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CO_2 Reductions Attributable to Smart Growth in California

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Executive Summary

In order to estimate the greenhouse gas emissions reductions possible with smart growth policies for inclusion in the Draft AB 32 Scoping Plan, the California Air Resources Board (CARB) applied a methodology based in part on that which is developed and applied in *Growing Cooler,* a book we helped to author, published by the Urban Land Institute earlier this year. This paper reviews and recommends refinements to the CARB analysis.

The Draft AB 32 Scoping Plan includes a projection that smart growth policies can contribute 2.3 million metric tons of carbon dioxide (CO_2) equivalents (MMTCO2E) towards the state's 2020 target level through a 2% reduction of vehicle miles traveled (VMT) relative to trend by 2020.

We recommend that CARB revise its estimate which is currently too low due to 1) a series of assumptions that need to be adjusted based on additional data; and, 2) the omission of non-VMT CO_2 reductions associated with smart growth.

Highlights of our findings include:

- CARB's analysis does not adequately consider evidence indicating a clear trend toward higher density residential development in the last decade. Further, while there is a significant shift away from sprawl development, new data make it clear that consumer demand for higher density development is not being met at present due to inadequate supply.

- The CARB estimate does not include savings associated with the development of a smart transportation funding program that emphasizes roadway maintenance, transit enhancements, and bicycle and pedestrian facilities.

- Additional policy mechanisms currently under consideration, such as Pay-As-You-Drive insurance and congestion pricing, are not evaluated and could contribute additional CO_2 reductions.

- The CARB estimate does not include savings associated with reduced residential energy use afforded by compact development.

- The CARB estimate does not include potential savings from gas prices at or above what the state is currently experiencing.

- The CARB estimate does not include potential reductions in long distance commuting by improving jobs-housing balance within the major regions of the state.

Our analysis addresses many of the factors excluded from the CARB analysis, and indicates that CO_2 reductions in the range of 14.4 – 17.9 MMTCO$_2$E by 2020 are demonstrably achievable. This estimate includes a reduction of 3.0 - 3.6 MMTCO$_2$E from residential energy savings associated with compact development. Excluding these energy savings, we estimate VMT reductions due to certain smart growth policies can achieve a reduction of 11.4 – 14.3 MMTCO$_2$E. These findings are summarized in Table A.

The first two categories of savings, VMT reduction with compact development, and VMT reduction with smart transportation policies, are inextricably linked in Regional Transportation Plans. Transportation investments that serve compact rather than sprawl development typically include different kinds of roads (e.g. complete streets), less investment in new freeway capacity, and more investment in transit, pedestrian and bicycle facilities. For the most part the savings in one category cannot be achieved without the other.

Table A. Estimated CO_2 Reduction with Smart Growth in California (2010-2020)

	CO_2 Reduction (million metric tons)
VMT Reduction with Compact Development	4.1 – 5.7
VMT Reduction with Smart Transportation Policies	4.0
VMT Reduction with Measures Under Evaluation	3.3 – 4.6
Total	11.4 - 14.3
Building Energy Savings	*3.0 – 3.6*
Total with Building Energy Savings	*14.4 – 17.9*

This range of savings does not represent the upper bounds of what might be achievable in this sector. Two potentially significant areas for additional savings are excluded from our analysis because of insufficient data. First, our estimates assume real gas prices in the range of $2.00 to $2.50 per gallon rather than current prices, or potentially even higher prices in the future. Second, our estimates assume the current pattern of jobs-housing imbalance within some regions (e.g., insufficient housing for employment in Bay Area, and more housing than jobs in the Central Valley).

I. Introduction

In 2006, California Governor Arnold Schwarzenegger signed Assembly Bill 32, the *Global Warming Solutions Act (AB 32)*. The law directs the California Air Resources Board (CARB) to develop a plan for reducing California's greenhouse gas (GHG) emissions to 1990 levels by 2020.

With the passage of AB 32, California embarked on creating the nation's first comprehensive legal structure for addressing GHG emissions. This historic action has already spurred other states to pass similar laws, and the implementation of AB 32 will continue to establish new precedents for others to follow.

Since the beginning of the AB 32 implementation process, "Smart Land Use and Intelligent Transportation" has been identified as a key strategy for achieving the mandate of AB 32. Transportation accounts for 38% of California's GHG emissions, and CARB and the Climate Action Team (CAT) recognize that development patterns have an important influence on driving behavior.

CARB's Draft AB 32 Scoping Plan, released in June 2008, includes several strategies to address the GHG emissions associated with land use. It also includes a projection that smart growth policies can reduce vehicle miles traveled (VMT) by 2% relative to trend by 2020, thereby contributing 2.3 $MMTCO_2E$ of reductions toward the state's 2020 target level. Because California is the first state to develop policies around land use and climate change, these estimates are potentially precedent-setting.

The Role of *Growing Cooler*

The new Urban Land Institute book *Growing Cooler* includes methodology for forecasting the GHG emissions reductions associated with compact, transit-oriented, and walkable development. Since CARB largely relied on methodology from *Growing Cooler* (GC), a book we co-authored, we reviewed the CARB projection for consistency with the methods and assumptions in GC. Our most important conclusion is that the CARB projection, validated by CARB and ourselves using methodology from Chapter 2 of GC, understates the benefits of smart growth by only considering VMT reductions associated with land use changes. This limitation is a major one. Quoting from the book:

> Making reasonable assumptions about growth rates, the market share of compact development, and the relationship between VMT and CO_2, smart growth could, by itself, reduce total transportation-related CO_2 emissions from current trends by 7 to 10 percent in 2050. This reduction is achievable

> with land-use changes alone. It does not include additional reductions from complementary measures, such as higher fuel prices and carbon taxes, peak-period road tolls, pay-as-you drive insurance, paid parking, and other policies designed to make drivers pay more of the full social costs of auto use.
>
> This estimate also does not include the energy saved in buildings with compact development, or the CO_2-absorbing capacity of forests preserved by compact development. Whatever the total savings, it is important to remember that land use changes provide a permanent climate benefit that would compound over time. The second 50 years of smart growth would build on the base reduction from the first 50 years, and so on into the future. More immediate strategies, such as gas tax increases, do not have this degree of permanence (Ewing et al. 2008, pp. 9-10).

Limitations of Chapter 2 prompted the authors of GC to include two additional chapters. Chapter 8 estimates the VMT reduction possible with a combination of land use and transportation policies, as opposed to land use policies alone. The four policy levers whose benefits are estimated in Chapter 8 are (1) higher density (compact development); (2) a shift in some funds from highway expansion to maintenance; (3) increased spending on transit; and (4) higher gas prices due to gas tax hikes, a carbon tax, or cap-and-trade.

Chapter 7 estimates the residential energy and associated GHG reductions with compact development. This is on top of any CO_2 reduction due to lower VMT. It is an additional reduction benefit over what would be realized by existing green building or energy efficiency programs, since it anticipates a shift in the housing stock due to compact development.

So for consistency with GC, the authors of this study needed to, first, re-estimate the VMT and associated CO_2 reductions that will follow from compact development in California; second, estimate the added VMT and associated CO_2 reductions with complementary transportation policies; and third, estimate the residential energy and associated CO_2 reductions with compact development. These transportation policies are as much a part of smart growth as is compact land development. In fact, the two are inextricably linked, particularly in the regional planning context that CARB has chosen as the framework for achieving reductions from this sector. While these two strategies are discussed sequentially in keeping with GC methodology, they must be implemented together to be fully effective.

II. VMT and CO_2 Reduction with Compact Development

Like the forecast in GC, CARB validated its forecast of CO_2 reductions with compact development using the formula:

% Market Share of Compact Development
x
% of Total Development Built between 2010 and 2020
x
% VMT Reduction with Compact Development
x
Ratio CO_2/VMT Reduction with Compact Development
x
Baseline Projection of CO_2 in 2020
=
CO_2 Reduction with Compact Development by 2020

A brief discussion of each factor follows, taken straight from GC.

Market Share of Compact Development

The first factor that will determine CO_2 reduction with compact development is market penetration during the forecast period, 2010 to 2020. The market share of compact development in the United States is growing but probably still small. No comprehensive inventory exists.

Two factors, however, suggest that whatever the market share is today, it will increase dramatically during the forecast period. One factor is the current undersupply of compact development relative to demand. The other factor is changing demographics.

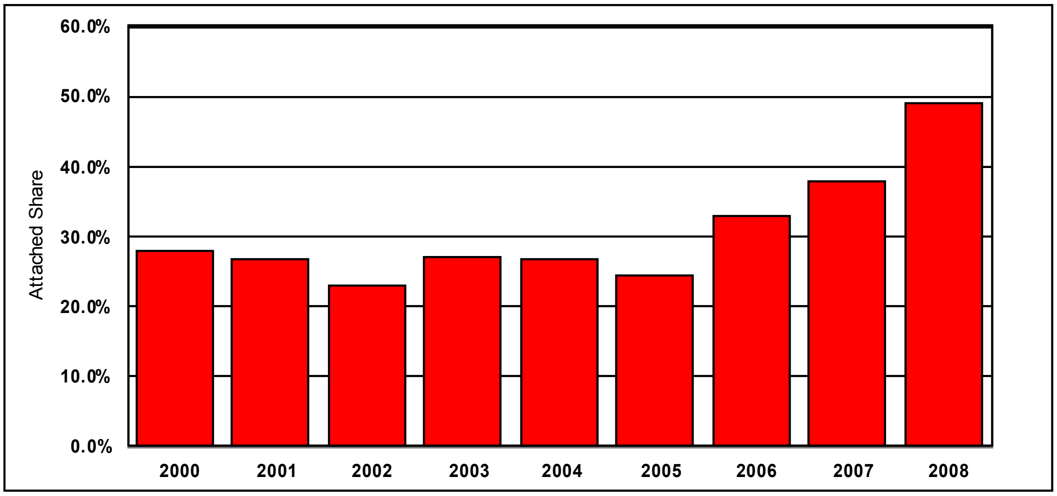
Recent research published in the *Journal of the American Planning Association* indicates that about half of all American households now want smart growth features in their neighborhoods (Handy et al. 2008). This is up from about a third over the last decade. Given that new construction and replaced units combined only add about 1.5% annually to the nation's housing stock, it would take to 2050 or beyond to meet this pent-up demand.

In addition, there is the emerging "energy crisis," as the world's supply of fossil fuels is beginning to lag behind world demand. Lagging supply in the face of growing demand will mean higher fossil fuel prices and that may lead the domestic market to seek more energy-efficient automobiles and places to live.

The longer-term effects of higher fuel prices on urban form are speculative, but that there will be an effect is certain. One outcome may be smaller lots, smaller homes, more integrated land uses, and thus more compact development than in the past.

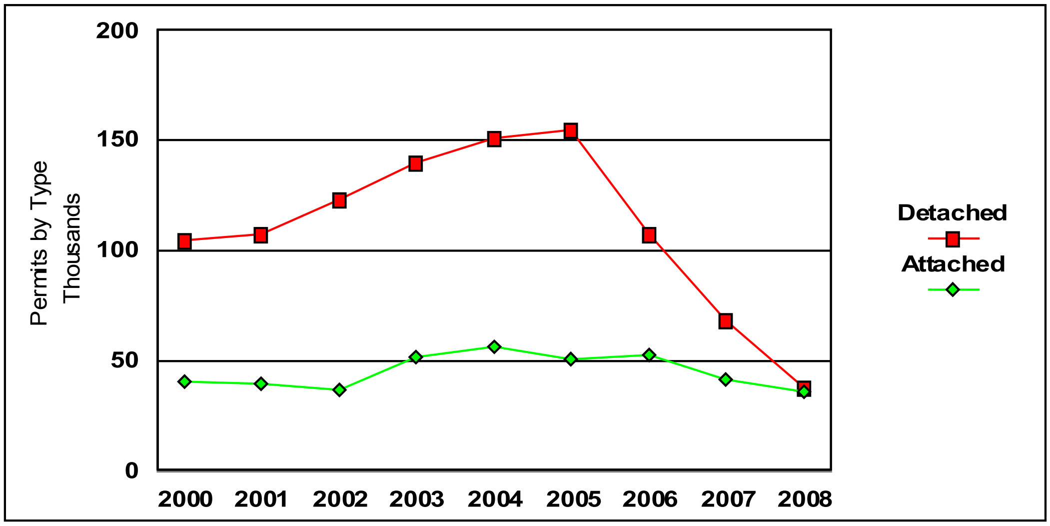
The share of new attached units to all units constructed in California is increasing. This is partly due to the "sub-prime meltdown" since about 2006 but also due to changing demographics and housing market trends. Figure 1 illustrates the growing share of attached residential construction to all construction since 2000 (including figures annualized for 2008). By 2008, attached units accounted for about half of all new residential units constructed.

Figure 1. Attached Unit Share of All New Residential Construction in California, 2000-2008



Source: Census permit data based on analysis by Arthur C. Nelson.

Figure 2. Detached and Attached Units Constructed in California, 2000-2008



Source: Census permit data based on analysis by Arthur C. Nelson.

Figure 2 illustrates trends in the actual number of attached and detached units built. Notably, over the period 2000 through 2008 detached construction varied from a low of about 40,000 units to a high of 150,000. Attached units only varied between about 40,000 to about 50,000 units, ending at half of all units.

This might be dismissed as a temporary outcome of the sub-prime mortgage meltdown, but for the following. Analysis of new construction trends reported by the American Housing Survey for the state's principal metropolitan areas over the period 1998 through 2004 indicate important shifts in demand (see Table 1, page 11).

For the period 1998 through 2004, compact development in California's major metropolitan areas was nearly 40% of all new construction. More recent Census permitting data indicate that since 2003, attached housing (multifamily and townhouse) has accounted for about a third of all new residential construction, up from about a quarter during the 1990s. If the share of new detached units on small lots (under 7,000 square feet) rose from the third it was during the period 1998 to 2004 to half, about two-thirds of all new residential construction (detached and attached) would be in compact forms.

Indeed, there is evidence that since 2004 the market has shifted further in the direction of compact development. In the Sacramento region, for instance, 61% of new residential construction in 2007 was either attached or on single family lots of 5,500 square feet or less (Hanley Wood Market Intelligence, 2008).

Table 1. New Construction During 1998-2004

Attached Share	16.6%
Apartment Share	**7.4%**
Townhouse Share	**9.2%**
Detached Share	83.4%
Cluster/Small Lot as Share of Detached	30.6%
Cluster/Small Lot Share, Weighted	**22.7%**
Compact Share	**39.3%**

Source: Analysis of American Housing Survey data for Anaheim-Santa Ana (2002), Los Angeles (2003), Oakland (1998), Riverside-San Bernardino (2002), Sacramento (2004), San Diego (2002), San Francisco (1998) and San Jose (1998) by Arthur C. Nelson.

A healthy share of nonresidential development follows population. With more than half of future residential development in compact settings, nonresidential development is likely replaced at higher intensity/density; this is especially important considering that two-thirds of future nonresidential development will be the rebuilding of the existing stock.

We will assume that between 2010 and 2020, the lower bound on the proportion of compact development is 50% and the upper bound is 70%. This is consistent with long-term demographic and lifestyle trends, the current undersupply of compact development, and the growing efforts at the local and regional level for blueprint planning and complementary open space protection. This still leaves a substantial portion of total development (new and existing) as it is today, sprawling and auto oriented.

Increment of New Development or Redevelopment Relative to the Base

The cumulative effect of compact development also depends on how much new development or redevelopment occurs relative to a region's existing development pattern. The amount of new development and redevelopment depends, in turn, on the time horizon and the area's growth rate. The longer the time horizon and the faster the rate of development or redevelopment, the greater will be the regionwide percentage change in VMT per capita.

A recent article in the *Journal of the American Planning Association* began with the following words: "More than half of the built environment of the United States we will see in 2025 did not exist in 2000, giving planners an unprecedented opportunity to reshape the landscape" (Nelson 2006). In the context of California, we estimate, as does CARB, that a quarter (25%) of California's built environment in 2020 will be built between 2010 and 2020. Where we differ is in the percent that will be compact versus sprawling.

Reduction in VMT per Capita with Compact Development

Four different empirical literatures inform the discussion of urban development and its impacts on VMT, the primary determinant of transportation-related CO_2 emissions:

- Aggregate travel studies, such as sprawl index research conducted for Smart Growth America;
- Disaggregate travel studies, such as Smart Growth Index elasticity estimates;
- Regional simulation studies, such as Portland's LUTRAQ (Land Use, Transportation, Air Quality) study; and
- Project simulation studies, such as the EPA's Atlantic Station study.

The core of GC, Chapter 4, reviews each literature in turn and presents order-of-magnitude effect sizes. For two literatures—disaggregate travel studies and regional simulation studies—the sample of studies is large enough to permit meta-analyses of study results. The different literatures provide a consistent picture. Compact development has the potential to reduce VMT per capita by anywhere from 20 to 40 percent relative to sprawl.

The actual reduction in VMT per capita depends on two factors: how bad trend development patterns are in terms of the so-called "five Ds" (density, diversity, design, destination accessibility, and distance to transit); and how good alternative growth patterns are in terms of these same five Ds. The five Ds are qualities of the urban environment that urban planners and developers can affect, which in turn affect travel choices.

Considering all the evidence presented in GC, it is reasonable to assume an average reduction in VMT per capita with compact development relative to sprawl of 30%. This fraction applies to each increment of development or redevelopment but does not affect base development.

Ratio of CO_2 to VMT Reduction

Compact development may not reduce CO_2 emissions by exactly the same proportion as VMT. The "Synthesis" section in Chapter 3 of GC indicates that a 30 percent reduction in VMT would be expected to produce a 28 percent reduction in CO_2. This figure factors in CO_2 penalties associated with cold starts and reduced vehicle operating speeds. Thus the ratio of CO_2 to VMT reduction would be around 0.93.

We will conservatively assume a CO_2 reduction equal to nine-tenths of the VMT reduction. This is the ratio of CO_2 reduction to VMT reduction for one scenario versus another in the target year, 2020. The effects of increased vehicle efficiency and fuel switching already have been incorporated into both scenarios. The ratio of CO_2 to VMT will decline under all scenarios, doubtless dramatically. However, in the projections for CARB's Scoping Plan, compact development in 2020 is being compared to trend development in 2020, not to development in the base year, 2010.

Forecasts

Table 2 lists the assumptions made by CARB for the target year 2020. CARB assumed that about 30% of new development in California will be in compact configurations, and that about 25% of the development on the ground in 2020 will have been built between 2010 and 2020. The other assumptions are straight from GC.

Table 2. Assumptions Relating to Compact Development, VMT, and CO_2

	CARB 2020
Compact Market Share	30%
% Development/Redevelopment	25%
% VMT Reduction	30%
Ratio CO_2/VMT Reduction	90%
Baseline CO_2 Projection	115 MMTCO2E

Plugging CARB assumptions into the formula above, we confirm CARB's 2% reduction in urban transportation CO_2 with compact development by 2020.

CARB 2020**:** % CO_2 reduction = 0.3 x 0.25 x 0.3 x 0.9 = 2%

Using the CARB baseline projection of 115 MMTCO2E from passenger vehicles in 2020, we arrive at CARB's estimate of savings with smart growth of 2.3 MMTCO2E.

CARB 2020: CO_2 reduction = 0.02 x 115 = 2.3 MMTCO2E

We and CARB agree on the percent of the built environment that will be constructed between 2010 and 2020, the % VMT reduction associated with compact development, and the ratio of CO_2 to VMT reduction. Where we differ is in the market penetration assumed by CARB, and the baseline CO_2 projection to which the % reduction is applied. Even during a time of relative economic robustness (1998-2004) where low interest rates and favorable financing led to the nation's highest rate of home ownership ever (69% in

2004), about 40% of California's new residential development was at compact densities. Demographic changes favoring even more compact residential development (see Nelson 2006) combined with the fallout of the "sub-prime meltdown" and rising energy prices suggest that compact residential development will meet 50% to 70% of the demand for new housing. As nonresidential development mostly follows people, it is reasonable to assume that a similar if not higher share of future nonresidential development will also be compact. In sum, one can easily justify a 50 to 70% market share for compact development between 2010 and 2020, and a base CO_2 emission level of 120 MMTCO2E, as detailed below.

To get to the heart of the matter, these two adjustments would increase the percentage reduction in CO_2 with smart growth to a probable range of 3.4 to 4.7% by 2020. These reductions, again, are through land use changes alone.

Lower 2020 Re-estimate: % CO_2 reduction = 0.5 x 0.25 x 0.3 x 0.9 = 3.4%
Upper 2020 Re-estimate: % CO_2 reduction = 0.7 x 0.25 x 0.3 x 0.9 = 4.7%

As to the base CO_2 emission level, CARB appears to have misinterpreted the nature of the baseline to which GC assumptions are applied. The baseline in GC is all urban VMT, weighted by vehicle type, not all passenger VMT, urban and rural. Compact development will have no effect on interregional travel by passenger cars, included in the CARB baseline, but should have a substantial effect on commercial as well as passenger vehicle VMT within urban areas. As noted earlier, our analysis does not account for reduced interregional commuting and associated VMT that would likely result from improved jobs-housing balance within the major regions of the state.

As of 2006, the most recent year available, 82% of California's VMT was in urban areas, and hence subject to smart growth. Urban VMT is a lesser (and unknown) proportion of statewide VMT weighted by vehicle CO_2 emission rates. But the urban share of VMT is increasing with each passing year, as the state becomes ever more urbanized. Indeed, between 2001 and 2006, the urban share increased by more than 2%. Therefore, we will assume that by 2020, 82% of the weighted VMT will be in urban areas. Therefore, the baseline CO_2 emissions of which % reductions should be applied is approximately 120 mm tons, and the total CO_2 reduction with compact development will be between 4.1 and 5.7 million metric tons, as shown in Table 3 (page 15).

Lower 2020 Re-estimate: CO_2 reduction = 3.4% x 120 = 4.1 MMTCO2E
Upper 2020 Re-estimate: CO_2 reduction = 4.7% x 120 = 5.7 MMTCO2E

Table 3. Comparison of Assumption and Forecasts

	CARB 2020	Ewing 2020 low	Ewing 2020 high
Compact Market Share	30%	50%	70%
% Development/Redevelopment	25%	25%	25%
% VMT Reduction	30%	30%	30%
Ratio CO_2/VMT Reduction	90%	90%	90%
Baseline CO_2 Projection	115 MMT	120 MMT	120 MMT
CO_2 Reduction	2.3 MMT	4.1 MMT	5.7 MMT

Other Land Use Measures Under Evaluation

The Draft Scoping Plan includes one measure under evaluation that could improve on the above estimates. This regulatory program, known as Indirect Source Review, is designed to address air pollutant emissions associated with residential and commercial developments. A landmark Indirect Source Rule (ISR) was adopted for criteria pollutants by the San Joaquin Valley Air Pollution Control District, and several other air districts in California have followed suit.

Adoption of a statewide Indirect Source Rule for greenhouse gas emissions would reduce future VMT generated by the “non-compact” component of development. With an Indirect Source Rule in place, even outlying development would have a strong incentive to include changes in site design, street layout, transit amenities, mix of uses, and other elements that can reduce VMT. The goal is to reduce per capita VMT generated by future residents, workers, or shoppers down to the threshold at which no off-site mitigation must be funded. With ISR, outlying developments—which account for 30 to 50% of all development through 2020 in the analysis here—may generate lower VMT than anticipated. Our analysis did not assume the implementation of an ISR and this is one reason why the 4.1 – 5.7 MMT estimate may be considered conservative.

III. CO_2 Savings with Smart Transportation Policies

Chapter 8 of GC estimates the combined effect of compact development, shifts in funding from highways to transit, and increases in road user charges. It does so with data from the Texas Transportation Institute's Urban Mobility database (Schrank and Lomax 2007). The TTI Urban Mobility Report is released annually amid much fanfare and media interest. It is widely accepted as the most complete assessment of congestion in the nation's urban areas. The report is based on data collected by the federal government from states and transit operators. In the last two years, it has undergone a substantial update and refinement. In sum, the TTI database is the best available.

What makes the TTI database so useful, for our purposes, is the fact that it provides data for many urbanized areas over many years. The annual series begins in 1982 and runs through 2005. It includes 85 urbanized areas ranging in size from the mega region of New York and northern New Jersey to the subregion of Boulder, Colorado. Essential data not contained in the TTI database are available from other sources, specifically transit data from the Federal Transit Administration's National Transit Database and income data from the U.S. Census Bureau and the U.S. Bureau of Economic Analysis (BEA). Our final database includes 84 urbanized areas over a 21-year period. Lack of certain transit data forced us to exclude one urbanized area (Boulder) and the first three years of the series (1982 through 1984).

For Chapter 8, two structural equation models (SEMs) were estimated with this national dataset: a cross-sectional model for 2005, the last year in the series, and a longitudinal model for the two ten-year periods, 1985 to 1995 and 1995 to 2005. The cross-sectional model was used to capture long-term relationships between transportation and land use. Each urbanized area has had decades to arrive at quasi equilibrium among density, road capacity, transit capacity, and VMT.

However, there is not enough spatial variation in fuel prices across the United States to detect effects on VMT in a cross-sectional sample. In 2005, the average price of gasoline (in the TTI dataset) varied by just 44 cents across the 85 urbanized areas. The average price of gasoline can fluctuate that much or more from year to year. So a longitudinal analysis was required to capture short- and medium-term responses to fuel price fluctuations.

Ideally in this analysis, we would have used models and elasticity values specific to California. We could not estimate a cross sectional model for California, having only nine large urbanized areas in the TTI sample. We were able to estimate a longitudinal model by dividing the period 1985 to 2005 into four 5-year time steps, and computing rates of change in all variables, including fuel prices, for all nine urbanized areas during all four periods. This gave us a marginally adequate sample size of 36 (four periods x nine urbanized areas).

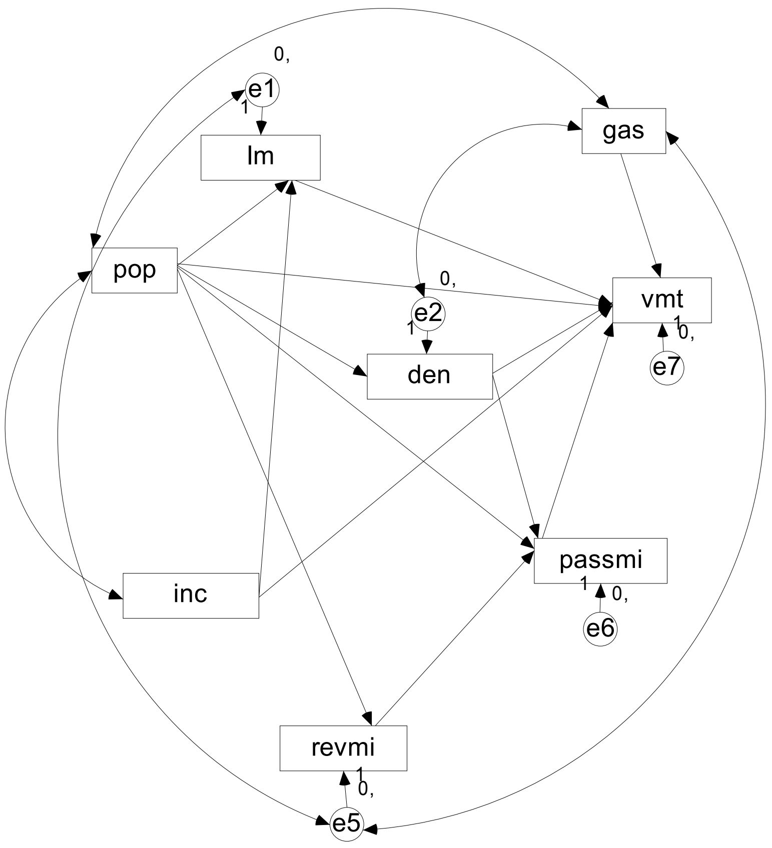
All variables in the longitudinal model are defined in Table 4. All were computed as annual percentage rates of change during the 5-year period relative to the base values. Percentage rates of change have the advantage of reducing the influence of extreme values and allowing parameter estimates to be interpreted as elasticities.

Table 4. Variables in the Longitudinal (Time-Step) Model

Variable	Definition	Source
vmt	Annual percent change in freeway and principal arterial daily VMT over five years (1985–1990, 1990-1995, 1995-2000, and 2000–2005)	TTI urban mobility database
pop	Annual percent change in population over five years	TTI urban mobility database
den	Annual percent change in gross population density over five years	TTI urban mobility database
lm	Annual percent change in freeway and principal arterial lane miles per thousand people over five years	TTI urban mobility database
inc	Annual percent change in real annual per capita income over five years (adjusted for CPI)	Census/BEA
gas	Annual percent change in real average fuel price over five years (adjusted for implicit price deflator)	TTI urban mobility database
revmi	Annual percent change in transit revenue miles over five years	National Transit Database
passim	Annual percent change in transit passenger miles over five years	urban TTI mobility database

Details regarding estimation, interpretation, evaluation, and application of structural equation models (SEMs) are provided in Chapter 8 of GC. The SEM that achieved the best fit with the California data is shown in Figure 3 (page 18).

Figure 3. Longitudinal Model Relating Changes in Land Use, Transportation, and Fuel Prices to Changes in VMT



Elasticities of VMT with respect to urban variables from the two national models, and the one California model, are compared in Table 5 (page 19). An elasticity is just a percentage change in one variable with respect to a 1 percent change in another variable. The elasticity of VMT with respect to highway lane miles, 0.46 in the national cross sectional model, implies a 0.46% increase in VMT for every 1% increase in highway lane miles.

California elasticities are, for the most part, consistent with national elasticities. For our purposes, the most significant difference is the elasticity of VMT with respect to transit service, which is very low for the State of California. We attribute this to the small sample of California cases, and hence large sampling error. We therefore adopt the best-estimate elasticities from the national study, as reported in Chapter 8 of GC.

Table 5. Elasticities of VMT with Respect to Urban Variables

	National Cross Sectional	National Longitudinal	California	Best Estimate
Population	0.97	0.87	0.77	0.95
Real per capita income	0.53	0.54	0.09	0.54
Population density	–0.21	–0.15	-0.15	–0.30
Highway lane miles	0.46	0.68	0.57	0.56
Transit revenue miles	–0.08	–0.02	-0.01	–0.06
Transit passenger miles	–0.07	–0.03	-0.01	–0.06
Real fuel price	NA	–0.17	-0.11	–0.17

Source: R. Ewing et al., Growing Cooler: The Evidence on Urban Development and Climate Change, Urban Land Institute, Washington, D.C., p. 127.

Parenthetically, the elasticity of VMT with respect to density has been bumped up to –0.30, in order to account for the absence of compactness measures other than density. When land use mix within subareas of a region, street accessibility, and other built environmental variables are missing from the analysis, density soaks up some of their effects, but not all of them. The assumed elasticity value is consistent with the literature reviewed in Chapter 4 of GC.

The elasticity values suggest that VMT is most sensitive to lane miles of highway capacity, less sensitive to land use patterns, less sensitive still to the real price of fuel (adjusting for inflation), and least sensitive to revenue miles of transit service.

Making realistic assumptions about changes in annual growth rates of the urban variables under a low-carbon scenario, Chapter 8 of GC finds that the largest potential effect on VMT is that of a fuel price increase (road user charges), second is a slow down in highway expansion, third is an increase in density, and last is an increase in transit service (see Table 6, page 20). As described earlier, compact development patterns typically go together with greater transit revenue miles, increased funding for bicycle and pedestrian facilities, and a shift in emphasis from highway expansion to highway maintenance.

The CARB Scoping Plan already gives ample consideration to the possibility of increases in road user charges. These are built into the discussions of cap-and-trade, carbon taxes, congestion pricing, and Pay-As-You-Drive insurance. The potential benefits of these are described at the end of this section.

Table 6. VMT Growth under a Low-Carbon Scenario (Chapter 8 of GC)

	Elasticities of VMT with Respect to Policy Variables	Change in Annual Growth Rates (% above/ below Trend)	Effect on Annual VMT Growth Rate (% below Trend)
Population density	–0.30	1	–0.077
Highway lane miles	0.55	–1	–0.114
Transit revenue miles	–0.06	2.5	–0.046
Real fuel price	–0.17	2.7	–0.144

Source: R. Ewing et al., Growing Cooler: The Evidence on Urban Development and Climate Change, Urban Land Institute, Washington, D.C., p. 127.

What is not considered, and is central to the concept of smart growth, is a shift in transportation spending that will help the state to achieve its objectives of reducing GHG emissions. While highway expansion has short-term benefits in the form of congestion relief, it also induces additional traffic and outlying development, thereby increasing VMT. A smart transportation program includes some highway expansion but puts its emphasis on highway maintenance, transit expansion, and bicycle and pedestrian facilities.

Using the same dataset from TTI that was used originally to estimate the models in Chapter 8 of GC, Table 7 (page 21) summarizes the annual rates of growth of transportation and related variables for California's nine large urbanized areas. The areas collectively house 24.5 million residents, or two-thirds of the California population. The pattern in California differs from that nationally. Of particular note:

- VMT grew at a faster rate than population, but the spread is not as great in California as it is nationally.
- Density increased modestly in most areas.
- Lane miles increased at a good clip, but not as fast as population. This differs from urbanized areas nationwide.
- The real price of gasoline was up over the 20 years, after initially dipping and then rising rapidly to above its original level.
- Real per capita income rose modestly in most places.
- Revenue miles of transit service was the fastest growing variable, growing faster than VMT in most areas.

Table 7. Annual Growth Rates of Transportation and Related Variables (1985-2005)

	Pop	Density	VMT	Lane Miles	Real Gas Price	Transit Revenue Miles	Real Income
Bakersfield CA	3.1%	-1.3%	3.7%	1.7%	0.9%	3.7%	-0.1%
Fresno CA	2.4%	-0.1%	2.7%	1.3%	0.9%	2.2%	0.4%
Los Angeles-Long Beach-Santa Ana CA	0.9%	0.2%	1.9%	1.1%	0.9%	2.9%	0.2%
Oxnard-Ventura CA	1.5%	0.7%	2.3%	2.4%	0.9%	6.4%	-0.3%
Riverside-San Bernardino CA	3.2%	0.9%	4.0%	2.2%	0.9%	5.6%	-0.1%
Sacramento CA	3.3%	1.7%	3.1%	1.5%	0.9%	4.9%	1.1%
San Diego CA	2.2%	1.1%	3.2%	1.4%	0.9%	4.3%	1.2%
San Francisco-Oakland CA	1.1%	-0.7%	2.0%	1.0%	0.9%	1.6%	1.2%
San Jose CA	1.2%	0.4%	1.9%	0.9%	0.9%	1.6%	1.0%
Average	2.1%	0.3%	2.7%	1.5%	0.9%	3.7%	0.5%

The smart growth scenario in GC assumes that new development is built to densities of 75 percent higher than today's, roughly 13 units per acre on average, with a wide mix of housing types. With this, total average density would rise by about 50 percent between now and 2050. This is tantamount to a rise in average density of about 1 percent per year (beyond a relatively flat trend). If transit revenue miles were to grow at a 1 percent faster rate (accelerating to 4.7% per year), and highway lane miles were to grow at a moderate rate of 1% per year, with the balance of funding going to alternative modes and road maintenance, this would constitute a smart transportation program that complements the rise in density.

Given the elasticities in Table 5, the 1 percent increase in rate of transit service expansion would be expected to slow VMT growth in California's urban areas by 0.06%, while the 1 percent growth rate of highway expansion would slow VMT growth by 0.28%. Through 2020, these two changes together would cut CO_2 emissions by 4.0 $MMTCO_2E$.

2020 Estimate: CO_2 reduction = 3.3% x 120 = 4.0 $MMTCO_2E$

It is important to note that these VMT elasticities are derived in the context of $2.00 or $2.50 gasoline. With higher gas prices we are likely to see even greater reductions in

VMT for a given increase in transit service, thus these estimates are conservative and probably represent the lower bound of what is possible. A recent study conducted by the Congressional Budget Office (CBO) reveals that Californians changed their driving habits, switched to public transportation when they could, and reduced VMT in response to increasing gas prices. According to the CBO report, *Effects of Gasoline Prices on Driving Behavior and Vehicle Markets*, which analyzed data collected from multiple sensors on a dozen metropolitan highways in California, “for every 50 cent increase in the price of gasoline, the number of freeway trips declined by about 0.7 percent in areas where rail transit was available as a substitute for driving; transit ridership on the corresponding rail systems increased by a commensurate amount.” (CBO, 2008)

Other Transportation Measures Under Evaluation

In addition to these savings from changes in the transportation system, there are clearly significant reductions that could result from changes in the cost of driving, as noted in the above discussion of elasticities.

CARB acknowledges that road use pricing may take place through carbon fees or cap-and-trade. More directly, CARB included three transportation measures in Section C of the Draft Scoping Plan, “Other Measures Under Evaluation:” congestion pricing, Pay-As-You-Drive insurance, and public education programs to reduce vehicle travel (which could include financial incentives to use alternatives as well as educational programs).

Pay-As-You-Drive (PAYD) insurance is a measure which can be implemented quickly and achieve substantial reductions by 2020. As noted in the Draft Scoping Plan, in this program, “insurance premiums are set based on driving record and other traditional risk factors, but are broken down into per mile charges. Motorists would have the opportunity to lower their insurance costs by driving less. PAYD insurance offered to a large percentage of California drivers would have the potential to significantly reduce vehicle miles traveled and greenhouse gas emissions.”

The Draft Scoping Plan estimates a reduction of 1 $MMTCO_2E$ from PAYD. A recent analysis by the Brookings Institute estimates reductions of 8% in VMT and 11 $MMTCO_2E$ are possible with PAYD. A more conservative analysis by NRDC estimates that half of California drivers (those who drive the least) would choose PAYD by 2020, if available, and reduce their driving by 4-8%. This would result in a savings of 1.3–2.6 $MMTCO_2E$, which we believe is a reasonable estimate. Since CARB released their Draft Scoping Plan, Insurance Commissioner Steve Poizner has released draft regulations for a PAYD Program in California. Despite the fact that the draft regulations call for voluntary PAYD policies to be provided by insurance companies, we believe that due to the equity, economic and environmental benefits of this program, coupled with increasing gas prices, there is sufficient momentum to justify the 2020 adoption rates described above.

Congestion pricing is also being evaluated for inclusion in the Scoping Plan. The Draft Scoping Plan describes congestion pricing as follows:

> Research has shown that sending market signals that reflect the cost of driving can improve transportation system efficiency and reduce emissions. In a congestion pricing program, vehicles are charged a price, or toll, for traveling during peak hours on congested routes. Drivers who continue to travel on these routes during peak periods would pay more, but experience a faster, easier trip. Others would defer trips to off-peak hours, shift travel to less congested roadways, or switch to transit, carpools, or vanpools. Greenhouse gas emission reductions would come directly from the relief of severely congested traffic, some reduction in vehicle travel, and from the investment of funds in transit infrastructure that would provide additional transportation options during congested hours. Regional planning agencies would need legal authority from the State to implement congestion pricing measures.

It is difficult to estimate the potential emission reductions from congestion pricing because it depends on the pricing method and the price level. It may take the form of cordon pricing, which was adopted in London and is being studied currently by San Francisco. More likely it will take place in the form of tolled highway lanes, including a proposal in the Bay Area for a network of high occupancy toll lanes which would allow solo drivers to use excess capacity in the high occupancy vehicle lanes for a fee. And while the exact scope of congestion pricing is hard to predict, metropolitan areas around the country and in California are exploring this mechanism as a means of generating revenue and managing demand.

The Draft Scoping Plan estimates savings of up to 1 MMTCO_2E with congestion pricing. Given the large number of congestion pricing programs now being proposed, but the significant uncertainties in timing and overall impact, this seems a reasonable estimate.

Finally, CARB included as under evaluation "Public Education and Programs to Reduce Vehicle Travel" which is described as follows:

> Engaging the public to reduce their transportation carbon footprint through voluntary actions can provide immediate greenhouse gas benefits. Large scale public education programs in California have been successful in reducing energy use and waste. Similar outreach programs to encourage increased transit use, consolidation of vehicle trips, walking, biking, and other actions could help reduce growth in vehicle travel. Employer programs can reduce or mitigate impacts of commute trips, such as telecommute and flex-time work schedules.

This of course represents a significant mix of program types, many of which have proven very successful already in California. An increasing number of employers are giving out free transit passes. Another successful California program has been Safe Routes to Schools, first piloted in Marin County and then funded as a statewide program. Because these small but effective programs are usually considered outside of the typical transportation investment realm, the Bay Area Metropolitan Transportation Commission recently invested $400 million in a “Transportation Climate Action Campaign” that bundles eight such programs. MTC estimates that by the year 2015, the program will reduce annual GHG emissions by 153,000–576,000 $MTCO_2E$.

If these programs were implemented intensively, and had a dedicated funding source, they could have a significant impact. Without knowing the exact scale of the program, the Draft Scoping Plan estimates that these programs could result in up to 1 $MMTCO_2E$ of reductions by 2020. Again, this seems a reasonable estimate.

Summing the benefits of these 3 mechanisms—PAYD insurance, congestion pricing and education and incentive programs—we would expect an additional savings of:

2020 Estimate: CO_2 reduction = 1.3–2.6 MMT + 1 MMT + 1 MMT = 3.3–4.6 $MMTCO_2E$

IV. Residential Energy and CO_2 Savings with Compact Development

Chapter 7 of GC (and a companion piece in *Housing Policy Debate* by Ewing and Rong, 2008) quantifies the residential energy savings associated with compact development. In compact patterns, housing units are smaller and higher shares of units are attached or in multifamily buildings. The smaller units mean less space that must be heated in the winter and cooled in the summer. The attached single family and multifamily buildings have fewer exposed exterior walls and less heat transfer into and out of buildings. CO_2 reductions for the residential sector are in direct proportion to the energy savings.

From analysis in Chapter 7, residential energy use decreases with rising energy price, increases with increasing annual household income, and varies by race/ethnicity. Controlling for these covariates, the amounts of delivered energy use for space heating, cooling, and all other uses are all strongly related to the physical characteristics of housing units. Old houses are less energy efficient than new ones. Detached houses require more energy than attached ones. Compared to those living in multifamily housing, otherwise comparable households living in single-family detached housing consume 54 percent more energy for space heating and 26 percent more energy for space cooling. Not surprisingly, energy for heating, cooling, and all other uses increases with house size. Compared to a household living in a 1000-square-feet house, an otherwise comparable household living in a 2000-square-feet house consumes 16 percent more energy for space heating and 13 percent more electricity for cooling.

Housing mix varies across U.S. metropolitan counties. Among the counties in the GC sample, the highest share of multifamily housing is 99 percent in compact New York County, while the lowest is 0.6 percent in sprawling New Kent County, Virginia. Some of the difference in house type is related to sociodemographics, and some is related to urban form.

Median house size also varies across U.S. metropolitan counties. Among the counties in the GC sample, the smallest median house size is about 1,000 square feet in compact San Francisco County, and the largest is approximately 2,300 square feet in sprawling Waukesha County, Wisconsin. Some of the difference in house size is related to sociodemographics, and some is related to urban form.

The national patterns of house type and size are evident in California as well (see Table 8, page 26). The metropolitan areas one thinks of as more sprawling (and rated more sprawling according to EPA's sprawl index) have more square feet per person in their single-family detached units, have higher proportions of single-family detached units, and have lower proportions of multifamily units.

Table 8. Housing Characteristics of California's Metropolitan Areas

	Square Feet per Person	% Single-Family Detached	% Single-Family Attached	% Multifamily
Bakersfield	926	76%	2%	20%
Fresno	822	59%	0%	41%
Los Angeles	954	47%	7%	45%
Modesto	1217	68%	5%	24%
Oakland	1189	55%	7%	38%
Riverside-San Bernardino	1166	63%	6%	26%
Sacramento	1097	61%	4%	33%
Salinas	878	61%	4%	30%
San Diego	1132	48%	12%	38%
San Francisco	1063	41%	8%	51%
San Jose	1260	58%	6%	32%
Santa Barbara	674	41%	7%	48%
Stockton	1278	65%	4%	31%

Source: Analysis of American Housing Survey data for 2005 by Reid Ewing.

From Chapter 7 of GC, the likelihood of a household living in a single-family attached or multifamily home declines as the number of household members and annual household incomes increase; to wit, larger and higher income households are more likely to opt for a single-family detached home. Controlling for these influences, people's choice of house type is strongly related to urban form. The odds of households living in multifamily housing are 5.7 times greater for compact counties than for sprawling counties.

Also from Chapter 7, house size increases with the number of household members and with annual household income. Controlling for these covariates, the choice of house size is significantly related to urban form. Houses are 23 percent larger in sprawling counties than in compact counties.

Considering all the evidence, Chapter 7 of GC concludes that households living in compact environments consume 20 percent less residential energy than otherwise comparable households living in sprawling environments. Using assumptions from the previous section regarding the market for compact development and the share of all development built between 2010 and 2020, a 20% reduction in residential energy consumption with compact development translates into a 3 to 3.6% reduction in total CO_2E produced by the residential sector.

Lower 2020 Estimate: % CO_2 reduction = 0.5 x 0.3 x 0.2= 3%

Upper 2020 Estimate: % CO_2 reduction = 0.6 x 0.3 x 0.2 = 3.6%

These figures apply to the entire residential sector, including water heating and appliances. They do not include commercial buildings, which also save energy in compact patterns. Thus, it would seem to be conservative to apply these percentages to all CO_2 emissions associated with buildings themselves. Buildings are the second largest contributor to California's greenhouse gas emissions. CARB estimates that approximately one-quarter of greenhouse gases can be attributed to buildings. Thus, the savings with smart growth would be between 3 and 3.6 $MMTCO_2E$.

Lower 2020 Estimate: CO_2 reduction = 3% x 100 = 3 $MMTCO_2E$
Upper 2020 Estimate: CO_2 reduction = 3.6% x 100 = 3.6 $MMTCO_2E$

While these savings are due to compact development, it may make sense to identify these savings in the Energy Efficiency section (where Green Buildings are listed). This is because the savings are measured in building energy savings (GWh), not in reduced vehicles miles traveled.

V. Conclusion

In part using methodology from the book *Growing Cooler*, CARB estimated that smart growth would yield 2.3 million metric tons of savings in CO_2. In Table 9 (p. 29), we have re-estimated the savings from reduced VMT with compact development, and have also estimated the savings associated with smart transportation policies and compact building design. We have also provided an assessment of the measures CARB has included as “Under Evaluation.” We arrive at a total savings of between 14.4 – 17.9 $MMTCO_2E$.

The California Climate Action Team estimated CO_2 savings with Smart Land Use and Intelligent Transportation of 18 mm tons, later reduced to 10 mm tons. This estimate was based on the regional blueprint plans, which are essentially a combination of compact development and smart transportation policies. The Climate Action Team reduction did not include building energy savings. Excluding building energy savings, the GC methodology would place the reduction range at 11.4 – 14.3 $MMTCO_2E$, very much in line with the revised CAT estimate.

It is important to note that this estimate does not represent the upper bound of what is possible from smart growth policies for several reasons:

- Our estimate does not include potential savings from gas prices at or above what the state is currently experiencing. The VMT savings projected in this report are derived from historical data collected at a time when gas was $2.00 to $2.50 per gallon.

- Our estimate does not include potential reductions in long distance commuting due to improved jobs-housing balance within the major regions of the state.

- Our estimate does not assume implementation of an Indirect Source Rule (ISR) With an ISR, even outlying developments—which account for 30 to 50% of all development through 2020 in the analysis here—may generate lower VMT than anticipated.

Table 9. Estimated CO_2 Reduction with Smart Growth in California (2010-2020)

	CO_2 Reduction (million metric tons)
VMT Reduction with Compact Development	4.1 – 5.7
VMT Reduction with Smart Transportation Policies	4.0
VMT Reduction with Measures Under Evaluation	3.3 – 4.6
Total	11.4 – 14.3
Building Energy Savings	*3.0 – 3.6*
Total with Building Energy Savings	*14.4 – 17.9*

VI. References

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