Predicting Energy Consumption and Costs from New Development

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ABSTRACT

This report assays the reduction in driving energy consumption and other variables resulting from smart growth infill rather than sprawl. These benefits result from:

- less driving and resulting air and water pollution reductions;
- less water use, and air and water pollution from lawn runoff;
- less construction material used, reducing polluting mining and deforestation (loss of carbon sinks), and energy directly used in construction; and
- the conversion of less natural area (carbon sinks) into urban sprawl.

The magnitude of these benefits is assayed by a calculator available free on-line to the public at **www.sierraclub.org/sprawl/density/**

Introduction

No one should be stigmatized for living in sprawl because the relationships explored by this Healthy Growth Calculator have only been publicized in the last 10 to 15 years (Newman & Kenworthy, 1989; Holtzclaw, 2004; Bürer, Goldstein & Holtzclaw, 2004) We live in housing that's available. This Calculator at **www.sierraclub.org/sprawl/density/** will help us evaluate how to grow more efficiently, reducing future energy consumption.

Since WW II our federal, state and local policies, the banking industry, and the freeway and housing builders have required, have funded and have built sprawl. Now we're driving long distances, stuck in congestion, while converting our limited petroleum reserves into foul, unhealthy air and global warming gases. As a consequence, our driving miles, energy consumption and global warming gas production have grown much faster than our population. If our communities are to prosper and use energy more efficiently, we must learn how to grow smarter. The residents of our communities deserve the options of walking, or taking a train or bus to jobs, markets, restaurants, personal business, recreation and services – more choice, so they don't have to get into their car and drive for a loaf of bread.

In order to understand the big picture of community and regional growth and its consequences, we have elaborated on the small picture – the residential neighborhood. Its characteristics – location, density, local commerce, public transit, and walking and bicycling conditions – drive our choices, our level of consumption and our pollution. The Calculator is designed to assist residents and planners mull the future of their community and how its walkability and convenience could be enhanced. It can help them explore and evaluate potential land use futures in a series of community planning sessions (charettes).

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Healthy Growth Calculator

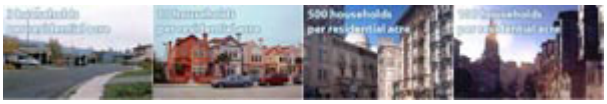
To this end the Healthy Growth Calculator was designed using studies and equations to calculate representative consequences of developing over a range of urban densities. It was developed using measurements of existing conditions and consequences, not just theoretical analyses, www.sierraclub.org/sprawl/density/, Figure 1. It also allows users to enter their car's gas mileage and the price of gas to gauge driving costs, or the costs averted by not having a car. Or to evaluate the neighborhood's average driving costs.

Figure 1. Calculator Home Page

Healthy Growth Calculator

Using the calculator to Build Healthy Communities

This calculator is designed to offer a big picture perspective to decisions regarding growth.



Explore the consequences to your community of your decisions, and their fairness to all residents – including those who can no longer drive, or those who would rather walk or take public transit for some trips.

When neighbors come together to plan their community's future, this website can show them some of the benefits of Smart Growth to both your community and your environment. Enjoy

First: What do you pay for gas?

Your Car's Miles Per Gallon

Cost of a Gallon of Gas

Density

The next step brings up Figure 2. The first thing to notice is that the Calculator makes a big deal out of density. That's because density – residential density (households/residential acre, or hh/res ac) -- is the most important predictor of most of the impacts of communities on the environment, as we will see shortly. This page allows you three choices: 1) proceed to a map of the U.S. showing the locations of the projects analyzed; 2) or to a picture list of the projects; 3) or to just pick a residential density to analyze.

The Healthy Growth Calculator compares each of 45 projects and neighborhoods from around the country to the average conditions in sprawl. To understand how the calculator works, let's select a neighborhood in San Francisco to compare with sprawl.

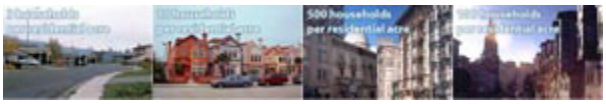
The selected neighborhood, Figure 3, at 500 hh/res ac is the highest density neighborhood we have detailed data for. Some insist that a place this dense is unbearably crowded. They confuse over-crowding (people/room) with high density (hh/res ac). A community can have neither, either, or both. Population/sq mi reflects both crowding and density, limiting its utility to density analyses. Hh/res ac measures residential density, and not over-crowding.

Typical of a high density neighborhood, only a fraction of the buildings are residential. This 3 by 4 block area, bordering Union Square on the west, is 85 percent non-residential –

markets, restaurants, hotels, live theatres, and with a wealth of nearby jobs, making it very convenient for residents.

Figure 2. Where Do You Want to Live?

Healthy Growth Calculator: Where do you want to live?



Choose an existing project from the map:

This map was built using the Google API and works best with a modern browser like Mozilla Firefox, but also works with IE6, NN7, Opera and Safari.

Or look at a list of **projects**.

OR -- Just choose a density:

☐ ***1***	Lowest density of single-family dwellings in sprawl.
☐ ***3***	Typical of single-family dwellings in sprawl.
☐ ***10***	Row houses with occasional single-family dwellings and apartment houses. Examples: lower density areas of larger cities, and older suburbs.
☐ ***100***	Mostly 3-5 story apartment houses with occasional mid- to high-rises and single-family dwellings. Examples: northeast San Francisco (Russian, Nob and Telegraph Hills, North Beach), River North in Chicago, Beacon Hill in Boston, along Connecticut Ave. in DC, and compact neighborhoods throughout the country.
☐ ***500***	Mostly mid- to high-rises. Examples: the Upper East and West Sides in Manhattan, and smaller neighborhoods in Chicago, San Francisco and elsewhere.

In the first variable calculated, Figure 4, sprawl is on the left – generally it's under 5 households/residential acre (hh/res ac), averaging 3, and the selected neighborhood on the right. A household in the selected 500 hh/res ac neighborhood occupies only 0.6% as much land as the average household in sprawl. Building at high density cuts the bulldozing of forests, wetlands and other carbon sinks to accommodate human occupation.

While this describes one of the densest census tracts we analyzed, the conclusions apply on a lesser scale to lower density growth, as shown by other examples in the Calculator.

Figure 3. West of Union Square, San Francisco

Figure 4. Households per Residential Acre

Sprawl	vs	Your Choice
		 choose density or place
3		500

Roads, Driveways and Sidewalks

Our visual impression of big cities is that much land is covered by roads and sidewalks – think Manhattan, Chicago or San Francisco. It is. But the same number of households living in sprawl, driving long distances to shopping centers and office parks with all the necessary parking, would cover immense land with roads and parking, as shown in Figure 5. You may not notice all this pavement in sprawl because it's so spread out that you can't see all at once, and it has spots of green camouflage, called lawns, here and there.

Figure 5. Roads & Sidewalks

Sprawl	vs	Your Choice
233,333		1,400

Square Yards per 1000 Households

The Calculator shows that the sprawl housing covers 170 times as much land with concrete and asphalt.[1] That would exacerbate the heat island effect over built-up areas, raising temperatures and ozone concentrations. And the mining and transportation of materials, and building of those roads would release pollution and global warming gases.

Water Use

The household in sprawl consumes 6 times as much water, much of the extra going to water lawns, Figure 6 (Kimberly Knox; Sakrison, 1998). Much of the water used on lawns carries fertilizer and pesticides off as runoff into streams and rivers. The rivers dammed to provide this water often drown forests, reducing their utility as carbon sinks. Reducing water consumption also reduces the energy used to pump the water to the consumer.

Figure 6. Water Use

Sprawl	vs	Your Choice
1,032		172

Gallons per household each day

Local Shopping

One fifth of the average family's trips are commutes; the other 80% are shopping, eating, school, visiting and recreation. The high density community has at least 150 times more of these destinations nearby, within a short walk, bike or bus ride, Figure 7. My apartment is in the dense Nob Hill/Russian Hill/Chinatown area (100 hh/res ac), 1 mile north of this Union Square neighborhood, and has over 700 restaurants within a 1 mile walk. By contrast, the shopping centers in sprawl are typically off freeway exits, and may not be easily accessible by foot or bike.

[1] Assumes a 10 yard wide half-street and sidewalk along a 70 yard front for each 1 acre lot, or 700 sq. yards per residential acre.

Figure 7. Local Shopping

Sprawl	vs	Your Choice
1.6		240.9

Employees per acre

This calculation and most of the following are based upon data developed for the Location Efficient Mortgage studies of the Chicago, Los Angeles and San Francisco metro areas by the Institute for Location Efficiency (Holtzclaw, Clear, Dittmar, Goldstein & Haas, 2002). The nearly 3000 neighborhoods are their Metropolitan Planning Agencies' travel analysis zones, generally each a census tract or two. This analysis applies to neighborhoods in metropolitan areas or within commuting distance of major job centers, not to isolated rural towns.

Transit Service

Figure 8 shows that transit service is zero, or very near, in sprawl and high in high density. Providing public transit to sprawl is very expensive. Buses have to drive great distances to access few residences, lengthening and slowing the trips, and consequently pick up few riders. Bus companies can't afford to provide frequent service. A vicious circle. However, the residents of the dense, convenient areas have thousands more buses and trains nearby – Choice! Where trips are short and many people are walking, many will ride transit. The measure is the average number of buses per hour stopping within ¼ mile, or light or heavy rail cars stopping within ½ mile, of the house (Holtzclaw, Clear, Dittmar, Goldstein & Haas, 2002). It includes some double counting on routes with more than one stop within that distance from the house.

Figure 8. Transit Service

Sprawl	vs	Your Choice
0		1,337

Average buses per hour

Vehicles

Those living in dense areas, where most trips can easily be walked or on transit, can save money on cars, and save time and effort on maintenance, fueling, etc. And generally, nearby parking is meager and expensive. So those in sprawl have 20 times more cars per household, involving huge releases of air pollutants and global warming gases in mining and transporting materials, and manufacturing those vehicles, Figure 9 (Holtzclaw, Clear, Dittmar, Goldstein & Haas, 2002). The equation was developed using the nearly 3000 neighborhoods in metro Chicago, San Francisco and LA. The data is very dense and the equations more accurate below 100 hh/res ac. But with fewer zones above that and only one at 500 hh/res ac, the data indicate that the equation underestimates auto ownership at 500 hh/res ac by 30%, so auto ownership there is 1.4 times higher. The vehicles available data used is from the U.S. Census.

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Figure 9. Vehicles

Sprawl	vs	Your Choice
2.0		0.1

per Household

Parking Spaces

Those living where transportation options are pretty much limited to the car have parking in their garages (theoretically not filled with junk), driveways, curbside, and in lots or garages where they study, work, shop and recreate. While it's hard to count all these, it's variously estimated at 5 to 9 spaces per car. The calculator uses 7, see Figure 10.

Much of the pollution and global warming gas emission required to mine, manufacture and transport the materials and construct these lots and garages is not included in the previous streets, driveways and sidewalks analysis.

Figure 10. Parking Spaces

Sprawl	vs	Your Choice
14.2		0.8

per Household

Parking. More land for parking, less for nature.

Annual Mileage

Consequently, high density residents drive much less. The Calculator shows 5 times less driving than in sprawl, Figure 11 (Holtzclaw, Clear, Dittmar, Goldstein & Haas, 2002). But, due to the few zones above 100 hh/res ac used to develop the equations, it overestimates the driving at the high density of 500 hh/res ac. The 1 data point at this density shows only 1/4 as much driving as the equations calculate. Additionally, residents of Manhattan, at perhaps an average of 200 hh/res ac, drive 1/9 that of those living in sprawl.

Figure 11. Mileage

Sprawl	vs	Your Choice
22,844		4,594

Average vehicle miles traveled per household each year

Annual Gasoline Consumption and Auto Costs

The Calculator allows users to adjust the miles per gallon and the cost of gas – for their car or for the area's average, and calculates the annual household gas consumption and auto costs based upon AAA costs per car, Figure 12 (Holtzclaw, Clear, Dittmar, Goldstein & Haas, 2002). Those living at high density save big bucks on auto costs, the second highest expense for the average American household. The average household in the San Francisco neighborhood saves $13,600 annually.

Figure 12. Auto Costs

Sprawl	vs	Your Choice
$2,513		$505
Average cost of fuel alone each year		
$14,968		$1,379
Total average costs each year		

Pollution from Driving

The Calculator estimates the annual household emissions of Volatile Organic Compounds (VOCs), Nitrogen Oxides (NO_x), particulates (PM_{10}) and carbon dioxide (CO_2), using EPA estimates per gallon or mile, Figure 13.[2] Of course, they are much higher in sprawl. Since the Calculator overestimates driving at 500 hh/res ac, the actual pollution would be 4 times lower still.

Figure 13. Pollution

Sprawl	vs	Your Choice
60		12
Pounds of Volatile Organic Compounds per Household per year		
151		30
Pounds of Nitrogen Oxide per Household per year		
274		55
Pounds of Particulates per Household each year		
16.0		3.2
Tons of Greenhouse Gases per Household each year		

[2] Based on the calculated VMT and miles per gallon: 24 g VOC /gallon, 60 g NOx/gal, 28 lb CO_2/gal and 0.012 lbs PM10/mile (primarily re-entrained road dust).

Conclusions

The Healthy Growth Calculator can be used to estimate the benefits of developing new neighborhoods or infilling already developed neighborhoods with convenient, compact smart growth. The Healthy Growth Calculator can help users to identify the relatively greater impacts of sprawl on:

- forests and wetlands (carbon sinks) lost.
- pollution from mining, manufacturing and transporting building materials and vehicles.
- pollution from driving.
- air and water pollution from use of fertilizers, herbicides and pesticides on lawns.
- ozone buildup from the heat island effect.

Recommendations

Cities and counties should use the Calculator to assist residents and planners to mull the future of their communities and how walkability and convenience could be enhanced. It can help them explore and evaluate potential land use futures in a series of community planning sessions (charettes).

References

Bürer, Mary, David Goldstein, and John Holtzclaw. 2004. Location Efficiency as the Missing Piece of The Energy Puzzle: How Smart Growth Can Unlock Trillion Dollar Consumer Cost Savings. ACEEE Summer Study on Energy Efficiency in Buildings Proceedings. ACEEE, Washington, DC.

Holtzclaw, John. 2004. A Vision of Energy Efficiency. ACEEE Summer Study on Energy Efficiency in Buildings Proceedings. ACEEE, Washington, DC.

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

Knox, Kimberly. SF Water Dept. Water Conservation (personal communication): 55 g/p-d for multi-family units (~50 du/res ac). Assume 80% is indoor use (44 g/p-d), and 3.8 persons per household. Indoor.

Newman, Peter and Jeff Kenworthy. 1989. Cities and Auto Dependence: An International Sourcebook; Gower Publishing.

Sakrison. 1998. "Water Use in Compact Communities: The Effect of New Urbanism, Growth Management and Conservation Measures on Residential Water Demands" Washington Dept of Ecology, Table 11 for 4, 7 and 12 du/ac, and extrapolated to higher and lower densities. Outdoor.

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