UNIVERSITY OF CINCINNATI

Date: May 26, 2009

I, Samuel A. McKinley, hereby submit this original work as part of the requirements for the degree of: Master in Community Planning

It is entitled:
Toward a Greenhouse Gas Inventory at the Neighborhood Scale

Student Signature: Samuel A. McKinley

This work and its defense approved by:

Committee Chair: Carla Chifos, Ph.D, AICP
David J. Edelman, Ph.D, AICP
Elizabeth Blume, MCP, AICP
Terry Grundy, MA

Approval of the electronic document:

I have reviewed the Thesis/Dissertation in its final electronic format and certify that it is an accurate copy of the document reviewed and approved by the committee.

Committee Chair signature: Carla Chifos, Ph.D, AICP
Towards a Neighborhood-Scale Carbon Calculator

A thesis submitted to the
Division of Research and Advanced Studies
at the University of Cincinnati

in partial fulfillment of the
requirements for the degree of
MASTER OF COMMUNITY PLANNING
in the School of Planning
College of Design, Architecture, Art and Planning

2009

by

Samuel A. McKinley
Bachelor of Urban Planning, University of Cincinnati, 1996

Thesis Committee:
Chair: Carla Chifos, Ph.D., AICP
Terry Grundy, MA
Elizabeth Blume, MCP, AICP
Abstract

The project is an attempt to develop a useful, reasonable, and accessible model for a greenhouse gas (GHG) inventory at the scale of a city neighborhood. It is useful because neighborhood groups, city administrations, and other interested parties can use it to compare and contrast the GHG emissions of different neighborhoods in a meaningful way, and so inform policy decisions. It is reasonable because, while it may not precisely quantify every GHG emitted in a neighborhood, it gives a fair representation of the differences between neighborhoods. It is accessible because the components that produce the final inventory are readily available and understandable to competent lay people (non-planners), or are provided and explained to make them so.

Review of the relevant literature on greenhouse gas inventories and thermal forcing revealed no previous GHG inventories at the neighborhood scale. Procedures at the scale of an entire city were used as guideposts, but the procedures were modified to make sense at the neighborhood scale. Literature review further suggested that the fact that a given area is organized as a neighborhood plays a role in a GHG emissions inventory, apart from the simple scalar issue arising from addressing an area smaller than a city. Specifically, organization as a neighborhood necessitates looking at varied residential types, commercial types, building scales and how they use energy. Conversely, an inventory of a randomly-defined area of a city could be meaningful by simply using a city-scale inventory, arithmetically scaled down to reflect the smaller scale and population. Finally, the fact that different inputs to the inventory are treated discretely gives the model the quality of robustness – a category of data that is unattainable can be substituted with more generalized data and still produce meaningful comparisons. This is especially true if there is an existing larger-scale GHG inventory as a standard.

The initial study area is the Clifton neighborhood of Cincinnati, Ohio, as determined by the neighborhood’s community council. The procedures and data requirements were developed using Clifton as a touchstone in reality. The study then looks at the Cincinnati neighborhoods of Corryville, Mt. Adams, Mt. Washington, North Avondale, and Westwood, as well as the GHG inventory of the entire city to validate the model.
Acknowledgements

For this thesis I owe my Thesis Chair, Dr. Carla Chifos, AICP, a great debt for her excellent guidance, support and patience. The rest of my committee, Liz Blume, AICP, and Terry Grundy, MA, provided key support at the end, insights along the way, and turned all the presentations into wonderful opportunities to discuss planning. Finally, Andrew Rhone, of OKI provided vehicle miles travelled data for any area I asked for, and did it in record time.

For my Master’s studies in general, my wife and two children deserve the most acknowledgement for their unending support, patience and understanding. Behind them stand innumerable people who helped me along my way.
Table of Contents

Towards a Neighborhood-Scale Carbon Calculator .......................................................... i
Abstract .......................................................................................................................... ii
Acknowledgements ........................................................................................................ iii
Table of Figures .................................................................................................................. 1
List of Tables ..................................................................................................................... 1

Chapter 1: Introduction ...................................................................................................... 2
   I. Background ................................................................................................................ 2
   II. Problem Statement .................................................................................................. 5

To determine and demonstrate the utility, efficacy, and current state of knowledge of Greenhouse
Gas Inventories at a scale smaller than city-wide ........................................................... 5

III. Research Questions ................................................................................................... 8
From the available literature, what would be necessary and appropriate elements for a
Greenhouse Gas Inventory at a neighborhood scale? ....................................................... 8
When the available data and models are applied to real example neighborhoods, what works
well, and where are the gaps and areas in need of further research? ............................... 9

IV. Objectives .................................................................................................................. 11
To develop a model of a Greenhouse Gas Inventory at the scale of a neighborhood. .......... 11
To determine the current state of knowledge, numbers and calculations available for a
Greenhouse Gas Inventory at the scale of a neighborhood. ........................................... 11
To refine the developed model neighborhood-scale Greenhouse Gas Inventory by applying it
to real example neighborhoods. .................................................................................... 12
To demonstrate the broader utility and applicability of the research project. ...................... 12
To suggest directions for further research in this area of inquiry. ....................................... 12

V. Expected Results ........................................................................................................ 13

VI. Methodology ............................................................................................................. 14
   1. Through literature review, determine a “Best Practices” model for a greenhouse gas
      inventory at the neighborhood scale ........................................................................ 14
   2. In further literature review, search for data to fill in the components of the model
      neighborhood-scale greenhouse gas inventory ........................................................... 15
   3. Assess the data and report on which of the initially-determined components have available
      or calculable numbers, which require rule-of-thumb estimates, and which are not
determinable at this time. ............................................................................................... 15
   4. Reassess and revise the model in light of the available data ..................................... 15
   5. Analyze a real example neighborhood, to see how a neighborhood-scale greenhouse gas
      inventory works, in light of the data available .......................................................... 15
   6. Perform, as thoroughly as possible, a greenhouse gas inventory of the example
      neighborhood .............................................................................................................. 16
   7. Analyze and report upon the results of the application of the revised model to the example
      neighborhood. The analysis will look at how thorough an inventory was possible. The
      reporting will highlight areas where further study is necessary. .................................. 16
   9. Analyze and report on the broader applicability of the current state of knowledge as applied. .............................................................................................................. 16

VII. Study Area .................................................................................................................. 17
Table of Figures

Figure 1: The Clifton Neighborhood of Cincinnati, Ohio. Inset shows Clifton among all the neighborhoods of Cincinnati. Source: CAGIS 10
Figure 2: Full Thesis Project Schedule 19
Figure 3: Location of Hamilton County and Cincinnati in the broader region 34
Figure 4: Location of the six study areas in Hamilton County and Cincinnati 35
Figure 5: Official neighborhood boundaries vs. TAZ-determined approximations used as study areas 36
Figure 6: Clifton Study Area Map (Source: CAGIS 2000) 47
Figure 7: Corryville Study Area Map (Source: CAGIS 2000) 48
Figure 8: Mt. Adams Study Area Map (Source: CAGIS 2000) 49
Figure 9: Mt. Washington Study Area Map (Source: CAGIS 2000) 51
Figure 10: North Avondale Study Area Map (Source: CAGIS 2000) 52
Figure 11: Westwood Study Area Map (Source: CAGIS 2000) 54

List of Tables

Table 1: Cincinnati, Ohio, regional electricity eCO$_2$ (Source: EIA eGRID) 20
Table 2: Energy use per resident of owned and rented housing in the East North Central region of the Midwest (Source: EIA 2009) 20
Table 3: Metric tons eCO$_2$ per million BTU, specific to residential uses in the study areas region (Source: EIA 2009) 20
Table 4: Average eCO$_2$ per neighborhood resident (Source: EIA 2009, U.S. Census 2000, and CAGIS 2000) 20
Table 5: Non-Residential space in study neighborhoods (Source: CAGIS 2000) 20
Table 6: BTU - physical unit conversions (Source USEPA 2009) 20
Table 7: Sources of energy and conversions to physical units and eCO$_2$ (Source: EIA & EPA) 20
Table 8: Per-person GHG from non-residential buildings, by neighborhood (Source: EIA, USEPA, & CAGIS 2000) 20
Table 9: eCO$_2$ from Vehicle Miles Travelled per person, by neighborhood (Source: USEPA, EIA, and U.S. Census, and CAGIS 2000) 20
Table 10: Citywide eCO$_2$ aggregate and per-person (Source: City of Cincinnati 2008) 20
Table 11: Clifton eCO$_2$ results (Source: City of Cincinnati, OKI, CAGIS 2000, U.S. Census, EIA, and USEPA) 20
Table 12: eCO$_2$ per person for the Corryville study area (Source: City of Cincinnati, OKI, CAGIS 2000, U.S. Census, EIA, and USEPA) 20
Table 13: eCO$_2$ per person for the Mt. Adams study area (Source: City of Cincinnati, OKI, CAGIS 2000, U.S. Census, EIA, and USEPA) 20
Table 14: eCO$_2$ per person for the Mt. Washington study area (Source: City of Cincinnati, OKI, CAGIS 2000, U.S. Census, EIA, and USEPA) 20
Table 15: eCO$_2$ per person for the North Avondale study area (Source: City of Cincinnati, OKI, CAGIS 2000, U.S. Census, EIA, and USEPA) 20
Table 16: eCO$_2$ per person for the Westwood study area (Source: City of Cincinnati, OKI, CAGIS 2000, U.S. Census, EIA, and USEPA) 20
Table 17: Citywide and neighborhood eCO$_2$ assessments and components (Source: City of Cincinnati, OKI, CAGIS 2000, U.S. Census, EIA, and USEPA) 56
Table 18: Neighborhood “Index” Numbers 56
Chapter 1: Introduction

I. Background

The present project will look at how to do a Greenhouse Gas (GHG) inventory of neighborhoods. It will look at the current state of knowledge on GHG inventories in general, attempt to develop a reasonable model for a GHG inventory at the neighborhood scale, then apply this model to an existing neighborhood.

This project has its roots in work on Cincinnati, Ohio’s, Climate Protection Team. I served briefly on the Land Use Subcommittee, along with over 20 others. There was one idea that made it through brainstorming, selection, and refining, only to have the chairperson threaten to cede it to another subcommittee. The idea was that zoning and other direct land controls could have an effect on the city’s output of Greenhouse Gases (GHGs), its “carbon footprint.” When the chair saw my enthusiastic defense of this idea, she quickly assigned me to look into it and write it up – quickly enough that I couldn’t get out of it.

Once I started to research the subject, I found that there really were not handy or very comprehensive numbers showing the direct connections between development patterns and GHGs, much less on the whole chain of land controls to development patterns to GHGs. I ended up proposing a neighborhood-based incentive that would encourage each neighborhood to continually improve its score on the U.S. Green Building Council’s (USGBC) Neighborhood Development standard, LEED-ND (USGBC 2008). For the quantitative effects on carbon footprint of enforcing the LEED-ND standard, I had to fall back on the USGBC’s assertion that building construction and operation accounts for 40% of atmospheric carbon on the one hand, and examples of buildings whose construction and operation contributed zero atmospheric carbon on the other (ZEDfactory 2008). This did not really answer the original question, but the idea has survived several rounds of City editing since its introduction (City of Cincinnati 2008).

It turns out that the problem of the possible effects of land controls on GHGs is enormous. Working through the problem logically, one must first establish concrete links between land
controls and development patterns. Then, one must establish concrete, quantifiable connections between development patterns and GHGs.

Land controls – primarily zoning codes and subdivision regulations – are among a city’s primary powers. These are the tools that allow a city to shape itself. However, anyone who has worked in, with, or against a City Planning or Zoning Department knows that the link between land controls and development patterns is not 100% direct. Still, it would seem to be possible to say that, if a particular zoning or subdivision regulation is put in place, the development pattern that it enforces would have a specific affect on the city’s GHG production.

It seems logical that, to a large extent, it is the shape or internal pattern of cities that determines its GHG emissions. New York City manages to accommodate some eight million residents with the lowest per-capita GHG emissions in the nation, while Los Angeles’ citizens produce eight times more (Owen 2004, 1).

There is no lack of sources that say “Urban Sprawl” or “Suburban Sprawl,” or similarly-named development patterns, are responsible for high levels of carbon emissions (Ewing 2007, Galster 2001, etc.). More specifically, there is plenty of support for the idea that the increased number of car trips required by sprawling development patterns largely causes the extra carbon emissions (Ewing 2002, Norman 2006). However, there could be other ways land controls affect GHG emissions.

For instance, the study that showed Los Angeles’ inhabitants generating eight times the GHGs of New York City’s (Owen 2004) also showed large regional variations among similarly-patterned cities. This was a result of the sources and amounts of space heating and electricity used in the different regions. That is, if a city needs less heating and cooling and generally uses natural gas for heat and hydro-electric for electricity it starts out with much lower GHG emissions, which can make up for quite a bit of sprawl. So, the next question would be how can land controls affect inhabitants’ use of electricity and heat? An extreme example is that one would expect people living in compact apartments to use less heat than those in large houses on large lots.
All this is partly just to say that the question that eventually led to the present study – how to affect GHG emissions through land controls – is very large and intractable. It also establishes that there seems to be some link between the development patterns in a city – influenced, if not entirely enforced through land controls – and the Greenhouse Gas emissions of that city. While the problem might be too large and intractable to solve at one go, it is still valuable to work on a manageable piece of it.

Since land controls do not take on a whole city homogeneously, it makes sense to look at a scale smaller than city-wide. This study takes the neighborhood as its scale. A neighborhood is smaller than a city. A neighborhood generally has a range of land uses, some range of development patterns, yet hangs together in some way. If an area does not hang together in some way, people generally do not think of it as a neighborhood. Therefore, it provides a useable, identifiable study size, at a scale smaller than city-wide.

Finally, if we are ever to know whether land controls have an affect on GHG emissions, we must have some way to quantify these emissions. Thus, the present study will look at how to do a GHG inventory at the neighborhood scale.
II. Problem Statement

To determine and demonstrate the utility, efficacy, and current state of knowledge of Greenhouse Gas Inventories at a scale smaller than city-wide.

To the vast majority of the world’s nations, global warming from human-caused greenhouse gas (GHG) emissions is a serious, increasingly immediate and obvious threat (U.S. Conference of Mayors 2008). In the United States, the issue is often caught up in politics. The U.S. Senate has never ratified the treaty to follow the Kyoto Protocols, unlike all but one other nation on the planet. President Bill Clinton committed his administration to following the Protocols anyway, while President George Bush immediately stopped any such efforts.

When, in 2005, the Protocols became binding upon all signatories, Seattle Mayor Greg Nickels committed Seattle to following them, despite the U.S.’s non-ratification. He then challenged all U.S. Mayors to make the same commitment (U.S. Conference of Mayors 2008).

Since 2005, 902 Mayors have committed their cities to following the Kyoto Protocols’ GHG-reduction demands (U.S. Conference of Mayors 2008). Called the “Mayor’s Climate Protection Commitment,” this movement commits cities to reduce their GHG level to 7% below 1990 levels by 2012. This is the Protocols’ target for the U.S. While it is entirely possible the Mayors made this commitment merely to win over environmentally-concerned constituents, they soon discovered there are groups prepared to hold them accountable. The U.S. Conference of Mayors is not the least of these – the Mayors’ prestige among peers depends on action to meet the commitment.

Having made this commitment, and having discovered they will be held accountable for it, these Mayors have to figure out how to meet the commitment. They have to find a credible baseline, then figure out how to reduce their cities’ GHG emissions by the requisite amount. Many have discovered that 1990 data for their cities are not available, so they must find a later year for which there are good data, and estimate how much their cities’ GHG emissions grew
from 1990 to that year (City of Cincinnati 2008). Then they can set a GHG-reduction target based on that estimate.

The next question for cities is how to accomplish the reductions. City governments have a finite set of powers at their disposal. The U.S. Conference of Mayors’ 2007 Climate Protection Strategies and Best Practices Guide consists mostly of changes to operations of City administration, tree plantings, and efforts to influence changes in city users’ behavior. There are one or two zoning proposals, but really very few propositions for use of City regulatory powers (ICLEI 2007).

As argued in the Introduction of the present study, land controls (basically land use, zoning, and subdivision regulations) could be a valuable and powerful tool for a city’s GHG reduction program, and land controls work at a scale smaller than city-wide. This is how we get to neighborhood scale: it is a recognizable sub-unit of many cities.

The first step in working to reduce GHGs is to assess what the current situation is, to determine a baseline. However, there does not appear to be a recognized model of a GHG inventory at the neighborhood scale. While it is impossible to prove a negative (i.e., that neighborhood-scale GHG inventories do not exist), there is a logical argument for why a model might not have been created already.

First, nobody may have had the motivation to perform one. It is hard to imagine a neighborhood council, or similar organization, deciding to do one on its own. There is a Mayors’ Climate Protection movement, but not a Neighborhood Climate Protection movement. The motivation would not seem probable at the city administration level, since land controls as a GHG-reduction strategy have been given such short shrift.

Second, it may be that a neighborhood-scale GHG inventory is more difficult than it might at first seem. At least one study found that accuracy in GHG inventories is harder to come by, the smaller the scale (Kates 1998, 1). Entire countries track their use of all the fuels, animals, and so on which eventually generate greenhouse gases, and it is a simple calculation to estimate output from these. Within the U.S., states also keep track of these factors, although they do not have quite as effective a “cordon” to make sure they catch everything. Fuels, animals, and other sources can
move more freely across state borders than national borders, plus the origin of the gases
themselves is a bit harder to ascertain at a smaller scale.

There is hope for the present study however. As of November 23, 2008, 602 American
University presidents have signed something called the “Presidents’ Climate Commitment”
(American College and University Presidents’ Climate Commitment 2008). The Commitment
basically parallels the Mayors’ Climate Challenge, but is specifically aimed at college and
university campuses. Although a campus may have a useful cordon (ability to track GHGs
through their utility bills and all the vehicles that enter and leave campus), the scale is still much
like that of a neighborhood.
III. Research Questions

- From the available literature, what would be necessary and appropriate elements for a Greenhouse Gas Inventory at a neighborhood scale?

- When the available data and models are applied to real example neighborhoods, what works well, and where are the gaps and areas in need of further research?

From the available literature, what would be necessary and appropriate elements for a Greenhouse Gas Inventory at a neighborhood scale?

The present study seeks to complete one step towards helping city administrations reduce the aggregate carbon loading of the atmosphere from their cities. Obviously, city administrations operate completely within their cities, so the changes they can make generally are at a scale smaller than that of the whole city. This is why the term “neighborhood” is in the first research question. A neighborhood is a sub-area of a city, but has some defining characteristics or at least spatial organization or coherence of its own.

We cannot completely determine greenhouse gas emissions directly. Air monitoring is generally only performed for particulates and “criteria” pollutants: particulate matter, sulfur dioxide, carbon monoxide, nitrogen dioxide, ozone, and lead (EPA 2008). Some of these are certainly considered greenhouse gases, but the most prevalent GHG, CO₂, is missing.

Also, there is the problem of electricity generation, which may turn out to be one of the most significant sources of GHGs. Electricity is produced remotely from almost all neighborhoods, but each neighborhood can be considered responsible for a portion of the output. As discussed earlier, there are large regional differences between U.S. cities, based on whether they get their electricity through coal or hydro (Owen 2004). A neighborhood could be said to be responsible for a proportion of the local utility’s carbon output. So it would make sense to allocate some of the carbon loading from electricity production, based on the proportion of the local generating plants’ output used within the neighborhood. This obviously could not be measured directly within the neighborhood.
Fortunately, there is an appropriate and recognized model for indirect assessment of GHG output: the GHG inventory. These are routinely performed and updated from the household and business-site level, all the way up to the national and even continental level. Generally, a GHG inventory will happen for every signatory of the U.S. Conference of Mayors’ Climate Protection Commitment, every university signatory to the Presidents’ Climate Challenge, and many businesses and other institutions. There is even specialized software to handle this (ICLEI 2008). However, none of these inventories seem to exist at just the neighborhood level.

The answer to this first research question will be in the components that show up in inventories at scales smaller and larger than the neighborhood. The present study will examine lists of components in reputable GHG inventories and accept or reject them according to their relevance to the neighborhood scale. It appears that common sense will be the primary discriminatory tool, since there is no real literature at this scale.

When the available data and models are applied to real example neighborhoods, what works well, and where are the gaps and areas in need of further research?

The answer to this question will be useful for two reasons. The first reason is to test the neighborhood-scale greenhouse gas inventory model developed through literature review. The second reason is to improve the model, by learning about its strengths, pitfalls, and gaps as only a test against a real neighborhood can do.

A careful reading of this research question may provoke another question: what neighborhood will the study use as its test example? The answer is that the author’s home neighborhood, Clifton, within the city of Cincinnati, will have the honor. If part of the object is to develop a greenhouse gas inventory model that will be useful for any neighborhood, any neighborhood will do for the initial test subject. Outside the obvious physical convenience, the author is also intimately familiar with the neighborhood, having lived there for much of his life. Figure 1, below, shows the neighborhoods of Cincinnati, with a close-up of Clifton.
The term “neighborhood” has a specific meaning in Cincinnati. The city consists of 51 delineated neighborhoods, which together comprise the entirety of the city. Each neighborhood has specific boundaries, jealously guarded by its own neighborhood council. The neighborhood councils vary greatly in activism and efficacy, although each council is eligible for up to $7,000 in annual funds from the City (City of Cincinnati 2 2008). The neighborhood councils do not have any direct authority or representation at the City level, as the City Council is elected on an at-large basis.

Figure 1: The Clifton Neighborhood of Cincinnati, Ohio. Inset shows Clifton among all the neighborhoods of Cincinnati. Source: CAGIS
IV. Objectives

- **To develop a model of a Greenhouse Gas Inventory at the scale of a neighborhood.**

- **To determine the current state of knowledge, numbers and calculations available for a Greenhouse Gas Inventory at the scale of a neighborhood.**

- **To refine the developed model neighborhood-scale Greenhouse Gas Inventory by applying it to real example neighborhoods.**

- **To demonstrate the broader utility and applicability of the research project.**

- **To suggest directions for further research in this area of inquiry.**

---

**To develop a model of a Greenhouse Gas Inventory at the scale of a neighborhood.**

As was explained in the “Research Questions” section, the premise of this study is that developing a model Greenhouse Gas (GHG) Inventory at a neighborhood scale would be an essential step toward giving city administrations another tool for reducing the GHG emissions of their cities. Specifically, it seems difficult for cities to link precise GHG reduction numbers to changes in land controls. The present study will attempt to make available a first step in establishing that link: a way to perform GHG inventories on specific areas of a city, in this case a neighborhood.

---

**To determine the current state of knowledge, numbers and calculations available for a Greenhouse Gas Inventory at the scale of a neighborhood.**

The first step in achieving this objective will be to find what the relevant literature has to say about GHG inventories that might adjust down to the neighborhood scale. Some set of necessary elements will develop from this search. The next step will be to see, also from literature review, if there are sources of valid numbers, either to plug into a GHG inventory or to calculate answers.
To refine the developed model neighborhood-scale Greenhouse Gas Inventory by applying it to real example neighborhoods.

Literature review will permit the development of a rather theoretical model of a Greenhouse Gas Inventory at the neighborhood scale. In order to really make it useful, it is necessary to apply it to an actual neighborhood. From this application, some adjustment of the model is bound to occur, as various elements turn out to be difficult to quantify, of limited utility, or have better substitutes available.

The first example neighborhood will be the Clifton neighborhood of Cincinnati, Ohio, shown in Figure 1, on page 10. Additional neighborhoods will be assessed and include Corryville, Mt. Adams, Mt. Washington, North Avondale, and Westwood.

To demonstrate the broader utility and applicability of the research project.

Once the model is more refined through testing on one example neighborhood, the present study will look at data available for another neighborhood. In this way, its more general utility will begin to emerge. Some feedback to adjust the model will undoubtedly show up at this stage as well.

To suggest directions for further research in this area of inquiry.

It is of course highly unlikely that an absolutely perfect model of a neighborhood-scale greenhouse gas inventory will result from this (apparently) first attempt at it. Some elements of the inventory will undoubtedly turn out to be difficult or impossible to quantify, thus suggesting some further research. Also, a discussion of ways to use the results of the present study will suggest further research.
V. Expected Results

- It is possible to develop an ideal model for a Greenhouse Gas Inventory at the neighborhood scale.
- There is adequate, reliable literature and data available for many components of this model, but not all.
- A significant portion of the model will rely on rule-of-thumb approximations.
- There will be significant, but not crippling, portions of the model where there are not available, credible data.
- It is still possible to develop a useful model for a Greenhouse Gas Inventory at this scale.
- The Greenhouse Gas Inventory will probably be best expressed as some sort of index number, which can will not necessarily directly represent tons of CO₂, but will still offer useful comparisons among neighborhoods.
- Developing and applying the index will suggest areas urgently in need of further research.
- Developing and applying the index will be demonstrably useful to planners and city decision-makers.
VI. Methodology

1. Through literature review, determine a “Best Practices” model for a greenhouse gas inventory at the neighborhood scale.

2. In further literature review, search for data to fill in the components of the model neighborhood-scale greenhouse gas inventory.

3. Assess the data and report on which of the initially-determined components have available or calculable numbers, which require rule-of-thumb estimates, and which are not determinable at this time.

4. Reassess and revise the model in light of the available data.

5. Analyze a real example neighborhood, to see how a neighborhood-scale greenhouse gas inventory works, in light of the data available.

6. Perform, as thoroughly as possible, a greenhouse gas inventory of the example neighborhood.

7. Analyze and report upon the results of the application of the revised model to the example neighborhood. The analysis will look at how thorough an inventory was possible. The reporting will highlight areas where further study is necessary.

8. Analyze and report on the broader applicability of the current state of knowledge as applied.

1. Through literature review, determine a “Best Practices” model for a greenhouse gas inventory at the neighborhood scale.

There are many, many sources for greenhouse gas inventories. For one, the U.S. Council of Mayors’ Climate Challenge includes some 884 signatories as of November, 2008: all either will conduct, are in the process of conducting, or have completed a greenhouse gas inventory of their city (U.S. Conference of Mayors 2008). The American College and University Presidents’ Climate Commitment’s 602 signatories (as of Nov. 2008) are similarly obligated (American College and University Presidents’ Climate Commitment, 2008). There are also inventories of entire nations, as well as some level of analysis for every state in the U.S. (USEPA 2008). What seems to be missing is greenhouse gas inventories specifically at the neighborhood scale. So while there are ample models in general, getting to the right scale will require some adaptation. The purpose of this step
in the methodology is to develop a proposed model for a neighborhood-scale greenhouse gas inventory, by reviewing and analyzing existing literature for relevant components.

2. In further literature review, search for data to fill in the components of the model neighborhood-scale greenhouse gas inventory

   The purpose of this second step is to ascertain what data are available to plug into the model developed in the previous step. These data may include specific, calculated numbers, such as vehicle miles traveled by residents of a given neighborhood, as well as more “rule-of-thumb” numbers, such as per-person electricity use in different types of housing.

3. Assess the data and report on which of the initially-determined components have available or calculable numbers, which require rule-of-thumb estimates, and which are not determinable at this time.

   This step will, to some extent, proceed in tandem with 2. That is, while searching for data, there will be some discrimination among them.

4. Reassess and revise the model in light of the available data.

   Since the present project envisions applying the model developed, it obviously will be necessary for it to be possible to come out with a credible total at the end. If certain data are simply unavailable and can’t be estimated, that part of the model may have to drop out.

5. Analyze a real example neighborhood, to see how a neighborhood-scale greenhouse gas inventory works, in light of the data available.

   As was explained earlier, the model developed in previous steps will be analyzed against the particulars of the Cincinnati, Ohio, neighborhood of Clifton. The author chose this neighborhood strictly for convenient. However, if the model is robust enough to serve any neighborhood, any neighborhood should do. The Clifton neighborhood has its own unique characteristics, as does any neighborhood. Part of the analysis is to ferret out some of those unique characteristics and see how they affect the validity of the model.
6. Perform, as thoroughly as possible, a greenhouse gas inventory of the example neighborhood.

This step is not the same as the previous, analytical step. It is one thing to look back and forth between a proposed model and a real neighborhood, making adjustments to the model and looking for further data from the neighborhood. It is a different process to take a model that is as good as it can be, and to actually run it on a neighborhood. The object of this step will be to compile a real estimate of the GHG emissions of Clifton, and to learn by going through the process.

7. Analyze and report upon the results of the application of the revised model to the example neighborhood. The analysis will look at how thorough an inventory was possible. The reporting will highlight areas where further study is necessary.

In this step, the project will take stock of how well the model worked when run on a real neighborhood. Changes to the model will be made based on the experience and knowledge gained from the process, and a report prepared.

9. Analyze and report on the broader applicability of the current state of knowledge as applied.

The object of this step is to look at how useful the model neighborhood-scale greenhouse gas inventory might be for other neighborhoods, and differently-defined areas of cities. It will consist of analysis similar to the level of step 5, but on a different neighborhood. That is, the model won’t be run, but will be compared to basic characteristics of another real neighborhood, to give an idea of the model’s validity. The resulting report will also detail directions for further study.
VII. Study Area

The initial study area – the real neighborhood against which the study will test a proposed model greenhouse gas inventory – is the Statistical Neighborhood Approximation called Clifton, in Cincinnati, Ohio. This neighborhood has been chosen entirely for the convenience of the researcher. Since the process is to test the model against a real neighborhood, and then try to generalize it for use in other neighborhoods, starting with the neighborhood in which the researcher lives is perfectly valid. If the resulting model is, as anticipated, generalizeable and fairly easy to apply, several other neighborhoods will be chosen for their variety and the model applied to them.

As it happens, Clifton has some characteristics that may make it an interesting place to develop and apply a neighborhood-scale greenhouse gas inventory. First, it is near the University of Cincinnati, so it contains a number of students. It has a clearly identifiable neighborhood business district, surrounded by relatively dense apartment housing. It is considered a walkable neighborhood, but then it would be expected that a high number of students cannot afford cars. Within the neighborhood boundaries there also are areas of single-family detached housing of varying density, as well as purpose-built duplexes, and a number of large houses cut up into smaller apartments. Finally, the single-family area ranges up to a number of truly grand houses, some on several acres. Still, some of these estates are only a fifteen minute walk from the neighborhood business district, and even the most distant are perhaps two miles away from the NBD. The neighborhood even contains undeveloped parkland, dedicated as a bird sanctuary.

As the project progresses, these characteristics and many others will prove to be of varying degrees of relevance. Block-by-block census data are included, from CAGIS and from the U.S. Census Bureau. Also included are building heights, footprints, approximate square footages, parcel sizes, roadway area, parking lot outlines, incomes, approximate building and
land purchase prices and valuations (CAGIS). Traffic volumes and TAZ-level trip data are included from OKI, the local MPO. However, an important part of the research is determining the availability of relevant data and adjusting the model accordingly. As such, availability of data is actually a data point itself.

Additionally, the “Data & Results” Chapter includes inventories for the Cincinnati, Ohio, neighborhoods of Corryville, Mt. Adams, Mt. Washington, North Avondale, and Westwood, in order to contrast with the Clifton neighborhood, thereby helping to validate the study’s model.
Figure 2: Full Thesis Project Schedule
I. Introduction

The literature in this area of inquiry is perhaps best summed up by the title of a Sierra Club report: “Sprawl Costs Us All” (Sierra Club 2000). Sierra Club is the nation’s oldest and largest grassroots environmental organization, and anti-sprawl is one of its major program areas. The point of citing this title is that it captures a thread of seeming conventional wisdom that assumes sprawling development patterns of cities contribute disproportionately to atmospheric carbon loading or Greenhouse Gas (GHG) emissions. Pulling the concept apart and trying to quantify it and prove it has provided quite a number of authors with interesting research questions, as it does the present study.

An analytical look at the sprawl-GHG link yields a number of questions. First, has anyone defined “sprawl?” What is it about sprawl that causes greater GHG emissions and are the GHG contributions of sprawl to global warming really all that significant? Is there a way to measure directly the GHG emissions of different areas or are there proxies or ways to estimate the GHG emissions of different areas?

There is a body of literature answering these questions, but the present study approaches the GHG-sprawl connection at the point of seeking a useful and accurate way to compare the GHG emissions of varied neighborhoods. Complete answers to the two research questions should arise from the present study: 1) From the available literature, what would be necessary and appropriate elements for a Greenhouse Gas Inventory at a neighborhood scale? 2) when the available data and models are applied to a real example neighborhood, what works well, and where are the gaps and areas in need of further research? However, there is an appreciable amount of research around those questions too.

---

1 In fact, the report only deals with the ways government subsidizes sprawl. However, most of the rest of the “Sprawl” area of Sierra Club’s website deals with the connections between GHG emissions and urban and suburban development patterns.
II. What role does “sprawl” play in this study and has anyone defined it?

This question is obviously important to a clear discussion of the links between development patterns and GHG emissions. If the link was presented in mathematical terms, it might go something like (degree of sprawl) x (area of sprawl) = (amount of GHG), probably with some constant built in. In other words, a clear concept of degree of sprawl and what areas are recognizable as sprawl is essential.

While the term may show up all over the literature on climate change and cities, two writers seem to stand out as having tried to answer the question “what exactly is sprawl?” in a direct way. Both Reid Ewing and George Galster have grappled with the question, though each has taken his own approach. One of Galster’s journal articles has an especially evocative title: “Wrestling Sprawl to the Ground: Defining and Measuring an Elusive Concept” (Galster 2001).

Both Ewing and Galster show that there are multiple dimensions to sprawl. It is not as simple as, say, low population per area. Galster proposes eight dimensions of sprawl, which cover a broad range of land use and development characteristics: density, continuity, concentration, clustering, centrality, nuclearity, mixed uses, and proximity (Galster 2001, 1). He defines each with daunting-looking equations, then applies the procedure to 13 selected urban areas, finally compiling them into a single index number for each urban area. New York City ends up best, while Atlanta ends up worst of the 13 (Galster 2001, 27).

Ewing also includes dimensions of land use and centrality, but is more focused on the transportation consequences of sprawl. His indicators are residential density; neighborhood mix of homes, jobs, and services; strength of activity centers and downtowns; and accessibility of the street network. He tested his indicators on 83 U.S. Metropolitan Statistical Areas (MSAs), ranking New York City as the least sprawling, Riverside, CA, as the most. Atlanta was again well to the sprawl end of the spectrum (Ewing 2002).

So the answer to this question is “yes, and it’s complicated.” As the methodology of the present study consists largely of examining and testing possible factors in the GHG emissions of
neighborhoods, it is not necessarily essential to include a sprawl index. However, the study would not be complete without some recognition of the phenomenon.

III. What is it about sprawl that causes greater GHG emissions and are the GHG contributions of sprawl to global warming really all that significant?

Reid Ewing again figures prominently in this area. His *Growing Cooler: The Evidence on Urban Development and Climate Change* is very current, available in a 2008 revision from the Urban Land Institute (Ewing 2008). *Growing Cooler* goes even further than his earlier work toward emphasizing transportation. In fact, he basically resolves the entire sprawl index into vehicle miles traveled (VMT) as the most pertinent component for GHG production. This certainly makes some sense, since land use, centrality and the other factors are important to GHG emissions because they cause people to drive farther in their sprawling instances. In effect, when it comes to GHG emissions, he is saying that VMT can be taken as a proxy for all the sprawl indicators.

Marilyn Brown, in a report for the Brookings Institute (2008), uses a “partial carbon footprint.” This is just the carbon output of the transportation sector and residential buildings. Industrial, commercial, and government buildings are left out of the footprint. The report is intended as a policy guide, so it may be that not only the comparative magnitudes of the factors included and left out are important, but also their susceptibility to policy initiatives.

Brown connects urban development patterns, and especially building operations, even more directly in a report for the Pew Center for Global Climate Change, entitled *Towards a Climate-Friendly Built Environment* (2005). This report focuses even more on building operations, but includes industrial, commercial, and government buildings. It goes further into the arrangement of the buildings, calling for greater densities so as to allow better public transportation opportunities, neighborhood heating and localized electric power distribution and generation.
Finally, Norman, in a 2006 article affirmatively states that the best focus for reducing GHG emissions in metropolitan settings is on VMT. However, he goes on to say that the best focus for reducing energy use is on building operations.

All of these reports address the relationship between GHG emissions and development patterns in some way. Their actual calculations are probably beyond the scope of the present study, but may provide some opportunity for synthesis, and certainly provide context.

IV. Is there a way to measure directly the GHG emissions of different areas or are there proxies or ways to estimate the GHG emissions of different areas?

Kates (2008) says that the most important GHG, CO$_2$, is not measured directly. Furthermore, while the other GHGs, such as methane and chlorofluorocarbons are tracked directly in the U.S., CO$_2$ tends to get harder to track, even indirectly, at more local scales. This is because countries and states generally account for the hydrocarbons used within their borders, and they cover large enough areas to be more certain which emissions to allocate within their borders.

On the other hand, a vast literature has grown up around the indirect method of measuring CO$_2$ – the GHG inventory. Brugman, writing for ICLEI in 1996 pointed out that the focus has been towards modifying operations and policies at the local, city level, going all the way back to the 1992 Earth Summit (Brugman 1996).

Later, Betsil, in a paper prepared for the Open Meeting of the Human Dimensions of Global Environmental Change Research Community, at Rio de Janeiro, in 2001, pointed out that ICLEI had been recruiting city governments to take action against climate change ever since the 1992 Earth Summit (Betsil 2001).

Both writers cautioned against the city being taken as the only scale of climate change action. They acknowledged that the GHG emissions of cities are significant and that cities may be more susceptible to ICLEI organization, but pointed out that it takes quite a few cities to add up to a global effect.
The predominant and more recent literature in the U.S. on this topic is sponsored by the U.S. Council of Mayors’ Climate Protection movement. This movement began in 2005, when the final signatory necessary for the Kyoto Protocol to go into effect signed on, with the United States still glaringly absent. Since 2005, 902 mayors have committed their cities to reductions of GHG emissions, in line with the goals the Kyoto Protocol lays down for nations (USCM 2008). A parallel (essentially identical) movement among colleges and universities, called the Presidents’ Climate Commitment has also arisen, with 602 signatories at the end of 2008 (American College and University Presidents’ Climate Commitment 2008).

As part of the Climate Protection commitments, each city (and university or college) must perform a GHG inventory, to give a baseline against which reductions are measured. It is these inventories, still largely informed, supported, and even governed by ICLEI, that give the best proxy for CO₂ emissions at the local scale.

V. From the available literature, what would be necessary and appropriate elements for a Greenhouse Gas Inventory at a neighborhood scale? And, when the available data and models are applied to real example neighborhoods, what works well, and where are the gaps and areas in need of further research?

The second question, testing and exploring data and models on a real example neighborhood is where the present study really starts to depart from the available literature. As such, it will remain for the process of the study to answer the question.

The first question has an extensive literature around it. As pointed out above, 902 U.S. mayors and 602 university and college presidents have committed to following the Kyoto Protocol within their individual institutions (USCM 2008 and American College and University Presidents’ Climate Commitment 2008). Each institution must complete a GHG inventory at some point, and quite a number have. Again, ICLEI is the major source of knowledge and support on these efforts (ICLEI 2007), although the Intergovernmental Panel on Climate Change provides an alternative source (IPCC).
While ICLEI has developed software for accounting GHG emissions, they do not give a hard-and-fast list of sources for all to track. They do call for completeness and for allocating some external sources, such as electrical power plant emissions, to the locality (ICLEI 2007).

By way of example, a couple of cities have inventoried the following factors in their GHG inventories. The City of Chicago tracked the six major categories of GHGs from the Kyoto Protocol (Center for Neighborhood Technology 2008): carbon dioxide (CO$_2$), methane (CH$_4$), nitrous oxide (N$_2$O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF$_6$). The compounds other than CO$_2$ were converted to equivalent values for atmospheric warming of CO$_2$ or eCO$_2$, using IPCC methodology (Houghton 2001). The major source categories counted were Waste and Wastewater, Industrial Processes and Product Use, Transportation, and Energy.

The City of Clearwater, FL, focused primarily on City operations. They used ICLEI software, counting the emissions and eCO$_2$ for the same gases as Chicago, but their more limited scope allowed for a fuller listing of sources. Specifically, they counted

- Building electricity use
- Building natural gas use
- Electricity for streetlight, traffic signal, bridge light, median light, parking lot lights, and signage lighting
- Natural gas used for water and sewer departments
- Electricity used for water and sewer departments
- City vehicles, including boats
- Employee commuting
- Solid waste

They did not count air travel, methane released from historic landfills or wastewater treatment operations. Carbon sequestration, such as from urban forests and other biomass, is not included in the ICLEI software (City of Clearwater 2008).
The present study will, as part of its process, look more closely at others’ GHG inventories. It will attempt to formulate a reasonable list of factors that should go into a GHG inventory at the scale of a neighborhood, taking into account what data are appropriate and available for the neighborhood scale. The literature around the sprawl-GHG emissions, all the way through city-scale GHG inventories, provides the context and informs the research.
Chapter 3: Neighborhoods’ Role in Greenhouse Gas Emissions

Greenhouse gas (GHG) emissions studies or inventories operate as calculators. Researchers put in quantitative expressions of the extent of a number of activities. A GHG calculator multiplies each number by some factor, which then results in some estimated quantity of Carbon Dioxide (CO₂) emissions produced, or converts some other gas emission into its equivalent of CO₂ in causing global warming (eCO₂). In short, some quantity of any number of factors is fed in and an estimate of global warming contribution comes out.

These inputs and outputs are not necessarily highly accurate. The best hope for them is that they are reproducible and repeatable in different places and times, so that whatever the meaning of a GHG emissions inventory in one place is, it will have the same meaning in another place.

There are at least two different perspectives from which to view Greenhouse Gas emissions at the neighborhood level. One perspective is that of scale, while the other is that of function. That is, one set of issues is important because a neighborhood is smaller than a city but larger than an individual household. Another set becomes important because a neighborhood is, at least to some degree, a distinctive functional unit.

Another way to state this is that there are some factors that may be characteristic of a given neighborhood, while others are simply important because of the area’s being smaller than a city. So, if there is a significant difference in electricity use between apartment dwellers and residents of single-family detached houses, and some neighborhoods are characterized by a large number of apartments, the electricity use of the apartment dwellers in that neighborhood becomes an important factor. Similarly, if a given neighborhood has the characteristic of being particularly walkable for residents to meet their non-work travel needs, then car use (in this case, lack thereof) would be fall into the category of factors important for neighborhoods. The first group of issues are mostly those that operate at the city-wide scale. For instance, one would
expect any randomly-chosen area of a city to use a certain amount of electricity, which would be similar on a per capita basis to that of the whole city. One would expect there to be variations, due to scale and functional characteristics.

I. Scale

The way this becomes important for a neighborhood scale is that inputs change importance, simply because of scale. Furthermore, the way they might be measured would change. For instance, a metropolitan area might be served by several electrical power plants, so it would seem obvious to attribute those plants’ emissions to the metropolitan area. How do we attribute the emissions to a neighborhood? Maybe it is appropriate to simply use a per-capita “charge” for each neighborhood resident. However, might there be a difference between per-capita electricity use in a single-family suburban community of very new houses, as opposed to a dense, inner-city neighborhood of apartment buildings built in the 1920s, and is this difference significant? If a per-capita charge will not work, what is the appropriate measurement? Therefore, electricity use is one factor that appears to present problems for a neighborhood scale GHG inventory’s numbers having the same meaning in different locations.

GHGs are mostly CO$_2$, which comes largely from burning fossil fuels. However, a not insignificant amount of GHGs come from the direct emission of other gases. Many of these are much more powerful contributors to global warming per unit, but occur in such small quantities that they do not have the overall impact of CO$_2$. Two examples would be gas from decay in landfills and methane from farm animals. At the neighborhood scale, these would mostly drop away, where they might be important at the scale of a city or larger. That is, only a very few unfortunate neighborhoods contain large landfills, and fewer still contain cows. Therefore, it seems reasonable to concentrate on emissions from burning fossil fuels.

Conversely, the carbon from wood-burning fireplaces is counted more easily as trees cut down at the regional scale, while at the neighborhood scale this is probably not appropriate. That is, few neighborhood homeowners burn wood cut on their own property. Still, with the
popularity of gas burning fireplaces, and the general rarity of any fireplaces, this may not be such a large factor.

People burn fossil fuels in four major categories: electricity, transportation, construction, and direct use of heat from combustion. Electricity is used in indoor and outdoor lighting, space heating, air conditioning, water heating, cooking, large appliances, and small appliances and electronics, as well as water pumping and sewage processing. Transportation mostly burns gasoline, some diesel, and some propane, and a very little bit of biomass. Construction includes fossil fuels used in internal-combustion engines, electricity and fossil fuels used to power hand tools, the production of concrete and other manufactured materials, as well as VMT from the delivery of materials and labor. Direct use of heat would include primarily natural gas space heating, water heating, cooking, with a lesser amount of propane used in these functions. The northeast part of the U.S. has traditionally relied heavily on fuel oil for heat, although this has been slowly decreasing. Again, the scale of a neighborhood plays a role in these factors, because variations in their use becomes more significant at this smaller scale.

Electricity

Again, on a regional, state, or somewhat on a city scale, it is safe to use electricity production as an aggregate for electricity use, attributing a per-capita use to residents. However, at the neighborhood scale, habits and uses of electricity might be very different. Some neighborhoods rely heavily on electricity for space heating, while others even in the same region may rely more on natural gas or fuel oil. Different time periods saw different heating sources in fashion, so housing from different eras may use different heat sources. Likewise, single family versus multi-family versus large multi-family would have different tendencies, in different ages of buildings to use electricity for water heating and cooking.

Air conditioning is almost always electrically-powered, although some large area chillers could use other power sources for their pumps. In any case, this is one factor that probably can be
attributed on a per-capita basis. The pertinent variable here would be how many days times degrees above 70° an area averages.

Indoor lighting is another factor that could vary greatly in different areas. With some houses moving towards compact fluorescent lights, and even LEDs, this could also show significant differences between neighborhoods.

Other large and small appliances and electronics probably vary little by neighborhood in whether they use electricity. Clothes dryers may use natural gas instead of electricity, but probably without the dependable inter-neighborhood variation of cooking and space heating. For all the others, economic status is probably one of the most important variables, for efficiency on one side, and degree of use on the other. That is, households with more money might be expected to purchase newer, more efficient appliances. However, they would also tend to use more small appliances and electronics. Housing type would also be important here, as apartment-dwellers are much less likely to choose their own appliances, by efficiency or any other factor.

Outdoor lighting, including traffic lights and signage might also vary quite a bit by neighborhood, with the differences becoming significant at that scale. Some fewer older neighborhoods even depend largely on natural gas for street lighting.

The final sub-category to examine at the neighborhood scale is water. A considerable amount of electricity (although other fuels are possible) is used in delivering tap water and removing and treating both run-off and sanitary water. Also, there would be considerable variations among neighborhoods. A neighborhood with many acres of grass lawns would see some amount of additional use for watering, while a dense neighborhood of apartment blocks might have large amounts of runoff to treat.

**Transportation**

Transportation in the United States primarily uses gasoline, followed by diesel, and some propane, largely in school buses and some other large trucks. The fuel used probably would not vary too much among neighborhoods as a function of the sub-city scale. It would vary more by
the internal land use characteristics, with more diesel used in neighborhoods with more commercial activity, schools and institutions. A far more important characteristic would be the extent of use – or vehicle miles. Both of these are determined more by the functional characteristics of individual neighborhoods, not by the fact of choosing a scale smaller than a city.

Construction

Construction produces a significant amount of GHGs. According to the U.S. Green Building Council, some 39% of the lifetime GHG emissions of a building are released during its construction. Some of this will show up in accounting for VMT, for the delivery of materials and labor. However, some will show up in the loss of carbon-absorbing biomass, resulting from timber and other fiber materials. A large amount is emitted in the production of concrete and any steel used in the building. Heavy equipment, like bulldozers and backhoes, also burn fossil fuels, mostly diesel, and with not necessarily very well cleaned exhaust. Finally, power tools can use electricity and sometimes gasoline. The gasoline-burning power tools do not generally have very clean exhaust.

Construction can show up as a GHG inventory factor in any piece of a city. It is not really dependent on being a participant in a neighborhood, but will show quite a bit of variation between any two areas of a city. A GHG inventory of a neighborhood should probably include some amortized factor for construction. That is, a neighborhood of recent “greenfield” construction would have a greater impact on global warming than one whose entire building stock was erected by 1900.

Direct Heat

As discussed in the section on electricity, focusing on GHGs in an area smaller than a city would make differences in sources of direct heat significant. Direct heat essentially would be space heating, water heating, and cooking. These do show up as characteristically electric in one neighborhood, versus natural gas in another.
II. Functional Characteristics

The American Heritage Dictionary (2009) gives as its first definition of neighborhood “A district or area with distinctive characteristics.” Issues strictly of scale do make a difference in a GHG inventory of a neighborhood – when the focus is on a slice of a city, rather than the entire city, certain factors become more important in differentiating areas. However, certain functional characteristics of a neighborhood, as opposed to a randomly-chosen slice of a city, are important as well.

The primary emissions factor that follows from how a neighborhood is arranged is vehicle miles traveled (VMT). The occurrence of specific land uses – say large multi-family apartment blocks, versus large-lot single-family houses – necessarily makes a difference, but it would make a difference in any piece of a city, coherent or not. It is the arrangement of those land uses that makes a difference because a neighborhood is a neighborhood. Public transportation makes a difference in VMT, and the level of public transportation service usually relates to the density of an area, but public transportation makes a direct difference, no matter how you slice a city.

The arrangement of land uses largely determines how often residents and users of the neighborhood need to drive. While perhaps not that many people are lucky enough to live and work in the same neighborhood, work commutes account for less than half of VMT. It is all the incidental trips, the ones that well-arranged neighborhoods can make possible without a car, that account for the majority of VMT in the U.S.

The Clifton neighborhood of the present study, for instance, includes some 12,000 people, the vast majority of whom are within a 10-minute walk of a neighborhood business district that includes a 10,000 square foot grocery store, a pharmacy of approximately the same size, a six-screen movie theater, 10 restaurants, two coffee houses, two yoga instructors, an ice cream shop, a public library branch, and several other stores and banks. Outside the business district, but still within a 10-minute walk for the majority of residents, are a public elementary school, two private
schools, several preschools and churches. In other words, even if one has to do a work commute by car, the other 60% or so of VMT could be replaced by walking.

III. Conclusion

A greenhouse gas inventory at a neighborhood scale must take note of a number of factors that may be safely treated in the aggregate at a larger scale. These further break down into two categories: those that make a difference strictly because of the smaller geographic scale, and those that become important differentiators because one is studying an actual neighborhood. Those that become important because of scale are further differentiated largely by styles and habits, reflecting the time period of construction.
Chapter 4: Data & Analysis

I. Introduction & Study Areas

Six neighborhoods of the city of Cincinnati are evaluated for per-person greenhouse gas emissions. They are Clifton, Corryville, Mt. Adams, Mt. Washington, North Avondale, and Westwood. The author resides in the Clifton neighborhood, so this was taken as a starting point. The point of the study was not just to come up with a number, but also to get some sense, on the way, of how meaningful the number might be. Furthermore, the methodology is proposed to apply to any neighborhood. Therefore, a neighborhood with which the author is intimately familiar provides a good touchstone for data quality and potential problems for the other neighborhoods. The following figures (Figures 3-4) show the locations of the neighborhoods and study areas, within Cincinnati, Hamilton County, and the region.

Figure 3: Location of Hamilton County and Cincinnati in the broader region
Data availability and descriptiveness were the main determinants in the final numbers produced. As discussed above, many important factors could go into calculating greenhouse gas at a neighborhood scale. Vehicle Miles Travelled, or VMT are extremely important, and were the focus of much of Reid Ewing’s research cited above.

In fact, evaluation of VMT ended up playing a major role in determining the precise boundaries of the study areas. Cincinnati has 51 delineated official neighborhoods, each with a City-recognized community council. These community councils work with the City to set the geographic boundaries for each neighborhood, and there are many areas that are disputed. For the present study, the community council-delineated boundaries were not the most important.
Building-by-building data can work well with council boundaries, but Census and Travel Assignment Zone (TAZ) data use borders that do not precisely follow their lines. Fortunately Census Blocks, at least within the city, do follow the larger TAZ boundaries very closely. This does not hold true outside the city limits, however, which is why only city neighborhoods were used in the present study.

Figure 5: Official neighborhood boundaries vs. TAZ-determined approximations used as study areas

Further methodological factors are worth mentioning at this point. First, the TAZs to study were chosen to approximate the official neighborhood boundaries as closely as possible, without including or excluding significant business district or residential areas. Also, disputed areas were avoided, which produces the most remarkable result in the North Avondale study area. A final strategy was to avoid major institutions, or basically anything that could be called a
“campus.” These do not operate at the strictly neighborhood level, but are important at the city or regional scale. In fact the University of Cincinnati, whose medical campus was a major part of Corryville, but which is left out of this study, is a signatory of the Presidents’ Climate Challenge (2007), and thus pursuing its own greenhouse gas emissions studies. A huge city park, Eden Park, explains the discrepancy between the Mt. Adams study area and official neighborhood boundary.

Embodied energy, or the energy used in construction and materials, is significant, contributing anywhere from 8% (Community Solution 2007) to as much as 40% (USGBC 2009) of a building’s lifetime energy use. Obviously, the building users make a big difference with what they do in the buildings as well, in both residential and non-residential buildings. However, while building age was considered as a factor in the final greenhouse gas numbers, it does not appear in the final results. The building data available en masse from CAGIS do not include year built for 100% of buildings, and because of uneven recognition of major renovations, do not provide a solid foundation for such calculations. The County Auditor, of course, has reliable year-built data, but they are not available in the aggregate, only on a building-by-building basis.

On the other hand, we have data from the Department of Energy’s Energy Information Administration (EIA) that can tell us the average person’s energy use, according to their region of the country or their income or whether they own or rent or by the age of the building they occupy. We have census statistics that can tell us how many people in a neighborhood live in a building their household owns or that they rent. We can extract from the local Geographical Information Systems a guess about when a building was built, unless the date happens to reflect just a major renovation. We can tell how many buildings are single family detached or attached, or contain 2-4 units, or five or more. We cannot tell how many people live in which size buildings, how many live in buildings of what age nor whether those buildings contain two, three, four, five, or fifty units.

We also have believable numbers for vehicle miles travelled. The Ohio, Kentucky and Indiana Council of Governments (OKI), which is the Metropolitan Planning Organization (MPO) for the Cincinnati area, was able to provide the number of trips originating in each Transportation
Assignment Zone (TAZ) in each study area. These are based on surveys and modeling, and represent the best available travel data for the area. The data are further distinguished by single-occupancy passenger vehicle, two-person-occupancy passenger vehicle, three-person-occupancy passenger vehicle, “single-unit” or “straight” trucks, and multi-unit or “semi-“ trucks. For the purposes of this study, the multi-passenger vehicle distinctions are immaterial. They would lower VMT for passenger vehicles, since more than one person is accomplishing a trip purpose in one set of vehicle miles. USEPA provides average fuel consumption, in miles per gallon, for passenger vehicles, single-unit trucks, and multi-unit trucks. USEPA also provides eCO$_2$ conversions for liquid fuels that fold in diesel and other fuels used in vehicles.

The next step, in the Results chapter, will present final numbers for each neighborhood. To get them to compare to the citywide numbers from the citywide Climate Action Plan, numbers that do not really apply at the neighborhood scale will be included. Emissions from City operations such as safety, sewer and water, and administration do not link that well to neighborhoods, but are still attributable as the neighborhoods are part of the larger city. Moreover, as above, the numbers will just make more sense if they compare directly to the City numbers, by having all the same components parts, just with neighborhood-specific calculations where possible. The converse should be pointed out here as well – where the data used in the present study are unavailable for some future neighborhood assessment for one of the components, the citywide numbers could just be carried over.

II. Residential eCO$_2$

Of the data that are reliable from the study area neighborhoods, the matching EIA data that seem most descriptive of different neighborhoods are the rent vs. own data. The population that lives in rented vs. owned housing in each neighborhood is fairly dependable, coming from the Census Bureau, although in 2009 the data are getting about as out of date as they can be. EIA also tells us how much energy residents of the Eastern part of the North Central region use, per person. Assuming that renters in this part of the country use energy to one extent, compared to
owners at another, that is similar to the relationship nationwide, we can calculate eCO₂ numbers for residents of the six neighborhood study areas. Note, though, that the rent vs. own relationship is a rough stand-in for housing type. That is, we’re further assuming that renters have a stronger tendency to live in multi-unit buildings, while owners have a stronger tendency to live in single-family detached housing, at least to an extent that would make a difference in the aggregate data.

This gives us the energy use, in BTU’s, of residents in owned or rented housing in the census’ East North Central region of the Midwest. From that, we can convert to eCO₂ since we have the carbon signature of energy use in this area (EIA 2009). Table 2 shows the balance of energy sources used in the region. The EIA site also includes direct conversions from BTU to eCO₂ for each source, except electricity. However, another EIA resource, the eGRID spreadsheets, shows the regional electricity plants and fuel mix used for utility companies. The eCO₂ conversion from electricity BTUs was developed from eGRID. The key generating plants and their fuel mixes are shown in Table 1.

Table 1: Cincinnati, Ohio, regional electricity eCO₂ (Source: EIA eGRID)

<table>
<thead>
<tr>
<th>Plant Name</th>
<th>Plant annual net generation (MWh)</th>
<th>Plant annual CO₂ emissions (lbs)</th>
<th>Plant annual CH₄ emissions (lbs)</th>
<th>Plant annual N₂O emissions (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gibson</td>
<td>22,442,805.0</td>
<td>43,492,788,500.0</td>
<td>493,002.9</td>
<td>739,504.4</td>
</tr>
<tr>
<td>W H Zimmer</td>
<td>10,340,814.0</td>
<td>17,927,932,450.0</td>
<td>203,218.1</td>
<td>304,827.2</td>
</tr>
<tr>
<td>Miami Fort</td>
<td>7,566,870.0</td>
<td>15,220,985,250.0</td>
<td>172,618.7</td>
<td>258,779.3</td>
</tr>
<tr>
<td>Cayuga</td>
<td>6,547,154.0</td>
<td>12,935,798,288.0</td>
<td>146,907.3</td>
<td>219,441.3</td>
</tr>
<tr>
<td>Walter C Beckjord</td>
<td>6,523,513.0</td>
<td>13,495,594,898.8</td>
<td>154,595.3</td>
<td>229,041.5</td>
</tr>
<tr>
<td>Wabash River</td>
<td>4,725,718.0</td>
<td>10,776,276,055.0</td>
<td>121,432.8</td>
<td>181,997.5</td>
</tr>
<tr>
<td>East Bend</td>
<td>3,705,966.0</td>
<td>7,330,874,200.0</td>
<td>83,097.6</td>
<td>124,646.4</td>
</tr>
<tr>
<td>R Gallagher</td>
<td>2,876,904.0</td>
<td>6,262,210,140.0</td>
<td>70,984.0</td>
<td>106,476.1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>64,729,744.0</strong></td>
<td><strong>127,442,459,781.8</strong></td>
<td><strong>1,445,856.7</strong></td>
<td><strong>2,164,713.6</strong></td>
</tr>
<tr>
<td>Avg Lbs/MWh</td>
<td>1968.84</td>
<td>0.02234</td>
<td>0.03344</td>
<td>296</td>
</tr>
<tr>
<td>eCO₂ Factor</td>
<td>1</td>
<td>23</td>
<td>296</td>
<td></td>
</tr>
<tr>
<td>Lbs eCO₂</td>
<td>1968.84</td>
<td>0.51</td>
<td>9.90</td>
<td></td>
</tr>
<tr>
<td><strong>Total eCO₂/MWh</strong></td>
<td><strong>1979.25</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Now that we have the energy use in the study area for each person in a rented or owned home, the conversion factor of energy to eCO₂ for the region, and the number of people in each study neighborhood who live in rented or owned homes, we can calculate the per-person eCO₂ for each neighborhood:
III. Non-Residential eCO₂

While residential energy-use data from EIA are generally based on households and persons, the data for non-residential buildings are based on square feet of space in buildings (EIA 2009). Square feet of non-residential buildings for each study area are listed in Table 5.

The neighborhoods were chosen with some eye to variability, to put the greenhouse gas inventory methodology to the test. The maps, above, show wide variance in geographical area, while Table 4 shows huge diversity in population. Table 5 also shows great variability in the amount of non-residential building square footage serving the population. North Avondale has a mere 12 square feet per person (basically all institutional), while Corryville shows 393 square feet per person. The Corryville study area, despite cutting out as much campus institutional buildings as possible, still includes a few large office buildings. Non-residential space in Mt. Washington, on the other hand, is largely small-scale or neighborhood-serving commercial, as are the spaces in Mt. Washington and Westwood. Mt. Adams shows the effect of at least one large office building, as well as some riverfront commercial forced in by the TAZ use.

<table>
<thead>
<tr>
<th>Neighborhood</th>
<th>Total Pop.</th>
<th>Pop. In Owned</th>
<th>Pop. In Rented</th>
<th>eCO₂/Person - Owned</th>
<th>eCO₂/Person - Rented</th>
<th>Gross eCO₂ - Owned</th>
<th>Gross eCO₂ - Rented</th>
<th>Avg. eCO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clifton</td>
<td>6,690</td>
<td>2,687</td>
<td>4,003</td>
<td>2.421246</td>
<td>1.736238</td>
<td>6,505.89</td>
<td>6,950.16</td>
<td>2.01</td>
</tr>
<tr>
<td>Corryville</td>
<td>3,294</td>
<td>512</td>
<td>2,782</td>
<td>2.421246</td>
<td>1.736238</td>
<td>1,239.68</td>
<td>4,830.21</td>
<td>1.84</td>
</tr>
<tr>
<td>Mt. Adams</td>
<td>1,596</td>
<td>652</td>
<td>944</td>
<td>2.421246</td>
<td>1.736238</td>
<td>1,578.65</td>
<td>1,639.01</td>
<td>2.02</td>
</tr>
<tr>
<td>Mt. Washington</td>
<td>12,092</td>
<td>7,392</td>
<td>4,700</td>
<td>2.421246</td>
<td>1.736238</td>
<td>17,897.85</td>
<td>8,160.32</td>
<td>2.15</td>
</tr>
<tr>
<td>North Avondale</td>
<td>1,801</td>
<td>1,346</td>
<td>455</td>
<td>2.421246</td>
<td>1.736238</td>
<td>3,259.00</td>
<td>789.99</td>
<td>2.25</td>
</tr>
<tr>
<td>Westwood</td>
<td>27,447</td>
<td>12,382</td>
<td>15,065</td>
<td>2.421246</td>
<td>1.736238</td>
<td>29,979.87</td>
<td>26,156.43</td>
<td>2.05</td>
</tr>
</tbody>
</table>
The EIA gives 105.2 thousand BTU/sq.ft. as the energy intensity for non-residential space in the study area climate zone (EIA 2009). Table 6, also from the USEPA, shows the conversion factors of BTUs of energy to appropriate physical units it takes to produce that energy with each different source. Table 7 shows the component sources in that energy and the amount of eCO₂ it generates in the study areas’ region.

### Table 5: Non-Residential space in study neighborhoods (Source: CAGIS 2000)

<table>
<thead>
<tr>
<th>Neighborhood</th>
<th>Non-Res SF</th>
<th>Total Pop.</th>
<th>Non-Res SF/Person</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clifton</td>
<td>1,736,435</td>
<td>6,690</td>
<td>260</td>
</tr>
<tr>
<td>Corryville</td>
<td>1,294,741</td>
<td>3,294</td>
<td>393</td>
</tr>
<tr>
<td>Mt. Adams</td>
<td>557,688</td>
<td>1,596</td>
<td>349</td>
</tr>
<tr>
<td>Mt. Washington</td>
<td>1,548,980</td>
<td>12,092</td>
<td>128</td>
</tr>
<tr>
<td>North Avondale</td>
<td>22,098</td>
<td>1,801</td>
<td>12</td>
</tr>
<tr>
<td>Westwood</td>
<td>2,781,929</td>
<td>27,447</td>
<td>101</td>
</tr>
<tr>
<td>(Total)</td>
<td>7,941,871</td>
<td>52,920</td>
<td>150</td>
</tr>
</tbody>
</table>

### Table 6: BTU - physical unit conversions (Source USEPA 2009)

<table>
<thead>
<tr>
<th></th>
<th>Btu Equivalent</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity (site)</td>
<td>3.412</td>
<td>Btu/kilowatthour</td>
</tr>
<tr>
<td>Electricity (primary)</td>
<td>10.338</td>
<td>kilowatthour¹</td>
</tr>
<tr>
<td>Natural gas</td>
<td>1.031</td>
<td>Btu/cubic foot</td>
</tr>
<tr>
<td>Fuel Oil No.1</td>
<td>135,000</td>
<td>Btu/gallon</td>
</tr>
<tr>
<td>Kerosene</td>
<td>135,000</td>
<td>Btu/gallon</td>
</tr>
<tr>
<td>Fuel Oil No.2</td>
<td>138,690</td>
<td>Btu/gallon</td>
</tr>
<tr>
<td>LPG (propane)</td>
<td>91,330</td>
<td>Btu/gallon</td>
</tr>
<tr>
<td>Wood</td>
<td>20,000,000</td>
<td>Btu/cord</td>
</tr>
</tbody>
</table>

### Table 7: Sources of energy and conversions to physical units and eCO₂ (Source: EIA & EPA)

<table>
<thead>
<tr>
<th>Percent of 105.2 Thous. BTU/sq.ft. for climate zone</th>
<th>Electricity</th>
<th>Natural Gas</th>
<th>Fuel Oil</th>
<th>Propane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Intensity (Thousand BTU/sq.ft.)</td>
<td>46.05%</td>
<td>37.6%</td>
<td>10.61%</td>
<td>6.75%</td>
</tr>
<tr>
<td>BTU to Units Conversion (Convert to kWh)</td>
<td>(Convert to Therms) (Convert to Bbl) (Convert to Bbl)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conversion Factor</td>
<td>3.412</td>
<td>100,000</td>
<td>135,000</td>
<td>91,330</td>
</tr>
<tr>
<td>eCO₂ Factor (Metric Tons eCO₂/unit)</td>
<td>0.0008978</td>
<td>0.0500</td>
<td>4.3000</td>
<td>0.2319</td>
</tr>
<tr>
<td>Metric Tons eCO₂/sq.ft.</td>
<td>0.0127</td>
<td>0.0197752</td>
<td>0.0084610</td>
<td>0.0003659</td>
</tr>
<tr>
<td>Total eCO₂/sq.ft.</td>
<td>0.0413481</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The real goal is to determine the amount of eCO₂ attributable to each neighborhood and thus to each neighborhood resident for non-residential space. So Table 8, an extension of Table 5, brings all the calculations to show the per-person non-residential component of neighborhood greenhouse gas emissions:

Table 8: Per-person GHG from non-residential buildings, by neighborhood (Source: EIA, USEPA, & CAGIS 2000)

<table>
<thead>
<tr>
<th>Neighborhood</th>
<th>Non-Res SF</th>
<th>Total Pop.</th>
<th>Non-Res SF/Person</th>
<th>Gross Metric Tons eCO₂</th>
<th>Per Person Metric Tons eCO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clifton</td>
<td>1,736,435</td>
<td>6,690</td>
<td>260</td>
<td>71,784</td>
<td>10.73</td>
</tr>
<tr>
<td>Corryville</td>
<td>1,294,741</td>
<td>3,294</td>
<td>393</td>
<td>53,525</td>
<td>16.25</td>
</tr>
<tr>
<td>Mt. Adams</td>
<td>557,688</td>
<td>1,596</td>
<td>349</td>
<td>23,055</td>
<td>14.45</td>
</tr>
<tr>
<td>Mt. Washington</td>
<td>1,548,980</td>
<td>12,092</td>
<td>128</td>
<td>64,035</td>
<td>5.30</td>
</tr>
<tr>
<td>North Avondale</td>
<td>22,098</td>
<td>1,801</td>
<td>12</td>
<td>914</td>
<td>0.51</td>
</tr>
<tr>
<td>Westwood</td>
<td>2,781,929</td>
<td>27,447</td>
<td>101</td>
<td>115,005</td>
<td>4.19</td>
</tr>
<tr>
<td>(Total)</td>
<td>7,941,871</td>
<td>52,920</td>
<td>150</td>
<td>328,317</td>
<td>8.57</td>
</tr>
</tbody>
</table>

IV. Vehicle Miles Travelled

The final factor that will go into the analysis is vehicle miles travelled, or VMT. For this analysis, as mentioned above, the Ohio, Kentucky and Indiana Council of Governments (OKI) provided trip origination counts for each Transportation Assignment Zone (TAZ) in each study area. Since they were only origination numbers, all but the same-TAZ numbers were doubled. Almost all originated trips have a return, after all, unless a trip happens to be the instance of somebody moving out of the neighborhood. A somewhat more precise, but much more cumbersome, method would have been to analyze all the TAZs in the OKI region and count every trip to or from the study area TAZs.

The USEPA, on its “Clean Energy Calculations & References” web page (USEPA 2009) gives both the average miles per gallon for each type of vehicle (passenger car = 22.9 mpg, single-unit truck = 8.8 mpg, multi-unit truck = 5.9 mpg), and .00881 Metric Tons eCO₂ per gallon of gasoline burned. Metric tons of eCO₂ are presented for each neighborhood in Table 9:
There is dramatic variation among the neighborhoods on this measure. The high number, Mt. Adams’ 10.68 metric tons of eCO$_2$/person/year, is over five times as high as the low, North Avondale’s 2.10 metric tons of eCO$_2$/person/year. The median value would be 4.92, and all but the two extremes are relatively close to the median.

V. Analysis – Neighborhoods

1. Citywide

In 2007, Cincinnati Mayor Mark Mallory signed the U.S. Conference of Mayors’ Climate Commitment. City Council voted to pursue the development of a Climate Action Plan, which was completed and adopted by Council in 2008. While most of this document (nearly 200 pages) is Appendices containing specific idea contributions from the citizen participants in the plan (those of the author and one of his committee members are among them), ten pages at the front give the results of a greenhouse gas inventory of the whole city. Table 10 presents the results from the report, but expanded to include a column for per-person eCO$_2$ emissions for the city, based on the U.S. Census revised 2005 estimate of 331,283. Later tables will present comparative data for each neighborhood study area.

Table 9: eCO$_2$ from Vehicle Miles Travelled per person, by neighborhood (Source: USEPA, EIA, and U.S. Census, and CAGIS 2000)

<table>
<thead>
<tr>
<th>Neighborhood</th>
<th>VMTcar</th>
<th>VMTsut</th>
<th>VMTmut</th>
<th>Total Fuel</th>
<th>Metric tons eCO$_2$/day</th>
<th>Metric Tons eCO$_2$/yr.</th>
<th>Population</th>
<th>eCO$_2$/ Person</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clifton</td>
<td>225.269</td>
<td>4.012</td>
<td>4.445</td>
<td>11,046</td>
<td>97</td>
<td>35,521</td>
<td>6,680</td>
<td>5.31</td>
</tr>
<tr>
<td>Corryville</td>
<td>129.369</td>
<td>2.182</td>
<td>1.748</td>
<td>6,194</td>
<td>55</td>
<td>19,916</td>
<td>3,294</td>
<td>6.05</td>
</tr>
<tr>
<td>Mt. Adams</td>
<td>105.302</td>
<td>1.910</td>
<td>2.851</td>
<td>5,299</td>
<td>47</td>
<td>17,039</td>
<td>1,596</td>
<td>10.68</td>
</tr>
<tr>
<td>Mt. Washington</td>
<td>327.019</td>
<td>7.472</td>
<td>11.295</td>
<td>17,044</td>
<td>150</td>
<td>54,807</td>
<td>12,092</td>
<td>4.53</td>
</tr>
<tr>
<td>North Avondale</td>
<td>21.462</td>
<td>711</td>
<td>932</td>
<td>1,176</td>
<td>10</td>
<td>3,782</td>
<td>1,801</td>
<td>2.10</td>
</tr>
<tr>
<td>Westwood</td>
<td>615.760</td>
<td>13.577</td>
<td>12.372</td>
<td>30,529</td>
<td>269</td>
<td>98,170</td>
<td>27,447</td>
<td>3.58</td>
</tr>
</tbody>
</table>
The “Waste” sector comes in as a negative number because of landfill gas capture and re-use (City of Cincinnati 2008). Also since both Waste and City Administration and Safety are more easily counted at the city level, the per-person eCO\textsubscript{2} numbers from the city study will simply be carried over to the neighborhood studies.

2. Clifton

The Clifton neighborhood, shown in Figure 6, is near the University of Cincinnati, as is the Corryville neighborhood. However, Clifton has a much stronger neighborhood business district and a broader range of socio-economic characteristics among its residents than does Corryville. Housing types range from four-story apartment buildings, mostly near the business district toward the south, to fairly large single-family detached houses (some cut up into apartments) on 3,500 square foot lots, to grand houses in estate settings at the northern end of the neighborhood.

Table 10: Citywide eCO\textsubscript{2} aggregate and per-person (Source: City of Cincinnati 2008)

<table>
<thead>
<tr>
<th>Category</th>
<th>Metric tons eCO\textsubscript{2}</th>
<th>Metric Tons eCO\textsubscript{2}/person</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>1,571,402</td>
<td>4.74</td>
</tr>
<tr>
<td>Non-Residential</td>
<td>4,774,541</td>
<td>14.41</td>
</tr>
<tr>
<td>Transportation</td>
<td>2,251,539</td>
<td>6.80</td>
</tr>
<tr>
<td>Waste</td>
<td>-127,005</td>
<td>-0.38</td>
</tr>
<tr>
<td>City Administration &amp; Safety</td>
<td>432,179</td>
<td>1.30</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>8,902,656</strong></td>
<td><strong>26.87</strong></td>
</tr>
</tbody>
</table>

Table 11: Clifton eCO\textsubscript{2} results (Source: City of Cincinnati, OKI, CAGIS 2000, U.S. Census, EIA, and USEPA)

<table>
<thead>
<tr>
<th>Category</th>
<th>Citywide Metric Tons eCO\textsubscript{2}/person</th>
<th>Clifton Metric Tons eCO\textsubscript{2}/person</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>4.74</td>
<td>2.01</td>
</tr>
<tr>
<td>Non-Residential</td>
<td>14.41</td>
<td>10.73</td>
</tr>
<tr>
<td>Transportation</td>
<td>6.80</td>
<td>5.31</td>
</tr>
<tr>
<td>Waste</td>
<td>-0.38</td>
<td>-0.38</td>
</tr>
<tr>
<td>City Administration &amp; Safety</td>
<td>1.30</td>
<td>1.30</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>26.87</strong></td>
<td><strong>18.97</strong></td>
</tr>
</tbody>
</table>
Table 11 shows the results for the Clifton neighborhood, compared to those of the city of Cincinnati. Clifton’s eCO$_2$ for each of its 6,690 residents is nearly 30% lower than for the city as a whole – 18.97 vs. 26.87 metric tons of eCO$_2$ for Clifton and the city, respectively. The largest percentage difference by category is in the Residential sector. In fact differences of this order show up in all six neighborhoods. In fact, the number the City gives seems a bit high as it is close to the EPA’s regional average per household, while the number calculated for the present study is more in line with the regional average. However, the data the City Climate Action Plan gives is aggregated for the entire city, so only the calculation of its value per person appears in the present study. Also, the City was able to work with truly aggregate data, starting with the total citywide electricity, natural gas, and other fuels numbers from the local utility provider, Duke Energy. Unfortunately, this also means that it is virtually impossible to “look inside” Duke’s data and discover where the important differences lie.

The next most significant difference is in the eCO$_2$ resulting from non-residential buildings. The City had to take into account industrial as well as all other types of non-residential buildings, while the study areas include no significant industrial facilities. Most of the remaining industry within the city limits is concentrated in a few other neighborhoods.

Finally, VMT generate numbers a different from and lower than the City’s by approximately 20%, 6.83 versus 5.31 metric tons of eCO$_2$ per person for Clifton. Clifton would be expected to have a lower number, since it is a fairly walkable neighborhood, with many essential services located within 10 minutes’ walk of most residents. This pattern shows well in the map of Figure 6.
3. Corryville

Table 12 shows the eCO$_2$ per person figures for the part of the Corryville neighborhood studied, versus the numbers calculated by the City.

<table>
<thead>
<tr>
<th>Category</th>
<th>Citywide Metric Tons eCO$_2$/person</th>
<th>Corryville Metric Tons eCO$_2$/person</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>4.74</td>
<td>1.84</td>
</tr>
<tr>
<td>Non-Residential</td>
<td>14.41</td>
<td>16.25</td>
</tr>
<tr>
<td>Transportation</td>
<td>6.80</td>
<td>6.05</td>
</tr>
<tr>
<td>Waste</td>
<td>-0.38</td>
<td>-0.38</td>
</tr>
<tr>
<td>City Administration &amp; Safety</td>
<td>1.30</td>
<td>1.30</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>26.87</strong></td>
<td><strong>25.06</strong></td>
</tr>
</tbody>
</table>
Corryville’s total is much closer to the City’s. Non-residential is actually higher than citywide, probably because of some large-scale office buildings located in the study area. Transportation is nearly as high as the City’s number, although there is still a major difference in the Residential sector. Corryville has a relatively large number of renting residents, which could account for this.

Figure 8 shows the Corryville study area, and its overall pattern shows up well. It is mostly block grids of small buildings, with some much larger buildings along the main streets at the periphery.

Figure 7: Corryville Study Area Map (Source: CAGIS 2000)
4. Mt. Adams

Mt. Adams is the only study area that returned a higher number than the City, as shown in Table 13. The Transportation sector is basically responsible for this, producing 10.68 metric tons of eCO$_2$, versus the citywide number of 6.80, some 57% higher. This is somewhat unexpected, as Mt. Adams has the densest feel and the strongest-seeming neighborhood business district of any of the areas, as shows in the center of the area in Figure 8. On the other hand, it is a very affluent neighborhood, which can drive VMT higher, and lacks some of the essential services, such as a grocery store, that are present in Clifton. Non-residential is very closely aligned with the citywide number, while the Residential sector is lower, but very much in line with the other neighborhoods.

Figure 8: Mt. Adams Study Area Map (Source: CAGIS 2000)
5. **Mt. Washington**

Mt. Washington, shown in Figure 9, at the far eastern edge of the city of Cincinnati, has a largely suburban character, but does feature a relatively cohesive neighborhood business district. The area also includes several large apartment complexes. Its calculated $eCO_2$, in Table 14, is less than half that of the City’s. It is lower in every sector calculated, with the biggest difference being in the Non-residential sector. A look back at Table 8 shows that it has a much lower number of Non-residential square feet of building space per resident than do any of the three previous neighborhoods. It is in line with the previous three in the Residential sector, in fact even a little higher. Finally, VMT is lower than the previous three neighborhoods.

### Table 13: $eCO_2$ per person for the Mt. Adams study area (Source: City of Cincinnati, OKI, CAGIS 2000, U.S. Census, EIA, and USEPA)

<table>
<thead>
<tr>
<th>Category</th>
<th>Citywide</th>
<th>Mt. Adams</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Metric Tons</td>
<td>Metric Tons</td>
</tr>
<tr>
<td></td>
<td>$eCO_2$/person</td>
<td>$eCO_2$/person</td>
</tr>
<tr>
<td>Residential</td>
<td>4.74</td>
<td>2.02</td>
</tr>
<tr>
<td>Non-Residential</td>
<td>14.41</td>
<td>14.15</td>
</tr>
<tr>
<td>Transportation</td>
<td>6.80</td>
<td>10.68</td>
</tr>
<tr>
<td>Waste</td>
<td>-0.38</td>
<td>-0.38</td>
</tr>
<tr>
<td>City Administration &amp; Safety</td>
<td>1.30</td>
<td>1.30</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>26.87</strong></td>
<td><strong>27.77</strong></td>
</tr>
</tbody>
</table>

### Table 14: $eCO_2$ per person for the Mt. Washington study area (Source: City of Cincinnati, OKI, CAGIS 2000, U.S. Census, EIA, and USEPA)

<table>
<thead>
<tr>
<th>Category</th>
<th>Citywide</th>
<th>Mt. Washington</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Metric Tons</td>
<td>Metric Tons</td>
</tr>
<tr>
<td></td>
<td>$eCO_2$/person</td>
<td>$eCO_2$/person</td>
</tr>
<tr>
<td>Residential</td>
<td>4.74</td>
<td>2.15</td>
</tr>
<tr>
<td>Non-Residential</td>
<td>14.41</td>
<td>5.30</td>
</tr>
<tr>
<td>Transportation</td>
<td>6.80</td>
<td>4.53</td>
</tr>
<tr>
<td>Waste</td>
<td>-0.38</td>
<td>-0.38</td>
</tr>
<tr>
<td>City Administration &amp; Safety</td>
<td>1.30</td>
<td>1.30</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>26.87</strong></td>
<td><strong>12.90</strong></td>
</tr>
</tbody>
</table>
6. North Avondale

The North Avondale study area has by far the lowest eCO$_2$ number of all, at 5.78 metric tons of eCO$_2$, as shown in Table 15. The most significant factor is in the Non-residential sector. The study area has essentially nothing but residential structures, as shown in Figure 10. Even the few buildings that came up as non-residential are institutions that have taken over large old houses. On the other hand, the Residential number is the highest of any area studied. The eCO$_2$ from VMT is also lower than the citywide number. This is somewhat surprising, since the study area, in fact the whole official neighborhood of North Avondale, contains almost no essential service businesses.
Table 15: eCO₂ per person for the North Avondale study area (Source: City of Cincinnati, OKI, CAGIS 2000, U.S. Census, EIA, and USEPA)

<table>
<thead>
<tr>
<th>Category</th>
<th>Citywide Metric Tons eCO₂/person</th>
<th>North Avondale Metric Tons eCO₂/ person</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>4.74</td>
<td>2.25</td>
</tr>
<tr>
<td>Non-Residential</td>
<td>14.41</td>
<td>0.51</td>
</tr>
<tr>
<td>Transportation</td>
<td>6.80</td>
<td>2.10</td>
</tr>
<tr>
<td>Waste</td>
<td>-0.38</td>
<td>-0.38</td>
</tr>
<tr>
<td>City Administration &amp; Safety</td>
<td>1.30</td>
<td>1.30</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>26.87</strong></td>
<td><strong>5.78</strong></td>
</tr>
</tbody>
</table>

Figure 10: North Avondale Study Area Map (Source: CAGIS 2000)
7. Westwood

The final study area, Westwood is geographically the largest and most populous study area. With 27,447 residents, it is more than twice as populous as the second-most, Mt. Washington, which has 12,092 residents. On the other hand, its eCO₂ per resident is less than half that of the city as a whole, as shown in Table 16. The most significant difference is in the area’s Non-residential sector. The area does not have as much non-residential space as the first three neighborhoods. However, Transportation and Residential are also lower than citywide, although Residential is in line with the other five neighborhoods.

Transportation is surprisingly low, since it is such a large area and looks on the map (Figure 11) to be suburban in character.

Table 16: eCO₂ per person for the Westwood study area (Source: City of Cincinnati, OKI, CAGIS 2000, U.S. Census, EIA, and USEPA)

<table>
<thead>
<tr>
<th>Category</th>
<th>Citywide</th>
<th>Westwood</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Metric Tons eCO₂/ person</td>
<td>Metric Tons eCO₂/ person</td>
</tr>
<tr>
<td>Residential</td>
<td>4.74</td>
<td>2.05</td>
</tr>
<tr>
<td>Non-Residential</td>
<td>14.41</td>
<td>4.19</td>
</tr>
<tr>
<td>Transportation</td>
<td>6.80</td>
<td>3.58</td>
</tr>
<tr>
<td>Waste</td>
<td>-0.38</td>
<td>-0.38</td>
</tr>
<tr>
<td>City Administration &amp; Safety</td>
<td>1.30</td>
<td>1.30</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>26.87</strong></td>
<td><strong>10.74</strong></td>
</tr>
</tbody>
</table>
8. Conclusion

The neighborhood data used as inputs for the present report came down to essentially three points:

- Housing (renting vs. owning)
- Vehicle Miles Travelled
- Non-residential building space

From other chapters, it is obvious that many more data inputs could be imagined to solve the problem of a neighborhood-scale greenhouse gas inventory. However, these were the ones reasonably available, and that had other, larger-scale data to go with them. Calculating the data for the neighborhoods themselves was fairly easy, which is a positive feature that will be
discussed at more length in the next chapter. However, getting them to make sense in terms of eCO2 and for the correct climate zone or region was quite challenging. Going forward, and again to be discussed in the next chapter, the hard parts are done for neighborhoods in the city of Cincinnati. Calculating any other neighborhood’s eCO2 by the model in the present report is almost trivial, since all the conversion factors and region-specific inputs are now calculated. The only neighborhood-specific data that are somewhat challenging to obtain are a TAZ configuration that satisfactorily approximates the official neighborhood and aligns with Census blocks, and obtaining VMT data from the local MPO. However, the last VMT data requested of OKI, which included 19 TAZs, each of which produced a table over 2,600 records in length, were available within three hours of the request.
Chapter 5: Results, Conclusions, & Recommendations

I. Results

The neighborhoods studied show huge variation. The highest eCO\textsubscript{2} number, Mt. Adams’ 27.77, is almost five times the lowest, North Avondale’s 5.78. Two neighborhoods, Corryville at 25.06 and Mt. Adams at 27.77, cluster quite closely with the City’s 26.87. Table 17 shows all the data for the City and all the neighborhood study areas. The last two components of each neighborhood’s columns are simply carried over from the City numbers, as they did not seem to apply at the neighborhood scale. Again, at this initial point in the pursuit of a carbon calculation technique at the neighborhood scale, it seems important to have the results look like those established at a larger scale to at least some degree.

Table 17: Citywide and neighborhood eCO\textsubscript{2} assessments and components (Source: City of Cincinnati, OKI, CAGIS 2000, U.S. Census, EIA, and USEPA)

<table>
<thead>
<tr>
<th>Category</th>
<th>Citywide Metric Tons eCO\textsubscript{2}/person</th>
<th>Clifton Metric Tons eCO\textsubscript{2}/person</th>
<th>Corryville Metric Tons eCO\textsubscript{2}/person</th>
<th>Mt. Adams Metric Tons eCO\textsubscript{2}/person</th>
<th>Mt. Washington Metric Tons eCO\textsubscript{2}/person</th>
<th>North Avondale Metric Tons eCO\textsubscript{2}/person</th>
<th>Westwood Metric Tons eCO\textsubscript{2}/person</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>4.74</td>
<td>2.01</td>
<td>1.84</td>
<td>2.02</td>
<td>2.15</td>
<td>2.25</td>
<td>2.05</td>
</tr>
<tr>
<td>Non-Residential</td>
<td>14.41</td>
<td>10.73</td>
<td>16.25</td>
<td>14.15</td>
<td>5.30</td>
<td>0.51</td>
<td>4.19</td>
</tr>
<tr>
<td>Transportation</td>
<td>6.80</td>
<td>5.31</td>
<td>6.05</td>
<td>10.68</td>
<td>4.53</td>
<td>2.10</td>
<td>3.58</td>
</tr>
<tr>
<td>Waste</td>
<td>-0.38</td>
<td>-0.38</td>
<td>-0.38</td>
<td>-0.38</td>
<td>-0.38</td>
<td>-0.38</td>
<td>-0.38</td>
</tr>
<tr>
<td>City Administration &amp; Safety</td>
<td>1.30</td>
<td>1.30</td>
<td>1.30</td>
<td>1.30</td>
<td>1.30</td>
<td>1.30</td>
<td>1.30</td>
</tr>
<tr>
<td>Total</td>
<td>26.87</td>
<td>18.97</td>
<td>25.06</td>
<td>27.77</td>
<td>12.90</td>
<td>5.78</td>
<td>10.74</td>
</tr>
</tbody>
</table>

Table 18: Neighborhood "Index" Numbers

<table>
<thead>
<tr>
<th></th>
<th>Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clifton</td>
<td>18.05</td>
</tr>
<tr>
<td>Corryville</td>
<td>24.14</td>
</tr>
<tr>
<td>Mt. Adams</td>
<td>26.85</td>
</tr>
<tr>
<td>Mt. Washington</td>
<td>11.98</td>
</tr>
<tr>
<td>North Avondale</td>
<td>4.86</td>
</tr>
<tr>
<td>Westwood</td>
<td>9.82</td>
</tr>
</tbody>
</table>

An obvious alternative would be just to use the numbers that are calculated specifically for each study area, and refer to them as an “index” or “indicator,” rather than trying to make them fit with the citywide results. In fact, it would make sense to leave the citywide number completely out of it, and just use the index to compare neighborhoods to each other. This would give a result that looks like Table 18. However, there is still so much variation that the index numbers would be sure to be called into question. At least the “full” eCO\textsubscript{2} numbers answer for the same sectors as the City numbers.
So, since the results vary so widely, the next question is, “What do they really tell us about the neighborhoods?” Again, the numbers are based on rent vs. own, gross square footage of non-residential building floor space, and Vehicle Miles Travelled.

The rent vs. own number is being used as a stand-in for housing type, since that is as close as we can get to population in different housing types. There is a sizeable distinction in the energy use of owners vs. renters in the national data from EIA: 40.3 million BTUs/person/year for those living in households who own versus 28.9 million BTUs/person/year for those in rentals (EIA 2009). This actually turns out to be greater than the variation in energy use among housing types, the renters at least. Renters’ use varies between 24.6 for mobile homes and 31.5 for single-family attached. Owners’ use, meanwhile varies between 29.5 for mobile homes and 49.5 for units in 2-4 unit buildings. Figuring out the reason for that could occupy a researcher for quite a while. This presents the problem that a neighborhood of rented single-family detached housing or very large condominium buildings would skew the numbers badly.

The problem with using direct housing type data, on the other hand, is that multi-unit buildings are given in ranges in both EIA data and local data. Therefore, we would have no idea how many actual units there were, much less the population living in each of those types.

While the data from the EIA on commercial buildings gets fairly specific, the data used to determine the square footage have two problems: determining use and determining real building square footage. In the local geographical information systems database, CAGIS, land uses are given as code numbers from one or more of 170 land uses. They are entered as text data, rather than numerical data, so that some can have multiple codes, separated by commas. Part of the object of the present study was to try to assess multiple neighborhoods at a fairly high level of data management, in order to make the results repeatable. In this instance, this means dealing with records of thousands of buildings, where land use data may or may not have more than one entry in the cell. Finally, there is no reliable distinction, either in the CAGIS data or the EIA data between different non-residential uses. One would expect a hospital to have a very different eCO₂
output than a greengrocer, but it is impossible to make this distinction. In such a situation, the best that can be hoped is that the inevitable errors are at least not biased in one direction.

As to the building square footage, the County Auditor maintains records that seem very accurate. It is within the Auditor’s legal mandate that they be accurate. However, those are only searchable on a building-by-building basis. The GIS records of building square footage are calculated from stereo-photogrammetry fly-overs. The polygons that result are as likely as not to include decks, porches, and even parking pads. It is those polygons that give the building footprint’s square footage. Next, being stereo-photogrammetry, building heights are calculated, with the result divided by 11 to give the number of stories above ground. Again, it is hoped that at least the errors are unbiased.

The results in Table 17, above, show that neighborhoods pay a steep penalty, in terms of their attributable eCO₂ for having more gross non-residential space. This raises the question of what these inventory numbers might encourage. If a neighborhood wanted to lower its numbers, should it chase out all the non-residential users from the neighborhood? Perhaps not, though, as the Westwood neighborhood has many non-residential buildings, but they are individually small and do not add up to as much space as Corryville, with its large office buildings. Therefore, the present methodology could be said to encourage small, neighborhood retail in favor of larger institutions and stores, that probably are not related to the neighborhood in any case. It also is likely that VMT would be reduced if there were non-residential building users that primarily served residents within walking distance. What is unknown, and perhaps the subject of someone’s future study, is whether the VMT reduction would be enough to overcome the non-residential space penalty.

Finally, VMT are modeled by the local MPO from trip numbers generated from household surveys, as well as cordon and other traffic counts. They reflect specifically trips begun in a given TAZ, and the distance from that TAZ’s centroid to the centroid of the TAZ where the trip ends. The data are basically one-way on the trips. There are over 2,600 TAZs in the MPO’s area, which makes it impractical to directly model all the return trips. Therefore, a very simple model was
applied to represent these. It was assumed that, unless a trip catches somebody leaving the TAZ forever, every trip will have a return sooner or later. Furthermore, it is likely these would be on the same day, with only overnight trips not returning. So, all VMT to destinations outside the origin TAZs were simply doubled, rather than trying to assign all the return trips from all 2,600-plus TAZs.

One thing this methodology misses are trips through the neighborhood. This is especially significant in the cases of the Clifton and Mt. Adams study areas, which include stretches of Interstate highway. However, it is probably entirely appropriate to omit these trips, as it would not make much sense to saddle a neighborhood’s carbon assessment with Interstate trips that really have nothing to do with the neighborhood. Trips originating in the neighborhood that then proceed onto the Interstate are still represented.

So, the data have some problems. That does not mean that they say nothing about characteristics of neighborhoods and their users. We can identify renter-heavy versus owner-heavy neighborhoods. Those neighborhoods accommodating large businesses and institutions also stand out. We can also almost spot neighborhoods with a good retail structure. Finally, neighborhoods that generate a lot of vehicle trips also stand out.

II. Neighborhood Culture, Leveraging the Model and Results, and Future Research

The difficulties with the data do not render them useless. If nothing else, they can serve as a starting point for neighborhood groups who would like to undertake more work on greenhouse gas emissions, with an eye to reducing them for their neighborhood. City Administrative departments who want to leverage Cincinnati’s neighborhood structure might also find it a useful starting point to stir up competition among neighborhoods to work towards reducing their emissions.

The sectors addressed in the present study are essentially the same as those addressed at larger scales. For future research, individual neighborhoods could start with these numbers, and start to refine them. It would be much easier for a neighborhood to organize a small group to go
through all the building records for its commercial space than it is trying to find the right data to assess thousands of buildings across six neighborhoods. It would be possible for them to go door-to-door and find out what heating equipment is really in use in commercial spaces.

It is also quite easy (and maybe even fun to the right age group, if presented properly) to count mailboxes on multi-family buildings and thus determine the actual number of units in the buildings. With knowledge of the precise number of units in each building and closer approximations of building square footage, by direct observation or visits to the Auditor’s website, researchers could turn to EIA’s residential tables that look at energy use by square foot in different housing types.

Perhaps the model could be refined to leave out the large buildings that are not truly “of” the neighborhood. Of course this leaves the problem of aligning TAZs for VMT data. It is possible and accepted to interpolate partial TAZs, and a more realistic endeavor when there are only a few to deal with, as would be the case for a neighborhood group.

If a neighborhood could refine the data to the point where its residents would be willing to accept them as reflecting reality, the next question is what to do with them. As mentioned above, they could be used to set up competition among neighborhoods. Neighborhoods wanting to be perceived as “green” could use their results as marketing tools, perhaps attracting green-oriented businesses and residents. Such a strategy was proposed in the Cincinnati Climate Action Plan, except that it was proposed to use the USGBC’s LEED for Neighborhood Development program as a basis. Perhaps that still could be incorporated, although a simple, final eCO₂ number would be more easily compared and understood.

Once the base numbers were established, the neighborhoods could begin reduction work in earnest. If they have the constituent numbers available, going all the way back to energy use by space and/or person, any reduction actions could come out of those and the eCO₂ recalculated. For instance, a neighborhood drive to install compact fluorescent bulbs would have a calculable impact on energy use per bulb replaced. Just subtract that from the previous total and recomputed the eCO₂ number.
Similarly, a new neighborhood service business could use its market reach data to estimate a reduction in VMT. A new neighborhood school would have even easier-to-determine impacts on VMT. Even better would be a neighborhood pushing for pedestrian connectivity and other walkability improvements and using those, or even actual before-and-after pedestrian counts to subtract VMT from their numbers.

Even with the numbers from the present study, this would be valid. A real, knowable reduction in energy use should come out of the neighborhood’s total.

III. Conclusion

The hypothesis behind the title of the present study – “Toward a Neighborhood-Scale Carbon Calculator” – is borne up by the results. The study considered the current thought on calculating carbon in urban settings. Then it held these up against the special characteristics of neighborhoods, as opposed to larger areas and even households and individuals. Finally, it used the available data to get as close to possible to an assessment of eCO$_2$ that would be immediately understandable, further testing the procedure across six very different neighborhood-based study areas. While the developed model and results have some problems, they do point the way toward how an individual neighborhood can determine its emissions of greenhouse gases, and why it might wish to do so.
References


Sierra Club 2000. “Sprawl Costs Us All.” Published through a grant from the Sierra Club Foundation.

