, more efficient use of land, reduced fuel needs for buildings and vehicles – resulting in substantial cost savings – and, in a broader sense, increased energy security and lower energy prices.

We expect that the actions taken by cities and counties to reduce both vehicle miles traveled and the energy used in buildings will result in more compact, mixed-use, and transit-oriented development. This style of development has a number of benefits beyond carbon emission reductions. It 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.

It is likely that by reducing vehicle miles traveled, 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.

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 program. The extent of city carbon budgets co-benefits is 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.

4. CONCLUSION

As localities strive to minimize greenhouse gas emissions, compact, mixed-use, and transit-oriented development which promotes walking, bicycling, and mass transit use will naturally become more viable. Reduced trip distances will allow these alternative modes to compete with the automobile, helping to improve mobility and access for all residents. The tools available to local governments to reduce greenhouse gas emissions – in the form of zoning ordinances, building codes, pricing policies, public education, and investment decisions – are many and can be utilized to great effect.

Despite this promising outlook, implementation of a city carbon budgets program will not be easy. It will take time and considerable effort. It will require accompanying investments in data collection and tool development. Political forces will push back. Incentives, such as revamped transport funding formulas based on attaining greenhouse gas targets, are necessary for this initiative to gain local support and to be effective.

A city carbon budgets policy would provide a durable and integrating framework for managing greenhouse gas emissions at the local level. It 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, and to take action to reduce emissions in a way that is best for their community. It is difficult to imagine a serious effort to reduce local greenhouse gas emissions without a carbon budgets policy or something similar.

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