Location Efficiency as the Missing Piece of The Energy Puzzle: How Smart Growth Can Unlock Trillion Dollar Consumer Cost Savings

Mary Jean Bürer and David B. Goldstein, Natural Resources Defense Council
John Holtzclaw, Sierra Club

ABSTRACT

This report reviews recent research on location efficiency and uses these results to project scenarios for reductions in energy use, global warming pollutants, and consumer costs. It begins by reviewing the literature on location efficiency. Location efficiency reflects the average amount of car ownership and distance driven for a household located in a particular neighborhood. In the analysis the energy efficiency potential of smart growth developments (the type that are occurring in the US) are estimated using location efficiency research findings. The results show energy savings of a comparable magnitude after ten years to other major building energy efficiency policies, such as construction codes, appliance standards, and DSM programs. Consumer present value savings are an order of magnitude higher at \$2.3 trillion. Policy options for expanding smart growth and realizing its potential are briefly discussed.

Introduction

The design of communities to provide better access with less use of automobiles – now commonly known as “smart growth” – can result in significant energy savings in the transportation sector and much larger savings in overall societal costs. These general conclusions have been claimed for over a generation, but generally have not figured heavily in analyses of energy savings or global warming pollutants reduction because reliable means of quantifying the results of different decisions concerning community infrastructure were not available.

This is no longer the case. Recent research on location efficiency, corroborated by other studies looking at smart growth more broadly, provide a basis for predicting the results of specific scenarios for community development and transportation infrastructure provision in the United States; some evidence suggests that these results may be applicable throughout the world.

We review the location efficiency research and corroborating evidence in Section II. We discuss in Section III a methodology for applying these results towards the evaluation of scenarios of varying level of “smartness” in land use planning and transportation infrastructure provisions.

We apply this methodology in Section IV to real world examples of smart growth that are being developed in the United States, and project what would happen if the new construction market were to follow these models. We calculate results in terms of reductions in automobile ownership and use, reductions in energy use for gasoline, related reductions in greenhouse gas emissions, and tabulate the results in terms of economic benefits to society.

The calculations show that within ten years of initiating smart growth development, the efficiency potential can yield nationwide reductions of cumulative global warming pollutants of approximately 595 million metric tons of carbon dioxide or 162 million metric tons of carbon-

(carbon, like carbon dioxide, is measure of greenhouse gas emissions). This equals about 10% of total US global warming pollutants in 2001.

A contribution on this order of magnitude of carbon emissions is comparable to savings from other classes of measures that have been looked at in a number of studies that project what it would take to meet the requirements of the Kyoto Protocol (Geller, et. al. and others). In broad terms, these studies all find that policies such as improved fuel economy (CAFE) standards for automobiles, upgraded appliance and equipment efficiency standards, upgraded new construction energy codes, the provision of public benefits funds by which utilities or other administrators can promote energy efficiency in the utility sector, the provision of incentives for combined heat and power systems in the industrial sector and in buildings, the development of tax incentives or other long-term incentives for advanced levels of energy efficiency in buildings and vehicles, and the retirement of obsolete and highly-polluting coal-fired power plants, each account for roughly 10% of the Kyoto-required reductions in global warming pollutants.

So together they predict that the entire emission reduction goal can be met by measures that are justified solely on economic or public health grounds. Smart growth has the same general order of magnitude of savings as these or other measures, but has not been discussed nearly as much.

But in terms of economic benefits, the improvement in net present value savings from these policies cumulatively tends to be (depending on which study one cites) in the range of about $500 billion for the U.S. economy after 10 years (e.g. NRDC 1991). By comparison, the savings from enhanced location efficiency from 10 years of new construction are about $2.3 trillion[1] all by themselves.

Background on Location Efficiency Research

Location efficiency research developed gradually beginning with studies of transit and auto use (Pushkarev and Zupan 1977), but a major beginning for this work started when Peter Newman and Jeffrey Kenworthy conducted a survey of 32 major cities around the world that found that the residents of American cities consumed nearly twice as much gasoline per capita as Australians, nearly four times as much as the more compact European cities and ten times that of three compact westernized Asian cities, Hong Kong, Singapore and Tokyo (Newman and Kenworthy 1989). Gasoline use varied as a function of density both within the subset of American cities and worldwide. Their data suggest that driving is reduced 30 percent every time density doubles. A travel survey in the Greater Toronto Area suggested that doubling density results in a decrease in per capita Vehicle Miles Traveled (VMT) of about 25 percent (University of Toronto, York University 1989). A comparison of cities in Washington state found housing density, population density, jobs-housing balance and retail-housing balance to co-vary and to be associated with reduced driving (Pivo, et. al. 1995).

A 1990 study analyzed the effects of density, transit service and pedestrian and bicycle friendliness using neighborhood-scale data (Holtzclaw in CEC 1991). This study found that high residential density, nearby shopping, good transit and a good walking environment go together, while low density zones usually lacked nearby shopping, good transit and a good walking environment. The study found that residents of higher density communities drive less: 20 to 30 percent per household as neighborhood density doubles. Comparing the extremes, the Nob Hill

[1] This figure is the total consumer savings resulting mostly from a reduction in auto ownership, calculated with the present value factor for 100 years of lifetime for the developments compared.

area was found to have 32 times higher household density, much better public transit and 200 times more local shopping (retail and service employees per acre) than San Ramon, while only about 1/4 the household auto ownership and VMT.

Using a household travel study in the Seattle area, Frank and Pivo found that employment density, population density, land-use mix and jobs-housing balance are associated with less auto use (Frank and Pivo 1994). These relationships held up even when household demographics, car ownership and transit are controlled.

The Natural Resources Defense Council (NRDC) followed up Holtzclaw's 1991 study with a study of 27 neighborhoods that ranged from 1.8 households/residential acre to 100 in San Francisco, Los Angeles, San Diego and Sacramento (Holtzclaw 1994). This study found similar results to the 1991 study; the 27 neighborhoods showed statistically significant reductions in driving associated with high residential density and the quality of transit service. Doubling residential density was shown to lower auto ownership and VMT 16%, while doubling public transit service reduced VMT an additional 5%.

Kara Kockelman, in a study of over 1000 travel analysis zones and 1,200 census tracts in the San Francisco Bay Area, found that the following influence household VMT: household size, auto ownership, income, weighted jobs within 30 minutes, dissimilarity of the zone's major land use from its neighbors, and the balance of land uses within each zone within a half mile (Kockelman 1996). Kockelman further found that the following influence household auto ownership: household size, income, weighted jobs within 30 minutes, dissimilarity of the zone's major land use from its neighbors, the balance of land uses within the zone, and population density. Using the 1990 National Personal Transportation Survey (NPTS), Robert Dunphy and Kimberly Fisher reported on the average VMT of the respondents, aggregating together households from around the country whose ZIP codes had the same population density (Dunphy and Fisher 1996). Dunphy and Fisher' research shows a decrease of 21% in daily driving as density doubles across the whole density range. For the five ranges above 4000 persons/square mile (about 4 households/residential acre) the decrease is 38% in daily driving as density doubles, explaining 86% of the variance.

Finally, a more comprehensive research paper on location efficiency was based on multi-variable regression analysis in which vehicle miles traveled (VMT) per vehicle and vehicle ownership per household as dependent variables were correlated with a limited number of independent variables (Holtzclaw, et al. 2002).

The study gathered data on all 1,100 travel analysis zones (TAZs) in the metropolitan San Francisco Bay Area; 1,700 TAZs in the LA metro area and 300 in the Chicago metro area. Separate equations were derived for car ownership per household and vehicle miles traveled (VMT) per car. The paper estimated VMT per household by multiplying cars per household by VMT per car; and estimated the costs of car ownership by multiplying car ownership by the fixed costs of a car and VMT by the variable costs.

The research first tried to fit the independent variables to each of the dependent variables individually; the variable with the highest R^2 was used first, and then it checked for the next variable that produced the highest R^2 when used second. After 5 variables, the statistics did not get much better when additional variables were tested.

In general, the variable with the highest degree of explanatory power was compactness of development – housing units per residential acre. Other variables with very high explanatory power included transit service density (number of buses or trains per hour within walking distance of the house), household income, and household size. Pedestrian and bicycle friendliness was also statistically significant, but much less so, and explained less variation between neighborhoods. (For the Bay Area, a variable based on the number of jobs within a 30 minute drive was statistically significant, but not very important, in the results.)

The statistical fit was exceptionally good. The R^2 for car ownership exceeded 0.9 for San Francisco. All three metro areas showed similar results. The equations show, roughly, variations in VMT per household – of 2:1 as we go from suburban densities to the types of densities typical of northeastern San Francisco (at a constant family size and income, as well as constant transit service), while going from essentially no public transportation to the levels of public transportation in northeast San Francisco reduced driving by about one-third, holding everything else constant. See Figure 1 below for a 3-D graph of the results and Figures 2 for a scatter plot showing how strong the correction of car ownership with density really is.

Figure 1. Impact of Density and Transit on Driving
(San Francisco Bay Area)

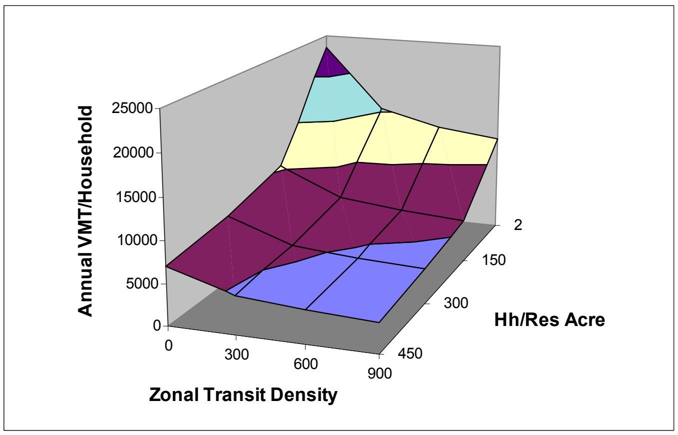
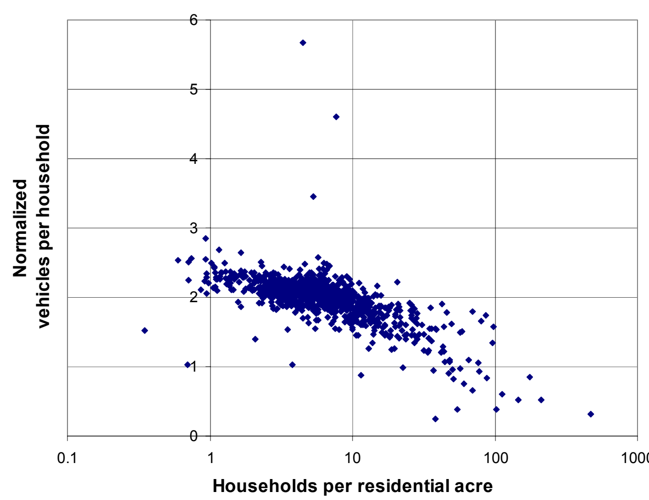


Figure 2. Adjusted Veh/Hh vs. Residential Density, in San Francisco



Methodology in Determining Total Consumer Savings and Global Warming Impacts of Location Efficiency

Using the Holtzclaw, et. al. equations,[2] assuming a relationship between household/residential acre density, household/ total acre density, and transit service,[3] and using the US average for personal income,[4] and an assumed average household occupancy[5] pedestrian

[2] Assumed San Francisco location efficiency equations.
[3] Used calculator for San Francisco Bay Area to obtain transit service for a changed density. See: http://www.sflcv.org/density/
[4] Assumed household income of $40,228 (US Census) and divided by household occupancy.
[5] Assumed 2.1 for Brownfield developments, and 2.6 for Greenfield developments.

friendliness[6] in average US infill and greenfield smart growth and sprawl developments, we calculated annual household VMT reduction and the associated benefits per household for six example smart growth developments as compared to a baseline development.[7] We then calculated total benefits in the US by multiplying by the number of housing starts in the US from 2005-2015.[8]

To calculate the location efficiency potential over a future period, for example, 10 years, 20 years, or 50 years, we constructed a base case for "business as usual" characteristics of neighborhoods and transportation infrastructure, and then compared this to policy case(s) in which the neighborhood parameters are changed in plausible ways to produce lower demands for driving. We then used the equations from (Holtzclaw, et al. 2002.) to calculate resultant reductions in automobile ownership and in distance driven. These reductions can then be used to calculate environmental and economic impacts as follows:

> *For energy savings*, we multiply the reductions in the levels of (vehicle ownership) * (miles traveled per car) in the policy case by the average US Btu/mile[9] in order to get an estimate of energy and gasoline consumption, which can be compared to the base case.
>
> *For emissions reductions*, we use, in the case of global warming pollutants, an emissions factor for just carbon dioxide based on energy, including upstream emissions. We omit other global warming pollutants emitted in combustion as well as additional methane and N2O from air conditioner use, leaks, etc.
>
> *For costs saved*, we took the average new vehicle cost to the consumer from ORNL and calculated the present value cost of owning a vehicle over its lifetime, including other ownership costs like insurance.[10] The estimates of the fixed costs of owning a car were multiplied by predicted car ownership in the policy case and then the estimate of variable costs of owning a car times the mileage in the policy case and compared with base case results. More specifically this methodology involved the calculation of cost savings using the 2004 new car cost of $26,000 (Edmunds.com). This amount divided by the present value factor of 12 (the PV factor for a 15 year life is 11.95), gives $1905/car/year. We then added this amount to the other ownership costs (for an average car taken from AAA). See: www.ouraaa.com/news/library/drivingcost/driving.html. These costs made up a total of $1307/car/year. The sum of the total car ownership costs was $3212/vehicle/year. This is lower than the direct AAA figure because they do the calculation in nominal dollars and focus on new cars. This cost was first added to the operating cost using 13 cents/mile from AAA (same reference). The operating costs are based on fuel, maintenance, and tires. That total was multiplied by the number of vehicles predicted to be owned by the household in each case.

---

6 Assumed 1.44 (Oakland, CA's Rockridge) for smart growth development, and .16 (San Ramon, CA) for baseline development.

7 The baseline development has a density of 3 households/ residential acre. This is similar to the sprawl average that is used on http://www.sflcv.org/density/. Note that the average US residential area is approximately this density.

8 See: www.nahb.org, Housing Starts in Jan. 2004 were 1,903,000. We assumed 2 million in 2005 and that housing start growth increased 2% per year. Assumed also annual benefits were unchanged over the 10 years.

9 Based on 115,000 Btu/gallon, from www.ORNL.gov

10 As 2nd order variables that cut both ways, parking and transit costs were not included. Residents of high density housing near downtown or good public transit are less likely to have to park in expensive downtown parking near work. Transit costs are low compared to auto costs.

The final total costs were then calculated with the present value factor for 100 years of lifetime for the developments compared. That factor was calculated to be 31.6 (assuming a 3% real discount rate). A 100 year lifetime was chosen because the characteristics of a neighborhood in terms of density and transit tend to be stable on a timescale of at least 100 years. That is, a decision to build a low density subdivision that is difficult to serve with public transit is not likely to be reversed for at least 100 years unless the cost of automobiles increases so drastically as to make these neighborhoods economically infeasible to live in; an unlikely eventuality.

There are two ways to improve location efficiency in the midterm. The first is to expand transit service at existing location, for example, by running buses or trains more frequently along existing routes. This is a relatively fast, but expensive, way to reduce the impacts of inefficient locations because the lead time for expanding existing transit systems is relatively short, based on the amount of time it takes to order new vehicles.[11] We did not model this option, however.

In the mid-term, the efficiency potential can be estimated by assuming that traditional suburban sprawl development is replaced by smart growth development. As seen from Fig. 1, the "smartness" of growth – the location efficiency of a particular development – is a continuous function of the relevant parameters: there is no single level of any parameter that qualifies a development as "smart" as opposed to "dumb;" rather, there are continuous gradations of "smartness." To estimate a plausible efficiency potential, we look at a sampling of real life smart growth developments that have been constructed. We include examples of urban infill (brownfield) as well as developments in areas where infrastructure does not already exist (greenfield) smart growth development examples. The infill developments looked at were: 1) Russian Hill neighborhood in San Francisco, "the Crossing", Mountain View, California, 3) "Atlantic Station", Atlanta, Georgia, 4) "Fruitvale Transit Village", Fruitvale, California. The greenfield developments considered were: 1) Santa Fe, New Mexico, and 2) Addison, Texas.[12] However, urban infill is generally the way to achieve the highest levels of location efficiency not only for the new development, but for the surrounding neighborhoods.

For each of these smart growth example neighborhoods, we calculate the effect on car ownership and distance driven, and thus compute the effects on energy use, global warming pollutants, and private costs.

We present the results as efficiency "potentials" representing what would happen if all new development occurred following these smart growth templates. While we recognize that achievement of 100% of this technical potential is unlikely, any assumption about what fraction of this potential is likely to be realized would be speculative at this point: there are no methodologies available that can translate specific policy changes into expected results in terms of development. However, the potentials calculated here are conservatively low, in that, by basing the calculations on real developments rather than hypothetical ones, we ignore the possibility that the same types of policy changes that would permit a much greater fraction of growth to resemble these example projects would also overcome market barriers and market failures that make these projects less optimal than they could be.[13]

---

[11] Note that in Latin America, new bus rapid transit systems; which require new rights of way and stations as well as vehicles, were constructed and operated in three years. They serve riderships of ~half a million per day in each city.

[12] More information on these developments are found in : Benfield 2001; and Parker 2002.

[13] As an example, consider the potential impact of the availability of Location Efficient Mortgages®. Location Efficient Mortgages® are only minimally available today, but could become available nearly universally if the lending industry decided to offer them. A Location Efficient Mortgage® recognizes the reduced transportation expenditures calculated as described above by allowing a family of a given income and credit rating to borrow one

Results

If all housing starts were to be built in the US like the smart growth developments cited above, assuming 50% were greenfield and 50% were brownfield infill, then the total savings after 10 years based on a projected level of 24.3 million housing starts from 2005-2015,[14] would be about: 977 trillion miles of travel reduced,[15] 5,690,000 trillion Btu saved,[16] 49.5 billion gallons of gasoline saved,[17] 1.18 billion barrels of oil saved, 595 million metric tons of CO2 emissions reduced (10% of total US emissions of global warming pollutants in 2001)[18], and $2.18 trillion savings.[19] See Table 2.

Total savings if all developments were greenfield vs. if all were infill are also shown in Table 2. Household annual savings are summarized in Table 3. Detailed inputs as well as outputs for this calculation are provided in Table 4. The annual savings for one household are about: 8,198 miles of travel reduced, 47.4 million Btu of energy reduced, 415 gallons of gasoline use reduced, 9.9 barrels of oil saved, and 5 metric tons CO2 reduced.[20] Total present value of consumer savings is about $97,700.[21]

---

additional dollar per month for every one dollar per month in transportation savings associated with the location. It functions analogously to an Energy Efficient Mortgage in which a dollar in utility cost savings entitles the prospective home buyer to spend an additional dollar per month on debt service costs.

If Location Efficient Mortgages® were available widely, they would allow smart growth developments such as those looked at in doing this analysis to be more successful economically to their developers because the same types of homes would be available to a wider pool of potential buyers – that is, a pool that includes buyers of more moderate income that would otherwise be allowed under mortgage underwriting conventions to purchase them. The availability of Location Efficient Mortgages® would greatly increase the number of developments that would "pencil out" financially.

The availability of Location Efficient Mortgages® would also allow these developments to be even more location efficient than they currently are. For example, if developers and prospective home buyers knew that by increasing the density or transit availability in a particular project compared to the base case, more expensive homes could be built at the same level of affordability, the entire market, from the developer and his or her lenders to the real estate agent to the buyers might recognize a mutual interest in higher density and higher transit access levels, and the additional housing prices that could be affordable under these circumstances could lead to a source of financing that could, for example, pay for the additional transit service.

[14] Based on a projected increase from 1,903,000 housing starts/year in 2004 (NAHB) to 2,000,000 housing starts in 2005. Assumed 2% growth per year. Therefore, assumed 24,337,431 housing starts from 2005-2015.

[15] Based on Holtzclaw, et. al. location efficiency calculator, with given assumptions.

[16] Based on 5,822 Btu/vehicle mile traveled, DOE, ORNL, Transportation Energy Data Book (1999).

[17] Based on 115,000 Btu/gallon, from www.ORNL.gov

[18] The carbon dioxide estimate expressed in tons carbon dioxide is based on emissions associated with gallons of gasoline (19 lbs/gallon). There are other global warming pollutants like methane and N2O from air conditioners and cold-starts that were not included. Number of vehicle trips reduced was not calculated either.

[19] The consumer savings estimates are based on the assumption that the smart growth project and its benefits occur for 100 years.

[20] The carbon dioxide estimate is based on emissions associated with energy only. There are other global warming pollutants like methane and N20 from air conditioners and cold-starts that were not included. Number of vehicle trips reduced was not calculated either.

[21] This is assuming total life of the smart growth development that the household is located in equals 100 years. Note that if we assumed an analysis lifetime of 30 years – equivalent to the mortgage – the value would still be about $60,000.

Table 1. Cumulative Savings from Total Housing Starts with Average Household Savings Assuming 50% are Greenfield & 50% are Brownfield Developments

Years	# Housing Starts	Years of Savings	VMT reduced	Btu reduced	Gallons of gasoline reduced	Barrels of crude oil reduced	Metric tons CO2 emissions reduced
2006	2,040,000	10	1.67E+11	9.73638E+14	8.47E+09	2.02E+08	1.02E+08
2007	2,080,800	9	1.54E+11	8.93799E+14	7.77E+09	1.85E+08	9.34E+07
2008	2,122,416	8	1.39E+11	8.10378E+14	7.05E+09	1.68E+08	8.47E+07
2009	2,164,864	7	1.24E+11	7.23262E+14	6.29E+09	1.50E+08	7.56E+07
2010	2,208,162	6	1.09E+11	6.32338E+14	5.50E+09	1.31E+08	6.61E+07
2011	2,252,325	5	9.23E+10	5.37487E+14	4.67E+09	1.11E+08	5.62E+07
2012	2,297,371	4	7.53E+10	4.3859E+14	3.81E+09	9.08E+07	4.58E+07
2013	2,343,319	3	5.76E+10	3.35521E+14	2.92E+09	6.95E+07	3.51E+07
2014	2,390,185	2	3.92E+10	2.28154E+14	1.98E+09	4.72E+07	2.38E+07
2015	2,437,989	1	2.00E+10	1.16359E+14	1.01E+09	2.41E+07	1.22E+07
Total Housing Starts 2006-2015	22,337,431		9.77E+11	5.68953E+15	4.95E+10	1.18E+09	5.95E+08

Table 2. Cumulative Savings if All Developments are Infill vs. if all were Greenfield

Total Savings						
Development Type	**Travel, VMT**	**Energy, Btu**	**Gasoline, Gallons**	**Oil, Barrels of Crude**	**CO2 emissions, Metric tons**	**Cost, US $**
Infill Average	1.19E+12	6.93E+15	6.02E+10	1.43E+09	7.24E+08	2.78E+12
Greenfield Average	1.24E+13	4.45E+15	3.87E+10	1.43E+09	4.65E+08	1.59E+12
Average	9.77E+11	5.69E+15	4.95E+10	1.18E+09	5.95E+08	2.18E+12

Table 3. Average Annual Savings per Average Smart Growth Household

Average Annual Savings per Household

VMT/Hh savings	Energy savings, Btu	Gallons of gasoline	Barrels of crude oil	Metric tons CO2 emissions saved	Cost Savings
8,198	47,727,335	415	9.9	5.0	$ 97,701

Table 4. Smart growth developments, LE factors and annual household savings for each development type

Development	Hh/Res Ac	Hh/Tot Ac	Hh/Res Ac Base	Hh/Tot Ac Base	Inc/Cap	Pop/Hh	Zon Tr Den	Zon Tr Den Base	Ped/Bi Fr	Ped/Bi Fr Base	Veh/Hh calc
Infill											
Russian Hill (SF)	100.00	50.00	3	1.5	20,109	2.1	126	0	1.44	0.16	.72
The Crossing (Mountain View)	22.06	11.03	3	1.5	20,109	2.1	50	0	1.44	0.16	.21
Atlantic Station, Atlanta, Georgia	23.30	11.65	3	1.5	20,109	2.1	53	0	1.44	0.16	.19
Fruitvale Transit Village, Oakland	63.58	31.79	3	1.5	20,109	2.1	163	0	1.44	0.16	.79
Averages	52.24	26.12	3	1.5	20,109	2.1	98	0	1.44	0.16	.98
Greenfield											
Sante Fe, New Mexico	14.00	7.00	3	1.5	16,242	2.6	29	0	1.44	0.16	.51
Addison, Texas	13.75	6.88	3	1.5	16,242	2.6	26	0	1.44	0.16	.53
Averages	13.88	6.94	3	1.5	16,242	2.6	27.5	0	1.44	0.16	.52
Average of two	33.06	16.53	3	1.5	18,175	2.35	63	0	1.44	0.16	.25

Development	Veh/Hh calc Base	VMT/Veh calc	VMT/Veh calc Base	VMT/Hh calc	VMT/Hh calc Base	VMT/Hh savings	Energy for SG, Btu	Energy baseline, Btu
Infill								
Russian Hill (SF)	1.80	8573	10410	6190	18704	12,514	36,038,586	108,896,466
The Crossing (Mountain View)	1.80	9118	10410	11022	18704	7,683	64,167,792	108,896,466
Atlantic Station, Atlanta, Georgia	1.80	9098	10410	10803	18704	7,902	62,893,147	108,896,466
Fruitvale Transit Village, Oakland	1.80	8734	10410	6874	18704	11,831	40,018,553	108,896,466
Averages	1.80	8881	10410	8722	18704	9,982	50,779,520	108,896,466
Greenfield								
Sante Fe, New Mexico	1.96	9471	10613	14322	20824	6,503	83,380,011	121,239,392
Addison, Texas	1.96	9477	10613	14501	20824	6,324	84,423,326	121,239,392
Averages	1.96	9474	10613	14411	20824	6413	83,901,669	121,239,392
Average of two	1.88	9,177	10,511	11,567	19,764	8,198	67,340,594	115,067,929
if 50%i/50%b								

Table 4 (continued). Smart growth developments, LE factors and annual household savings for each development type

Development	Energy savings, Btu	Gallons of gasoline savings	Barrels of crude oil savings	metric tons CO2 emissions saved	Auto Cost Project	Baseline Cost	Cost Savings
Infill							
Russian Hill (SF)	72,857,880	634	15	7.61	$ 98,718	$ 259,209	$ 160,491
The Crossing (Mountain View)	44,728,674	389	9	4.67	$ 167,970	$ 259,209	$ 91,239
Atlantic Station, Atlanta, Georgia	46,003,319	400	10	4.81	$ 164,898	$ 259,209	$ 94,311
Fruitvale Transit Village, Oakland	68,877,913	599	14	7.20	$ 108,116	$ 259,209	$ 151,093
Averages	58,116,946	505	12	6.07	$ 134,925	$ 259,209	$ 124,284
Greenfield							
Sante Fe, New Mexico	37,859,381	329	8	3.96	$ 212,320	$ 284,712	$ 72,392
Addison, Texas	36,816,066	320	8	3.85	$ 214,868	$ 284,712	$ 69,843
Averages	37,337,724	325	8	3.90	$ 213,594	$ 284,712	$ 71,118
Average of two	47,727,335	415	10	4.99	$ 174,260	$ 271,960	$ 97,701

Conclusions

The present value of the lifetime cost savings over 10 years for all housing starts in the US is approximately $2.18 trillion savings, or over 20% of a year's GDP, providing a demonstration of the high social cost-effectiveness of smart growth investments. The additional societal benefits of the global warming pollutant reductions and the gasoline dependency reduction from the gasoline savings over ten years for all new housing starts in the US makes smart growth investments appear to be one of the top mitigation strategies for both solving global warming and reducing gasoline dependency.

The ten-year accumulated savings of such smart growth developments could be about 49.5 billion gallons of gasoline saved (44% of total US highway usage of gasoline in 2001), 1.18 billion barrels of oil saved (20% of US production of oil in 2002), and 595 million metric tons of CO2 emissions reduced (10% of total US emissions of global warming pollutants in 2001)[22]. Finally, the total consumer savings from smart growth developments over this period are about 20% of annual GDP in 2003.[23] Instead of spending $20 billion each year on Persian Gulf oil alone[24], American consumers could be saving the present value worth of about $2.2 trillion dollars over the period of 10 years.

[22] All comparisons use data from the US DOE Transportation Energy Data Book, Edition 23, 2003.
[23] $11,252.3 billion (fourth quarter 2003) final GDP estimate. See: http://www.bea.doc.gov/bea/newsrel/gdpnewsrelease.htm
[24] NRDC, Dangerous Addiction : Breaking the Chain of Oil Dependence. See: http://www.nrdc.org/air/transportation/oilsecurity/excerpt.asp

Investing in smart growth developments will also: 1) bring additional social benefits to this country and the world, and 2) allow Americans to spend their money on locally provided services like housing, local transportation, or entertainment, restaurants, or in-state produced products, as opposed to oil and vehicles that are produced out of the state or country.

References

Arigoni, Danielle. *Affordable Housing and Smart Growth: Making the Connection,* National Neighborhood Coalition and Smart Growth Network, Smart Growth Network Subgroup on Affordable Housing, see: http://www.smartgrowth.org/library/article.asp?resource=244, 2001.

Benfield, Kaid, et. al. *Solving Sprawl: Models of Smart Growth in Communities Across America*, 2001.

California Energy Commission, *Inventory of Greenhouse Gas Emissions and Sinks, 1990-1999,* Nov. 2002.

Clemmer, S., D. Donovan, A. Nogue, J. Deyette. *"Clean Energy Blueprint: A Smarter National Energy Policy for Today and the Future,"* Union of Concerned Scientists, 2001.

Dunphy, Robert, and Kimberly Fisher. *A Transportation, Congestion, and Density: New Insights*, Transportation Research Record No. 1552, Washington DC: Transportation Research Board, pp89-96, November 1996.

U.S. DOE, *Transportation Energy Data Book:* Edition 23 – 2003.

Federal Highway Administration. "GIS Tools for Transportation and Community Planning", The FHA's Transportation and Community and System Preservation Pilot Program (TCSP), see: http://www.fhwa.dot.gov/tcsp/case7.html, July 31, 2003.

Frank, Lawrence, and Gary Pivo. *Relationships Between Land Use and Travel Behavior in the Puget Sound Region,* Washington state DOT, WA-RD 351.1, 1994.

Geller, H., S. Bernow, W. Dougherty. *"Meeting America's Kyoto Protocol Target: Policies and Impacts."* American Council for an Energy Efficient Economy, Report No. E993, 1999.

Geller, H., S. Nadel, R.N. Elliott, M. Thomas, J. DeCicco. *Approaching the Kyoto Targets: Five Key Strategies for the United States.* American Council for an Energy Efficient Economy, Report No. E981, 1998.

John Holtzclaw, Robert Clear, Hank Dittmar, David Goldstein and Peter Haas. "Location Efficiency: Neighborhood and Socio-Economic Characteristics Determine Auto Ownership and Use---Studies in Chicago, Los Angeles and San Francisco", *Transportation Planning and Technology*, Vol. 25(1), pp 1-27, March 2002.

Holtzclaw, John. "Explaining Urban Density and Transit Impacts on Auto Use*",* Natural Resources Defense Council, San Francisco, in California Energy Commission, Docket No. 89-CR-90, 15 January 1991.

Holtzclaw, John. *Using Residential Patterns and Transit To Decrease Auto Dependence and Costs*. Natural Resources Defense Council, San Francisco, and California Home Energy Efficiency Rating Systems, Costa Mesa, California, 1994.

Interlaboratory Working Group on Energy Efficient and Low Carbon Technologies. *Potential Impacts of Energy Efficient and Low Carbon Technologies by 2010 and Beyond.* U.S. Department of Energy, Sept. 1999.

Kockelman, Kara Maria. *Travel Behavior as a Function of Accessibility, Land Use Mixing, and Land Use Balance: Evidence from the San Francisco Bay Area*, Thesis for Masters of City Planning, UC Berkeley, 1996.

Newman, Peter and Jeffrey Kenworthy. *Cities and Automobile Dependence: An International Sourcebook*, Gower Publishing, 1989.

NRDC. *America's Energy Choices: Investing in a Strong Economy and a Clean Environment. Alliance to Save Energy, American Council for an Energy-Efficient Economy*, Natural Resources Defense Council, Tellus Institute, and Union of Concerned Scientists, 1991.

NRDC. *Energy Innovations: A Prosperous Path to a Clean Environment. Alliance to Save Energy, American Council for an Energy-Efficient Economy*, Natural Resources Defense Council, Tellus Institute, and Union of Concerned Scientists, 1997.

NRDC. *Dangerous Addiction: 2003 Breaking the Chain of Oil Dependence,* March 2003.

Parker, Terry, et. al. *Statewide Transit-Oriented Development Study: Factors for Success in California,* Business, Transportation and Housing Agency, California Department of Transportation, September 2002.

R. Cervero and R. Ewing. Travel and the Built Environment: A Synthesis. *Transportation Research Record 1780*, pp. 87-113, 2001

Pivo, Gary, Paul Hess and Abhay Thatte. *Land Use Trends Affecting Auto Dependence in Washington's Metropolitan Areas, 1970 - 1990*, Washington state DOT, WA-RD 380.1, 1995.

Boris Pushkarev and Jeffrey Zupan, *Public Transportation and Land Use Policy*, (Bloomington, Indiana: Bloomington University Press, 1977), 5.

University of Toronto/York University. *The Transportation Tomorrow Survey: Travel Survey Summary for the Greater Toronto Area*, June 1989.