The carbon footprint of metropolitan America has a distinct geography that is not well understood or recognized in the national climate debate, partly because data on GHG emissions is so inadequate.

Perhaps as a result, metros and the built environment are often neglected when solutions to the climate challenge are being discussed, yet they are major emitters and they are poised to be a part of the solution.
Economic development has traditionally gone hand-in-hand with energy consumption.

Source: U.S. Environmental Protection Agency and the Energy Information Administration.
Nuclear energy has enabled France to grow its economy while shrinking its carbon footprint.

The purchasing power parity (PPP) theory uses the long-term equilibrium exchange rate of two currencies to equalize their purchasing power.

U.S.: 20.1 tCO2/capita = 5.5 tC/capita

Singapore actually leads all 28 countries in Asia in terms of its per-capita emissions, which are about 15.2 tons per person per year or 27.9 when marine bunkering is included. GDP per capita (2005) = $26,000.

To give a quick comparison:

Republic of Korea is at 10.0,
Japan at 9.6,
China at 2.7.

By some accounts, China has just overtaken the U.S. and Europe to become the world’s largest carbon emitter.

However, the U.S. will remain the most CO2 intensive--in terms of CO2 per capita.

(The Middle East may soon become the most energy intensive.)
The built environment in the U.S. is concentrated in its largest metropolitan areas, making them central to achieving meaningful carbon reductions.


Metropolitan America is the locus of technological, entrepreneurial, and policy innovations and so is poised to play a leadership role in solving the nation’s energy and climate challenges.

The activities of Smart Growth America, the creation of Climate Communities and the 825+ signatories to the U.S. Mayor’s Climate protection agreement are a testament to this.

But while many cities are claiming leadership and are committing to climate goals, without adequate benchmarking and comparative analysis, it is difficult to confirm or refute best practices and policies.
Carbon dioxide is the most prevalent greenhouse gas (GHG) emitted in the United States. And carbon emissions come primarily from the energy used in buildings and transportation.

Other gases include: PFCs, HFCs, and SF6.

Transportation and residential buildings are the focus of our research and are arguably the source of emissions most under the control of individuals.

Buildings account for 39% of U.S. emissions, transportation accounts for one-third, and industry is responsible for 28 percent. An effective climate strategy must focus on reducing carbon emissions from all three sectors.

Emissions from the residential, commercial, and transportation sectors each increased by more than 25% over the past 25 years. Industrial emissions have declined over this same period as the country has moved away from energy-intensive manufacturing and toward a service and knowledge economy.

As a result, consumers are increasingly the driving force of domestic energy consumption and carbon emissions. Residential and commercial buildings and road transportation are expected to dominate energy demand and carbon growth in the future. Total U.S. carbon emissions are projected to grow by 16% between 2006 and 2030.
Our footprints cover 77% of carbon emissions for transportation.
The majority of residential energy use came from space and water heating, lights, and cooling in 2005.

Our footprints cover 100% of carbon emissions from households.
The U.S. is growing, and will be adding a substantial amount of new housing by 2030—over 30 million new units, in fact.

The U.S. will also be upgrading or replacing another 20 million housing units by 2030. As we build and upgrade the nation’s housing stock, we have an opportunity to address 2 key national goals: affordability and sustainability.

Rising energy costs add a whole new dimension to the affordability calculus, bringing the combined housing/ transportation/ energy cost burden up to 70% or more in some places.
The climate challenge: U.S. emissions are projected to increase 16 percent from 2006 to 2030.

Carbon emissions in the U.S. have increased about 1% annually since 1980.

Changes in Global T$_{\text{avg}}$: 1600 to 2100

Annual growth rate of CO2 is 0.6%, according to EIA’s AEO 2008.

Last time T was 2°C above 1990 levels was 130,000 years ago, and sea level was 4-6 m higher.

We must turn this trend around to avert the worst effects of a changing climate.
This study fills an important data gap by producing comparable carbon footprints for U.S. metro area

- Partial carbon footprints were estimated for transportation and residential energy use
- Individual or per capita carbon footprints are the focus
- This way we can compare metro area footprints across metro areas of varying size
- This gets at the relative efficiency of energy use in one metro area compared to other metro areas and the national average

The report presents the most comprehensive set of carbon footprints for metropolitan areas available to date. It uses a methodology with a consistent set of data and algorithms.

Our carbon footprints represent the carbon emitted from highway transportation (personal and freight vehicles) and residential energy, which are the two largest sources of carbon emissions in the U.S., accounting 47% of total carbon emissions.

We do not include emissions from the commercial buildings sector, although I anticipate that the residential results are a precursor of this sector because building practices, densities, and fuels are often common across these two sectors.

We also do not include industry or non-highway transportation including air, rail, rapid transit, and waterways.

The geography we used is the metropolitan statistical area or “metro area,” defined by OMB as of 2003. Metro area have a core urban area of 50,000 plus adjacent counties with a high degree of commuting to the core urban area. There are currently 362 metro areas in the U.S. (http://www.census.gov/population/www/estimates/aboutmetro.html)

For this study, we selected the largest 100 metropolitan areas based on their employment in 2005.

The carbon footprints reported here are the most comprehensive to date for a dataset this size and for two points in time. This provides a starting point for what we hope will be an ongoing discussion about data needs and the geography of the nation’s carbon footprint.
Transportation methodology

- Passenger and freight vehicles miles traveled (VMT) was estimated at the metro-level using HPMS data
- Fuel consumption was estimated by incorporating VMT, types of vehicles, and fuel cycle multipliers
- Fuel consumption was then converted to carbon emissions

HPMS = Highway Performance Monitoring System
Residential methodology

- Residential electricity data was obtained from Platts Analytics
- Fuel data was obtained from EIA and the Residential Energy Consumption Survey
- All energy consumption data was aggregated to the metro-level and converted to equivalent carbon emissions

From FERC and Rural Utility Services (RUS) forms, reported by utilities mapped only zip-code-level service territories.
This study fills an important data gap by producing comparable partial carbon footprints for metro areas

**Per Capita Footprints**

- This report uses *individual* or *per capita* carbon footprints
- This way we can compare metro area footprints across metro areas of varying size (New York vs. Boise)
- This gets at the relative efficiency of energy use in one metro area compared to other metro areas and the national average
Which carbon emissions belong to a metro area?
Consumption vs production dichotomy

Analysis reveals five major findings

1. Large metro areas offer greater energy and carbon efficiency than the nation as a whole.
2. Carbon emissions increased slower in metropolitan America than the rest of the country between 2000 and 2005.
3. Per capita emissions vary substantially by metro area.
4. Development patterns and rail transit play an important role in determining carbon emissions.
5. Fuel mix and electricity prices are also important determinants of emissions.
Large metro areas offer greater energy and carbon efficiency than the nation as a whole

The 100-metro average per capita carbon footprint is smaller than the U.S. average (2.24 vs 2.60 tons; 14% smaller)

The 100 largest metros emit only 56% of the U.S. transportation and residential carbon emissions (while housing 65% of the nation’s population and producing 76% of the nation’s GDP)—indicating these metros are where we should look for effective reduction strategies.
1- The carbon footprint of the largest 100 metros is 14% smaller than the U.S. average.

U.S. footprint is 16% larger than the average metro footprint.

(The 100 metro footprint is 14% smaller.)
Carbon emissions increased more slowly in large metro areas than the rest of the country between 2000 and 2005

1.1% (100 metros) vs 2.2% (nationally)
Climate scientists are calling for substantial cuts in global carbon emissions to stabilize carbon concentrations in the atmosphere.

Unfortunately, U.S. trend is increasing.
53 of 100 largest metro areas saw growing per capita footprints 2000-2005.

This upward trend will need to be reversed to meet climate goals.

Carbon emissions grew faster for auto than freight transport and for electricity than residential fuels.

“Plug loads” in particular are growing rapidly.
### Per capita footprints vary substantially by metro area

<table>
<thead>
<tr>
<th>Largest per capita carbon footprints, 2005</th>
<th>Tons of carbon per capita</th>
<th>Smallest per capita carbon footprints, 2005</th>
<th>Tons of carbon per capita</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lexington, KY</td>
<td><strong>3.455</strong></td>
<td>Honolulu, HI</td>
<td><strong>1.356</strong></td>
</tr>
<tr>
<td>Indianapolis, IN</td>
<td>3.364</td>
<td>Los Angeles, CA</td>
<td>1.413</td>
</tr>
<tr>
<td>Cincinnati, OH</td>
<td>3.281</td>
<td>Portland, OR</td>
<td>1.446</td>
</tr>
<tr>
<td>Toledo, OH</td>
<td>3.240</td>
<td>New York, NY</td>
<td>1.495</td>
</tr>
<tr>
<td>Louisville, KY</td>
<td>3.233</td>
<td>Boise City, ID</td>
<td>1.507</td>
</tr>
<tr>
<td>Nashville, TN</td>
<td>3.222</td>
<td>Seattle, WA</td>
<td>1.556</td>
</tr>
<tr>
<td>St. Louis, MO</td>
<td>3.217</td>
<td>San Jose, CA</td>
<td>1.573</td>
</tr>
<tr>
<td>Oklahoma City, OK</td>
<td>3.204</td>
<td>San Francisco, CA</td>
<td>1.585</td>
</tr>
<tr>
<td>Harrisburg, PA</td>
<td>3.190</td>
<td>El Paso, TX</td>
<td>1.613</td>
</tr>
<tr>
<td>Knoxville, TN</td>
<td>3.134</td>
<td>San Diego, CA</td>
<td>1.630</td>
</tr>
</tbody>
</table>

Top 5 lowest emitters: Honolulu (1.36 tC/person), Los Angeles, Portland, New York, Boise

Top 5 highest emitters: Lexington (3.46 tC/person), Indianapolis, Cincinnati, Toledo, Louisville

The difference between metros is substantial
Lexington, KY emits 2.5 times as much carbon on a per person basis as
Honolulu does

This reflects a wide range of carbon efficiencies and very different “vulnerabilities” to climate policies and carbon markets.

We’re hoping that our study will promote a virtuous competition to spur innovative solutions to climate and energy challenges.

The differences are even more pronounced when adjusting CO2 emissions for a metro area’s economic output (4-to-1 ratio—Youngstown to San Jose), but the geography is similar.
3 - The Mississippi River roughly divides the country into high and low emitting metros

There’s notable regional variation

High emitters are mainly in the Eastern U.S. (esp. SE)—East of the Mississippi and South of New York State.

Low emitters mainly on West Coast (CA, WA, OR). (All but 1 of the lowest 10 emitters.)

Many of the high emitters are located in the fast-growing parts of the U.S., which underscores the need for “smart growth,” so that new investments don’t “lock in” poor practices.
Development patterns and rail transit play an important role in determining carbon emissions

- Density and concentration of development tend to be higher in the lowest-emitting metro areas
- Many metro areas with small per capita carbon footprints also have sizeable rail transit ridership
  - There are exceptions: Washington, Baltimore, and Atlanta have high rail transit ridership but also have larger than average carbon footprints

Footprints tend to be small in areas with high density and good rail transit (think LA, NY, San Francisco) NYC—757 miles per capita each year.

Freight traffic is tricky - metros with or near port cities or along freight corridors face special challenge from thru-traffic (Bakersfield and Riverside, CA; Jacksonville and Sarasota, FL). Port cities experience significant freight thru traffic.

Growth in VMT is likely to cancel out improvement in fuels and MPG—like running up a down escalator.

Although with the doubling of gasoline prices, VMT is beginning to shrink.
Lexington averages 0.46 people per developable acre vs 1.0 average.
The large freight footprints also occur in metros with lower densities, which leave more space for industrial developments that attract freight.
Fuels mix and electricity prices (plus weather) are all important on residential side

Areas that rely on high-carbon fuels like coal for their electricity (think Washington, D.C.) emit much more than areas that rely on cleaner fuels like hydropower for their electricity (think Seattle). There’s a 7-to-1 ratio across states: very controversial.

DC is served by utilities at 0.28 tC/MWh, while Seattle has 0.04 tC/MWh.

Areas with higher average electricity prices have smaller residential footprints (CA-14 cents, NY-17 cents, HI-23 cents vs. KY-7 cents, TN-8 cents, GA-9 cents). But, there are exceptions, low emitters in low-cost regions (WA, ID, OR at 6-7.5 cents).

Areas facing duel loads—e.g., both heating and cooling needs, like Washington, DC—have larger residential footprints.

In these areas, either the furnace or the air conditioner is running 12 months of the year.
5 – Regression analysis can explain a majority of the variation across the metros (N=97)

Dependent Variable: Metric tons of carbon emitted per capita from highway transportation and residential energy

<table>
<thead>
<tr>
<th>Regression Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple R</td>
</tr>
<tr>
<td>R Square</td>
</tr>
<tr>
<td>Adjusted R Square</td>
</tr>
<tr>
<td>Standard Error</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Coefficients</th>
<th>Std Error</th>
<th>t Stat</th>
<th>Pvalue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>3.1959</td>
<td>0.5164</td>
<td>6.2153</td>
</tr>
<tr>
<td>Heating degree days</td>
<td>0.0001</td>
<td>0.0000</td>
<td>2.5555</td>
</tr>
<tr>
<td>Cooling degree days</td>
<td>0.0002</td>
<td>0.0001</td>
<td>2.3213</td>
</tr>
<tr>
<td>Electricity price</td>
<td>-4.0773</td>
<td>0.0226</td>
<td>-3.7405</td>
</tr>
<tr>
<td>Metro population</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.8565</td>
</tr>
<tr>
<td>Population density</td>
<td>-0.1788</td>
<td>0.0116</td>
<td>-3.4093</td>
</tr>
<tr>
<td>Rail transit dummy</td>
<td>-0.1675</td>
<td>0.1010</td>
<td>-1.6560</td>
</tr>
<tr>
<td>GNP/persion</td>
<td>0.0000</td>
<td>0.0000</td>
<td>1.2150</td>
</tr>
<tr>
<td>Population concentration</td>
<td>-1.4259</td>
<td>0.3359</td>
<td>-4.2507</td>
</tr>
</tbody>
</table>

Fuels mix and electricity prices (plus weather) are all important on residential side

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Areas facing duel loads—e.g., both heating and cooling needs, like Washington, DC—have larger residential footprints.

In these areas, either the furnace or the airconditioner is running 12 months of the year.
As part of this project, we surveyed policy responses at all levels of governments, and found innovative activity in states and localities throughout the country.

But, metro actors—such as mayors, county officials, chambers of commerce, major university leaders, and state officials—need supportive policy from the federal governments to shrink their carbon footprints and achieve the emissions reductions we need as a nation.

We identified two tiers of policies. First, we think there are five basic, economy-wide policies that must be adopted to help the nation shrink its carbon footprint:
Washington should address several economy-wide flaws to shrink the nation’s carbon footprint

<table>
<thead>
<tr>
<th>Economic flaws</th>
<th>Recommended federal response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon based energy is underpriced</td>
<td>Price carbon to account for the external costs of fossil fuel combustion</td>
</tr>
<tr>
<td>Federal energy RD&amp;D is underfunded</td>
<td>Increase energy RD&amp;D funding to catalyze innovation and market uptake</td>
</tr>
<tr>
<td>National energy standards are lacking</td>
<td>Establish a national renewable electricity standard</td>
</tr>
<tr>
<td>State utility pricing policies and regulation thwart energy efficiency improvements</td>
<td>Help states reform electricity regulations to incentivize efficiency</td>
</tr>
</tbody>
</table>

1. Price carbon to account for the external costs of fossil fuel combustion

Uncertainty regarding the future legal treatment of GHGs hinders investment in low-carbon system

This would go a long way to encourage widespread changes in the energy efficiency and reduce the carbon intensity of the U.S. economy.

2. New technologies are crucial as is further development of existing technology.

• We would like to see the federal government ramp up energy R&D, perhaps in line with other national priorities such as for health care and defense.

3. 25 States and the District of Columbia have mandatory renewable energy targets; others have goals

• The federal government should pass a national renewable electricity standard that would give businesses some certainty to make investments needed to transition to cleaner technology.

4. Utility profits need to be decoupled from sales.
Economy-wide flaw: Lack of data at spatial resolutions needed to make informed decisions

Recommended response: Collect and disseminate needed data, set performance goals, and tie funding streams to outcomes

Reliable energy and emissions data are difficult to find at the local and metro level. So we think the federal government should collect and invest in better energy and emissions data at small unit geographies. This needs to be a sustained effort so that localities can continue to benchmark their progress on energy consumption and carbon emissions.

Disseminating information on best practices is also important, as is setting performance goals and tying funding streams to outcomes.
Market flaw: Transportation decision making is biased toward highways and is geographically fragmented

Recommended response:
• Adopt a position of “modal neutrality” to make transit and compact development options more feasible
• Engage in regional freight planning to introduce more energy efficient freight operations

The federal government offers no incentives to join up transportation, housing, energy, and land use policies

Transportation, housing, and other programs are often stove-piped; metropolitan areas are seldom given the tools needed to innovate; and much decision-making happens at the local rather than regional level
**Market flaw:** Misplaced incentives to upgrade existing buildings – the “landlord-tenant problem”

**Recommended response:**
- Require energy cost disclosure in resale documentation
- Create opportunities for “on-bill” utility financing of energy-efficient retrofitting
- Consider developing “green leases”

Washington does not adequately promote energy efficiency in its housing and building code policies and federal incentives for energy efficiency investments are tilted toward new homes and higher-income households.

The federal government should require the disclosure of energy costs when people are selling their homes, so that they are aware of what they are getting and how higher energy prices may influence their household budgets. This could be modeled after the 2003 U.K. Energy Performance Buildings Directive.

The feds should also work with utility companies to create on-bill financing options, allowing homeowners to pay the up-front costs of efficiency improvements in their monthly utility bills from the savings generated.
Three federal legislative initiatives could promote these policy recommendations

• Transportation reauthorization bill
• Federal climate legislation
• Federal tax bill

Many of these recommendations are in the energy platforms of Senators McCain and Obama.

We see 3 domestic policy vehicles moving in the next 2 years that will have meaningful effects on housing and sustainability:
---the reauthorization of SAFETEA-LU
---federal climate legislation
---major tax legislation
For more information, see:

www.brookings.edu/metro/CarbonFootprint.aspx

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