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RESIDENTIAL CONSTRUCTION TRENDS IN AMERICA'S METROPOLITAN REGIONS: 2012 EDITION

Office of Sustainable Communities
Smart Growth Program

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Front cover photos:

- *Top left:* Suburban homes in American Canyon, CA. Photo courtesy of Thor Muller.
- *Top right:* New infill residential building with ground floor commercial surrounded by existing building stock in Washington, D.C. Photo courtesy of U.S. EPA.
- *Bottom left:* Suburban housing outside of Las Vega, Nevada. Photo courtesy of John Krzesinski.
- *Bottom middle:* Highland Garden Village infill housing in Denver, Colorado. Photo courtesy of U.S. EPA.
- *Bottom right:* Rockville Town Center in Rockville, Maryland, 15 miles from downtown Washington, D.C., is a mixed-use infill project with apartments, condominiums, office space, a public library, and stores. Photo courtesy of Dan Reed, www.justupthepike.com.

Back cover photos:

- *Top left:* New infill residential building with ground floor commercial surrounded by existing building stock in Washington, D.C. Photo courtesy of U.S. EPA.
- *Top right:* Suburban homes in Village of Loch Loyd, Missouri. Photo courtesy of Craig L. Patterson.
- *Bottom left:* New infill homes in the High Point neighborhood of Seattle, Washington. Photo courtesy of U.S. EPA.
- *Bottom middle:* Rockville Town Center in Rockville, Maryland. Photo courtesy of Dan Reed.
- *Bottom right:* Infill housing in the Barrio Logan neighborhood of San Diego, California. Photo courtesy of U.S. EPA.

Executive Summary

Across the United States, many urban, suburban, and even rural neighborhoods are experiencing dramatic transformations. Parking lots, underused commercial properties, and former industrial sites are being replaced by condominiums, apartments, townhouses, and small-lot single-family homes. These examples of residential infill—or building new homes in previously developed areas—can help to expand housing choices, make neighborhoods livelier, increase the tax base, safeguard rural landscapes, reduce infrastructure costs, and protect natural resources. Infill can also provide significant environmental benefits when compared with conventional greenfield[1] suburban development—including reduced transportation emissions from new residents and reduced stormwater pollution washing off of new roadways and other paved surfaces.

While case studies about successful infill housing projects abound, big questions still remain: Do such examples add up to a fundamental shift in the geography of residential construction? Is infill housing on the rise? Two previous U.S. Environmental Protection Agency (EPA) studies[2] considered these questions by examining residential building permit data at the county or jurisdictional level. Both studies found that, in more than half of the largest U.S. metropolitan regions, central cities and inner suburbs had increased their share of new residential building permits compared to the rest of the metropolitan region. This 2012 study takes advantage of newly available data to paint a more detailed picture of infill development trends. It compares the location of new homes to data about preexisting land cover to determine where infill development was taking place in 209 U.S. metropolitan regions between 2000 and 2009. The findings affirm the overall conclusions of the previous two reports.

Nearly three out of four large metropolitan regions saw an increased share of infill housing development during 2005-2009 compared to 2000-2004. Among the 51 large metropolitan regions (population one million or greater) examined in this study, 36 saw an increased share of infill housing development during 2005-2009 compared to 2000-2004. In many regions, this increase was substantial. Miami increased from 40 percent infill to 49 percent infill. Providence, Rhode Island, increased from 20 percent to 29 percent. Several medium-sized metropolitan regions (population 200,000 – one million) saw even greater shifts towards infill housing.

Infill accounted for one-fifth of new housing construction. Among all 209 metropolitan regions examined in this study, 21 percent of all new home-building occurred in previously developed areas. Northeastern metropolitan regions experienced the most infill construction, with 32 percent of all new housing units built in previously developed areas. In the South, infill accounted for just 16 percent of new home construction.

Infill residential development varied widely among metropolitan regions. Eight out of ten new homes in San Jose, California, were infill. New York, Los Angeles, and San Francisco all saw a majority of new home construction in previously developed areas during the same period. In Austin, Texas, however, infill accounted for only 7 percent of new housing construction. In medium-sized regions, such as Prescott, Arizona, infill's share was as low as 2 percent.

[1] "Greenfield development" is a common term used to describe new development in areas that were not previously developed, such as pastures, croplands, wilderness, and open space.

[2] Thomas, J. *Residential Construction Trends in America's Metropolitan Regions*. U.S. Environmental Protection Agency. January 2009 and January 2010.

Infill is associated with higher home prices and rail transit investment. Metropolitan regions that had a larger share of infill housing development tended to also have higher median home sales prices, more miles of rail transit per capita, and higher transit ridership per capita.

Greenfield home construction exceeded infill in nearly all metropolitan regions. During the later period of this analysis (2005 and 2009), infill as a share of new home construction exceeded 50 percent in only four metropolitan regions. The other 205 metropolitan regions were still adding more housing in greenfield areas than in previously developed areas.

Overall, the findings indicate that infill is a significant portion of residential construction in many metropolitan regions. Yet significant opportunity remains for regions that seek to capture a greater share of new home construction within previously developed areas. Resources are available for local, regional, and state leaders who wish to coordinate land use, housing, and transportation policies in ways that more effectively support infill housing development. Appendix B presents a list of such resources.

Contents

1. Introduction

Rockville Town Center is a vibrant place integrating new apartments and condominium homes with retail, offices, a public library, and a plaza that hosts a variety of outdoor events. Built in 2007 on the site of a failed suburban shopping mall in Rockville, Maryland, nearly 15 miles from downtown Washington, D.C., the Town Center provides a heart and central gathering place in a suburban community that previously had neither.

Figure 1. Rockville Town Center in Rockville, Maryland, 15 miles from downtown Washington, D.C., is a mixed-use infill project with apartments, condominiums, office space, a public library, and stores. Photo credit: Dan Reed.

This example of infill housing—or building new homes in a previously developed area—is far from unique. Similar developments are popping up in urban, suburban, and even rural communities across the United States. Development and redevelopment activities are transforming vacant and underused properties into apartment buildings, condominiums, townhomes, and small-lot single-family homes. One significant benefit of infill development is the ability to support smart growth[3] by locating new homes closer to public transit, stores, workplaces, schools, and other amenities. Studies of consumer preferences and demographic trends indicate that there is a growing demand for the kinds of housing choices that infill development often offers—walkable neighborhoods, shorter commute times, and diverse housing types.[4] Living in this kind of neighborhood allows residents to drive less if they choose—potentially saving money on fuel, parking, and even car ownership.

This kind of infill development also offers significant environmental benefits. Research studies show that people who live in neighborhoods that are walkable, transit accessible, and closer to jobs and services drive less, on average, than people who live in conventional suburban neighborhoods that are more isolated from such amenities.[5] Less driving means fewer emissions from transportation, per resident. Furthermore, reusing land in areas that are already surrounded by buildings, roads, and infrastructure can help reduce pressure to develop open land on the fringes of the metropolitan region—such as farms and other working lands, recreational areas, or environmentally sensitive wild lands. Preserving these areas can offer significant water quality benefits. Building new homes in open space areas results in significantly more paved surfaces than infill construction, due in large part to the new and expanded

[3] The term "smart growth" refers to community development and conservation strategies that promote vibrant, compact, and walkable neighborhoods while preserving natural lands and critical environmental areas, protecting water and air quality, and reusing already-developed land. See www.epa.gov/smartgrowth/about_sg.htm for more information.

[4] Nelson, A. *The New California Dream: How Demographic and Economic Trends May Shape the Housing Market: A Land Use Scenario for 2020 and 2035*. Urban Land Institute. 2011.

Belden Russonello & Stewart LLC. *2011 Community Preference Survey: What Americans are looking for when deciding where to live*. National Association of Realtors. 2011.

[5] Ewing, R., & Cervero, R. "Travel and the Built Environment." *Journal of the American Planning Association*. 2010, 76(3).

roadways needed to serve new homes.[6] When rainwater washes over paved surfaces, it collects and carries pollutants that deteriorate water quality in local streams and waterways.[7]

The environmental benefits of infill development can be substantial. For instance, a 2011 EPA study examined the air quality impacts of 163 infill projects on brownfield properties in five different U.S. metropolitan regions.[8] The study assumed that had any of these infill projects not moved forward, an equivalent amount of development would have occurred at a more conventional alternative location within the same metropolitan region.[9] EPA found that on average these infill projects, relative to a conventional alternative, would result in 32 to 57 percent less air pollution from vehicle emissions per capita. Figure 2 compares the environmental performance of these infill projects compared to their conventional alternatives in each of the five cities studied.

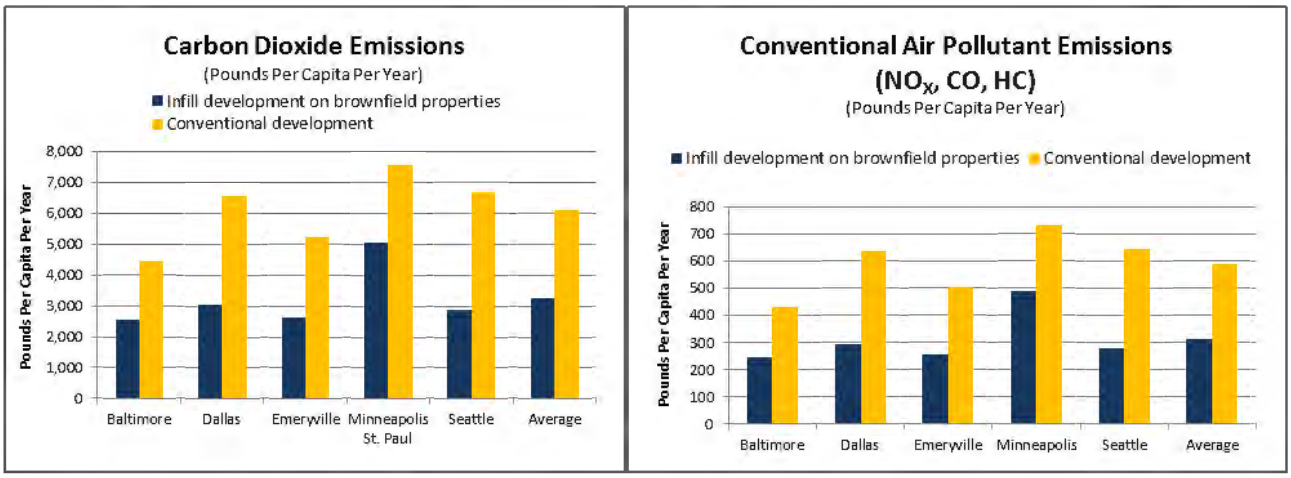

Figure 2. Environmental performance of infill development on brownfield properties when compared to a conventional alternative development site. Source: U.S. Environmental Protection Agency. *Air and Water Quality Impacts of Brownfields Redevelopment: A Study of Five Communities*. 2011.

There are also fiscal reasons that motivate some regions to emphasize infill housing development. Infill takes advantage of previous investments in existing infrastructure (such as water, sewer, and roads) and avoids the cost of expanding new infrastructure to the outer periphery of a metropolitan region.[10] The same principle has been shown to apply to schools and municipal services.[11] Infill housing can also raise surrounding property values, increase a community's tax base, and attract more retail to serve the larger resident population.[12]

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[6] Richards, L. "Water Quality Benefits of Brownfield Redevelopment, Infill Development, and Other Smart Growth Strategies." *Proceedings of the Water Environment Federation (Watershed 2002)*. 2002.

[7] U.S. Environmental Protection Agency. *Our Built and Natural Environments*. 2001.

[8] U.S. Environmental Protection Agency. *Air and Water Quality Impacts of Brownfields Redevelopment: A Study of Five Communities*. 2011.

[9] The study authors selected the alternative locations for each brownfield from sites available within the fastest growing zones of the metropolitan region, in terms of percent population or employment growth. In many, but not all, cases these alternative development locations were in greenfield areas far outside of the urban core.

[10] Burchell, R., et al. *Costs of Sprawl—2000*. Transportation Research Board - National Research Council. 2002.

[11] Coyne, W. *The Fiscal Cost of Sprawl: How Sprawl Contributes to Local Governments' Budget Woes*. The Environment Colorado Research and Policy Center. 2003.

[12] Leonard, J., & Mallach, A. *Restoring Properties, Rebuilding Communities: Transforming Vacant Properties in Today's America*. Center for Community Progress. 2010.

Figure 3. A deteriorating and underused shopping center (left) in Denver, Colorado, was redeveloped into Dahlia Square Senior Apartments (right), which provides affordable homes next to a new medical center. Photo credit: EPA.

While there are many examples of infill housing development in metropolitan regions across the United States, it is less clear whether these examples add up to a fundamental shift in the geography of residential construction. Previous studies have shed a little light on the matter. In a pair of reports released in 2009 and 2010,[13] EPA examined residential building permit data at the county or jurisdictional level. Both studies found that, in more than half of the largest U.S. metropolitan regions, central cities and inner suburbs had increased their share of new residential building permits compared to the rest of the metropolitan region.

Although the two previous studies' findings were notable, the picture of residential construction that they painted was incomplete. Many urban and suburban jurisdictions include both developed and undeveloped areas. Such places can, and often do, include both infill housing construction as well as home construction in open space areas at the periphery. A jurisdiction-level analysis of building permits cannot differentiate between these two kinds of construction.

This study uses new data and spatial analysis techniques to examine residential construction at a much finer geographic scale. It compares the location of new housing development to preexisting land cover to determine the percentage of all new homes that are infill, or built in previously developed areas. The result is a much more detailed picture of the spatial distribution of residential construction. This analysis examined trends in all 209 metropolitan regions across the contiguous United States that have populations over 200,000, and it covered two time periods: 2000 to 2004 and 2005 to 2009.

The study's findings affirm the overall conclusions of the previous two reports. First, as would be expected, the 2008 downturn in the housing market resulted in fewer housing units built in the later half of the decade.[14] However, in many large metropolitan regions (population one million or greater), the percentage of housing units built in previously developed areas increased. Among the 51 large metropolitan regions examined in this study, 36 saw an increased share of infill housing construction from 2005 to 2009 when compared to 2000 to 2004. Miami increased from 40 percent infill to 49 percent infill. Providence, Rhode Island, increased from 20 percent to 29 percent. Several medium-sized metropolitan regions[15] saw even greater shifts towards infill housing. For instance, Santa Barbara, California, increased from 32 percent infill to 48 percent infill. Gainesville, Florida, increased from 8

[13] Thomas, 2009 and 2010.

[14] See Appendix C for a more detailed discussion regarding the significant reduction in total homes built 2005-2009 when compared to 2000-2004 found in the study data.

[15] Medium-sized metropolitan regions are those with populations greater than 200,000 and less than one million.

percent to 22 percent. Among all 209 metropolitan regions studied, infill accounted for 21 percent of new home construction during the entire period of study—2000 to 2009.

Figure 4. Single-family homes under construction in Syracuse, New York. These homes were built within an existing residential neighborhood not far from the city center.
Photo credit: Syracuse Center of Excellence.

While infill accounts for a significant portion of the U.S. housing market, there is a wide disparity among metropolitan regions. Between 2000 and 2009, eight out of ten new homes built in the San Jose, California, metropolitan region were in previously developed areas. New York, Los Angeles, and San Francisco all saw a majority of new home construction in previously developed areas during the same period. However, infill accounted for only 7 percent of new housing construction Austin, Texas. In smaller regions such as Prescott, Arizona, infill's share was as low as 2 percent.

2. Background

Studies of consumer demand indicate that a growing number of Americans are seeking alternatives to the suburban neighborhoods most commonly associated with late-twentieth century housing construction. National studies conducted in 2006 and 2008 indicate that conventional (large-lot) suburban homes account for only 25 to 30 percent of total demand, with the remainder divided between multifamily buildings, townhomes, and small-lot single-family homes.[16] A 2011 survey commissioned by the National Realtors Association found that nearly six in ten adults would prefer to live in a walkable neighborhood with a mix of houses and stores and other businesses nearby.[17] The survey also found that six in ten would choose a smaller house and lot if it meant their commute time would be 20 minutes or less. In many metropolitan regions, housing prices reflect this shift in consumer preference and demand. A 2012 study of the Washington, D.C., metropolitan region found that more walkable neighborhoods command higher prices and rents.[18] A related study found that in the 1990s, the most expensive neighborhoods in the Washington, D.C.; Atlanta; Columbus, Ohio; and Seattle regions were in the outer suburbs. Today, in those same regions, central-city neighborhoods have the highest price per square foot.[19]

[16] See Nelson 2011. Note that the definition of small-lot homes in these studies varied between one-eighth of an acre to one-quarter acre.
[17] Belden Russonello & Stewart, 2011.
[18] Leinberger, C., & Alfonzo, M. *Walk this Way: The Economic Promise of Walkable Places in Metropolitan Washington, D.C.* The Brookings Institution. 2012.
[19] Leinberger, C. "The Death of the Fringe Suburb." *The New York Times*. November 26, 2011. Many metropolitan regions with strong infill development have experienced rising housing costs in central cities. Appendix B lists resources relevant to addressing housing affordability in such situations.

One important driver of this shift in housing demand is demographics. During the Baby Boom era of the 1940s to 1960s, over half of U.S. households had children. Today, fewer than one-third have children, and this percentage is declining.[20] More Americans are having children later in life or not having children at all. In addition, as the baby boomers age, the number of older, empty-nest households is growing.[21] According to one study, between 2010 and 2020, households without children will generate more than 80 percent of the demand for new housing.[22] Amenities typically found in outer suburbs—large backyards and good schools—might not be a priority for many childless households.

Another driver of housing demand is energy costs. Volatile gas prices during the past decade have made people more aware of the transportation costs of living in outer suburbs, where driving is usually the only transportation option. On average, residents of these areas need to drive many more miles to reach jobs, shopping, entertainment, schools, and other destinations compared to residents living closer to the central city or inner suburbs. As a result, they are more vulnerable to spikes in gas prices than people who live in neighborhoods where they can walk, bike, or take public transit to their destinations. Although many homes in outer suburbs are less expensive than comparable homes in inner suburbs and central cities, adding transportation costs can make the closer-in homes a better deal overall.[23]

Even as demand for homes in walkable urban neighborhoods is on the rise, significant barriers still hinder the ability of the market to meet this demand through infill home construction. For instance, many infill projects still must acquire regulatory waivers or public investments in infrastructure to advance. A 2004 study of infill transit-oriented development found that such projects often must obtain updates to zoning codes; more flexible parking regulations;[24] assistance with land assembly; or improvements to water, sewer, and local streets.[25] Even when localities address these issues, permitting processes can still require multiple public hearings, which can add significant time and cost to an infill development project.[26] Finally, some potential redevelopment sites face the burden of real or perceived contamination, and therefore developers often need assistance to evaluate conditions and conduct any necessary cleanup.

Despite these barriers, many local, regional, and state governments are adopting policies to encourage infill development. Examples include designating priority growth areas, requiring "concurrency" (no new construction without adequate infrastructure in place), or targeting state infrastructure investments to previously developed areas. Market-based incentives—such as transfer of development rights

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[20] Nelson, 2011.

[21] Joint Center for Housing Studies. *The State of the Nation's Housing 2012*. Harvard University. 2012.

[22] Nelson, 2011.

[23] Lipman, B. *A Heavy Load: The Combined Housing and Transportation Burdens of Working Families*. Center for Housing Policy. 2006.; ULI Terwilliger Center for Workforce Housing and the Center for Housing Policy. *Beltway Burden: The Combined Cost of Housing and Transportation in the Greater Washington, DC, Metropolitan Area.* 2009.

[24] Many localities require developers to provide a minimum number of parking spots on site for each new housing unit built. Such regulations can significantly increase the cost of building infill housing in areas where many potential residents may not need (or wish) to own a car. A survey of infill developers in 2009 by the Urban Land Institute found that 70% consider minimum parking requirements a significant burden on infill development projects.

[25] Cervero, R. et al. *Transit-Oriented Development in the United States: Experiences, Challenges, and Prospects*. Transit Cooperative Research Program. 2004.

[26] Farris, J. "The Barriers to Using Urban Infill Development to Achieve Smart Growth." *Housing Policy Debate*, 2001, 12(1).; McConnell, V., & Wiley, K. *Infill Development: Perspectives and Evidence from Economics and Planning*. Resources for the Future. 2010.

programs[27]—are also increasingly popular ways to preserve farmland and natural resources in growing metropolitan regions. When successful, these strategies have the added fiscal benefit of encouraging the efficient use of public funds in supporting the infrastructure needs of new housing construction.

3. Findings

- ***Infill accounted for 21 percent of all new housing construction between 2000 and 2009.*** Among all 209 metropolitan regions included in this study, 21 percent of new home-building occurred in previously developed areas. Northeastern metropolitan regions experienced the most infill construction, with 32 percent of all new housing units built in previously developed areas. In the south, infill accounted for only 16 percent of new home construction.[28] Figure 5 shows large metropolitan regions with the highest percentage of infill home construction. Figure 6 shows medium-sized regions with the highest percentage of infill home construction.

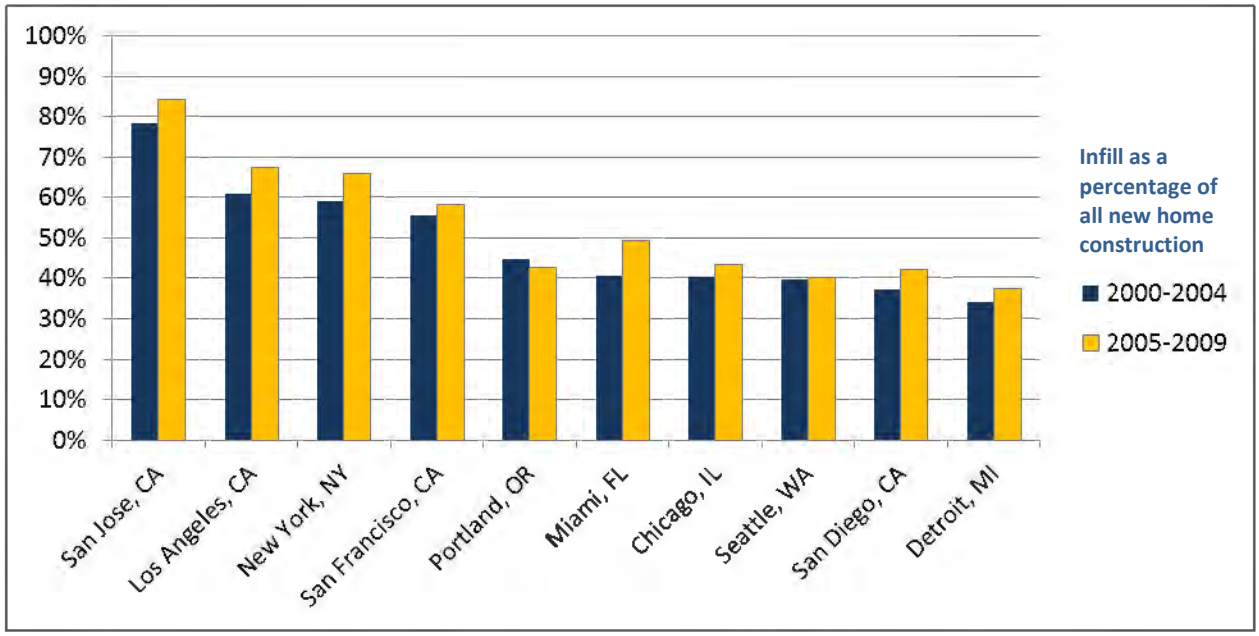

Figure 5. Large metropolitan regions with the greatest share of infill home construction.
Source: EPA analysis of 2009 American Community Survey 5-Year Estimates, 2001 National Land Cover Database, Protected Areas Database of the United States (PADUS) version 1.2., and 2011 Navteq NAVSTREETS.

[27] Transfer of Development Rights (TDR) programs seek to preserve rural or environmentally sensitive areas by allowing landowners' to transfer (or sell) the right to build on their property to a landowner in a location where the government wants to encourage development. The purchasing landowner generally benefits from a change in zoning allowing for increased density.

[28] Infill accounted for 23 percent of all housing development in midwestern metropolitan regions and 25 percent in the west.

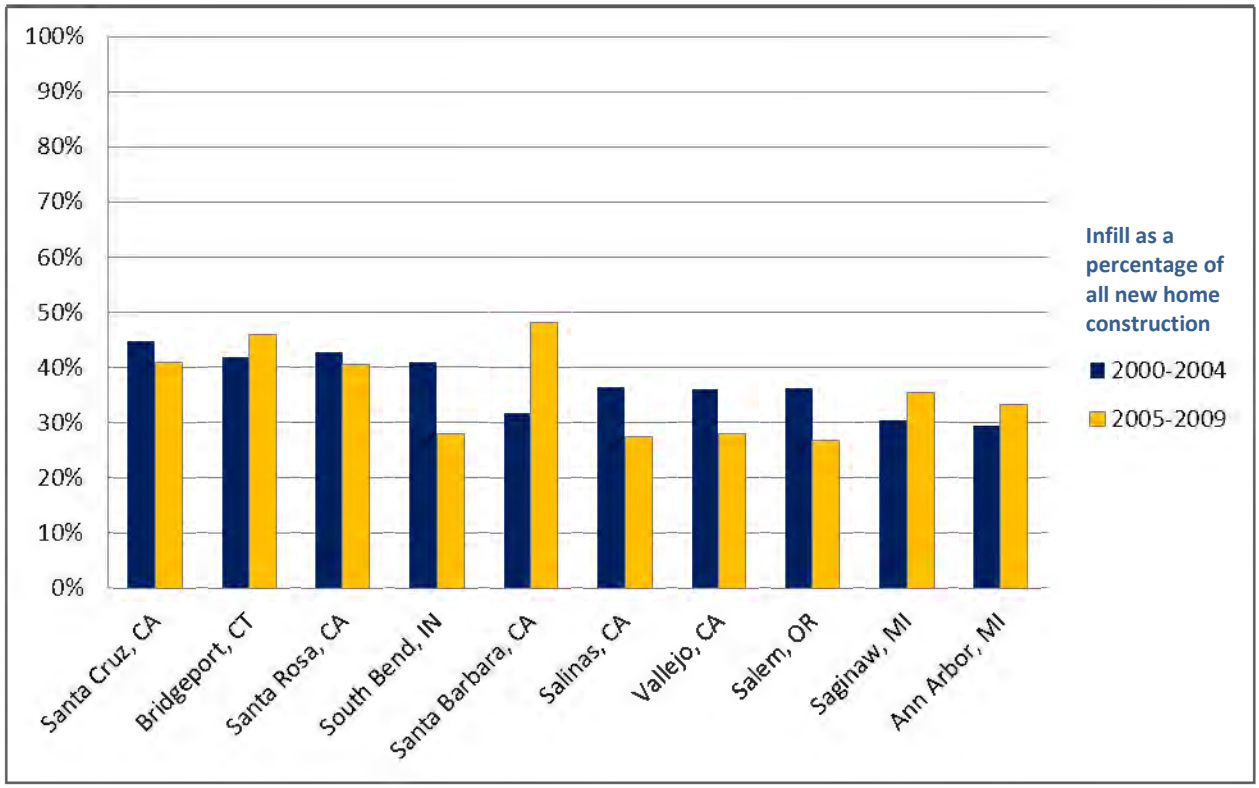

Figure 6. Medium-sized metropolitan regions with the greatest share of infill home construction.
Source: EPA analysis of 2009 American Community Survey 5-Year Estimates, 2001 National Land Cover Database, Protected Areas Database of the United States (PADUS) version 1.2., and 2011 Navteq NAVSTREETS.

- ***Seventy-one percent of large metropolitan regions saw an increased share of infill housing development.***
  Among 51 large metropolitan regions examined in this study, 36 saw an increased share of infill housing development during 2005-2009 when compared to 2000-2004. In many regions, this increase was dramatic. Figure 7 presents large metropolitan regions with the greatest increase in the share infill home construction. Figure 8 presents findings for medium-sized regions.

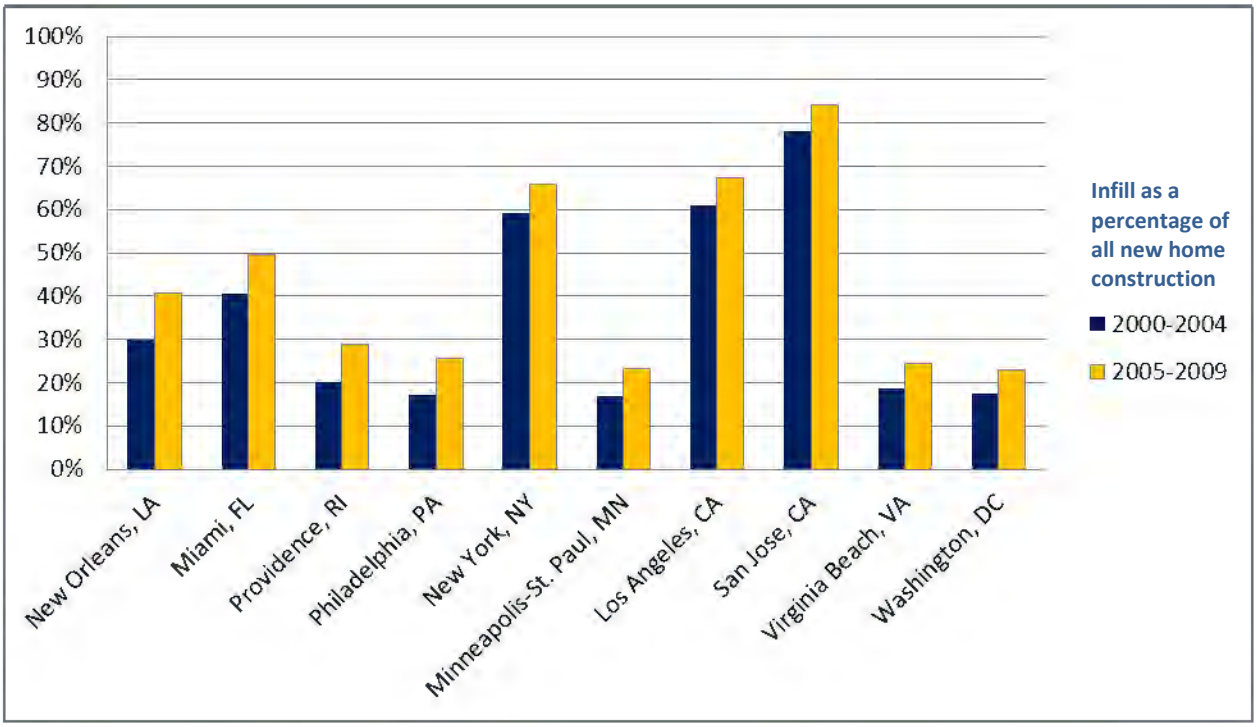

Figure 7. Large metropolitan regions with the greatest increase in share of infill home construction.[29]
Source: EPA analysis of 2009 American Community Survey 5-Year Estimates, 2001 National Land Cover Database, Protected Areas Database of the United States (PADUS) version 1.2., and 2011 Navteq NAVSTREETS.

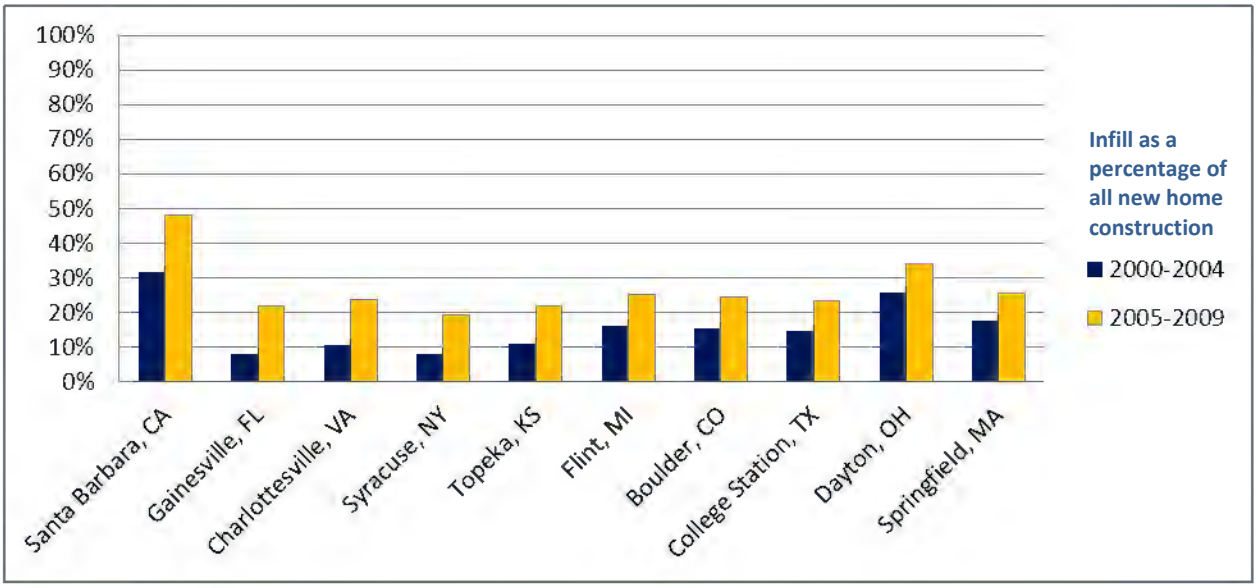

Figure 8. Medium-sized metropolitan regions with the greatest increase in share of infill home construction.
Source: EPA analysis of 2009 American Community Survey 5-Year Estimates, 2001 National Land Cover Database, Protected Areas Database of the United States (PADUS) version 1.2., and 2011 Navteq NAVSTREETS.

[29] Note that the large increase in percentage infill home construction in New Orleans is likely shaped by the rebuilding activity that followed Hurricane Katrina in 2005.

- ***Infill as a percentage of total housing construction varied widely among regions.***
  The proportion of new homes built in previously developed areas varies widely among metropolitan regions. Across the entire period of study, San Jose, California, leads the way among large metropolitan regions with 79.7 percent infill development. New York, Los Angeles, and San Francisco all saw a majority of new home construction in previously developed areas during the same period. However, infill accounted for only 7 percent of new housing construction Austin, Texas. In smaller regions, such as Prescott, Arizona, infill's share was as low as 2 percent. Two maps show how outcomes varied across the country. Figure 9 shows all U.S. metropolitan regions in the study. Figure 10 uses proportional symbols to show the overall volume of infill and total residential construction in the 51 largest metropolitan regions. Statistics for all large and medium-sized metropolitan regions are in Appendix A.

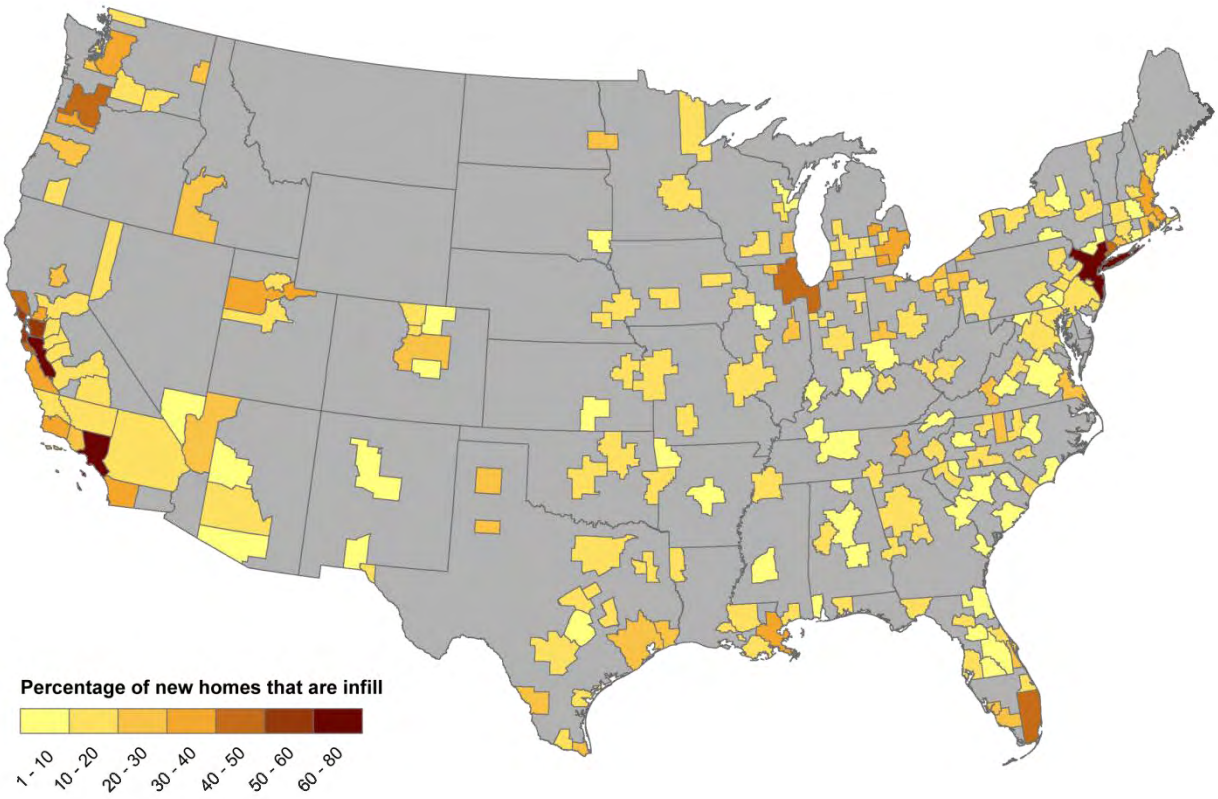

Figure 9. Percentage of new home construction that is infill, 2000 - 2009.
Source: EPA analysis of 2009 American Community Survey 5-Year Estimates, 2001 National Land Cover Database, Protected Areas Database of the United States (PADUS) version 1.2., and 2011 Navteq NAVSTREETS.

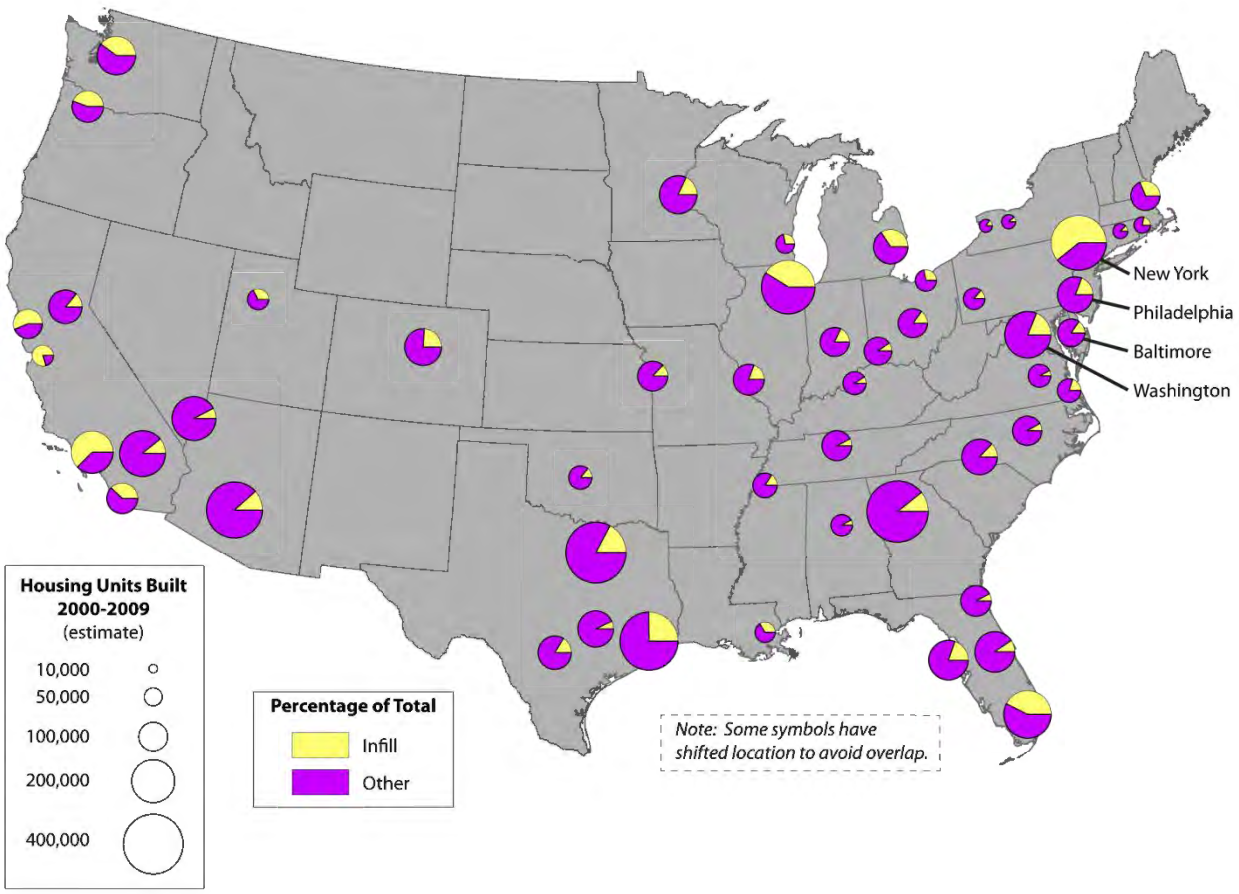

Figure 10. Residential construction volumes (total and infill) in large metropolitan regions.
Source: EPA analysis of 2009 American Community Survey 5-Year Estimates, 2001 National Land Cover Database, Protected Areas Database of the United States (PADUS) version 1.2., and 2011 Navteq NAVSTREETS.

- ***Regions with higher shares of infill development also tend to have higher home prices.*** This study found that metropolitan regions with higher median home sales values during the study period tended to also have a larger share of infill housing development.[30] This finding could be expected given that infill redevelopment projects are often capital intensive and therefore more likely to be built in places where demand is high so that developers can recoup their costs in home sales or rents. Home prices are also higher in regions with urban sub-markets that are supply-constrained. Such areas often have higher demand for a greater variety of housing options such as condominiums, townhomes, and small apartments—products that are typical of infill housing development.

[30] This study calculated the correlation (r) between median home sales price (2000-2009) and percentage of new homes that are infill (2000-2009) to be +0.62. Data on median home sales prices by metropolitan region was obtained from National Association of Realtors.

- ***Regions with higher investment in rail transit tend to have higher shares of infill development.*** Metropolitan regions with more miles of rail transit per 100,000 in population tend to also have higher shares of infill residential construction.[31] Furthermore, regions with greater transit ridership per capita also tend to have higher shares of infill.[32] One possible explanation for this finding is that regions with a greater investment in transit are also more likely to be encouraging Transit Oriented Development (TOD) near rail transit stations. TOD areas generally include a mix of residential and commercial uses with urban design features that promote transit ridership. TOD projects often involve redeveloping underutilized land near existing transit stations within previously developed urban and suburban areas. Rockville Town Center (profiled at the beginning of this report) is an example of TOD. Further analysis could help determine whether infill housing development is more common in areas that are near rail and fixed-guideway transit stations.

- ***Among all regions analyzed, infill home construction did not increase significantly in share.*** While several metropolitan regions experienced a significant increase in share of infill development during 2005-2009 when compared to 2000-2004, the total share of infill among all metropolitan regions remained 21 percent in both periods. Even among large metropolitan regions, the share of infill development only shifted from 23 percent (2000-2004) to 24 percent (2005-2009). This is because some of the fastest growing metropolitan regions, such as Houston, Denver, and Las Vegas, experienced a slight decrease in share of infill development during the study period.

- ***Greenfield home construction exceeds infill in nearly all metropolitan regions.*** During the later period of this analysis (2005 and 2009), infill as a share of new home construction exceeded 50 percent in only four metropolitan regions. The other 205 metropolitan regions were still adding more housing in greenfield areas than in previously developed areas.

4. Residential Construction Trends Not Captured by This Analysis

Given the many connotations associated with the word "infill," it is important to clarify what this study does not capture.

- **Quality or characteristics of new housing development**
  For many practitioners and advocates, the term "infill development" suggests a great deal about the quality of neighborhood design where new homes are being built. Therefore it is important to emphasize that this study does not consider neighborhood characteristics such as walkability, transit accessibility, housing affordability, street connectivity, housing density, or land use mix. Nor does the study consider green building practices or landscape design features that can mitigate some of the environmental impacts of building new homes. Instead, this study only considers whether or not new homes were built in areas that were previously developed.

[31] This study calculated the correlation (r) between directional route miles of rail lines per 100,000 residents (2010) and percentage of new homes that are infill (2000-2009) to be +0.44. This is statistically significant at less than 1% ($p<0.01$). EPA and University of Utah developed data on mileage of transit service by metropolitan region based on an analysis of data from the National Transit Database.

[32] This study calculated the correlation (r) between annual transit passenger miles per capita (2010) and percentage of new homes that are infill (2000-2009) to be +0.51. This is statistically significant at less than 1% ($p<0.01$). EPA and University of Utah developed data on transit ridership based on an analysis of data from the National Transit Database.

- **"Spillover" housing development outside metropolitan region boundaries**
  Metropolitan statistical areas (or MSAs) are aggregations of counties that surround an urbanized area. In most cases an MSA encompasses the entire housing market for a metropolitan region. In some cases metropolitan area housing markets spill over into an adjacent MSA or rural counties. For instance, it could be argued that the Los Angeles regional housing market has spilled beyond the borders of the Los Angeles MSA to also include parts of the neighboring Riverside-San Bernardino MSA. Infill as a share of all housing construction is much lower in Riverside-San Bernardino than it is in Los Angeles. Therefore, excluding this "spillover," housing development potentially overestimates the percentage of housing construction that is infill in the Los Angeles regional housing market—even though the trend is measured accurately within the boundaries of the Los Angeles MSA.

- **Infill in low density suburban areas**
  Infill housing construction is not just an urban phenomenon. It is happening in suburban areas too. In many (possibly most) cases, this study correctly classifies this suburban redevelopment activity as infill. For instance, a close examination of Figure 13 (in Appendix C) shows suburban infill housing construction in previously developed areas outside of Washington, D.C., such as Rockville and Wheaton, Maryland, and Alexandria, Virginia. However, in some cases this study's approach does not classify redevelopment in lower density suburban areas as infill. An example is new residential construction in the former site of Stapleton Airport at the outskirts of Denver. See the methodology section (Appendix C) for a more detailed explanation.

- **Effects of the 2008 decline in the housing market**
  In the wake of the U.S. housing market decline of 2008 and subsequent economic recession, many analysts have speculated about the relationship between residential housing development patterns and housing market resiliency. For instance, a 2011 analysis of Zillow housing price data by zip code in six major U.S. housing markets between 2008 and 2011 showed that housing prices in outer suburbs declined at a higher rate than did prices in established neighborhoods closer to the region's core.[33] Another 2012 report on real estate demand predicts that housing prices will bounce back faster in walkable cities than in the outer suburbs.[34] This study sheds no new insight on this issue. The housing market decline happened midway through the second period of analysis (2005-2009), preventing a clear comparison of trends before and after the housing market decline. Furthermore, the home construction data used in this study is based on the American Community Survey 5-Year Estimates. This data was collected through surveys on an ongoing basis between 2005 and 2009. Surveys conducted earlier during this time period would not count new homes built later in the period. For instance, if the Census surveyed a census block in 2006, it would not have counted new homes built in that same block in 2008. Therefore the estimates for new homes built 2005-2009 are weighted more heavily towards home construction activity during the beginning of the analysis period (before the housing market decline) and against activity that occurred towards the end of the period.

[33] Strozier, Matthew. "Mapping Home-Value Drops by Zip Code." *The Wall Street Journal*. June 28, 2011.
[34] Keely, L., van Ark, B., Levanon, G., & Burbank, J. *The Shifting Nature of U.S. Housing Demand: The U.S. housing market is growing again—but not as we knew it*. Demand Institute. 2012.

5. Questions for Further Research

This study's findings contribute to a growing body of evidence that the geography of residential construction is changing in many U.S. metropolitan regions. Further research could help to quantify the environmental impacts of these trends. For instance, what would have been the environmental outcomes in San Jose, California—where nearly 80% of new homes were infill—if all residential construction had occurred in greenfield areas? What would be the difference in terms of vehicle emissions, stormwater runoff, or loss of habitat and agricultural land?

Further study could also investigate the fiscal impacts of infill development. Advocates of infill argue that the infrastructure costs of greenfield development and the often-related disinvestment in developed areas can put a strain on local government budgets.[35] In the past few years municipalities have had to deal with extreme budget problems, with some cities even declaring bankruptcy or going into receivership.[36] Further research could help to determine whether there is a measurable relationship between infill housing trends and per capita infrastructure expenses. It could also be possible to estimate the infrastructure costs avoided in a metropolitan region by focusing on infill when compared to an alternative scenario where all new housing was built in greenfield areas.

Additional analysis could also help explain *why* some regions have more infill housing development than others. As discussed in Section 2 above, a wide array of factors contribute to the demand for infill development. Likewise there are a wide variety of barriers to infill projects. Therefore it is difficult to isolate the effect of one type of policy or regional characteristic. Nonetheless, further research could provide greater insight into the combination of circumstances, policies, and market dynamics that are associated with a higher (or lower) share of infill housing development. Such insights would allow communities wishing to realize the fiscal, social, and environmental benefits of infill development to better understand which policy strategies might be most effective.

One direction for further research could begin with a systematic assessment of land use and growth management policies affecting the metropolitan regions in this study. This information could help answer questions such as:

- Did any regions with a higher share of infill housing have policies in place to encourage infill? Were there any commonalities between policies that were in place in these regions?
- Did any regions with a lower share of infill housing have policies in place to encourage infill? Were there any commonalities between policies that were in place in these regions?
- Did policies aimed at encouraging infill development appear to have any effect on infill housing outcomes? If so, under what circumstances were those effects most evident?

Further analysis could help to identify market characteristics or other circumstances associated with metropolitan regions that had particularly high or low shares of infill housing development. These insights could help shed light upon the conditions that can make infill housing development most viable or likely to occur, and the conditions under which growth management policies can be most effective. Research questions that fall into this category include:

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[35] For examples, see Smart Growth America. *Smart Growth Benefits Municipal Budgets*. 2010.; Muro, M. *Investing in a Better Future: A Review of the Fiscal and Competitive Advantages of Smarter Growth Development Patterns*. The Brookings Institution. 2004.

[36] Christie, J. "Stockton, California Files for Bankruptcy," *Reuters*. June 28, 2012.; Berg, N. "The 7 Biggest Cities Ever to File for Bankruptcy." *The Atlantic Cities*. June 27, 2012.

- What patterns of demographic change occur in regions with a higher or lower share of infill development?
- What kinds of economic activity predominate in regions with a higher share of infill development? Or what employment sectors are on the rise in these regions?
- Do these regions differ economically from regions with a lower share of infill development?
- Is there any relationship between the built environment (e.g., street intersection density, drinking and waste water infrastructure, housing density, land use mix, etc.) and infill housing development in the regions studied?
- How is quality or frequency of transit service related to infill housing development?
- What other characteristics or circumstances are associated with regions that had a higher share of infill housing? How do these characteristics differ from those in regions with a lower share of infill housing?

The findings of this study could enable a more systematic analysis of the relationship between infill housing development and housing market dynamics. Such findings could help to inform the development of policies to promote stronger housing market resiliency. Specific research questions to this end could include:

- Did median home sales prices fall less dramatically in metropolitan regions with a higher share of infill housing construction?
- Are prices rebounding in these regions more quickly when compared to those with a lower share of infill housing?
- Are home sales prices rebounding any differently in neighborhoods that experienced an influx of infill development, when compared to other neighborhoods in the same metropolitan region?

Finally, a number of previous research studies have identified a relationship between urban redevelopment—including infill housing development—and rising home prices in the surrounding neighborhood.[37] These studies draw attention to the need for communities experiencing or promoting infill housing to proactively consider and address housing affordability impacts. Further research could clarify what kinds of policy strategies have been most successful at preserving housing affordability and preventing displacement in neighborhoods experiencing an influx of infill development.

[37] For examples, see Brueckner, J. and Rosenthal, S. "Gentrification and Neighborhood Housing Cycles: Will America's Future Downtowns Be Rich?" *Review of Economics and Statistics*, 91(4), 725-743. 2009.; Immergluck, D. "Large Redevelopment Initiatives, Housing Values and Gentrification: The Case of the Atlanta Beltline." *Urban Studies*, 46(8). 2009.

Appendix A. Study Results for All 209 Metropolitan Regions

Table 1 presents results for all large metropolitan regions (population one million or greater). Table 2 presents results for medium-sized metropolitan regions (population 200,000 – one million). Note that these construction statistics are based on estimates from the American Community Survey. "Total" refers to the total number of homes built in the metropolitan region. "% Infill" refers to the percentage of total housing construction classified as infill by this study. These statistics do not include housing units in block groups that were screened out of this analysis. See Appendix C for details.

Metropolitan Region (population one million or greater)	2000-2004		2005-2009		2000-2009	
	Total	% Infill	Total	% Infill	Total	% Infill
Atlanta-Sandy Springs-Marietta, GA	344,046	10.6%	115,606	11.1%	459,652	10.7%
Austin-Round Rock-San Marcos, TX	113,921	6.6%	44,203	8.0%	158,124	7.0%
Baltimore-Towson, MD	70,880	14.4%	22,795	18.4%	93,675	15.3%
Birmingham-Hoover, AL	40,782	7.6%	15,891	8.8%	56,673	7.9%
Boston-Cambridge-Quincy, MA-NH	75,886	29.9%	28,841	35.0%	104,727	31.3%
Buffalo-Niagara Falls, NY	16,323	15.6%	4,495	17.0%	20,818	15.9%
Charlotte-Gastonia-Rock Hill, NC-SC	114,374	14.0%	40,833	10.5%	155,207	13.0%
Chicago-Joliet-Naperville, IL-IN-WI	258,848	40.2%	93,667	43.3%	352,515	41.1%
Cincinnati-Middletown, OH-KY-IN	72,949	9.6%	21,896	10.9%	94,845	9.9%
Cleveland-Elyria-Mentor, OH	42,042	27.3%	13,540	29.1%	55,582	27.7%
Columbus, OH	82,901	15.5%	21,236	12.8%	104,137	14.9%
Dallas-Fort Worth-Arlington, TX	326,232	17.5%	118,640	16.6%	444,872	17.2%
Denver-Aurora-Broomfield, CO	121,894	24.7%	36,911	20.8%	158,805	23.8%
Detroit-Warren-Livonia, MI	115,707	33.8%	29,516	37.2%	145,223	34.5%
Hartford-West Hartford-East Hartford, CT	20,483	11.6%	6,579	16.4%	27,062	12.7%
Houston-Sugar Land-Baytown, TX	291,138	26.6%	119,777	21.6%	410,915	25.2%
Indianapolis-Carmel, IN	80,865	19.2%	24,118	15.1%	104,983	18.3%
Jacksonville, FL	79,697	7.4%	33,873	8.1%	113,570	7.6%
Kansas City, MO-KS	81,151	12.6%	25,954	14.7%	107,105	13.1%
Las Vegas-Paradise, NV	170,776	8.2%	64,522	6.1%	235,298	7.6%
Los Angeles-Long Beach-Santa Ana, CA	164,556	61.0%	51,584	67.5%	216,140	62.6%
Louisville/Jefferson County, KY-IN	51,404	9.6%	15,304	7.1%	66,708	9.1%
Memphis, TN-MS-AR	55,733	15.3%	16,552	18.1%	72,285	15.9%
Miami-Fort Lauderdale-Pompano Beach, FL	216,986	40.6%	59,099	49.4%	276,085	42.5%
Milwaukee-Waukesha-West Allis, WI	33,523	27.3%	10,777	30.8%	44,300	28.2%
Minneapolis-St. Paul-Bloomington, MN-WI	133,491	16.9%	38,318	23.3%	171,809	18.3%
Nashville-Davidson-Murfreesboro-Franklin, TN	77,837	6.1%	31,588	10.8%	109,425	7.5%

Metropolitan Region (population one million or greater)	2000-2004		2005-2009		2000-2009	
	Total	% Infill	Total	% Infill	Total	% Infill
New Orleans-Metairie-Kenner, LA	30,214	29.9%	18,043	40.7%	48,257	33.9%
New York-Northern New Jersey-Long Island, NY-NJ-PA	277,389	59.1%	93,159	65.9%	370,548	60.8%
Oklahoma City, OK	44,218	14.4%	18,726	12.4%	62,944	13.8%
Orlando-Kissimmee-Sanford, FL	149,230	9.5%	48,532	9.6%	197,762	9.5%
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	118,366	17.1%	39,573	25.5%	157,939	19.2%
Phoenix-Mesa-Glendale, AZ	274,133	12.0%	109,246	10.9%	383,379	11.6%
Pittsburgh, PA	42,789	13.6%	13,052	15.6%	55,841	14.1%
Portland-Vancouver-Hillsboro, OR-WA	90,163	44.8%	29,891	42.8%	120,054	44.3%
Providence-New Bedford-Fall River, RI-MA	24,658	20.2%	7,498	28.9%	32,156	22.2%
Raleigh-Cary, NC	76,870	8.0%	28,508	8.6%	105,378	8.2%
Richmond, VA	46,306	7.1%	17,635	9.5%	63,941	7.7%
Riverside-San Bernardino-Ontario, CA	180,955	11.3%	75,350	10.1%	256,305	11.0%
Rochester, NY	18,991	10.1%	5,759	14.7%	24,750	11.1%
Sacramento-Arden-Arcade-Roseville, CA	103,516	13.0%	31,719	16.5%	135,235	13.8%
Salt Lake City, UT	39,303	33.6%	12,554	29.2%	51,857	32.5%
San Antonio-New Braunfels, TX	91,755	17.5%	42,352	12.7%	134,107	16.0%
San Diego-Carlsbad-San Marcos, CA	89,633	37.0%	26,280	42.1%	115,913	38.2%
San Francisco-Oakland-Fremont, CA	77,510	55.6%	24,433	58.4%	101,943	56.2%
San Jose-Sunnyvale-Santa Clara, CA	39,784	78.2%	13,148	84.1%	52,932	79.7%
Seattle-Tacoma-Bellevue, WA	131,137	39.7%	46,878	40.1%	178,015	39.8%
St. Louis, MO-IL	86,614	18.8%	30,549	20.4%	117,163	19.2%
Tampa-St. Petersburg-Clearwater, FL	142,716	19.9%	48,246	19.4%	190,962	19.8%
Virginia Beach-Norfolk-Newport News, VA-NC	50,368	18.7%	17,866	24.5%	68,234	20.3%
Washington-Arlington-Alexandria, DC-VA-MD-WV	200,497	17.6%	62,406	23.0%	262,903	18.9%

Table 1: Housing construction statistics, large metropolitan regions (populations greater than one million).

Metropolitan Region (population between 200,000 and one million)	2000-2004		2005-2009		2000-2009	
	Total	% Infill	Total	% Infill	Total	% Infill
Akron, OH	19,333	18.9%	5,523	16.0%	24,856	18.2%
Albany-Schenectady-Troy, NY	18,830	11.6%	5,480	11.4%	24,310	11.6%
Albuquerque, NM	41,265	8.9%	14,748	8.5%	56,013	8.8%
Allentown-Bethlehem-Easton, PA-NJ	22,230	10.8%	8,028	16.2%	30,258	12.2%
Amarillo, TX	6,645	28.6%	2,553	25.9%	9,198	27.8%
Ann Arbor, MI	14,580	29.4%	2,917	33.3%	17,497	30.0%
Appleton, WI	10,489	14.1%	2,095	18.0%	12,584	14.7%
Asheville, NC	19,592	11.9%	7,032	10.2%	26,624	11.4%
Atlantic City-Hammonton, NJ	10,537	16.7%	3,690	17.0%	14,227	16.8%
Augusta-Richmond County, GA-SC	21,046	6.5%	8,677	8.2%	29,723	7.0%
Bakersfield-Delano, CA	26,852	12.2%	13,259	9.6%	40,111	11.3%
Barnstable Town, MA	7,654	10.9%	1,220	10.7%	8,874	10.9%
Baton Rouge, LA	34,097	17.2%	12,681	16.1%	46,778	16.9%
Beaumont-Port Arthur, TX	10,429	28.2%	4,742	32.7%	15,171	29.6%
Bellingham, WA	9,479	17.3%	3,530	14.8%	13,009	16.6%
Binghamton, NY	2,707	6.6%	710	11.5%	3,417	7.6%
Boise City-Nampa, ID	40,623	28.9%	16,564	19.9%	57,187	26.3%
Boulder, CO	11,648	15.5%	2,327	24.3%	13,975	17.0%
Bremerton-Silverdale, WA	7,795	14.5%	2,849	10.6%	10,644	13.5%
Bridgeport-Stamford-Norwalk, CT	13,371	41.6%	4,872	45.8%	18,243	42.8%
Brownsville-Harlingen, TX	19,642	24.2%	6,234	28.7%	25,876	25.3%
Burlington-South Burlington, VT	5,606	10.2%	1,924	13.1%	7,530	10.9%
Canton-Massillon, OH	9,152	25.5%	2,585	22.4%	11,737	24.8%
Cape Coral-Fort Myers, FL	73,005	20.9%	26,193	21.4%	99,198	21.1%
Cedar Rapids, IA	10,410	14.0%	3,763	11.8%	14,173	13.4%
Champaign-Urbana, IL	7,523	31.2%	3,926	26.1%	11,449	29.4%
Charleston, WV	6,951	13.6%	1,814	16.5%	8,765	14.2%
Charleston-North Charleston-Summerville, SC	36,985	6.4%	14,680	6.2%	51,665	6.4%
Charlottesville, VA	10,007	10.7%	2,676	23.5%	12,683	13.4%
Chattanooga, TN-GA	19,493	9.5%	7,369	13.6%	26,862	10.6%
Chico, CA	6,184	25.5%	2,042	19.5%	8,226	24.0%
Clarksville, TN-KY	13,240	2.8%	6,487	2.8%	19,727	2.8%
College Station-Bryan, TX	11,409	14.8%	3,849	23.5%	15,258	17.0%

Metropolitan Region (population between 200,000 and one million)	2000-2004		2005-2009		2000-2009	
	Total	% Infill	Total	% Infill	Total	% Infill
Colorado Springs, CO	34,946	9.2%	11,216	6.3%	46,162	8.5%
Columbia, SC	36,650	5.8%	12,773	9.4%	49,423	6.7%
Columbus, GA-AL	11,359	15.8%	4,201	16.4%	15,560	16.0%
Corpus Christi, TX	12,826	16.0%	5,469	21.6%	18,295	17.7%
Davenport-Moline-Rock Island, IA-IL	7,451	14.3%	2,583	17.6%	10,034	15.1%
Dayton, OH	19,326	25.9%	5,501	33.9%	24,827	27.7%
Deltona-Daytona Beach-Ormond Beach, FL	30,370	19.1%	8,166	17.5%	38,536	18.8%
Des Moines-West Des Moines, IA	24,176	10.7%	10,700	10.4%	34,876	10.6%
Duluth, MN-WI	7,414	12.9%	2,195	17.4%	9,609	14.0%
Durham-Chapel Hill, NC	28,687	14.0%	9,613	20.5%	38,300	15.7%
El Paso, TX	24,994	10.3%	10,281	11.1%	35,275	10.5%
Erie, PA	4,348	21.5%	1,437	26.8%	5,785	22.8%
Eugene-Springfield, OR	10,803	28.1%	3,899	28.3%	14,702	28.1%
Evansville, IN-KY	12,068	6.6%	3,277	5.7%	15,345	6.4%
Fargo, ND-MN	9,912	22.9%	3,712	17.3%	13,624	21.4%
Fayetteville, NC	16,425	15.4%	8,177	15.5%	24,602	15.5%
Fayetteville-Springdale-Rogers, AR-MO	28,426	8.5%	11,974	7.5%	40,400	8.2%
Flint, MI	15,089	15.9%	3,431	25.2%	18,520	17.6%
Florence, SC	7,251	10.3%	1,806	6.4%	9,057	9.5%
Fort Collins-Loveland, CO	18,068	16.5%	5,493	8.4%	23,561	14.6%
Fort Smith, AR-OK	8,888	11.8%	2,945	5.6%	11,833	10.3%
Fort Wayne, IN	12,612	17.4%	3,433	16.3%	16,045	17.2%
Fresno, CA	24,733	18.7%	11,828	19.9%	36,561	19.1%
Gainesville, FL	13,308	8.1%	5,729	21.9%	19,037	12.3%
Grand Rapids-Wyoming, MI	26,343	12.4%	5,813	16.1%	32,156	13.0%
Greeley, CO	21,564	7.5%	6,055	6.2%	27,619	7.2%
Green Bay, WI	14,333	6.7%	3,083	3.4%	17,416	6.1%
Greensboro-High Point, NC	33,271	24.2%	11,529	27.3%	44,800	25.0%
Greenville-Mauldin-Easley, SC	29,366	9.7%	10,203	14.9%	39,569	11.1%
Gulfport-Biloxi, MS	13,240	16.6%	9,787	22.4%	23,027	19.1%
Hagerstown-Martinsburg, MD-WV	12,851	9.0%	4,931	8.1%	17,782	8.8%
Harrisburg-Carlisle, PA	14,315	13.3%	5,044	11.0%	19,359	12.7%
Hickory-Lenoir-Morganton, NC	13,513	9.6%	3,476	7.3%	16,989	9.1%

Metropolitan Region (population between 200,000 and one million)	2000-2004		2005-2009		2000-2009	
	Total	% Infill	Total	% Infill	Total	% Infill
Holland-Grand Haven, MI	12,470	18.8%	3,332	19.0%	15,802	18.8%
Houma-Bayou Cane-Thibodaux, LA	7,987	18.0%	2,333	15.7%	10,320	17.4%
Huntington-Ashland, WV-KY-OH	7,280	18.8%	1,785	16.1%	9,065	18.2%
Huntsville, AL	18,555	5.2%	8,473	3.4%	27,028	4.6%
Jackson, MS	22,337	6.8%	8,521	7.2%	30,858	6.9%
Kalamazoo-Portage, MI	11,517	15.2%	3,311	19.5%	14,828	16.1%
Kennewick-Pasco-Richland, WA	11,680	18.0%	4,659	13.7%	16,339	16.7%
Killeen-Temple-Fort Hood, TX	20,752	12.2%	9,167	9.9%	29,919	11.5%
Kingsport-Bristol-Bristol, TN-VA	9,560	4.1%	2,830	1.5%	12,390	3.5%
Knoxville, TN	29,754	19.2%	11,975	25.2%	41,729	20.9%
Lafayette, IN	8,427	17.3%	2,267	9.9%	10,694	15.7%
Lafayette, LA	11,431	18.7%	4,201	14.7%	15,632	17.7%
Lake Havasu City-Kingman, AZ	16,434	27.1%	5,461	19.2%	21,895	25.1%
Lakeland-Winter Haven, FL	40,901	4.9%	17,467	7.4%	58,368	5.6%
Lancaster, PA	14,278	7.8%	4,857	9.6%	19,135	8.3%
Lansing-East Lansing, MI	15,883	13.5%	3,433	17.5%	19,316	14.2%
Laredo, TX	11,016	20.9%	3,807	19.4%	14,823	20.5%
Las Cruces, NM	9,063	10.7%	4,344	4.3%	13,407	8.6%
Lexington-Fayette, KY	21,972	14.5%	8,953	12.7%	30,925	14.0%
Lincoln, NE	12,375	15.1%	3,811	15.3%	16,186	15.2%
Little Rock-North Little Rock-Conway, AR	31,592	8.2%	12,981	10.8%	44,573	9.0%
Longview, TX	4,997	14.2%	1,851	8.6%	6,848	12.7%
Lubbock, TX	11,267	24.6%	4,694	9.7%	15,961	20.2%
Lynchburg, VA	7,098	1.3%	2,385	3.7%	9,483	1.9%
Macon, GA	7,858	10.6%	2,369	12.4%	10,227	11.0%
Madison, WI	28,195	11.7%	8,520	13.1%	36,715	12.0%
Manchester-Nashua, NH	10,787	14.1%	2,619	18.3%	13,406	14.9%
McAllen-Edinburg-Mission, TX	45,228	17.5%	16,857	15.4%	62,085	16.9%
Medford, OR	11,052	14.9%	3,356	17.8%	14,408	15.6%
Merced, CA	10,276	15.7%	4,051	8.1%	14,327	13.6%
Mobile, AL	12,657	9.6%	4,975	8.6%	17,632	9.3%
Modesto, CA	19,257	13.6%	6,282	14.4%	25,539	13.8%
Montgomery, AL	14,888	7.5%	5,975	4.8%	20,863	6.7%

Metropolitan Region (population between 200,000 and one million)	2000-2004		2005-2009		2000-2009	
	Total	% Infill	Total	% Infill	Total	% Infill
Myrtle Beach-North Myrtle Beach-Conway, SC	28,507	11.2%	10,527	8.1%	39,034	10.4%
Naples-Marco Island, FL	35,148	27.5%	7,173	23.1%	42,321	26.7%
New Haven-Milford, CT	11,564	30.3%	3,962	26.3%	15,526	29.3%
Norwich-New London, CT	5,661	5.3%	2,703	3.7%	8,364	4.8%
Ocala, FL	27,686	3.7%	10,471	6.2%	38,157	4.4%
Ogden-Clearfield, UT	22,817	18.6%	8,073	11.9%	30,890	16.9%
Olympia, WA	11,140	24.0%	5,122	11.4%	16,262	20.0%
Omaha-Council Bluffs, NE-IA	27,267	18.2%	10,017	13.1%	37,284	16.8%
Oxnard-Thousand Oaks-Ventura, CA	19,669	24.5%	5,223	27.6%	24,892	25.1%
Palm Bay-Melbourne-Titusville, FL	32,145	19.7%	12,144	21.4%	44,289	20.1%
Pensacola-Ferry Pass-Brent, FL	23,327	11.3%	8,625	14.9%	31,952	12.3%
Peoria, IL	8,387	11.2%	3,027	3.1%	11,414	9.1%
Port St. Lucie, FL	32,494	16.3%	12,939	19.4%	45,433	17.2%
Portland-South Portland-Biddeford, ME	19,114	10.5%	5,844	9.3%	24,958	10.2%
Poughkeepsie-Newburgh-Middletown, NY	15,988	5.0%	4,603	6.1%	20,591	5.3%
Prescott, AZ	16,887	1.8%	5,400	1.4%	22,287	1.7%
Provo-Orem, UT	22,442	20.6%	9,894	17.8%	32,336	19.7%
Reading, PA	11,372	16.5%	3,123	8.9%	14,495	14.8%
Reno-Sparks, NV	27,469	13.8%	8,839	12.8%	36,308	13.6%
Roanoke, VA	8,096	22.3%	1,909	26.6%	10,005	23.1%
Rockford, IL	10,461	22.7%	3,975	20.5%	14,436	22.1%
Saginaw-Saginaw Township North, MI	4,982	30.4%	976	35.2%	5,958	31.2%
Salem, OR	12,215	36.3%	4,170	26.8%	16,385	33.8%
Salinas, CA	9,187	36.4%	2,259	27.4%	11,446	34.6%
San Luis Obispo-Paso Robles, CA	11,421	18.5%	3,765	22.0%	15,186	19.4%
Santa Barbara-Santa Maria-Goleta, CA	9,439	31.6%	2,325	48.2%	11,764	34.9%
Santa Cruz-Watsonville, CA	5,016	44.7%	1,570	41.0%	6,586	43.8%
Santa Rosa-Petaluma, CA	14,216	42.6%	4,923	40.4%	19,139	42.1%
Savannah, GA	16,992	9.5%	7,633	10.0%	24,625	9.7%
Scranton--Wilkes-Barre, PA	7,677	16.8%	2,562	15.6%	10,239	16.5%
Shreveport-Bossier City, LA	12,596	17.5%	5,507	13.1%	18,103	16.2%
Sioux Falls, SD	11,083	10.4%	3,717	7.2%	14,800	9.6%
South Bend-Mishawaka, IN-MI	7,666	40.8%	2,191	28.0%	9,857	38.0%

Metropolitan Region (population between 200,000 and one million)	2000-2004		2005-2009		2000-2009	
	Total	% Infill	Total	% Infill	Total	% Infill
Spartanburg, SC	12,801	3.4%	3,887	3.2%	16,688	3.4%
Spokane, WA	13,463	25.3%	6,426	19.8%	19,889	23.5%
Springfield, IL	6,165	11.2%	2,127	18.9%	8,292	13.2%
Springfield, MA	7,662	17.6%	3,029	25.4%	10,691	19.8%
Springfield, MO	22,381	19.1%	9,462	16.0%	31,843	18.2%
Stockton, CA	30,050	13.9%	9,283	17.2%	39,333	14.7%
Syracuse, NY	11,191	8.1%	3,119	19.3%	14,310	10.5%
Tallahassee, FL	16,359	15.0%	6,341	19.8%	22,700	16.3%
Toledo, OH	16,402	23.7%	4,853	20.4%	21,255	22.9%
Topeka, KS	6,410	10.9%	1,836	21.9%	8,246	13.4%
Trenton-Ewing, NJ	8,297	15.1%	2,359	19.7%	10,656	16.1%
Tucson, AZ	48,838	9.0%	18,944	9.4%	67,782	9.1%
Tulsa, OK	31,492	18.1%	11,755	12.9%	43,247	16.7%
Tuscaloosa, AL	9,972	14.8%	4,695	15.5%	14,667	15.1%
Tyler, TX	7,024	10.7%	3,413	10.9%	10,437	10.7%
Utica-Rome, NY	3,297	4.4%	1,430	11.4%	4,727	6.5%
Vallejo-Fairfield, CA	15,199	35.9%	3,819	28.0%	19,018	34.3%
Visalia-Porterville, CA	13,009	18.4%	6,332	12.5%	19,341	16.4%
Waco, TX	8,009	13.7%	2,630	14.3%	10,639	13.8%
Wichita, KS	18,168	10.0%	6,875	8.5%	25,043	9.6%
Wilmington, NC	26,754	4.3%	7,820	6.0%	34,574	4.7%
Winston-Salem, NC	21,009	14.7%	7,065	13.4%	28,074	14.4%
Worcester, MA	16,608	5.2%	5,414	11.4%	22,022	6.7%
Yakima, WA	5,173	18.0%	1,859	14.6%	7,032	17.1%
York-Hanover, PA	15,038	3.5%	5,315	8.0%	20,353	4.7%
Youngstown-Warren-Boardman, OH-PA	10,751	20.8%	2,319	23.8%	13,070	21.3%

Table 2. Housing construction statistics, medium-sized metropolitan regions (population between 200,000 and one million).

Appendix B: Resources on Smart Growth and Infill Residential Construction

There are a number of resources available to communities that are seeking to promote infill housing construction through the adoption of smart growth strategies.

- ***Essential Smart Growth Fixes for Urban and Suburban Zoning Codes***
  U.S. Environmental Protection Agency. 2009.
  In many localities, land development codes and ordinances create significant barriers to infill development that can help to achieve smart growth objectives. This report describes the most common problems local governments face in implementing smart growth strategies and a variety of actions communities can take to address them.
  www.epa.gov/smartgrowth/essential_fixes.htm

- ***Creating Great Neighborhoods: Density in Your Community***
  Local Government Commission, EPA, National Association of Realtors. 2003.
  Nearly all infill housing projects increase the density of development within existing communities. There is an increasing recognition nationwide that density is an integral component to the creation of neighborhoods that offer convenience, value, and a high quality of life. This publication highlights the success of nine community-led efforts to create vibrant neighborhoods through density, provides readers with an understanding of the connections between smart growth and density, and introduces five time-tested design principles to ensure that density becomes a community asset and not a liability.
  www.epa.gov/smartgrowth/density.htm

- ***Getting to Smart Growth: 100 Policies for Implementation***
  Smart Growth Network and International City/County Management Association. 2002.
  This primer describes concrete techniques for putting smart growth principles into practice. The policies and guidelines presented in this primer have proven successful in communities across the United States and range from formal legislative or regulatory efforts to informal approaches, plans, and programs.
  www.epa.gov/smartgrowth/getting_to_sg2.htm#1 (Also available in Spanish.)

- ***Getting to Smart Growth II: 100 More Policies for Implementation***
  Smart Growth Network and International City/County Management Association. 2003.
  This document follows the format of the first volume but with an entirely new set of 100 policies and more examples and case studies.
  www.epa.gov/smartgrowth/getting_to_sg2.htm#2 (Also available in Spanish.)

- ***Creating Equitable, Healthy, and Sustainable Communities: Strategies for Advancing Smart Growth, Environmental Justice, and Equitable Development***
  U.S. Environmental Protection Agency. 2012
  Without the appropriate engagement and planning, infill development in low-income communities can cause the displacement of existing residents due to rising rents and other costs of living. However, the smart growth, environmental justice, and equitable development fields offer ways of minimizing displacement and building healthy, sustainable, and inclusive neighborhoods. This publication provides approaches that low-income, minority, tribal, and overburdened communities can use to shape infill development that responds to their needs

and reflects their values.
www.epa.gov/smartgrowth/equitable_development_report.htm

- ***Brownfields Federal Programs Guide***
  U.S. Environmental Protection Agency. 2011.
  Many promising locations for infill housing development are brownfields—properties with known or suspected contamination issues. This guide describes nearly two dozen federal programs that can provide technical and financial support to communities seeking to assess, cleanup, and redevelop brownfields. Additionally, this guide includes a quick reference matrix that identifies specific types of projects with potential funding sources as well as tax credits and other financial incentives.
  www.epa.gov/swerosps/bf/partners/bf_fed_pr_gd.htm

- ***From Vacancy to Vibrancy: A guide to redeveloping underground storage tank sites through area-wide planning***
  Smart Growth America. 2012.
  In response to increasing demand for homes in close-in neighborhoods, many cities and towns are pursuing redevelopment of places that have struggled with blight and disinvestment for years. Properties with known or suspected contamination issues frequently impede redevelopment initiatives, leaving land vacant in spite of federal, state, and local programs to support cleanup. This guide describes how multi-site planning can turn small sites, particularly those regulated as underground storage tank sites, into community assets.
  www.smartgrowthamerica.org/from-vacancy-to-vibrancy

- ***Brownfields Resource Center***
  Center for Creative Land Recycling
  This online resource center provides information on funding opportunities, regulatory processes, and additional resources relevant to brownfield redevelopment. Resource listings are available for each state in the western United States.
  www.cclr.org/resources

Appendix C: Methodology

There is no universally accepted methodology for identifying and measuring infill housing construction. The one commonality between previous studies[38] is first defining the boundaries of previously developed areas in each metropolitan region. New homes built in these areas are considered to be infill development. This study adopts the same general approach. However, its methods and definitions differ from previous studies because it uses new, nationally available data sources that have never previously been used to measure housing construction trends.

This study combines data about the location of new housing construction with data about land cover and protected land uses in order to calculate the total percentage of all new home construction that is infill—or built in previously developed areas. It compares infill housing construction trends in all metropolitan regions with populations greater than 200,000 in the conterminous United States (excluding Alaska and Hawaii). There were three main steps in this study. (1) Determine the location of new home construction. (2) Determine the location of infill areas. (3) Calculate for each metropolitan region the percentage of all new housing construction that is infill. Each step is described in detail below.

A Note about American Community Survey Estimates

The 2009 ACS 5-Year Estimates are based on continual monthly surveys that happened over a 5-year period, 2005-2009. Each survey includes a sample of housing unit addresses across the country. While all surveys during this period will count housing units built 2000-2004, many housing units built 2005-2009 did not exist when earlier surveys took place. As a result, it is likely that the ACS significantly underestimates the total number of new housing units built during 2005-2009. Furthermore, the estimates are weighted more heavily to housing construction trends in 2005 and 2006 than they are in later years of the survey period (since those housing units existed during more of the surveys that contributed to the 5-Year Estimates).

Due to this limitation, it does not make sense to compare the total volume of housing units built between the two time periods in this analysis. However, there is no indication that comparing infill housing as a percentage of total housing construction is at all problematic.

[38] For examples of previous studies that measure infill housing development, see McConnell, V., & Wiley, K. *Infill Development: Perspectives and Evidence from Economics and Planning*. Resources for the Future. 2010.; Wiley, K. *An Exploration of the Impact of Infill on Neighborhood Property Values*. (Dissertation), University of Maryland, Baltimore County (UMBC). (UMI No. 10221). 2009.; Landis, J., Hood, H., Li, G., Rodgers, T., & Warren, C. "The Future of Infill Housing in California: Opportunities, Potential, and Feasibility." *Policy Debate*, 17(4). 2006.; Steinacker, A. "Infill Development and Affordable Housing: Patterns from 1996-2000." *Urban Affairs Review*, 38(4). 2003.; Farris, J. "The Barriers to Using Urban Infill Development to Achieve Smart Growth." *Housing Policy Debate*, 12(1). 2001.

Step 1: Determine the location of new home construction.

Data on the precise geographic location of new home construction are not nationally available. However, the 2009 American Community Survey (ACS) 5-Year Estimates provide housing unit counts for each census block group,[39] broken down by the time period of construction.[40] This study obtained data regarding homes built during two different time periods, 2000 to 2004 and 2005 to 2009, for all census block groups within the 209 metropolitan areas included in the study.

Step 2: Determine the location of infill areas.

This study analyzed land cover data to classify the development status of census block groups in 2001. All new homes built in block groups classified as Fully Developed are considered to be infill. This study defines infill housing as new homes built in census block groups that were fully developed in 2001. All new housing built in block groups that are not classified as Fully Developed in 2001, by definition, are not infill. In other words, this study assumes that if a block group has open space available for development, then all new homes built in that block group will go there. The analysis to classify the development status of block groups involves three sub-steps, each described below.

Note that there is a temporal mismatch between the start year of the study period (2000) and the available land cover data (2001). This study included additional analysis steps to address this temporal mismatch and minimize resulting error in the analysis. This analysis is described in Step 2(c) below.

Step 2(a). Isolate areas of each block group that are available for development.

Before analyzing land cover to determine whether or not a block group is Fully Developed, this study first isolated only the portions of each block group that are available for development. Isolating only areas that are available for development helps to ensure the correct classification of block groups. For instance, a block group inside a city might include both a large urban park and a dense residential neighborhood. When determining whether or not this block group is Fully Developed, it is essential to first screen out the park from the analysis. This is because it is safe to assume any new homes built in the block group would not be built in the park.

This study obtained two national datasets to identify public lands and preserved areas. Each dataset is described in Table 3.

Public and Preserved Areas Boundary Description	Source
NAVTEQ land use & water features: Local, state, and regional parks; animal parks (zoos); cemeteries; beaches; lakes; rivers; and other water features.	NAVTEQ 2011
Protected Areas Dataset – U.S. (PADUS) version 1.2: Designated[41] public lands (primarily federal, state, and tribal as well as some local government) and private conservation lands (e.g., private nature preserves or land trust easements) from authoritative data sources.	U.S. Geological Survey, Gap Analysis Program, 2011

Table 3. Datasets used to identify public and protected land areas not available for development.

[39] A block group is a unit of census geography that is smaller than a census tract and larger than a census block. Block groups vary in size based on population density. In a dense urban area, a block group can be as small as 1 or 2 acres in size. In rural areas, block groups can encompass thousands of acres.

[40] The ACS table for this variable is B25034, "Year Structure Built".

[41] PADUS differentiates land areas with status that is "Designated – Legally or administratively decreed" from those that are simply "Proposed" protection status as well as land areas with "other" and "unknown" status.

An overlay analysis in GIS removed these public and protected areas from census block group boundaries. This resulted in the creation of a GIS layer that contained the boundaries of land area within each census block group that is privately owned and available for development.

Step 2(b). Summarize land cover in each block group.

The 2001 National Land Cover Database (NLCD) uses satellite imagery to classify land cover for the entire United States at a spatial resolution of 30 meters. NLCD differentiates four categories of developed land cover as well as several categories of undeveloped land such as agricultural and woodland areas. Table 4 includes definitions for NLCD categories key to this study.

NLCD Land Cover Class	Description
Developed, Open Space	Areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.
Developed, Low Intensity	Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20% to 49% of total cover. These areas most commonly include single-family housing units.
Developed, Medium Intensity	Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50% to 79% of the total cover. These areas most commonly include single-family housing units.
Developed, High Intensity	Highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses, and commercial/industrial uses. Impervious surfaces account for 80% to 100% of the total cover.

Table 4. National Land Cover Database 2001 land cover class descriptions.

This study used NLCD data to summarize the total acreage of developed and undeveloped land cover classes in all census block groups in the study area. Developed land cover is defined as any of the four NLCD Developed land cover types (Developed, Open Space; Developed, Low Intensity; Developed, Medium Intensity; and Developed, High Intensity). All other NLCD land cover classes are considered to be undeveloped land cover.

Step 2(c). Classify block groups as fully developed or not fully developed.

As noted above, this study assumes that infill development only occurs in block groups that are almost exclusively developed land cover in areas that are available for development. Note that this assumption does not exclude vacant lots surrounded by developed land cover. In most cases, NLCD classifies such lots as Developed, Open Space due to their small size and proximity to more intensely developed land cover. Figure 11 provides a good example. The 2002 image on the left shows conditions in the block group shortly after NLCD data was collected. According to the 2001 NLCD, 100 percent of the land cover in this block group was developed. Notice that the left-hand side of the block group includes a few large vacant lots covered in grass and shrubs. The NLCD classified these areas as Developed, Open Space, most likely due to the grassy land cover and close proximity to higher intensity developed land cover surrounding the vacant lots. The 2009 image on the right shows new townhomes built on some of those vacant lots. This is a clear example of infill housing development in a block group that was Fully Developed before the construction occurred.

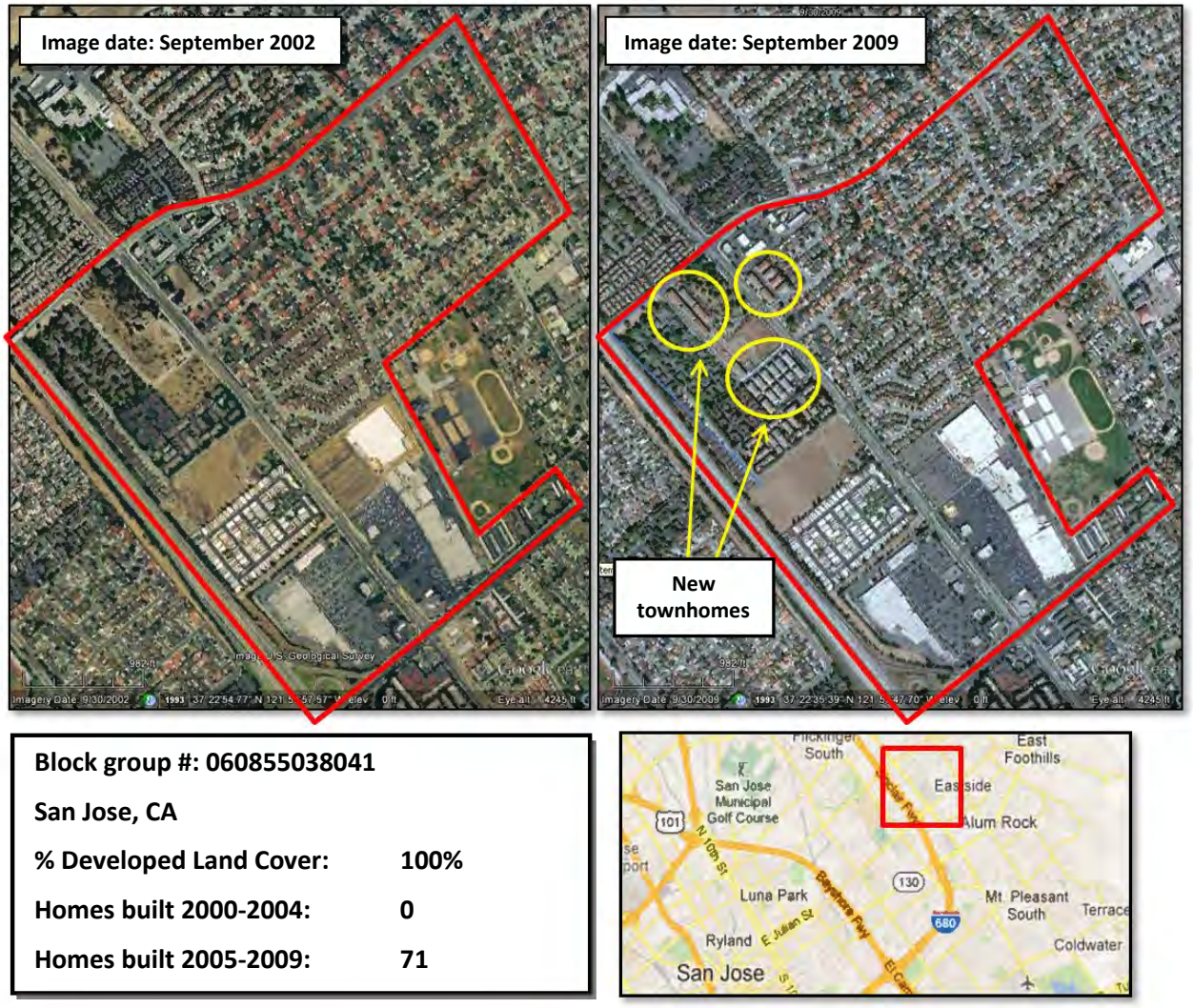


Figure 11. Aerial imagery of example block group in San Jose, California. Imagery and map courtesy of Google.

This study tested a variety of different thresholds to use for classifying block groups as Fully Developed or Not Fully Developed. It was essential to select a threshold that is conservative enough to only select block groups with almost exclusively developed land cover. At the same time, the definition should not be so restrictive that it eliminates a significant number of block groups where infill is actually occurring. Figure 12 provides an example of a block group with 80 percent developed land cover. In 2001 this block group had a significant amount of land still available for development that was not permanently protected as open space. The new homes subsequently built in the block group were all located in greenfield areas on the outskirts of existing developed areas. It was important to classify block groups such as this one as Not Fully Developed.

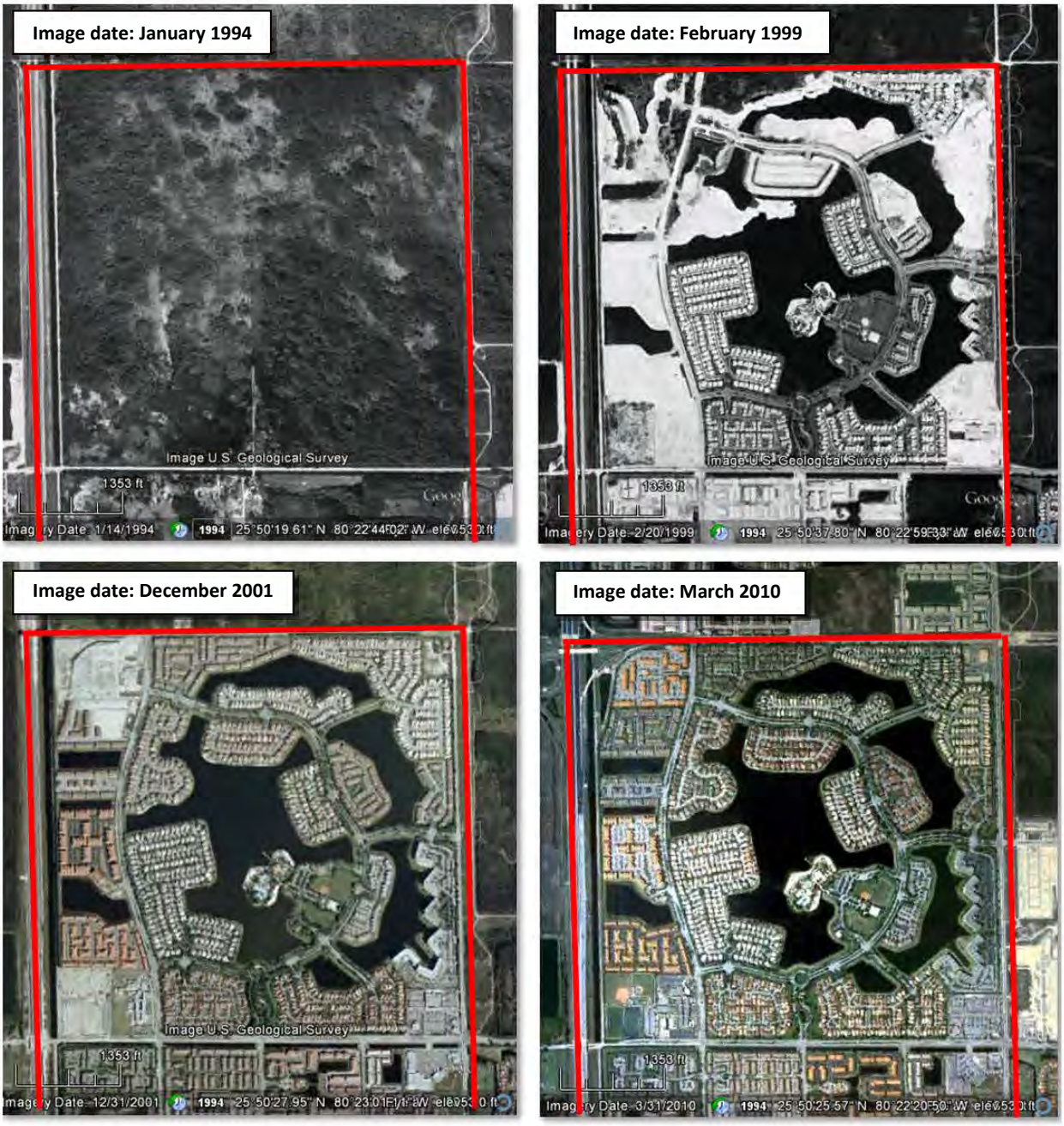
Figure 12. Aerial imagery of example block group in Ankeny, Iowa – suburb of Des Moines, Iowa.
Imagery and map courtesy of Google.

This study spot checked dozens of block groups that experienced housing growth from 2000 to 2009 in seven metropolitan regions: Washington, D.C.; Atlanta; San Jose, California; Riverside, California; Miami; Seattle; and Des Moines, Iowa. Block groups were selected both at random and based on the known locations of archetypical infill and greenfield housing development. Analysis indicated that a 90 percent threshold for developed land cover worked adequately well in most circumstances to differentiate (and classify) Fully Developed and Not Fully Developed block groups. However, two categories of special cases required refining this definition further. Each case is described below.

Special Case 1: Block groups cleared for greenfield housing development in 2001

A review of preliminary classification results in Miami, and Riverside, California, revealed a systematic problem related to the time-period mismatch between land cover and housing construction data. Both regions featured block groups at the periphery classified as Fully Developed despite a large percentage of all housing units built after 2000. Analysis of historic aerial photography circa 2001 showed large residential subdivisions that were platted, cleared, and prepared with streets, infrastructure, and amenities (e.g., golf courses) in advance of home building.

Figure 13 provides an example in Doral, Florida, a primarily residential area approximately 12 miles west of Miami. The 1994 image shows conditions before construction began—nearly 100 percent vegetated and undeveloped land cover. The 1999 image shows a new subdivision under construction. Notice that nearly all land was either cleared or transformed into artificial lakes, while home construction had only commenced in part of the area. Comparison of the images from 1999 and late 2001 indicates that a large portion of the new homes were built during that interval. According to the NLCD, this block group had 91 percent developed land cover in 2001. As a result, the preliminary analysis classified the block group as Fully Developed and therefore counted all 2,931 new homes built 2000 to 2009 as infill.



Block Group #1208600090091 Doral, FL (outside Miami)	
Percent of developed land cover, 2001:	91%
Homes built 2000-2004:	2,848
Homes built 2005-2009:	83
Percent of homes built after 1980:	100%
Jobs per acre (2008):	0.47

Figure 13. Example block group in Doral, Florida. Partial block group boundaries shown in red.
Imagery and map courtesy of Google.

As this example demonstrates, it was essential to refine the definition of Fully Developed to avoid counting this kind of greenfield housing development as infill. This study tested a variety of techniques for identifying and reclassifying block groups with characteristics similar to those shown in Figure 13. Two criteria proved to be most useful for identifying block groups to be reclassified:[42]

1. greater than 90 percent of homes built after 1980; and
2. less than eight workers per acre of land available for development.

Both criteria must be true for a block group to be reclassified as Not Fully Developed. Each criterion requires some explanation. Criterion One identifies block groups that have experienced nearly all of their residential growth between 1980 and 2009. While the year 1990 could have been used, 1980 was chosen for a few reasons. First, not all block groups build out as quickly as the example in Figure 13. Secondly, infill predominantly happens in older neighborhoods—not neighborhoods built after 1980. Criterion Two was added to avoid reclassifying formerly non-residential urban block groups that experienced significant residential redevelopment since 1980 (such as former industrial areas redeveloped as urban neighborhoods). Such examples tend to be mixed-use (residential and commercial) and therefore have notable employment density. The eight workers per acre threshold served well to differentiate such block groups from ones dominated by greenfield residential development.

Special Case 2: Block groups in central-city areas with less than 90 percent developed land cover

Spot checking of known infill housing development locations in Seattle and Miami revealed examples of block groups in fully developed central-city areas that nonetheless fell below the 90 percent threshold and were therefore initially classified as Not Fully Developed. A few factors could contribute to this outcome: steep slopes rendering areas available for development to be undevelopable; local parks and preserved areas that are not included in the NAVTEQ or PADUS databases used to screen for such areas; and very mature tree cover.

To correct for this problem, this study classified block groups that met each of the following narrow criteria to be Fully Developed:

1. greater than 70 percent developed land cover; and
2. scored in the top 10 percent on the index of metropolitan-area centrality developed for EPA's Smart Location Database.[43]

The centrality index Criterion Two scores block groups in a metropolitan region based on the cumulative number of working-age people within 30 miles, weighted by distance (i.e., closer workers weighted more heavily than those further away). Block groups in the top 10 percent are located almost exclusively in city centers and the immediately surrounding neighborhoods.

[42] Note that land cover data for years earlier than 2001 was not available for this analysis. So analysis of land cover before development occurred was not possible.

[43] For details about the Smart Location Database see Ramsey, K., & Thomas, J. *EPA's Smart Location Database: A National Dataset for Characterizing Location Sustainability and Urban Form*. U.S. Environmental Protection Agency. 2012. This analysis used a regionally-standardized version of the variable D5ae (Working-age population within 30 miles adjusted by travel time using gravity model) to identify block groups that match this criterion.

Step 3: Calculate the percentage of all new housing construction that is infill

The final step in this analysis is calculating—for each metropolitan region—the percentage of all new housing units that are infill (i.e., built in block groups that are classified as Fully Developed). All other housing construction, by definition, is not infill. This definition relies on one key assumption: if a block group is Not Fully Developed, then all additional housing units will be built in undeveloped land areas that are available for new development.

This study measured infill housing construction in 209 metropolitan regions across the contiguous United States. In summary, each calculation involved the following three steps:

- **Total homes**: Sum of housing units built in all block groups located inside the metropolitan statistical area.
- **Infill homes:** Sum of housing units built in Fully Developed block groups located inside the MSA.
- **Percentage of all homes that are infill**: Infill homes divided by total homes.

Summary Definition of Fully Developed Block Groups (areas where infill construction can occur)

This study defines Fully Developed blocks groups as those that meet either of the following criteria:

- greater than 90 percent developed land cover;

  or

- greater than 70 percent developed land cover ***and*** scored in the top 10 percent on an index of metropolitan-area centrality.

However, any block group that meets the following additional criteria is **Not Fully Developed** (even if it meets one of the two criteria above):

- greater than 90 percent of homes built after 1980 ***and*** less than eight workers per acre of land available for development.

Any block group not classified as **Fully Developed** is, by default, **Not Fully Developed.**

This study calculated these metrics for both time periods (2000 to 2004 and 2005 to 2009) as well as the entire study period (2000 to 2009). Figure 14 illustrates the results of this analysis in the Washington, D.C., metropolitan region.

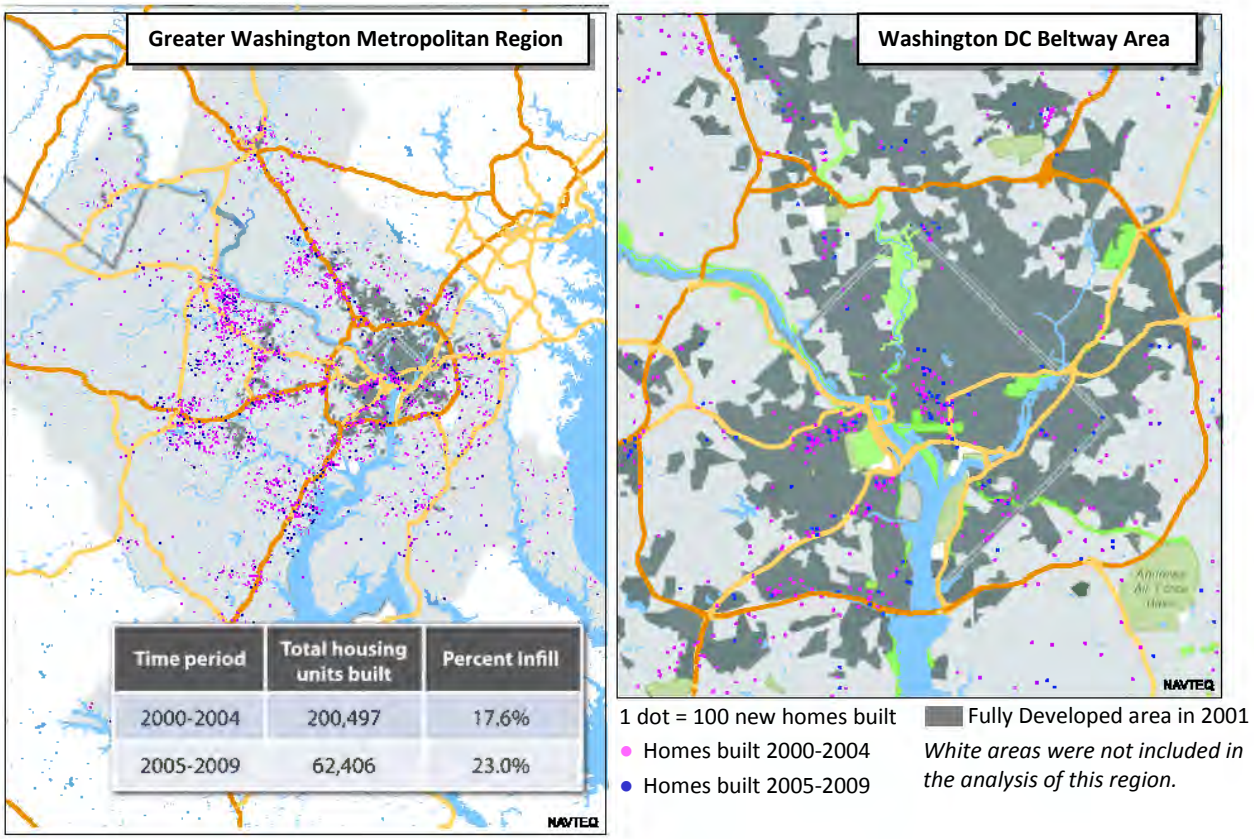


Figure 14. New homes built in the Washington, D.C., metropolitan region, 2000-2004 and 2005-2009. Homes built in the dark grey areas ("Fully Developed area in 2001") are considered to be infill. All other homes are assumed to be not infill. Source: EPA analysis of 2009 American Community Survey 5-Year Estimates, 2001 National Land Cover Database, Protected Areas Database of the United States (PADUS) version 1.2., and 2011 Navteq NAVSTREETS.

Identifying Infill in Lower Density Suburban Areas

As noted in Section 4, this analysis occasionally classifies some infill housing development in lower density areas as greenfield. This does not seem to be a common problem. In many cases, this study correctly classifies this suburban redevelopment activity as infill. For instance, a close examination of Figure 14 shows suburban housing construction in Fully Developed areas outside of Washington, D.C., such as Rockville and Wheaton, Maryland, and Alexandria, Virginia. However, in some cases this study does not classify redevelopment in lower density suburban areas as infill. An example is new residential construction in the former site of Stapleton Airport at the outskirts of Denver. This study did not count these new homes as infill. This is because the former airport was located in a block group that also included large areas of privately owned undeveloped land—even though the land cover analysis did pick up the airport grounds as developed land cover. This example draws attention to the challenges of conducting an analysis at the block group scale—where block groups vary in size based on residential density. A more detailed study based on local parcel data would likely have classified the Stapleton redevelopment as infill.

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