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Reducing Greenhouse Gases from Personal Mobility: Opportunities and Possibilities

by Wendell Cox
Project Director: Adrian T. Moore

Reason Foundation

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Executive Summary

Federal, state and local governments are considering or have implemented policies that seek to reduce human emissions of greenhouse gases (GHGs). This study seeks to assess the relative merits of specific policies intended to reduce GHGs from automobiles. (It does not consider whether or not reductions in GHGs are actually desirable.)

Current policies and proposals for reducing GHGs from autos would require implementation of strong land use restrictions (compact development). Technological alternatives for reducing GHG emissions have received considerably less attention.

We estimated the costs of a range of such policies, beginning with government documents and reports prepared in cooperation with organizations advocating behavioral policies. Behavioral strategy costs and the costs of technological strategies were evaluated against the upper limit on acceptable costs for GHG emissions reductions as estimated by the Intergovernmental Panel on Climate Change. (This upper limit, \$50/ton of carbon dioxide equivalent in 2020–2030, is used because of its source, not because we endorse that value).

GHG emission reduction goals cannot be realistically achieved by applying “fair share” quotas to economic sectors. Depending on the availability of strategies requiring expenditures less than \$50 per ton, a sector might account for more or less of the eventual reduction in GHG emissions than its share of total emissions. A “fair share” approach would require some unnecessarily expensive strategies, while neglecting some less costly strategies. As an example, IPCC research indicates

that transportation represents 23% of global emissions, yet estimates the economic potential for GHG reduction in transport to be less than one-half that figure (10% or less).

Research by McKinsey & Company and The Conference Board found that substantial GHG emission reductions can be accomplished cost-effectively while "maintaining comparable levels of consumer utility" (an economic term denoting quality of life). This means "no change in thermostat settings or appliance use, no downsizing of vehicles, home or commercial space and traveling the same mileage" and "no shift to denser urban housing."

Sustainability is often narrowly defined as pertaining to the environment, such as GHG reduction. However, environmental sustainability also depends upon achieving other dimensions of sustainability, including financial, economic and political.

Behavioral Strategies (Compact Development)

Proponents of this approach argue that GHG reduction will require radical changes in lifestyles. Their solution is *behavioral strategies* (compact development) to increase urban densities and change the way people travel.

The two most prominent reports on this approach (*Driving and the Built Environment* and *Moving Cooler*) predict that compact development could reduce GHGs from autos by between 1% and 9% between 2005 and 2050. *Driving and the Built Environment* acknowledges that there will still be significant increases in overall driving (vehicle miles traveled or VMT).

Compact development raises various issues:

- **Reasonable Expectations:** Projected results from the most aggressive scenarios appear to be implausible based upon reservations stated in *Driving and the Built Environment* and broader criticisms of *Moving Cooler*. It is suggested that a range of 1% to 5% is more realistic for the maximum GHG emissions reductions from autos between 2005 and 2050 under compact development policies.

- **Traffic Congestion and Compact Development:** Even this modest level of GHG reduction could be further diminished by the "GHG Traffic Congestion Penalty." The higher densities required under compact development would cause greater local traffic congestion. As traffic slows and moves more erratically, the GHG reductions from less driving are diminished. Further traffic congestion retards the quality of life of households and imposes economic costs on metropolitan areas.

- **Housing Affordability and Compact Development:** Compact development is associated with higher housing prices. This is burdensome to lower income households, which are disproportionately minority. Assessing the impact of compact development on house prices, a Latino (Hispanic) think tank noted "an increase is always the result." The increased household expenditures for mortgage interest and rents alone could amount to nearly $20,000 per GHG ton annually, nearly 400 times the IPCC $50 maximum expenditure by 2050 (2010$). This loss of housing affordability would represent a huge transfer of wealth from lower and middle income households.

- **Infrastructure Costs and Compact Development:** Despite theoretical claims that suburban infrastructure is more expensive than in more dense areas, data for metropolitan areas indicates no such premium.

- **Higher Densities:** Compact development would require unprecedented increases in density, well beyond those envisioned by current compact development policies. This densification could require aggressive use of eminent domain and could be prevented by neighborhood resistance and public reaction.

Compact development is incapable of reducing GHG emissions within the IPCC $50 maximum expenditure. Compact development's higher than necessary expenditures could reduce economic growth, increase congestion costs, and result in public resistance and greater social imbalances. Because of its detrimental impact on financial, economic and political sustainability, compact development is unsustainable as a strategy for reducing GHG emissions from autos.

Facilitative Strategies

The alternate view is that technology solutions can achieve sufficient GHG reduction from autos. These *facilitative strategies* would alter the underlying GHG intensity of how people live and travel without requiring major changes in behavior or the standard of living.

There is substantial potential for reducing GHGs:

- The trend of present fuel efficiency improvements, if they can be continued beyond 2030, would produce auto-related GHG reductions of 18% by 2050 (from 2005). And if VMT increases at a lower rate, as some experts now project, a 33% reduction could be achieved.

- If the average auto were to achieve the best current hybrid fuel economy by 2040, GHGs would fall 55% between 2005 and 2050.

- Emerging fuel technologies also offer promise. Hydrogen fuel cells and zero-emission cars (principally plug-in electric vehicles), if paired with electricity from hydro-power, could help reduce GHGs from autos by 2050.

Various issues are examined with respect to facilitative strategies:

- **GHG Reduction and VMT Increases:** Department of Energy projections indicate that auto GHG emissions will decline, even though total driving will continue to increase.

- **Maximum Expenditures:** Facilitative strategies that would require more than the $50 IPCC maximum expenditure are rejected.

- **Quality of Life:** Current technologies can be implemented without retarding Americans' quality of life. However, some of the more advanced technology strategies may reduce quality of life by requiring smaller autos. Under either scenario, people could continue to live in houses of the same size at affordable prices, to travel the same mileage, and there would be no necessity for a shift to denser urban housing. Research associates greater economic growth with geographic mobility, which is preserved even under the more advanced technologies.

- **Relying on Technology:** Based upon the current availability of far more fuel-efficient technologies, such as hybrid vehicles, it is plausible to assume continued GHG reductions after 2030. The emerging strategies could accelerate the improvement. Of course, as noted above, any projection is uncertain.

New technologies have the potential to achieve substantial GHG emission reductions at costs within the $50 IPCC maximum expenditure per ton. This could be accomplished while preserving quality of life. As a result, public acceptance is more likely.

Conclusions and Recommendations

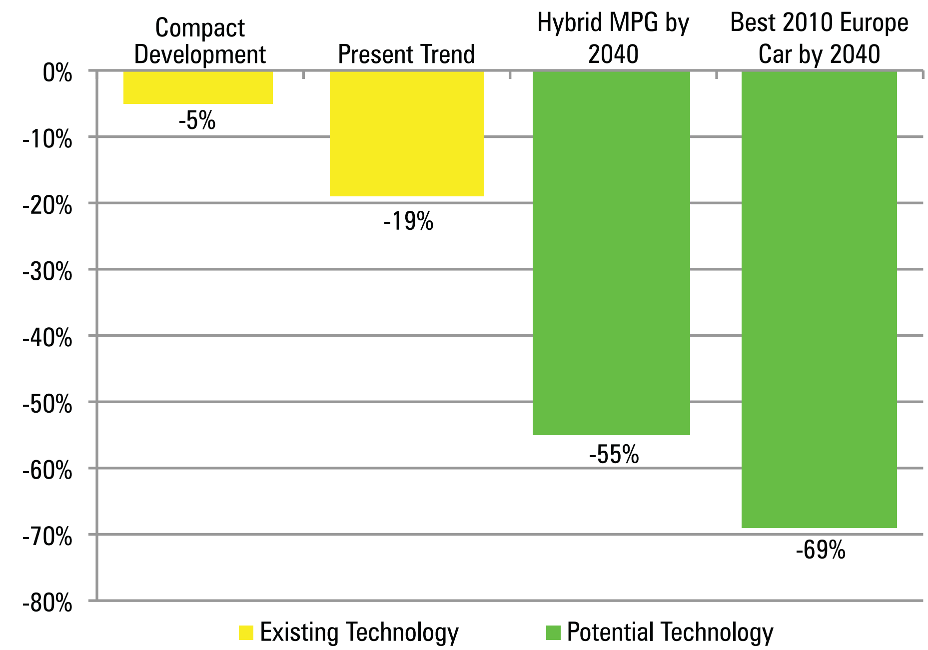
Generally, existing and likely future technologies have a far greater potential to reduce GHG emissions than compact development.

Based upon *Driving and the Built Environment* and *Moving Cooler*, compact development provides little possibility of achieving a reduction of more than 5% in auto GHGs by 2050.

On the other hand, wider application of existing technologies could produce GHG emission reductions of up to 54% by 2050 with current hybrid technology. GHG reductions from new technologies, such as electric cars, could be even greater. These technologies are potentially sustainable financially, economically and politically, and thus environmentally.

By contrast, imposing compact development would be enormously expensive, is likely to reduce economic growth substantially, and could stifle opportunity for lower income households, which are disproportionately African-American and Hispanic. These factors render compact development unsustainable financially, economically and politically, and thus environmentally.

Figure ES1: Long Term GHG Emission Reductions (Various Strategies from 2005 to 2050)



As governments consider policies intended to reduce GHG emissions from autos:

- Compact development strategies should be neither mandated nor encouraged.
- Technology strategies should receive priority.

At the same time, any such policies other than removing government-imposed barriers to new technology development and adoption should be implemented with great caution.

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Part 1

Introduction

The population of the United States is expected to increase 42% (129 million) between 2010 and 2050.[1] Metropolitan areas will grow even more, at 55% (142 million), as non-metropolitan populations decline.[2] At the projected 42% growth by 2050, achieving an 83% reduction in total GHG emissions below current levels—as some have advocated—would require an 88% reduction in GHG emissions *per capita*, when compared with current levels.

The personal mobility sector (automobiles, sport utility vehicles and small trucks, hereinafter referred to as "autos") represents a particular challenge, because of its near total reliance on fossil fuels, which produce carbon dioxide (CO_2), the most common GHG.

Some national interest groups and members of Congress have expressed support for strong land use policies (compact development) to reduce GHG emissions from autos. At the same time, technological alternatives for reducing GHG emissions have received considerably less attention.

This report does not evaluate the merits of greenhouse gas reduction objectives, but limits its analysis to the impacts of strategies to reach such objectives, once established. The purpose of this analysis is to compare the potential and expenditures required materially to reduce auto GHG emissions through two different policy approaches: compact development and vehicle technology.

Assumptions: This analysis is based upon the following assumptions:

1. That the United States will adopt a GHG emission reduction program.
2. That there is a risk that GHG emissions reductions could be very costly to households and the economy and could lead to higher levels of poverty.
3. That, consistent with these economic concerns, any mandated GHG emissions reductions must be achieved at the least cost to households and the economy.

This analysis relies on readily available documentation likely to frame policies that government is expected to adopt, including reports from the United Nations Intergovernmental Panel on Climate Change (IPCC).[3]

The Uncertainty of Projections: Projections are inherently uncertain. The most highly regarded authorities and models cannot predict with certainty the behavioral changes that might result from proposed policies. Further, it is beyond the ability of anyone reliably to predict the technological advances that may occur in the future. Longer term projections tend to be less certain than shorter term projections. Generally, the time horizon of GHG emissions projections is long: up to 40 years (to 2050). The projections contained in this report and other GHG-related reports should be viewed in light of these uncertainties.

Maximum Expenditure per GHG Ton: The IPCC identified a range of $20 to $50 per ton of GHG removed as the maximum required to achieve sufficient GHG reductions.

> *… diverse strands of evidence therefore suggest a high level of confidence that carbon prices of 20–50 US$/tCO2-eq (75–185 US$/tC-eq) reached globally in 2020–2030 and sustained or increased thereafter would deliver deep emission reductions by midcentury consistent with stabilization.*[4]

For the purpose of this analysis, any expenditure above the $50 level is excessive. It is important to minimize expenditures to reduce negative impacts on households and the economy by keeping the costs of any policies to reduce GHG emissions as low as possible. Failure to do so will retard the quality of life for households and increase poverty. If all of the GHG emission reduction were achieved at $50 per ton in the United States, the annual expenditures would exceed $300 billion, which is more than 2% of gross domestic product in 2009.

The Inappropriateness of Fair Share GHG Reductions: GHG emission reduction goals cannot be cost-effectively achieved by a “fair share” approach to emitting sectors. For example, a sector (such as automobiles or buildings) might represent 10% of GHG emissions. However, that does not mean that 10% of the GHG emissions reductions must be obtained from that sector. There may be insufficient low cost opportunities, for example, such that imposing the 10% quota would require implementation of overly costly strategies in the sector, while less costly strategies in other sectors are not implemented. On the other hand, if there is an abundance of low cost possibilities, imposition of the 10% quota would result in missed opportunities, as other, more costly options are implemented in other sectors. Either eventuality would impose higher than necessary costs on households and the economy.

Whether there is a shortage or an excess of low cost opportunities, the “fair share” (or quota) approach would disadvantage both households and the economy, because it would require implementation of some unnecessarily expensive strategies, while neglecting some less costly strategies.

Thus, in the longer run, the potential to reduce GHG emissions cost-effectively in the auto sector may be greater or less than its current share in overall emissions. As an example, IPCC research indicates that transportation represents 23% of global emissions, yet estimates the economic potential for GHG reduction in transport to be less than one-half that figure (10% or less).[5] Any inability to achieve a reduction share equaling its emission share is not a concern in the auto sector or any other sector, because there are ample alternatives to achieve the overall GHG emission reduction objective at lower costs.

Quality of Life: A report by McKinsey & Company and The Conference Board and co-sponsored by organizations supporting the “behavioral strategies” critiqued below (the Environmental

Defence Fund and the National Resources Defence Council) concludes that strategies are available for substantially reducing GHG emissions in the United States, while "maintaining comparable levels of consumer utility" (an economic term denoting the quality of life). This means, "no change in thermostat settings or appliance use, no downsizing of vehicles, home or commercial space and traveling the same mileage" and no "shift to denser urban housing."[6] [7] These findings have been criticized as overly optimistic. But if the McKinsey findings were correct, it would mean that substantial GHG emissions reductions can be achieved without diminishing the quality of life.[8]

Behavioral Strategies (Compact Development): Advocates of compact development believe that people must materially change their behaviors and living conditions to reduce GHG: automobile use must be reduced and urban densities must be increased. This is based upon an assumption that any GHG emission reductions from vehicle technology will be more than offset by GHGs from a continuing increase in driving.

Behavioral strategies rely on compact development to increase metropolitan population densities, which, it is presumed, would materially reduce auto use and associated GHG emissions. Compact development prohibits urban development beyond the current urban boundaries and imposes infill quotas,[9] development moratoria, costly development fees and other measures that limit where development can occur and require higher densities. Compact development strategies can also require that development within urban growth boundaries be directed toward particular portions of the urban area (or urban footprint)[10] in which densities are already higher or where there is more intensive transit service (see "Behavioral Strategies," below). Compact development strategies are also referred to as "smart growth" or "growth management."

Facilitative Strategies: The alternate view is that facilitative strategies can achieve material GHG emissions reductions, while *facilitating* the continuation of current lifestyles and living standards. Facilitative strategies allow urban development to occur consistent with consumer preferences[11] and within fundamental environmental standards.

Dimensions of Sustainability

Sustainability is often narrowly restricted to environmental factors, such as reducing GHGs. This one-dimensional focus recurs in research that identifies a particular strategy as likely to reduce GHGs, followed by an implementation recommendation, without regard to other factors. However, the mere potential of a strategy to reduce GHGs is not sufficient. Strategies must be cost-effective and must not materially impede economic growth or unreasonably intrude on people's lifestyle choices, or they could be rejected by the public. Three additional dimensions of sustainability are prerequisites to achieving environmental sustainability.

(1) Financial sustainability pertains to affordable GHG reduction. This is important because spending too much on less cost-efficient strategies would reduce the resources available to achieve GHG reduction objectives. We assume that financial sustainability requires a maximum expenditure of less than $50 per metric ton of GHG removed, consistent with the IPCC report.

(2) Economic sustainability requires that GHG reduction strategies not materially reduce economic growth, job creation or poverty reduction. Rapid personal mobility is associated with better urban economic performance.[12] Researchers at the University of Paris found that labor productivity is greater in urban areas where more jobs can be accessed in a fixed time (such as 30 minutes). This was confirmed in U.S. research by David Hartgen and M. Gregory Fields.[13] Generally, travel by transit takes up to twice as long as travel by car, according to Bureau of the Census data.[14]

Other data indicate that traffic congestion is costly to both consumers and businesses[15] and that less congested freight traffic is important to metropolitan economic performance.[16] The Environmental Protection Agency has also noted travel produces "benefits to vehicle owners, which reflect the value to drivers and other vehicle occupants of the added (or more desirable) social and economic opportunities that become accessible with additional travel."

The mobility provided by the auto is especially important to lower income households. Research by the Progressive Policy Institute has shown that minority and low income employment is improved by having access to cars, noting that "In most cases, the shortest distance between a poor person and a job is along a line driven in a car."[17] A Brookings Institution report also concluded: "Given the strong connection between cars and employment outcomes, auto ownership programs may be one of the more promising options and one worthy of expansion."[18]

(3) Political sustainability requires that GHG reduction strategies be acceptable to the public. If strategies cost too much (financial unsustainability), materially hobble the economy (economic unsustainability) or otherwise retard the quality of life, they may not be acceptable to the public. Political sustainability is consistent with research by Harvard economist Benjamin Friedman, who found that economies that fail to grow can lapse into social instability.[19]

Part 2

Behavioral Strategies (Compact Development)

A. Proposed Strategies: Compact Development

Behavioral strategies seek to transfer travel from cars to transit and non-motorized modes (such as walking and biking) and to mandate higher densities. Land use regulations would force most development into existing urban footprints or even to the most densely populated sections of existing urban footprints. The higher densities are intended to reduce the amount of driving, as measured by vehicle miles of travel (VMT). GHG emissions are generally presumed to be reduced by a corresponding percentage. Intercity travel would be steered away from cars and airlines[20] to expanded intercity rail services, especially high speed rail.[21] Policies such as these were advocated by many planners and organizations long before there was serious concern about reducing GHGs.[22]

There is considerable support for compact development in Washington, DC. For example, Secretary of Transportation Ray Lahood has spoken of "coercing" people from their cars.[23] The Obama administration has established a "livability" partnership among three federal departments to advance compact development (see Box 1: The Livability Agenda, on page 8). Senators Jay Rockefeller (D, WV) and Frank Lautenberg (D, NJ) have introduced legislation that would require annual per capita driving reductions.[24]

B. Compact Development: Opportunities and Possibilities

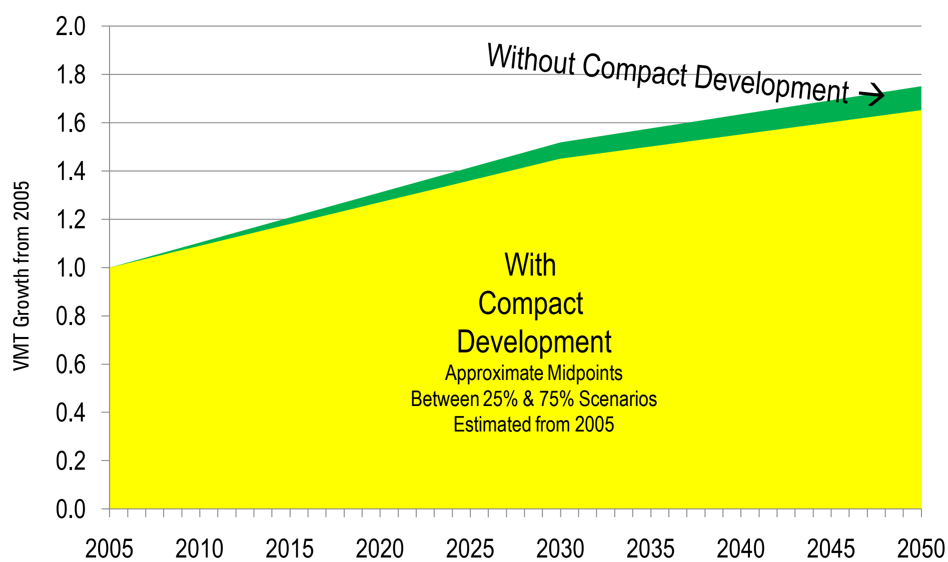
California's Senate Bill 375, enacted in 2008, has been cited as a model for national compact development proposals. SB375 accelerates approvals and provides exemptions for high density housing located on major transit routes and requires a minimum development density for new housing of 15,000 per square mile (six times the U.S. urban average).[25] This is nearly 25 persons per acre and 10 dwellings per acre at the average household size.

Driving and the Built Environment: *Driving and the Built Environment: The Effects of Compact Development on Motorized Travel, Energy Use and CO_2 Emissions,*[26] produced by a special committee of the Transportation Research Board at the request of Congress, assesses the potential of compact development to reduce GHGs. The report reviews doubling the density of either 25% or 75% of all new development. *Driving and the Built Environment* projects compact development-related GHG (and VMT) reductions in the 25% scenario at approximately 1.0% in 2030 and 1.5%

in 2050 (midpoints of the projected ranges). Under the 75% scenario, compact development-related GHG (and VMT) reductions would be 6.8% in 2030 and 10.4% in 2050.[27] The report did not estimate the costs of the compact development strategies.

Despite the densification, VMTs would still rise substantially between now and 2050 due to continued economic and population growth, according to *Driving and the Built Environment* (Figure 1). In 2050, without densification, VMT would increase 74%. With 75% densification, VMT would increase 60%. In other words, although densification would require widespread coercion to force people to live at higher density than they would prefer, VMTs would continue to rise.

Figure 1: VMT With and Without Compact Development (Based Upon *Driving and the Built Environment*)



Maximum Densification:

The maximum densification scenario of *Driving and the Built Environment* would require 75% of new development to be at substantially higher densities than would otherwise occur.[28] This density is already higher than all of the nation's urban areas with more than 1,000,000 population except for Los Angeles.[29] Yet, according to the projections in *Driving and the Built Environment*, VMT would continue to rise strongly with or without the strong land use policy interventions.

The challenge of building most new development at such high densities and the modest potential VMT reductions from a much higher 2050 base may have been at least partially behind this caveat in *Driving and the Built Environment*:

> *…the committee believes that reductions in VMT, energy use, and CO_2 emissions resulting from compact, mixed use development would be in the range of less than 1 percent to 11 percent by 2050, although the committee members disagreed about whether the changes in development patterns and public policies necessary to achieve the high end of these findings are plausible.*[30]

Driving and the Built Environment refers to dramatic changes in "housing trends," "land use policies" and "public preferences" in describing the feasibility difficulties with its higher densification scenario.[31]

Moving Cooler: *Moving Cooler,*[32] by Cambridge Systematics was sponsored by multiple organizations, some of which have long advocated compact development.[33] *Moving Cooler* indicates that its policies would require "considerable—and in some cases major—changes to current transportation systems and operations, travel behavior, land use patterns and public policy and regulations."[34]

Moving Cooler's policies would mandate densification, rather than creating incentives, as in California SB 375. The three densification scenarios would require 43%, 64% or 90% of future development to be in the most dense portions of urban areas.[35]

Expenditures: *Moving Cooler* predicts that its land use strategies would not impose substantial costs. Yet, *Moving Cooler* indicates that its transit strategies would require expenditures of nearly $600 per GHG ton removed, in 2050.[36] These expenditures are many times the IPCC $50 maximum expenditure. If the entire 83% proposed GHG reduction were achieved at an expenditure of $600 per ton,[37] it would require more than $3.5 trillion, an amount equal to 25% of the present gross domestic product. This amount is far beyond the most aggressive estimates of the expenditures of GHG emission reduction. Finally, *Moving Cooler* does not deal with the housing price increases that are inevitably associated with rationing developable land under compact development (see "Housing Affordability and Compact Development," below).

GHG Impacts: The GHG emission reductions from *Moving Cooler's* compact development scenarios[38] were similar to those of *Driving and the Built Environment* at from 1% in the 43% densification scenario, 3% in the 64% densification scenario and 5% in the 90% densification scenario in 2030. In 2050, the GHG emissions would be 2% in the 43% densification scenario, 5% in the 64% densification scenario and 9% in the 90% densification scenario.[39]

AASHTO Objections: For months the *Moving Cooler* coalition included the American Association of State Highway and Transportation Officials (AASHTO) as one of its principal sponsors.[40] AASHTO represents state transportation departments, which oversee highways and some transit systems and have proposed high speed rail systems. AASHTO withdrew from the *Moving Cooler* coalition over technical and objectivity concerns. AASHTO indicated that *Moving Cooler* attributes unrealistic GHG reductions to its strategies and underestimates the potential for more fuel-efficient cars, telecommuting, ridesharing and improved transportation operations. According to AASHTO, *Moving Cooler* "did not produce results upon which decision-makers can rely."

AASHTO researchers further said that *Moving Cooler* relied on "assumptions that are not plausible," analysis that was "flawed and incomplete," costs that were "incomplete and misleading," projected greenhouse gas emission results that were "not comparable or plausible" and contained "many assumptions" that were "extreme, unrealistic and in some cases, downright impossible." AASHTO dismissed *Moving Cooler* because its "heroic assumptions about land use and travel behavior and extraordinary pricing do not come close to providing the GHG reductions needed by 2050."[41]

THE LIVABILITY AGENDA

The Obama administration has established a "livability partnership" among the Environmental Protection Agency, the Department of Housing and Urban Development, and the Department of Transportation. The "livability partnership" would impact transportation significantly. Its principles call for "reliable and timely access" to employment and other urban destinations, "expanded business access to markets," increasing mobility, and lowering the combined costs of housing and transportation.

Compact development (smart growth) strategies would be relied upon heavily to achieve such objectives. This would include directing "growth to developed areas with existing infrastructure," reducing VMT and encouraging travel by transit and non-motorized modes, principally walking and bicycling.[42]

In proposing this program the Administration acknowledges the extent to which "automobile congestion impacts our communities and lives" and notes that "we … need to give that time and money back to our economy and our citizens."

In fact, the livability partnership has no potential to meet any of these objectives. The best evidence of this is that under the aggressive (and characterized as doubtful) 75% scenario in *Driving and the Built Environment*, VMT in 2050 would be from 43% to 78% higher than in 2000. It is estimated that the more aggressive of the compact development scenarios proposed in *Driving and the Built Environment* would increase VMT per square mile of urban land up to 50%.[43] Congestion would be thus be worsened. This would *increase* congestion costs. Moreover, because greater traffic congestion results in more intense air pollution, air quality would be worse than without compact development.

The greater traffic congestion would *retard* business access to markets. As traffic slows down (as is inevitable in traffic congestion), access to employment and other urban destinations would be *less* reliable and timely for people, reducing workers' access to jobs and employers' access to workers. Finally, as more people are "lured" or "coerced" out of their cars to ride transit, or to walk or bicycle, mobility would be further retarded and far fewer jobs would be accessible within the typical one-way commute time of less than 30 minutes. Based upon the connection between greater mobility and greater economic growth, these longer travel times could lead to lessened economic growth and greater poverty.

The higher housing prices induced by compact development would burden households and impose excessive costs on the economy. Thus, the livability partnership seems likely to make urban life *less* livable, by increasing travel times, reducing access, increasing costs and intensifying air pollution. Moreover, such policies would concentrate the population where there is greater air pollution.

Paradoxically, the livability agenda would diminish the quality of life by forcing people to live in smaller houses, drive smaller cars, travel less and live in denser urban housing.

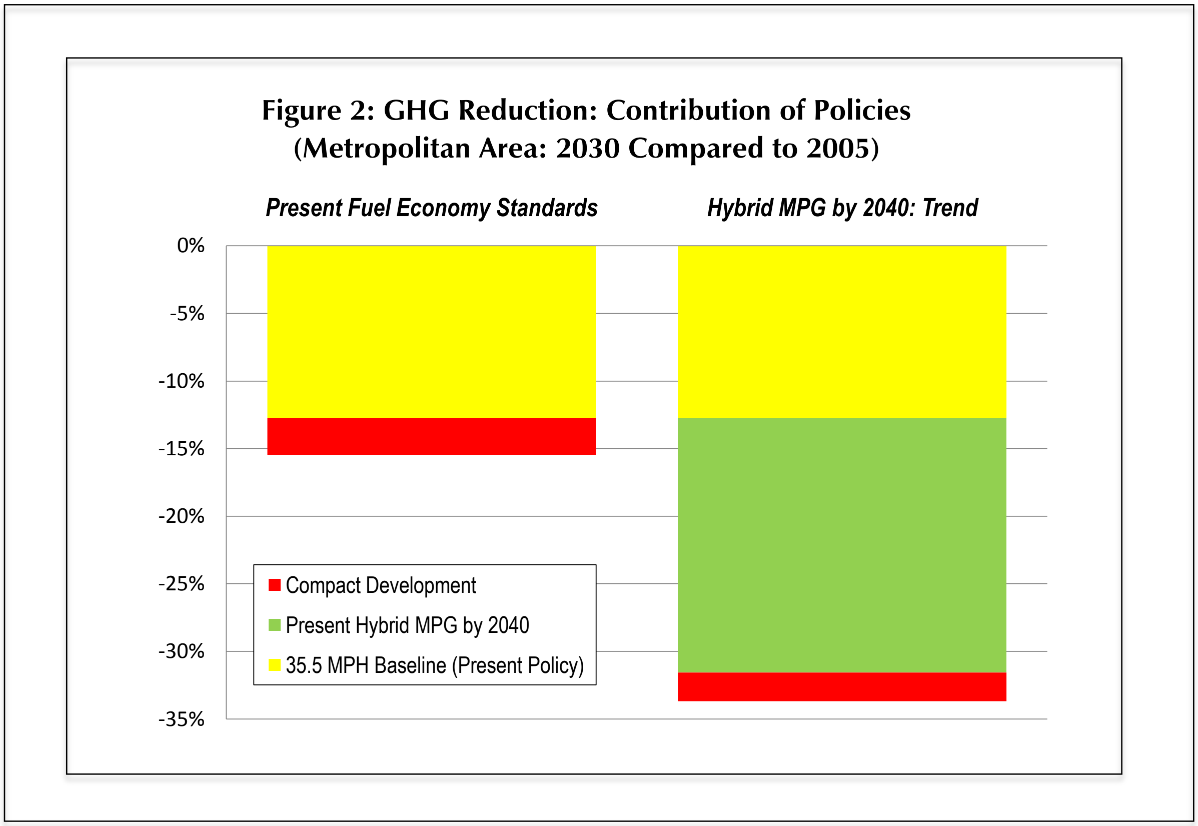
Federal Legislative Proposals: Several transportation and climate change bills introduced in Congress in recent years have reflected the Administration's livability agenda. Typical provisions would require metropolitan planning organizations (MPOs) to meet specific GHG emissions reduction targets and to consider such strategies as encouraging walking, bicycling and transit and zoning that drives development to existing areas. This preoccupation with *means* rather than *ends* would likely result in only modest improvements in GHG emissions, because densification is likely to produce only small reductions in VMT, while the slower and more congested traffic conditions would diminish the GHG reductions from reduced travel (discussed above).

There is also a threat of federal interference in local land use decisions from the federal promotion of compact development. Legislative proposals typically grant the EPA wide authority to develop regulations with respect to the GHG reduction elements in planning processes. Legislative proposals typically grant the EPA wide authority to develop regulations with respect to the GHG reduction elements in planning processes. Federal agencies could intrude into state and local policy as the EPA did when it singled out Atlanta over air quality issues and worked to enact state planning legislation more to its liking.

In addition, legislative proposals have included substantial barriers to expanding highways, unless the expansion is limited to high-occupancy vehicle lanes, and defined "sustainable" as "transit, walking and bicycles." This definition means that a Toyota Prius hybrid, which would produce approximately 40% *less* in GHG emissions per passenger mile than U.S. transit rail and bus services[44] is not considered "sustainable," while more GHG-intensive transit services are considered sustainable.

A Metropolitan Area Example: Some have proposed requiring metropolitan areas (and states) to meet GHG emission targets. However, the most effective strategies— fuel economy and fuel technology improvements—are generally beyond the authority of state and local governments, and the potential of compact development, which is under the control of state and metropolitan authorities, is miniscule. The options available to state and local governments are heavily skewed toward behavioral strategies, which are exceedingly expensive and have only marginal potential for reducing GHG emissions (see: "The GHG Traffic Congestion Penalty," on page 12).

The limited potential of state or metropolitan targets is illustrated for a prototypical metropolitan area of 3,000,000 population (Figure 2).[45] The first alternative compares compact development to the present 35.5 MPG baseline and the other compares the impacts if fuel economy improved to the hybrid level by 2040. The gains from compact development are tiny compared to the fuel technologies.



C. Compact Development: Examination

A number of issues are raised by compact development.

Compact Development and the Quality of Life: The compact development strategies as proposed would diminish the quality of life. Houses would be smaller, people would travel less and there would need to be a shift to denser urban housing.

Traffic Congestion, Compact Development and GHG Emissions: The compact development reports assume a one-to-one (1:1) relationship between VMT and GHG reductions, i.e., that a 10% reduction in VMT will yield a 10% reduction in GHGs. But the inevitable increase in traffic congestion from higher densities renders this assumption invalid, as is discussed in this section.

Higher Densities and Traffic Volumes: National Housing and Transportation Survey data indicate that overall traffic volumes increase as population densities rise (Table 1). For example, the most densely populated urban census tracts (over 10,000 persons per square mile) generate 3.5 times as much VMT as the average density census tract (approximately 2,400 per square mile).[46]

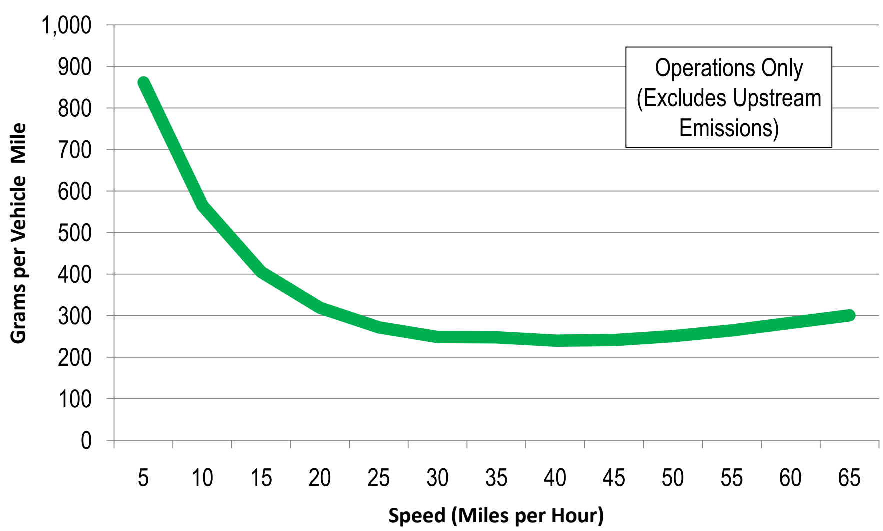
As is discussed below, a U.S. Department of Transportation report (*Emissions Benefits of Land Use Strategies*) indicates that VMT reductions only become significant at much higher densities than average in the United States.

Table 1: Population and VMT By Density: Urban Census Tracts					
	Average Population Density	Change from Lower Category	Average Daily VMT (Total)	Change from Lower Category	Exhibit: Share of Urban Population
Under 500	240		7,420		1%
500–1,999	1,160	383%	34,400	364%	25%
2,000–3,999	2,800	141%	71,660	108%	29%
4,000–9,999	5,780	106%	126,490	77%	31%
10,000 & Over	18,130	214%	220,390	74%	15%
Exhibit: Average	2,380		63,420		
Compared to Average	7.6		3.5		

NOTE: Estimated by this author, based upon University of South Florida, Center for Urban Transportation Research VMT forecasting model prepared for the National Surface Transportation Policy and Revenue Study Commission

***Higher Densities and Traffic Congestion*:** Under compact development, road capacities would not be increased to accommodate the higher demand created by densification. As a result, the higher volume traffic would slow and traffic congestion would intensify, with more "stop and go" operations. Slower urban speeds and greater traffic congestion *reduce* fuel efficiency, which renders the one-to-one (1:1) VMT to GHG relationship assumption invalid. As vehicle speeds decline, GHG emissions increase, regardless of the distance driven (Figure 3).[47] Further, as traffic congestion becomes more severe, local air pollution ("criteria" pollutants, such as carbon monoxide, volatile organic compounds and NOx) become more intense, which increases the health hazards that justified auto environmental standards in the first place.

Figure 3: Effect of Speed on GHG Emissions (Data from California Air Resources Board)



The GHG Traffic Congestion Penalty: Research indicates a substantially diminishing rate of GHG reduction as traffic congestion increases. A one-half hour trip in congested conditions was found to reduce VMTs 62%, due to slower speeds and more stop and start operation. However, the reduction in GHGs is much less, at only 12%.[48] In this example, a 1% reduction in VMTs produces only a 0.19% reduction in GHGs[49] in more congested conditions (Table 2). This is an 81% loss in GHG emissions relative to the 1:1 relationship assumed in the compact development reports. In this regard, a UCLA public policy center told the California Air Resources Board: "VMT is an inadequate proxy for vehicle greenhouse gas emissions."[50]

Driving and the Built Environment does not discount GHG emissions from reduced VMTs to account for the slower speeds and greater traffic congestion that are likely to be produced by densification. As a result, the projections in *Driving and the Built Environment* are probably optimistic.

Table 2: Comparison of a 30-Minute Trip in Average and Congested Conditions

	Less Congested Conditions	Congested Conditions	Difference
Trip Time Assumed (Minutes)	30.0	30.0	0.0%
Average Speed (MPH)	41.9	15.8	-62.2%
Distance Traveled (VMT)	21.0	7.9	-62.2%
Fuel Consumed (Gallons)	0.56	0.49	-11.9%
Exhibit: Liters of Fuel per 100 KM	6.3	14.7	133.3%
Miles Per Gallon	37.3	16.0	-57.2%
GHG Grams (Trip)	6,225	5,496	-11.7%
Reduction in GHGs Relative to VMT			18.8%

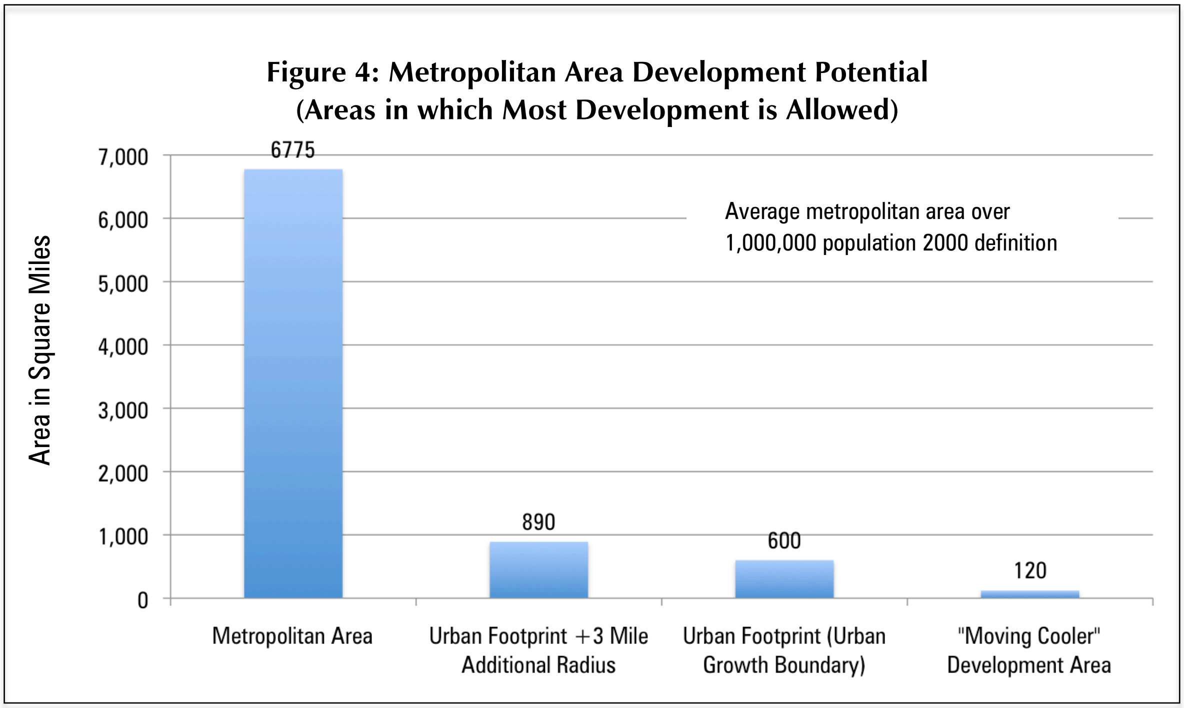
Source: Martin Treiber, Arne Kesting and Christian Thiemann, How Much Does Traffic Congestion Increase Fuel Consumption and Emissions? Applying a Fuel Consumption Model to the NGSIM Trajectory Data, paper presented to the Annual Meeting of the Transportation Research Board, 2008.

***Economic Impact of Traffic Congestion*:** As a result of traffic congestion, travel times would increase with compact development. This would include both auto travel and travel diverted to transit, because transit trips currently take significantly longer.[51] The mobility research indicates that this additional travel time would retard economic growth. The slower travel times would raise costs for trucks, delivery vans and on-site services (such as plumbers). All of this would retard economic productivity.

Densification: A Radical Departure: The high densification scenarios of *Driving and the Built Environment* and *Moving Cooler* would represent a radical departure from both present urban planning practice and the current urban form. Most new development would be restricted to a small portion of land within the urban footprint (see "Maximum Densification" under "*Driving and the Built Environment"* and *"Moving Cooler,"* above). These forced densification policies could require population densities to double or even triple (depending on population growth rates), in places like Berkeley, Boulder (Colorado), Brooklyn, Chicago, San Francisco and other dense sections of urban areas.

As Figure 4 indicates (on the next page), the availability of land for development would be radically reduced.[52] Even this depiction understates the aggressiveness of the proposed policies since there would be considerable land for development in the greater metropolitan area or in an area, say for example, three miles beyond the urban footprint. However, comparatively little vacant land would be available for development within the urban footprint[53] and even less in the *Moving Cooler* developable area or the smaller development area in *Driving and the Built Environment*.

This scarcity of developable land within the urban footprint has already increased prices in areas with compact development (see "Housing and Compact Development," below). The more restrictive environment in the high densification strategies of *Moving Cooler* and *Driving and the Built Environment* could raise land prices even more.



Finally, the high densification scenarios under each of the two compact development reports would very likely bring drastic development reductions to most inner suburban areas and virtually all outer suburban areas. This is because little of land area in these suburbs reaches the density thresholds required for most development in *Moving Cooler* and *Driving and the Built Environment*. For example, future development could be severely retarded in larger suburbs such as Mesa (Phoenix area), Arlington (Dallas-Fort Worth area), Gresham (Portland, Oregon area), Bellevue (Seattle area), and Schaumburg (Chicago area), Aurora (Denver), Overland Park (Kansas City), Bloomington (Minneapolis-St. Paul), Moreno Valley (Riverside-San Bernardino), Waukesha (Milwaukee), O'Fallon, (St. Louis, Missouri area), Sandy Springs (Atlanta) and many others.

Housing Affordability and Compact Development: Compact development is associated with restrictions that lead to higher housing prices and a loss of housing affordability. Compact development policies prohibit development on large areas of otherwise buildable land by strategies such as urban growth boundaries, building moratoria and other growth controls. The result is to reduce the quantity of developable land, which results in higher land prices. The higher housing prices reflect a simple economic phenomenon: when the supply of any good (such as land for building) or service is limited, sellers are able to command a higher price. A result is that, for example, equal-sized building lots that are otherwise virtually identical except in the potential for development authority can have substantially different prices.[54]

Making Land Scarce: Since consumers prefer larger lots, compact development would be achieved by radically reducing the land available for development, especially residential development. The extent of this reduction is shown in Figure 4 (above), which indicates that new urban development is outlawed on most land within a metropolitan area with an urban growth boundary. The high densification scenarios in *Driving and the Built Environment* and *Moving Cooler* take the limitation much further, reducing the gross developable land by another 80%. The scarcity is exacerbated by the fact that most vacant land for development in a metropolitan area is outside the urban footprint (the area likely to be included in an urban growth boundary), and that much less land is vacant within the urban footprint. Further, even less vacant land is likely to be available in the small area designated for development under the high densification scenarios in *Driving and the Built Environment* and *Moving Cooler*.

Association between Compact Development and Higher House Prices: The association between compact-development-induced land scarcity and higher house prices has been noted by many economists:[55]

- Nobel Laureate economist Paul Krugman of Princeton University and *The New York Times* noted that the house price bubble was most pronounced in metropolitan areas with strong land use regulation.[56]

- Edward Glaeser, Joseph Gyourko and Raven Saks associated higher house prices in some metropolitan areas with more restrictive regulations.[57]

- William Fischel associated the inordinately high house price increases in California from 1970 to 1990 with land use regulation, including growth management strategies, voter initiatives and court decisions (See: "Estimating the Impact of Compact Development on Housing Affordability," below).[58]

- Former Reserve Bank of New Zealand Governor Donald Brash wrote that, "the affordability of housing is overwhelmingly a function of just one thing, the extent to which governments place artificial restrictions on the supply of residential land."[59]

- A United Kingdom government report by Kate Barker, a member of the Monetary Policy Committee of the Bank of England, blamed that nation's loss of housing affordability on its prescriptive land use policies under the Town and Country Planning Act of 1947 (The *Barker Report*).[60]

- A New Zealand government report by Arthur Grimes, Chairman of the Board of the Reserve Bank of New Zealand, blamed the loss of housing affordability in the nation's largest urban area, Auckland, on overly restrictive land use policies.[61]

- Theo Eicher, founding director of the University of Washington's Economic Research Center, associated more than 70% of the 1989 to 2006 house price increases in Washington (state) municipalities with land use regulation.[62]

An analysis by the Federal Reserve Bank of Dallas noted the association between metropolitan area house price increases in the 2000 to 2006 housing bubble and more restrictive land use regulation:

> *Demand for housing, driven by low interest rates and a growing economy, combined with supply restrictions—such as zoning laws, high permitting costs and "not in my backyard" regulations—to contribute to rapid price appreciation…. [L]ow levels of construction in the face of strong demand contributed to significant price appreciation…*[63]

The Federal Reserve Bank of Dallas further noted that in less restrictively regulated markets such as Atlanta, Dallas-Fort Worth and Houston, flexibility with respect to housing supply spared those metropolitan areas the price increases that occurred in the more restrictive markets:

> *… Atlanta, Dallas-Fort Worth and Houston weathered the increased demand largely with new construction rather than price appreciation because of the ease of building new homes.*

Impact on Metropolitan Economies: Research by Raven Saks of the Federal Reserve Board indicated that compact development policies were associated with lower employment growth:

> *…metropolitan areas with stringent development regulations generate less employment growth than expected given their industrial bases.*[64]

Impact on Minorities: The loss of housing affordability disproportionately disadvantages minority households, due to their generally lower incomes. California's Tomas Rivera Policy Institute, a Latino research organization, raised concerns about the impact of compact development on housing affordability:

> *Whether the Latino homeownership gap can be closed, or projected demand for homeownership in 2020 be met, will depend not only on the growth of incomes and availability of mortgage money, but also on how decisively California moves to dismantle regulatory barriers that hinder the production of affordable housing. Far from helping, they are making it particularly difficult for Latino and African American households to own a home.*[65]

The Tomas Rivera Policy Institute report also noted: "While there is little agreement on the magnitude of the effect of growth controls on home prices, an increase is always the result."

Compact development advocates largely ignore the upward impact on house prices. *Driving and the Built Environment* notes only that "restricting the amount of single-family housing through zoning or other measures that increase compact development could raise the costs of that housing, contributing to housing affordability problems."[66] *Moving Cooler* indicates that its land use policies would have a net positive impact on consumers between 2010 and 2050 of approximately $1 trillion in net benefits. However, *Moving Cooler* gives virtually no consideration to the house price increases that the laws of elementary economics, corroborated by significant economic research, associate with compact development.

Yet, a seminal report by compact development advocates, the *Costs of Sprawl—2000*, indicates the potential for seven of ten recommended land use tactics to raise housing prices (Table 3).[67]

Table 3: Prescriptive Planning Policies & Housing Affordability

	Strategy	Potential to Increase Housing Prices
1	Regional Urban Growth Boundaries	YES
2	Local Urban Growth Boundaries	YES
3	Regional Urban Service Districts	YES
4	Local Urban Service Districts	YES
5	Large-Lot Zoning in Rural Areas	YES
6	High Development Fees & Exactions	YES
7	Restrictions on Physically Developable Land	YES
8	State Aid Contingent on Local Growth Zones	
9	Transferable Development Rights	
10	Adequacy of Facilities Requirements	

Source: From Table 15.4, "Costs of Sprawl—2000"

Affordability Experience: The relationship between higher house prices and compact development policies is evident in the following examples:

- Median house values rose 30% in highly regulated California from 1970 to 2000 relative to the national rate (adjusted for household income).[68]

- In highly regulated Portland, Oregon, median house values rose nearly 60% relative to other major urban areas, as compact development policies were strengthened between 1990 and 2000. House prices continued to rise well above the national rate from 2000 to the 2006 peak of the housing bubble (adjusted for household income).[69]

During the housing bubble (2000 to 2006), median house prices in the major metropolitan markets with compact development rose substantially more than in metropolitan areas without compact development. This is illustrated by comparing the trend in a widely used indicator of housing affordability, the Median Multiple, which is the median house price divided by the median household income. Over at least the last four decades, the Median Multiple has tended to average 3.0 (3 years of household income) or less in U.S. metropolitan areas.[70] From 2000 to 2006, the increase in the Median Multiple was 2.5 (2.5 times household incomes) in the compact development metropolitan areas. From 2000 to 2006, the increase in the Median Multiple was 2.5 (2.5 times household incomes) for a total Median Multiple of 5.5 in the compact development areas. By contrast, the Median Multiple rose 0.7 (the equivalent of 0.7 times household incomes) in the metropolitan markets without compact development, little more than one-fourth the rate of metropolitan areas with compact development.[71] The overwhelming share of the U.S. house price escalation and subsequent losses that led to the international financial crisis (the "Great Recession") was concentrated in California and Florida, which rely heavily on compact development strategies.[72]

Impact on the Price of Rental Housing: Moreover, there is a general (though lagged) relationship between house prices and rents.[73] Thus, higher house prices are likely to lead to higher rental rates for the approximately one-third of households who do not own their own homes. These households tend to have lower incomes than home-owning households.

Estimating the Impact of Compact Development on Housing Affordability: The long-term land use restrictions proposed in *Driving and the Built Environment* and *Moving Cooler* would have significant impacts on housing affordability, the housing sector and the economy.

An estimate of the future additional housing expenditures under compact development is projected for the horizon year of 2050 (from 2010). The projection is developed using the 1970–2000 annual increase in California relative to that of the nation (house prices adjusted for household incomes).

The California experience is appropriate as a base for projection for two reasons:

1. California housing prices are well above the national average. However, this differential has developed since 1970. As late as 1971, California housing prices were similar to the national average.[74]

2. William Fischel has associated the increase in California housing prices relative to the nation with its stronger land use regulation. Fischel found that the rise in California housing prices from 1970 relative to the nation could not be explained by factors such as higher construction cost increases, population growth, quality of life, amenities, the state's property tax reform initiative (Proposition 13), land supply or water issues.[75]

It is estimated that additional consumer expenditures for housing would exceed $1.5 trillion (2010$) annually in 2050 (purchase price, financing and rent). The GHG emission reductions from *Moving Cooler* would be approximately 78,000,000 tons in 2050 (including upstream lifecycle emissions). This renders an expenditure per ton of GHG emissions of $19,700. This is nearly 400 times the IPCC maximum expenditure of $50 (Table 4). Even at the implausible maximum (high densification scenario) *Moving Cooler* projection, the expenditure per ton would be approximately 325 times the IPCC maximum.[76]

Expenditures of this magnitude are clearly unsustainable, but the estimates do suggest the intense pressure that would be placed on housing markets and household budgets. Housing affordability could be substantially weakened as households would likely pay a larger share of their income for housing than at present.

All of this would result in a massive rearrangement of the economy and composition of the Gross Domestic Product and possible economic disruption. The potential for housing market distortions to produce economic distress is illustrated by the recent experience of the Great Recession, which was closely related to unprecedented house price inflation and deflation, much of it in California. The additional housing expenditures in 2050 are projected at 3.7% of the 2050 Gross Domestic Product. This is an amount that rivals the *entire* national projected reduction in Gross Domestic

Product from GHG emission reduction efforts under the proposed cap-and-trade legislation (1.0% to 3.5%), according to the Congressional Budget Office.[77]

Aside from the clear economic shock, the increased cost of housing is likely to lead to a massive redistribution of income away from middle income and lower middle income households and from owners of land on the urban periphery to central city land holders, financial institutions and others. Economic crises hurt those at the bottom the most.

Because the compact development policies proposed in both *Driving and the Built Environment* and *Moving Cooler* are considerably more restrictive than the compact development policies in place in California in the base period used in this calculation, the estimates above could be conservative.

Table 4: Additional Consumer Expenditures for Housing Associated with Compact Development Policies: 2050

	Annual: 2050
Higher House Prices & Mortgage Payments	$1,450,000,000,000
Higher Rent Payments	$90,000,000,000
Total Additional Expenditures	$1,540,000,000,000
Annual GHG Tons Removed	78,000,000
Additional Consumer Expenditures per GHG Ton Removed	$19,700
IPCC Maximum Expenditure per GHG Ton Removed	$50
Times IPCC Maximum Expenditure	394
Projected Gross Domestic Product: 2050	$41,260,000,000,000
Additional Expenditures as a Share of GDP	3.7%

Methodology: House purchase prices, financing and rents in 2010$.

Estimate based upon house cost increases in California compared to the rest of the nation. Compact development house prices and financing increases at the California annual house value multiple (median house value divided by household income adjusted) compared to the nation from 1970 to 2000 U.S. Census. Reduced for the home mortgage income tax deduction at a 25% marginal rate.

Homeownership and renting is at the 2008 metropolitan rate of 66.4%. 72.4% of homeowners purchasing in 2010 or later have mortgages, which average 90% of the house price principal, with a 7% annual mortgage rate[78] (fixed 30-year term). Data from American Community Survey.

The owned housing stock turns over each 12 years (based upon National Association of Realtors and Census Bureau data).

The metropolitan area share of the national population would rise from 84% to 92%, based upon UN urban projections.

Real personal and gross domestic product estimated based upon Goldman Sachs estimate at (estimate was in 2006$, adjusted to 2010$ and based upon projected 2010 GDP), http://www.chicagogsb.edu/alumni/clubs/pakistan/docs/next11dream-march%20%2707-goldmansachs.pdf.

The baseline house value to household income ratio would continue to decline at the annual 1970–2000 rate.

From 2010 to 2040, the national rent to house price ratio would decline at the 2000 California 1970–2000 rate, based upon U.S. Census data...

Houses sold 2011 or later included in metropolitan areas over 1,000,000 population in 2008. Houses sold in 2021 or later included in metropolitan areas under 1,000,000 population in 2008.

GHG reduction from *Moving Cooler* for land use and transit, high (maximum) densification scenario, adjusted upward to account for life cycle.

Infrastructure Costs and Compact Development: Compact development proponents claim lower density development has higher infrastructure costs compared to infill development.[79] This, however, presumes that the costs of labor and materials are the same in compact urban cores as suburban areas, when in fact they are often higher. Moreover, higher densities can require retrofitting or replacing existing infrastructure, which tends to be older in more dense areas and may be unable to handle the higher volumes produced by the additional population. This can be particularly costly. Finally, Cox and Utt's analysis of the actual data indicates that costs are no higher in suburban areas.[80]

Community Resistance to Densification: Densification could lead to substantial NIMBY[81] reactions, such as forced a policy reversal in Portland in the early 2000s. In 2002, voters of the Portland Metro district approved a measure that outlawed forced densification in existing neighborhoods by a 66% to 34% margin.

It would be very difficult, if not impossible, to consolidate land parcels to transform such dense neighborhoods to meet higher density targets. Such a strategy could require local and regional governments to use far more aggressive eminent domain initiatives than those that sparked a national reaction and new state laws after the Supreme Court's "Kelo" decision.[82]

Inaccuracy of Behavioral Projections: The use of computer models to predict behavior, as in *Driving and the Built Environment* and *Moving Cooler,* is fraught with error.[83] An international study led by Oxford professor Bent Flyvbjerg found frequent and significant over-estimation of ridership in transportation projects during planning processes.[84] This is despite substantial experience obtained over many years that should have materially improved accuracy. Projecting changes in VMT over a 40-year period in urban areas is considerably more complex than shorter term projections of transportation behavior in specific corridors. As a result, these far more complex projections could be even less accurate and prone to an even larger upward bias than the less complex transportation projections.

The Problem of "Self-Selection:" Modeling results are made more uncertain by "self-selection." Self-selection is the tendency for people to choose residential locations that facilitate their preferred lifestyles, rather than changing their lifestyles based upon where they live. This issue was stated as follows in a paper by David Brownstone of the University of California, Irvine, which was commissioned in association with *Driving and the Built Environment:*

> *Households choose their residential (and work) locations based, among other things, on their preferences for different types and durations of travel. The observed correlations between higher density and lower VMT may just be due to the fact that people who choose to live in higher density neighborhoods are also those that prefer lower VMT and more transit or non-motorized travel. If this is the case, then forcing higher densities may not lead to anywhere near the reduction in VMT 'predicted' by observed correlations.*[85]

Driving and the Built Environment notes that self-selection could cause upward biases, which would overstate VMT reductions.[86]

Density and Driving: A Weak Relationship: Moreover, a U.S. Department of Transportation report, *Emissions Benefits of Land Use Strategies* concluded that: "The threshold value at which density seems to have a meaningful effect upon VMT, or trips, is somewhere probably between 6,000 and 7,000 persons per square mile."[87] Only two large U.S. urban areas have densities that high (Los Angeles and San Francisco).

Significant doubt was also raised about the potential for higher densities to reduce VMT in the Brownstone research:

> *There is evidence that there is a statistically significant link between aspects of the built environment correlated with density and VMT. Very few studies provide enough detail to judge whether this link is large enough to make manipulating the built environment a feasible tool for controlling VMT, but those that do suggest that the size of this link is too small to be useful.*[88]

Brownstone also indicates that: "the magnitude of the link between the built environment and VMT is so small that feasible changes in the built environment will only have negligible impacts on VMT."[89]

Residential GHG Emissions: Both *Driving and the Built Environment* and *Moving Cooler* imply that residences in auto-oriented suburban areas produce greater GHG emissions than higher-density areas.[90] This is counter to the Australian research cited below and raises further doubts about the potential for compact development strategies to reduce GHG emissions.

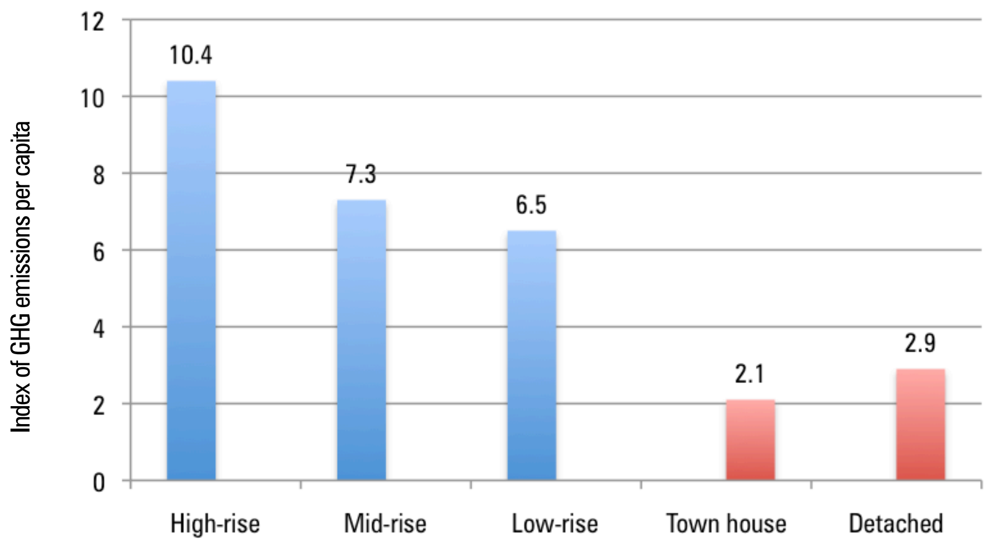
In perhaps the most comprehensive spatial research to date, the Australian Conservation Foundation allocated virtually all of the nation's GHG emissions to households based upon their residential location. The surprising result was that, all things considered, GHG emissions per capita were higher in more compact areas than in suburban areas, where there is more driving and where there is more detached housing.[91] Another report found that transportation and housing GHG emissions were greater in the core of Adelaide than in the suburbs, despite its higher density and lower rate of automobile usage. As the latter report indicates:

> *The densification of housing in central locations per se is not a sufficient condition for achieving a reduction in per capita greenhouse gas emissions in the built environment.*[92]

Expenditures: The expenditures under compact development's GHG reductions would be well above the IPCC maximum expenditure of $50 per ton as evidenced by the transit and housing reviews.

Exclusion of Common Energy: The authoritative source, the Residential Energy Consumption Survey (RCES)[93] includes only energy use reflected on residential utility bills, but excludes the common energy consumed in higher density housing.[94] Common energy is used for elevators, air conditioning, heating, water heating, building lighting, and commonly provided heating, cooling and water heating. Common energy can be substantial. An Australian study found that lower density housing produces less GHGs per capita than higher density when common energy is included (Figure 5).[95]

Figure 5: GHG Emissions by Housing Type (Annual Tons per Capita)



Source: Paul Myors, Rachel O'Leary and Rob Helstroom, *Multi Unit Residential Buildings Energy and Peak Demand Study*, Energy Australia, October 2005.

Building Materials and Construction Energy GHGs: Building materials used to construct detached houses produce less GHGs than those used in multiple unit housing. For example, wood, which is used to a greater extent in detached housing, tends to be less GHG-intensive than concrete and steel, which are used to a much greater extent in high rise construction. While the research is limited, data from one study indicated that GHGs from building materials used in multiple unit housing were from 3 to 14 times those of detached housing per square foot.[96] No estimates of GHG production from construction activities were identified.

Carbon Neutral Housing: Houses are becoming less GHG intensive. Britain requires that all new housing be carbon neutral by 2016. Carbon neutral housing has been developed, such as a 2,150 square foot detached house in Japan,[97] a 2,000 square foot detached house in the Shetland Islands,[98] and a 3,800 square foot detached house in the Washington, DC suburbs.[99] Thus, technology could conceivably eliminate housing type as a GHG concern.

D. Compact Development: Prospects

There are serious doubts about the feasibility of achieving the GHG emission reductions contained in the most aggressive densification scenarios in *Driving and the Built Environment* and *Moving Cooler*. The highest densification scenarios would require even greater efforts to coerce people into preferred lifestyle choices and would therefore seem to be even more out of reach. In the worst case, this could present a material threat to the well-being of households and economic growth.

The maximum density scenarios in *Driving and the Built Environment* and *Moving Cooler* would reduce GHG emissions from autos between 5% and 6% by 2030 from 2005 levels and approximately 9% by 2050. However, these projections seem implausible due to the extent of policy intervention required, as indicated in the reservations stated in *Driving and the Built Environment* and broader criticisms of *Moving Cooler*.[100] It is suggested that ranges of 1% to 3% in 2030 and 1% to 5% are more realistic for the maximum GHG emissions reductions from autos between 2005 and 2050 under compact development policies (See: "*Driving and the Built Environment:* Maximum Densification," above).[101]

Even these projections, however, are optimistic, because:

- The projections may not sufficiently account for the "GHG Traffic Congestion Penalty" (discussed above), by which GHG emissions reductions are diminished as traffic congestion increases (which is inevitable with higher densities). The "GHG Traffic Congestion Penalty" alone could diminish the projected GHG reductions by as much as two-thirds.

- Projections of behavioral changes are likely to be highly inaccurate, exhibiting an upward bias (see "Inaccuracy of Behavioral Projections," above).

Compact development policies could reduce economic productivity by forcing people to spend more time traveling to work and other activities due to increased congestion. Compact development would diminish the quality of life. The size of homes and yards would be reduced, while people would travel less and there would need to be a shift to denser housing.

Compact development could also lead to higher housing prices, higher rents and fewer opportunities for low income, especially minority, households to make economic gains. All of this could undermine public acceptance, an eventuality raised in *Driving and the Built Environment*, which questioned whether the substantial changes in "public preferences" were achievable.[102]

The expenditures under compact development's GHG reductions would be well above the IPCC maximum expenditure of $50 per ton as evidenced by the transit and housing reviews alone. As a result of its high expenditures, compact development policies are generally inappropriate for reducing GHG emissions from cars. This is because there are sufficient policies in other sectors to achieve the necessary GHG emission reductions within the maximum expenditure level.

Part 3

Facilitative Strategies (Technology)

A. Proposed Strategies: Technology

Facilitative strategies would reduce GHG emissions without interfering with the ability of people to live as they prefer.

B. Technology: Low GHG Opportunities and Possibilities

The most important facilitative strategies in transportation employ technology to improve the fuel economy of autos and reduce the GHG intensity of vehicle fuels. It's useful to compare the 35.5 MPG baseline, which reflects current federal CAFE fuel economy standards, with various technology opportunities. All GHG reduction projections include upstream life-cycle emissions.[103]

Present Technology and Policy: Existing technology and the latest fuel economy (CAFE) standards have considerable potential for reducing GHGs from autos.

Present Fuel Economy Standards: The new fuel economy standards would reduce GHGs 11% in 2030 from the 2005 base (Figure 6).[104] This assumes that overall driving (nationwide VMT) would increase 38% from 2010 to 2030, consistent with U.S. Department of Energy projections. In recent years, even before the much higher fuel prices, there were indications that the rate of VMT increase was slowing. This has also been documented in a Brookings Institution report, which noted that the decline was underway even before the large gasoline price increases.[105] This continues a trend of declining VMT increases going back at least to the 1950s, according to AASHTO's *Bottom Line* report. Steven Polzin of the University of South Florida has projected that future VMT growth will be more moderate than in the past, in a report for the United States Department of Transportation.[106]

In recognition of this development, AASHTO examined a lower-VMT-growth scenario in its *Bottom Line* report, in which VMT would increase 22% from 2010 to 2030, rather than the Department of Energy rate of 38%. At this lower VMT rate, the GHG emissions reduction from autos would be 19% (rather than 11%) by 2030 from 2005 (Figure 7).[107]

If that is true, then consumers would presumably prefer those more fuel efficient (but otherwise identical) cars and manufacturers would produce them with no prodding, so there is little need for government imposed fuel efficiency standards. Moreover, it indicates that there is substantial potential for additional progress.[108]

Figure 6: Potential to Reduce Auto GHGs with Baseline VMT Growth (EIA Projection and Trend)

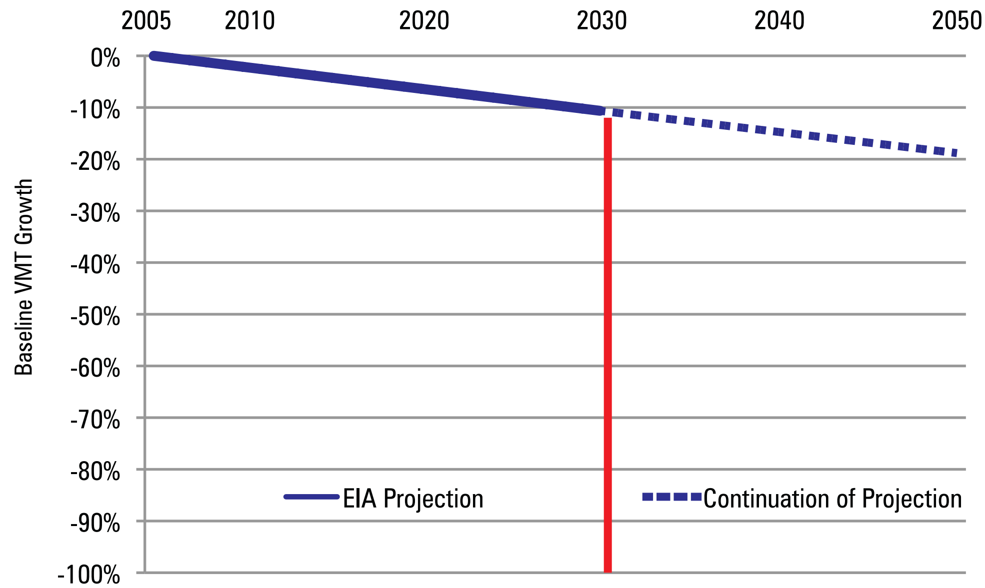
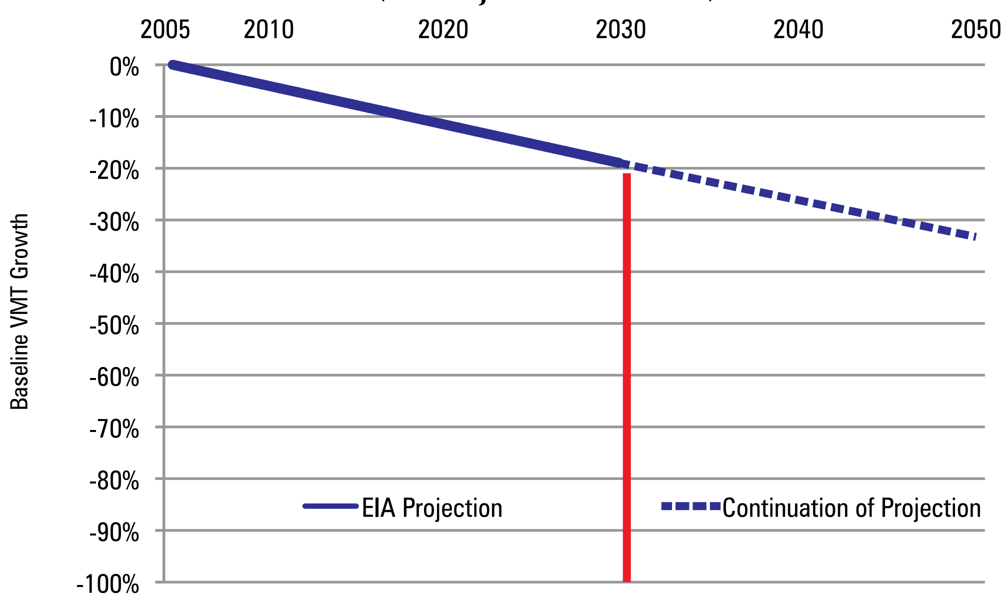


Figure 7: Potential to Reduce Auto GHGs with Lower VMT Growth (EIA Projection and Trend)



Continuation of the Trend: If the rate of fuel economy improvement from 2010 to 2025 could be sustained beyond that year, then GHGs from personal mobility would be reduced 18% by 2050, while VMT and the population continued to increase.[109] With the lower VMT growth-rate scenario, the decrease in auto GHGs would be 33% from 2005 to 2050 (Figures 6 and 7).

This longer term trend is plausible. Further, there are considerable opportunities for further advances in vehicle and fuel technology, which could improve GHG emissions reductions well beyond this fuel economy level. Potential opportunities are described below.

Additional Possibilities Using Present Technology: Other presently available strategies could further reduce auto-related GHGs.

Telecommuting (or working at home) eliminates the work trip thereby reducing emissions from commuting.[110] If the 2000–2008 trends continue, more people will work at home in 2020 on weekdays than commute by transit to work.[111] Already, working at home accounts for a larger market share of commuters than transit in 36 of the nation's 50 metropolitan areas with more than 1,000,000 population. The working at home commute share exceeds that of transit in more than 90% of metropolitan areas of all sizes.[112]

Improved traffic management and operations, especially from Intelligent Transportation Systems could reduce GHGs from congested traffic by up to 20%.[113]

There is also additional potential for reducing auto GHGs using existing technology or the mandates of present policy (Figures 8 and 9). Implementation could require financial incentives or more stringent fuel economy standards. These opportunities are not recommended as policy requirements, but rather are shown to indicate the potential for achieving greater GHG emission reductions through improved fuel economy.

***Hybrids*:** Hybrid vehicles can now achieve overall fuel efficiency of approximately 50 miles per gallon.[114] If the nation's personal mobility fleet were to achieve the *current* fuel efficiency of the best present hybrids by 2040, GHG emissions would fall 55% by 2050, despite continuing increases in VMT.[115] GHGs would decline 64% with the lower VMT increase rate. There are indications that the cost premium of hybrids over conventional vehicles could disappear, which suggests the possibility that such a conversion could be achieved within the $50 per ton maximum expenditure level.[116]

Europe: European fuel economy is substantially higher than that of the United States. The most fuel efficient new cars in Europe, such as a Volkswagen Polo model, now achieve 66 miles per (US) gallon.[117] If the U.S. light vehicle fleet were to achieve this fuel economy by 2040, GHGs would drop 69% by 2050. GHGs would decline 75% with the lower VMT increase rate. The expenditures required for these fuel economy improvements are not known, however the car model used in this projection retails for considerably less than the average car price.

However, fuel economy of this magnitude might not be accomplished without downsizing vehicles. This would diminish the quality of life. However, this would not impact other transportation and residential factors, such as the size of home or commercial space or the amount of vehicle travel, nor would a shift to denser urban housing be required. In view of the association between mobility, job creation and greater economic growth, this reduction in the quality of life might not have negative economic consequences.

Figure 8: Potential to Reduce Auto GHGs with Baseline VMT Growth: Additional Strategies

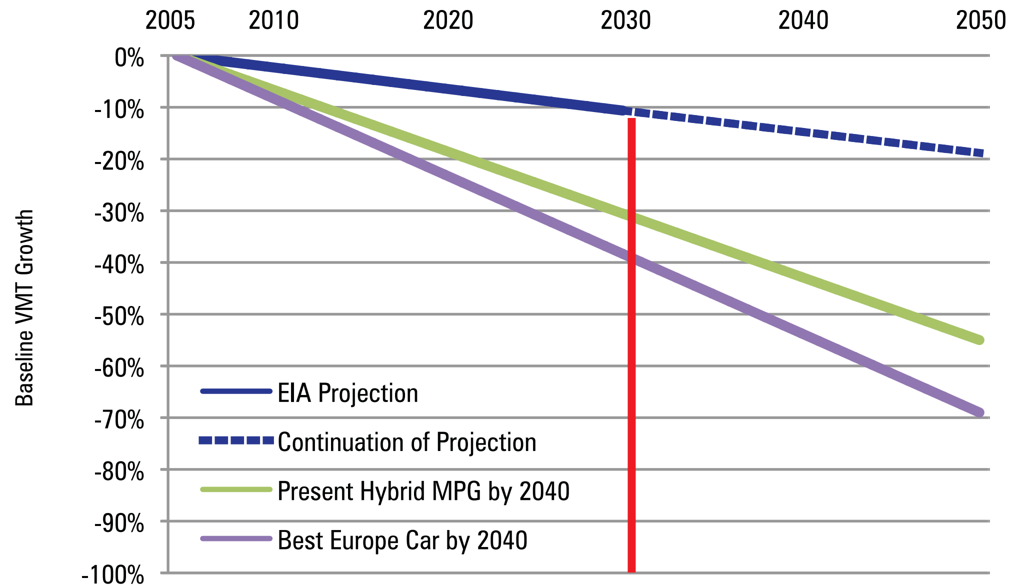
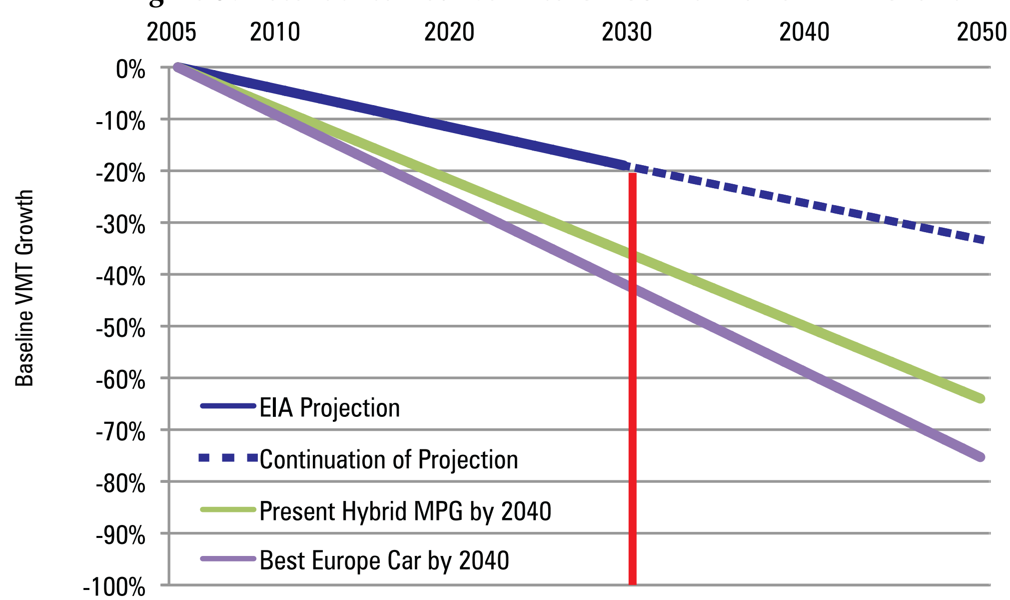


Figure 9: Potential to Reduce Auto GHGs with Lower VMT Growth



Future Technologies: There is the potential for further improvement in auto emissions from more advanced technologies. No evaluation is offered of any of the possibilities cited below, and, indeed, some are in the very early stages of development and may proceed no further. However, it is useful to note the volume of research that is underway, which may be a reminder of the potential of human research and entrepreneurship in developing advanced technological approaches.

Electric Vehicles: Electric vehicles could hold the greatest promise for GHG emission reduction. For example:

Plug-in hybrid vehicles will soon be available. A report by Massachusetts Institute of Technology researchers indicates the potential for plug-in hybrid vehicles to produce life-cycle GHG emissions of 139 grams per mile by 2030.[118] This is the equivalent of approximately 80 miles per gallon. If the vehicle fleet could achieve this efficiency by 2050, automobile GHGs would be reduced 61% from 2005 levels.

The same report identifies the potential for battery electric vehicle emissions to reach 186 grams per vehicle mile by 2030 or the equivalent of 60 miles per gallon. If the vehicle fleet could achieve this efficiency by 2050 automobile GHGs would be reduced 33% from 2005 levels. Under the lower VMT growth scenario, GHG automobile emissions would be reduced 47% by 2050.

Because battery electric vehicles are fully powered from the electricity grid and do not use fossil fuels directly, there is substantial potential for further reducing GHG emissions as electricity generation becomes less carbon intensive. If the carbon intensity of electricity generation could be reduced 50% by 2050 (a development considered "plausible" by the MIT report) and battery vehicle fuel efficiency were achieved by 2050, auto GHG emissions could be reduced 66%. At the lower VMT growth rate, the reduction in GHG emissions would be 74%.

Further, there is potential for electric cars that produce little or no GHG emissions. For example, German researchers have proposed using "redox flow" batteries that would be recharged at service stations by exchanging new battery fluid for spent fluid (which would then be recharged for use in another car). The fluid would be recharged through a chemical process.[119] Such cars would not rely on the electricity grid.

Fuel Cell Vehicles: The U.S. Congress mandated research on fuel cell technology in the Energy Policy Act of 2005. The resulting report by the National Research Council[120] found that a strategy principally relying on hydrogen fuel-cell vehicles (also biofuels and fuel economy) could reduce life-cycle GHGs 85% by 2050. GHGs would drop 88% at the VMT growth rate.[121] The report predicts that the technology could become commercially viable (and affordable) by the early 2020s.

Conventional Vehicle Advances: Volkswagen has developed a two-seat car that achieves 235 miles per gallon and reports indicate that it could be marketed within the next few years.[122] At this early stage of responding to GHG emission reduction mandates, this advance indicates that there may be substantial potential to improve conventional vehicle fuel economy even more in the future.[123]

C. Technology: Examination

Various issues are examined with respect to these technologies.

GHG Reduction and VMT Increases: Advocates of compact development have often suggested that auto GHG emission reduction advances will be cancelled out by emissions from VMT growth. However, contrary to this claim, auto GHG emissions are projected to decline 7% by 2025, despite the continuing (29%) projected increase in driving (VMT). As the analysis above shows, there is the potential for even more substantial reductions in auto GHG emissions, even while driving continues to increase.

Quality of Life: Some of the future technology-oriented policies could retard the quality of life because they would require reductions in vehicle size. However, people could continue to live in houses of the same size, to travel the same mileage, and no shift to denser urban housing would be required. As a result, new technology, implemented within the IPCC maximum expenditure level, would not otherwise diminish the quality of life and would represent no threat either to households or to the economy.

Housing Affordability: These new technologies would have virtually no negative effect on housing affordability, because they would allow continued development of inexpensive land on the urban fringe, consistent with household preferences. Thus, there would be no massive transfer of wealth, unlike under compact development.

Relying on Technology: There may be a concern that GHG emission reductions are so important that any and all potential actions should be implemented without delay and without consideration of expenditure levels. Or, it may be thought that it is too great a gamble to rely on the development of technological solutions.

Yet, there is considerable evidence that technology is advancing and that it does not require a leap of faith to believe that GHG emissions can be reduced sufficiently. The analysis above describes a number of existing and potential technologies that offer the possibility of deep reductions in auto-related GHGs. Based upon the current availability of far more fuel-efficient technologies, such as hybrid vehicles, it is plausible to assume continued GHG reductions after 2030. Of course, as noted above, any projection is uncertain.

Expenditures: Some of the more advanced technology strategies outlined above may not be achievable within the $50 IPCC maximum expenditure per ton. The maximum expenditure criteria would eliminate such strategies from implementation. At the same time, there are sufficient additional less costly strategies in other sectors to reduce GHG emissions at $50 per ton or less.

D. Technology: Prospects

Technological solutions have the potential to achieve material GHG emissions reductions from autos. The reductions can be achieved while allowing the economy to grow with minimal interference, thus maintaining or increasing job growth and minimizing poverty. It is thus possible to sustain the quality of life by not requiring smaller houses, less travel or denser urban housing. As a result such technologies are likely to be politically acceptable.

The use of autos will continue to increase rapidly in developing nations. American technology advances could be exported to assist such countries in reducing their GHGs as driving increases.

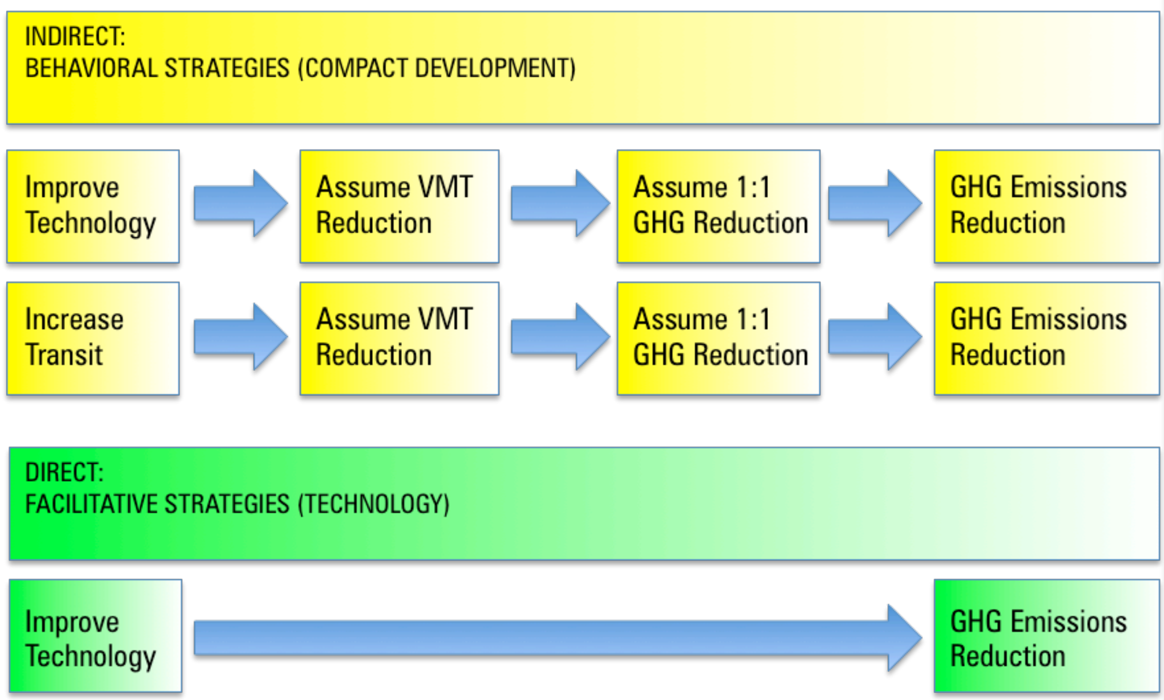
According to the criteria we established at the beginning of this paper, technology strategies (like other strategies) are appropriate to the extent that they can produce GHG reductions at less than the $50 expenditure level. Major reductions in U.S. auto GHG emissions can be achieved at expenditure levels below the IPCC maximum expenditure of $50 per ton, even while driving continues to increase. Indeed, if the EPA assessment of current fuel economy standards is to be believed, they can be achieved at essentially no additional cost.

Part 4

Conclusions and Recommendations

Direct and Indirect Approaches: New automobile technologies promise superior results by *directly* addressing GHG emissions without the need to regulate behavior. Compact development seeks to reduce GHGs *indirectly*, such as through restricting auto travel and regulating land use (Figure 10).

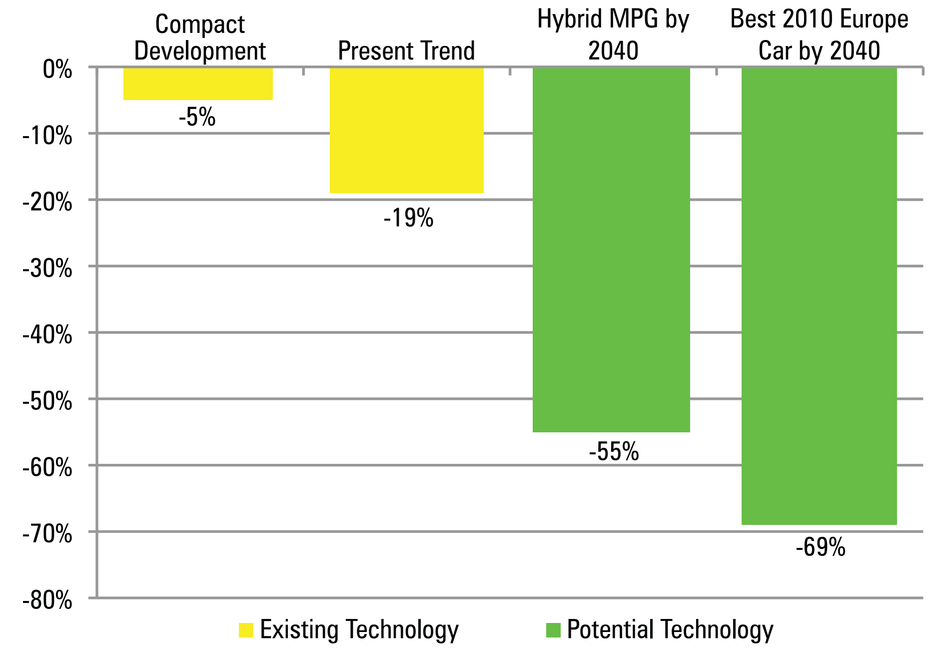
Figure 10: Indirect vs. Direct Strategies (Compact Development vs. Technology)



Generally, new technology has a far greater potential to reduce GHG emissions than compact development. *Driving and the Built Environment* notes that fuel economy strategies produce superior results (Figure 11 and Table 5).

> *In short, over the longer time frame (i.e., to 2050), the impacts of continuing improvements in fuel economy beyond 2020 on energy use and CO_2 emissions significantly outstrip those from more compact development.*[124]

Figure 11: Long -Term GHG Emission Reduction (Various Strategies: 2005–2050)



Comparing Compact Development and Technology: 2030: The greater effectiveness of technology strategies is illustrated by the fuel economy standards adopted in 2007 and 2008. These new standards reduced projected 2030 GHGs more than 30% from the previous standards from a 2005 base. This is despite a 97% projected increase in driving over the period.

In contrast, compact development would have produced a reduction of from 1% to an implausible 6% from the previous fuel economy standards between 2005 and 2030.[125] This is the equivalent of a less than 1 mile per gallon improvement in fuel efficiency.[126]

In the shorter term (2020), technology is projected to produce auto GHG emission reductions that are considerably better than that of compact development. Robert Poole of Reason Foundation characterized the lower range projected reductions for compact development as what would be called "a rounding error" in engineering.[127]

Comparing Compact Development and Technology: 2050: Based upon *Driving and the Built Environment* and *Moving Cooler*, compact development provides little possibility of achieving a reduction of more than 5% in auto GHGs by 2050. Reductions of up to 9% are theoretically possible, but improbable. The actual potential could be considerably less, given the impact of greater traffic congestion in the more dense urban areas that would be the result of compact development.

On the other hand, technology could produce GHG emission reductions of up to 55% by 2050 with present hybrid technology. GHG reductions from developing technologies, such as electric cars, could be even greater.[128]

Comparing the Dimensions of Sustainability: Compact development is overly expensive, could materially reduce economic growth, and could stifle opportunity for lower income households, which are disproportionately African-American and Hispanic. Further, compact development would substantially increase housing expenditures, which, again, would fall hardest on low income households. Compact development would result in a huge transfer of wealth from lower and middle income households to financial institutions and owners of developable land. These factors render compact development financially, economically and politically unsustainable. As a result, compact development is environmentally unsustainable. Yet, compact development has gained significant support in Washington through the Administration's "livability program," the draft surface transportation reauthorization bill, and the two cap-and-trade bills.

By contrast, new technology has the potential to materially reduce GHG emissions from autos. New technology can be economically and politically sustainable. As a result, new technology can be environmentally sustainable (Figure 12 on page 34).

Table 5: Greenhouse Gas Emissions Impacts: Compact Development vs. Technology

				Change from 2005	
	2005	2030	2050	2030	2050
BASELINE DRIVING RATE: EIA TREND					
Vehicle Miles (VMT): Billions	2,687	3,755	5,130	40%	91%
COMPACT DEVELOPMENT (BEHAVIORAL STRATEGIES): Millions of Annual GHG Tons					
Driving and the Built Environment: 25% Scenario Midpoint	2000 Base Scaled to 2005			-1%	-1%
Driving and the Built Environment: Midpoint between 2 Scenarios	2000 Base Scaled to 2005			-3%	-5%
Driving and the Built Environment: 75% Scenario Midpoint	2000 Base Scaled to 2005			-6%	-9%
Moving Cooler: Expanded Current Practice	1,500	1,486	1,475	-1%	-2%
Moving Cooler: Aggressive Deployment	1,500	1,459	1,422	-3%	-5%
Moving Cooler: Maximum Deployment	1,500	1,426	1,359	-5%	-9%
USDOT Report: *Emissions Benefits of Land Use Strategies*					
FACILITATIVE STRATEGIES: Millions of Annual GHG Tons					
Fuel Economy					
Pre-2007 CAFE Standards	1,500	1,886	2,577	26%	72%
Early 2009 EIA Projection	1,500	1,341		-11%	
2009 CAFE Standards (35.5 MPG Baseline): Trend Continuation	1,500		1,236		-18%
Hybrid Fuel Efficiency by 2040	1,500	969	670	-35%	-55%
European Standard Fuel Efficiency by 2040	1,500	801	458	-47%	-69%
Plug In Hybrid Fuel Efficiency by 2050: Present Electricity Generation Mix	1,500		712		-53%
Electric (Battery) Fuel Efficiency by 2050: Present Electricity Generation Mix	1,500		955		-36%
Electric (Battery) Fuel Efficiency by 2050: 50% Generation Improvement	1,500		477		-68%
Fuel GHG Intensity					
Hydrogen Fuel Cell Strategy Mix	1,500		229		-85%
LOWER VMT GROWTH RATE (AASHTO)				**Change from 2005**	
	2005	**2030**	**2050**	**2030**	**2050**
Vehicle Miles (VMT): Billions	2,687	3,405	4,155	27%	55%
COMPACT DEVELOPMENT (BEHAVIORAL STRATEGIES): Millions of Annual GHG Tons					
Driving and the Built Environment: 25% Scenario Midpoint	2000 Base Scaled to 2005			-1%	-1%

Table 5: Greenhouse Gas Emissions Impacts: Compact Development vs. Technology

				Change from 2005	
	2005	**2030**	**2050**	**2030**	**2050**
Driving and the Built Environment: Midpoint between 2 Scenarios	2000 Base Scaled to 2005			-3%	-4%
Driving and the Built Environment: 75% Scenario Midpoint	2000 Base Scaled to 2005			-5%	-8%
Moving Cooler: Expanded Current Practice	1,500	1,487	1,479	-1%	-1%
Moving Cooler: Aggressive Deployment	1,500	1,463	1,437	-2%	-4%
Moving Cooler: Maximum Deployment	1,500	1,433	1,386	-4%	-8%
Driving the Built Environment: 25% Scenario Midpoint	2000 Base Scaled to 2005				
Driving the Built Environment: 75% Scenario Midpoint	2000 Base Scaled to 2005				
USDOT Report: *Emissions Benefits of Land Use Strategies*	Little at Low Density				
FACILITATIVE STRATEGIES: Millions of Annual GHG Tons					
Fuel Economy					
Pre-2007 CAFE Standards	1,500	1,710	2,087	14%	39%
Early 2009 EIA Projection	1,500	1,216		-19%	
2009 CAFE Standards (35.5 MPG Baseline): Trend Continuation	1,500		1,001		-33%
Hybrid Fuel Efficiency by 2040	1,500	878	542	-41%	-64%
European Standard Fuel Efficiency by 2040	1,500	727	371	-52%	-75%
Plug In Hybrid Fuel Efficiency by 2050: Present Electricity Generation Mix	1,500		577		-62%
Electric (Battery) Fuel Efficiency by 2050: Present Electricity Generation Mix	1,500		773		-48%
Electric (Battery) Fuel Efficiency by 2050: 50% Generation Improvement	1,500		387		-74%
Fuel GHG Intensity					
Hydrogen Fuel Cell Strategy Mix	1,500		185	-100%	-88%

NOTES:
Base driving rate annual increase 1.6% (from Energy Information Administration)
Lower VMT Growth Rate annual increase 1.0% (from AASHTO)
Hydrogen Fuel Cell Strategy Mix based upon National Academy of Sciences report
Moving Cooler and Driving and the Built Environment Maximum scenarios considered improbable (see text)

Recommendations: As governments consider policies intended to reduce GHG emissions from autos:

1. Compact development strategies should be neither mandated *nor* encouraged.
2. Technology strategies should receive priority.

Technology strategies should thus be favored, consistent with the expected policy requirements to reduce GHG emissions. At the same time, government policies should be implemented with great caution. This imperative was stated by Massachusetts Institute of Technology Professor Richard K. Lester: "A steady stream of cost-reducing innovations in many different fields of energy technology—if sustained over decades—could bring the nation's climate and energy security goals within reach. But there are profound doubts about the government's ability to engineer this."[129] In the end, better overall results are likely to be achieved with greater reliance on market-based strategies.

Figure 12: Dimensions of Sustainability (Potential to Reduce AUTO GHG Emissions)

Dimensions of Sustainability	Behavioral Strategies: (Compact Development Policies)	Facilitative Strategies (Technology)
Financial Sustainability Can the strategy reduce GHG emissions within the IPCC $50 expenditure range maximum per ton?	NO	YES
Economic Sustainability Can the strategy be implemented without impairing economic growth, job creation or poverty minimization?	NO	YES
Political Sustainability Will the strategy have public support and compliance?	NO	YES
Environmental Sustainability Does the strategy have the potential to materially reduce GHG emissions from autos?	NO	YES

About the Author

Wendell Cox is principal of Wendell Cox Consultancy (Demographia), an international public policy firm and specializes in urban policy, transport and demographics. He has provided consulting assistance to the United States Department of Transportation and was certified by the Urban Mass Transportation Administration as an "expert" for the duration of its Public-Private Transportation Network program (1986–1993). He has consulted for public authorities in the United States, Canada, Australia and New Zealand and for public policy organizations and lectured widely. He serves as visiting professor at the Conservatoire National des Arts et Metiers (a national university) in Paris, where he lectures on transport and demographics.

Related Reason Studies

David T. Hartgen, et al., *Impacts of Transportation Policies in Greenhouse Gas Emissions in U.S. Region*, October 2010, Policy Study No. 387.

Kenneth Green, *Q&A About Forests and Global Climate Change*, September 1, 2001.

Steven Schroeder and Kenneth Green, *Reducing Global Warming Through Forestry and Agriculture*, July 1, 2001, E-brief 105.

Kenneth Green, *Mopping up After a Leak: Setting the Record Straight on the "New" Findings of the Intergovernmental Panel on Climate Change (IPCC)*, October 1, 2000.

Kenneth Green, *A Plain English Guide to Climate Change*, August 1, 2000.

Kenneth Green, *Climate Change Policy Options and Impacts*, February 1, 1999.

Kenneth Green, *13 Questions Asked About the Science of Climate Change*, October 1, 1998.

Kenneth Green, *Evaluating the Kyoto Approach to Climate Change*, February 1, 1998

Kenneth Green, *Plain English Guide to Climate Change*, December 1, 1997.

Steven J. Moss and Richard McCann, *Nuts and Bolts: The Implications of Choosing Greenhouse-Gas Emission Reduction Strategies*, November 1, 1993.

Steven J. Moss and Richard McCann, *Global Warming: The Greenhouse, White House, and Poorhouse Effects*, September 1, 1993

Endnotes

[1] The U.S. Bureau of the Census projects a population increase from 310 million in 2010 to 439 million in 2050. One of the principal reasons that metropolitan area populations decline is that non-metropolitan areas (counties and, in New England, towns) gain population and are reclassified into metropolitan areas.

[2] Based upon the United Nations estimate that the urban population will increase from 82.3% in 2010 to 90.4% in 2050. http://esa.un.org/unup/index.asp?panel=1.

[3] A critical analysis of the conclusions and assumptions of such reports is beyond the scope of this paper.

[4] Intergovernmental Panel on Climate Change, "Mitigation from a cross-sectoral perspective,"2007, www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-chapter11.pdf p. 660 (20–50 US$/tCO2-eq is $20 to $50 per GHG ton).

[5] Transport share figure from http://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-chapter5.pdf. GHG emission reduction share calculated from Figures SPM.1 and SPM.6 in http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-spm.pdf.

[6] *Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost?* McKinsey & Company and The Conference Board, Executive Report, December 2007, www.mckinsey.com/clientservice/ccsi/pdf/US_ghg_final_report.pdf, p. ix. This report was co-sponsored by the Environmental Defense Fund, the Natural Resources Defense Council (NRDC), Shell, National Grid, DTE Energy and Honeywell, pages xii and 80.

[7] See for example Howard W. Pifer III, W. David Montgomery, Dean C. Maschoff and Anne E. Smith "Managing the Risks of Greenhouse Gas Policies," Charles River Associates, January 2008, available at: http://www.crai.com/uploadedFiles/RELATING_MATERIALS/Publications/BC/Energy_and_Environment/files/Managing%20the%20Risks%20of%20Greenhouse%20Gas%20Policies.pdf

[8] Paradoxically, compact development advocates have coined "livability" to denote strategies that would require diminishing the quality of life. See Box: The Livability Agenda.

[9] "Infill" refers to development that occurs within currently developed areas (within the current urban footprint).

[10] An urban area (urban footprint or urban agglomeration) can be described as the lights visible from the air at night. An urban area is not defined by jurisdictional boundaries, such as city limits or county or state boundaries (see: http://demographia.com/db-define.pdf).

[11] Proponents of compact development sometimes contend that less restrictive land use strategies do not reflect genuine consumer preferences. However, the fact that compact development must impose strict land use regulations in an attempt to shape people's behavior in ways that would not otherwise occur demonstrates this contention to be invalid.

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12 A comprehensive review of the social costs and benefits is provided in Joel Schwartz, "The Social Benefits and Costs of the Automobile," in Wendell Cox, Alan Pisarski and Ronald D. Utt, *21st Century Highways: Innovative Solutions to America's Transportation Needs* (Washington, D.C.: Heritage Foundation, 2005).

13 http://usj.sagepub.com/cgi/content/abstract/36/11/1849 and http://reason.org/news/show/gridlock-and-growth-the-effect and http://www.newgeography.com/content/001044-traffic-congestion-time-money-productivity.

14 Calculated from U.S. Bureau of the Census American Community Survey data, summarized at http://www.publicpurpose.com/ut-commute2007.pdf.

15 For example, see the annual Texas Transportation Institute *Mobility Report* (http://mobility.tamu.edu/ums/).

16 Delcan and Economic Development Research Group, "Economic Impact, Analysis of Investment in a Major Commercial Transportation System for the Greater Vancouver Region," Vancouver: Greater Vancouver Gateway Council, 2003, http://www.edrgroup.com/edr1/library/lib_trans_air/P099-Vancouver-economic-impact.shtml and Economic Development Research Group, "The Cost of Congestion to the Economy of the Portland Region," December 5, 2005: http://www.metro-region.org/library_docs/trans/coc_exec_summary_final_4pg.pdf.

17 Margy Waller and Mark Alan Hughes, "Working Far from Home: Transportation and Welfare Reform in the Ten Big States," Progressive Policy Institute, August 1, 1999. See also Anne Kim, "Why People Need Affordable Cars," Blueprint: Ideas for a New Century www.ndol.org/ndol_ci.cfm?contentid=251220&kaid=114&subid=143.

18 Evelyn Blumenberg and Margy Waller, "The Long Journey to Work: A Federal Transportation Policy for Working Families," Center for Urban and Metropolitan Policy, Brookings Institution, July 2003, p. 2.

19 http://www.randomhouse.com/acmart/catalog/display.pperl?isbn=9780679448914

20 Passenger rail systems, especially high speed rail, are often suggested as being less GHG intensive than airlines. Substantial progress, however, is likely, with the world airline industry having pledged to reduce GHGs 50% by 2050 (http://www.earth-stream.com/Earth/Community-and-Politics/Kyoto-protocol/Airlines-Pledging-to-Cut-Emissions-by-50-_18_193_729_205869.html). Michigan Technological University research indicates that biofuels could reduce the GHG intensity of jet fuel by more than 80% (http://www.greenaironline.com/news.php?viewStory=432).

21 This could increase truck volumes because of the speed incompatibility between freight trains and passenger trains (see: Wendell Cox, Alan Pisarski, David Ellis [Texas Transportation Institute] and Tim Lomax [Texas Transportation Institute], *The Importance of Freight Mobility and Reliability to Economic Growth*, 2009).

22 Despite decades' long opposition to suburban development by many in the planning community, suburban areas have accounted for nearly all of the metropolitan population increase in the United States, Western Europe and Japan for as many decades. See: http://demographia.com/db-highmetro.htm.

23 http://www.boston.com/news/politics/politicalintelligence/2009/05/lahood_defends.html.

24 A more radical bill would require a 16% reduction in driving over 20 years, introduced by Representatives Rush Holt (Indiana), Russ Carnahan (Missouri) Jay Inslee (Washington.).

25 Assumes the national average household size.

26 *Driving and the Built Environment: The Effects of Compact Development on Motorized Travel, Energy Use and CO_2 Emissions*, a National Research Council report requested by the United States Congress, http://www.nap.edu/catalog/12747.html.

27 These figures are slightly different from those most reported in the media, which compared the 2050 business as usual baseline to the 2050 scenarios.

28 Assumes 3.8 houses per acre and the national average household size.

29 Despite popular impressions to the contrary, Los Angeles is the most dense major urban (urbanized) area in the country, with a population density of over 7,000 persons per square mile (2000 census). An urban or urbanized area is the "footprint" of urbanization, or the agglomeration, as defined by the U.S. Bureau of the Census. By comparison, the New York urbanized area has a density of 5,300 per square mile. Los Angeles (also San Francisco and San Jose) are more dense than New York because their suburbs are substantially more dense than the far-flung suburbs of New York in both New York State and New Jersey (See: http://demographia.com/db-ua2000pop.htm).

30 *Driving and the Built Environment,* p. 116.

31 Ibid.

32 *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions*, 2009, http://movingcooler.info/

33 Such as the Urban Land Institute and the Environmental Defense Fund.

34 *Moving Cooler,* p. 5.

35 *Moving Cooler* recommended other policies as well, such as encouraging more environmentally-friendly driving behavior. *Moving Cooler* indicates that this would reduce GHGs *more* than compact development. *Moving Cooler* proposes that people pay for parking in front of their houses and indicates that smaller houses might be required. Overall, the *Moving Cooler* strategies, (compact development and other policy proposals) would reduce GHGs in 2050 between 18% and 24% from 2005.

36 Calculated from the data in *Moving Cooler*. The experience suggests that transit costs would be even higher. *Moving Cooler* assumes that the expenditures per passenger mile will remain constant as transit expands. The reality is that transit expenditures per passenger mile have risen strongly relative to inflation. In the 25 years since of highway user fees were first dedicated to transit, expenditures per passenger mile have increased by 46% *after inflation* and *after accounting for increased ridership* (See: http://www.publicpurpose.com/ut-tr8297x.pdf).

37 Compact development advocates generally tend to favor implementation of intercity high-speed rail systems. The data in *Moving Cooler* indicate that high speed rail would require expenditures of more than $7,000 per ton of GHG emissions removed in 2050, a figure well above the IPCC maximum expenditure level of $50. Further, the Reason Foundation report on the California High Speed Rail Project estimated that the cost per greenhouse gas ton removed would be as much as $10,000, far higher than the *Moving Cooler* intercity rail projection (http://reason.org/files/1b544eba6f1d5f9e8012a8c36676ea7e.pdf).

38 Based upon GHG emissions reductions projections for transit and land use strategies.

39 *Moving Cooler* includes commercial vehicle emissions (such as from trucks). This calculation is based upon 2005 auto GHGs only.

40 A national association representing state departments of transportation.

[41] AASHTO Statement on *Moving Cooler* Report, and C. Kenneth Orski, "A Tenditious Report has Transportation Community Up in Arms," *Innovation Briefs*, August 18, 2009.

[42] http://www.epa.gov/ocir/hearings/testimony/111_2009_2010/2009_0616_lpj.pdf.

[43] Estimated from data in *Driving and the Built Environment*.

[44] Estimated from National Transit Database data compiled by Randal O'Toole (http://ti.org/NTD08sum.xls).

[45] The percentage decline in GHGs from compact development is the same in the "Present Fuel Economy Standards" and "Hybrid MPG by 2040: Trend" scenarios. The actual reduction in tons is lower (as indicated in the figure), because it is calculated on a smaller total GHG emission base.

[46] The ICLEI-Local Governments for Sustainability Density-VMT Calculator" yields a 61% increase in traffic volumes for each doubling of density (http://www.icleiusa.org/library/documents/8-Density-VMT%20Calculator%20(2).xls). This is based upon research by the Sierra Club, long a proponent of compact development.

[47] http://www.arb.ca.gov/msei/onroad/downloads/pubs/co2final.pdf.

[48] Martin Treiber, Arne Kesting and Christian Thiemann, *How Much Does Traffic Congestion Increase Fuel Consumption and Emissions? Applying a Fuel Consumption Model to the NGSIM Trajectory Data*, paper presented to the Annual Meeting of the Transportation Research Board, 2008.

[49] Calculation (-0.12% divided by-. 62%).

[50] http://www.arb.ca.gov/cc/sb375/rtac/meetings/070709/commentaddendum.pdf.

[51] Transit work trips take 80% longer than work trips in single-occupant autos. Calculated from the American Community Survey, 2006 (United States Bureau of the Census).

[52] This figure is based upon the *Moving Cooler* high densification scenario. The developable area under the *Driving and the Built Environment* high densification scenario would be smaller.

[53] In theory, urban growth boundaries are often promoted as providing sufficient vacant land to accommodate new development for a period, such as 20 years. The reality is that planning authorities (such as in Portland) have tended to draw such boundaries with little vacant land beyond the urban footprint. Moreover, even a genuine 20-year supply (for example) can increase land prices because landowners within the urban growth boundary are able to command higher prices from sellers, while landowners outside experience a substantial reduction in their property values because it cannot be developed. The three-mile area beyond the urban footprint is shown as an example to illustrate the likely development area in an urban area without compact development policies.

[54] This is illustrated in the United Kingdom, where compact city policies have been in effect for more than 60 years. Dr. Timothy Leunig of the London School of Economics has reported that agricultural land on which housing is not permitted can escalate in value 500 times when rezoned to allow housing: "Turning NIMBYs into IMBYs," *The Guardian,* September 2, 2004. http://society.guardian.co.uk/housingdemand/0,14488,1192601,00.html.

[55] http://demographia.com/db-dhi-econ.pdf.

[56] http://www.nytimes.com/2005/08/08/opinion/08krugman.html and http://select.nytimes.com/2006/01/02/opinion/02krugman.html

[57] http://real.wharton.upenn.edu/~gyourko/Working%20Papers/working%20papers%202005/AER%20Proceedings-NBER%20version-122804.pdf

58 William Fischel, *Regulatory Takings, Law, Economics and Politics* (Cambridge, MA: Harvard University Press, 1995), pp. 218-252.

59 Donald Brash, Introduction to the *4th Annual Demographia International Housing Affordability Survey*, http://www.demographia.com/dhi.pdf.

60 Kate Barker, *Review of Housing Supply: Delivering Stability: Securing Our Future Housing Needs: Final Report—Recommendations* (Norwich, England: Her Majesty's Stationery Office, 2004 and 2006). www.hmtreasury.gov.uk/consultations_and_legislation/barker/consult_barker_index.cfm, and *Barker Review of Land Use Planning,* http://www.hm-treasury.gov.uk/media/4EB/AF/barker_finalreport051206.pdf.

61 Arthur C. Grimes, *Housing Supply in the Auckland Region,* Center for Housing Research Oater New Zealand (2007). http://www.hnzc.co.nz/chr/pdfs/housing-supply-in-the-auckland-region-2000-2005.pdf.

62 http://depts.washington.edu/teclass/landuse/housing_020408.pdf.

63 http://www.dallasfed.org/research/houston/2008/hb0801.pdf.

64 Raven E. Saks, *Job Creation and Housing Construction: Constraints on Metropolitan Area Employment Growth,* http://www.federalreserve.gov/pubs/feds/2005/200549/200549pap.pdf.

65 Waldo Lopez-Aqueres, Joelle Skaga and Tadeusz Kugler, *Housing California's Latino Population in the 21st Century: The Challenge Ahead* (Los Angeles, CA: The Tomas Rivera Policy Institute, 2002) (http://www.trpi.org/PDFs/housing_ca_latinos.pdf). "Growth controls" are compact development policies.

66 *Driving and the Built Environment,* p. 115.

67 Robert W. Burchell, George Lowenstein, William R. Dolphin, Catherine C. Galley, Anthony Downs, Samuel Seskin and Terry Moore, *Costs of Sprawl—2000,* (Washington, DC: Transportation Research Board, 2002, Table 15-4).

68 Calculated from U.S. Bureau of the Census data.

69 Calculated from U.S. Bureau of the Census and Harvard University Joint Center on Housing data.

70 http://demographia.com/dhi.pdf, Figure 4 and data from the United States Census.

71 Calculated from Harvard University Joint Center on Housing median house price divided by median household income data. This is despite generally *higher* housing demand in the less restrictively regulated metropolitan areas, which attracted 900,000 new residents (domestic migrants) from elsewhere during 2000–2008, compared to a loss of 1,800,000 domestic migrants in the more restrictively regulated markets (See: http://demographia.com/db-2008mighaffcat.pdf).

72 http://www.heritage.org/Research/Economy/wm1906.cfm.

73 See, for example, http://morris.marginalq.com/DLM_fullpaper.pdf.

74 Fischel, pp. 234–236.

75 Ibid, pp. 218–252.

76 *Moving Cooler* dismisses the potential for house price increases, saying "While there are potential concerns with the effects on property values, these may be offset by decreased transportation costs." In fact, transportation costs are often higher in compact development metropolitan areas. Moreover, the higher housing costs in compact development metropolitan

areas are far larger than could conceivably be negated by higher transportation costs. For example, according to the ACCRA cost of living index from the first quarter of 2008, housing costs in the three largest metropolitan areas without compact development (Dallas-Fort Worth, Houston and Atlanta) were approximately three times those of Los Angeles, San Francisco and San Diego, all with compact development regulations. Average transportation costs were also higher in the California metropolitan areas. Estimated from ACCRA data (http://www.coli.org/).

77 http://www.cbo.gov/ftpdocs/105xx/doc10573/09-17-Greenhouse-Gas.pdf.

78 This compares to the 9.0% average annual rate in from 1971 to September of 2009 (http://www.freddiemac.com/pmms/pmms_archives.html).

79 Burchell, et al., *Costs of Sprawl*—2000.

80 Wendell Cox and Joshua Utt, *The Costs of Sprawl Reconsidered: What Does the Actual Data Show?* (Washington, DC: Heritage Foundation, 2004) (http://www.heritage.org/Research/SmartGrowth/bg1770.cfm.

81 NIMBY is an abbreviation for "Not in My Back Yard."

82 *Kelo v. City of New Haven*. See, for example: http://www.nytimes.com/2006/02/21/national/21domain.html?_r=1&hp&ex=1140584400&en=0cc052e291d00295&ei=5094&partner=homepage.

83 Research gaps could exacerbate compact development projection errors, such as (1) building material GHGs by housing types, (2) construction energy GHGs by housing type, (3) residential GHGs by housing type, including common energy, and (4) traffic congestion impacts on GHGs. It will be particularly important for the Environmental Protection Agency to develop genuine and credible models to predict the impact of traffic congestion on GHG reduction for use by state and metropolitan planners. Current legislative proposals would require planners to rely on EPA models.

84 http://www.amazon.com/exec/obidos/ASIN/0521009464/qid%3D1028792510/sr%3D1-3/ref%3Dsr_1_3/102-6346546-5055320.

85 http://onlinepubs.trb.org/Onlinepubs/sr/sr298brownstone.pdf, p. 2.

86 *Driving and the Built Environment,* pp. 35-46.

87 *Emissions Benefits of Land Use Strategies,* http://www.fhwa.dot.gov/environment/conformity/benefits/, Appendix D, page 5.

88 Brownstone, p.7.

89 Ibid, p.1.

90 See: Box 2: Residential Greenhouse Gas Emissions.

91 http://www.propertyoz.com.au/library/RDC_ACF_Greenhouse-Report.pdf

92 http://www.informaworld.com/smpp/content~content=a916934688~db=all~jumptype=rss

93 http://www.eia.doe.gov/emeu/recs/,

94 Based on email communication to the author from Eileen O'Brien, RECS Survey Manager, Energy Information Administration, United States Department of Energy (September 19, 2007).

95 Paul Myors, Rachel O'Leary, and Rob Helstroom, Energy Australia. &. Rachel O'Leary and Rob Helstroom, *Multi Unit Residential Buildings Energy & Peak Demand Study*, https://www.basix.nsw.gov.au/information/common/pdf/alts_adds_req/energy_mu_study.pdf.

96 Calculated from data in http://www.ecn.nl/docs/library/report/1997/c97065.pdf&ei=UHGuSvOuH5auNej2sLcM&sig2=OOaon-GtD8vSLFXyHa3How&ct=b

97 http://www.japancorp.net/Article.Asp?Art_ID=18691

98 http://www.zerocarbonhouse.com/Contactus.aspx

99 http://www.greenspur.net/projects/projects_mcleanva.htm

100 For example, see Alan Pisarski's evaluation at http://www.newgeography.com/content/00932-uli-moving-cooler-report-greenhouse-gases-exaggerations-and-misdirections and other criticisms, summarized at http://www.newgeography.com/content/00984-taking-fun-out-fighting-global-warming.

101 This is the range of the lowest densification scenarios and the middle densification scenario in *Moving Cooler* and the midpoint between the lowest densification and highest densification scenarios in *Driving and the Built Environment*.

102 *Driving and the Built Environment*, p 15.

103 This includes GHGs produced in fuel extraction (such as drilling for oil), fuel production and transport. For petroleum, it is assumed that upstream GHGs add 28% to the emissions from conventional vehicle operations and 30% for hybrid vehicles, based upon the Argonne National Laboratories "GREET" model. See: http://www.transportation.anl.gov/modeling_simulation/GREET/ and http://www.transportation.anl.gov/modeling_simulation/GREET/pdfs/esd_39v2.pdf. For plug-in electric vehicles, life cycle GHGs would include electric power generation and transmission losses (which were not included in recent claims of more than 200 miles per gallon for future cars by some automobile manufacturers). See: http://www.newgeography.com/content/00977-vetting-volt-toward-meaningful-electric-car-fuel-consumption-ratings).

104 All 2030 and 2050 GHG emission changes are in relation to a 2005 base, unless otherwise noted.

105 http://www.brookings.edu/~/media/Files/rc/reports/2008/1216_transportation_tomer_puentes/vehicle_miles_traveled_report.pdf.

106 http://www.cutr.usf.edu/pdf/The%20Case%20for%20Moderate%20Growth%20in%20VMT-%202006%20Final.pdf.

107 The "lower rate" refers to a lower driving rate scenario in http://bottomline.transportation.org/FullBottomLineReport.pdf.

108 http://www.epa.gov/otaq/climate/regulations/420d09003.pdf, Table 6-18.

109 All projections in this section use a 35.5 mile per gallon baseline, which assumes that driving increases at the rate projected by the United States Department of Energy, Energy Information Administration (EIA) *Annual Energy Outlook: 2011*.

110 See: http://reason.org/files/853263d6e320c39bfcedde642d1e16fe.pdf and http://www.itif.org/files/Telecommuting.pdf.

111 Ibid.

[112] Calculated from data in 2007 American Community Survey, shown in http://www.publicpurpose.com/ut-commute2007.pdf.

[113] http://www.cert.ucr.edu/research/pubs/TRB-08-2860-revised.pdf.

[114] 2010 Toyota Prius.

[115] Projections extended from 2040 to 2050.

[116] http://www.consumerreports.org/cro/cars/new-cars/news/2008/10/affordable hybrids/overview/affordable-hybrids-ov.htm and http://www.reuters.com/article/ousiv/idUSTKX00276320070510

[117] http://www.nextgreencar.com/view-car/26041/VW-Polo-Diesel-Manual-5-speed

[118] http://web.mit.edu/sloan-auto-lab/research/beforeh2/files/kromer%20msc%20thesis%202007.pdf.

[119] http://www.sciencedaily.com/releases/2009/10/091012135506.htm.

[120] http://www.nap.edu/catalog.php?record_id=12222. Report requested by the United States Congress in the Energy Policy Act of 2005.

[121] Reduction from 2005. Calculated from data in Tables 6.3 and 6.9. http://www.nap.edu/catalog.php?record_id=12222.

[122] http://www.volkswagen.de/vwcms_publish/vwcms/master_public/virtualmaster/de3/unternehmen/mobilitaet_und_nachhaltigkeit/technik___innovation/Forschung/1_Liter_Auto.html.

[123] President Obama also believes that substantial fuel economy improvements are possible, having proposed producing one million 150 mile per gallon cars by 2015. http://www.barackobama.com/pdf/factsheet_energy_speech_080308.pdf

[124] *Driving and the Built Environment,* p. 105.

[125] Not adjusted for the "GHG Traffic Congestion Penalty."

[126] Based upon the projected increase in fuel economy in 2030 compared to pre-2008/2009 fuel economy standards for 2030 (a 10 mile per gallon increase from 2010 to 2030).

[127] http://reason.org/news/show/surface-transportation-innovat-70.

[128] Research indicates that lower costs "induce" additional driving (in VMT, though not necessarily in overall travel times). The Environmental Protection Agency assumes that this effect (which EPA calls the "rebound" effect) would be 10% and that the effect is declining over time. If the EPA rebound effect is applied to the technology estimates, the reduction from present fuel economy technologies would be between 27% and 66% in 2050 (compared to 33% and 69%). http://www.epa.gov/otaq/climate/regulations/420d09903.pdf and http://www.epa.gov/otaq/climate/regulations/420d09901.pdf.

[129] http://online.wsj.com/article/SB20001424052748704007804574573771532217650.html?mod=djemITP

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