UNIVERSITY OF CALIFORNIA, BERKELEY

BERKELEY • DAVIS • IRVINE • LOS ANGELES • RIVERSIDE • SAN DIEGO • SAN FRANCISCO SANTA BARBARA • SANTA CRUZ

ENERGY AND RESOURCES GROUP
310 BARROWS HALL
UNIVERSITY OF CALIFORNIA
BERKELEY, CA 94720-3050
TEL (510) 642-1139
FAX (510) 642-1085
DIRECTOR, RENEWABLE AND APPROPRIATE ENERGY LAB (RAEL)
DIRECTOR, TRANSPORTATION SUSTAINABILITY RESEARCH CENTER (TSRC)

DANIEL M. KAMMEN
CLASS OF 1935 DISTINGUISHED CHAIR IN ENERGY
PROFESSOR IN THE ENERGY AND RESOURCES GROUP
PROFESSOR OF PUBLIC POLICY IN THE GOLDMAN SCHOOL
PROFESSOR OF NUCLEAR ENGINEERING
E: kammen@berkeley.edu
http://rael.berkeley.edu
http://tsrc.berkeley.edu

Frequently Asked Questions

for the following academic paper:

Christopher M. Jones and Daniel M. Kammen, Spatial Distribution of U.S. Household Carbon Footprints Reveals Suburbanization Undermines Greenhouse Gas Benefits of Urban Population Density. *Environ. Sci. Technol.*, 2013, dx.doi.org/10.1021/es4034364

Project website: http://coolclimate.berkeley.edu/maps

Press release: Suburban sprawl cancels carbon-footprint savings of dense urban cores

Questions answered in this document:

Draft copy. Updated 1/10/14 by Jones and Kammen

1. What is the purpose of the study?

The purpose of the study is two-fold:

a) to develop household carbon profiles of each zip code, city, county and U.S. State
b) to analyze the effect of population density and level of urbanization on full life cycle greenhouse gas emissions.

Additional motivations by the authors are:

c) to help cities better understand the primary drivers of household carbon footprints in each location
d) to present in a visually striking way the impacts and interactions of our energy, transportation, land use, shopping and other choices
e) to motivate cities to use this information to begin to create highly tailored climate action plans for their communities

2. What are some limitations of previous related work?

a) Other studies have considered only a relatively small number of case studies
b) Most studies have only considered partial household GHG impacts, e.g., vehicle fuel consumption and household energy
c) Most other similar studies have tended to address one spatial scale (e.g., metropolitan areas, or cities) and not multiple spatial scales

3. How does the methodology address previous limitations?

a) This is the first study of household carbon footprints to include every U.S. location, including essentially all zip codes, cities, counties and metropolitan areas.
b) It one of the first, and the most geographically comprehensive study to compare population density with full life cycle greenhouse gas emissions (most studies focus on limited impacts, such as vehicle fuel consumption and/or household energy)
c) It is one of the first studies to evaluate household carbon footprints at multiple spatial scales (zip codes, cities, counties, metropolitan areas)

4. What is the methodology used to estimate household carbon footprints?

a) The model uses national household energy, transportation, and consumer expenditures surveys along with local census, weather and other data – 37 variables in total – to approximate greenhouse gas emissions resulting from the energy, transportation, food, goods and services consumed by average households in essentially all populated U.S. zip codes. See the paper and online supporting materials for detailed descriptions of the methods.

5. What do the data show that is consistent with previous studies?

a) There is a strong correlation between population density and average household carbon footprints of large central cities ($r^2 = 0.3$).

b) The primary drivers of carbon footprints are household income, vehicle ownership and home size, all of which are considerably higher in suburbs. Other important factors include population density, the carbon intensity of electricity production, energy prices and weather. The model includes 37 local variables in total.

c) Central cites and suburbs have important social, economic and environmental interdependencies

6. What do the data show that is new and potentially relevant to future city planning?

a) Population dense central cities have significantly lower carbon footprints than less dense central cites; however, these cities also have more extensive suburbs. When considering the net effect of all metropolitan residents (suburbs and central city residents together), larger, more populous and population-dense metropolitan areas have slightly higher average carbon footprints than less populous and lower population-dense metropolitan areas.

    i. Note: this is the primary finding of the paper that is used in the title. The implication for policy is that suburban sprawl undermines, or cancels, the benefits of urban population density. Urban development planning should focus on impacts at metropolitan as well as more local scales, as is typical in regional transportation planning.

b) There is no correlation between population density and average household carbon footprints of zip codes (Figure 2a), cities (Figure 2b), counties (Figure 2c), or metropolitan areas (Figure 2d)...adjusted r^2 for all of these locations is <0.01.

    i. Note: This is consistent with other recent research showing there is a huge range of household greenhouse gas emissions at any given population density. It would be incorrect to say population density is correlated with lower household carbon footprints.

c) There is no correlation between population density and average household carbon footprints of suburbs (adjusted r-squared = 0.006). See Table 3, model 2.

    i. Note: there is a correlation for central cities, but there is not a correlation for suburbs. Suburbs are different. The next two points explain how.

d) When classifying suburbs into low, medium and high population, more populous and population dense suburbs have higher HCF. Large suburbs have population densities 3 times larger than mid-sized suburbs, and 6% higher carbon footprints. See Table 1.

   i. Note: this is largely because more population dense suburbs have higher incomes than less dense suburbs. Higher incomes translates to important social, cultural and economic benefits, but higher incomes also generally correspond with higher consumption and greenhouse gas emissions.

e) When controlling for income and household size, there is a fairly strong correlation between population density and HCF in central cities (r^2=0.32), suburbs (r^2=0.30) and all cities (r^2=0.30).

   i. Note: if policies can control for income, or even encourage lower income infill, then population density has a strong potential impact on lowering greenhouse gas emissions of those locations. In central cities, population density lowers carbon footprints, regardless of income, although the benefits are higher with low income densities.

   ii. In suburbs (which account for nearly 50% of the U.S. population), increasing population density has lead to higher incomes, and thus higher consumption, while not reducing vehicle emissions sufficiently since people still travel long distances to reach central cities, or to travel within large suburban areas.

f) There is an inverted-U relationship between population density and HCF; HCF increases at from low to medium population densities, and decreases from medium to high population densities. The turning point is about 3,000 persons per square mile, which is very close to medium population density of all locations, and a little higher than the population density of larger suburbs (which have densities of 2,700 persons per square mile).

   i. Note: this helps explain why larger suburbs have higher carbon footprints; they are located to the left of the inflection point, while less dense suburbs are even further left on the x-axis. See Figure 2.

7. What are the potential limitations of population density suggested by the authors?

The authors suggest different implications for suburbs and for central cities. Below is a line-by-line summary of the paragraph in the Discussion section describing potential implications for urban planning. Note, these are not findings, but comments by the authors to generate policy discussion and future research.

a) *As a policy measure to reduce GHG emissions, increasing population density appears to have severe limitations and unexpected trade-offs.*

    i. Note: our primary conclusion is the population density has contributed to lower household carbon footprints in urban core cities, but low carbon central cities also tend to have high carbon footprint suburbs. Planners need to consider economic, social and environmental interrelationships between central cities and suburbs in planning more sustainable communities.

    ii. Note: The data show the effect of existing population density on existing urban infrastructure and household carbon footprints. Our data does not suggest how HCF changes over time as population density changes over time so our comments are somewhat speculative here based on past historical data. To the extent that the future policies look like the past policies, the limitations and tradeoffs we suggest may be valid and worth considering in future planning.

b) *In suburbs, we find more population-dense suburbs actually have noticeably higher HCF, largely because of income effects*.

    i. This is one of our most surprising findings that has been missed in previous research that has explored only a limited number of (mainly central) cities, or large metropolitan areas. This finding is relevant to 50% of the U.S. population living in U.S. suburbs. The implication is suburbs should be treated differently than central cities.

c) *Population density does correlate with lower HCF when controlling for income and household size; however, in practice population density measures may have little control over income of residents.*

    i. Note: <u>this statement is in reference to suburbs only and should not be taken out of context</u>; population density correlates with lower HCF regardless of income in central cities. In suburbs, however, we have historically seen that more population dense cities have higher incomes, and higher carbon footprints. Cities seeking to reduce community-wide greenhouse gas emissions from a lifecycle perspective may want to consider ensuring sufficient low income and middle-income infill housing is built. From the perspective of global greenhouse gas emissions, it is good for high income households to move the centers of suburbs rather than in more distant sprawl, but from the perspective of suburbs themselves, this may result in an increase in average household carbon footprints (when considering the full life cycle perspective).

d) Increasing rents would also likely further contribute to pressures to suburbanize the suburbs, leading to a possible net increase in emissions.

    i. Note: this statement is in reference to higher incomes in suburbs and not a statement about population density and rents generally; it should not be taken out of context: increasing housing stock should generally decrease rents, not increase rents, by decreasing demand for housing. Higher incomes, on the other hand, should increase property values and rents. Other researchers have pointed out that reducing supply of single-family homes may increase property values and rents for more spacious, single-family homes, which are highly sought by suburban dwellers, but this is not a point we make in the paper. More research is needed on this important question and debate, but this is far beyond the scope of the current study.

e) As policy measure for urban cores, any such strategy should consider the larger impact on surrounding areas, not just the residents of population dense communities themselves.

    i. Note: transportation planning is frequently done at a regional level. A good example of this is California's SB375, which encourages regional targets and plans to lower greenhouse gas emissions from transportation. City planners; however, are primarily concerned with reducing emissions from their own jurisdictions and may not be concerned with impacts outside of their jurisdictions. Our comment is very consistent with “smart growth” ideology and policies that seek to take a more holistic view of socio, economic and environmental impacts of growth.

f) The relationship [between population density of urban cores and HCF] is also log-linear, with a 10-fold increase in population density yielding only a 25% decrease in HCF.

    i. Note: this is a factual statement of our results. We chose a 10-fold increase as the example, because it shows the full range of our results in the fewest words. A doubling of population density from 5,000 persons to 10,000 persons per square mile, would have been a more realistic example. This corresponds to about a 5% decrease HCF, based on current data. Our intention was to show the limitations of density in reducing global greenhouse gas emissions. The U.S. Emits five times the global average per capita emissions and globally, humanity needs to reduce emissions by

80%, so planners should arguably be thinking about how to achieve a 10 to 20 fold decrease in emissions. Given limited technical capacity in cities, we suggest that population density has limited potential and call for more tailored solutions; which in our view are urgently needed.

g) *Generally, we find no evidence for net GHG benefits of population density in urban cores or suburbs when considering effects on entire metropolitan areas.*

   i. Note: this statement is in reference to impacts of population density on entire metropolitan regions, not cities; it should not be taken out of context. One of the most alarming findings, in terms of planning is that metropolitan regions all have very similar household carbon footprints when you consider the net impacts of residents of urban cores and suburbs together. Worse still, we find larger, more population dense metropolitan areas have slight higher HCF. This discouraging finding, along with the urgent need for very dramatic reductions suggest that a new framework to address community-scale greenhouse gas emissions is urgently needed.

8. What does the paper recommend to improve future urban planning?

The paper suggests that "an entirely new approach of highly tailored, community-scale carbon management is urgently needed." We recommend that cities understand the size and composition of household carbon footprints in their locations and then develop customized plans that address the largest opportunities to reduce those impacts. Until now, cities and counties have lacked a way to estimate total household carbon footprint in their jurisdictions without paying for expensive and time-consuming studies. We hope municipalities will use the benchmarking carbon footprint profiles and data in this study to aid in this process.

9. What resources are available to help tailor promising solutions to existing communities?

Project resources:

a) CoolClimate Maps (project website): http://coolclimate.berkeley.edu/maps - online interactive map showing average household carbon footprints of over 31,000 U.S. zip codes.
b) CoolClimate Calculator. http://coolclimate.berkeley.edu/carboncalculator - a free online carbon footprint management tool that includes benchmark carbon foot print estimates for essentially every U.S. zip code, city, county and all 50 U.S. states. Users can compare their personal household carbon footprints to local averages, and create customized climate action plans from 40 common greenhouse gas reduction measures. Municipal governments are using the tool to prioritize promising GHG mitigation strategies for residents.

c) ICLEI Community Greenhouse Gas Protocol, Appendix I. Provides overview and methods for cities to create consumption-based greenhouse gas inventories using the CoolClimate method and datasets.
d) Behavior, Energy and Climate Change Conference: http://beccconference.org – the premier conference dedicated to understanding human behavior, energy and climate change.
e) CoolCalifornia Challenge: http://coolcalifornia.org/community-challenge. a statewide carbon footprint reduction competition for California cities.

Recommended resources:

a) Cost of Sprawl Revisited. TCRP Report 39. http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_39-a.pdf. Landmark study demonstrating social, economic and environmental costs of suburban sprawl.

b) Community-based social marketing: http://cbsm.com. Learn how to choose the most promising actions to target, identify the barriers and benefits of taking those actions, use effective CBSM tools to reduce barriers and increase benefits, pilot programs for success, and bring to scale

10. What are the limitations of the current study?

a) The CoolClimate estimate should be considered benchmarks. We do not measure consumption or emissions, but rather estimate consumption of energy, transportation, food, goods and services based on locally-available data (37 variables in total, the most important of which are vehicle ownership, income, household size, population density, energy and fuel prices, the carbon-intensity of electricity and weather.

b) We assume a linear relationship between expenditures and emissions for goods and services. This is consistent with all similar studies on household carbon footprints. Unlike most such studies, we do not assume a linear relationship between income and food consumption; we have previously shown that while higher income households spend more on food, they do not eat more of any category of food than lower income households. Similarly, we know upper income households spend more on alcohol, but this does not mean that they drink more; rather they drink more expensive alcohol.

c) Our model tends to underestimate consumption (and therefore emissions) at high or low levels of transportation and household energy. This is the nature of using multivariate regression analysis.

d) See the paper and supporting materials for more discussion on limitations and model validation.

11. What does the paper say about Smart Growth?

Due to tight paper length (which the paper is at the absolute limit), the authors were not able to include additional references or discussion of smart growth literature that has helped inform this study. As a result, the paper itself does not explicitly say anything about "smart growth" policies other than the description of the effect of population density on household carbon footprints. Population density, of course, is only one factor in smart growth strategies. Other strategies are very consistent with our concept of tailored solutions, including increasing access to public transit, making cities more pedestrian and cycle friendly, colocation of housing with jobs, entertainment and shopping, and other smart growth policies. The authors personally are strong advocates of smart growth policies that consider a holistic view of the impacts of growth, development and urban infrastructure on individual behavior.