Chapter 8

Features of Climate-Smart Metropolitan Economies

Marilyn A. Brown, Frank Southworth, and Andrea Sarzynski

Meeting the climate challenge requires the leadership of metropolitan America. With two-thirds of the U.S. population and nearly three-quarters of the nation's economic activity residing in the nation's 100 largest metropolitan areas, urban centers account for much of the nation's greenhouse gas (GHG) emissions. At the same time, metropolitan America is the traditional locus of technological, entrepreneurial, and policy innovations. Its access to capital and a highly trained workforce have enabled metropolitan areas to play a pivotal role in expanding U.S. business opportunities while solving environmental challenges. With supportive federal policies, metropolitan areas can provide the low-carbon climate-smart leadership that is required to meet the nation's targets and timetables necessary to avoid dangerous levels of atmospheric greenhouse gases.

Many metropolitan actors are already at the forefront of state and national climate action. For example, nearly 940 mayors have signed the U.S. Mayor's Climate Protection Agreement, representing almost 30% of the U.S population.[1] However, the lack of adequate data on emissions and comparative analysis make it difficult to confirm or refute best practices and policies. To help provide benchmarks and expand our understanding of carbon emissions, this chapter quantifies highway transportation and residential carbon emissions of the 100 largest U.S. metropolitan areas in 2000 and 2005. The carbon emissions from transportation and residential sources – representing some of the most consumer-dominant sources of greenhouse gas emissions – provide a foundation for identifying the pricing, land use, and other policy interventions that could reduce the energy consumption and climate impacts of the U.S. economy.[2]

The Climate Challenge

Carbon dioxide accounted for 84 percent of U.S. greenhouse gas (GHG) emissions in 2005, and is one of the most important contributors to climate change (see Figure 1). The vast majority of anthropogenic carbon dioxide is released when we burn carbon-based fuels, such as coal and oil, for energy.[3] (Here, the terms “carbon emissions” or “carbon footprint” both indicate emissions of carbon dioxide.)

Residential and commercial buildings account for 39 percent of the carbon emissions in the United States. Transportation accounts for one-third of U.S. emissions, and industry is responsible for 28 percent (see Figure 2). An effective climate strategy must focus on reducing carbon emissions from all three sectors.

[figures 1 and 2 here]

Carbon emissions in the United States have increased by almost 1 percent per year since 1980.[4] Emissions from the residential, commercial, and transportation sectors each increased by more than 25 percent during the past 25 years.[5] Industrial emissions have declined during this same period as the country has moved away from energy-intensive manufacturing and toward a service and knowledge economy. Since much of what Americans once manufactured is now being imported from China, India, and other countries, standard accounts of U.S. greenhouse gas emissions exclude much of what the nation is actually “responsible” for, using the terminology of Louis Lebel, et al.[6]

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 percent between 2006 and 2030, making reductions all the more urgent to avoid the worst potential effects of a warming planet.[7]

Four factors determine carbon emissions: (1) population, (2) economic output, (3) energy intensity of the economy, and (4) carbon intensity of the energy system.[8] Shrinking the nation's carbon footprint, while allowing for population and economic growth, requires a strategic focus on reducing both *energy* and *carbon intensities*. This requires either reducing the amount of energy needed to power the economy and/or reducing U.S. reliance on high carbon emitting fuels, such as coal and petroleum. Reductions can be made in each sector as well as through multi-sector approaches.

Reductions of the magnitude needed to curtail global climate change – often estimated to be on the order of magnitude of 50 to 80% below current emission levels by mid-century – will not be easy. Energy intensity is much higher in the United States than in many other developed countries, resulting in a national footprint of 5.5 metric tons of carbon per capita compared to a global average of approximately 1.2 metric tons per person.[9] Despite recent improvements, U.S. energy intensity is comparably high relative to the world average and compared to many other developed nations such as Japan, which produces a dollar of GDP with less than half of the energy that is required in the U.S.[10] Although China overtook the United States and Europe in 2006 to become the world's largest carbon emitter, the United States will likely remain one of the most carbon- and energy-intensive nations on Earth, well into the future.[11]

The following section reviews trends and facts relevant to the transportation and buildings sectors, and the role that development patterns may play in reducing U.S. energy consumption and carbon emissions.

Transportation

Transportation is responsible for one-third of the nation's carbon footprint. Highway transport accounted for 80 percent of this total, dominated by automobiles (30 percent), light duty trucks (27 percent), and freight transport (20 percent). Air- and water-based transport is responsible for a majority of the remainder. The transportation sector is also the fastest growing. Between 1991 and 2006, transportation accounted for nearly one-half of the growth in U.S. carbon emissions.[12] With its dominant contribution to transportation emissions, highway transport trends deserve attention.

Suburbanization and rising wealth following World War II dramatically transformed American living and driving patterns. The country saw a ubiquitous increase not only in daily travel distances, but also in the frequency with which households used their vehicles to get to work, to shop, and to carry out a variety of personal business. Between 1970 and 2005, the average annual vehicle miles traveled (VMT) per household increased almost 50 percent, from 16,400 to 24,300.[13] At the same time, vehicle ownership per household increased even as average household size fell.[14] Commercial truck travel increased even more rapidly than passenger travel, at an annual rate of 3.7 percent compared with 2.8 percent for passenger travel.[15] This increased travel is responsible for worsening traffic congestion, wasted fuel, and rising carbon emissions.[16]

Despite significantly improved automotive engine technologies, miles per gallon (mpg) gains have leveled off since the mid-1980s, in part due to a consumer preference for more powerful and larger vehicles.[17] While significant fuel has been saved by advances in motor technology, most gasoline-fueled vehicles on the road today only use 15 percent of the fuel's energy to move the vehicle down the road and to power accessories such as air conditioning. The rest is lost to engine inefficiencies and idling.[18]

The U.S. transportation sector is primarily powered by gasoline, followed by diesel, which together accounted for 98 percent of U.S. vehicle fuel consumption in 2005. On a "well-to-wheels" life cycle energy basis, diesel is about 15% less carbon intensive than gasoline.[19] Thus, greater use of diesel technologies in the U.S. vehicle fleet would improve fuel efficiency and reduce carbon emissions.

Improvements in fuels and technology also have the potential to reduce carbon emissions from the transportation sector substantially. Promising developments are taking place in hybrid electric and cellulosic biofueled vehicle technologies. Cellulosic ethanol and biodiesel may prove to be important low-carbon fuel alternatives to gasoline and diesel.[20] For example, replacing one-quarter of projected gasoline use with cellulosic ethanol—a replacement rate viewed as achievable within 25 years—could cut carbon emissions by 15 to 20 percent.[21] Another promising alternative is hybrid electric systems that are recharged in off-peak hours by low-carbon electricity. Metropolitan areas are particularly well suited to low-carbon options because the capital investment needed to establish new refueling infrastructures is more economically feasible in high-density environments.

Under the Energy Independence and Security Act (EISA) of December 2007, automakers are required from 2011 on to increase the fuel economy of passenger vehicles by 40 percent, to a fleet average of 35 mpg by 2020.[22] The federal government is also directed to study and work toward "maximum feasible" fuel economy standards for small (8,500–10,000 pound) "work" trucks as well as medium and large commercial trucks. The production in recent years of a number of higher mpg automobiles suggests that significant increases in vehicle and truck fuel economy appear both feasible and justifiable. This includes the introduction of higher mpg conventional gasoline as well as diesel fuelled vehicles and a rapidly growing market for gasoline-electric hybrids that are attaining on the road fuel efficiencies well above the current 35 mpg national fuel economy standard set for 2020. [23]

After accounting for the effects from EISA, transportation energy use is projected to grow by 0.4 percent annually.[24] This increased energy use could drive up transportation carbon emissions 10.3 percent between 2006 and 2030.[25] During the same period, crude oil imports are forecast to rise from 66 to 71 percent of total supply, increasing U.S. vulnerability to petroleum supply and price disruptions. In the transportation sector in particular, energy and climate challenges are intertwined with energy security concerns.[26]

Buildings

Buildings—through the energy they use—are responsible for 39 percent of U.S. carbon emissions. Single-family homes, apartments, manufactured housing, and other residential buildings account for slightly more than one-half of these emissions, with commercial buildings (offices, businesses, hospitals, hotels, etc.) responsible for the remainder. In the United States, more than one-half of residential energy comes from the electricity households consume: 65 percent in 2000 and 68 percent in 2005.[27] Households use electricity for cooling (and some heating), for lighting, and increasingly for televisions, computers, and other household electronics.[28] More than one-half of the electricity in this country is generated from coal at central station power plants that have operated at about 35 percent efficiency for more than a half century. Almost two-thirds of the energy embodied in coal is lost through the release of low temperature waste heat either at the power plant or along its route to the end user.[29] Depending on how the electricity is ultimately used, as much as 98 percent of the energy in the coal used to produce electricity can be lost as waste heat.[30]

The balance of U.S. residential energy consists of direct fuel consumption. Natural gas is the most common source of heating in buildings and is also used for heating water and cooking. On an energy basis, natural gas has the lowest carbon intensity among fossil fuels.[31] Other building-integrated low-carbon energy options not widely used include solar photovoltaics, solar lighting, and solar water heating, which are virtually carbon-free, and geothermal heat pumps, which are a low-carbon source of heating and cooling.

The United States has made remarkable progress in reducing the energy use and carbon intensity of its building stock and operations. These improvements are largely the result of advances in the energy efficiency of U.S. buildings following the 1973–1974 OPEC oil embargo, motivated in part by the significant proportion of electricity generated from petroleum fuels and the greater reliance on fuel oil for home heating at that time. Since 1972, building energy use overall has increased at less than half the rate of growth of the nation's gross domestic product (GDP), and residential energy use per household has declined.[32] At the same time, homes have grown larger and we use a broader range of equipment, especially air conditioning in the South and electronic equipment nationwide.

Despite these impressive efficiency gains, the total energy used in buildings almost doubled between 1970 and 2005, and the nation can expect to see building energy consumption increase by 0.8 percent per year through 2030.[33] Because of the dominance of electricity in this sector, and the anticipated expansion of the nation's building stock to accommodate population growth, carbon emissions from the built environment are expected to grow rapidly. While this new growth is occurring, most of the current stock of buildings will continue to be occupied, although much of it will have been redeveloped, which presents the parallel opportunity to upgrade to eco-friendly features in current buildings as new functionality is delivered.

Development patterns

The spatial arrangement of buildings and transportation infrastructure in communities and urban systems can play a role in carbon reduction. Urban form links the energy consumed in different building designs, densities, and land-use configurations to the energy required to support daily travel, provide freight pickups and deliveries, and support a rapidly growing number of on-the-job service trips.

Carbon-reduction benefits from more spatially compact and mixed-use developments that also have access to rapid transit include:

- Reduced residential heating and cooling costs owing to smaller homes and shared walls in multi-unit dwellings
- The use of district energy systems for cooling, heating, and power generation
- Lower electricity transmission and distribution line losses
- Shorter freight and personal trips
- More use of public transit, and more walking and cycling instead of car trips
- Reduced waste streams
- Reduced municipal infrastructure requirements, including the reduced need for local street construction and shorter electric, communication, water, and sewage lines, requiring less energy and water treatment
- The use of micro grids to meet local electricity requirement with highly efficient distributed power generation
- Reuse and retrofitting of existing structures

Some studies have quantified the role of compact development in carbon reductions. For instance, the number of dwellings per acre is directly related to GHG emissions. With shared walls and generally smaller square footage, households in buildings with five or more units consume only 38 percent of the energy of households in single-family homes.[34] At a suburban density of four homes per acre, carbon dioxide emissions per household were found to be 25 percent higher than in an urban neighborhood with 20 homes per acre.[35]

Studies also show that household vehicle miles traveled vary with residential density and access to public transit.[36] Higher residential and employment densities, mixed land-use, and jobs–housing balance are associated with shorter trips and lower automobile ownership and use.[37] In comparing two households that are similar in all respects except residential density, the household in a neighborhood with 1,000 fewer housing units per square mile drives almost 1,200 miles more and consumes 65 more gallons of fuel per year over its peer household in a higher-density neighborhood.[38]

Less is known about how household behavior may change in response to changes in density or the concentration of housing or jobs. A recent simulation estimates that shifting 60 to 90 percent of new growth to development that is more compact would reduce VMT by 30 percent and cut U.S. transportation carbon dioxide emissions by 7 to 10 percent by 2050, relative to a trajectory of continued urban sprawl.[39] This effect is comparable to what might happen with a doubling of fuel prices.[40] It may be unrealistic to expect 60 to 90 percent of new growth in compact development, however, suggesting the secondary role that compact development might play to advances in efficiency, technology, and fuels. Other efficiency studies project even greater and more rapid GHG reductions from compact development, with savings of 10 percent of the U.S. 2001 level of GHGs possible within as few as 10 years, although again these results may be optimistic.[41]

A Partial Carbon Footprint of Metropolitan America

Metropolitan areas form the backbone of the American economy. Before researchers can evaluate the impact of existing carbon reduction efforts and of proposed policy changes, the nation needs a consistent set of emissions data for multiple periods and at a scale that can be tied to the activities, land uses, and infrastructure of metropolitan areas.

This study begins to fill that need by producing comparable partial carbon footprints for the 100 largest metropolitan areas in 2000 and 2005. The footprints are based on national databases for passenger and freight highway transportation and for energy consumption in residential buildings. The footprints do not include emissions from commercial buildings, industry, or non-highway transportation (that is, air, water, transit, or rail transportation).[42] The footprints also measure only fossil energy-derived carbon dioxide emissions; the impact of urban development on deforestation and other possibly significant impacts on the atmospheric GHG balance, are not considered.

Analysis of the partial carbon footprints of the top 100 largest metropolitan regions in the United States reveals five major findings:

1. *Large metropolitan areas offer greater energy and carbon efficiency than nonmetropolitan areas*

Despite housing two-thirds of the nation's population and three-quarters of its economic activity, the nation's 100 largest metropolitan areas emitted just 56 percent of U.S. carbon emissions from highway transportation and residential buildings in 2005. As a result, residents of metropolitan areas have smaller partial carbon footprints than the average American. The average metropolitan area resident's partial carbon footprint (2.24 metric tons) in 2005 was only 86 percent of the average American's partial footprint (2.60 metric tons). The difference is due primarily to less car travel and residential electricity use, rather than to freight travel and residential fuels.

2. Carbon emissions increased more slowly in metropolitan America than in the rest of the country between 2000 and 2005

Carbon emissions from highway transport and residences in major metropolitan areas increased 7.5 percent from 2000 to 2005, slightly less than the national increase of 9.1 percent. The population of the 100 metropolitan areas, on the other hand, grew by only 6.3 percent.

As a result, the average per capita footprint of the 100 metropolitan areas grew by 1.1 percent during the five-year period, while the U.S. partial carbon footprint increased twice as rapidly (by 2.2 percent) during this same timeframe. While 79 metropolitan areas saw overall growth in their highway transport and residential carbon emissions from 2000 to 2005, only 53 metropolitan areas increased their footprints on a per capita basis. Another 21 metropolitan areas saw their carbon emissions from highway transport and residences decline from 2000 to 2005.

In the 100 metropolitan areas and the nation at large, carbon emissions grew faster from 2000 to 2005 for auto transport and residential electricity use than for freight travel and residential fuels. Trenton, NJ, and Chattanooga, TN, saw the most growth in both total carbon emissions and per capita footprints.[43] Youngstown, OH, and Grand Rapids, MI, conversely, each saw their carbon footprints decline by 14 percent during the five-year period—the largest declines in the 100 metropolitan areas. Both of these urban areas suffered serious losses of economic activity over this period, which undoubtedly contributed to their shrinking carbon signatures. In contrast, Riverside, CA, Bakersfield, CA, and El Paso, TX, reduced their per capita footprints by more than 10 percent despite increasing their total emissions.

Reversing the rising trend in emissions—as many climate scientists warn must happen to mitigate the effects of climate change—poses a distinct challenge for many metropolitan areas and the nation as a whole. Based on data for these two points in time, metropolitan America is constraining the growth of its carbon footprints better than nonmetropolitan areas.

3. Per capita carbon emissions vary substantially by metropolitan area

In 2005, per capita carbon emissions were highest in Lexington, KY, and lowest in Honolulu. The average resident in Lexington emitted 2.5 times more carbon from transport and residences in 2005 than the average resident in Honolulu, at 3.46 metric tons compared with 1.36 metric tons. While readers might immediately defer to the different climatic conditions of these two urban areas – Lexington with a combination of winter heating and summer cooling "loads" and Honolulu with a Mediterranean climate that requires much less space conditioning – in fact, the factors affecting this wide range of carbon footprints are much more complex.

This variation is even more striking when adjusting for a metro area's economic output, or gross metropolitan product (GMP)—an indicator of *carbon intensity*. In this case, the carbon footprints range from a high of 97.6 million metric tons of carbon per dollar GMP in Youngstown, OH, to a low of 22.5 million metric tons per dollar GMP in San Jose, CA—more than a four-fold difference. While these two extremes compare a traditional "rust-belt" area with a "Silicon Valley" information economy, keep in mind that our carbon footprints are limited to emissions from residential and transportation activities. Thus, they do not reflect what would undoubtedly be an even more pronounced difference if we were to have included carbon emissions from the industrial activities in these two urban areas.

In other contrasts, residents in Nashville and St. Louis emitted twice as much carbon from transport and residences, on average, than residents in San Francisco or Seattle.

Regional variation in carbon emissions is apparent. Most notably, the Mississippi River roughly divides the country into high emitters and low emitters (see Figure 3). In 2005, all but one of the 10 largest per capita emitters—Oklahoma City being the exception—were located east of the Mississippi. On the other hand, all but one of the 10 lowest per capita emitters—New York being the exception—were located west of the Mississippi. California alone was home to six of the twenty lowest per capita emitters.

A north-south divide is also apparent. Seven of the highest per capita emitters were located south of the Mason-Dixon Line, including two each from Tennessee, Ohio, and Kentucky. In the northern mid-Atlantic region, Harrisburg, PA, Trenton, NJ, and Toledo, OH, are high per capita emitters.

[figure 3 here]

The West is the only region that reduced its partial carbon footprint between 2000 and 2005. The Midwest, Northeast, and South all increased their per capita carbon emissions. Reflecting the rapid growth and decentralization of many Southern cities, the carbon footprints of metropolitan areas in the South grew more rapidly than in any other region. The South has the dubious distinction of having the largest carbon footprints from both transport and residences of any region in both 2000 and 2005. Fourteen of the 20 metropolitan areas with the largest transportation footprints are in the Census-defined South, and half of the 20 with the largest residential footprints are in the South. Despite this geographic clustering, only 5 metropolitan areas appear in the top-20 list for both transportation and residential energy.

[figures 4 and 5 here]

4. Development patterns and rail transit influence carbon emissions[44]

Population density (that is, the number of persons per acre of developable land), concentration of development (referring to the evenness of population density), and rail transit (based on a threshold number of miles of rail transit lines) all tend to be higher in the lowest-emitting metropolitan areas.[45] Much of what appears as regional variation may actually be due to these spatial factors, as many of the older, denser cities in the Northeast, Midwest, and California (e.g., Boston, New York, Chicago, and San Francisco) are all low emitters.

Generally, knowing a metropolitan area's overall density helps predict its carbon emissions.[46] Dense metropolitan areas such as New York, Los Angeles, and San Francisco stand out for having the smallest transportation and residential footprints. Alternatively, low-density metropolitan areas such as Lexington, Nashville, and Oklahoma City are prominent among the 10 largest per capita emitters.

The benefits of density are not necessarily unique to metropolitan areas. The 100 largest metropolitan areas appear to perform better than than the rest of the country because of their overall density. However, large metropolitan areas have a patchwork of higher- and lower-density areas—density is not uniform across the entire metropolitan area. Therefore, whether in metropolitan areas or small towns, higher-density developments have smaller transportation and residential carbon footprints. This pattern is confirmed by examining population or employment concentration measures, which reflect clustering at the ZIP code scale.[47] This approach to compact development also generates other benefits for its residents, such as the health, safety, and community benefits of walkable communities.[48]

Many metropolitan areas with small per capita footprints also have sizable rail transit ridership. New York, San Francisco, Boston, and Chicago have some of the highest annual rail ridership in the nation, ranging from 296 to 757 miles per capita, and carbon footprints ranging from 1.5 to 2.0 tons of carbon per capita—much lower than the average of 2.2 tons for all 100 metropolitan areas. Looking just at carbon footprints from highway transportation highlights a cluster of low emitters located along the Washington to Boston corridor. In addition to benefiting from rail transit, these cities also tend to have high population densities characteristic of older cities of the Northeast.

There are exceptions to the rail-footprint connection. Washington, DC, Baltimore, and Atlanta, for example, all have high rail transit ridership but also have substantially larger-than-average carbon footprints, underscoring the multi-dimensional nature of carbon footprints.

Finally, freight traffic poses a problem for metropolitan areas trying to shrink their carbon footprints. Bakersfield, CA, for example, has the smallest residential footprint in the sample (at 0.35 metric tons per capita) but the largest transportation footprint in 2005 (at 2.2 metric tons), largely because of its freight traffic contribution. Jacksonville, FL, Sarasota, FL, and Riverside, CA, are similar, with the sixth, seventh, and ninth largest transportation footprints, combined with lower-than-average residential carbon footprints. All three metropolitan areas have or are near port cities with sizable freight traffic. They also report significant miles of travel by combination trucks, which typically involve low efficiency trips that either start or end outside the metropolitan area's boundaries (contributing to what Louis Lebel, et al., call the "logistics" part of a city's carbon footprint).[49]

5. Other factors, such as local climate, the fuels used to generate electricity, and electricity prices also influence footprints

Some areas may perform well on transportation but have large residential footprints. Cleveland, OH, Springfield, MA, and Providence, RI, fit this model. They fall among the 25 lowest emitters for highway transportation but are in the top 25 for residential emissions. These metropolitan areas have high emissions from residential fuels, as do many other Northeastern and Midwestern metropolitan areas.

Climate unmistakably plays a role in residential footprints. Many areas in the Northeast, for instance, have large residential footprints because of their stronger reliance on carbon-intensive home heating fuels such as fuel oil. Warm areas in the South often have large residential footprints because of their heavy reliance on carbon-intensive air conditioning. High-emitting metropolitan areas concentrate throughout the mid-latitude states of the eastern United States where there are substantial combinations of cooling and heating requirements. Alternatively, the 10 metropolitan areas with the smallest per capita residential footprints are all located along the Pacific Ocean, with its milder climate.

The fuel mix used to generate electricity matters in residential footprints. For instance, the Washington, DC, metropolitan area's residential electricity footprint was 10 times larger than Seattle's footprint in 2005.[50] The mix of fuels used to generate electricity in the nation's capital includes high-carbon sources like coal, while Seattle draws its energy primarily from essentially carbon-free hydropower. A high-carbon fuel mix significantly penalizes the Ohio Valley and Appalachian regions, which rely heavily on coal power production. Alternatively, the investor-owned utilities in some states, such as California, no longer purchase electricity from coal power plants, resulting in lower residential carbon footprints.

Electricity prices also appear to influence the residential footprint.[51] Each of the 10 metropolitan areas with the lowest per capita electricity footprints in 2005 hailed from states with higher-than-average prices, including California, New York, Michigan, and Hawaii. On the other hand, many Southeastern metropolitan areas with high electricity consumption have had historically low electricity rates.

* * *

To summarize, large metropolitan areas offer greater energy and carbon efficiency than nonmetropolitan areas, and metropolitan areas have development patterns that show promise for reducing carbon emissions.

Three pressing challenges, however, remain for metropolitan America: First, between 2000 and 2005, carbon footprints grew faster than the population in the 100 largest metropolitan areas, and the nation at large. Second, many of the fastest-growing metropolitan areas are also the least compact, such as Austin, TX, Raleigh, NC, and Nashville, TN. Third, some important factors may be largely beyond the grasp of metropolitan America, such as local climate.

Fortunately, many obstacles can be addressed by policy interventions. In the long run, however, metropolitan America will be hard-pressed to shrink its carbon footprint in the absence of supportive federal policy.

Climate-Smart Policies

Unlike Europe, Japan, and many other developed economies, the population in the U.S. is expected to continue to expand, rising from 300 million today to 420 million in 2050, according to U.S. Census Bureau projections.[52] As the U.S. population grows, the nation must reduce the energy intensity of its economic system and lower the carbon intensity of its energy consumption. Because such transformations require capital, they are often only cost-effective when capital assets are first being built, or when major upgrades, renovations, or system replacements are occurring. If improved technology is not installed at those points in time, the carbon-intensive status quo can be locked in for decades.[53]

The current U.S. economic downturn offers a period of reflection and opportunity to prepare for future demands. With the American Recovery and Reinvestment Act of 2009 (i.e., the “Stimulus Bill”), almost $40 billion of the Bill’s $787 billion appropriation is available to invest in climate-smart infrastructures and facilities. This includes, for example, $3.2 billion to fund a new Energy Efficiency and Conservation Block Grant (EECBG) program that will go to State, local, and tribal governments for energy efficiency and conservation projects. Such resources need to be focused on high-payoff investments that will facilitate the country’s transition to a low-carbon society.

Our research suggests that high-payoff investments are likely to come from investing in the nation’s metropolitan areas, which provide opportunities for more energy- and carbon-efficient lifestyles. In addition, such investment makes sense, as most all of the nation’s built environment and energy infrastructure is concentrated in metropolitan areas and a high percentage of the country’s coming growth will settle in metropolitan areas.

The existence of low-cost opportunities to create climate-friendly metropolitan environments does not necessarily mean that decision-makers and consumers will select low-carbon alternatives. Numerous flaws prevent the market from operating efficiently in tackling the climate challenge. Tackling these flaws requires both major economy-wide public policies, as well as actions focused at the metropolitan scale.

The most important economy-wide market failure is the lack of a price on carbon emissions. Thus, a key remedy involves getting energy prices right by internalizing the climate costs of fossil fuel combustion through carbon taxes or a cap and trade system.[54] Carbon pricing is arguably the most efficient policy mechanism to encourage efficient and low-carbon energy choices, and can only be realistically implemented at the national or international level. More local policies are prone to carbon leakage, spillovers, and free riders.[55] The federal government must also create new programs and policies and expand others to encourage decisions that shrink the nation's carbon footprint. These actions include increasing energy RD&D spending, developing a national renewable electricity standard, and providing better data and technical assistance to states and localities (see Table 1).

In addition, five federal initiatives are needed to promote climate-smart development and ensure success in metropolitan America (see Table 1). First, federal transportation policy must place highway and transit funding decisions on an equal footing, which would encourage new *transit-oriented development* and redevelopment of existing urban spaces. This in turn will improve prospects for reducing the nation's transportation footprint through expanded public transit use and non-motorized travel.

Second, the federal government must facilitate more energy-efficient freight operations, which concentrate in the nation's largest metropolitan areas. Federal actions should start with the establishment of a more effective *regional freight planning* relationship that considers both intra- and inter-metropolitan freight operations. Opportunities for reducing the freight carbon footprint include the use and maintenance of more energy efficient vehicles, the introduction of more energy-efficient intra-urban truck pickup and drop operations, and the location and operation of more energy-efficient freight intermodal terminals. Freight carriers as well as their customers stand to gain financially from more fuel efficient operations, but will need to be convinced of the monetary as well as environmental benefits of making the necessary changes. Efforts such as EPA's SmartWay Transport program, which informs trucking companies of ways they can reduce their fuel bills and associated carbon emissions, offer mechanisms by which the federal government can not only promote, but also support (via innovative financing mechanisms) the adoption of greener transportation options in metropolitan areas.[56]

Third, the federal government must make targeted efforts to improve housing decisions, such as by requiring greater *disclosure of home energy costs* and *"on-bill" financing* options, which would help to upgrade the energy integrity of the nation's building stock. With these disclosures, buyers can gauge energy costs and how those costs may be influenced by the building's current features. As one of the first examples in the U.S., Austin, Texas passed an ordinance in 2008 requiring energy audits before selling homes with a voluntary program for implementing cost effective upgrades; it also sets targets for audits of multifamily units.[57] With on-bill financing, the utility company (and state or federal agency) loans money to consumers, and the loan is repaid in monthly utility bill payments that are no greater than the monthly energy savings.[58] This financing mechanism provides a way for homeowners to borrow money for the purchase of energy-efficient equipment that would save them money in the long term. The effectiveness of this type of program is greatly enhanced by partnering with utilities because they already have an established billing relationship their customers, and they have access to information about energy usage patterns and payment histories.

Fourth, *federal housing financing* should be used to create incentives for energy- and location-efficient housing choices. The federal government has an opportunity to construct market-catalyzing financial products, such as energy-efficient and location-efficient mortgages (EEMs and LEMs). It should also reconsider the mortgage interest deduction, which encourages people to buy more and larger homes on larger lots in less-dense locales.[59] Current mortgage-lending practices encourage homebuyers to "drive until they qualify," by seeking more “affordable” housing farther from the urban core. Homes on the urban fringe become less affordable when energy prices climb, as illustrated when gasoline prices spiked in 2008.[60] Climate-smart housing policies would encourage re-populating the urban core and reducing sprawl, while reducing energy consumption.

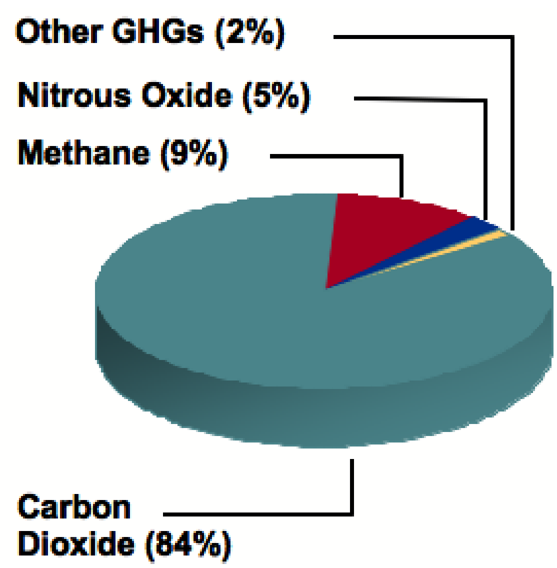
Finally, the federal government should issue a metropolitan challenge grant to encourage metropolitan areas to shrink their carbon footprints by integrating housing, transportation, and economic development policies. Without such holistic approaches, metro actors will be hard-pressed to develop the place-based transformative policies needed to address climate and energy challenges.

[insert Table 1]

Conclusion

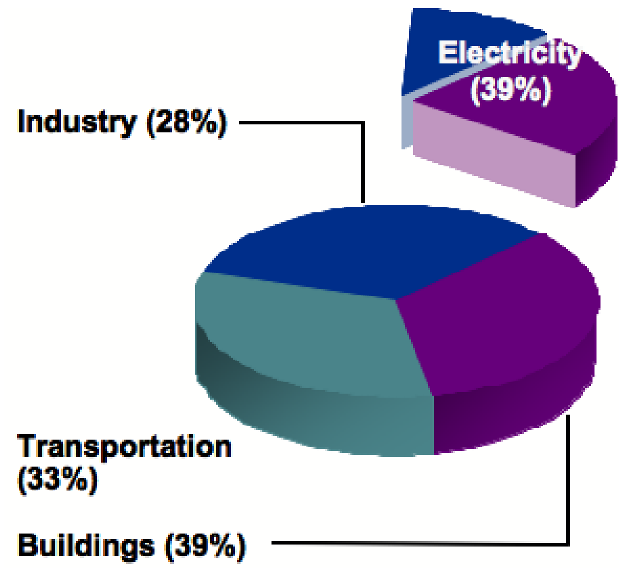
As the nation considers future actions to mitigate global climate change and strengthen energy security, metropolitan areas and the built environment have been largely left out of the discussion. Yet metropolitan areas have provided climate-smart leadership and they could play much bigger roles in the future. Together, a federal metropolitan portfolio of carbon policies could place metropolitan America squarely in the forefront of solutions to the nation’s energy and climate challenges.

Figures 1 and 2. Greenhouse Gas Emissions in the United States, 2005



U.S. GHG Emissions (2005)

Source: EPA. 2007. *Inventory of U.S. GHG Emissions and Sinks: 1990-2006*, 2007, Table 2-1



U.S. CO_2 Emissions by Sector (2005)

Source: EIA. 2007. *Annual Energy Outlook 2007*, Table A18.

Figure 3. Map of Per Capita Carbon Footprints, 2005

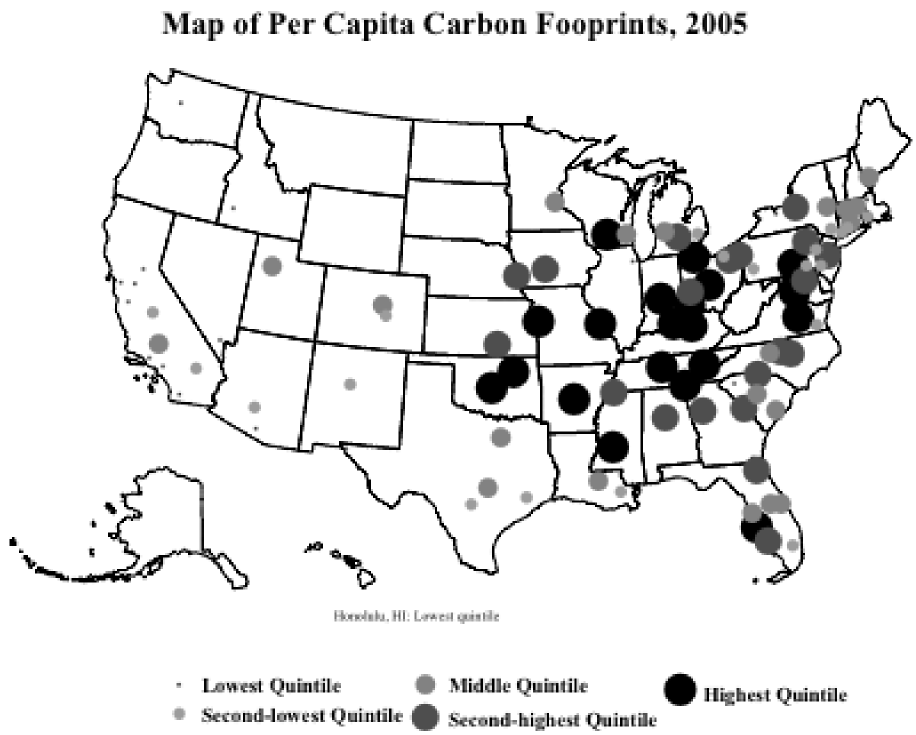


Figure 4. Map of Transportation Per Capita Carbon Footprints, 2005

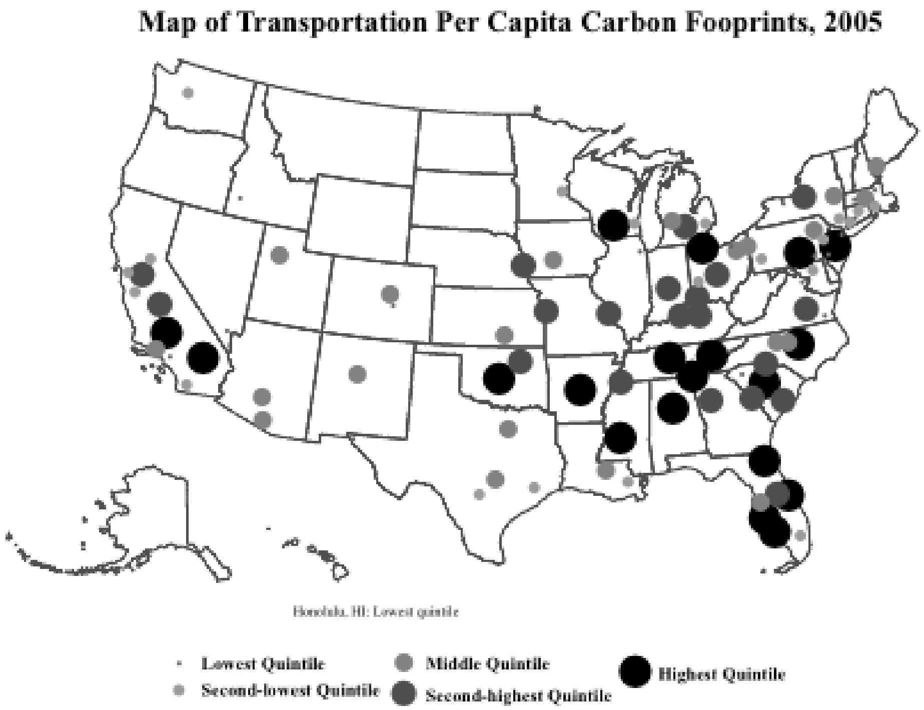


Figure 5. Map of Residential Per Capita Carbon Footprints, 2005

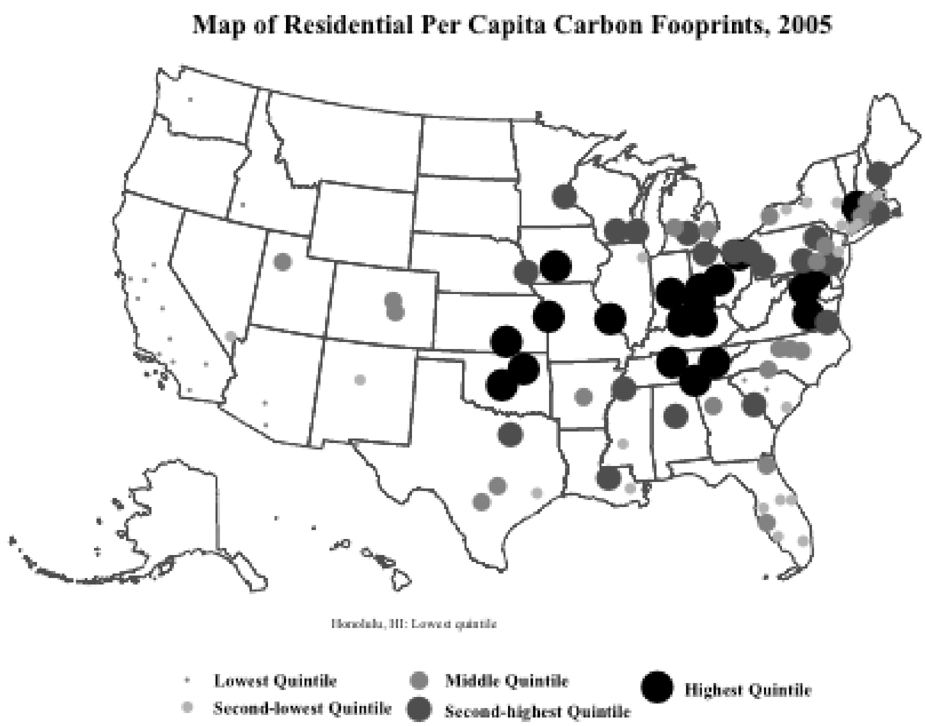


TABLE 1. Ten Recommended Policies That Would Help to Correct the Inadequacies or Flaws in Current Federal Policy

Flaws Addressed by the Policies	**Economy-wide Policies**
Underpriced energy	Put a price on carbon to account for the external costs of fossil fuel combustion
Underfunded federal energy RD&D	Increase funding of energy RD&D to increase energy-efficient and low-carbon innovations and accelerate their use
A lack of national standards	Establish a national renewable electricity standard to foster low-carbon energy markets in a rational and predictable policy environment
State utility pricing policies and cost-recovery regulations thwart energy efficiency improvements and low-carbon options	Help states reform their electricity regulations to promote energy efficiency
Inadequate information on local GHG emissions and best practices	Improve information collection and dissemination on emissions and best practices for states and localities
Flaws Addressed by the Policies	**Targeted Policies**
Federal transportation policy makes more energy-efficient development patterns less viable	Promote more transportation choices to expand transit and compact development options
Federal deference to state and local land use autonomy	Develop regional freight planning to introduce more energy-efficient freight operations
Federal government does not adequately promote energy efficiency in buildings in its housing and building code policies Federal incentives for energy-efficient investments are biased toward newly built homes and higher-income households	Require energy cost disclosure and "on-bill" financing to stimulate and scale up energy-efficient retrofitting
Federal transportation policy inhibits energy-efficient development patterns Mortgage tax policy and lending practices hinder climate-friendly development Federal government fails to leverage its housing finance activities to stimulate energy-efficient building	Use federal housing financing to create incentives for location-efficient mortgages and reform policies that lead to the overconsumption of housing
All of the above	Issue a metropolitan challenge to reward metro areas for developing innovative spatial solutions

NOTES

1. Steve Nicholas, Institute for Sustainable Communities, *Summit on America's Climate Choices*, Washington, DC (March 30, 2009).

2. This chapter draws from research conducted for the Brookings Institution. See Marilyn A. Brown, Frank Southworth, and Andrea Sarzynski, *Shrinking the Carbon Footprint of Metropolitan America* (The Brookings Institution, May 2008); Marilyn A. Brown, Frank Southworth, and Andrea Sarzynski, "The Geography of Metropolitan Carbon Footprints," *Policy and Society*, vol. 27 (2009), pp. 285-304.

3. Fuel combustion produced 94.2 percent of the carbon dioxide emitted in the United States in 2006. Environmental Protection Agency, "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2006" (2008).

4. Energy Information Administration, "Annual Energy Review" (2007), Table 12.1.

5. Ibid.

6. See http://intensityindicators.pnl.gov/trend_data.stm for "U.S. Energy Intensity Indicators: Trend Data" (U.S. Department of Energy); Louis Lebel and others, "Integrating Carbon Management into the Development Strategies of Urbanizing Regions in Asia," *Journal of Industrial Ecology*, vol. 11 (2007), pp. 61-81.

7. Energy Information Administration, *Annual Energy Outlook 2008* (2008), Table A18; Intergovernmental Panel on Climate Change, "Climate Change 2007: The Physical Science Basis; Summary for Policymakers" (2007).

8. Yoichi Kaya, "Impact of Carbon Dioxide Emission Control on GNP Growth: Interpretation of Proposed Scenarios," paper presented to the IPCC Energy and Industry Subgroup, Response Strategies Working Group, Paris, 1990.

9. The U.S. carbon footprint is derived from the Energy Information Administration, *Annual Energy Outlook 2008* (2008), Table A18. The global carbon footprint is derived from the U.S. Energy Information Administration, *Emissions of Greenhouse Gases Report* (U.S. Department of Energy, DOE/EIA-0573, December 3, 2008), and computed by dividing global emissions (28.1 billion metric tons of carbon dioxide) by the world population (6.4 billion) and converting from carbon dioxide to carbon by dividing by 3.67.

10. Council on Competitiveness, "Competitiveness Index: Where America Stands" (2006).

11. Ibid.

12. Energy Information Administration, "Annual Energy Outlook"; Frank Gallivan and others, "The Role of TDM and Other Transportation Strategies in State Climate Action Plans." *TDM Review* (2007): 10–14.

13. Bureau of Transportation Statistics, "National Transportation Statistics 2007" (2007), Table 1-32.

14. See http://cta.ornl.gov/data/index.shtml for "Transportation Energy Data Book," Table 8.5 (Oak Ridge National Laboratory); see www.census.gov/population/www/socdemo/hh-fam.html for "Families and Living Arrangements," Table HH-1 (U.S. Census Bureau).

15. Bureau of Transportation Statistics, "National Transportation Statistics 2007," Table 1-32.

16. David Schrank and Tim Lomax, "The 2007 Urban Mobility Report" (College Station, TX: Texas Transportation Institute, 2007).

17. Environmental Protection Agency, "Light-Duty Automotive Technology and Fuel Economy Trends: 1975 through 2007" (2007).

18. See www.fueleconomy.gov/feg/atv.shtml for "Advanced Technologies and Energy Efficiency" (U.S. Department of Energy and Environmental Protection Agency) .

19. See www.eia.doe.gov/oiaf/servicerpt/lightduty/chapter2.html for “Light-Duty Diesel Vehicles: Efficiency and Emissions Attributes and Market Issues” (Energy Information Administration, February 2009.).

20. The Energy Independence and Security Act of 2007 extends and adds to the 2005 Energy Policy Act Renewable Fuels Standard by setting a goal of 36 billion gallons of renewable fuel annually by 2022, including 16 billion gallons from cellulosic sources. See www.govtrack.us/congress/bill.xpd?bill=h110-6 for "H.R. 6: Energy Independence and Security Act of 2007."

21. National Commission on Energy Policy, "Ending the Energy Stalemate: A Bipartisan Strategy to Meet America's Energy Challenges" (2004).

22. Fred Sissine, "Energy Independence and Security Act of 2007: A Summary of Major Provisions" (Washington: Congressional Research Service, 2007).

23. See www.fueleconomy.gov/feg/choosing.shtml for "Choosing a More Efficient Vehicle" (U.S. Department of Energy and U.S. Environmental Protection Agency); www.afdc.energy.gov/afdc/data/vehicles.html for "Alternative Fuels and Advanced Vehicles Data Center. US HEV Sales by Model. 1999-2008." (U.S. Department of Energy).

24. Energy Information Administration, "Annual Energy Outlook," Table A2. Recently released 2008 estimates are substantially reduced over 2007 estimates.

25. Ibid, Table A18.

26. David B. Sandalow, *Freedom from Oil: How the Next President Can End the United States' Oil Addiction* (New York: McGraw Hill, 2007).

27. Energy Information Administration, "Annual Energy Review," Table 2.1b.

28. Ibid., Table A18.

29. Thomas R. Casten and Robert U. Ayres, "Energy Myth Eight - Worldwide Power Systems Are Economically and Environmental Optimal." In Benjamin K. Sovacool and Marilyn A. Brown, eds., *Energy and American Society - Thirteen Myths* (New York: Springer, 2007).

30. See http://www7.nationalacademies.org/energy/energy_booklet_pdf.pdf for "What you Need to Know About Energy" (National Academy of Sciences, 2008), p. 8.

31. Annex B, Environmental Protection Agency, "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2001" (2007).

32. Marilyn A. Brown, Frank Southworth, and Therese Stovall, "Towards a Climate-Friendly Built Environment" (Washington: Pew Center on Global Climate Change, 2005). See also Energy Information Administration, "Annual Energy Outlook," Table A2.

33. Energy Information Administration, "Annual Energy Outlook," Table A18.

34. Brown, Southworth, and Stovall, "Towards a Climate-Friendly Built Environment."

35. Patrick Mazza, "Transportation and Global Warming Solutions." *Climate Solutions Issue Briefing* (May 2004): 1–4.

36. John Holtzclaw, "A Vision of Energy Efficiency" (Washington: American Council for an Energy-Efficient Economy, 2004).

37. Mary Jean Bürer, David Goldstein, and John Holtzclaw, "Location Efficiency as the Missing Piece of the Energy Puzzle: How Smart Growth Can Unlock Trillion Dollar Consumer Cost Savings" (Washington: Natural Resources Defense Council, 2004).

38. Thomas F Golob and David Brownstone, "The Impact of Residential Density on Vehicle Usage and Energy Consumption," available at http://repositories.cdlib.org/itsirvine/wps/WPS05_01 (March 31 2008).

39. Reid Ewing and others, "Growing Cooler: The Evidence on Urban Development and Climate Change" (Washington: Urban Land Institute, 2007).

40. Based on a -0.3 long-term elasticity of VMT with respect to fuel price, a doubling of fuel prices would reduce VMT by 30 percent. See www.vtpi.org/tdm/tdm11.htm for "Transportation Elasticities: How Prices and Other Factors Affect Travel Behavior" (Victoria Transport Policy Institute).

41. Bürer, Goldstein, and Holtzclaw, "Location Efficiency as the Missing Piece"; Holtzclaw, "A Vision of Energy Efficiency."

42 Other than including the primary energy content of electricity by accounting for the energy lost in electricity generation and transmission, we do not use a full life-cycle assessment of carbon emissions. This means, for instance, that we are not including the carbon emissions embodied in the energy required to produce manufactured goods such as cars, trucks, and buildings. We are also slightly underestimating the GHG emissions from transportation fuels which, according to EPA's 2006 *Greenhouse Gas Emissions from the U.S. Transportation Sector 1990-1993, (Appendix B)* amount to a fuel cycle add-on for gasoline of about 0.24-0.31 or an add-on of 0.15-0.25 for truck diesel.

43. However, the 2000 daily vehicle miles of travel figures for Chattanooga, TN are identified as being unreliable in Highway Statistics 2000 (Table 72) as noted in footnote 43 of Southworth, Sonnenberg, and Brown, "The Transportation Energy and Carbon Footprints of the 100 Largest Metropolitan Areas."

44. Findings 4 and 5 are based on a multiple regression analysis that predicts per capita transportation and residential carbon footprints in 2005 using eight variables. Three variables describe a metro area's urban form: population density, population concentration, and presence of rail transit. Two variables describe a metro area's weather: cooling degree-days and heating degree-days. One variable is the average electricity price in the metro area's primary state. Two control variables were also used for the metro area's population size and its economic productivity (output/person). In combination, the six primary explanatory variables explain nearly half (49 percent) of the variation in per capita carbon footprints across metro areas. Specifically, per capita carbon footprints are lower in metro areas with higher population densities, higher concentrations of population, with at least 10 miles of rail transit infrastructure, fewer cooling degree-days, fewer heating degree-days, and higher electricity prices. Complete urban form measures are not available for Bridgeport, CT, Palm Bay, FL, and Honolulu, HI – resulting in a sample size of 97 metro areas for the regression analysis. For more information, see Marilyn A. Brown and Cecelia (Elise) Logan, "*The Residential Energy and Carbon Footprints of the 100 Largest Metropolitan Areas"* (Atlanta, Ga.: Georgia Institute of Technology School of Public Policy, May 2008), available at www.spp.gatech.edu/faculty/workingpapers.php;.Marilyn A. Brown, Frank

Southworth, and Andrea Sarzynski, “The Geography of Metropolitan Carbon Footprints,” *Policy and Society,* vol. 27 (2009), pp. 285-304.

45. Various urban form measures, including density, population concentration, and transit availability, were included in preliminary analyses. Population density was defined as the number of persons per acre of “developable” land, which excludes water bodies and protected lands such as national and state parks. Although this metric is useful, it is incomplete and does not capture spatial distribution patterns. Population concentration alternatively was defined as the degree to which population was distributed equally throughout the metro area, using a delta index. The values range from 0 to 1, and higher values indicate less clustering and more even distribution of population. For more information, see Frank Southworth, Anthon Sonnenberg, and Marilyn A. Brown. “The Transportation Energy and Carbon Footprints of the 100 Largest Metropolitan Areas,” (Atlanta, Ga.: Georgia Institute of Technology School of Public Policy, May 2008), available at www.spp.gatech.edu/faculty/workingpapers.php.

46. Brown, Southworth, and Sarzynski, "The Geography of Metropolitan Carbon Footprints."

47. For more information, see Southworth, Sonnenberg, and Brown, “The Transportation Energy and Carbon Footprints of the 100 Largest Metropolitan Areas”; Brown, Southworth, and Sarzynski, “The geography of metropolitan carbon footprints.”

48. For an in-depth discussion of the multi-dimensional concept of compact development, see Ewing and others, "Growing Cooler.”

49 Lebel and others, “Integrating Carbon Management into the Development Strategies of Urbanizing Regions in Asia.”

50 The carbon content of a metropolitan area’s electricity consumption was assumed to be the same as the generation mix of the state in which the area’s central city. Thus, for the nation’s capital, we used the carbon dioxide per MWh of electricity generation in the District of Columbia, which is one of the highest in the nation because of its reliance on coal. In actuality, residents of the Washington, DC, metropolitan area draw their electricity from a wider region including Maryland, Virginia, and possibly other states. With the assumption of a lower carbon-based electricity, Washington, DC’s carbon footprint would be

proportionately smaller. Our sensitivity analysis showed that Washington, DC, was one of just a few metropolitan areas where their carbon footprints were subject to significant deviations based on plausible alternative assumptions.

51. Brown, Southworth, and Sarzynski, "The geography of metropolitan carbon footprints."

52. See www.census.gov/population/www/projections/usinterimproj/natprojtab01a.pdf for "Projected Population of the United States, by Race and Hispanic Origin: 2000 to 2050" (U.S. Census Bureau, 2004).

53. Marilyn A. Brown and others, "Carbon Lock-In: Barriers to Deploying Climate Change Mitigation Technologies," (Oak Ridge National Laboratory, 2007).

54. For excellent coverage of potential carbon pricing policies, see "Evaluating the Role of Prices and R&D in Reducing Carbon Dioxide Emissions," (Congressional Budget Office, 2006); Robert N. Stavins, "A U.S. Cap-and-Trade System to Address Global Climate Change" (Brookings Institution, 2007).

55 Sovacool, Benjamin K. and Marilyn A. Brown. 2009. "Scaling the Policy Response to Climate Change," *Policy and Society* 27: 317-328.

56. See www.epa.gov/smartway/transport/index.htm for "Smartway Transport" (U.S. Environmental Protection Agency).

57. See www.cityofaustin.org/edims/document.cfm?id=123737 for "ORDINANCE NO. 20081106-047" (City of Austin, Texas, 2008).

58. For more information on this emerging public policy, see Marilyn A. Brown and others, "Making Homes Part of the Climate Solution: Policy Options to Promote Energy Efficiency" (Oak Ridge: Oak Ridge National Laboratory, TM-2009/104, Draft April, 2009); Matthew Brown, "Brief #3: Paying for Energy Upgrades Through Utility Bills" (Washington, DC: Alliance to Save Energy, 2009); Joel Rogers, "Seizing the Opportunity (For Climate, Jobs, and Equity) in Building Energy Efficiency," November 2007, Unpublished Manuscript.

59. See, for instance, William Gale, Jonathan Gruber, and Seth Stephens-Davidowitz, "Encouraging Homeownership through the Tax Code" (Washington: Urban-Brookings Tax Policy Center, 2007); Joseph Gyourko and Todd Sinai, "The Spatial Distribution of Housing-Related Tax Benefits in the United

States" (Cambridge, MA: National Bureau of Economic Research, 2001); Richard Voith and Joseph Gyourko, "Capitalization of Federal Taxes, the Relative Price of Housing, and Urban Form: Density and Sorting Effects," *Regional Science and Urban Economics* 32 (6) (2002): 673–690.

60. Christopher B. Leinberger, "The Next Slum?" *Atlantic Monthly*, March 2008, pp. 70-75.