Dane County Air Emissions Inventory

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Planning and Development Department
Department of Administration
County Board Office
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Executive Summary and Conclusions for Policy Makers

Dane County contracted with the University of Minnesota's Center for Science, Technology, and Environmental Policy to conduct an inventory of air emissions to help inform potential air quality improvement and energy conservation and renewable energy opportunities. The air emissions of interest in this study include carbon dioxide (CO_2) and other climate disrupting pollutants such as nitrous oxide (N_20) and methane (CH_4), which are often represented in total as carbon dioxide equivalents, or CO_2e. The other pollutants of interest are the criteria air pollutants, common air pollutants regulated by the Environmental Protection Agency (EPA) under the Clean Air Act. These include, sulfur oxides (SOx), nitrogen oxides (NOx), particulate matter (PM), and ozone. Ozone is considered a criteria air pollutant, but is formed through a chemical reaction of NOx and volatile organic compounds (VOCs). Therefore, this study does an emissions inventory of NOx and VOCs, but does not model concentration of ozone in the air.

Three types of inventories were conducted that each have different policy relevance. The first is an In-Boundary Emissions Inventory (IBEI), which analyzes territorial air pollutant emissions within the community and is important for pollutants with near-field health effects, particularly PM. The second is a trans-boundary Community-wide Infrastructure Use Footprint (CIF), which describes emissions associated with energy use in different infrastructure sectors supporting urban activities and their impact both within and outside of the county. This is relevant for more energy efficient community planning, which can reduce CO_2 and criteria air pollutant emissions that may have an impact regionally or globally. The third approach is a Consumption Based Emissions Footprint (CBF), which uses household consumption behavior and expenditures to determine the emissions attributable to a particular community and its resident households. This is difficult to do without getting detailed data on which businesses serve the household consumers. Therefore, this work focuses on the first two approaches.

In the first approach, the IBEI, we find transportation and agriculture within the boundary dominate CO_2e emissions, while the transportation and residential sectors dominate the PM emissions. PM in particular is a key pollutant in terms of health impact within the community. We conducted energy use and benchmarking studies and found that the average number of vehicle miles traveled per person per day (VMT) of 27 in Dane County is slightly less than the Wisconsin average of approximately 29. However, about 30% of GHG emissions and the majority of NOx emissions are attributable to transportation. Agricultural CO_2e emissions are mainly a result of methane and N_2O produced by livestock. This may present an opportunity to convert this methane to energy to reduce electricity sector emissions. This methane can be converted to biogas and used in CNG vehicles as well. The methane could also be converted to biogas to heat homes and reduce wood consumption. Residential PM emissions are sensitive to the amount of homes using wood as their primary heating fuel; this study assumes 6 percent of homes use wood fuel (EIA 2009).

In the second approach, the CIF, we examine the emissions and energy use of each infrastructure sector in Dane County. Adding trans-boundary emissions to the footprint reveals the air emissions contribution of inflows of electricity that are produced outside of the county. As shown in Figures 5 and 6, CO_2e emissions are dominated by transportation and electricity sectors, while PM emissions are dominated by electricity generation. Benchmarking of energy use indicates that Dane County residential electricity consumption is less than the WI average and the national average. However, residences in Dane County use more natural gas than the statewide average. We believe efficiency opportunities exist to reduce VMT, household heating loads, and water usage.

If Dane County wants to reduce its impact on the environment globally, the CO_2 and criteria air pollutant emissions resulting from the electricity sector are the most relevant. However, if local environmental concerns are more of a focus, then reducing VOC and NOx emissions from the transportation sector should be a primary goal by reducing VMT. Additionally, capturing methane from agriculture and utilizing it for heating and electricity generation purposes appears to be a way of reducing both PM and CO_2e emissions.

Table of Contents

List of Tables and Figures

List of Acronyms

CBF – Consumption Based Footprint
CH_4 – Methane
CIF – Community-wide Infrastructure Footprint
CO_2e – Carbon Dioxide Equivalent
CO_2 –Carbon Dioxide
DPSC – Direct Plus Supply Chain
eGRID – Emissions & Generation Resource Integrated Database
EIA – Energy Information Administration
GDP – Gross Domestic Product
GHG – Greenhouse Gas
GREET – The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model by Argonne National Laboratory
IBEI – In Boundary Emissions Inventory
ICLEI – International Council for Local Environmental Initiatives
IPCC – Intergovernmental Panel on Climate Change
kWh – Kilowatt Hour
kW – Kilowatt
LCA – Lifecycle Analysis
LCI – Lifecycle Inventory
MEF – Material Energy Flow
MPG – Miles per Gallon
MWh – Megawatt Hour
NAAQS – National Ambient Air Quality Standards
NREL – National Renewable Energy Laboratory
NO_x – Nitrogen Oxides
N_2O – Nitrogen Oxide
PM – Particulate Matter
SO_x – Sulfur Oxides
VOC – Volatile Organic Compound
WT – Water Supply Treatment
WWT – Waste Water Treatment
VMT – Vehicle Miles Travelled

Section 1: Introduction

Section 1.1 Motivation

Dane County contracted with the University of Minnesota's Center for Science, Technology, and Environmental Policy to conduct three inventories of air emissions to help inform air quality improvement and energy conservation opportunities for Dane County. These three inventories make up Phase 1 of what is envisioned to be a multi-phase project eventually culminating in a strategic plan for Dane County to reduce greenhouse gas and air pollution emissions and promote renewable energy and energy conservation. This effort was initiated in autumn 2013 by way of a recommendation of the Greenhouse Gas/Air Quality Workgroup of the Capital Region Sustainable Communities Partnership.

Section 1.2 Report Outline

This Phase 1 report uses state of the art science to "inventory" and "footprint" energy use, greenhouse gas emissions, and air pollution attributable to Dane County using three different methods as prescribed by the International Council for Local Environmental Initiatives (ICLEI) to inform different actors and audiences (ICLEI 2013).

After the introduction in Section 1, the following three inventory methods are discussed in Section 2:

1. In-Boundary Emissions Inventory (IBEI);
2. Trans-boundary Community-wide Infrastructure use Footprint (CIF); and
3. Consumption Based emission Footprint associated with household only use of infrastructure as well as other commodities and services (CBF).

These three approaches more effectively capture the in-boundary and trans-boundary environmental impact of Dane County air emissions from the perspective of 1) production, 2) community infrastructure planning, and 3) household consumption, respectively. This multiple perspective approach is recommended by ICLEI's community protocol (ICLEI 2013). Figure 1 further illustrates differences between the three methodologies. Where data are available we use bottom-up information generated from county specific data to provide greater insight into opportunities to reduce emissions.

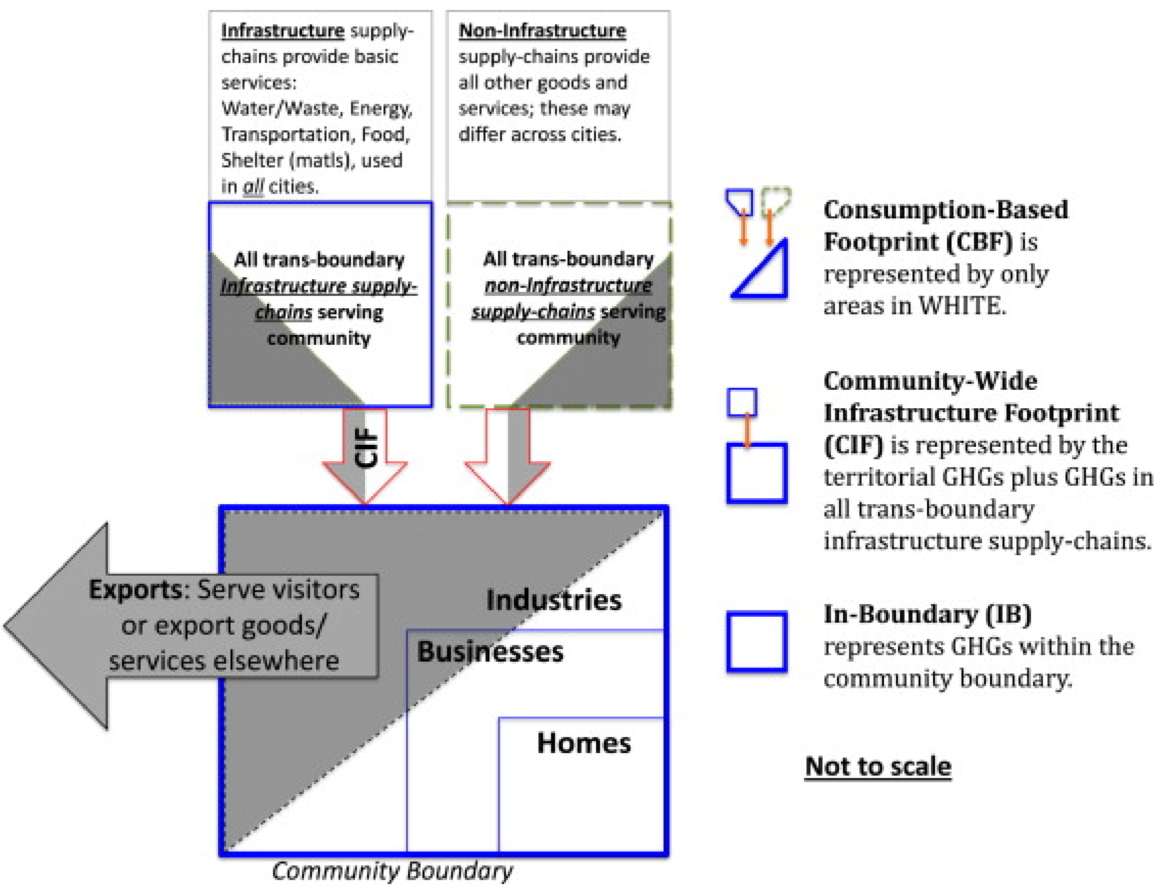
Results from each inventory/footprint approach are presented in Section 3 with a discussion of the high level actions pertaining to energy efficiency and conservation that have maximum potential for co-benefits across air pollution and climate-related pollutants.

Section 4 then provides a general description of efficiency and conservation actions that can be taken by communities to improve air quality and reduce greenhouse gas emissions. Sections 5 and 6 provide detail on the methods utilized in the three inventory/footprint approaches. Sections 1-6 constitute Phase 1 of this project.

It is envisioned that Phase 2 of the project will use the information from Phase 1 to develop air emission reduction goals and draft a strategic plan of actions that the county could take to achieve its goals by 2050. Phase 2 may include annual emission reduction goals and performance tracking metrics. It is intended that Phase 2 will emphasize combined action on air pollutants that reduce air quality (criterion pollutants and airborne toxics) or disrupt the climate (greenhouse gases), as this is the most cost-effective approach. Toward this end, Dane County budgeted $35,000 for 2016 to begin the next phase of this effort, which will include both an analysis of Dane County government's current greenhouse gas emissions and commencement of a countywide community climate action planning initiative (Dane County 2016).

Figure 1: Comparison of Footprint Methodologies

Note: ICLEI's GHG Protocol and other methodologies refer to in-boundary emissions as Scope 1, all direct GHG emissions. CIF emissions include Scope 2 emissions as well as some Scope 3 emissions. Scope 2 emissions are defined as indirect GHG emissions due to the consumption of electricity, heat, or steam. Scope 3 emissions are indirect GHG emissions related to purchased goods and services which are captured by consumption based footprints (CBF). These are difficult to determine because information on which products are manufactured within the boundary and used within or outside the county, and vice versa, is not readily available. Grey areas represent goods and infrastructure services which are exported or may serve areas outside the community.



Adapted from Chavez and Ramaswami (2013)

Section 1.3 Geographic Location & Context

Dane County is located in south-central Wisconsin, covers 1,197 square miles and is home to 510,000 people, nearly half of whom live in the city of Madison. Madison has long and repeatedly been hailed by many different sources as one of the most attractive, livable cities in the United States. As both the state capital and home to the University of Wisconsin-Madison, the area has enjoyed relative economic stability and prosperity. As a result, Dane County is growing by more people per year than any other town, city, village or county in the state of Wisconsin, adding a little over 5,000 people per year on average over the last 10 years. Other major population centers include the city of Fitchburg, city of Middleton, village of Oregon, city of Sun Prairie, city of Stoughton, village of Waunakee, and city of Verona. Overall, including these eight communities, the county has 61 municipalities, with eight cities, 19 villages and 34 towns. While 84 percent of the population resides within urban areas, 79 percent of the land area is rural. Dane County is fortunate to have an uncommon bounty of natural resources, including the Yahara chain of lakes, outstanding cold-water fisheries, unique glacial terrain, and some of the most productive agricultural soils in the world. Agriculture plays a substantial role in the Dane County culture and economy, and it is the predominant land use outside of the incorporated cities and villages. Dane County regularly ranks first in agricultural proceeds out of Wisconsin's 72 counties, and in the top 100 counties nationally out of over 3,000. There are 2.3 persons per household on average, with a total of 220,000 households in the county, 60 percent of which are occupied by owners and 40 percent of which are occupied by renters (US Census Bureau 2010). The median income of households in Dane County is $61,790 per year, with 12 percent of the population living below the poverty line.

Section 1.4 Pollutants Tracked

This study focusses on two types of emissions, tracking mass released annually in the year 2013:

- **Air Pollutant emissions** including those classified as criteria air pollutants under the Clean Air Act, 1970 (CAA 1970) and now regulated under the National Ambient Air Quality Standards (NAAQS); these include, sulfur oxides (SOx), nitrogen oxides (NOx), particulate matter (PM), and ozone. Ozone is considered a criteria air pollutant, but is formed through a chemical reaction of NOx and volatile organic compounds (VOCs), which are also tracked in this study.
    - This report focuses on the criteria air pollutants, except for lead and carbon monoxide, as they have been regulated to the point that ambient concentration levels no longer pose a threat to human health. For toxics, the focus is on VOCs, which in turn influence ozone.
- **Greenhouse Gas (GHG) Emissions** are those pollutants which are considered climate disruption emissions that contribute to global climate change and are represented as Greenhouse Gases (GHGs) by the Intergovernmental Panel on Climate Change (IPCC).

While air pollutant emissions have greater impact on local public health, greenhouse gas emissions have impacts globally. However, both these types of emissions are derived from energy use and industrial processes used to support local residential, commercial, and industrial activities. Tracking air pollutant emissions enables the identification of local activities which adversely affect local public health, while tracking greenhouse gas emissions shows how local activities are affecting global environmental health.

It is important to note that air pollution is regulated based on ambient concentration levels, i.e., mass of pollution per unit volume of air in the atmosphere (established by NAAQS). This report is an inventory of the mass (kg or tonnes) of emissions occurring as a result of activities taking place in Dane County, and is not a measure of compliance with ambient air pollution concentration standards. The relationship between emissions and concentrations is not always linear and depends on meteorology (air mixing and atmospheric chemistry); however, emissions contribute to airborne concentrations. Dane County seeks to uncover opportunities to reduce both traditional air pollutant emissions, as well as climate disrupting pollutants, associated with various activities occurring within Dane County.

Section 1.5 Methodology

The emissions inventories below follow the 2012 U.S. Community Protocol for Accounting and Reporting of GHG Emissions developed by ICLEI USA, expanded to include air pollution emissions beyond the GHG emissions captured by the ICLEI methodology. The ICLEI - USA method draws upon community infrastructure footprinting methods (Ramaswami et al. 2008, Hillman and Ramaswami 2010, Chavez and Ramaswami 2011, Ramaswami et al. 2011). Studies published by ICLEI USA and several research groups have shown that there are multiple ways of GHG accounting for communities (Wiedmann and Minx 2008, Kennedy et al. 2009, Kennedy et al. 2010):

1) **In-Boundary Emissions Inventory (IBEI)**. Under the IBEI method, emissions are tracked where they occur and mapped according to the IPCC categories: Energy, Transportation, Residential & Commercial Buildings, Industry, Agriculture, and Waste (IPCC 2007). This type of accounting gives a territorial emissions inventory also called a "production based account" which is appropriate for large regions like nations where large energy flows like electricity are produced and used within the study area boundary. This method is also appropriate for inventorying in-boundary air pollution emissions. However, this is not very useful for assessing the broader environmental impact of smaller regions such as cities or counties, particularly with respect to CO_2 and GHGs, because electricity and transport fuels used within city or county boundaries are often produced elsewhere.
2) **Trans-boundary Community-Wide Infrastructure Use Activity Based Footprinting (CIF)**. For GHGs associated with communities, many studies have shown that communities function as demand centers, and a vast majority of community-wide GHG emissions are associated with infrastructure services used to support community demand (Chavez and Ramaswami 2011, Ramaswami et al. 2011). Accordingly, the CIF method looks at the energy and GHGs needed to provide energy, water, wastewater, transportation, waste management, construction, and food supply used by the whole community (i.e. homes, businesses, and industries located in the county). This is consistent with the British Standards Institute and ICLEI Community Protocol "Direct plus supply chain" (DPSC) methodology (4). This approach includes the above in-boundary emissions to which are then added the supply chains of imported electricity (Scope 2) and other key supply chains (Scope 3)[1].

[1] For cities that produce more than they consume, exported electricity, food, or fuels, portion not consumed inboundary are excluded using this method

3) **Household Only Consumption Activity Based Footprint (CBF).** A third approach focuses on households only. The CBF approach estimates the GHG emissions associated with the purchase and use of products and services by households only including energy, food, and water used by households as well as other goods and services purchased by homes such as computers, medical services, clothing, etc. As a result, local businesses and industries that serve visitors or produce goods and services for export are allocated out, and excluded from the city's CBF (Jones and Kammen 2011).

In this report, we computed air pollution and GHG emissions using the first two approaches, articulating whether the associated emissions occur within or outside the county boundary. A third consumption-based approach to inform household consumption of the broad impacts of their personal consumption is also included – but only for GHG emissions. Since it is difficult to know how much households purchase from the local area versus from outside the study area – it is difficult to distinguish between household emissions (air pollution and GHGs) that are stimulated within Dane County, versus outside. Thus only GHG emission footprints are reported for the third household consumption-based footprint (CBF) approach. The CBF approach is mainly presented as a way for households to become aware of the full impacts of their personal purchasing behaviors.

Data were collected by the University of Minnesota with the help of Dane County staff. Whenever available, primary data specific to Dane County has been collected toward maximizing effective policy action. When primary data has not been available, UMN has used national or state-level datasets to estimate emissions. Estimated activity and consumption data is scaled based on population or income, while estimated emission factors are regional or technology-specific.

Section 2: Inventory Methods & Data Sources

The methodology to calculate emissions using the first two approaches is detailed below.

Section 2.1 In-Boundary Emissions Inventory(IBEI)

The general approach to quantify IBEI is to focus on the direct fuel consumption (fuel use) and associated air pollution and GHG emissions, as well as non-energy GHG emissions, only within the county boundary, expressed as follows:

$$IBEI = \sum_{i} Euse_s * (EF_{use}^{IB}) + NonEnergy\ Emissions$$

Here E_{use} is energy used in various sectors, s, organized according to categories matching those identified in the 2008 Final Report of the State of Wisconsin's Task Force on Global Warming (State of Wisconsin 2008):

- Electricity Generation (i.e. stationary source combustion in electric utilities);

- Industrial, Residential, Commercial Sources of Stationary Combustion (e.g., energy used in furnaces and boilers in homes, businesses and industry, excluding electricity use);
- Transportation (i.e. mobile combustion);
- Non-Energy Industrial Process Emissions (not associated with fuel combustion); and
- Agricultural and Waste Emissions (not associated with fuel combustion, such as methane releases from wastewater treatment)

The ways to estimate E_{use} in each sector, *s*, are detailed in Appendices A and B.

EF refers to emission factors, or the mass of pollutant released per unit mass of fuel combusted, corresponding to the use of fuels in the source categories referenced above.

A. In-Boundary GHG emission factors $EF_{use}^{IB,GHG}$ drawn from ICLEI USA, which in turn are drawn from IPCC. More detailed greenhouse gas emission factors for electricity generation are estimated using the EPA's most up-to-date Emissions & Generation Resource Integrated Database (eGRID) emission factors (EPA 2014a).
B. In-Boundary Air pollutant emission factors, $EF_{use}^{IB,Air}$, associated with fuel use in the various source sectors, are drawn from a variety of sources.
    a. The default air pollution emission factors are developed using the AP-42 Compilation of Air Pollutant Emissions Factors from the USEPA (EPA 2000). These emission factors are sensitive to the choice of technology used for pollution control. Where such specific technology data were unavailable, we used the worst case of uncontrolled air pollutant emissions.
    b. Supplemental air pollution emission factors are sourced from Argonne National Laboratory's Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model (GREET) and National Renewable Energy Laboratory's US LCI database (US LCI 2012).
C. Total Non-Energy process emissions associated with agriculture, industry, and waste are sourced from ICLEI and EPA's WARM model.

The data sources for estimating emission factors used in IBEI are shown in Appendix B.

Section 2.2 Community-Wide Infrastructure Use Emissions Footprint (CIF)

The second approach focuses on community-wide energy and material use – represented as direct Material-Energy Flow (MEF_{use}) - associated with key infrastructure use sectors organized as:

- Electricity-use by the community (separated into residential, commercial and industrial sectors);
    - Note that almost all of the electricity used by Dane county is produced outside of the boundary – hence the use of the word *footprint* to include electricity generated outside Dane County to support use by the community, called Scope 2.

- Non-electricity energy use, i.e., fuel used by the community (separated into residential, commercial and industrial sectors);
- Fuel used in transportation in the community; and
- Other key material flows shaped by the community's use of infrastructure such as the flow of fuels to support transportation, water/wastewater, food, and construction materials

This CIF footprint combines the direct use of material and energy flow (MEF_{use}) with life cycle assessment (LCA) of producing these flows. By accounting for direct and indirect emissions, this approach captures Scope 1, 2, and 3 emissions for the whole community, associated with the use of the infrastructure sector, *i*.

The general equation to calculate CIF is as follows:

$$CIF = \sum_i MEF_i * (EF_{i,use}^{IB} + EF_{i,production}^{IB+TB})$$

where *i* represents the infrastructure sector, i.e. electricity, non-electricity energy, transportation, water supply/wastewater treatment (WT/WWT), waste, construction material, and food supply.

EF represents the GHG emission factor of producing the infrastructure service, which can be represented in two terms: $EF_{i,use}^{IB}$, the emission factor for the use phase, occurring within the study area boundary; and $EF_{i,production}^{IB+TB}$, the emission intensity of producing the service including local production (IB) as well as the supply chain/life cycle emissions occurring outside the city boundary (TB). $EF_{i,production}^{IB+TB}$ indicates that emissions from production can occur both in-boundary (IB) and trans-boundary (TB).

Where possible, these emissions have been separated by residential, commercial and industrial[2] sectors. The in-boundary emission factors for GHG and air pollution are the same as in the first approach. For the food, cement, and fuel sectors, additional emission factors are added to account for Scope 3 trans-boundary emissions. Additionally, the MEF_{use} data can be normalized to develop benchmarks to detail the efficiency of each infrastructure sector.

Data sources for MEF and EF used in computing CIF are shown in the tables in Appendix B. Data were collected by the University of Minnesota with assistance from Dane County staff and other entities including RENEW Wisconsin and the Wisconsin Department of Natural Resources (DNR). Where available, primary data was collected to make the inventory results as relevant, accurate, and functional as possible.

Because of the large geographic area and number of municipalities within Dane County, primary data collection was limited in certain sectors. First, data on agricultural and manure management practices was limited to estimations from relevant experts. A countywide inventory of manure

[2] Community-wide GHG footprinting is different from household consumption footprints. Household consumption footprints include supply chains of all goods and services used by households, but do not include energy used by businesses that export services elsewhere.

management practices would increase the certainty of agricultural emissions estimates. Second, researchers at the University of Minnesota had little success reaching out to the waste water treatment plants in the county, with a 40 percent response rate. Because of this lack of data, a general approach using population served was employed to estimate emissions from WWT facilities. Data on industrial practices within the county was limited. Researchers at the University of Minnesota relied on existing, secondary data sources to estimate emissions from industrial practices. However, this data may not be readily available due to privacy and trade secret concerns on the part of industrial facilities. Lastly, data on waste handling practices was limited. Researchers used two existing databases to estimate waste management practices in the county (WI DNR 2013a, WI DNR 2013b). These databases had limited data on recycling practices and no data on composting practices.

Data collection is a time-consuming process that could be expedited and made less costly by maintaining current, countywide information on energy use, agricultural practices, waste handling practices, and industrial processes.

Emission Factor Uncertainty

In using AP-42 to calculate air pollutant emissions, the authors acknowledge the emission factors are specific to control technology. In the absence of specific control technology information, the emission factors used were assumed to be uncontrolled (i.e. absent of control technology). This may overestimate actual emissions occurring in certain sectors (i.e. industrial) if USEPA or WI DNR has mandated certain control equipment. Given that Dane County has only been designated as a Nonattainment area for all criteria air pollutants once in the past 25 years (EPA 2015)[3], the authors assume less restrictive control technologies present in the region. Additionally, relying on AP-42 assumes that the combustion technology currently being utilized in Dane County is similar to technology from 10-20 years ago, which is generally the last time these emission factors were updated. If new combustion equipment has recently been installed, then these emission factors may again overestimate the emissions, however, given the lifetime and capital cost of such equipment.

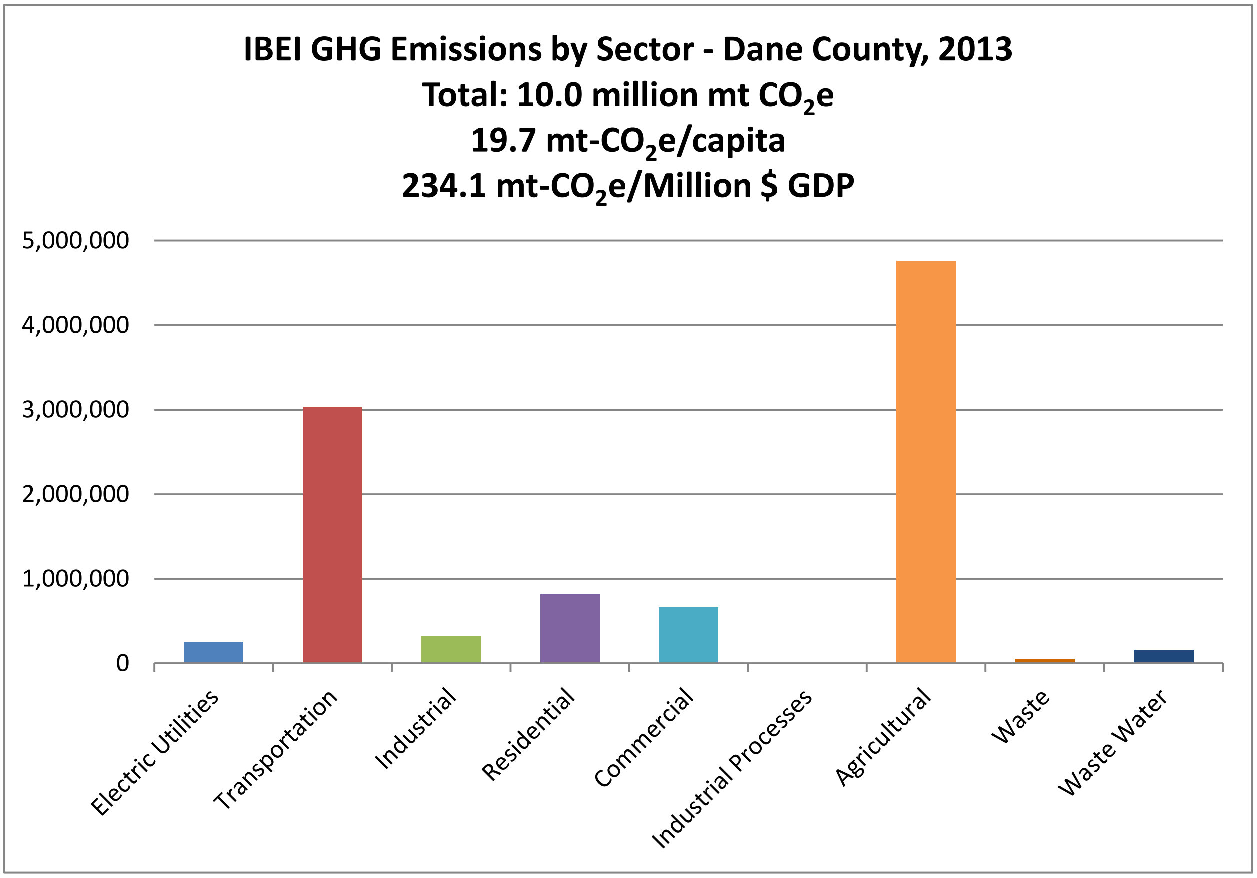
Section 3: Emissions Inventory & Footprint Results

Section 3.1 In-Boundary Emissions Inventory (IBEI):

Figure 2 shows the source-based territorial account for greenhouse gas emissions (in CO_2e) by sector for Dane County in 2013. The most significant contributors to direct emissions in Dane County are the transportation and agriculture sectors. Electric utilities are relatively minor contributors because the majority of electricity used in Dane County is imported. The aggregate territorial emissions (total = 10.0 million metric tonnes (mt) of CO_2e) are shown normalized either per unit GDP or per capita in the figure below. However, it should be cautioned that neither of which is an appropriate normalization metric in the case of territorial accounting, because imported electricity and household activity are not included in this approach. The corresponding air pollution emissions profile from territorial accounting is shown in Figure 3. A summary of the full set of results for all pollutants including GHGs is shown in Table A1.

[3] Dane County was listed as a Nonattainment area for SOx emissions in 1992.

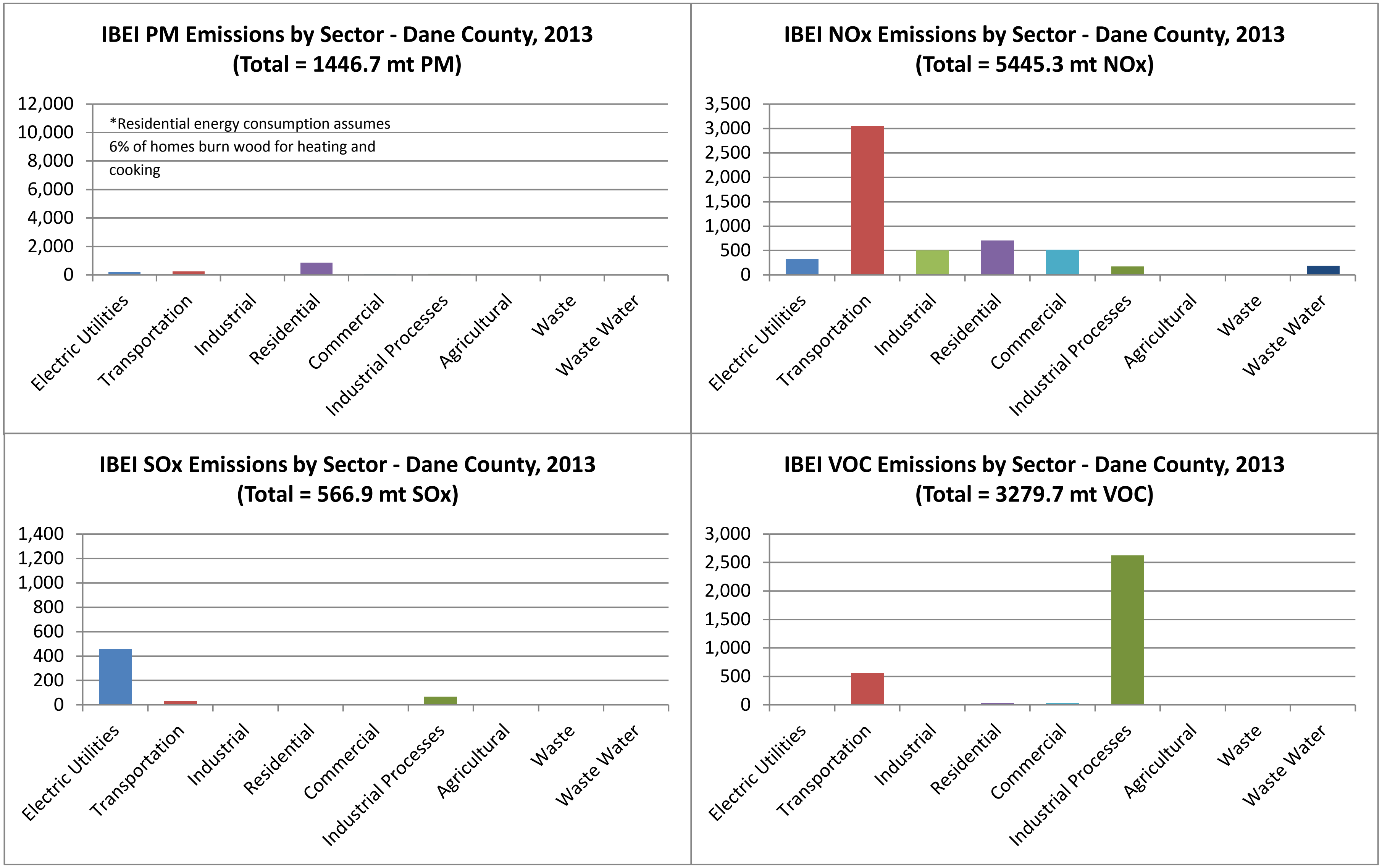
Figure 2: In-Boundary Emissions Inventory GHG Emissions by Sector – Dane County 2013



Agricultural emissions are almost all related to methane and nitrous oxide emissions from livestock activities. Transportation also dominates GHG emissions, arising from 72 percent gasoline use, 25 percent diesel, 2 percent jet fuel, and other fuel use.

Figure 3 shows source based air pollution accounting by sector. Particulate matter and ozone are the local air pollutants that have the most documented human health impacts (EPA 2014c). Since NOx and VOCs are precursors to ozone formation, transportation and industrial process emission reductions would have the greatest impact on ozone formation. Reduction in residential wood and biomass burning would have the most impact on PM emissions.

Figure 3: In-Boundary Emissions Inventory - Criteria Air Pollutant Emissions by Sector



Implications for Action:

- The agriculture and transportation sectors dominate the GHG emissions in Dane County, however, among these two sectors, only transportation is a significant contributor to criteria air pollutant emissions. Thus, focusing on transportation can provide both air pollution and climate-disruption benefits.
- The agricultural emissions are dominated by methane, so strategies to capture and use this as a transportation or residential fuel may be valuable.
- While transportation dominates the NO_x emissions, residential energy use appears to contribute the majority of PM emissions due to use of wood, propane, and LPG for heating homes.
    - This residential PM number is based on estimates that approximately 6 percent homes that use wood for heating (not cleaner burning natural gas) – derived from the “bottom up” data gathered in Dane County. Details methods are described in Appendix C.
    - The State of Wisconsin Household Energy Use report indicates 70 percent of Wisconsin homes use gas, and about 12 percent use electricity – thus, it is assumed that the remaining 18 percent of homes use wood, fuel oil, and propane equally.
- For air pollutants, industry is the major contributor of VOCs, which may include organic compounds released into the air during food processing, refrigerant manufacture, tire production, and/or steel fabrication.
- Electric Utilities contribute 81 percent of SO_x emissions. Surprisingly, transportation doesn’t contribute significantly to SO_x emissions due to use of ultra-low sulfur diesel.
- Transportation and electricity sector interventions seem to be where Dane County can make the most impact on criteria air pollutant reductions.

A summary table of all the results associated with IBEI is shown in Appendix A.

Section 3.2 Community-Wide Infrastructure Use-Activity Footprint (CIF) Results

The CIF captures energy as well as material use by the community, which can be normalized based on suitable metrics to represent the efficiency of *use* of material and energy in the various infrastructure sectors, hereafter, referred to as Infrastructure MEF_{use} benchmarks. These metrics are also useful to benchmark Dane County’s performance compared to other cities our team has studied. Note that climate (i.e. number of heating/cooling degree days) can play a large role in influencing energy use. Thus, in Figure 4, below, Dane County should be compared with other communities in the upper Midwest and with State of Wisconsin averages. The first benefit of the CIF approach is that it reports MEF_{use} benchmarks, which can stimulate action.

Figure 4: Benchmarks for Dane County

Benchmarking to Other Cities and Counties in the U.S.							
Benchmark	Activity Unit	Dane County (2013)	WI Average (2012)	Minneapolis (2008)	Austin, TX (2008)	Denver County (2008)	U.S. Average (2008)
Population	# of people	509,939	5.54 million	387,711	672,011	579,744	NA
Avg. Res. Electricity Use	kWh/hh/mo	649	683	478	1108	545	888
Avg. Res. Natural Gas Use	therms/hh/mo	64	36	60	26	45	58
Vehicle Miles Travelled	VMT/person/day	27	29	17	26	24	27
Water/ Wastewater	1,000 gal/capita/year	213	102	104	122	148	NA
Municipal Solid Waste	tons/capita	0.52	1.48	0.97	1.07	1.25	0.82
2002$ Spent on Food	2002-$/HH	$5,012	$6,490	$6,404	$5,975	$6,123	$5,426
Cement Use	mt/capita	0.59	0.29	0.32	0.67	0.50	0.36
GHG Emissions	mt-CO_2e/person (annual)	20.4	24.5	24	24.5	24.4	24.5

*WI average CO_2e/person/year assumed to be the same as national average

The MEF_{use} benchmarks show that:

- Dane County homes, at 649 kWh/month, use 5% less electricity than an average home in Wisconsin (with an average size of 2605 square feet). Assuming a 2.5 person household, this is approximately 260 kWh/person/month and 25.6 therms/person/month. The average Dane County home is 1850 square feet, while that of other cities, such as Minneapolis, is 1600 square feet. This could explain higher electricity use per household in Dane County versus Minneapolis given that they both are in cold climates. A combination of floor area and higher AC usage accounts for higher electricity use compared to Denver, but Dane County residential electricity use is well below the US average. Dane County use of natural gas is similar to Minneapolis but greater than the Wisconsin average, which could be due to increased wood/propane use in other areas of the state. The data suggest some opportunities for household energy efficiency particularly in terms of natural gas use.
- VMT in Dane county – simply normalized per capita – is 27 miles per person per day. This is similar to other metro areas in the US and confirmed with the State of WI report which identifies Milwaukee and Dane County as having high VMT per capita. Much of this may be

related to truck traffic; given the high level of diesel use (25 percent diesel among transport fuels in Dane County compared to 10-12 percent in US and other cities studied by (Hillman and Ramaswami 2010). The high level of diesel use may also be related to high agricultural activity.

  - The daily VMT broken down by car, truck and bus provided by Dane County is 21.8 million, 4.8 million, and 70,128 miles, respectively.
  - More analysis of the truck travel can help indicate if freight rail may be an efficiency strategy for the area more broadly.
- Water use per capita is likewise high in Dane County compared to other communities – this as well is likely due to agricultural water draws. The water data provided included agricultural, residential and industrial. Farms could not be separated out.
- In the cement use sector, Dane County appears to be using more cement than the state average, in line with that used in other growing communities like Denver and Austin in 2008.

All the MEF data are then combined with the EF as shown in Equation 2 to yield the aggregate GHGs associated with infrastructure use. Figure 5 shows the community-wide use-activity footprint (CIF) for greenhouse gas emissions (in CO_2e) for Dane County in 2013 by sector. Scope 1 emissions are solid bars, while scopes 2 & 3 which are trans-boundary GHG emissions occurring outside Dane County, are marked by hashed bars.

- While the transportation sector remains a significant contributor of GHG emissions using the CIF method, emissions from the electric power sector become much larger when accounting for electricity purchased from the grid but produced outside Dane County.
- The influence of transportation is now greater due to the upstream emission from fuel processing for producing the transportation fuels used in Dane.
  - Transportation emissions are not easily separated into personal (residential), commercial and industrial without more detailed transportation data tracking activities.
- The role of commercial, industrial, and residential sectors in buildings' energy use increase as well in the CIF approach compared to the IBEI approach. Adding in-boundary electricity and direct fuel use combustion emissions to the contributions of trans-boundary electricity and fuel use emissions results in the following distribution of buildings' energy use:
  - 57 percent Commercial
  - 30 percent Residential
  - 13 percent Industrial
  - These proportions illustrate the emphasis that can be made in these sectors for "building" efficiency & conservation by such actions as amending local or state building codes and/or incentives for green building and Leadership in Energy Efficiency and Design (LEED) building standards.
- The agricultural GHGs now represent GHGs from producing food eaten by Dane County residents (not the food produced locally – i.e. the local meat production to support local meat consumption is shown as Scope 1).
- Construction materials, such as cement contribute about 3 percent of total GHG emissions

Air pollution emissions associated with infrastructure use are similarly denoted by in-boundary and trans-boundary contributions in the next several figures.

PM emissions within the boundary (Figure 6) are mainly emitted due to agricultural and residential biomass burning. Diesel exhaust does not play a significant role in PM10 or PM2.5 emissions, which is consistent with Federal Highway Administration estimates (DOT 2006). Most SO_x emissions occur trans-boundary, but transportation and industrial process emissions are the two main sources within Dane County. Meanwhile, 71 percent of NO_x emissions (Figure 8) are attributable to the electricity and transportation sectors with the transportation sector being the largest contributor. VOC emissions within the boundary (Figure 9) are mainly attributable to the industrial and transportation sectors.

Figure 5: Community-wide Infrastructure Footprint GHG Emissions by Sector

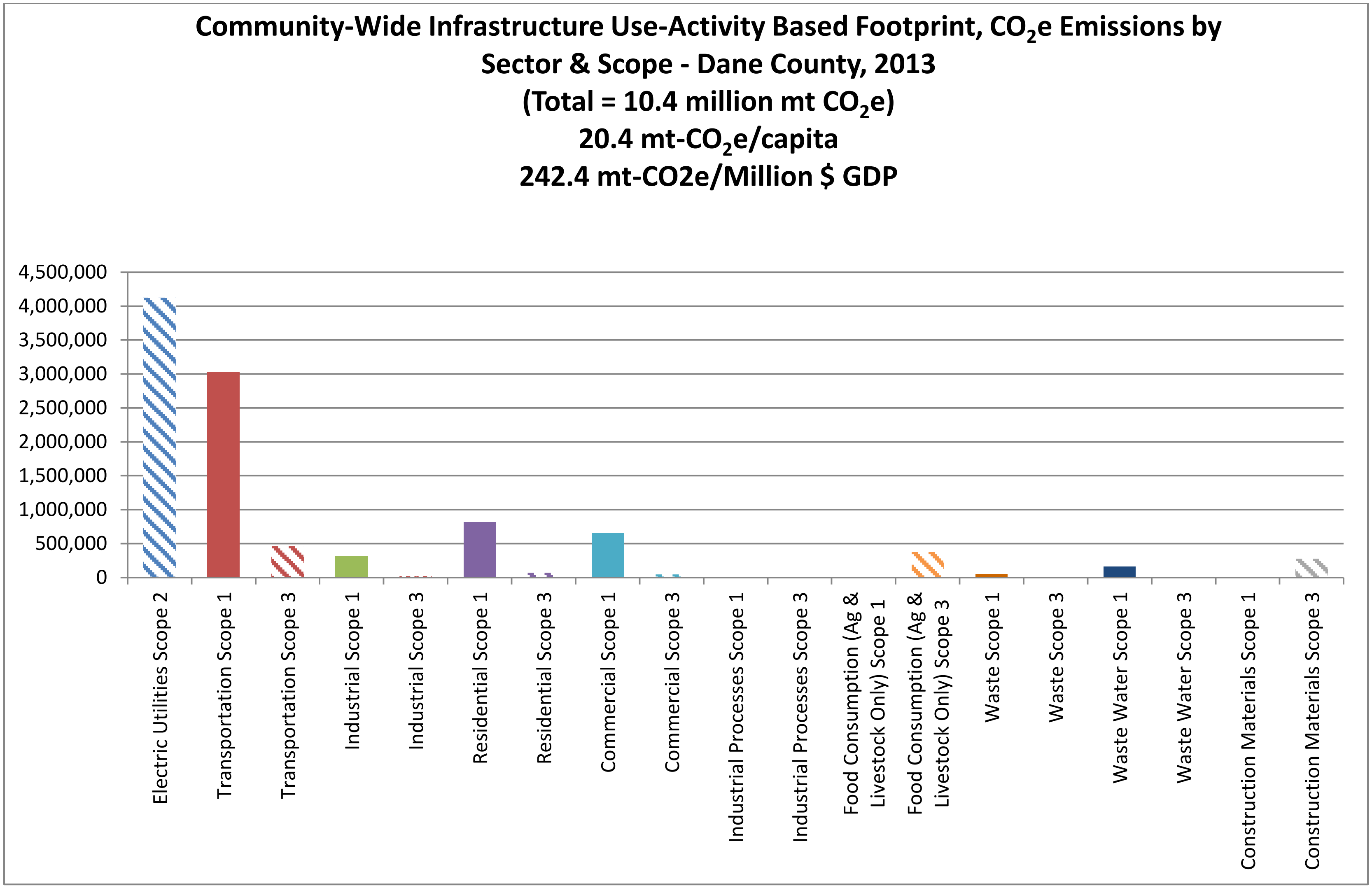


Figure 6: Community-wide Infrastructure Footprint PM Emissions by Sector

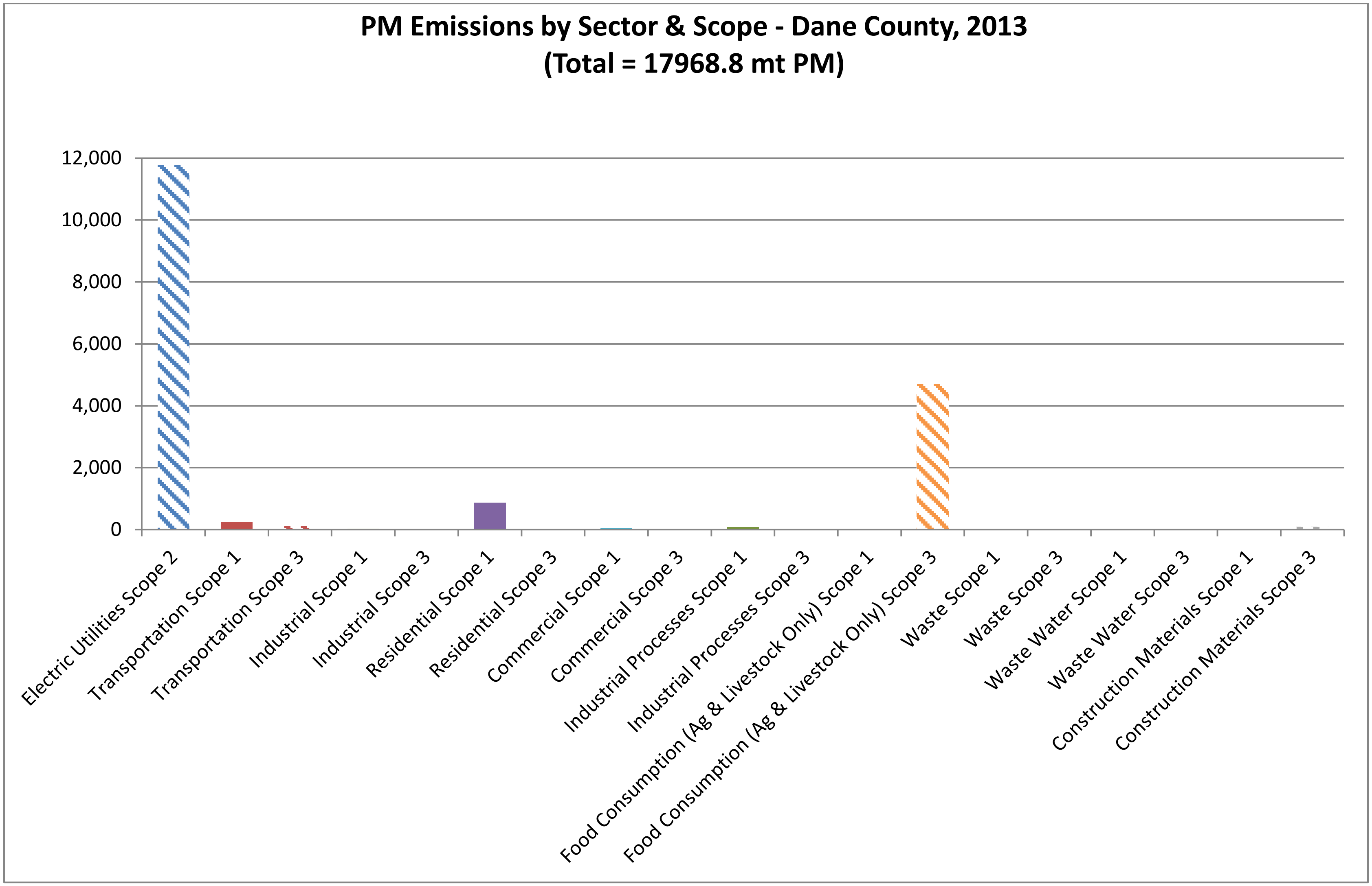


Figure 7: Community-wide Infrastructure Footprint SOx Emissions by Sector

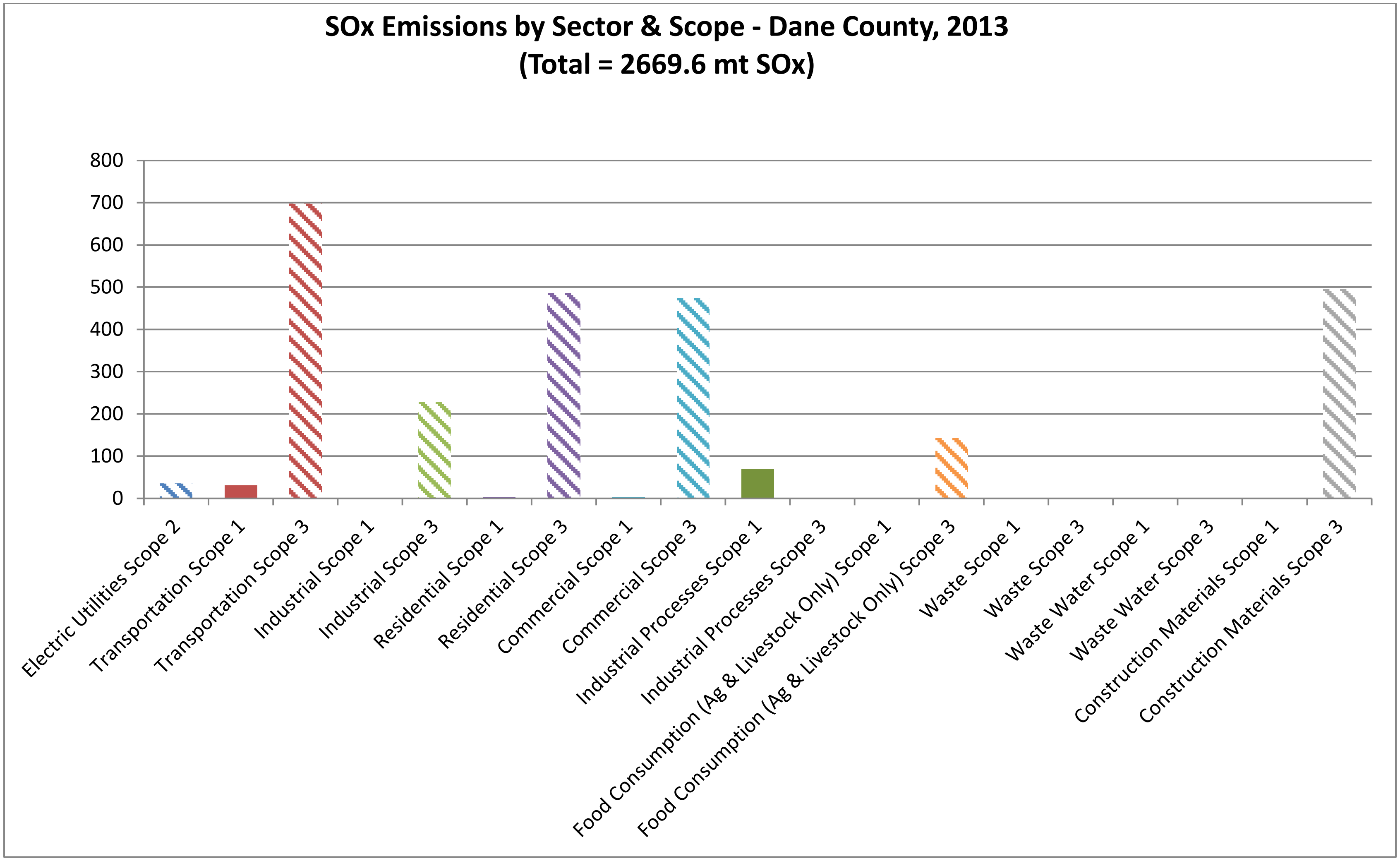


Figure 8: Community-wide Infrastructure Footprint NOx Emissions by Sector

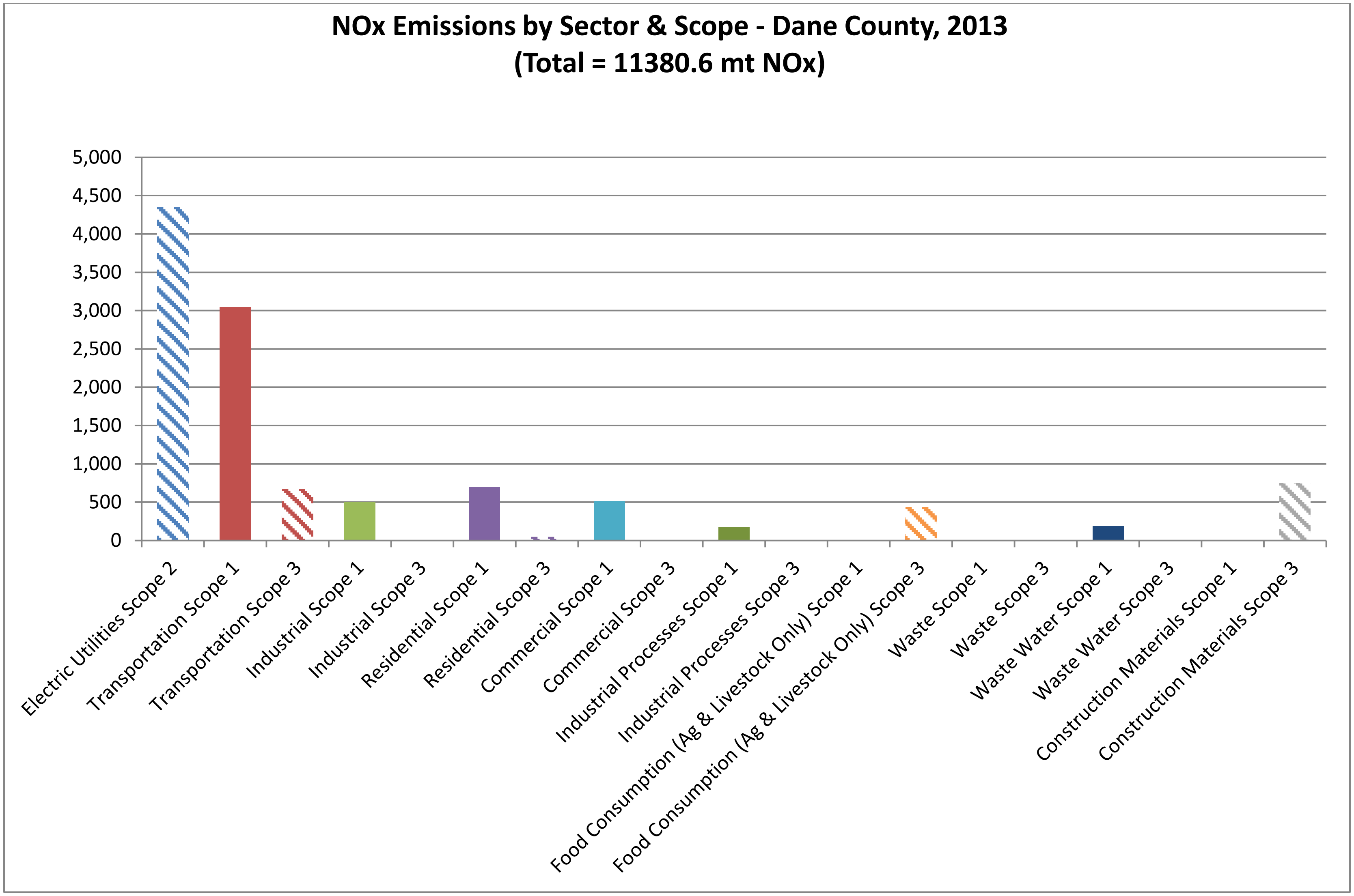
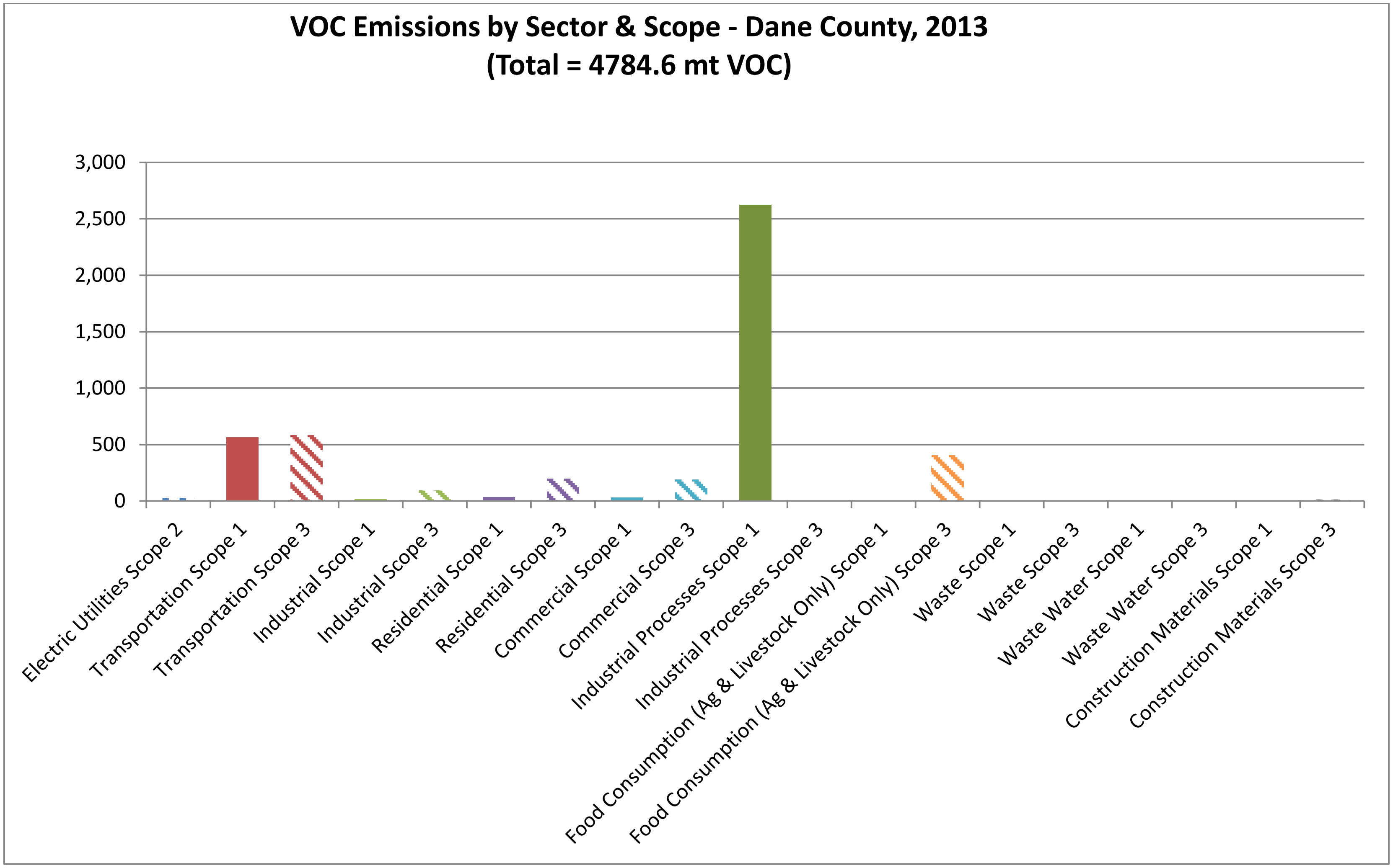


Figure 9: Community-wide Infrastructure Footprint VOC Emissions by Sector



Section 3.3 Household Only Consumption Activity Based Footprint (CBF) – GHG Emissions Only

Using the UC-Berkeley Carbon Footprint Model (Jones and Kammen 2011), a CBF was estimated for an average household in Dane County. The model uses consumption activity in four broad sectors -- transportation, household utilities, food, and shopping -- to determine the carbon footprint of a typical household, based on statistics specific to a specific county. Economic and demographic data specific to Dane County such as household size (2.34 persons per household) and median income ($62,303 per household) were used to estimate carbon emissions based on consumption of the average Dane County resident (US Census Bureau 2010). Using this model and specific bottom-up data, we calculate a CBF of 22.1 tCO_2e/person and 51.7 tCO_2e/household, which is similar the per capita results from both the IBEI and CIF.

Of the total GHG footprint of the household, the most emissions-intensive activity is transportation using personal vehicles (12 tCO_2e), followed by electricity consumption (9 tCO_2e). Purchasing electricity from renewable sources or installing rooftop solar PV could effectively cut a household's GHG footprint by about 20 percent. Buying an electric vehicle could cut a household's GHG footprint by 6.5 tCO_2e, approximately 10 percent. Household energy efficiency improvements like turning down the thermostat in the winter and switching to compact fluorescent light bulbs (CFLs) would reduce about 1.3 tCO_2e per household. Therefore, if households are concerned with reducing their carbon footprints, transportation and electricity usage would be the two activities that could produce the most impact. However, reducing consumption of certain goods (such as carbon-intensive foods) and making energy efficient improvements within the home (like using CFLs) could also have notable positive impacts.

Assumptions about the average household in Dane County in each of the four sectors are detailed below with more detail about the carbon intensity of each sector.

Transportation

Assuming a 2 car household, the following characteristics were used to calculate transportation-related emissions of 15.3 tons CO_2e/year.

Vehicle 1: 13000 mi/yr
Vehicle 2: 10600 mi/yr
Fuel Economy: 22 mpg
Public Transit (miles travelled): 478 mi/yr
Air Travel (miles travelled): 4300 mi/yr

Household Utilities

Using average household expenditures for heating and electricity utilities, household greenhouse gas emissions were calculated to be 16.9 tons CO_2e/year. Household floor space is based upon US Census data (AHS 2013), while household water consumption was determined through communication with various wastewater treatment plants in the county.

Household Electricity Use: $940/year
Utility Provider: Madison Gas & Electric Co

Household Natural Gas Use: $710/year
Household Fuel Use (propane, wood, etc.): $50/year
Household Floor Space: 1850 ft^2
Household Water Consumption: 100 gal/day

Food

Based on average daily calorie intake of a person with normal dietary requirements, the carbon footprint related to food was calculated to be 7 tons CO_2e/year.

Daily Calories per person
Meat: 543
Dairy: 286
Fruits & Vegetables: 271
Grains & Baked Goods: 669
Other (snacks, drinks, etc.): 736

Shopping

Based on average monthly household expenditures, the carbon footprint related to the purchase of goods and services was calculated to be 12.8 tons CO_2e/year.

Goods ($/month):
Clothing: 305
Furniture & Appliances: 344
Other Goods: 534

Services ($/month):
Health Care: 844
Education: 124
Information & Communication: 100
Vehicle Services: 163
Personal Business & Finance: 470
Home Maintenance & Repair: 28
Organizations & Charity: 152
Miscellaneous: 108

While all of these assumptions will vary greatly from household-to-household, the CBF footprint analysis demonstrates that individual and household decisions en masse can have notable local, regional, national, and global impacts on air quality and greenhouse gas emissions. Communities can contribute to the resolution of both local and global issues through the decisions of individuals.

Section 4: General Review of Conservation and Efficiency Opportunities

While the previous section provided specific insights about the sectors that can yield overlapping reductions (co-benefits) for reducing air pollution and climate-disrupters, this section summarizes some general approaches to achieving efficiency, conservation, and increased use of renewables in each of the infrastructure sectors. It begins by highlighting some of the more general sustainability efforts of Dane County and a few of its resident local jurisdictions to promote conservation and energy efficiency. These activities serve as a foundation for further action and provide examples of how other jurisdictions and private enterprises can similarly promote conservation, energy efficiency, and sustainability in their own communities.

Section 4.1 Overview of Local Energy Conservation and Renewable Energy Efforts

4.1.1 Dane County

Dane County government adopted a Sustainable Operations Plan in March 2016, which outlines a broad set of principles to provide a systematic framework for making informed and strategic decisions regarding all aspects of the county's operations. As noted in the plan, "The Dane County Board of Supervisors provided the initial direction for this planning effort with their unanimous adoption of Resolution 103, 2012-2013 in October 2012. Via this resolution, the county formally adopted a set of broad sustainability principles to provide a more systematic approach and a framework to make informed and strategic decisions regarding all aspects of county operations." Dane County government's sustainability goals include reducing dependence on fossil fuels, scarce metals and minerals, harmful chemicals, and synthetic substances, as well as reducing the impacts of county operations on the natural environment and reducing and eliminating barriers that undermine the ability of local residents to meet their basic human needs. Dane County's current sustainable operations objectives focus on transportation, water, waste, buildings and facilities, energy use, employee experience, and purchasing, as well as public education and outreach, as target areas for sustainable actions. The introductory purpose statement of the plan reads as follows:

> "Dane County government is pursuing a goal of becoming more environmentally, socially, and economically sustainable in its planning, operations, management, and policymaking. Over the last several years the county has initiated and implemented numerous efforts that are contributing to greater sustainability through energy conservation, greenhouse gas emission reductions, stormwater runoff reduction, renewable fuel vehicles, and employee wellness programs. This plan provides a more formal and comprehensive guideline for building on our existing efforts and achieving greater environmental, social, and economic sustainability across county departments and functions."
>
> "Through becoming a more sustainable local government we have the opportunity to create positive impacts that go beyond our operations and our jurisdictional boundaries. In developing this plan, we are embracing several general assumptions:
>
> 1. We can set an example for the broader community by operating in the most sustainable manner possible;
> 2. Economic, social, and environmental well-being are mutually interdependent;
> 3. County policy and investment choices have long-term impacts;

4. Sustainable practices can create long-term cost efficiencies;

5. Organizational awareness, responsibility, participation, and education are key elements of sustainability; and

6. Local actions can have regional, national, and global implications."

The plan includes very specific department-by-department sustainability actions and their associated costs, benefits, and timelines to implement. The county additionally hired a Sustainability Coordinator in the County Board Office to manage and facilitate efforts to improve the sustainability of the county's operations, management, and policymaking.

Dane County Executive Joe Parisi initiated the Dane County Climate Action Council in March 2013 to evaluate climate projections for Dane County by the University of Wisconsin-Madison and Wisconsin DNR and to make recommendations as to how Dane County government should most effectively prepare to respond to these projections. To further carry out these objectives and broaden its effectiveness throughout the county, Dane County may in the near future pursue a cooperative initiative to facilitate sustainability efforts across all municipalities and interested stakeholders within the county.

Cities within the county that already have similar sustainable action plans include Madison, Middleton, Fitchburg, and Monona. Coordinating across communities can create unique opportunities to bolster the efforts of individual municipalities and realize economies of scale across multiple jurisdictions. For example, a county-wide renewable energy program could increase the reach and resources available to incentivize the installation of renewable energy resources on homes and businesses countywide.

Dane County has initiated numerous conservation activities in the realm of public works and waste management, a sampling of which is listed below; many of these items are also noted in the Sustainable Operations Plan:

- In 2013, County Executive Joe Parisi created a cross-departmental Climate Change Action Council to assess county vulnerabilities to climate change impacts and create a climate change adaptation and resilience plan.
- Dane County has one of the most environmentally innovative landfills in the nation. The methane gas from the landfill is being burned to generate electricity sufficient to power 4,000 homes. Madison Gas & Electric purchases the electricity, and the county receives $3.3 million in annual revenue from it. Heat produced by the electrical generation process is used to heat the Clean Sweep building and new recycling facility; it will soon be piped nearby to heat the new Highway Department and Medical Examiner buildings at the county's new East District Campus.
- The new highway garage will also use the renewable compressed natural gas (CNG) from the landfill to run county fleet vehicles and have a renewable BioCNG filling station onsite. The landfill turns decaying trash into cleaner, cheaper, homegrown compressed natural gas that powers more than 40 county vehicles, including snowplows.
- Dane County is committed to reducing emissions generated by its vehicle fleet by adopting the goal of being "CNG by 2023." The County commissioned an analysis of its vehicle fleet and has

enacted a policy to replace inefficient vehicles that significantly contribute to greenhouse gas emissions with Compressed Natural Gas or hybrid vehicles. BioCNG has the lowest climate change emissions of any vehicle fuel being sold today – even lower greenhouse gas emissions than regular CNG because there is no need to drill for natural gas. BioCNG use as a transportation fuel represents an 88 percent reduction in greenhouse gas emissions compared to gasoline and diesel fuel (http://www.arb.ca.gov/fuels/lcfs/121409lcfs_lutables.pdf). Using CNG in 40 county fleet vehicles offsets the use of approximately 25,000 gallons of fossil-fuel gasoline and saves county taxpayers roughly $50,000 annually. These savings will continue to grow as more CNG vehicles are added to the fleet.

- Dane County is the first in the nation to install technology to capture carbon dioxide, the leading cause of climate change, from its landfill. The technology, once fully installed, is projected to reduce up to 59,000 tons of CO2 emitted annually by the landfill, which is the equivalent of taking 10,000 cars off the road.
- In 2016, Dane County built the state's largest municipally-owned solar project on the rooftops of the new Highway and Medical Examiner buildings. This project of 222 kW triples Dane County's installed solar generating capacity. The solar at the Dane County District Campus East will have 816 solar panels.
- Dane County Regional Airport's 100 kW solar installation on the rooftop of its Airfield Maintenance Facility is the second largest municipally-owned solar project in Wisconsin. The system's 376 panels are expected to generate 135,000 kilowatt-hours per year supplying 50 percent of energy needs.
- The county completed renewable energy and energy conservation upgrades at county facilities, such as LED runway lights and the noted solar panels at the Dane County Regional Airport and geothermal technologies at the new Badger Prairie Health Care Center and the Children's Zoo Barn.
- Dane County diverted nearly 75,000 tons of Construction & Demolition (C&D) waste to a recycling facility from January 2013 – July 2015. This operation was stopped in 2015 in order to convert the building into Dane County's own C&D recycling facility on county-owned land. Construction was completed and the new C&D recycling facility was opened in February 2016. This new facility separates waste from construction and demolition projects and recycles it locally, creating 19 new permanent jobs. Initially, the facility will process approximately 40,000 tons of C&D material annually. The facility will achieve a 70 percent recycling rate for all material it receives. Both the amount of C&D recycled and the number of jobs created from it are expected to double in the next few years.
- In 2014, the partnership of Dane County, Gundersen Health System, and three family dairy farms resulted in the successful construction and operation of a 2-megawatt bio-gas "Cow-Power" digester producing enough electricity to power 2,500 homes and reducing climate changing methane emissions equal to removing 4,000 cars from the road. This successful project in the Yahara Lakes Watershed also reduces algae-producing phosphorus by over 60 percent from the more than 20 million gallons of manure processed at the facility each year.

- A second digester partnership project owned by Clean Fuel Partners operating since 2011 also produces 2 megawatts of renewable electricity from 2,500 cows from three family dairies and also reduces phosphorus in processed manure by 60 percent. Both of these manure digester projects have the added benefit of less harmful agricultural run-off into the lakes.
- A cross-departmental Sustainability Work Group was created to strategically identify opportunities and help implement actions that improve the sustainability of the county's operations, management, and policymaking.
- Financial assistance is provided to departments and agencies for ongoing sustainability initiatives and projects through the budget process and through the SMART Fund for capital projects implemented by the Public Works and Transportation Committee's Sustainability Subcommittee. Since 2012 the SMART Fund has supported 43 projects, saved the county an estimated $525,000 annually in operating costs, and avoided an estimated 2,500 metric tons of CO_2 equivalent emissions annually.
- A Dane County Seed Library was established at several Dane County libraries, including the Bookmobile. The free seed library helps residents save money by growing their own food and participate in a culture of community sharing.
- The county is a member of Dane Buy Local to demonstrate support for locally owned businesses.
- Purchasing policies have been developed to support local business, for example:
    - RES. 257, 06-07 Local Food Purchase Policy;
    - RES. 320, 11-12 Recognizing Dane County's Commitment To Local Food Production and Access To Food As a Human Right; and
    - OA. 1, 13-14 Creating a Purchasing Preference for Locally Made Goods.
- Rain barrels to collect rooftop runoff were installed at the Fen Oak Resource Center. This system supplies water for the teaching gardens surrounding this county building. Fen Oak also has a composting system set up outside of the building lunch area so that it can be easily used by county employees during their breaks and lunch times.
- The county's contracted food service vender (Centerplate) utilizes a minimum of 30 percent locally grown and distributed food service products.
- The Dane County Sheriff's Office Freeway Service Team acquired a CNG bi-fuel system truck. The change will result in a 41.5 percent savings on fuel over the life of the truck.
- This project to complete a countywide Air Emissions Inventory to inform climate action planning is a significant step in understanding the sources of greenhouse gases and air pollution attributed to Dane County. It is a critical precursor to any strategic initiative of the Dane County community to reduce its contributions to GHGs and air pollution.
- Dane County allocated $35,000 in the 2016 Dane County budget for development of a communitywide Climate Action Plan. As part of this effort, Dane County is planning to update its 2011 Greenhouse Gas Emissions report, which inventoried and evaluated Dane County government's own operational contributions to greenhouse gases.

One of the primary themes that runs throughout these accomplishments is turning a waste product into both environmental and financial savings. For example, using methane from the landfill to fuel vehicles and heat buildings at a lower cost; diverting construction and demolition waste from the landfill to recycle material for reuse, while creating jobs; and building manure digesters to convert cattle waste into clean, renewable energy with added clean water benefits. As shown in Figure 2 of Section 3 above regarding In-Boundary Emissions, agriculture is an even greater source of GHGs in Dane County than transportation, which is primarily due to the methane generated by cattle. Given the strength of Dane County's agricultural sector, particularly the dairy industry, and the sheer numbers of cattle associated with it, this is not a surprise. One way that Dane County is working to turn this emission byproduct of one of the county's strongest industries into an affordable and plentiful source of energy is to promote the use of manure digesters.

But Dane County is not the only local public entity involved in such sustainability, conservation and renewable energy initiatives. The following subsections highlight a few of Dane County's local municipal efforts. While the four highlighted here comprise the most active communities on Dane County's local sustainability front, this is neither intended to be an all-inclusive list of communities and local innovations, nor is it meant to imply that there are no other similar initiatives by other municipalities, private enterprises, nonprofits, and utilities. Rather, it is simply intended as an example of the types of local public-sector activities already taking place in the county. Other communities and interested parties can look to this list to inspire their own actions to encourage sustainability, counter climate change, promote public health, and conserve fiscal resources. Of these four, the cities of Fitchburg, Middleton, and Monona are all Green Tier Legacy Communities (GTLC) under the state of Wisconsin's voluntary Green Tier program of the Department of Natural Resources (DNR). The Legacy Communities Charter is a "formal commitment of a municipality to superior environmental performance and sustainability practices." (WI DNR GTLC Program website) Dane County has more communities registered as GTLCs than any other county in the state, and it already has a solid foundation on which to base a broader community climate action planning initiative.

4.1.2 City of Fitchburg

As noted above, the city of Fitchburg is a Green Tier Legacy Charter community. Its 2015 GTLC Annual Report lists dozens of noteworthy accomplishments organized by the following categories: transportation; land use; energy; water; waste; and health. The city has a full-time Sustainability Specialist in its Public Works Department, along with other staff that facilitate the city's conservation efforts, including the city's Environmental Project Engineer. The city completed in-house its own 2012 Energy Consumption & Greenhouse Gas Emissions Report in which it measured and evaluated both municipal and communitywide energy consumption and greenhouse gas production. The city also has a standing Resource Conservation Commission, which produces an annual report to the City Council highlighting its sustainability activities in a number of categories: community outreach events; stormwater and groundwater initiatives; solid waste, refuse, and recycling; and energy conservation. The RCC has additional subcommittees around related topics, such as community outreach, organic waste, stream sampling, and municipal construction guidelines.

4.1.3 City of Madison

While the city of Madison is not a Green Tier Legacy Charter community like the other three cities referenced here, it has undeniably made a substantial commitment to and investment in conservation, perhaps the most of any town, city, or village in the county. The city's efforts go back over a decade to early initiatives like the 1998 resolution committing Madison to the International Cities for Climate Protection Campaign, the city's 2002 Climate Action Plan, the 2004 Mayor's Energy Task Force report entitled Building a Green Capital City: A Blueprint for Madison's Sustainable Design and Energy Future, and formal commitment to The Natural Step in 2005. More recently, the city adopted in 2011 The Madison Sustainability Plan: Fostering Environmental, Economic and Social Resilience. Notable programs include the MadiSUN solar initiative and the MPowering Madison Campaign to reduce municipal and community participant GHG emissions, and the city has implemented numerous sustainability policies, programs, and capital projects over the years. Madison has made great strides toward a more sustainable future and set an outstanding example. Similar to the other communities noted herein, Madison has dedicated sustainability staff, created the Sustainable Madison Committee to continue advancing sustainability efforts in the city, and established an expansive, user-friendly website with resources for both residents and businesses.

4.1.4 City of Middleton

Like the other cities noted here, Middleton has made a substantial commitment to sustainability and resource conservation. It is also a GTLC, like Fitchburg and Monona, with an equally extensive list of sustainability accomplishments listed in its most current annual GTLC report to DNR. It has full-time staff dedicated to sustainability and resource conservation, and it has a website dedicated to these efforts. The website includes a link to the city's 2010 Sustainable City Plan. Middleton created a Sustainability Committee that meets monthly and advises the City Council on sustainability matters and initiatives. The city also formally committed in 2009 by resolution to procure 25 percent of its electricity and 25 percent of its transportation fuels from renewable resources by 2025.

4.1.5 City of Monona

In 2012, the city of Monona similarly adopted a sustainability resolution, committing to reduce its energy dependence on fossil fuels by 25 percent by 2025. The resolution also created a Sustainability Committee to oversee the city's conservation efforts and make recommendations to the City Council. The same year, Monona became a Green Tier Charter Community, like the aforementioned cities of Fitchburg and Middleton. The city assigns the responsibility of supporting these efforts and staffing the Sustainability Committee to permanent, full-time staff in its Department of Public Works. In 2015, Monona adopted its first Sustainability Plan, and in 2016 had completed a draft Sustainability Implementation Plan document. In order to promote its efforts and aggregate related information in a single location, Monona created a sustainability website, which contains links to relevant material. Like the others discussed above, Monona has completed numerous sustainability projects, as outlined in its GTLC annual reports, perhaps the most notable of which is its solar installations on municipal buildings. Solar arrays were constructed on four municipal buildings: City Hall; Public Library; Public Works Garage; and Municipal Well No. 3. Combined they generate more than 210,000 kWh of energy each year, which account for roughly 30 percent of the energy needs of these buildings.

4.1.6 Summary and Synthesis of Local Conservation Efforts

As presented above, there are many outstanding initiatives and actions already being taken by Dane County and local municipalities to which other entities may look to spur ideas of their own. When reviewing the actions of the five jurisdictions above, some common fundamental elements of a conservation program start to emerge:

1. Formal commitment of the jurisdiction by resolution to sustainability principles;
2. Creation and appointment of a policy making sustainability oversight body;
3. Allocation of public staff time to support implementation of sustainability activities;
4. Creation and adoption of related planning and policy guidance documents;
5. Development of a website with a variety of resource links available to the community; and
6. Funding and implementation of conservation projects and activities.

Section 4.2 Water Utility Efficiency

In addition to the numerous sustainability activities of Dane County and its resident municipalities listed by jurisdiction above, there are many efficiency, renewable energy, and conservation opportunities that can be aggregated more generally by public infrastructure sector, starting with water utilities. Data was collected from the Wisconsin Public Service Commission's annual reports submitted by the municipal water utilities in Dane County (PSC 2013). These reports are submitted annually and give detailed information on a variety of the utility's operations including the number and type of customers served, total gallons sold, energy usage, and losses in the system. Out of the 29 municipal water utilities in Dane County, 14 had losses greater than or equal to ten percent of the total volume of water pumped through their systems. The PSC requires a justification in the annual report for any losses greater than 25%. But only one utility exceeded this level of leakage and was therefore required to report the cause of the excessive loss and planned actions to correct it.

On average, it takes 2 kWh to treat and deliver 1 gallon of water in Dane County (PSC 2013). There were a total of 1,593,000 gallons of water lost in municipal water systems countywide in 2013. This translates to 3,186 MWh of electricity or 2,340 mt-CO_2e. By targeting the systems with the most significant leakage problems (Belleville, Cambridge, Deerfield, Mazomanie, Mt. Horeb, Shorewood, and Verona) to reduce leakage rates to 10% would save 100,000 gallons of water, 200 MWh of electricity, and 147 mt-CO_2e emissions. Furthermore, the vast majority of water going into these municipal systems is taken from ground water. Thus, reducing usage will also reduce the burden being placed on limited ground water deposits, increasing the sustainability of the overall system.

Section 4.3 Recycling

Waste data was collected from the Wisconsin Department of Natural Resources' 2013 Landfill Tonnage Report (WI DNR 2013a) and Material Recovery Facilities Database (WI DNR 2013b). These sources do not contain any information on composting in Dane County, so emissions estimations from composting activities are omitted. The USEPA's Waste Reduction Model (WARM) (EPA 2015a) was used to estimate emissions from recycling and landfilling operations, given in mt-CO_2e. WARM reports Total Avoided emissions from recycling of 214,291mt-CO_2e, which is equivalent to the GHG emission of powering ~25,000 households.

Section 4.4 Existing Renewable Electricity Assets

There are a variety of renewable energy projects currently installed and operating in Dane County. As of 2013, there were two wind energy installations, three anaerobic digesters, and fifty solar photovoltaic installations operating county wide (M. Vickerman 2015). Figure 10 shows the total installed capacity and estimated electricity generation based on capacity factors taken from the U.S. Energy Information Administration (EIA 2015b). The EIA does not publish a capacity factor for anaerobic digesters, so an estimated capacity factor was calculated utilizing current generation data for the GL Dairy Biogas digester in Springfield, WI (D. Merritt 2015).Additionally, Dane County's Rodefeld Landfill captures methane and burns it to generate electricity, with a total of 30,173 MWh generated in 2013 (MGE 2015b). The EIA capacity factor was used to estimate the installed capacity of the landfill.

Figure 10: Installed Renewable Energy Assets 2013

Installed Renewable Energy Capacity & Estimated Generation, 2013			
Renewable Energy Technology	Installed Capacity (kW)	Capacity Factor	Estimated Generation (MWh)
Solar	4139	0.278	10080
Wind	10017	0.324	28431
Landfill	5000	0.689	30173
Anaerobic Digestion	3933	0.820	28252
Total	23089	-	96935

In 2014, an additional 275 kW of solar capacity was installed and brought online as well as 600 kW of capacity at the Maunesha River Dairy anaerobic digester (M. Vickerman 2015).

Section 4.5 Renewable Energy Opportunities

Solar and wind energy assets are considered emissions free. Each kWh of electricity produced with these systems displaces a kWh of electricity produced from the regional electricity grid. Based on non-baseload emission factors from eGRID (EPA 2014a), the installed solar and wind generation assets effectively reduced GHG emissions in Dane County by 30,830 mt-CO_2e in 2013. Based on the CBF, this is equivalent to the GHG emissions from electricity consumption of approximately 3,500 households.

Two Dane County community anaerobic digesters capture methane released by the processing of almost fifty million gallons of manure from six dairies per year (D. Merritt 2015). These systems with an installed capacity of 4 MW produce electricity from non-fossil fuel sources, displacing electricity demanded from the regional electricity grid. Because of the methane released by untreated manure is burned to create renewable electricity, the digester will reduce greenhouse gas emissions. The Wisconsin DNR in its Environmental Impact Statement estimates that by treating manure and replacing coal-fired electricity with renewable electricity, the two digester facilities will reduce emissions by

44,000 mt-CO_2e per year -- equivalent to the CO2 emissions from over 4,000 cars (WI DNR 2010; WI DNR 2013). Unlike solar and wind energy systems, which operate intermittently, these systems typically operate continuously, so it is appropriate to estimate avoided emissions using the annual emissions output rates from eGRID. Other avoided emissions are estimated using AP-42 emission factors (EPA 2000).

Currently, 18 percent of manure from dairy cattle, or 11 percent of total cattle and cow manure is anaerobically digested and used to produce methane. The GHG emissions reductions from this method of manure management are significant. Dane County is expanding the use of this technology and should continue to monitor the impacts of its proliferation. Landfill gas is primarily made up of methane (CH4) and carbon dioxide (CO_2), produced by microorganisms within the landfill under anaerobic conditions (EPA 2000).

Another source of renewable energy generation which may suit the interests of Dane County's industries and utilities is the use of biomass to generate electricity. The U.S. EPA has released a preliminary framework on determining GHG emissions from biomass energy operations (EPA 2014b). Both woody biomass and agricultural waste biomass have been used to displace fossil fuels in boilers to generate steam for both thermal and electricity generation applications. There are significant challenges to using biomass, including its lower heating value than fossil fuels. This may lead to the need for significant upgrades to fuel handling and storage facilities to handle a larger volume of material to generate the same amount of energy. Efforts to utilize biomass waste for energy generation should be evaluated on an individual project basis to determine feasibility, cost-benefit trade-offs, and emissions impacts.

Section 4.6 Other Community Actions

Similar to the Green Tier Legacy Communities program in Wisconsin, communities in Michigan[4] and Minnesota[5] have created networks to promote sustainability programs at the local level. These networks allow communities to learn best practices from one another while also showing how communities in the state compare to each other. Additionally, both Minnesota GreenStep cities and Michigan Green Communities provide rating systems to determine how much progress each community is making based upon the initiatives enacted. Besides tracking progress, this gives communities a roadmap for how to tackle an issue as broad as sustainability, while also illustrating the potential economic and community development benefits of these initiatives.

Tompkins County (Ithaca, NY) and Cambridge, Massachusetts are two similar communities that have set ambitious goals for energy and emissions reduction (Tompkins County 2016, Cambridge 2015). Both communities seek to use local short-term and long-term actions to achieve an 80% emissions reduction in their communities by 2050. Utilizing energy efficiency and renewable energy technologies, these communities have developed action plans to determine the feasibility of meeting their 2050 targets. These communities have utilized their baseline community-wide greenhouse inventories to evaluate the

[4] Michigan Green Communities http://migreencommunities.com/
[5] Minnesota GreenStep Cities http://greenstep.pca.state.mn.us/aboutProgram.cfm

effectiveness of policy options for meeting these targets. The Ithaca 2030 District in particular is being utilized as a way to highlight the role of high performance buildings in creating sustainable urban areas (Bardaglio 2016). Cambridge has also compiled a list of policy innovations being implemented in communities across the US seeking to achieve 80-100% emission reduction by 2050 (Cambridge 2014).

ICLEI and the World Wildlife Fund recently produced a report highlighting Atlanta, Portland, Minneapolis, and Cincinnati as leading communities in climate action planning (ICLEI 2015). These communities have all committed to ambitious targets of 80% emissions reductions by 2050. Commonalities between these cities' climate actions include strong local government leadership, consistency between state and local policy targets, and engagement with the private sector. While there is no common sector of action between these four communities, each city has targeted one specific energy driver to reduce. For example, Atlanta has targeted commercial building energy reduction through the Better Buildings Challenge program and utilizing Property Assessed Clean Energy (PACE) financing programs. Cincinnati has targeted the electricity production itself by utilizing community choice aggregation (CCA) to both secure lower electricity prices through a competitive bid process while also opting for 100% green energy. Minneapolis passed in ordinance to require large commercial buildings to annually benchmark their energy and water consumption while also engaging with the local electricity and natural gas utilities to create a Clean Energy Partnership (CEP) to help the city reach its emission reduction goals. Portland has targeted automobile emissions reduction through an urban growth boundary and extensive transit and bike networks.

Section 5: Conclusion

This report illustrates the progress Dane County has made through the efforts of Dane County staff and the cities of Madison, Middleton, Fitchburg, and Monona. It also illustrates the opportunities that exist for local governments and households to reduce local air pollution and climate-disrupting emissions. By distinguishing the location and infrastructure sector that these emissions are coming from, this report aims to inform policymakers of the main sectors driving air pollution emissions in Dane County and which sectors have the most impact within and outside of Dane County. Lastly, it is important to acknowledge that local actions do not exist in a vacuum, learning from successes and failures of communities within and outside of Wisconsin can help create sustainability policy that will reduce emissions and promote economic development.

Appendix A. Summary Tables for Source Based Accounting & Community-Wide Activity-Use Footprint Methods

Table 1. In-Boundary Emissions Inventory - Dane County, 2013

Sector	GHG Emissions (mt)					Criteria Pollutants (except Ozone) (mt)								Toxics (mt)
	CO_2e	CO_2	CH_4	N_2O	HFC / PFC	PM 10	PM 2.5	PM Tot	CO	NOx	Pb	Hg	SO_X	VOC
Electric Utilities: Electricity Produced within the boundary	252,965.19	252,409.25	4.93	1.58	NA	190.22		190.22	42.63	323.99	7.54E-03	1.38E-02	457.80	9.49
Transportation: Tailpipe Emissions Only within the boundary (On-Road & Air Travel)	5,590,167.96	5,505,739.32	187.32	174.26	NA	322.89	134.82	457.71	24054.51	5644.22	NA	NA	56.432	1043.84
Industrial: Non-Electricity Energy Use	317,443.24	315,739.83	6.05	5.79	NA	20.00		20.00	221.02	499.92	1.32E-03	6.84E-04	1.58	14.47
Residential: Non-Electricity Energy Use	813,706.57	785,966.34	818.42	18.21	NA	863.90		863.90	6414.70	702.04	8.00E-03	1.84E-03	3.90	36.80
Commercial: Non-Electricity Energy Use	658,524.78	654,991.10	12.55	12.01	NA	41.48		41.48	218.33	513.08	2.73E-03	1.42E-03	3.27	30.02
Industrial Processes: non-Energy Process Emissions	-	-	-	-	NA	84.05	-	84.05	NA	172.45	-	NA	69.83	2625.48
Agricultural: Non Energy Process Emissions	4,760,238.24	83.30	11,676.59	16,729.10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Waste: Non-Energy Emissions	49,934.00	22	1,778.89	0.39	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Waste Water: Non-Energy Emissions	156,258.02	-	5,184.78	41.83	NA	NA	NA	NA	NA	187.05	NA	NA	NA	NA

Community-Wide Infrastructure Use-Activity Based Foorprint - Dane County, 2013															
Sector	Scope	GHG Emissions (mt)					Criteria Pollutants (except Ozone) (mt)								Toxics (mt)
		CO_2e	CO_2	CH_4	N_2O	HFC / PFC	PM 10	PM 2.5	PM (total)	CO	NOx	Pb	Hg	SO_x	VOC
Electric Utilities: Electricity used by the Community supplied by the grid	Scope 2	4,122,699.24	4116408.30	62.07	71.53	NA	123.89		123.89	11691.09	3533.56	9.81E-02	1.94E-01	26.80	1.12E+01
Transportation: Tailpipe Emissions & Upstream Emissions from Transporft Fuel Processing & Transport (On-Road & Air Travel)	Scope 1	5,585,739.20	5,505,739.32	187.32	174.26	NA	322.89	134.82	457.71	24,054.51	5,644.22	NA	NA	56.43	1,043.84
	Scope 3	795106.20	667420.06	2070.88	15.43	NA	127.76	98.62	226.38	651.41	1239.79	NA	NA	1286.28	1077.85
Industrial: Non-Electricity Energy Use	Scope 1	354905.4875	353001.0469	6.7658534	6.4716859	NA	22.36		22.36	117.67	276.52	1.47E-03	7.65E-04	1.77	16.18
	Scope 3	25315.90	93482.47	697.56	NA	NA	NA	NA	NA	NA	NA	NA	NA	255.60	103.52
Residential: Non-Electricity Energy Use	Scope 1	707388.4605	703586.0712	2329.2398	12.923565	NA	2406.62		2406.62	18050.50	767.39	3.89E-06	3.45E-07	3.52	32.27
	Scope 3	179473.03	281627.04	2573.78	1.69	NA	17.75	14.34	32.10	140.57	271.93	NA	NA	734.80	293.65
Commercial: Non-Electricity Energy Use	Scope 1	736238.88	732288.19	14.04	13.43	NA	46.38		46.38	244.10	573.63	3.05E-03	1.59E-03	3.66	33.56
	Scope 3	52516.94	193926.08	1447.06	NA	NA	NA	NA	NA	NA	NA	NA	NA	530.23	214.74
Industrial Processes: non-Energy Process Emissions	Scope 1	-	-	-	-	NA	84.05	-	84.05	NA	172.45	1.20E-04	NA	69.83	2625.48
	Scope 3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Agricultural: Emissions Attributable to Food Consumption	Scope 1	NA	NA			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Scope 3	1466200	791700	17360.595	1676.23	6274.67	5654	1432.9	7086.9	5772.33	3038	NA	NA	2476	1386.17
Waste: Non-Energy Emissions	Scope 1	49,765.00	22	1,457.46	0.39	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Scope 3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Waste Water: Non-Energy Emissions	Scope 1	156,258.02	-	5,184.78	41.83	NA	NA	NA	NA	NA	187.05	NA	NA	NA	NA
	Scope 3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Construction Materials: Cement Used within the Community, Manufactured Elsewhere	Scope 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Scope 3	277329.34	276998.85	11.80	NA	NA	88.45	2.72E-02	88.47561404	328.69	747.03	NA	NA	496.03	15.00

Appendix B. Emission Factors & Sources Tables

Table B-1: IBEI Emission Factor Sources

* Blank Cells indicate unknown or n/a

Source-Based Direct Emissions Inventory - Dane County, 2013													
Sector	**GHG Emissions**					**Criteria Pollutants (except Ozone)**							**Toxics**
	CO_2e	**CO_2**	**CH_4**	**N_2O**	**HFC / PFC**	**PM 10**	**PM 2.5**	**CO**	**NOx**	**Pb**	**Hg**	**SO_2**	**VOC**
Electric Utilities: Electricity Produced within the boundary	eGRID	eGRID	eGRID	eGRID		eGRID + AP-42	eGRID + AP-42	eGRID + AP-42	eGRID	eGRID + AP-42	eGRID + AP-42	eGRID	eGRID + AP-42
Transportation: Tailpipe Emissions Only within the boundary (On-Road & Air Travel)	GREET	GREET	GREET	GREET		GREET	GREET	GREET	GREET	GREET	GREET	GREET	GREET
Industrial: Non-Electricity Energy Use	Utility Data + Ap-42	Utility Data + Ap-42	Utility Data + Ap-42	Utility Data + Ap-42		Utility Data + Ap-42	Utility Data + Ap-42	Utility Data + Ap-42	Utility Data + Ap-42	Utility Data + Ap-42	Utility Data + Ap-42	Utility Data + Ap-42	Utility Data + Ap-42
Residential: Non-Electricity Energy Use	Utility Data + RECS + Ap-42	Utility Data + RECS + Ap-42	Utility Data + RECS + Ap-42	Utility Data + RECS + Ap-42		Utility Data + RECS + Ap-42	Utility Data + RECS + Ap-42	Utility Data + RECS + Ap-42	Utility Data + RECS + Ap-42	Utility Data + RECS + Ap-42	Utility Data + RECS + Ap-42	Utility Data + RECS + Ap-42	Utility Data + RECS + Ap-42
Commercial: Non-Electricity Energy Use	Utility Data + Ap-42	Utility Data + Ap-42	Utility Data + Ap-42	Utility Data + Ap-42		Utility Data + Ap-42	Utility Data + Ap-42	Utility Data + Ap-42	Utility Data + Ap-42	Utility Data + Ap-42	Utility Data + Ap-42	Utility Data + Ap-42	Utility Data + Ap-42
Industrial Processes: non-Energy Process Emissions	WI DNR Air Pollution Emissions Inventory	WI DNR Air Pollution Emissions Inventory		WI DNR Air Pollution Emissions Inventory		WI DNR Air Pollution Emissions Inventory			WI DNR Air Pollution Emissions Inventory		WI DNR Air Pollution Emissions Inventory	WI DNR Air Pollution Emissions Inventory	WI DNR Air Pollution Emissions Inventory
Agricultural: Non Energy Process Emissions	Manure Mgmt data + ICLEI app G												
Waste: Non-Energy Emissions	EPA GHG Reporting Program (MRR)												
Waste Water: Non-Energy Emissions	ICLEI App F	ICLEI App F	ICLEI App F	ICLEI App F					WI DNR Air Pollution Emissions Inventory				

Table B-2: CIF Emission Factor Sources

* Blank Cells indicate unknown or n/a

Community-Wide Infrastructure Use-Activity Based Foorprint - Dane County, 2013														
Sector	**Scope**	**GHG Emissions**					**Criteria Pollutants (except Ozone)**							**Toxics**
		CO_2e	**CO_2**	**CH_4**	**N_2O**	**HFC / PFC**	**PM 10**	**PM 2.5**	**CO**	**NOx**	**Pb**	**Hg**	**SO_2**	**VOC**
Electric Utilities: Electricity used by the Community supplied by the grid	**Scope 2**	eGRID EF	eGRID EF	eGRID EF	eGRID EF		AP-42	AP-42	AP-42	AP-42	AP-42	AP-42	AP-42	AP-42
Transportation: Tailpipe Emissions & Upstream Emissions from Transporft Fuel Processing & Transport (On-Road & Air Travel)	**Scope 1**	GREET	GREET	GREET	GREET		GREET	GREET	GREET	GREET			GREET	GREET
	Scope 3	GREET	GREET	GREET	GREET		GREET	GREET	GREET	GREET			GREET	GREET
Industrial: Non-Electricity Energy Use	**Scope 1**	AP-42	AP-42	AP-42	AP-42		AP-42	AP-42	AP-42	AP-42	AP-42	AP-42	AP-42	AP-42
	Scope 3	NREL LCI	NREL LCI	NREL LCI									NREL LCI	NREL LCI
Residential: Non-Electricity Energy Use	**Scope 1**	AP-42	AP-42	AP-42	AP-42		AP-42	AP-42	AP-42	AP-42	AP-42	AP-42	AP-42	AP-42
	Scope 3	GREET & NREL LCI	GREET & NREL LCI	GREET & NREL LCI	GREET & NREL LCI		GREET	GREET	GREET	GREET			GREET & NREL LCI	GREET & NREL LCI
Commercial: Non-Electricity Energy Use	**Scope 1**	AP-42	AP-42	AP-42	AP-42		AP-42	AP-42	AP-42	AP-42	AP-42	AP-42	AP-42	AP-42
	Scope 3	NREL LCI	NREL LCI	NREL LCI									NREL LCI	NREL LCI
Industrial Processes: non-Energy Process Emissions	**Scope 1**	WI DNR Emissions Monitoring	WI DNR Emissions Monitoring		WI DNR Emissions Monitoring		WI DNR Emissions Monitoring	WI DNR Emissions Monitoring		EPA TRI	EPA TRI		WI DNR Emissions Monitoring	WI DNR Emissions Monitoring
	Scope 3													
Agricultural: Non-Energy Process Emissions from Producing Food	**Scope 1**	ICLEI App G	ICLEI App G	ICLEI App G	ICLEI App G									
	Scope 3	Carnegie Mellon EIO LCA	Carnegie Mellon EIO LCA	Carnegie Mellon EIO LCA	Carnegie Mellon EIO LCA	Carnegie Mellon EIO LCA	Carnegie Mellon EIO LCA	Carnegie Mellon EIO LCA	Carnegie Mellon EIO LCA	Carnegie Mellon EIO LCA			Carnegie Mellon EIO LCA	Carnegie Mellon EIO LCA
Waste: Non-Energy Emissions	**Scope 1**	EPA GHG Reporting Program (MRR)	EPA GHG Reporting Program (MRR)	EPA GHG Reporting Program (MRR)	EPA GHG Reporting Program (MRR)									
	Scope 3													
Waste Water: Non-Energy Emissions	**Scope 1**	ICLEI App F	ICLEI App F	ICLEI App F	ICLEI App F									
	Scope 3													
Construction Materials: Cement Used within the Community, Manufactured Elsewhere	**Scope 1**													
	Scope 3	NREL LCI	NREL LCI	NREL LCI			NREL LCI	NREL LCI	NREL LCI	NREL LCI			NREL LCI	NREL LCI

Table B-3: CIF Material and Energy Flow Data Sources

* Blank Cells indicate unknown or n/a

Sector	Scope	GHG Emissions				Criteria Pollutants (except Ozone)							Toxics
		CO_2e	CO_2	CH_4	N_2O	PM 10	PM 2.5	CO	NOx	Pb	Hg	SO_2	VOC
Electric Utilities: Electricity used by the Community supplied by the grid	**Scope 2**	Primary Utility Data											
Transportation: Tailpipe Emissions & Upstream Emissions from Transporft Fuel Processing & Transport (On-Road & Air Travel)	**Scope 1**	WI DNR Vehicle Fleet Data, Madison Transport Model, DCRA GHG Emissions Study, Fuel Data for regional airports											
	Scope 3												
Industrial: Non-Electricity Energy Use	**Scope 1**	Primary Utility Data, NG Use											
	Scope 3												
Residential: Non-Electricity Energy Use	**Scope 1**	Primary Utility Data, NG Use, estimated Fuel Oil & propane use from RECS											
	Scope 3												
Commercial: Non-Electricity Energy Use	**Scope 1**	Primary Utility Data, NG Use											
	Scope 3												
Industrial Processes: non-Energy Process Emissions	**Scope 1**	WI DNR Emissions Monitoring				WI DNR Emissions Monitoring			EPA TRI	EPA TRI		WI DNR Emiss	WI DNR Emissi
	Scope 3												
Agricultural: Non-Energy Process Emissions from Producing Food	**Scope 1**	USDA Animal Counts, Manure Mgmt via personal comm w/ Kevin Connors & Dave Merritt											
	Scope 3	Bureau of Labor Stats Consumer Expenditure Survey											
Waste: Non-Energy Emissions	**Scope 1**	WI DNR Landfill Report & Material Recycling Facilities reports											
	Scope 3												
Waste Water: Non-Energy Emissions	**Scope 1**	Based on Population Served, Personal Comm w/ Kamran Mesbah & primary data from DC WWTPs											
	Scope 3												
Construction Materials: Cement Used within the Community, Manufactured Elsewhere	**Scope 1**												
	Scope 3	Purchased Data from Dodge Analytics											

Community-Wide Infrastructure Use-Activity Based Foorprint Emissions Factors - Dane County, 2013														
Sector	Scope	GHG Emissions					Criteria Pollutants (except Ozone)							Toxics
		CO_2e	CO_2	CH_4	N_2O	HFC / PFC	PM 10	PM 2.5	CO	NOx	Pb	Hg	SO_x	VOC
Electric Utilities: (mt/MWh)	**Scope 2**	0.734263918	0.730647459	1.10178E-05	1.24829E-05		2.19902E-05		0.002075126	0.000627194	1.74E-08	3.44E-08	4.75612E-06	1.99E-06
Transportation: (g/mile) OR (g/gal)	**Scope 1**	198.43-1642.54 (6211.58)	197-1691.58 (6174.04)	0.0005-5.48 (0.192)	0.001-0.0361 (0.121)		0.02-0.1 (0.47)	0.007-0.038 (0.212)	0.346 - 55.95 (51.9)	0.082-4.57 (2.18)			0.0265-0.128	0.041-0.966 (2.91)
	Scope 3	-1655.08	-2670.33	1.11-21.27	1.04E-02 - 3.38		0.09-1.34	0.07-0.62	0.18-5.49	0.98-3.6			0.54-2.95	0.33-4.33
Industrial: (mt/therm)	**Scope 1**	0.005365171	0.0053	1.02281E-07	9.78336E-08		3.37971E-07		1.78E-06	4.18E-06	2.22E-11	1.16E-11	2.66819E-08	2.446E-07
	Scope 3	3.83E-04	1.41E-03	1.05451E-05									3.86389E-06	1.565E-06
Residential:	**Scope 1:** NG (mt/therm) Fuel Oil (mt/gal) Propane (mt/gal) Wood (lb/ton)	5.7E-03, 0.01, 0.01, 840	5.34E-03, 1.13E-02, 5.67E-03	1.02E-07, 8.07E-07, 9.07E-08, 30	9.78E-08, 2.27E-07, 4.08E-07		3.38E-07, 6.8E-07, 3.18E-07, 30.6		1.78E-06, 2.27E-06, 3.4E-06, 230.8	4.18E-06, 8.16E-06, 5.9E-06, 2.8	2.22E-11, 6.85E-11	1.16E-11, 6.08E-11	2.67E-08, 9.66E-08	2.45E-07, 3.23E-07, 4.54E-07
	Scope 3: NG (mt/therm) Fuel Oil (g/gal) Propane (g/gal)	3.83E-04, 1126.85, 1411.88	0.00141, 1051.83, 1029.82	1.055E-05, 2.48, 13.47	2.07E-02, 0.018		0.18, 0.19	0.14, 0.15	0.91, 1.55	1.69, 3.019			3.9E-06, 2.59	1.56E-05, 0.42, 0.98
Commercial: (mt/therm)	**Scope 1**	0.005365171	0.0053	1.02281E-07	9.78336E-08		3.37971E-07		1.78E-06	4.18E-06	2.22E-11	1.16E-11	2.66819E-08	2.446E-07
	Scope 3	3.83E-04	1.41E-03	1.05451E-05									3.86389E-06	1.565E-06
Industrial Processes: non-Energy Process Emissions	**Scope 1**	Reported Data, No EF	Reported Data, No EF		Reported Data, No EF		Reported Data, No EF	Reported Data, No EF		Reported Data, No EF	Reported Data, No EF		Reported Data, No EF	Reported Data, No EF
	Scope 3													
Agricultural: Non-Energy Process Emissions from Producing Food	**Scope 1**	ICLEI App G	ICLEI App G	ICLEI App G	ICLEI App G									
	Scope 3	Carnegie Mellon EIO LCA, No EF	Carnegie Mellon EIO LCA, No EF	Carnegie Mellon EIO LCA, No EF	Carnegie Mellon EIO LCA, No EF	Carnegie Mellon EIO LCA, No EF	Carnegie Mellon EIO LCA, No EF	Carnegie Mellon EIO LCA, No EF	Carnegie Mellon EIO LCA, No EF	Carnegie Mellon EIO LCA, No EF			Carnegie Mellon EIO LCA, No EF	Carnegie Mellon EIO LCA, No EF
Waste: Non-Energy Emissions	**Scope 1**	Reported Data, No EF	Reported Data, No EF	Reported Data, No EF	Reported Data, No EF									
	Scope 3													
Waste Water: Municipal Service (mt/cap) Private Septic (mt/cap)	**Scope 1**	0.32, 0.121		0.01, 4.34E-03	3.20E-05									
	Scope 3													
Construction Materials: (kg/kg)	**Scope 1**													
	Scope 3	0.928106	9.27E-01	3.95E-05			2.96E-04	9.11E-08	1.10E-03	2.50E-03			1.66E-03	5.02E-05

Appendix C. Detailed Data and Methods Used for In-boundary Source-Based Emissions Inventory (IBEI)

Emissions estimations are carried out by summing direct, measured emissions where possible or multiplying fuel use data by direct emission factors where available. Measured data is scarcely available, so emission factors were heavily relied upon. Furthermore, emission factors were not consistently available for all pollutants across all sectors, so data gaps are shown as NA, -, and ND for Not Available, No Emissions, and No Data Available, respectively (Appendix A).

AC.1 Stationary Source Emissions (Electricity Production in Dane County)

Stationary Source fuel combustion emissions include 4 categories, Electricity generation (power plant emissions), non-electricity direct fuel use (in homes), non-electricity direct fuel use (in commercial), non-electricity direct fuel use (industry).

Data was collected from the EPA's eGRID database for the Blount Street, Capital Heat and Power, Rodefeld Landfill, Diesel Generators, Fitchburg, Nine Springs, RockGen Energy Center, Sycamore, UW Madison Charter St. and West Campus Cogeneration facilities (EPA 2014a). This dataset includes annual electricity generation (MWh), heat input (MMBtu), and emissions (tons) of CO_2, CH_4, N_2O, NO_x, and SO_2. Other emissions were estimated using AP-42 emission factors (EPA 2000) according to plant fuel type and combustion regime and annual heat input provided by the eGRID dataset (EPA 2014d).

AC.2 Industrial Non Electricity energy Use/Fuel Combustion

Industrial energy use was reported by all the utilities from which data was collected including electricity as well as fossil fuels burned directly, such as natural gas. Electricity use for industrial applications was captured in section 3.1 Electricity Generation. Reported here are the emissions associated with natural gas use in the industrial sector. Natural gas use was reported by Madison Gas & Electric and Alliant Energy, who combined had 58 industrial natural gas customers in 2013. Source based emissions were estimated by multiplying reported natural gas use by the EPA's AP-42 emission factors for natural gas combustion (EPA 2000), assuming minimal control technology to be cautious. AP-42 reports emission factors for several types of natural gas boilers/turbines. Specific emission factors used include residential boilers for commercial & residential applications, turbines for electricity production, and large boilers w/ no control technology for industrial applications. Data on other individual fuel use such as coal and diesel were not available.

AC.3 Residential (Non Electricity) Energy Use/Fuel Combustion

Direct emissions in the residential sector are made up of those from direct fuel burning within the home (for space and water heating, cooking, etc.). The U.S. Energy information Administration conducts a residential energy consumption survey (RECS), which indicates that 78% of homes in Wisconsin use natural gas, 44% use propane, 17% use wood, and 4% use fuel oil (EIA 2009). Because data for residential natural gas use was only available for 64% of homes from utilities, these RECS percentages were used to estimate propane and fuel oil consumption assuming that each household using that fuel type would use it to meet its entire thermal energy needs (based on primary data gathered from IOUs). This allowed the calculation of fuel consumption for propane and fuel oil based on a standard Btu to gallon conversion (EIA 2015a). This method leads to an over estimate of fuel use because it is likely a typical household will not use a single fuel to meet all of its thermal energy demand. However, this is the appropriate method due to limited data availability. Source based emissions were estimated by multiplying the assumed consumption of each fuel described above by emission factors taken from the EPA's AP-42 database (EPA 2000).

Total IBEI PM emissions are sensitive to the number of homes assumed to use wood as a main heating fuel. Our initial estimates showed 17% of homes use wood for fuel in Dane County. If we assume 12% (EIA 2009) of this 17% use electricity instead based on the Wisconsin average, then the residential proportion of total PM emissions decreases from 75% to 60% (the currently reported value).

AC.4 Commercial (Non Electricity) Energy Use/Fuel Combustion

Commercial energy use was reported by all the utilities from which data was collected. Electricity use for commercial applications was captured in section 3.1 Electricity Generation. Reported here are the emissions associated with natural gas used by the commercial sector, as reported by Madison Gas & Electric and Alliant Energy, who combined had 15168 commercial natural gas customers in 2013. Source based emissions were estimated by multiplying reported natural gas use by the EPA's AP-42 emission factors for natural gas combustion (EPA 2000). It was assumed that for commercial spaces, a natural gas burner comparable to a residential furnace would be used. There are several categories of burner available in the AP-42 including residential furnaces, tangential-fired boilers, small boilers, and large wall-fired boilers. Data on any other direct fuel use by commercial establishments such as wood, fuel oil, and diesel were not available and not included.

AC.5 Transportation Emissions (In-Boundary only)

The transportation sector is accounted for by estimating emissions from on-road vehicle traffic and airline travel. On-road vehicle emissions are accounted for by combining an estimation of vehicle miles travelled (VMT) generated by the Madison Metropolitan Area Transportation Planning Board (D. Kanning 2015) and vehicle fleet characteristics, including vehicle counts by type and average fuel efficiency that were collected from the Wisconsin Department of Natural Resources (C. Bovee 2015). County-wide Fuel usage is estimated to be 72% gasoline, 25% diesel, and 2% jet fuel with aviation gas, CNG, and E85 all comprising less than 1%. Total Daily VMT using gasoline is estimated to be 14,467,617 miles while Total Daily VMT using diesel (including freight) is 2,776,583 miles. Argonne National Lab's GREET model provides operational emission factors for each vehicle and fuel type combination in the vehicle fleet for greenhouse gases and criteria pollutants via the EPA's MOVES model. These emission factors were used to calculate on-road, vehicle operation air pollution emissions for CO_2, CH_4, N_2O, PM_{10}, $PM_{2.5}$, CO, NO_X, and VOCs. Emission factors for other pollutants were not available, including Lead, Mercury, Chromium, and Arsenic.

In 2012, a sustainability study was completed for the Dane County Regional Airport (DCRA), which included a GHG emissions inventory following the Airport Cooperative Research Program's (ACRP)

Report 11 Guidebook for Preparing Airport Greenhouse Gas Inventories (ACRP 2009), which is also the method recommended by the ICLEI protocol (ICLEI 2013). Emissions from this report were available in units of carbon dioxide equivalent. This airport serves Dane, Iowa, and Cambridge Counties, of which Dane County makes up 86% of the total population. Thus, 86% of emissions from DCRA were attributed to Dane County. Additionally, fuel usage data was collected from Middleton Airport, a regional airport mainly serving the local general aviation community. This fuel usage data, along with the number of airplanes served, was used to estimate the fuel usage and subsequent GHG emissions at the twelve other general aviation airports and air strips located in Dane County for which data on the number of planes served was available from AirNav (AirNav 2015). Emissions for these airports were estimated using ICLEI's emission factors for direct emissions for the engines during take-off and landing (ICLEI 2013). Source based emissions from ground support vehicles and equipment is included in the DCRA inventory. It is assumed that there are no support vehicles at the smaller, general aviation airports, so emissions estimations only include fuel usage per the ICLEI protocol (ICLEI 2013).

AC.6 Industrial Process Emissions (Non-Energy)

Energy-related air pollution emissions computed above (5.2) were subtracted from the total industry sector pollutant emissions inventory provided by WI DNR to yield the non-energy industry process emissions.

Data on total criteria pollutant emissions were collected from the Wisconsin Department of Natural Resources' (DNR) Air Pollution Emissions Inventory (WI DNR 2015). Under the authority of s.285.17(1)(b), Stats. And Chapter NR 438, Wis. Adm. Code, the DNR collects data on any facility in the state that emits pollutant quantities above those listed in Table 1 of NR 438.03 (WI DNR 2014). There are exemptions given to protect proprietary information, however there were no cases of this type of exclusion in Dane County in 2013. The DNR prefers to collect emissions monitoring data, but also accepts data that enables it to calculate emissions using the EPA's AP-42 emission factors (EPA 2000). Pollutants captured under this process include nitrogen oxides (NO_X), particulate matter (PM_{10}), sulfur dioxide (SO_2), Lead, and GHGs (including carbon dioxide (CO_2), methane (CH_4), and Nitrous Oxide (N_2O).

AC.7 Agricultural Emissions

The method outlined in Appendix G of the ICLEI Protocol was used to estimate the total mass of climate disrupting emissions in the county due to agricultural practices. Livestock, primarily cattle, emit methane due to enteric fermentation of vegetation within their stomachs. Beyond enteric fermentation, manure management practices largely determine the emissions associated with livestock. The ICLEI protocol does not have a method for calculating emissions from crop production.

Animal population data were collected from the U.S. Department of Agriculture's National Agricultural Statistics Service for the year 2012, the most recent year available (USDA 2015). Data on manure management practices in the county was collected through personal communication with Kevin Connors and David Merritt. The emission factors used to calculate emissions from animal populations and manure management practices as a percentage of total manure production were taken from Appendix G of the ICLEI Protocol (ICLEI 2013). Also, a methane capture efficiency of 75% was assumed for the anaerobic digestion systems. The methane was then burned to produce electricity, producing CO_2 on a one-to-one molar basis.

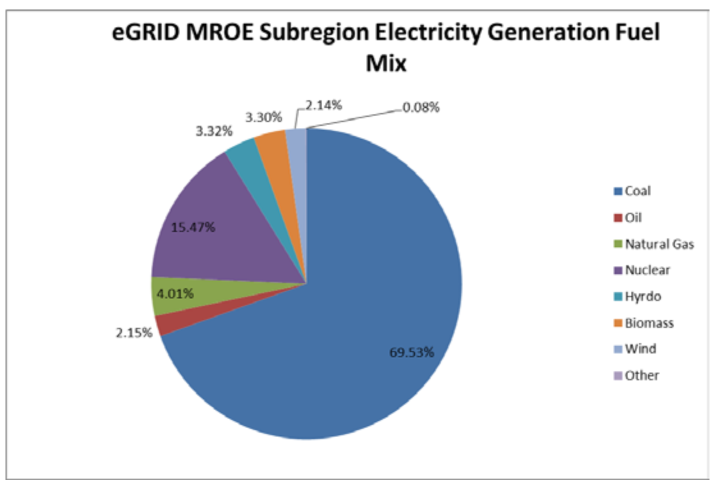
Appendix D. Detailed Data and Methods Used for Community-Wide Infrastructure Use Based Footprint (CIF)

AD.1 Electricity Use and Supply Emissions (Utilities)

Electricity Use

Data was collected from the investor owned utilities (IOUs) in Dane County (Madison Gas & Electric, Alliant Energy, and WPPI Energy), as well as five municipal electricity providers (Waunakee, Sun Prairie, Stoughton, Mt. Horeb, and Black Earth). IOUs provided primary data. Annual reports collected by the Wisconsin Public Services Commission (PSC) were used to collect data on municipal providers (8). Data was not collected from the Adams Columbia Electric Cooperative[6]. Using customer data provided by utilities, and assuming each residential household is a household or represents a single unit in a multi-unit building, it was determined that the collected data represented 94.25% of the total county population. The total electricity sales were then scaled up to 100% coverage to account for the existing gap in the data. The electricity use is divided into residential, commercial, and industrial sectors as described by the data sets provided by the utilities.

Electricity Supply



Dane County falls within eGRID's Midwest Reliability Organization East (MROE) region. eGRID's emission factors were used to estimate GHGs, sulfur dioxide, and nitrogen oxides emissions associated with the electricity supply, by multiplying these emission factors by total electricity use in Dane County in 2013. To calculate trace metals, particulate matter, carbon monoxide, and VOC emissions, AP-42 emission factors were used in conjunction with eGRID's fuel mix for the MROE region to create a weighted emission factor for each pollutant for the entire operational electricity generation fleet. However, carbon monoxide and particulate matter emissions primarily occur from coal and are highly dependent on the combustion regime, which is determined by the design of the power plant. Furthermore, the fleet of power plants supplying electricity to the region have a heterogeneous mix of combustion regimes and emissions treatment

[6] This data was not readily available. The decision to forego collecting this information was based on the combination of cost and time constraints and the minimal value of this small data set.

processes, introducing uncertainty to the estimation of those emissions, which are highly dependent on combustion process.

Since very little of the electricity used locally is produced locally (only 1.4%), these are all considered Scope 2 emissions assuming the same emission factor as the MROE region.

AD.2 Industrial Non-Electricity Energy Use Emissions

Direct

Community-Wide Use-Activity Based Scope 1 emissions for the industrial sector were calculated in the same manner as described in Appendix C Section AC.2 under the IBEI method.

Indirect

Upstream, Scope 3 emissions from natural gas use were estimated using the National Renewable Energy Laboratory's Life Cycle Inventory, which provides emission factors for multiple stages of the life cycles for a variety of products, including natural gas (US LCI 2012). The stages in the life cycles accounted for in this estimation include resource extraction, processing, and transport.

AD.3 Residential Non-Electricity Energy Use Emissions

Direct

Community-Wide Use-Activity Based Scope 1 emissions for the residential sector were calculated in the same manner as described in Appendix C Section AC.3 under the IBEI method.

Indirect

Upstream, Scope 3 emissions were estimated by multiplying the estimated consumption of each fuel type by upstream emission factors taken from the GREET model (Wang et al. 2015) and NREL's LCI (US LCI 2012). Because of limited availability of emission factors for upstream emissions for propane and fuel oil, surrogate fuels were used to estimate Scope 3 emissions. LPG emission factors were used in place of propane and conventional diesel fuel emission factors were used in place of fuel oil, both taken from the GREET model (Wang et al. 2015).

AD.4 Commercial Emissions

Direct

Community-Wide Use-Activity Based Scope 1 emissions for the commercial sector were calculated in the same manner as described in Appendix C Section AC.4.

Indirect

Upstream, scope 3 emissions from natural gas use were estimated using the National Renewable Energy Laboratory's Life Cycle Inventory (US LCI 2012), which provides emission factors for multiple stages of the life cycles for a variety of products, including natural gas (US LCI 2012). The stages in the life cycles accounted for in this estimation include resource extraction, processing, and transport.

There is uncertainty associated with the emission factors because they are dependent on combustion conditions inside the boiler, which is reliant on the type of system used to burn the natural gas. Because of this, an uncontrolled emission factor was used to give a conservative estimate, potentially inflating the reported emissions totals beyond actual emissions occurring in Dane County.

AD.5 Transportation Energy Use Emissions

The aviation fuel use at Dane County Regional Airport includes motor vehicles on airport property (both from customers and workers), ground support vehicles (only shown in CO2e not actual fuel usage), aircraft auxiliary power units, takeoff and landing, aircraft engine startup, aircraft taxi. These are included in the IBEI approach. The CIF approach also includes emissions from cruising altitude flying of the aircraft. These data all come directly from the DCRA Sustainability Report.

Community-Wide Use/Activity based Scope 1 emissions for the transportation sector were calculated in the same manner as described in Section AC.5 in Appendix C. From this method, an estimate of fuel usage by fuel type for the entire sector was generated by combining VMT and estimated fuel efficiency for on –road vehicles. Upstream emissions for the transportation sector were estimated by multiplying the total gallons used of each fuel type (gasoline, diesel, E-85, CNG, jet fuel, and aviation gasoline) by GREET's upstream emission factors. CO_2, CH_4, N_2O, PM_{10}, $PM_{2.5}$, CO, NO_X, and VOCs were estimated using GREET. Upstream emission factors were not available for aviation gasoline, so conventional gasoline was used as a surrogate fuel. It is assumed that the upstream energy use and emissions are similar for conventional gasoline and aviation gasoline.

AD.6 Industrial Processes Emissions

Community-Wide Use-Activity Based Scope 1 emissions for industrial activities were calculated in the same manner as described in Section 4.6 under the Source-Based Accounting method.

AD.7 Agricultural/ Food Related Emissions

Data on food consumption was collected from U.S. Bureau of Labor Statistics 2012-2013 Consumer Expenditure Survey (BLS 2012). Within this data set, neither Dane County nor Wisconsin specific data were available, so Midwest-specific household expenditure data was used. Emissions from food consumption were calculated using Carnegie Mellon's EIOLCA calculator tool (CMU 2008) and attributed to the Residential sector. This tool uses a dollar amount input to generate emissions outputs in metric tons. The EIOLCA tool groups them collectively into a single metric for simplicity and usability.

Upstream emissions associated with consumption of food and materials are estimated using the economic input-output model created by Carnegie Mellon University (CMU 2008). This model estimated life-cycle emissions associated with a certain amount of economic activity in a given sector. There was no way to distinguish between food produced inside the county and outside the county; a more robust data source of food supply chains would be needed to determine this allocation.

AD.8 Waste Handling & Waste Water Processing Emissions

The University of Minnesota attempted to gather primary data from landfills and materials recovery centers, including composting facilities, in Dane County with no success, so secondary sources were relied upon. Direct emissions data for the Rodefeld Landfill was collected via the U.S. EPA's Greenhouse Gas Reporting Program (GHGRP) database for the year 2013 (EPA 2015b).

Waste water in Dane County is handled by seventeen wastewater treatment plants, of which specific treatment process and energy use data was collected from seven. These treatment plants serve approximately 87% of the total county population. An estimated 10% of the population is served by private septic systems. Because a full data set was not captured for this sector, the ICLEI method of using population to calculate methane and nitrous oxide emissions was used (ICLEI 2013). Fugitive methane emissions were calculated separately for the septic systems, also based on population, following the ICLEI Protocol (ICLEI 2013).

AD.9 Construction Material Use Emissions

Data on ready-mix concrete consumption was purchased from Dodge Data & Analytics. This data set includes historical consumption data for 2010 through 2014 and projected use for 2015 through 2019. The data for the year 2013 was paired with industry concrete standards to calculate the amount of cement used in Dane County in 2013. Emission factors for cement were taken from NREL's Life Cycle Inventory (US LCI 2012) and multiplied by the cement use estimation.

Appendix E. WARM Model Output

5/19/2015 GHG Emissions Analysis — Summary Report

GHG Emissions Analysis — Summary Report

(Version 13, 3/15)

Analysis of GHG Emissions from Waste Management

GHG Emissions from Baseline Waste Management Scenario (MTCO2E):	23,553
GHG Emissions from Alternative Waste Management Scenario (MTCO2E):	-190,738
Total Change in GHG Emissions: (MTCO2E):	**-214,291**

	Baseline Scenario					Alternative Scenario						
Material	**Tons Recycled**	**Tons Landfilled**	**Tons Combusted**	**Tons Composted**	**Total MTCO2E**	**Tons Source Reduced**	**Tons Recycled**	**Tons Landfilled**	**Tons Combusted**	**Tons Composted**	**Total MTCO2E**	**Change (Alt - Base) MTCO2E**
Aluminum Cans	0	1,675	0	N/A	65	0	1,675	0	0	N/A	-15,255	**-15,320**
Steel Cans	0	542	0	N/A	21	0	542	0	0	N/A	-982	**-1,003**
Glass	0	3,626	0	N/A	141	0	3,626	0	0	N/A	-1,003	**-1,144**
HDPE	0	760	0	N/A	29	0	760	0	0	N/A	-669	**-698**
PET	0	632	0	N/A	25	0	632	0	0	N/A	-715	**-739**
Corrugated Containers	0	28,737	0	N/A	-2,391	0	28,737	0	0	N/A	-89,628	**-87,237**
Magazines / Third-class mail	0	256	0	N/A	59	0	256	0	0	N/A	-785	**-844**
Newspaper	0	1,760	0	N/A	-1,657	0	1,760	0	0	N/A	-4,841	**-3,184**
Mixed Paper (general)	0	9,609	0	N/A	-1,008	0	9,609	0	0	N/A	-33,883	**-32,875**
Mixed Paper (primarily residential)	0	13,079	0	N/A	-1,826	0	13,079	0	0	N/A	-46,120	**-44,295**
Mixed Paper (primarily from offices)	0	5,899	0	N/A	938	0	5,899	0	0	N/A	-21,158	**-22,096**
Mixed Metals	0	542	0	N/A	21	0	542	0	0	N/A	-2,372	**-2,393**
Mixed Plastics	0	2,299	0	N/A	89	0	2,299	0	0	N/A	-2,374	**-2,463**
Mixed Organics	N/A	89,520	0	0	8,355	N/A	N/A	89,520	0	0	8,355	**0**
Mixed MSW	N/A	130,432	0	N/A	19,973	N/A	N/A	130,432	0	N/A	19,973	**0**
Concrete	0	16,553	N/A	N/A	642	N/A	0	16,553	N/A	N/A	642	**0**
Fly Ash	0	1,998	N/A	N/A	77	N/A	0	1,998	N/A	N/A	77	**0**

Note: A negative value indicates an emission reduction; a positive value indicates an emission increase.
a) For an explanation of the methodology used to develop emission factors, see Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM) — available on the Internet at http://epa.gov/epawaste/conserve/tools/warm/SWMGHGreport.html
b) Emissions estimates provided by this model are intended to support voluntary GHG measurement and reporting initiatives.
c) Total emissions estimates provided by this model may not sum due to independent rounding.

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