CITY OF Ames

City of Ames
Community Greenhouse Gas Inventory

August 2020

Submitted By:

paleBLUEdot LLC — making change personal

ORANGE ENVIRONMENTAL

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Section 01

Introduction

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Introduction

Background

The City of Ames is committed to becoming a more sustainable organization, promoting conservation, and encouraging renewable energy within the community. As an organization, the City of Ames is committed to making environmentally sound choices in how it operates, in the equipment purchased, the services provided, and the policies that guide the organization's decision making.

The City was taking *green* actions before the term was coined. More than 40 years ago, Ames opened its waste-to-energy plant that processed county-wide municipal solid waste into a supplemental fuel for Ames Electric System. It was the first city in the nation to accomplish that.

More than 10 years ago, the City signed the U.S. Mayors' Climate Protection Agreement and continued its environmental leadership by implementing a comprehensive range of programs and services. Examples include purchasing wind power, converting lighting to LED, using hybrid public transit buses, providing electric vehicle charging stations, and developing an ever expanding system of bike lanes.

This Community Greenhouse Gas Inventory report is a continuation of the City's sustainability leadership as well as a fulfillment of the City's commitment under the U.S. Mayors' Climate Protection Agreement. More importantly, this inventory lays the groundwork for future emissions reductions efforts by the City of Ames.

> Without data, you're just another person with an opinion.
> W. Edwards Deming, Engineer, Professor, and Management Consultant

Project Overview

The City of Ames contracted with the paleBLUEdot and ORANGE Environmental team to prepare the following analyses:

1) Inventories for citywide and city operations sources of greenhouse gas (GHG) emissions
2) Renewable energy potential study
3) Climate vulnerability assessment

This report summarizes the results of the first commitment—preparing the GHG inventory. In order to better distinguish between the two inventories, the citywide study will be called the *Citywide Inventory*, and the City operations analysis will be called the *City Operations Assessment*. Both analyses are consistent with the internationally recognized assessment protocol developed by ICLEI-Local Governments for Sustainability USA. Accompanying this report is a spreadsheet file that generated all of the data for this report. The spreadsheet file contains information regarding the methodology used to estimate GHG emissions and the data sources. However, this report is intended as a stand-alone document that does not rely on the spreadsheets to explain the data and findings.

Introduction

The Value of The City of Ames Community Greenhouse Gas Inventories

The goal of the City of Ames inventories for citywide and city operations is to estimate the GHG emissions associated with the activities of the people who live, work, learn, travel, visit, and recreate within the City's geographical boundaries during three study years, 2014, 2016, and 2018. Both of the inventories must be transparent and able to be replicated, updated, and compared with future assessments Ames and assessments for peer cities.

Measuring the energy aspects of human activities and the associated GHG emissions offers a unique way to compare the effectiveness of various energy and sustainability best management practices. Greenhouse gas emissions and energy[1] serve as common denominators for the comparison of kilowatts of electricity, natural gas therms, tons of coal, and gallons of liquid fuels consumed; as well as vehicle miles traveled, tons of waste processed, and gallons of potable water distributed.

Every city prepares annual operating and capital improvement budgets. These assessments are akin to the environmental budget for the city. Recording these performance metrics is essential to promoting efficiency and sustainable change. Along with providing statewide benefits, the two GHG assessments will:

- Highlight opportunities to save resources and money.
- Provide a baseline for estimating the effectiveness of many sustainability measures.
- Inform subsequent analyses, plans, and policy decisions.
- Improve the City's competitiveness for federal and state funding opportunities that are targeted to cities that have taken steps to measure and improve their energy efficiency and reduce their carbon footprints.
- Assist in promoting public understanding of the City's effects on climate change.
- Serve as a model for other cities.

Greenhouse Gas Emissions (GHG) and Climate Change

The climate change we face today is caused by warming from greenhouse gases trapping infrared energy radiating from the earth. This is called the greenhouse effect. Greenhouse gases have been increasing in our atmosphere since the Industrial Revolution. Scientists attribute the global warming trend observed since the mid-20th century to human greenhouse gas (GHG) emissions which expand the "greenhouse effect" — warming that results when the atmosphere traps heat radiating from Earth toward space.

Figure A: Global GHG Emissions Since 1900

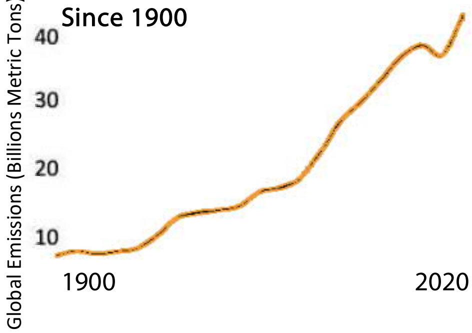


Figure B: Global Average Temperature Since 1900

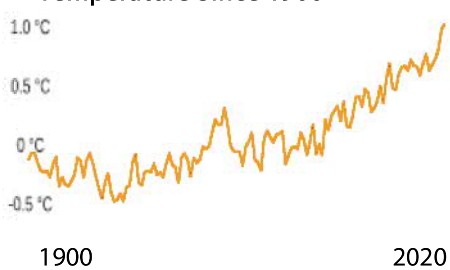
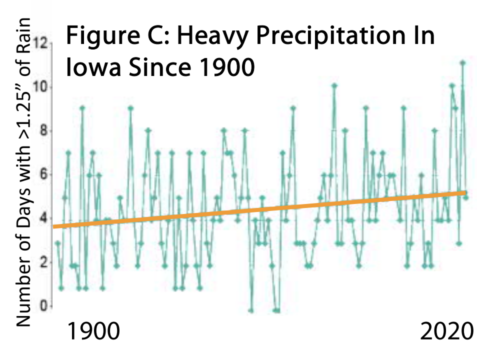


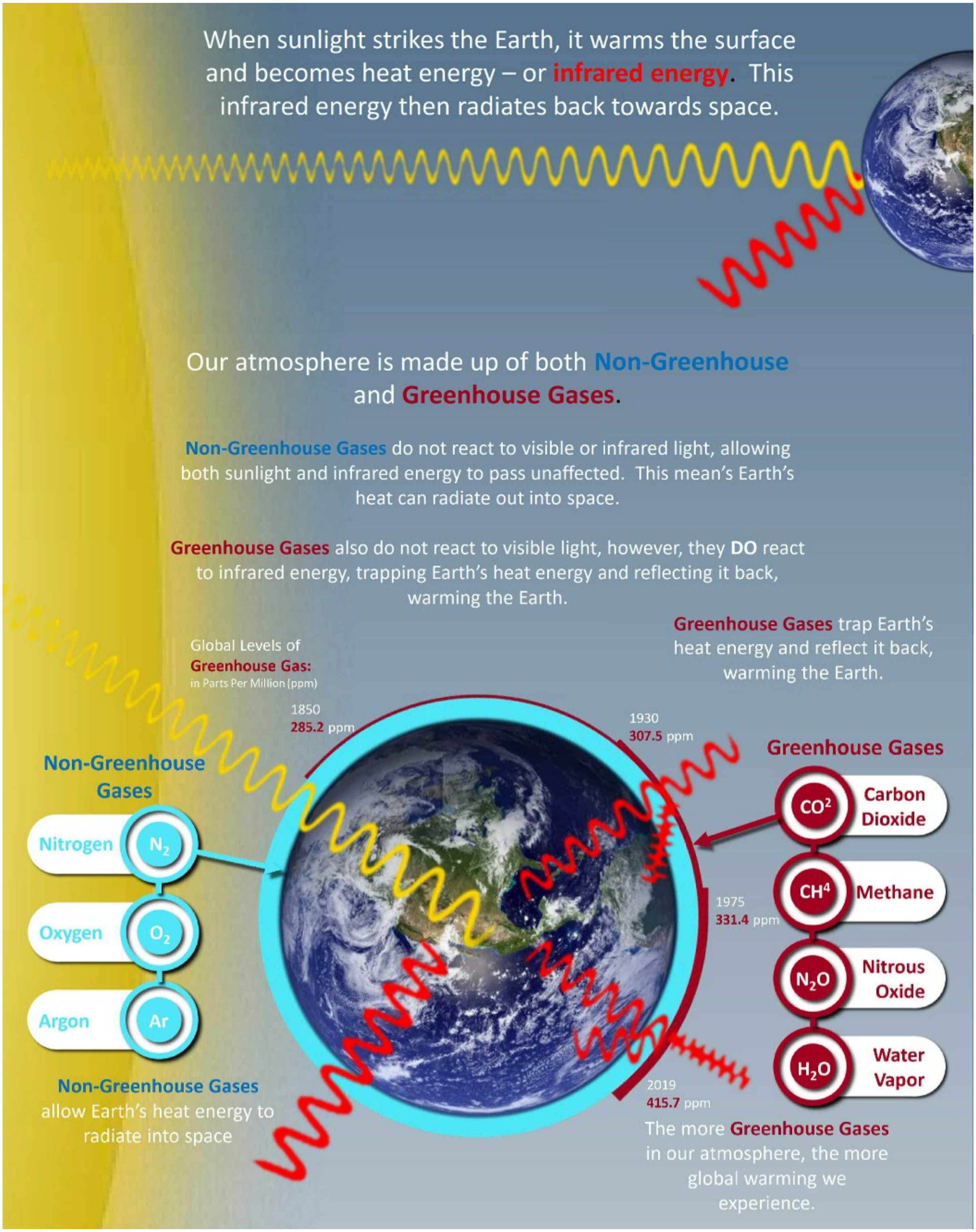
Figure C: Heavy Precipitation In Iowa Since 1900



[1] Energy is expressed as kBtu (a thousand British thermal units) or MMBtu (a million Btus).

Introduction

Figure D: GHG's Impact On Our Climate



Introduction

What is a Community Greenhouse Gas Inventory?

A community Greenhouse Gas (GHG) Inventory follows a standard protocol to quantify a city's greenhouse gas (GHG) emissions. GHG inventories fluctuate year-to-year as we change our energy consumption, get access to better data, or gain new knowledge about how GHGs impact the atmosphere.

What Are GHG's?

GHG's absorb radiation and trap heat in the Earth's atmosphere. They are the basis of the Greenhouse Effect. The more GHGs there are, the more heat that is trapped in our atmosphere, leading to Global Warming and Climate Change. GHGs measured in this inventory include carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

Why Measure GHG?

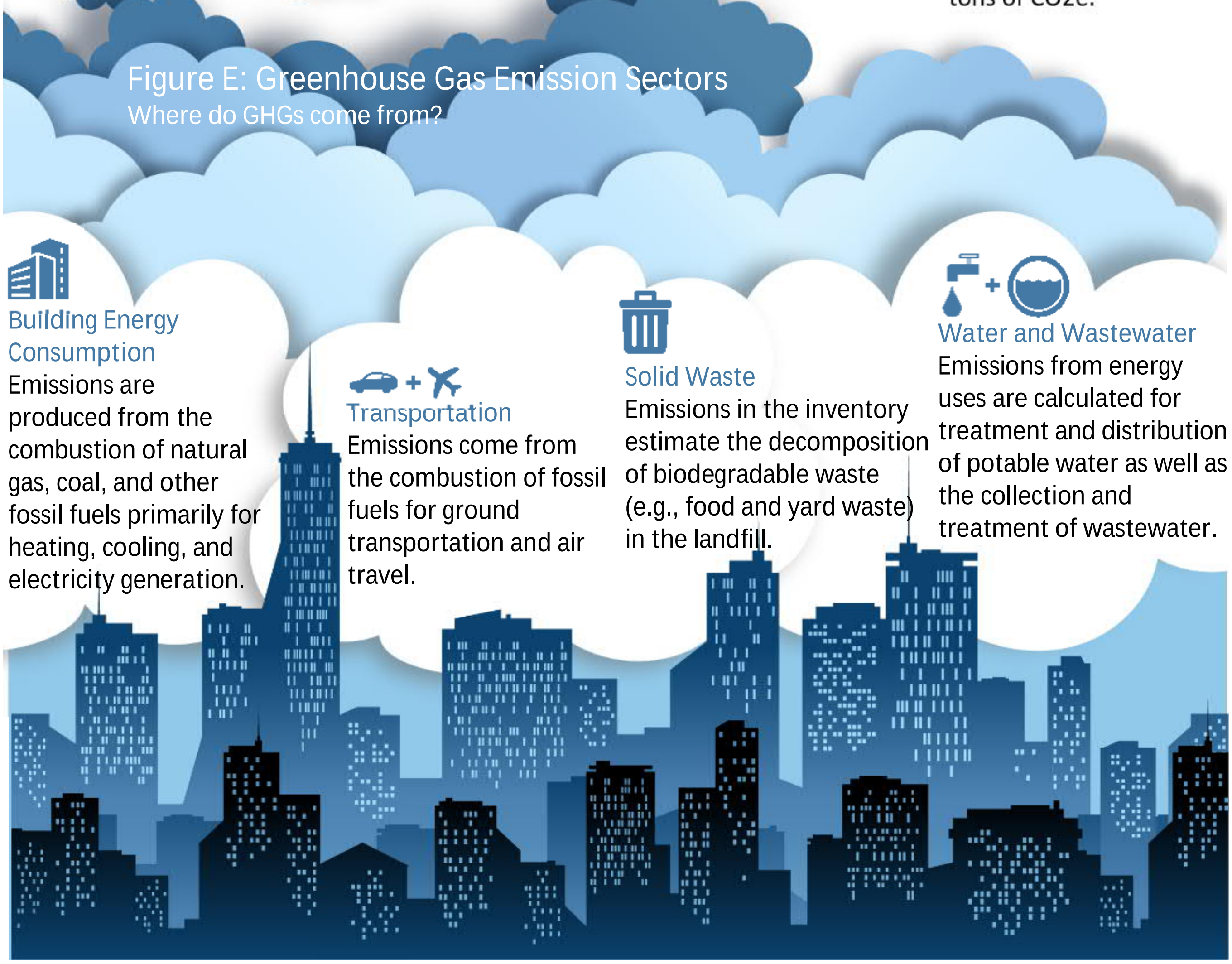
As described by David Osborne and Ted Gaebler "If you don't measure results, you can't tell success from failure. If you can't see success, you can't reward it. If you can't see failure, you can't correct it." GHG inventories are useful. Planners need them, elected officials want them, and the future may see their development as a basic requirement of state and federal funding.

What is CO2e?

Carbon Dioxide (CO_2) is a GHG emitted naturally and from fossil fuel combustion for energy and heat. Global warming contributions from other greenhouse gases are referred to in terms of "carbon dioxide equivalent" or CO_2e, which represents the amount of CO_2 that would have the same global warming potential as other GHGs. Community GHG inventories are tracked in terms of metric tons of CO_2e.

Figure E: Greenhouse Gas Emission Sectors

Where do GHGs come from?



Introduction

Methodology, Sources, and Terminology

This GHG inventory is assembled based on the Greenhouse Gas Protocol for businesses and communities established by GHG Protocol (www.ghgprotocol.org/) and is consistent with the protocol established by ICLEI Local Governments for Sustainability. The terminology used in this report is consistent with international Carbon Footprinting protocols. Unless noted otherwise, the Greenhouse Gas (GHG) emissions shown in this report are in CO2e: Carbon Dioxide Equivalent. GHG emissions are represented in Metric Tonnes (2,204.62 pounds) to be consistent with international standard reporting.

GHG inventories, generally, arrive at an estimated emission in each emissions sector by multiplying raw consumption data - total electricity consumed as an example - by an emissions factor which define the greenhouse gasses emitted per unit of raw consumption. The chart below illustrates the sources used for all raw consumption and emission factor data used in the GHG inventory calculations.

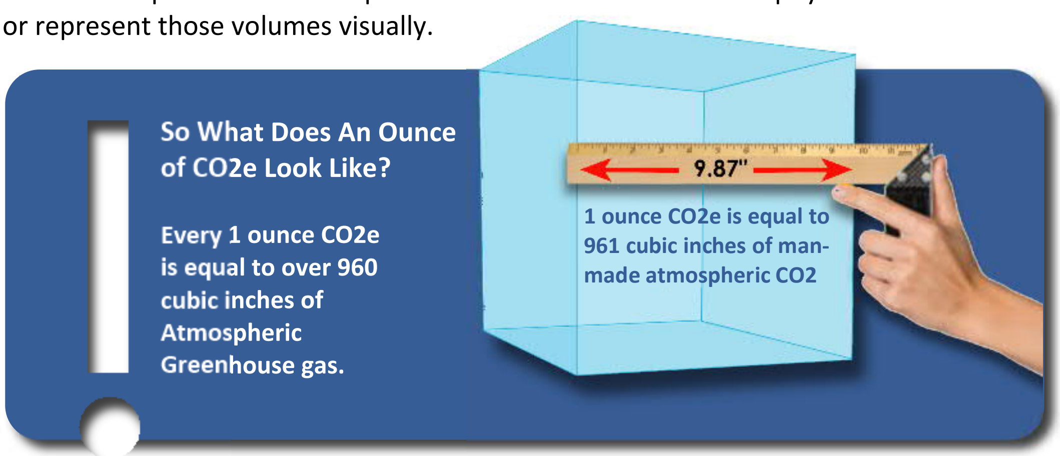
Figure F: Data Sources Used in the Greenhouse Gas Inventory

GHG Emission Sector	Project Resource
Residential Energy Consumption - Electricity	Data Source: Alliant Energy and Ames Municipal Electric System, Midland Power Cooperative, and Consumers Energy. Emissions Factors: Same as above
Residential Energy Consumption - Natural Gas	Data Source: Alliant Energy Emissions Factors: US Community Protocol default fuel emission factors
Commercial/Institutional Energy Consumption - Electricity	Data Source: Alliant Energy and Ames Municipal Electric System, Midland Power Cooperative, Consumers Energy, Iowa State University, and the Mary Greeley Medical Center. Emissions Factors: Same as above
Commercial Energy Consumption - Natural Gas	Data Source: Alliant Energy Emissions Factors: US Community Protocol default fuel emission factors
Transportation - On Road	Data Source: Iowa Department of Transportation VMT Estimates Emissions Factors: US EPA MOVES model
Transportation - Public Transit	Data Source: CyRide, in collaboration with ISU Emissions Factors: EPA Climate Leadership Emissions Factors
Transportation - Air Travel	Data Source: Ames Municipal Airport Emissions Factors: IPCC and US EPA Inventory of US GHG Emissions and Sinks
Waste - Solid Waste	Data Source: Ames Resource Recovery Plant (produces RDF), Boone County landfill (accepts RDF rejects). Ames Municipal Electric System co-fires RDF with natural gas. Emissions Factors: Iowa DNR Statewide Waste Characteristics Study / US Community Protocol Default Landfill Assumptions. RDF emissions factors.
Waste - Wastewater	Data Source: Ames Water & Pollution Control Emissions Factors: US Community Protocol population based emissions models / Fuel Mix Disclosure Report / US EPA eGRID
Water	Data Source: Ames Water & Pollution Control Emissions Factors: Above emission factors for electricity and natural gas consumption.

Greenhouse Gas Emissions as a Volume of Atmosphere

GHG emissions are typically communicated in terms of their weight in metric tons. It is important to recall that GHG emissions, as atmospheric pollution, occupy an increasing portion of the total physical volume of gasses making up the Earth's Troposphere (lower portion of Earth's atmosphere). To reflect the reality of GHG pollution as a physical volume some portions of this report translate GHG emissions into physical volumes of man-made atmosphere or represent those volumes visually.

Figure G: Visualizing Greenhouse Gas Emissions as a Volume.



Section 02

Findings In Brief

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Figure H: Findings In Brief - Citywide

2014 By The Numbers

GHG Emissions
1,311,879 MT
20.3 MT Per-Capita
25.8 MT Per Job

Population
64,773

GDP
$5,937,345,000
$91,664 GDP Per-Capita

Employment
34,706 Jobs

2018 By The Numbers

GHG Emissions
1,089,662 MT
16.5 MT Per-Capita
19.6 MT Per Job

Population
66,001

GDP
$6,586,260,000
$99,790 GDP Per-Capita

Employment
36,223 Jobs

Five-Year Trend Dashboard

GHG Emissions
-222,217 MT (-16.9%)
3.8 MT Per-Capita Decrease (-18.7%)
6.2 MT Per Job Decrease (-24.0%)

Population
1,228 (+1.9%)

GDP
$648,915,000 (+10.9%)
$8,126 Per-Capita Increase (8.9%)

Employment
1,517 Jobs (+6.6%)

Ames Citywide GHG Emissions Overview

Citywide total emissions for the City of Ames dropped 16.9% from 1,311,879 metric tonnes in 2014 to 1,089,662 metric tonnes in 2018. Over that same period of time, the city increased its population 1.9%, added 6.6% more jobs, and increased Gross Domestic Product by 10.9%.

Figure I: How Large Are Citywide GHG Emissions?

The city of Ames' total citywide emissions for 2018 are equal to **21.4 Billion** cubic feet of man-made greenhouse gas - seen below from Mary Greeley Medical Center from 3 miles away. This volume of atmosphere is equal to a cube **2,775** feet on each face. Each year, the volume of GHG emissions added to our atmosphere will remain active, impacting our climate for at least 100 years

Figure J: 2018 Ames Citywide GHG Emissions by Sector

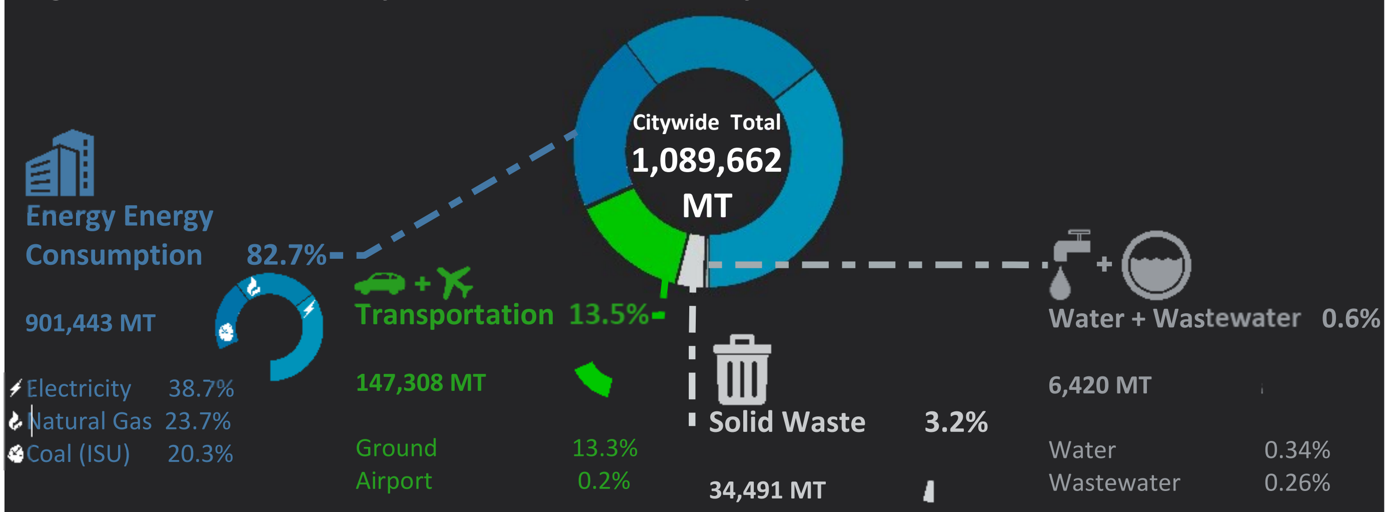
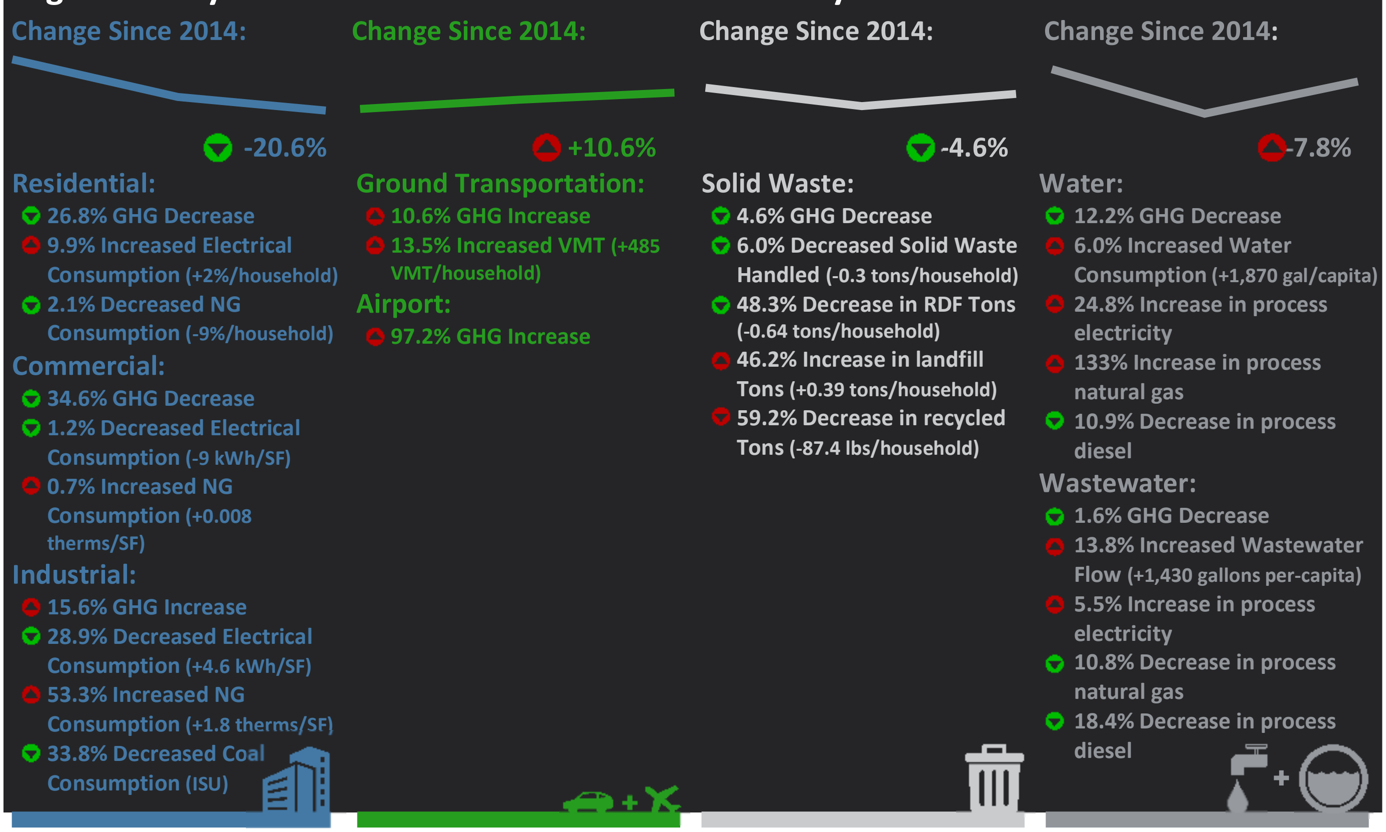


Figure K: Citywide GHG Emissions Five Year Trends by Sector



Per-capita emissions for electrical consumption have declined 29.4% since 2014 due to a decrease in the local GHG emissions factors for electricity generation in all sectors and a slight decrease in commercial electrical consumption.
Per-capita emissions for coal consumption decreased 33.8%, due to reduced usage by ISU.

Since 2014, vehicle miles traveled (VMT) increased by 13.5%, but the associated GHG emissions increased by only 9.9% due to more efficient vehicles and cleaner fuels.
Though a very small portion of the total, emissions at the municipal airport nearly doubled due to increased use of jet fuel.

Per-capita solid waste management amounts were -8% lower in 2018 compared to 2014, and per-capita emissions were -5% lower. The decrease in emissions was smaller than the decrease in the solid waste amounts due to a greater reliance on landfilling instead of RDF combustion. Landfilling has a significantly higher GHG emission rate.

Citywide water consumption has increased 6% since 2014, however GHG emissions decreased 12% due to improved process electrical emissions factors.
Wastewater flows have increased approximately 14% however GHG emissions decreased 1.6% due to improved process electrical emissions factors and decreased process natural gas and diesel use.

Figure L: Findings In Brief - City of Ames Operations

2014 By The Numbers

City Operations GHG (net)
76,018 MT
0.144 MT Per Building SF
127.4 MT Per Staff (FTE)
1.17 MT Per-Capita
3.2 MT Per Household

Ames Municipal Energy System GHG
313,692 MT

City Operations Grand Total
389,710 MT
0.74 MT Per Building SF
653.8 MT Per Staff (FTE)
6.0 MT Per-Capita
16.5 MT Per Household

2018 By The Numbers

City Operations GHG (net)
72,056 MT
0.136 MT Per Building SF
120.8 MT Per Staff (FTE)
1.09 MT Per-Capita
2.8 MT Per Household

Ames Municipal Energy System GHG
112,873 MT

City Operations Grand Total
184,929 MT
0.35 MT Per Building SF
309.9 MT Per Staff (FTE)
2.8 MT Per-Capita
7.3 MT Per Household

Five-Year Trend Dashboard

[redacted]
City Operations GHG (net)
-3,962 MT (-5.2%)
0.01 MT Per SF Decrease
6.6 MT Per Staff Decrease
0.01 MT Per-Capita Decrease
0.4 MT Per House Decrease

Ames Municipal Energy System GHG
-200,819 MT (-64.0%)

[redacted]ity Operations Grand Total
-204,781 MT (-52.5%)
0.39 MT Per SF Decrease
343.9 MT Per Staũ Decrease
3.2 MT Per-Capita Decrease
9.2 MT Per House Decrease

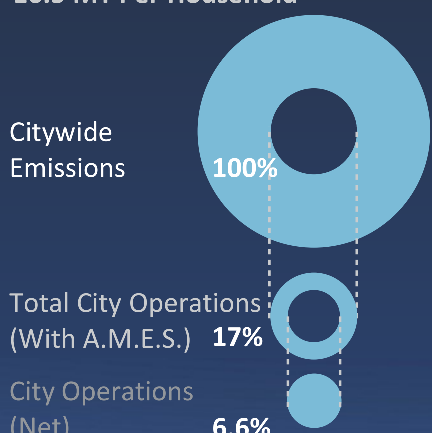


Figure M: 2018 Ames Operations Share of Citywide Emissions

The total City Operations GHG emissions (City Operations and Ames Municipal Electric System) are a sub-set of Citywide emissions. Net City Operations are 6.6% of Citywide emissions and the City Operations Grand Total (including AMPL) are 17.0%.

Figure N: How Large Are City Operations GHG Emissions?

The City of Ames' total operations emissions for 2018 equal **3.6 Billion** cubic feet of man-made greenhouse gas. This volume of atmosphere is equal to a cube **2,838** feet long, **1,136** feet wide and **1,136** feet tall as represented by the graphic to the right. Each year, the volume of GHG emissions added to our atmosphere will remain active, impacting our climate for at least 100 years

Figure O: 2018 City of Ames Operations GHG Emissions By Sector (net)

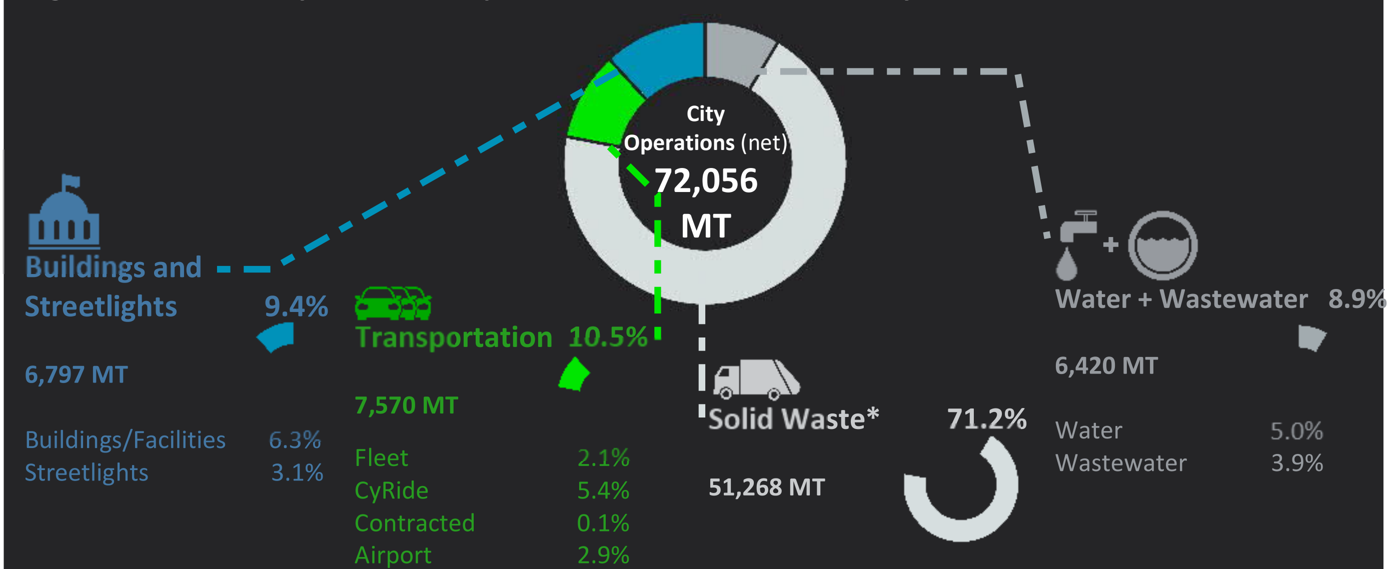
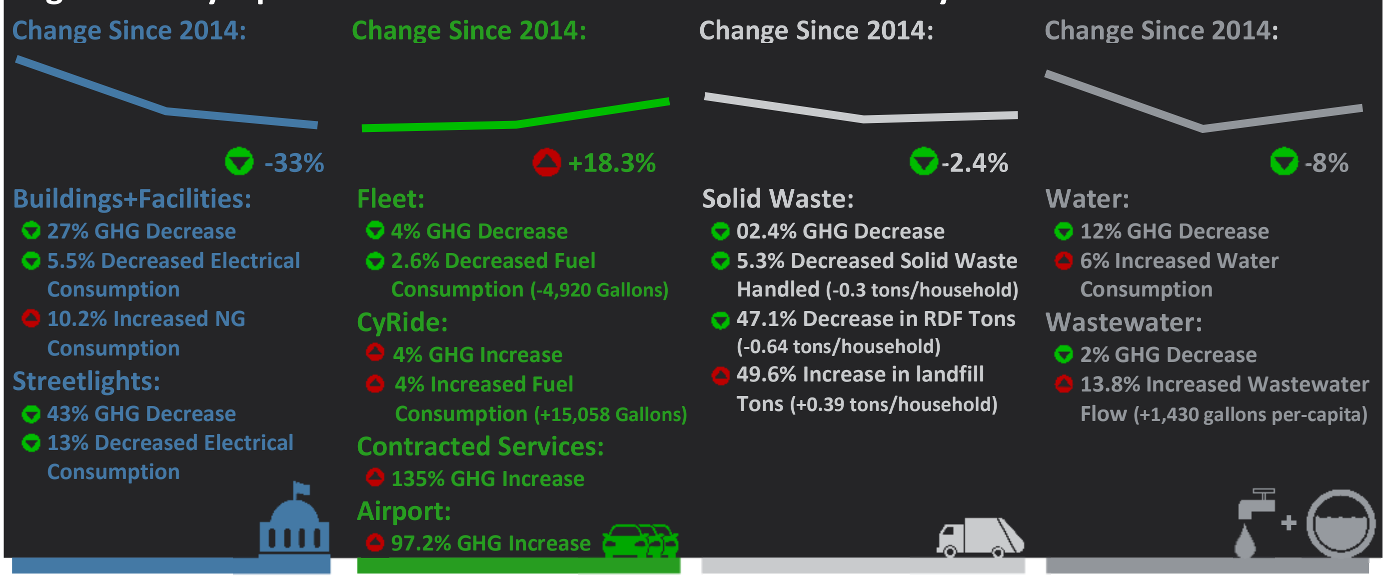


Figure P: City Operations GHG Emissions Five Year Trends by Sector



Building emissions were -27% lower than in 2014. In 2018, energy consumption for the category was 34,601 MMBtu. Energy consumption was 2.4% higher than in 2014. The decline in GHG emissions was greater than that for energy consumption because of the reduced electric emission factor. Streetlight emissions were -43% lower than in 2014, largely due to the reduced electricity emission factor and conversions to LED fixtures.

Although City fleet fuel consumption decreased 2.6%, Transportation emissions were 18% higher than in 2014. The increase in transportation emissions is due to increased emissions at the Ames Municipal Airport and fuel consumption for CyRide operations. Increases at the Airport are due to the dramatic increase in jet fuel consumption in 2017 and again in 2018. Airport fuel Consumption in 2018 was twice as large than in 2016

Total Solid Waste management amounts were -5.3% lower in 2018 compared to 2014, and total GHG emissions were -2.4% lower. The decrease in emissions was smaller than the decrease in the solid waste amounts due to a greater reliance on landfilling instead of RDF combustion.

* City Operations emissions for Solid Waste represent all municipal solid waste handling and Chantland RDF plant operations including transportation and Power Plant RDF emissions and landfill emissions. It is important to note this includes the majority of Story County.

Water consumption increased 6% from 2014 to 2018 while water processing GHG emissions decreased 12% due to an improved electrical emissions factor.

Wastewater flows have increased 13.8% since 2014 while wastewater related GHG emissions decreased 2% in the same timeframe. The emissions decrease is due largely to improved electrical emissions factors and reduced natural gas and diesel use in processing.


Arnold O.Chantland
RESOURCE RECOVERY
City of Ames

Section 03

Community Comparison

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Community Comparison

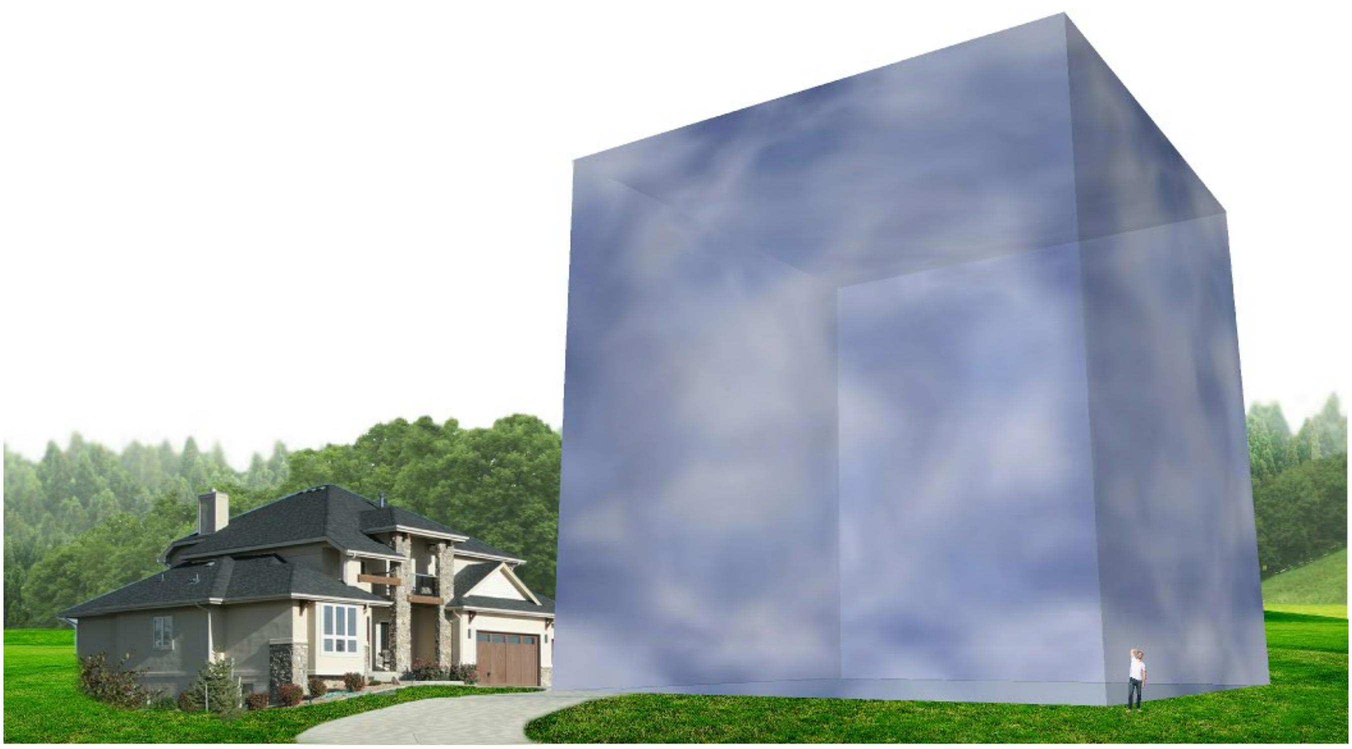
The results of community GHG inventories vary somewhat due to the information collected, variations in inventory methodology, community demographics, climate, economic factors, and regional considerations. Community wide emissions, then, are not always "apples to apples" numbers as the emissions captured by each community's inventory efforts may vary significantly. Consequently, a direct city-to-city comparison should not be viewed as a comprehensive comparison of Greenhouse Gas emission efficiencies. We believe, however, that as an emerging practice, municipalities should look towards building and sharing data in order to develop a stronger understanding of where each municipality can advance efficiencies and meet Greenhouse Gas reduction goals. In support of this goal, comparing total community emissions between communities can only be effectively done by adjusting for differences in overall community population. To make this adjustment, community GHG emissions are regularly compared based on a per-capita basis.

Understanding Ames' Per-Capita Citywide Emissions

As outlined in Section 2, the city of Ames' 2018 Citywide Emissions totaled 1,035,406 metric tons. By simply dividing this community wide emissions total by the total city population we arrive at an average of 15.7 metric tons (MT) per person. Of course, this number represents only an average. The actual emissions each individual resident may be responsible for generating can vary significantly based on a range of personal choices in energy and resource consumption and waste.

Figure Q: How Large Are Citywide Per-Capita GHG Emissions?

The City of Ames' citywide emissions per-captia for 2018 are equal to **323,750** cubic feet of man-made greenhouse gas. This volume of atmosphere is equal to a cube **69** feet on each face. Each year, the volume of GHG emissions added to our atmosphere will remain active, impacting our climate for at least 100 years.



Community Comparison

Community Cohorts

In recognition of the varying influences which effect a community's greenhouse gas emissions, the City of Ames Citywide emissions are compared against a range of community cohorts, or peer groups: **Iowa Communities**; other **"College Town" Communities** with significant student populations as well as others within the Big 12 division; **Regional Communities of Similar Size** with populations ranging from 50k - 100K; and **Other Regional Communities** with a range of population sizes offering.

Each of the charts below compare the city of Ames citywide GHG emissions against the above described cohorts. Peer cities with a green down arrow ( ) have citywide per-capita emissions lower than Ames' citywide GHG emissions. Peer cities with a red up arrow ( ) have citywide per-capita emissions higher than Ames' citywide GHG emissions.

Figure R: Iowa Community Comparison

	Citywide GHG Emissions (Thousand Metric Tons)	Per-Capita	Ames Comparison
Des Moines:	**2,490.4** TMT	**11.45** MT	
Iowa City:	**1,298.6** TMT	**17.68** MT	
Dubuque:	**819.4** TMT	**14.05** MT	
Statewide Average:		**24.99** MT	
City of Ames:	**1,089.7** TMT	**16.5** MT	

City of Ames Percentile Among Iowa Communities Compared: **75th**

Figure S: "College Town" Community Comparison

	Citywide GHG Emissions (Thousand Metric Tons)	Per-Capita	Ames Comparison
Ann Arbor, MI:	**2,209.2** TMT	**19.15** MT	
Austin, TX:	**13,500** TMT	**14.2** MT	
Bloomington, IN:	**1,639.6** TMT	**19.29** MT	
Dubuque, IA:	**819.4** TMT	**14.05** MT	
Evanston IL:	**785.1** TMT	**10.5** MT	
Iowa City, IA:	**1,298.6** TMT	**17.68** MT	
Lawrence, KS:	**1,329.8** TMT	**14.8** MT	
Lincoln, NE:	**4,700.5** TMT	**16.5** MT	
Morgantown, WV:	**805.7** TMT	**27.19** MT	
Urbana, IL:	**487.2** TMT	**11.59** MT	
Average: (population weighted)		**16.92** MT	
City of Ames:	**1,089.7** TMT	**16.5** MT	

City of Ames Percentile Among "College Town" Communities: **55th**

Figure T: Regional Communities of Similar Size

	Citywide GHG Emissions (Thousand Metric Tons)	Per-Capita	Ames Comparison
Bloomington, IN:	**1,639.6** TMT	**19.29** MT	
Burnsville, MN:	**766.1** TMT	**12.5** MT	
Dubuque, IA:	**819.4** TMT	**14.05** MT	
Eau Claire, WI:	**901.8** TMT	**13.68** MT	
Evanston, IL:	**785.1** TMT	**10.5** MT	
Iowa City, IA:	**1,298.6** TMT	**17.68** MT	
Lawrence, KS:	**1,329.8** TMT	**14.8** MT	
Average: (population weighted)		**14.65** MT	
City of Ames:	**1,089.7** TMT	**16.5** MT	

City of Ames Percentile Among Regional Communities of Similar Size: **75th**

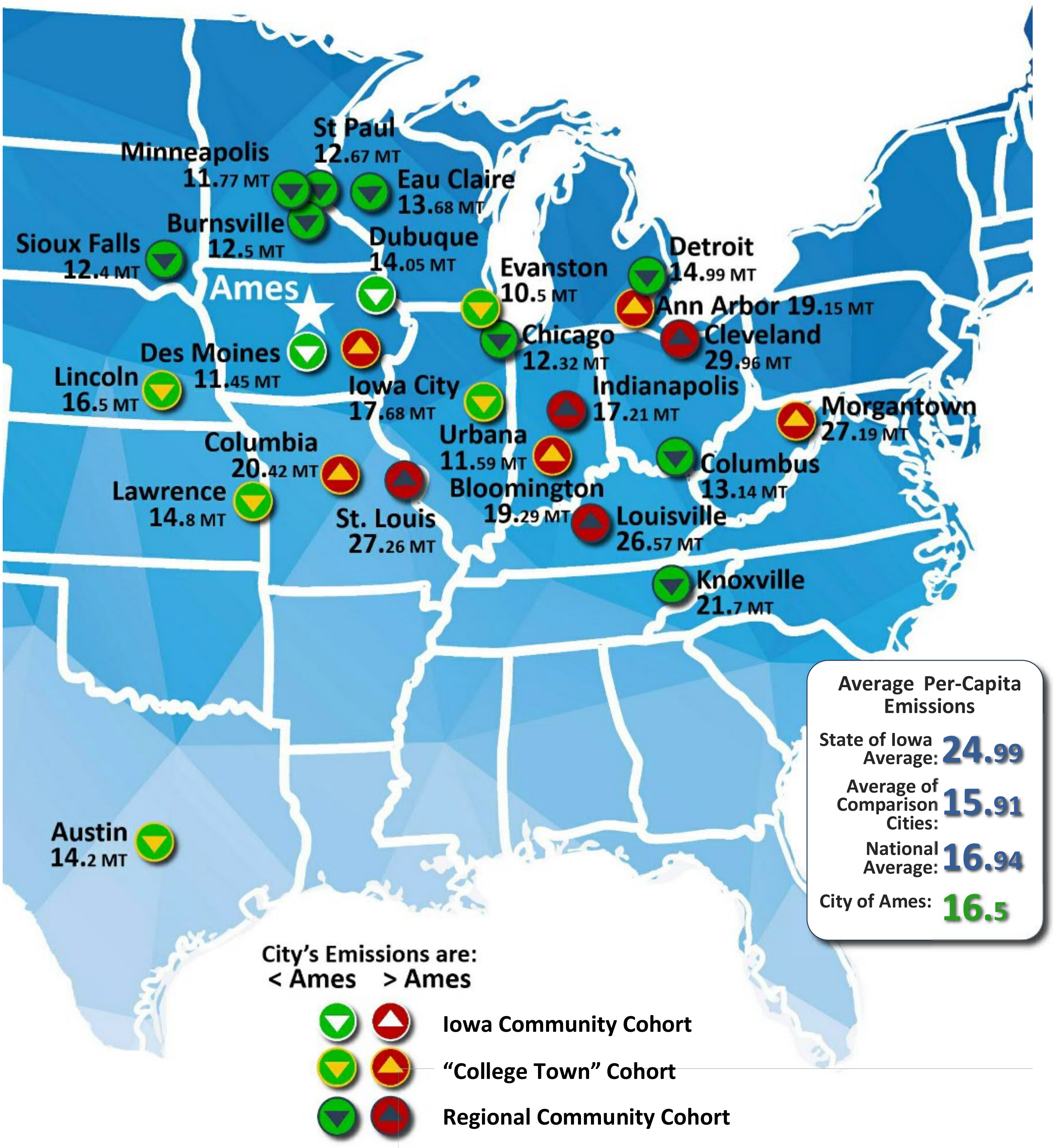
Figure U: Other Regional Communities

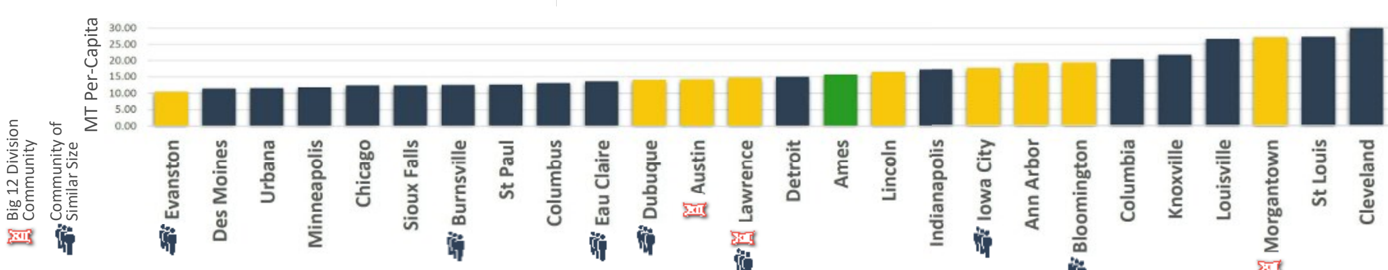
	Citywide GHG Emissions (Thousand Metric Tons)	Per-Capita	Ames Comparison
Chicago, Il:	**35,500** TMT	**12.32** MT	
Cleveland, OH:	**11,889** TMT	**29.96** MT	
Columbia, MO:	**2,421.3** TMT	**20.42** MT	
Columbus, OH:	**10,983** TMT	**13.14** MT	
Detroit, MI:	**10,329** TMT	**14.99** MT	
Indianapolis, IN:	**14,630** TMT	**17.21** MT	
Knoxville, TN:	**3,999.8** TMT	**21.7** MT	
Louisville, KY:	**16,000** TMT	**26.57** MT	
Minneapolis, MN:	**4,794** TMT	**11.77** MT	
St. Louis, MO:	**8,703** TMT	**27.26** MT	
St. Paul, MN:	**3,900** TMT	**12.67** MT	
Sioux Falls, SD:	**1,878** TMT	**12.4** MT	
Average: (population weighted)		**16.92** MT	
City of Ames:	**1,089.7** TMT	**16.5** MT	

City of Ames Percentile Among Other Regional Communities: **54th**

Community Comparison

Figure V: Community Comparison Cohorts Map

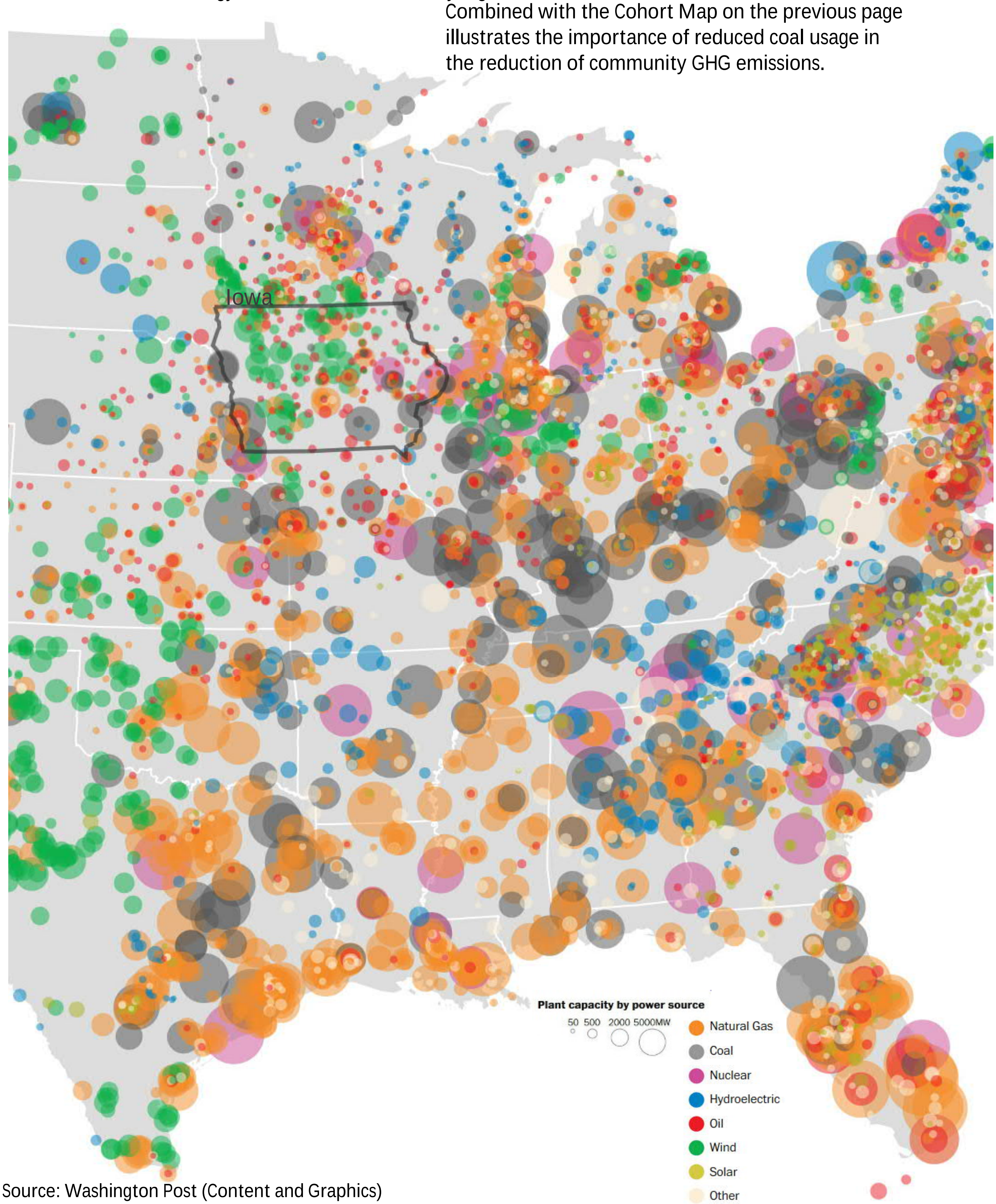




Community Comparison

Figure W: United States Power Source Heat Map

The heat map below includes every power source in the eastern portion of the US. Instances of high coal power and low renewable energy sources will result in very high emission factors for communities in those areas. Combined with the Cohort Map on the previous page illustrates the importance of reduced coal usage in the reduction of community GHG emissions.



Source: Washington Post (Content and Graphics)
https://www.washingtonpost.com/graphics/national/power-plants/?utm_term=.6e458c7b7b6e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Section 04

GHG Emissions Forecasting

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GHG Emissions Forecasting

Why Create a GHG Emission Forecast?

Increasing greenhouse gas emissions, and consequently, atmospheric concentrations, will have many effects on our global, regional, and local climate conditions. Future changes are expected to include a warmer atmosphere, a warmer and more acidic ocean, more powerful storms, broader swings in weather variability, and changes in precipitation patterns. The extent of future climate change depends our on-going GHG emissions. The more we emit, the broader our future climate changes will be. Put another way, the extent of climate change we experience in the future depends on the policies our communities put into place and the actions we as individuals take to reduce greenhouse gas emissions.

A GHG emission forecast supports GHG reduction planning efforts by anticipating what consumption levels and emissions may be like, by sector, if actions are not taken. The potential future trends illustrated in the forecast supports planners in identifying emission sectors which may benefit from prioritization or which may harbor the greatest potential benefits for reduction strategies. Finally, the completed GHG emission forecast, combined with the underlying assumptions used to create the forecast model, can be used as a *GHG reduction projection tool* during future climate action planning efforts.

Business-As-Usual Forecast

Emissions are typically forecast under a business-as-usual (BAU) scenario. The Intergovernmental Panel on Climate Change (IPCC) defines a "business-as-usual" baseline case as the level of emissions that would result if future development trends follow those of the past and no changes in policies take place. A BAU forecast assumes that no emission-reduction actions will be undertaken beyond those already in place, or committed to, in the base year. The BAU forecast bases future projections on anticipated demographic changes, such as population changes and projected jobs within a community.

This approach allows for analysis of a community's full emissions growth potential before identifying emissions reduction strategies. As noted above, BAU emission forecasts are critical in providing insight into the scale of reductions necessary to achieve an emissions target before considering reductions likely to result from federal and statewide actions (e.g., vehicle efficiency standards), inherent technological advancements (e.g., energy-efficient appliances, lighting technology), or new local voluntary or mandatory conservation efforts (e.g., green building requirements).

The City of Ames GHG forecasts included here were based on population and employment growth estimates provided by the City of Ames planning department which were developed in support of its 2020 comprehensive planning efforts These projections result in a total population of 79,779 and total employment of 47,303 by 2040. In addition to these data, information from the State of Iowa Department of Economic Development, Iowa State University, the US Environmental Protection Agency, US Department of Transportation, and US Energy Information Agency. Projected energy consumption included in the Business-as-Usual forecasts also incorporate projected energy demands based on weighted mean average projections of the RCP 8.5 climate model. Projected vehicle transportation emissions include future estimates on vehicle types and their fuel efficiency. The full assumptions used for the Business-as-usual GHG Emissions Forecast model are outlined in detail in the appendix of this report.

Uncertainty

GHG emissions forecasts are not predictions of what will happen, but rather modeled projections of what may happen given certain assumptions and methodologies. GHG forecasts in this report should be interpreted with a clear understanding of the assumptions that inform them and the limitations inherent in any modeling effort, as articulated in the forecast assumptions provided. The results of the forecast should be understood to contain uncertainty. Changes in industry structure over time, the particular impacts of policies, changing weather and economic conditions all add variability to how future emissions will develop.

GHG Emissions Forecasting

Recommended Emissions Pathway to Address Global Warming

As detailed in Section 5 GHG Reduction Goalsetting, the International Panel on Climate Change (IPCC) has provided recommendations on GHG emissions pathways to cap global warming at 1.5˚C and 2˚C respectively based on scientific studies. Future emission projections which fall within those recommendations can be seen to meet the Paris Agreement on global emissions and would support a capping of future global warming to between 1.5˚C and 2˚C. Future emissions projections which fall above the maximum recommended GHG emission pathway can be understood to be non-compliant with the Paris Agreement and the goal of limiting global warming to a maximum of 2˚C. The city of Ames citywide GHG emissions business-as-usual (BAU) forecast on the following page includes an illustration of these two recommended GHG emissions pathway goals in order to compare future Ames BAU emissions against these global warming goals.

Estimated Economic Risk of Climate Change to Ames by 2100

As outlined in the City of Ames Climate Vulnerability Assessment, a study by the University of California at Berkeley, climate impacts can be expected to increase agricultural damage, death rates, energy costs, and violent and property crime rates in the city of Ames. In addition, as annual average temperatures and the number of extreme heat days increase, economic productivity will decrease due to labor efficiency losses. By 2100 these impacts are calculated to impact the city of Ames' annual economy as follows (numbers shown in current dollars):

Annual % Change to GDP by Category:

Agriculture:	+	Mortality:	+	Energy:	+	Labor Productivity:	+	Property Crime:	+	Violent Crime:
-24.2%		+1.0%		+8.8%		-1.3%		+1.8%		+4.0%

= $61,181,951
Annual Cost Impact

Source: "Estimating economic damage from climate change in the United States"

Social Cost of Carbon

The social cost of carbon is a measure of the economic harm from climate change impacts, expressed as the dollar value of the total damages from emitting one ton of carbon dioxide into the atmosphere. Using the estimated economic risk of climate change to Ames illustrated above, a "Localized Social Cost of Carbon" estimate can be established. This estimate can then be used to calculate the economic impact, or savings, of the BAU forecast against other GHG emissions scenarios or goals. The Localized Social Cost of Carbon can be calculated as follows:

Estimated Localized "Social Cost of Carbon"
(in today's dollars):

Estimated Economic Risk of Climate Change:		Current Annual Emissions:		Current Estimated Localized Social Cost of Carbon:
$61,181,951 Annual Cost Impact	÷	1,089,662 Metric Tons	=	$56 Per Ton

GHG Emissions Forecasting

Figure X: City of Ames Citywide GHG Emissions Business as Usual Forecast

The chart below illustrates the citywide Business-as-Usual GHG projections for the City of Ames through 2050. Total GHG and breakdown by sector is provided for years 2030, 2040, ad 2050. Shown in blue are the IPCC recommended emissions targets for capping global warming to 2°C (3.6°F) and 1.5°C (2.7°F) respectively. All numbers are in Metric Tons.

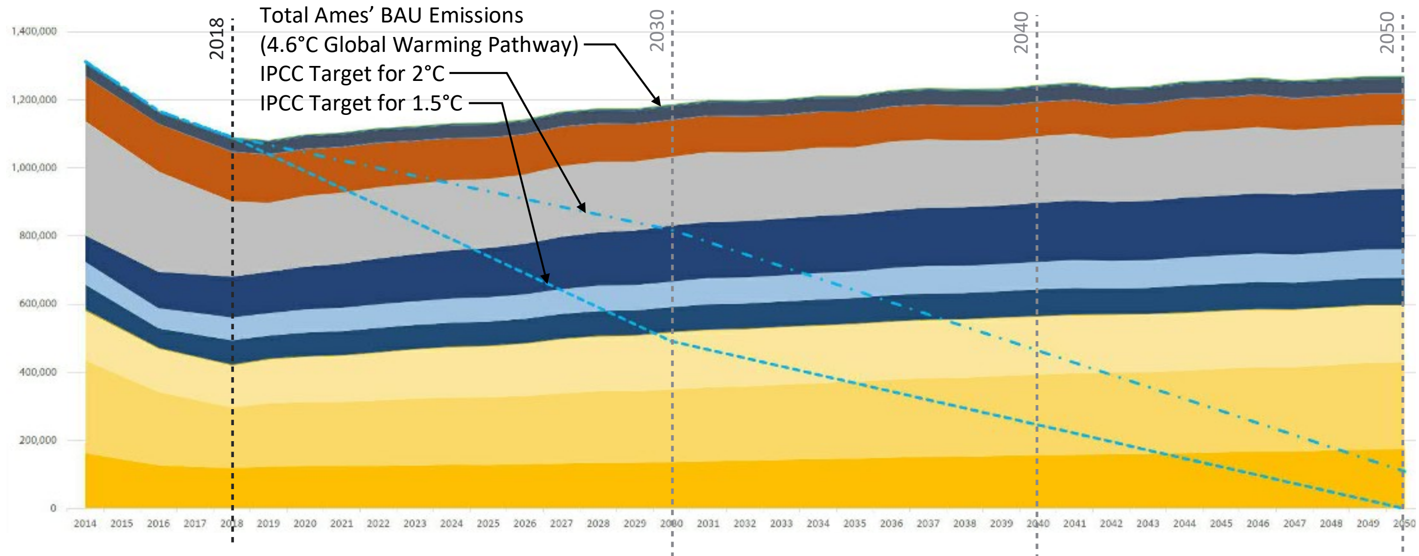


Chart Key	Emissions By Sector By Year: 2030	Emissions By Sector By Year: 2040	Emissions By Sector By Year: 2050
Wastewater Emissions	3,063	3,372	3,540
Water Emissions	3,871	4,261	4,474
Solid Waste Emissions	37,255	41,007	43,058
Airport Emissions	2,240	2,466	2,589
Transportation Emissions	106,911	99,564	90,341
* Building Energy Emissions - Coal	202,802	195,473	188,141
Industrial Natural Gas (NG) Emissions	163,906	173,462	177,154
Commercial Natural Gas (NG) Emissions	75,262	81,020	83,625
Residential Natural Gas (NG) Emissions	72,266	77,419	78,669
Streetlight Electric Emissions	2,435	2,307	2,178
Industrial Electric Emissions	167,104	170,235	166,771
Commercial Electric Emissions	212,349	235,602	254,146
Residential Electric Emissions	136,585	156,952	174,956

*The University is proceeding with planning to convert the remaining coal-fired boilers at the power plant to burn natural gas, which will result in a positive effect on future emissions. The proposed project is subject to final University and Board of Regents approvals.

Total Emissions For Year 2030: **1,182,177 MT**

IPCC Recommended Maximum Emissions For Year 2030 (Limiting global warming to 2°C) : **817,247 MT**

Total Emissions For Year 2040: **1,238,879 MT**

IPCC Recommended Maximum Emissions For Year 2040 (Limiting global warming to 2°C) : **463,106 MT**

Total Emissions For Year 2050: **1,265,169 MT**

IPCC Recommended Maximum Emissions For Year 2050 (Limiting global warming to 2°C) : **108,966 MT**

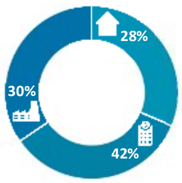
GHG Emissions Forecasting

Figure Y: City of Ames Citywide GHG Emissions Business as Usual Forecast Trends By Decade From 2014

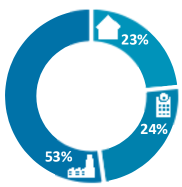
2030 **1,182,177 MT**
-9.89% From 2014 Baseline

Energy

Electricity Use: +35.9%
Residential: 238,742 MWH
Commercial: 369,066 MWH
Industrial: 263,282 MWH



Natural Gas Use: +43.1%
Residential: 13.64 MTherms
Commercial: 14.2 MTherms
Industrial: 30.93 MTherms



Coal Use: -39.3%
Iowa State: 63,172 Tons

Transportation

Ground: +24.1%
VMT: 309.9 MVMT

Airport: +112.9%
Emissions: 2,240 MT

Solid Waste

Waste Handled: +1.5%
MSW: 37,466 Tons

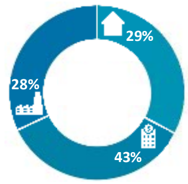
Water + Wastewater

Water GHG: -5.1%
Wastewater GHG: +6.3%

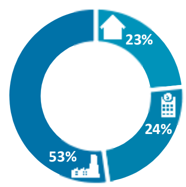
2040 **1,238,879 MT**
-5.56% From 2014 Baseline

Energy

Electricity Use: +56.8%
Residential: 289,585 MWH
Commercial: 432,227 MWH
Industrial: 283,115 MWH



Natural Gas Use: +52.5%
Residential: 14.61 MTherms
Commercial: 15.29 MTherms
Industrial: 32.73 Mtherms



Coal Use: -41.5%
Iowa State: 60,889 Tons

Transportation

Ground: +33.4%
VMT: 333.2 MVMT

Airport: +134.4%
Emissions: 2,466 MT

Solid Waste

Waste Handled: +11.8%
MSW: 41,239 Tons

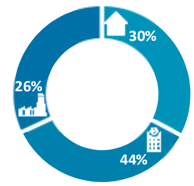
Water + Wastewater

Water GHG: +4.5%
Wastewater GHG: +17%

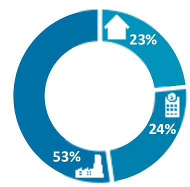
2050 **1,265169 MT**
-3.56% From 2014 Baseline

Energy

Electricity Use: +76.1%
Residential: 341,790 MWH
Commercial: 493,675 MWH
Industrial: 293,671 MWH



Natural Gas Use: +56.0%
Residential: 14.84 MTherms
Commercial: 15.78 MTherms
Industrial: 33.43 MTherms



Coal Use: -43.7%
Iowa State: 58,606 Tons

Transportation

Ground: +38.7%
VMT: 346.5 MVMT

Airport: +146.1%
Emissions: 2,589 MT

Solid Waste

Waste Handled: +17.3%
MSW: 43,638 Tons

Water + Wastewater

Water GHG: +9.7%
Wastewater GHG: +23%

The chart above provides an overview of some of the key trends, by decade for each of the emissions sectors, of the citywide Business-as-Usual GHG projections for the City of Ames through 2050. The projected trends, combined with the GHG Emissions Forecast in Figure X can be used to establish energy consumption and GHG emissions reductions priorities in a future Climate Action Planning effort.

GHG Emissions Forecasting

Understanding Impacts of BAU Forecast

Understanding what the BAU forecast means for Ames may be best achieved by placing emissions forecasts within both a local and a global perspective of climate change impacts. Local impacts can be viewed through the **Social Cost of Carbon**, while global impacts can be viewed through **Understanding Difference Between 1.5˚C, 2˚C, and 4.6˚C Degree Global Warming.**

Social Cost of Carbon

As outlined earlier in this section, the social cost of carbon is a measure of the economic harm from climate change impacts of the total damages from emitting carbon dioxide into the atmosphere. Using the localized cost of carbon established earlier in this report, the cumulative future economic impacts associated with the Ames' Citywide BAU forecast are*:

Cumulative Potential Future Economic Impacts Associated with Emissions

Through 2030:
$763 Million

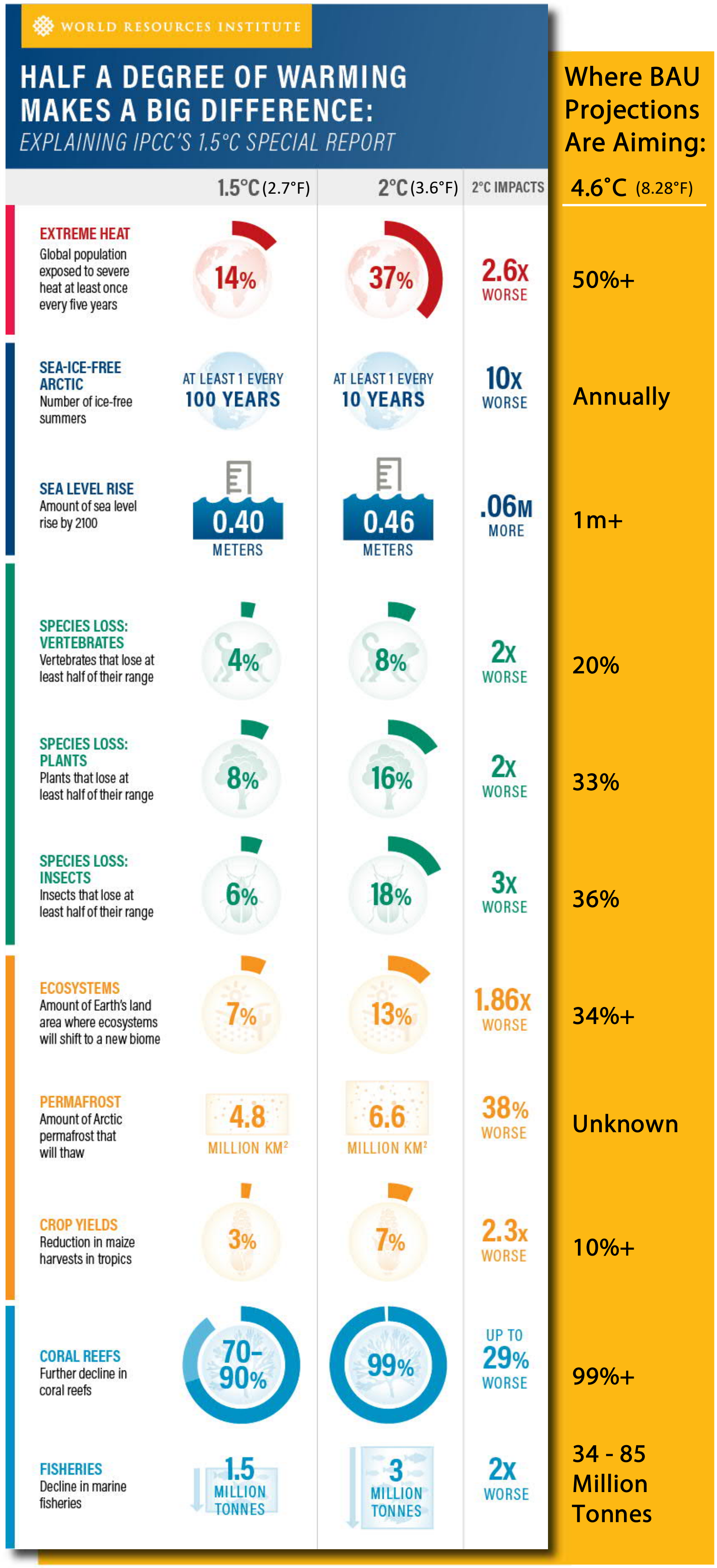
Through 2040:
$1,445 Million

Through 2050:
$2,148 Million

* Note, projections do not include potential future economic impacts associated with damage from increased extreme weather events or potential increased illnesses from vector-borne diseases.

Understanding Difference Between 1.5˚C, 2˚C, and 4.6˚C Degree Global Warming

The infographic to the right, created by the World Resources Institute summarizes some of the global climate change impact differences between reducing global emissions to cap global warming at 1.5˚C vs capping global warming to 2˚C. We've added an illustration of the impacts related to a 4.6˚C warming - which is where current Ames' Business-as-Usual projections point.



Source and Graphic: World Resources Institute

Section 05

GHG Reduction Goalsetting

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GHG Reduction Goalsetting

Setting reduction targets allows cities to track their progress towards reducing greenhouse gas emissions and measure success of climate programs. Reduction targets can motivate action, allow for comparability among cities, and provide a framework for monitoring changes in emissions. Methods of setting emissions reduction targets vary, and can be based on a community-wide emissions baseline or per-capita emissions.

Before setting a target, however, it is important to understand the concept of baseline year and establish target years to work towards. It is also helpful to get a general idea of targets that other peer communities are setting, and understand the global context of emissions reduction. It is also important to considering the emissions **Business-as-Usual forecasts** as outlined in Section 4 of this report.

Setting a Baseline

Commonly used baselines are between 2000-2010. However, the most important consideration when determining a baseline year is whether or not there is complete inventory data available. The City will want to make sure all the sectors included in the baseline are included in current/future inventories and created with the same methodology so they are comparable and consistent. paleBLUEdot recommends establishing 2018 as the baseline year for establishing GHG reduction goals.

Setting Target Years

Many organizations and jurisdictions set long-term emission reduction targets for the year 2050. To track progress towards meeting a long-term emissions reduction target, interim year targets are also common. We recommend that Ames set a 2050 target with one interim target. The interim target may be most useful if established as a 10 year plan interval.

Peer Communities

Though the goals established by the City of Ames should be entirely grounded in what is appropriate for the Ames community, reviewing the GHG reduction goals of peer communities can be helpful. Understanding the emission reduction goals of other communities in Iowa and others throughout the Midwest can help the community rapidly explore a range of goals and determine the more successful ways of framing long-term visionary climate goals.

GHG Emission Reduction Goal in Global Context

Establishing the City's GHG emission reduction goal within a global context is possible by grounding reduction goals within recommendations formulated by the International Panel on Climate Change (IPCC). This approach can help validate the appropriateness of the goal. The IPCC is the United Nation Environment Porgramme (UNEP) body for assessing the science related to climate change and providing support in climate action policy making. The scientific consensus of the international IPCC working groups is to reduce global GHG emissions as needed in order to limit global warming to 1.5°C. In addition, the Paris Agreement aims to limit global warming to 1.5 to 2 degrees C above pre-industrial levels, considered to be the threshold for dangerous climate change.

The UNEP Emissions Gap Report published in November 2019 calculates that by 2030, global emissions will need to be 25% lower than 2018 to put the world on the least-cost pathway to limiting global warming to below 2°C. To limit global warming to 1.5°C, the same report finds emissions would need to be 55% lower than in 2018 - an upward adjustment of earlier recommendations which suggested a 45% reduction.

GHG Reduction Goalsetting

Fair Share Citywide Emission Reductions To Meet Global Need

The concept of "Fair Share" has been introduced into international climate action discussions. Though there is no consensus on how "fair share" should be defined, the most common way of looking at the concept is a straight-line reduction economy-wide. This means that the share of emissions reductions for each jurisdiction (the City of Ames, the State of Iowa, the United States, etc) should match their share of global emissions - meaning if the US emits 25% of global emissions, the "fair share" of emissions reductions for the US would be 25% of the global emission reduction goals.

Based on a "Fair Share" model of GHG emission reduction, citywide reduction goals compatible with the Paris Agreement would look to target emission reductions of 25% to 55% below 2018 levels by 2030.

Climate Action Plan Approach to Emissions Reduction

paleBLUEdot recommends that the City of Ames develop a Climate Action Plan which is intended as a "living plan" rather than a static document. This means that the implementation phase of the plan should be characterized by intermittent measurement of progress and plan adjustments. Plan adjustments should look towards increasing implementation goals for actions which illustrate success, modify goals for actions which may fall short of desired outcomes, and identifying additional action opportunities.

As a "living plan", the emission reduction goal established by the City and addressed in the Climate Action Plan should be seen as a guiding constant and recognition should be given that initial implementation actions may not yet fully achieve plan goals. Intermittent plan progress measurements and adjustments should identify additional actions, or increases in action implementation targets as needed to meet the City's ultimate GHG reduction goal.

Establishing Guidance for the Climate Action Plan

The City can approach establishing GHG emission reduction goals prior to initiation Climate Action Planning, or allow detailed goals to be established through the Climate Action Planning effort. An advantage of establishing detailed goals through the Climate Action Planning effort is the ability to develop goals, emission sector strategies, and detailed actions in concert with each other. If detailed goals are established in the planning effort, the City may choose to establish a guiding GHG reduction vision prior to the initiation of CAP planning. An example of a GHG reduction vision is below:

> **Example GHG Reduction Vision**
> The City of Ames shall develop a Climate Action Plan with emission reduction goals compatible with the 2015 Paris Agreement.

City of Ames Citywide GHG Emissions:

1,035,406
Metric Tons

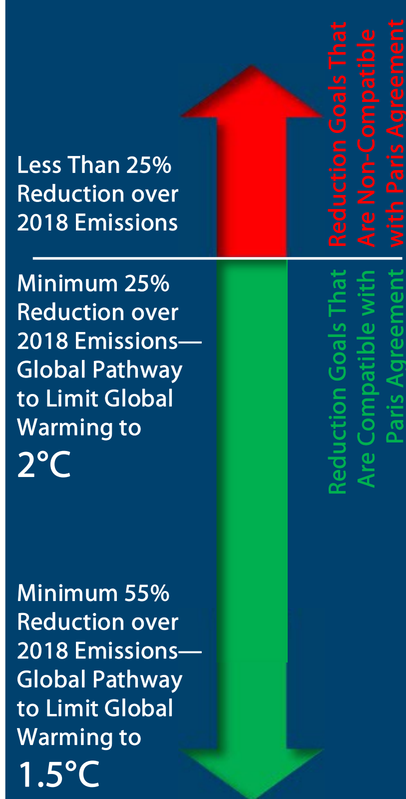
Annual Ames 2030 Citywide GHG Emissions Target To Limit Global Warming to 2°C:

776,555
Metric Tons
25% below 2018

Annual Ames 2030 Citywide GHG Emissions Target To Limit Global Warming to 1.5°C:

465,932
Metric Tons
55% below 2018

"Fair Share" Model Review of 2030 Emission Reduc-



Section 06

Example GHG Reduction Strategies

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I WENT SOLAR!
SunSmart Ames
YOU CAN TOO!
www.CityOfAmes.org/Solar

Example GHG Reduction Strategies

Reduction Recommendations

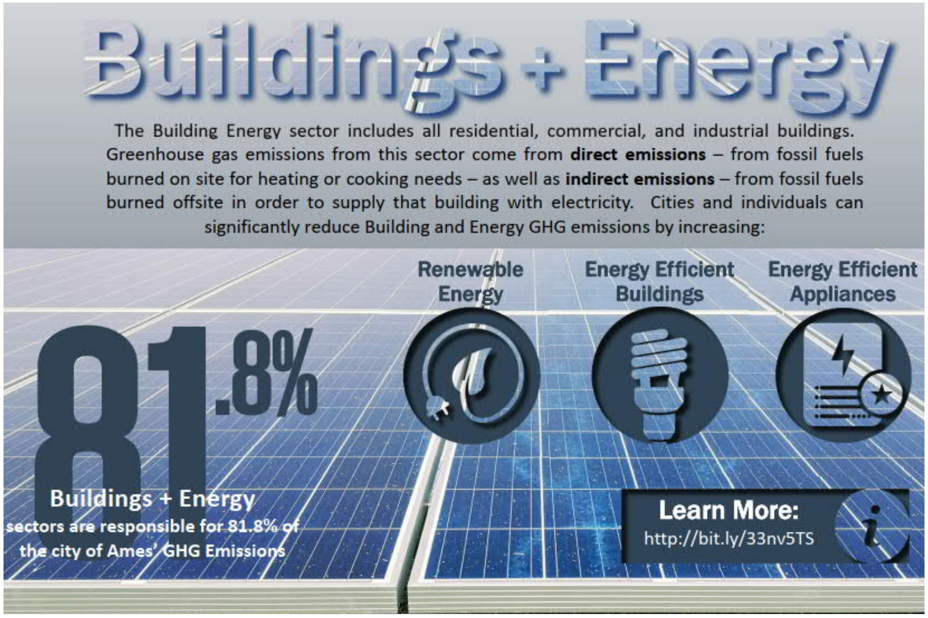
Cities are centers of communication, commerce and culture. City populations are increasing while global populations become more urban. What our cities do can set the agenda for a sustainable future.

In terms of size, cities occupy only two percent of the world's landmass. But in terms of climate impact, they leave an enormous footprint. The community of Ames' share of Iowa Statewide GHG emissions is over 33 times larger than the city's share of Iowa's land area. The city's business-as-usual emissions forecast illustrates these emissions growing with a 16% increase of citywide emissions by 2050, half of which may occur by 2030.

As outlined in the Findings section of this report, the Ames citywide GHG emissions saw a 21% reduction over the last five years. In that same time, emissions associated with the City's operations saw a 52.3% reduction. These are compelling achievements and illustrate the potential for significant and rapid GHG emissions drawdown.

This section provides a high level overview of example emissions reduction outcomes to consider. These are not intended to be exhaustive nor conclusive, but instead provide an overview of actions pursued by other communities in GHG reduction efforts.

For Ames, strategies and actions should be arrived at through a collaborative climate action planning effort which establishes city specific recommendations supported by feasibility and benefit assessment and including City staff, leadership, and community engagement



Renewable Energy

Increase renewable energy adoption within the Residential Sector.

Reduce fossil fuel use within city.

Energy Efficient Buildings

Increase energy efficiency in residential, commercial, and industrial buildings.

Energy Efficient Appliances

Decrease energy consumption for plug loads/stand-by power and appliances in residential, commercial, and industrial buildings.

Electric Vehicles

Increase adoption of Electric Vehicles for residents, businesses, and public Transportation.

Alternative Transport

Increase use of alternative transportation modes in lieu of vehicle use.

Waste Reduction

Encourage and explore a minimal waste strategy.

Recycling

Explore/enhance recycling opportunities.

Compost

Maximize organics diversion from waste stream.

Waste To Energy

Maximize efficiency of waste-to-energy process.

Reduce Outdoor Water Use

Decrease outdoor use of city water.

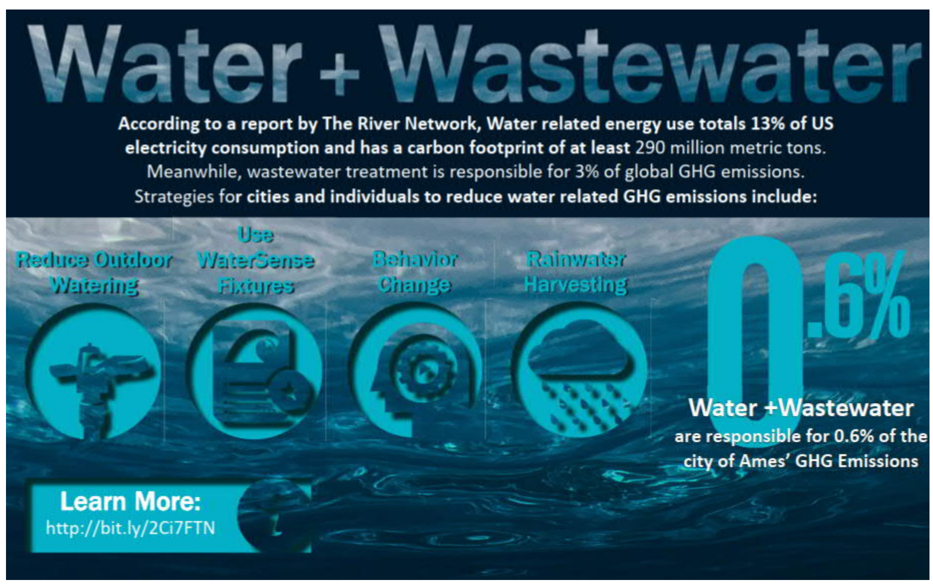
Water Conservation

Increase use of water efficient fixtures.

Increase water conservation behavior throughout the community.

Rainwater Harvesting

Increase rainwater harvesting throughout the community.



Example GHG Reduction Strategies

Next Steps

We recommend the City consider the following next steps:

1) Maintain and update Citywide and City Operations GHG inventories bi-annually to track GHG emission progress.

2) Initiate a Climate Action and Adaptation Planning effort. Effort should:
   - A Establish clear Citywide and City Operations GHG emissions reduction targets.
   - B Implement a community engagement effort to include community insight in the planning effort.
   - C Identify emissions reductions strategies and actions to meet Citywide and City Operations emissions targets.
   - D Identify climate adaptation strategies and actions to improve the City's resilience to the projected and potential climate impacts outlined in the City of Ames Climate Vulnerability Assessment
   - E Create an implementation plan providing clarification on timing, responsible partners and staff, and prioritization of reduction actions.

Section A1

Ames Greenhouse Gas Inventory Technical Report

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City of Ames Community Greenhouse Gas Inventory: Technical Report

Citywide Inventory and City Operations Assessment

2014, 2016, and 2018

August 2020

Photo from City of Ames web site

paleBLUEdot LLC + ORANGE ENVIRONMENTAL

www.paleBLUEdot.llc

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Part 1: Introduction

The City of Ames is committed to becoming a more sustainable organization, promoting conservation, and encouraging renewable energy within the City. The City was taking *green* actions before the term was coined. More than 40 years ago, the City opened its waste-to-energy plant that processed county-wide municipal solid waste into a supplemental fuel for the City's power plant. It was the first city in the nation to accomplish that.

Since 80% of Americans live in cities, the City of Ames recognized that cities needed to take the lead nationally to improve sustainability. More than 10 years ago, the former Mayor signed the U.S. Mayors' Climate Protection Agreement and the City continued its environmental leadership by implementing a comprehensive range of programs and services. Examples included purchasing wind power, converting lighting to LED, using hybrid public transit buses, providing electric vehicle charging stations, developing an ever expanding system of bike lanes, and converting the City's power plant from coal to cleaner burning natural gas, which reduced carbon emissions by more than 60%.

The City has developed an "EcoSmart" program, which has general guides to improve sustainability. This, and its "Smart" suite of programs (Smart Energy, Smart Ride, Smart Trash, Smart Water, and Smart Watersheds) make the City the environmental clearinghouse for the community.

1.1. Project Overview

The City contracted with the PaleBLUEdot and ORANGE Environmental, LLC to prepare the following analyses:

1. Inventories for citywide and city operations sources of greenhouse gas (GHG) emissions (Technical Report)
2. Renewable energy potential study
3. Climate vulnerability assessment

The purpose of this Technical Report is to summarize the results of the first commitment—preparing the GHG inventory. In order to better distinguish between the two analyses, the citywide analysis is called the *Citywide Inventory*, and the city operations analysis is called the *City Operations Assessment*. Both analyses are consistent with the internationally recognized assessment protocols developed by ICLEI-Local Governments for Sustainability USA (ICLEI Protocol).

All of the data, calculations, and information sources that generated the information in this Technical Report are included in a spreadsheet analysis provided to the City. Also, the appendices to this Technical Report include a listing of the primary sources, 2 tables that summarize the results, and a listing of the "Takeaways," which includes the key findings. The Takeaways pages also include a reference to the applicable section of the Technical Report.

1.2. Value of Greenhouse Gas Assessments

"If you don't measure results, you can't tell success from failure. If you can't see success, you can't reward it. If you can't see failure, you can't correct it." This often-quoted adage is from the book, *Reinventing Government* by David Osborne and Ted Gaebler who are well-known authors and urban consultants. Baseline assessments and indicators are useful. Planners need them, elected officials want them, and the future may see their development as a basic requirement of state and federal funding.

The goal of the Citywide Inventory is to estimate the GHG emissions associated with the activities of the people who live, work, learn, travel, visit, and recreate within the City's geographical boundaries during the three study years, 2014, 2016, and 2018. The goal of the City Operations Assessment is similar but with a narrower focus on the emissions associated with the City governmental activities. Both of the analyses must be transparent and able to be replicated, updated, and compared with future assessments for Ames and assessments for peer cities.

Measuring the energy aspects of human activities and the associated GHG emissions offers a unique way to compare the effectiveness of various energy and sustainability best management practices. Greenhouse gas emissions and energy[1] serve as common denominators for the comparison of kilowatts of electricity, natural gas therms, tons of coal, and gallons of liquid fuels consumed; as well as vehicle miles traveled, tons of waste processed, and gallons of potable water produced and distributed.

Every city prepares annual operating and capital improvement budgets. These GHG assessments are akin to the environmental budget for the City. Recording these performance metrics is essential to promoting efficiency and sustainable change. Along with providing citywide benefits, the two GHG analyses will:

- Highlight opportunities to save resources and money.
- Provide a baseline for estimating the effectiveness of many sustainability measures.
- Inform subsequent analyses, plans, and policy decisions.
- Improve the City's competitiveness for federal and state funding opportunities that are targeted to cities that have taken steps to measure and improve their energy efficiency and reduce their carbon footprints.
- Assist in promoting public understanding of the City's effects on climate change.
- Serve as a model for other cities.

[1] Energy is expressed as kBtu (a thousand British thermal units) or MMBtu (a million Btus).

1.3. Definitions, Data Sources, Methodologies, and Color Scheme

The greenhouse gases of carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4) are aggregated and reported as carbon dioxide equivalents (CO_2e), which is a commonly used unit that combines greenhouse gases of differing impact on the Earth's climate into one weighted unit. For this report, the term *greenhouse gas* (GHG) is shorthand for carbon dioxide equivalents. Greenhouse gas emissions are expressed in metric tons (tonnes), which equal 1,000 kilograms, or 2,204.6 US pounds. The use of the term CO_2 only refers to the individual greenhouse gas, carbon dioxide.

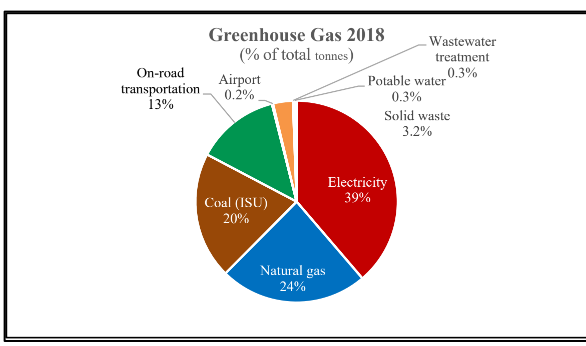
All of the sources of data for the assessments are transparent, fully identified, verifiable, and reliable. They consist of City and county records, staff reports, and utility records; internationally recognized methodologies and published scientific papers regarding the calculation of GHG emissions; data from federal and state agencies (US Department of Transportation, US Environmental Protection Agency, Iowa Department of Transportation), and other peer-reviewed, published sources. This analyses also include the information prepared by Iowa State University for its GHG assessment.

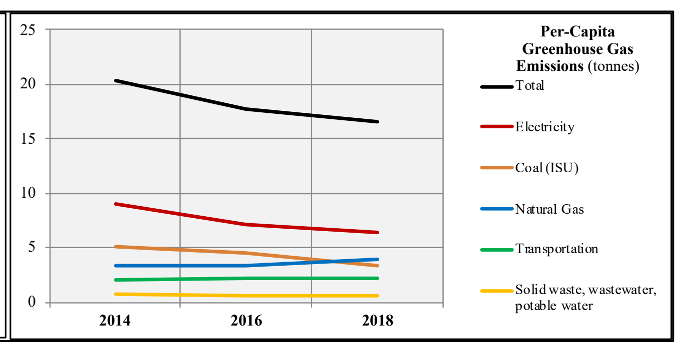
The charts generally follow the color scheme at right in order to aid interpretation.

Color Scheme for Charts		Color
Fuels:		
	Electricity	
	Electricity emission factor	
	Natural gas	
	Coal	
	RDF	
Energy and GHG:		
	MMBtu	
	GHG	
Emissions sources:		
	Buildings	
	Parks	
	Streetlights	
	Transportation	
	Solid waste	
	Landfill	
	Water	
	Wastewater	
Totals		

1.4. Summary of the Citywide Inventory Results

The pie chart below shows the breakout of GHG emissions in 2018 by the various categories, and the line chart graphs the changes in emissions over the 3 Study Years. The table below provides that primary data for the 3 Study Years and lists the percent 2018 changes from the 2014 base Study Year.





1.4.1. The picture in 2018: The above pie chart shows that the emissions from electricity (39%) and natural gas (24%) were the largest sources, followed by coal

(20%), and on-road transportation (13%). Solid waste management, water production, and wastewater treatment accounted for the remaining 4% of the total. Iowa State University is a major factor in citywide emissions. In 2018, it accounted for 39% of the total citywide emissions. The above line chart graphs the data in the table below. Citywide GHG emissions in 2018 were -17% lower than in 2014. For the Electricity category, the 2018 amount was less than in 2014 by -28%, and the Natural Gas category was 19% larger. Compared to 2014, citywide GHG emissions in 2018 for the Transportation category were 11% higher, and emissions for the Solid Waste category were -5% lower.

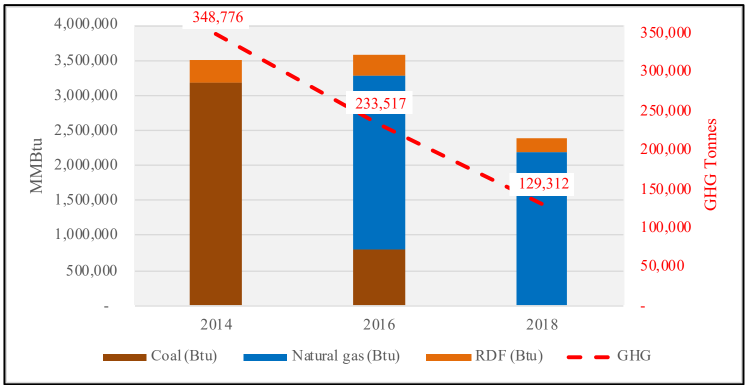
Category	2014	2016	2018	Change from 2014
Electricity	583,958	471,528	422,123	-28%
Natural gas	217,620	222,929	258,092	19%
Coal	334,019	293,916	221,228	-34%
Transportation	133,148	140,581	147,308	11%
Solid waste	36,172	31,947	34,491	-5%
Wastewater treatment	2,883	2,539	2,836	-2%
Potable water	4,079	3,214	3,584	-12%
Total	1,311,879	1,166,654	1,089,662	-17%

Citywide greenhouse gas emissions (tonnes), 2014-2018

1.4.2. **Energy changes in 2018 compared to 2014:** The most important change factor was the role of coal. Starting with the University, its emissions were -14% lower in 2018 than in 2014, and virtually all of that decrease was due to reduced emissions from its combined heat and power (CHP) plant because it replaced a lot of its coal with natural gas.

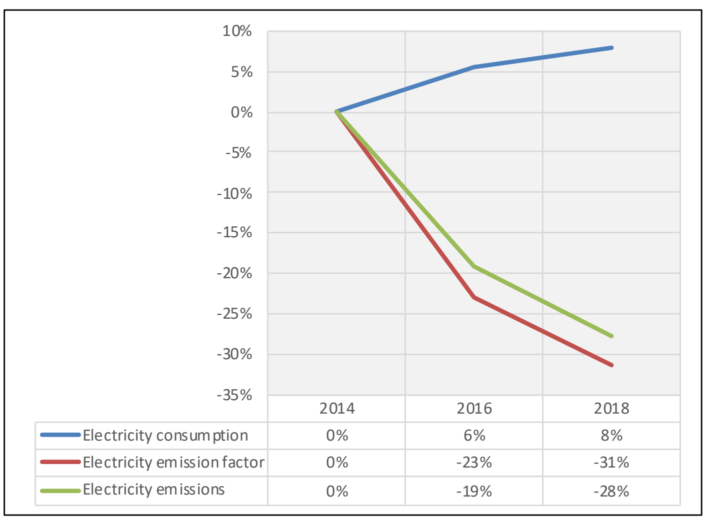
Secondly, the Ames Municipal Electric System (AMES)[2] totally replaced coal with natural gas in 2016. That had a very large effect on the electrical system's emission factor (GHG tonnes per MWh). It was -43% lower in 2018 compared to 2014 for produced power (refer to the bar chart below). However, the AMES bought 42% to 54% of the power it distributed from the electric grid over the 3 Study Years and the electrical grid's emissions factor was only -9% lower in 2018 compared to 2014. As a result, the reduction for the AMES's blended emission factor (both produced and purchased power) was less dramatic, -34% lower in 2018 compared to 2014.

[2] The AMES includes a power plant (units 7 and 8), the Dayton Substation, a wind farm, and a soon-to-come solar farm.



Fuel mix and energy for produced power at the Ames Municipal Electric System, 2014-2018, and associated greenhouse gas emissions (red dashed line and right vertical scale)

The following chart illustrates the 3 key factors that account for the substantive reduction in emissions for the Electricity category in 2018 compared to 2014. It shows the 8% increase in electricity consumption. The AMES was the largest source of citywide power (generally 86% of the power consumed within the City) but there were 5 other sources, each with its own emission factors that varied from year to year. The line chart shows that the calculated emission factor for the citywide Electricity category was -31% lower in 2018 compared to 2014. This substantive reduction played a crucial role in the -28% reduction in GHG emissions for the Electricity category.

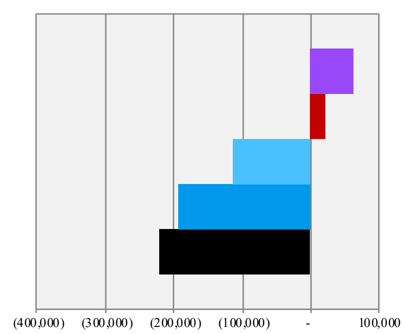


Percent change in citywide electricity consumption, blended electricity emission factors, and greenhouse gas emissions, 2014-2018

1.4.3. The role of transportation: The Transportation category drove emissions in the opposite direction; up, not down, compared to 2014. Increased vehicle miles traveled (10% higher) and use of jet fuel instead of aviation gas at the Ames Municipal Airport increased transportation emissions by 11%. The Transportation category accounted for 10% of total citywide emissions in 2018.

1.4.4. Citywide emission totals: The overall net effect in 2018 was that, compared to 2014, energy consumption of all kinds (electricity, natural gas, liquid fuels, coal, and refuse derived fuel) was 2% higher, but total emissions (including fugitive emissions from landfills and wastewater treatment) were -17% lower. The change from 2014 to 2018 can be summed in 5 key numbers (refer also to the chart below):

- Consumption for the Electricity category was 8% higher in 2018 compared to 2014.
- Since electricity is of prime importance, replacing coal with natural gas had the largest impact at both the University's CHP plant and the AMES because it significantly reduced the electricity emissions factors. The AMES reduced its in-plant emission factor by -43%.
- The overall blended emission factor for the Electricity category was -31% lower than in 2014.
- The University reduced its overall emissions by -14%.
- On a per-capita basis, the reduction was -18%.

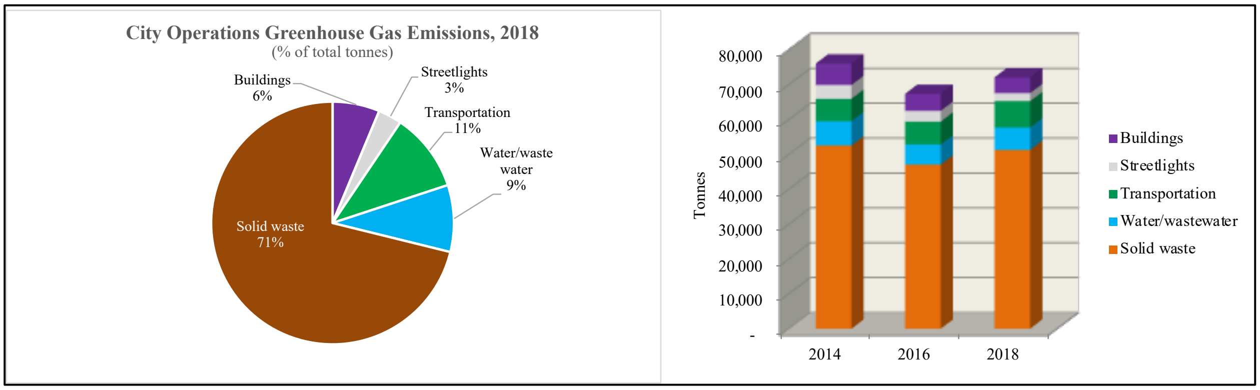


	Tonnes
Net increased emissions in other categories	61,944
Increased electricity consumption	20,931
Reduced coal at ISU CHP plant	(112,791)
Gas replaced coal at AMES	(192,302)
Total	(222,218)

Key factors responsible for 2018 citywide greenhouse gas emissions being lower than in 2014

1.5. Summary of the City Operations Assessment Results

1.5.1. The picture in 2018: The bar and line charts and the table below provide the basic results for the City Operations Inventory. Overall emissions were -53% lower in 2018 compared to 2014. The AMES accounted for 61% of total City operations emissions in 2018. As mentioned above, the system's emissions from produced power were -43% lower than in 2014 due to the replacement of coal by natural gas. Also, the system produced -32% less electricity but instead purchased additional energy from the electricity grid to meet needs. [3]



Greenhouse gas emissions in 2018, and 2014-2018 (excluding the AMES)

Category	2014	2016	2018	Change from 2014
Buildings and facilities	6,164	4,880	4,528	-27%
Streetlights and signals	3,956	3,077	2,269	-43%
Transportation	6,401	6,580	7,570	18%
Water	4,079	3,214	3,584	-12%
Wastewater	2,883	2,539	2,836	-2%
Solid waste	52,535	47,056	51,268	-2%
Subtotal	**76,018**	**67,346**	**72,056**	**-5%**
Ames Municipal Electric System	313,692	206,717	112,873	-43%
Grand total	**389,710**	**274,063**	**184,929**	**-53%**

City operations greenhouse gas emissions (tonnes), 2014-2018

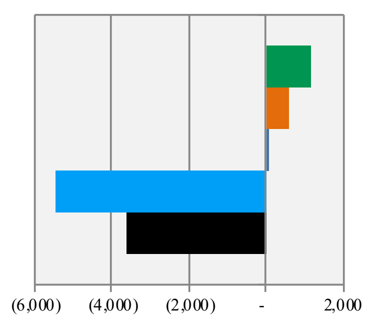
The ICLEI Protocol requires the emissions associated with the combustion of the waste that the City processes into refuse derived fuel (RDF) be allocated to the Solid Waste category. These emissions are significant considering every ton of RDF resulted in close to 1 tonne of GHG emissions. The City's Chantland RDF plant sent fewer tons of RDF to the AMES power plant in 2018 due to extended down time of one of the plant's boilers that year. Thus, emissions associated with RDF combustion were lower in 2018 compared to 2014. However, more waste was landfilled and the emission rate for the landfill is about 50% higher than for RDF processing. As a result, emissions for the Solid Waste category were largely unchanged from the 2014 level.

[3] It's important to keep in mind that while the Citywide Inventory must account for the energy and emissions from 100% of the electricity consumed within the City boundaries, the City Operations Assessment must account only for the energy and emissions associated with the electricity the AMES produces within the City (no purchased electricity).

1.5.2. Changes in 2018 compared to 2014: The following information is calculated excluding the energy and emissions from the AMES:[4]

- Electricity and natural gas consumption for the Buildings and Facilities category was 2% higher in 2018 compared to 2014.
- Electricity consumption for streetlights and signals was -1% lower due primarily to conversions to LED fixtures.
- Emissions from the Transportation category, which comprise 11% of total emissions in 2018, were 18% higher in 2018 than in 2014.
- Total energy consumption (electricity, natural gas, liquid fuels) was -15% lower in 2018 than in 2014 and total emissions were -5% lower.[5] If the AMES is included, emissions were -53% lower in 2018 compared to 2014. Changes in the water and wastewater categories did not have substantive effects on overall emissions.

The chart below shows the key factors responsible for 2018 GHG emissions for City facilities (excluding the AMES) being -5% lower than in 2014. Replacing coal with natural gas avoided 5,500 GHG tonnes for the electricity consumed by City facilities. This reduction more than offset the increases from transportation, solid waste management, and increased natural gas usage in City facilities.



	Tonnes
Transportation	1,169
Solid waste	587
Natural gas	123
Gas replaced coal at AMES	(5,451)
Total	(3,571)

Key factors responsible for 2018 greenhouse gas emissions for City facilities (excluding AMES) being lower than in 2014

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[4] Because the emissions from the AMES equal about 3 times those from all other City facilities combined, excluding it from the analysis of other City facilities is necessary to highlight changes. Changes in the water and wastewater categories did not have substantive changes to overall emissions.

[5] This is a rare instance where reductions in energy consumption were greater than in emission reductions. The reason was change in the management of solid waste, which, on average, accounts for 68% of city operations emissions (excluding AMES). There was a significant drop in RDF combustion in 2018, which decreased the associated energy; however, landfill emissions that year increased but they have no effect on the energy consumption calculation.

Part 2: Citywide Inventory

2.1. Introduction to Part 2

Part 2 describes the methodology for the preparation of the Citywide Inventory portion of the Project. Part 3 describes the results of the analysis. This Technical Report and the 30 spreadsheets that inform it were prepared consistent with the most applicable and current guides available; namely, the *U.S. ICLEI Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions*, 2019 (ICLEI Community Protocol), and the *Local Government Operations Protocol for the Quantification and Reporting of Greenhouse Gas Emissions Inventories*, Version 1.1, May 2010 (Governmental Operations Protocol).[6]

The ICLEI Community Protocol addresses the important questions of what to measure and how to measure it. These are no small matters. It has taken more than two decades of international collaboration to derive the best methods. The Protocol begins by clarifying the terms *Sources* and A*ctivities* and then divides emission Sources and Activities into two main categories, *Required* and *Optional*. To address small Sources and Activities and allow their exclusion, the Protocol sets a minimum size threshold, called *de minimis*. The ICLEI Community Protocol also describes methods to avoid double-counting emissions for facilities that are shared among multiple communities.

Some GHG assessments also include estimates of what are called *upstream* emissions or *life-cycle* emissions, which account for the embodied energy in food and products consumed within the city but produced outside of the city. Since upstream emissions are not a Required Source or Activity according to the ICLEI Community Protocol, they are not included in this Technical Report.

2.2. Sources and Activities

The following are the definitions of Sources and Activities from the ICLEI Community Protocol (p. 11): A Source is, “Any physical process inside the jurisdictional boundary that releases GHG emissions into the atmosphere (e.g., combustion of gasoline in transportation; combustion of natural gas in electricity generation; methane emissions from a landfill).” An Activity is, “The use of energy, materials, and/or services by members of the community that result in the creation of GHG emissions either directly

[6] ICLEI, along with its several international partner agencies, is considered the international leader in GHG assessment protocols for local governments. According to its website, ICLEI – Local Governments for Sustainability is “an international association of almost 1,000 local governments worldwide and more than 250 in the US that have made commitments to sustainable development and climate protection. ICLEI, founded in 1990 as the International Council on Local Environmental Initiatives and now known officially as ICLEI – Local Governments for Sustainability, strives to advance solutions to global climate change through cumulative local action. ICLEI provides technical and policy assistance, software training, climate expertise, information services and peer networking to help members build capacity, share knowledge and implement sustainable development and climate protection at the local level.”

(e.g., use of household furnaces and vehicles with internal combustion engines) or indirectly (e.g., use of electricity created through combustion of fossil fuels at a power plant, consumption of goods and services whose production, transport and/or disposal resulted in creation of GHG emissions).” While Sources are bound by the geography (the community boundary), Activities are not.

2.3. Required and Optional Emission Sources and Activities

The ICLEI Community Protocol divides the realm of possible emission Sources and Activities into two major groups: Five Basic Emissions Generating Activities (Required Activities), and Additional Community Emission Sources and Activities (Optional Sources and Activities). The subsections below describe the various spreadsheets prepared for the City and identify whether each emission category is a Required or an Optional metric.

2.3.1. Five Basic Emissions-Generating Activities (Required Activities): To be consistent with the ICLEI Community Protocol, the following activities must be included in a citywide assessment (Required Activities). These Activities are required at the city scale because 1) cities are the level of government with the greatest authority and responsibility over the emissions-generating Activity; 2) the data needed to estimate emissions are reasonably available; 3) the emissions associated with the Activity tend to be significant in magnitude; and 4) the Activity is important and common across U.S. cities. The following descriptions are adapted from the ICLEI Community Protocol:

2.3.1.1 Use of purchased electricity: The Protocol requires the inclusion of power plant emissions associated with generating electricity used within the jurisdictional boundary of the city regardless of the location of the electricity generation facility. Since the City owns and operates the Ames Municipal Electric System (AMES), which provides about 87% of the power within the City, it has considerable control over electricity emissions, and it can influence electricity use in local buildings through local building codes, financial incentives, minimum regulatory requirements, technical assistance, and other programs. The Citywide Inventory includes all emissions from the consumption of electricity within the City. The City is also served by 3 other power providers.

2.3.1.2. Use of fuel in stationary applications: Each assessment must include the combustion emissions associated with fuels used in stationary applications within the jurisdictional boundary of the city (e.g., natural gas and liquid fuels used in furnaces, boilers, and emergency generators). Local governments can often influence use of fuels in stationary combustion applications through the same tools listed above for purchased electricity. The Citywide Inventory includes the emissions associated with natural gas, generator fuels, and coal combustion.

2.3.1.3. On-road motor vehicles: Transportation fuels used by on-road motor vehicles comprise a major source of emissions. Local governments can influence transportation emissions by developing bicycle, pedestrian, and public transit infrastructure, and by focusing new development along transit corridors, among other strategies. The Citywide Inventory includes emissions associated with vehicle miles traveled (VMT) within the City boundaries.

2.3.1.4. Use of energy in the production and distribution of potable water and wastewater treatment: The Protocol requires the collection of energy-related emissions associated with wastewater treatment and the production and delivery of potable water, regardless of the location of the water delivery and treatment infrastructure. Since the City owns and operates both the potable water and wastewater treatment systems, it has substantive control over their energy consumption. Furthermore, the City can influence community water use through local building codes, promoting or providing incentives to foster water conservation and efficiency, and through other programs and services. At the request of City staff, the Citywide Inventory segregates the emissions associated with the consumption of electricity, natural gas, and generator diesel for the production and distribution of potable water.

2.3.1.5. Solid waste management: Although this Activity usually comprises a very small portion of a community's total emissions (generally less than 2%), the Protocol requires its inclusion because local governments can influence to some degree the amount of solid waste generated and the management methods. Since the City owns and operates the Resource Recovery facility, it also has pricing power to influence waste management. The Citywide Inventory accounts for the emissions associated with the burning of refuse derived fuel (RDF) at the AMES, as well as the end-of-life emissions (projected future methane emissions) of the RDF rejects and mixed municipal waste that is sent to the Boone County landfill.

2.3.2. Additional Community Emission Sources and Activities (Optional Sources and Activities): The ICLEI Community Protocol recommends the inclusion of numerous optional emission Sources and Activities (Optional Sources and Activities) such as those associated with local rail travel, marine activities, and airplane travel. Expanding GHG inventory reporting to include Optional emission Sources and Activities is purely voluntary and is not required for a GHG emissions inventory report to be considered compliant with the Community Protocol.

However, by including a broader set of emission-generating Activities and Sources in their reporting, a local government can provide a more complete picture of how the community contributes to GHG emissions.

The Citywide Inventory includes one such Optional Activity—airplane travel, because the City owns the Ames Municipal Airport.

2.4. Scopes

The ICLEI Protocol defines 3 *Scopes* to categorize emission sources. For the Citywide Inventory, Scope 1 emissions stem from sources within the City boundary (e.g., emissions associated with natural gas for heating, on-road and air transportation, and waste management facilities for solid waste and wastewater located within the City). For the City Operations Assessment, Scope 1 emissions are from sources that the City owns or controls including the AMES.

Scope 2 refers only to indirect emissions associated with the consumption of purchased electricity, steam, heating, or cooling. For the Citywide Inventory, emissions associated with electricity consumption within the City boundaries are Scope 2 emissions. For the City Operations Assessment, the category refers to electricity consumed by city-owned facilities.[7]

Scope 3 emissions include all other indirect emissions not covered in Scope 2. For the Citywide Inventory, the category includes emissions associated with landfilling waste in the Boone County landfill that was generated within the City. For the City Operations Assessment, the category includes contractor services and official travel.

2.5. De Minimis Emission Threshold

The ICLEI Community Protocol defines *de minimis* emissions as "a quantity of GHG emissions from any combination of sources and/or gases, which, when summed, equal less than five percent (5%) of community GHG emissions that are required to be included in the community GHG emissions report. These emission sources must be identified and described in the community GHG emissions report, but need not be quantified." The Citywide Inventory excludes several de minimis emission Sources and Activities that are sometimes included in other assessments, such as emissions associated with refrigerant and fire suppressants leakage, and minor combustors of liquid fuels (e.g. fuel oil, propane, and diesel-powered heaters). Other assessments for cities have shown that these excluded emission Sources and Activities are not likely to

[7] Although the AMES produces most of the electricity consumed within the City and, thus, might be considered a source of Scope 1 emissions, it is mixed with power from the 3 other electricity producers plus purchased power, and renewable sources. Since the electrons can't be separated, this analysis assumes electrical consumption is a Scope 2 source for the Citywide Inventory. For the City Operations Assessment, all emissions associated with on-site power production within the AMES are Scope 1 emissions because the City owns the facility.

exceed the *de minimis* threshold. There are no other known large Sources or Activities within the City that are not already included.

2.6. Demographics

Figure 1 graphs the growth in population and households in the City from 2008 to 2018.[8] Focusing on the study period of 2014-2018, there were about 1,200 additional people (a 2% increase) and 1,900 more households (an 8% increase) in 2018 than in 2014. The table in Figure 2 lists employment data for the City. In 2017, there were a total of 35,200 workers in the City, which was 1,500 more than in 2014, a 6% increase.

In the Fall of 2017, Iowa State University had an enrollment of more than 36,000.

Figure 1: Population and Households, 2008-2018
(Note that the Y axis does not start at zero)

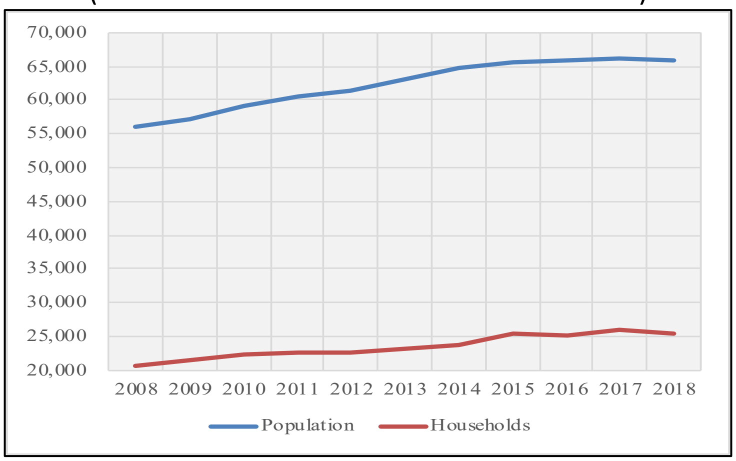


Figure 2: Employment, 2010-2017

Year	Employee of Private Company Workers	Self-employed in own incorporated business workers	Private not-for-profit wage and salary workers	Local, state, and federal government workers	Self-employed in own not incorporated business workers and unpaid family workers	Total
2010	17,082	507	2,951	11,500	1,087	33,127
2011	16,833	450	3,061	11,134	1,105	32,633
2012	16,848	490	3,179	11,360	1,192	33,069
2013	17,147	463	2,965	11,169	1,164	32,908
2014	17,956	466	3,076	11,073	1,084	33,655
2015	18,606	445	2,962	11,284	1,107	34,404
2016	18,623	491	2,649	11,779	1,436	34,978
2017	19,368	424	2,451	11,665	1,292	35,200
Change since 2014						
Number	1,412	(83)	(625)	592	208	1,545
Percent change	8%	-18%	-20%	5%	19%	6%

[8] Years prior to the 3 study years are included for additional context.

2.7. Weather

Weather has indirect effects on energy and water consumption. For example, hot, dry weather increases the demand for air conditioning and irrigation, warmer winter weather reduces the demand for space heating. Heavy snowfalls increase City costs for plowing.

Figure 3: Weather Data

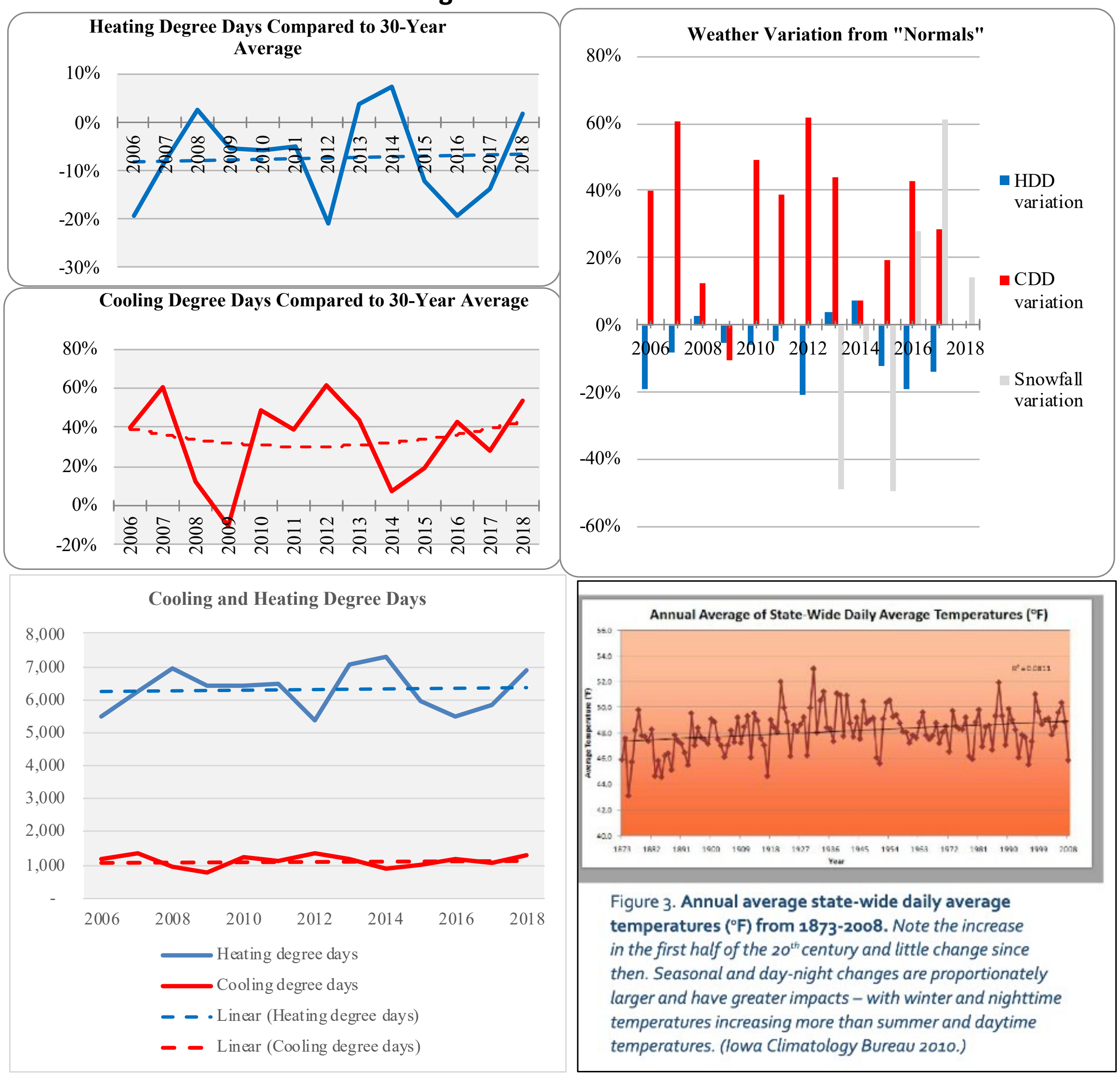


Figure 3. **Annual average state-wide daily average temperatures (°F) from 1873-2008.** *Note the increase in the first half of the 20th century and little change since then. Seasonal and day-night changes are proportionately larger and have greater impacts – with winter and nighttime temperatures increasing more than summer and daytime temperatures. (Iowa Climatology Bureau 2010.)*

The 5 charts above in Figure 3 depict weather conditions for the City.[9] The first chart shows how heating degree days (HDD) varied from an historic 30-year *normal*. [10] The long-term trend, affected by climate change, is for a decrease in HDD and a reduced need for winter heating. The chart's trendline shows the entire 12-year period (2006-2018) had fewer heating degree days than the 30-year normal. The second chart does the same for cooling degree days (CDD), except that climate change is causing an increase in the number of CDD and an increased demand for air conditioning. The trend line shows that the 12-year period was well above the 30-year normal for cooling degree days.

The third chart, "Weather Variations from "Normal," combines the variations of HDD and CDD on a bar graph and adds the variation of snowfall over a 6-year average. The tall red bars above the baseline demonstrate the years with warm-to-hot summers and the blue bars below the baseline show the years with warmer winter temperatures.

The fourth chart, "Cooling and Heating Degree Days," is less dramatic than the other charts. The description under the fifth chart explains that daily average temperatures increased statewide over the first half of the 20th century but stayed relatively flat through 2008. The fourth chart confirms that long-term trend through 2018—relative flatness; however, the other charts show that "flatness" is still well above (warmer than) the 30-year normal.

[9] Heating degree days (HDD), are a measure of how much (in degrees), and for how long (in days), outside air temperature was lower than a specific base temperature (or balance point). They are used for calculations relating to the energy consumption required to heat buildings. Cooling degree days (CDD) are a measure of how much (in degrees), and for how long (in days), outside air temperature was higher than a specific base temperature. They are used for calculations relating to the energy consumption required to cool buildings. The so-called *normal* is the 30-year averages (1981-2010) of Heating Degree Days and Cooling Degree Days.

[10] The color convention on all of the charts has HDD in blue (a higher number implies colder weather) and CDD in red (a higher number indicated hotter weather).

Part 3: Citywide Inventory Results

3.1. Overall Citywide Energy Consumption and Emissions

This section describes the overall findings regarding GHG emissions of the Citywide Inventory.[11] It also describes the primary factors that account for the changes in emissions.

Figure 4 summarizes the citywide GHG emissions. It is important to note that the data in the Electricity and Natural Gas categories are net amounts. Consistent with the ICLEI Protocol, energy and emissions from electricity and natural gas consumption to manage solid waste and wastewater are included in those respective categories. They are netted out of the Electricity and Natural Gas categories. To avoid confusion, all data that relies on electricity and natural gas consumption (e.g., electricity emission factors) are based on the net amounts in the Electricity and Natural Gas categories. Since City staff requested potable water be broken out as a separate category, the same is true for the Potable Water category.

Citywide emissions totaled 1.31 million tonnes in 2014 and 1.09 million tonnes in 2018 (Figure 4). This is a significant -17% decrease from the 2014 total. When considered on a per-capita and per-household bases, the amounts were 16.5 tonnes and 42.8 tonnes respectively in 2018, which are even larger decreases from the 2014 rates, -18% and -23% respectively.

Figure 5 summarizes the citywide energy consumption (electricity, natural gas, coal, and liquid fuels). The 2018 total of 10,700,000 MMBtu in 2018. On a per-capita basis, the 2018 rate of approximately 163 MMBtu per-capita was stable over the 3 Study Years.

[11] The totals for energy and GHG emissions for the Solid Waste category are not directly comparable between the Citywide Inventory and City Operations Assessment. Since the City's population equals about 67% of Story County's population, only about 67% of energy consumption and GHG emissions are attributed to the City in the Citywide Inventory. However, 100% are included in the City Operations Assessment.

Figure 4: Citywide Greenhouse Gas Emissions (tonnes)

Category	2014	2016	Change	2018	Change	Change from 2014
Electricity	**583,958**	**471,528**	**-19%**	**422,123**	**-10%**	**-28%**
Residential	162,831	127,490	-22%	119,079	-7%	-27%
Commercial and institutional	271,006	213,721	-21%	177,347	-17%	-35%
Industrial	146,135	127,200	-13%	123,374	-3%	-16%
Streetlights and signals	3,987	3,118	-22%	2,323	-26%	-42%
Natural gas	**217,620**	**222,929**	**2%**	**258,092**	**16%**	**19%**
Residential	72,837	56,720	-22%	71,316	26%	-2%
Commercial and institutional	66,905	59,427	-11%	67,386	13%	1%
Industrial	77,878	106,782	37%	119,390	12%	53%
Coal (ISU CHP plant) [1]	**334,019**	**293,916**	**-12%**	**221,228**	**-25%**	**-34%**
Transportation	**133,148**	**140,581**	**6%**	**147,308**	**5%**	**11%**
On-road	132,096	139,537	6%	145,234	4%	10%
Ames Municipal Airport	1,052	1,044	-1%	2,074	99%	97%
Solid waste	**36,172**	**31,947**	**-12%**	**34,491**	**8%**	**-5%**
RDF production & combustion	20,951	15,599	-26%	9,812	-37%	-53%
Landfilling	15,222	16,348	7%	24,679	51%	62%
Wastewater treatment	**2,883**	**2,539**	**-12%**	**2,836**	**12%**	**-2%**
Potable water	**4,079**	**3,214**	**-21%**	**3,584**	**12%**	**-12%**
Total	**1,311,879**	**1,166,654**	**-11%**	**1,089,662**	**-7%**	**-17%**
Per-capita	20.3	17.7	-13%	16.5	-7%	-18%
Per-household	55.7	46.3	-17%	42.8	-8%	-23%
Normalized total [1]	1,311,879	1,307,838	-0.3%	1,281,964	-2%	-2%

Notes:

(1) Assumes the blended electricity emission factor for the citywide consumption of electricity was unchanged from the 2014 rate.

Figure 5: Citywide Energy Consumption (MMBtu)

Category	2014	2016	Change	2018	Change	Change from 2014
Electricity	**2,048,442**	**2,162,039**	**6%**	**2,211,092**	**2%**	**8%**
Residential	613,754	638,261	4%	674,675	6%	10%
Commercial and institutional	1,011,499	1,061,521	5%	999,100	-6%	-1%
Industrial	408,287	446,720	9%	524,228	17%	28%
Streetlights and signals	14,902	15,537	4%	13,089	-16%	-12%
Natural gas	**4,106,042**	**4,206,214**	**2%**	**4,869,659**	**16%**	**19%**
Residential	1,374,289	1,070,195	-22%	1,345,579	26%	-2%
Commercial and institutional	1,262,354	1,121,273	-11%	1,271,432	13%	1%
Industrial	1,469,400	2,014,747	37%	2,252,648	12%	53%
Coal (ISU CHP plant) [1]	**2,393,058**	**2,105,742**	**-12%**	**1,584,976**	**-25%**	**-34%**
Transportation	**1,743,879**	**1,840,428**	**6%**	**1,869,598**	**2%**	**7%**
On-road	1,729,239	1,825,900	6%	1,840,750	1%	6%
Ames Municipal Airport	14,640	14,528	-1%	28,848	99%	97%
Solid waste (RDF)	**219,439**	**208,228**	**-5%**	**148,412**	**-29%**	**-32%**
Wastewater treatment	**22,500**	**23,203**	**3%**	**22,567**	**-3%**	**0.3%**
Potable water	**17,317**	**17,730**	**2%**	**24,471**	**38%**	**41%**
Total	**10,550,678**	**10,563,585**	**0.1%**	**10,730,775**	**1.6%**	**1.7%**
Per-capita	163	160	-2%	163	1%	-0.2%
Per-household	448	419	-6%	421	0.4%	-6%

Notes:

(1) Iowa State University's combined heat and power plant (CHP) produces thermal energy (heating and cooling) and electricity for the ISU campus using coal, natural gas, and renewable and purchased electricity. Fuels other than coal are accounted for in the electricity and natural gas categories.

Figure 6: Energy Flows for the City of Ames

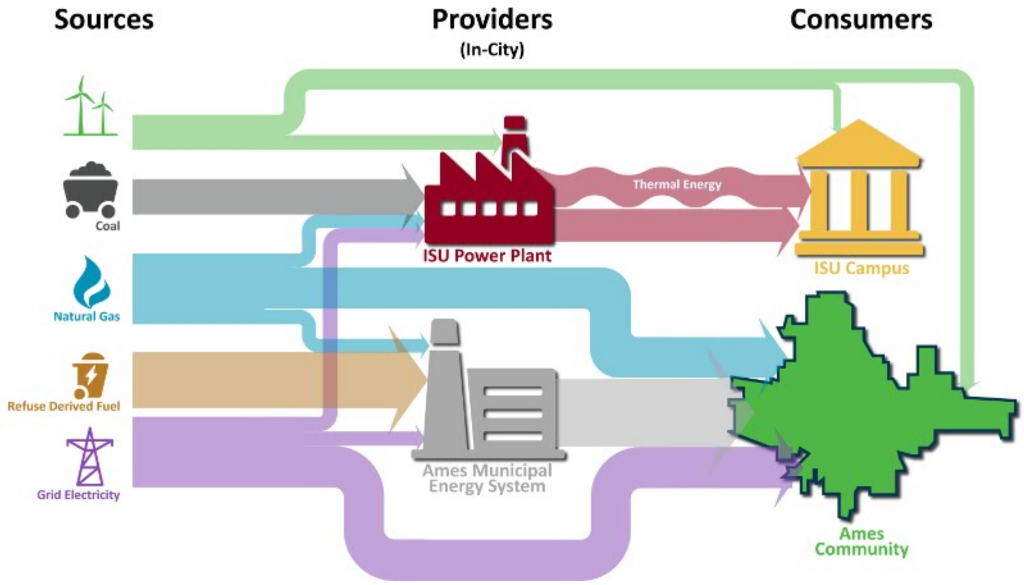


Figure 6 illustrates the energy flows for the City. The University's combined heat and power plant burns coal and natural gas from Alliant Energy to provide electricity, heating, and chilled water to the campus. It also distributes electricity to the campus from the Midcontinent Independent System Operator (MISO) and from wind and solar facilities. The City's Ames Municipal Electric System burned coal (up through 2016), natural gas (starting in 2016), and refuse derived fuel to produce electricity. Alliant Energy provides natural gas throughout the City and a limited amount of electricity. Two other utilities, Consumers Electric and Midland Power Cooperative, distribute very small amounts of electricity within the City that they purchase from the Central Iowa Power Cooperative (CIPCO).

3.2. Category shares

Figure 7 graphically portrays citywide energy consumption and GHG emissions by the primary categories in 2018. The largest emission source is electricity (39% of the total). Note that the coal used by the University's combined heat and power plant has its own category (20% of total emissions).[12] The energy output of the plant is primarily for heating and cooling. The 2 pie charts also demonstrate the tremendous carbon content of coal since it provided 15% of the energy in 2018 but resulted in 20% of the total emissions. On-road transportation accounted for 13% of total citywide emission in 2018 and the other 3 categories (airport, solid waste, potable water, and wastewater treatment) together totaled 4%.

[12] The analysis captures the plant's emissions associated with natural gas consumption and purchased electricity in their respective energy categories.

The line charts graph changes over the 3 Study Years. The most dramatic change in GHG emissions is for electricity, and for energy consumption it is natural gas (more detail below).

Figure 7: Citywide Category Shares

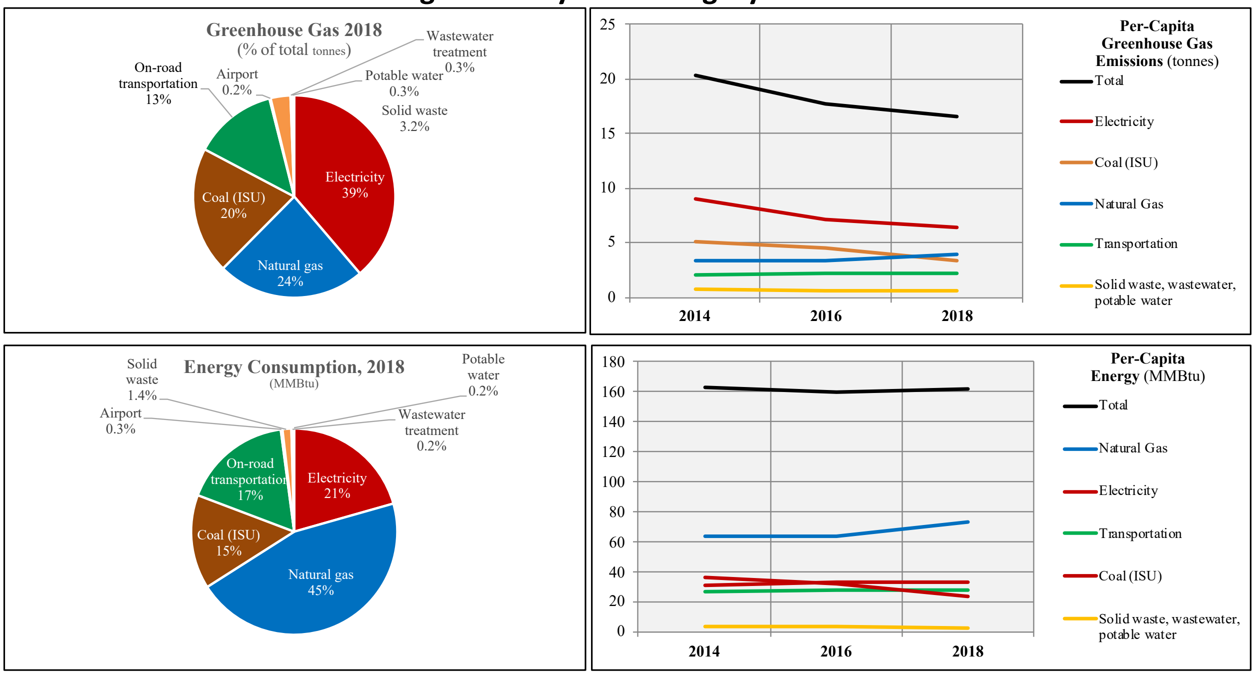
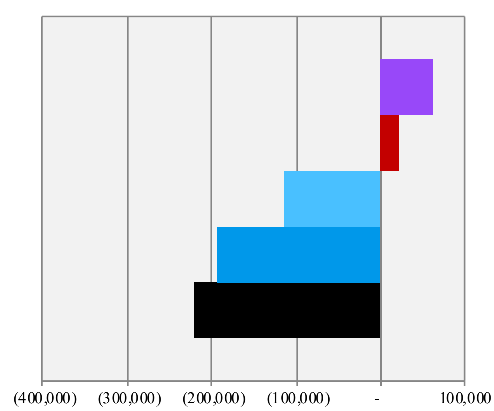


Figure 8: Citywide Causes for Emission Change, 2018 Compared to 2014



	Tonnes
Net increased emissions in other categories	61,944
Increased electricity consumption	20,931
Reduced coal at ISU CHP plant	(112,791)
Gas replaced coal at AMES	(192,302)
Total	(222,218)

Figure 8 illustrates the 4 factors that had the greatest effect on decreasing GHG emissions in 2018 compared to 2014:

- Most importantly, natural gas replaced coal at the AMES, which avoided 192,300 tonnes in 2018.
- Secondly, reduced coal consumption in the University's combined heat and power plant saved 112,800 tonnes.
- Increased consumption in the Electricity category resulted in 20,900 additional tonnes.
- Figure 8 also shows the cumulative effect. When combined with the 61,900 additional tons (from net increases from other categories, primarily natural gas consumption that was 19% higher in 2018 than in 2014), the net total equals the 222,200-tonne decrease in emissions.

3.3. Electricity

It's best to review the effects of electricity consumption when the data are viewed as follows:

- Focus on the change in the data over time.
- Because utility emission factors have declined, examine change assuming the emissions factors were unchanged from the Base Year, 2014 in this case.
- Since population and households change, focus on the per-capita and per-household changes.
- Since energy consumption, and especially electricity consumption, is the dominant source of GHG emissions, focus on the category's share of total citywide emissions.

3.3.1. Electric utilities: Four utilities provide electricity within the City. In 2018, Ames Municipal Electric System (AMES) provided 88% of the power and Alliant Energy, plus very small amounts from Consumers Energy and Midland Power Cooperative, provided 5%. Consumers Energy and Midland Power Cooperative distribute power they purchase from the Central Iowa Power Cooperative (CIPCO). These percentages do not include the power generated by Iowa State University's combined heat and power (CHP) plant, but they do include the power the University purchased from the Midcontinent Independent System Operator (MISO) via the City (7% of the total power).

3.3.2. Electricity consumption and greenhouse gas emissions: Citywide consumption for the Electricity category totaled 645,400 MWh in 2014 and 679,100 MWh in 2018 (an 8% increase as measured in Btus).[13] The associated GHG emissions were 584,000 tonnes in 2014 and 422,100 tonnes in 2018, a -28% decrease.

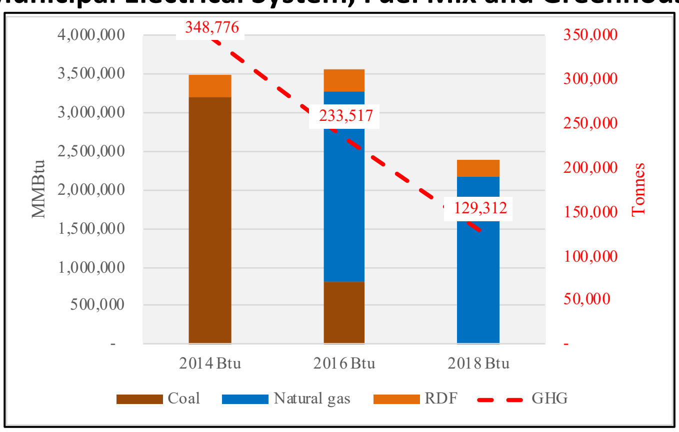
[13] Consistent with the ICLEI Protocols, electricity data in the Electricity category excludes electricity consumed as part of the solid waste, wastewater treatment, and potable water categories. Electricity consumption in those categories is counted with those categories, not in the Electricity category.

Emissions from electricity constitute the largest single component of the total citywide GHG footprint; namely, 39% of the total in 2018 (Figure 7).

Per-capita consumption was 10,000 and 10,300 kWh in 2014 and 2018 respectively. The consumption rate in 2018 was 3% higher than in 2014. Per-capita emissions were 9.0 and 6.4 tonnes in 2014 and 2018 respectively, which makes the 2018 per-capita emissions rate -29% lower than in 2014. The declines in total and per-capita GHG emissions overpowered the increase in consumption because of the significant decrease in the GHG emissions factors, especially that of the AMES. The citywide blended emission factor in 2018 was -31% lower than in 2014 (this includes all sources of power). Had the emission factors not decreased, consumption would have resulted in an additional 192,300 tonnes in 2018.[14]

3.3.3. Ames Municipal Electric System, Alliant Energy, and emission factors: The electricity emission factors for produced power at the Ames Municipal Electric System (AMES) have declined significantly (-43%) since 2014, primarily due to the replacement of coal with natural gas (Figure 9).

Figure 9: Ames Municipal Electrical System, Fuel Mix and Greenhouse Gas Emissions



The GHG emission factor for grid electricity the AMES distributed was -9% lower in 2018 than in 2014. The blended emission factor for both in-plant produced and purchased power at the AMES in 2018 was -34% lower in 2018 compared to the 2014 blended rate.

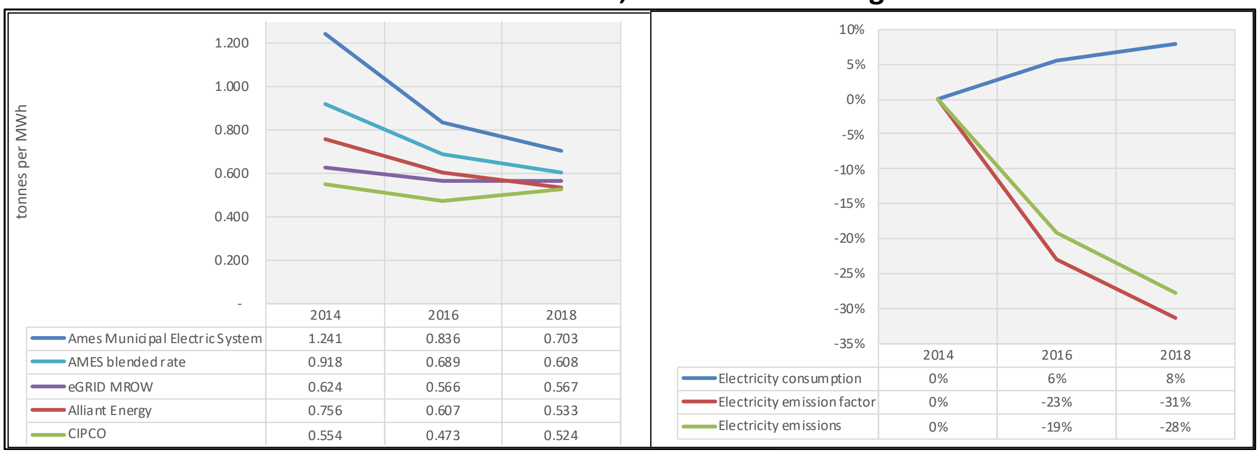
The chart on the left of Figure 10 graphs the emission factors over the 3 Study Years for the 3 electric utilities and the electric grid (eGRID). It shows how the emission factors for the AMES and Alliant Energy have declined (Alliant Energy's

[14] The calculations in the above 2 paragraphs are available in the accompanying "Takeaways" pages and the spreadsheet analysis.

emission factor was -29% lower in 2018) while those for eGRID (MROW)[15] and CIPCO have remained relatively flat.

The chart on the right shows the slight percentage increase in consumption in the Electricity category over the 3 Study Years (8%). The other 2 lines illustrate the significant percentage decreases in the citywide blended emission factor for the 6 sources of power (the AMES, Alliant Energy, ISU, Consumers Energy, Midland Cooperative, and purchased grid electricity), and the resultant percentage decrease in emissions for the Electricity category. The combination of all consumption in the Electricity category yielded a combined emission rate in 2018 that was -31% lower in 2018 compared to 2014.

Figure 10: Electricity Emission Factors, Electricity Consumption, and Greenhouse Gas Emissions; and Percent Change 2014-2018



	2014	2016	2018
Ames Municipal Electric System	1.241	0.836	0.703
AMES blended rate	0.918	0.689	0.608
eGRID MROW	0.624	0.566	0.567
Alliant Energy	0.756	0.607	0.533
CIPCO	0.554	0.473	0.524

	2014	2016	2018
Electricity consumption	0%	6%	8%
Electricity emission factor	0%	-23%	-31%
Electricity emissions	0%	-19%	-28%

3.3.4. Iowa State University electricity emissions: Iowa State University (ISU) operates a combined heat and power (CHP) plant that provides steam heat (50% of output), chilled water (28% of output), and electricity (27% of output) to the ISU campus and various other facilities (2019 data). For the College of Veterinary Medicine (Vet Med), the University purchases natural gas through Alliant Energy and electricity from the City.

The University prepared a GHG assessment that showed that energy consumption (electricity and natural gas) accounted for 99% of the footprint. Campus vehicles, potable water, and sanitary sewers accounted for the remaining 1% of the energy consumption. Greenhouse gas emissions were 452,000 tonnes in 2014 and 387,000 tonnes in 2018, which was -14% lower than in 2014. The primary reason for the decrease was the replacement of significant amounts of coal combustion with natural gas at the University's CHP plant. The University is proceeding with planning to convert the remaining coal-fired boilers at the power plant to burn natural

[15] City staff determined that the most appropriate emission factor to use for grid-purchased electricity is via the Environmental Protection Agency's eGRID site.

gas. The proposed project, which will result in a positive effect on future emissions, is subject to final University and Board of Regents approvals.

3.4. Citywide Natural Gas and Coal Consumption [16]

Alliant Energy provides natural gas service to the University, the City, and the AMES. The associated GHG emissions in 2018 were 258,100 tonnes, 3.9 tonnes per-capita. The per-capita emissions were 19% higher in 2018 than in 2014. The increase is due to the replacement of coal with natural gas at the AMES (21.8 million more therms) and the University's combined heat and power plant (6.9 million more therms). Also, the new Water Treatment Plant required more natural gas than the old facility; however, the amount, 35,400 additional therms, was dwarfed by the increases at the other 2 facilities.

The combined impact of replacing coal with natural gas had a profound effect on decreasing citywide emissions. Focusing on the 2 coal users, emissions from the AMES and the University's CHP plant were -63% and -15% lower in 2018 than in 2014 respectively. These reduced GHG tonnes equal 105% of all of the GHG reductions in the 2018 Study Year compared to the 2014 Study Year. They more than offset the increased emissions from other categories. As mentioned above, the University is proceeding with planning to convert the remaining coal-fired boilers at the power plant to burn natural gas, which will have a net positive effect even though it will require increased natural gas usage.

Examining these important improvements on a per-capita basis makes the effects even more compelling. Per-capita emissions for the 2 facilities in 2018 were -31% lower than in the Base Year, 2014.

Because the electricity emission factor for on-site production at the AMES is significantly lower than that for the grid electricity the plant purchases, producing (rather than purchasing) more power will lower citywide GHG emissions.

Key findings, Electricity and Natural Gas:

- Compared to 2014, citywide consumption for the Electricity category was 8% higher in 2018 and per-capita electricity consumption was 3% higher.
- The blended emission factor for the Electricity category was -31% lower in 2018, and the resultant emissions for the Electricity category were -28% lower than in 2014.
- Overall, per-capita emissions were -29% lower than in 2014.
- Had the GHG emission rate not declined, electricity consumption would have resulted in an additional 192,300 tonnes in 2018. With this *normalized* emissions

[16] All of the calculations in this section are available in the accompanying "Takeaways" pages and the spreadsheet analysis.

factor, per-capita GHG emissions in 2018 would have increased to 9.3 tonnes instead of the actual 6.4 tonnes.

- Emissions from electricity constitute the largest single component of the total city GHG footprint. Emissions in 2018 were 39% of the City's total.
- The complete replacement of coal with natural gas in the AMES and partial replacement at the University's CHP plant had a profound effect on decreasing citywide emissions. Nearly all of the GHG reductions in the 2018 Study Year compared to the 2014 Study Year were due to these replacements.
- Replacing coal with natural gas resulted in emissions from consumption for the Natural Gas category that were 19% higher in 2018 than in 2014.
- The anticipated elimination of coal use at the University's combined heat and power plant will have a net positive effect, even though it will result in increased natural gas usage.

3.5. Citywide Transportation

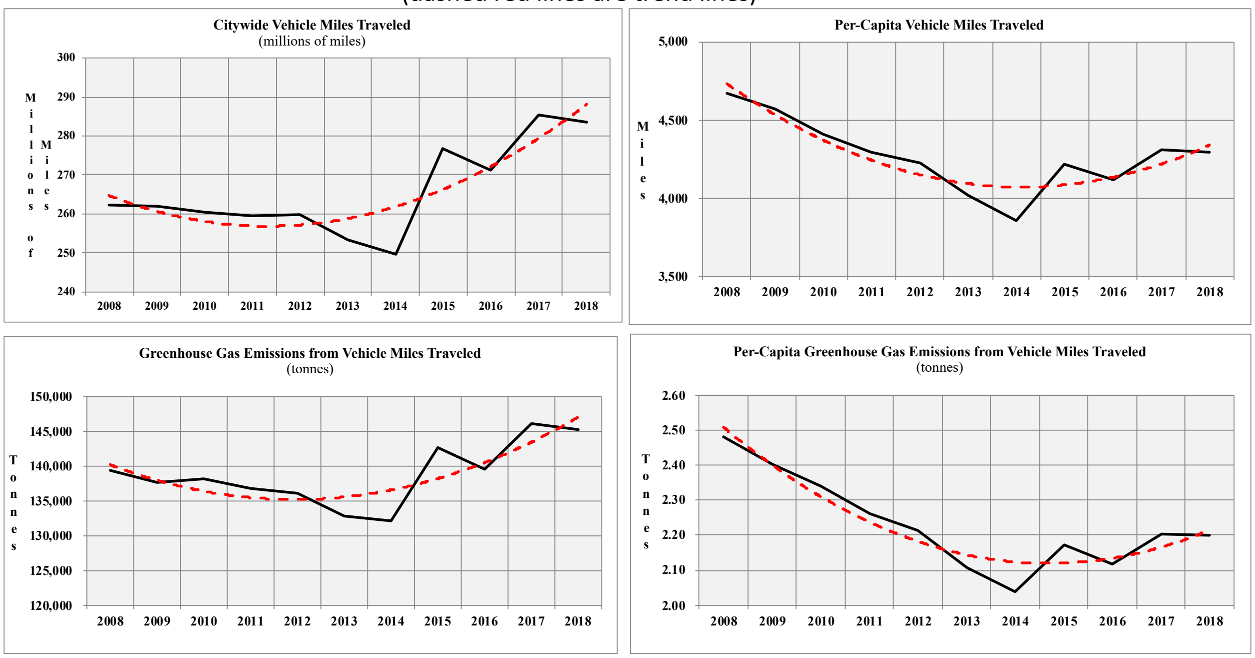
3.5.1. On-road transportation: The ICLEI Community Protocol defines on-road transportation as a Required Activity. The procedure to estimate GHG emissions stemming from on-road transportation depends on two key factors: determining vehicle miles traveled (VMT) and the vehicle emission rate (in metric tons of GHG per million VMT). The Iowa Department of Transportation provides annual VMT for Iowa cities and counties. The Federal Highway Administration provides data for estimating the national vehicle emission rates for a particular year based on a number of factors including VMT and fuel consumption rates by vehicle and fuel types.

Figure 11 illustrates long-term trends using data from 2008 to 2018. Note that none of the vertical axes start at zero. This is to highlight the changes over time. The red dashed lines are trend lines to smooth out annual fluctuations. Also note that VMT in 2014 was at an unusually low level.

Total vehicle miles traveled (VMT) within the City in 2018 was 283.4 million miles in 2018, 13% higher than in 2014. In 2018, the per-capita rate was 4,300 miles, which was 11% higher than in 2014 (refer to the top 2 charts).

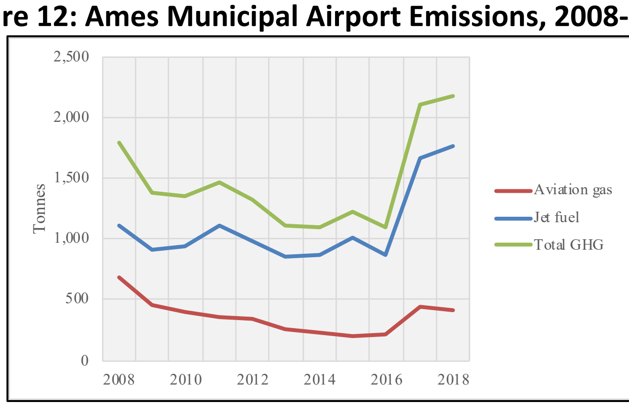
The associated GHG emissions were 10% higher in 2018 and per-capita emissions were 8% higher than in 2014. The primary reason for the percentage differences between increases in VMT and their associated GHG emissions is that the GHG emission rate declined. The biggest factors accounting for this decline are the steadily increasing efficiency of the vehicle fleet, and the shift to cleaner fuels, including fuels with ethanol and biodiesel blends.

Figure 11: Citywide On-Road Transportation, 2008-2018
(dashed red lines are trend lines)



3.5.2. Ames Municipal Airport: Emissions associated with operations at the Ames Municipal Airport totaled 2,100 tonnes in 2018, which were almost twice as high as in 2014. The increase was primarily due to increased use of jet fuel instead of aviation gas. Jet fuel consumption in 2018 was 101% larger than in 2016 (refer to Figure 12).

Figure 12: Ames Municipal Airport Emissions, 2008-2018



The transportation category accounted for 15% of total citywide emissions in 2018. Emissions in 2018 were 11% higher than in 2014; however, on the per-capita basis, they were 9% higher than in 2014.

Key findings, Transportation:

- Total VMT within the City in 2018 was 283.4 million miles, 4,300 miles per-capita. VMT was 13% higher in 2018 compared to 2014, but the associated GHG emissions were 10% higher primarily due to more efficient vehicles and cleaner fuels. Per-capita GHG emissions for on-road travel in 2018 were 8% higher than in 2008.

- Emissions associated with the Ames Municipal Airport constitute a very small portion of overall citywide emissions. However, emissions were almost twice as high as in 2014 primarily due to increased use of jet fuel instead of aviation gas.
- Total emissions in the transportation category were 11% higher than in 2014 but only 9% higher on a per-capita basis.
- Transportation accounted for 15% of total citywide emissions in 2018.

3.6. Solid Waste Management

The City accepts municipal solid waste (MSW) from throughout most of Story County. For the Citywide Inventory, only waste generated within the City is counted, so the data are apportioned on a population basis (the City population is about 67% of the County's population).[17] The City processes the burnable fraction into refuse derived fuel (RDF) at its Chantland Resource Recovery Plant, and then burns the fuel at the AMES to generate electricity. After converting the burnable portion of the MSW into RDF at the Chantland Resource Recovery facility, the City sends the remainders to the Boone County landfill and the City landfills waste that is inappropriate for processing into RDF.

On average over the 3 Study Years, 43% of the waste collected from Story County was processed into RDF and 4% was recovered metals for recycling. The rest (53%) included waste that was sent directly to the Boone County landfill plus the rejects from RDF processing.

3.6.1. Refuse derived fuel amounts and emissions: The energy to run the RDF plant is not large; however, the ICLEI Protocol requires the emissions associated with the combustion of the RDF be allocated to the solid waste category. These emissions are significant considering every ton of RDF resulted in 0.92 tonnes of GHG emissions in 2014. The emission rate varies somewhat and was 0.84 tonnes per ton in 2018, a -8% decline.

The Chantland RDF plant sent fewer tons of RDF to the power plant in 2018 due to extended down time of one of the boilers at the AMES power plant that year. Thus, emissions associated with RDF combustion were -47% lower in 2018 compared to 2014. City staff explained that subsequent years will likely see RDF combustion amounts returning to the historic, pre-2018 levels.

3.6.2. Landfilling: Due to the down time in 2018 at the power plant, rejects were 6% higher in 2018 than in 2014. The City landfills waste that is inappropriate for processing into RDF. This RDF waste stream was 133% higher in 2018 than in

[17] For the City Operations Assessment, 100% of the emissions are counted as Scope 1 emissions.

2014. The combined landfilled streams (RDF rejects plus direct-to-landfill waste) were 66% higher in 2018 than in 2014.

The Boone County landfill does not have a methane recapture system so the associated GHG emissions are higher than if it did (1.3 tonnes per ton of waste). Per-capita, landfill emissions from citywide waste in 2018 were about 800 pounds, which were 59% higher than in 2014, again due to the downtime at the Ames power plant. Emissions from landfilled waste comprised 72% of the total emissions in 2018 for the waste management category.

3.6.3. Citywide, per-capita comparisons: It helps to *normalize* waste management on a per-capita basis according to Iowa's waste management hierarchy.[18] The following calculations do not account for recycled materials because citywide and countywide data on amounts were not available. According to the ICLEI Protocol, no additional GHG emissions are associated with recycled waste so its exclusion has no effect on the GHG or energy calculations.[19] Total per-capita waste was 1,050 lbs. in 2018, -8% less than in 2014. Per-capita emissions from overall waste management were 1,150 pounds in 2018, which was -6% lower than in 2014. The decrease in emissions was smaller than the decrease in the amount of waste managed. The primary reasons for the decrease were 1) a greater reliance on landfilling (which has a higher GHG emission rate compared to RDF production and combustion, and 2) the decrease in the emission rate for RDF combustion.

The left chart in Figure 13 below shows the per-capita amounts of waste that were processed into RDF and the amounts sent to a landfill. The right chart shows the per-capita emissions from processing and combusting the RDF and landfilling the RDF rejects and non-processed waste.

3.6.3.1. RDF amounts and emissions: In 2018, 320 lbs. per-capita were converted to RDF and burned, a -49% drop from 2014 (Figure 13, left chart). RDF comprised 30% of the total waste stream in 2018. Per-capita, RDF emissions from citywide waste in 2018 totaled 330 pounds, which were -54% lower than in 2014, again due to the downtime at the power plant (Figure 13, right chart).

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[18] Iowa state law (Section 455B.301A(1)) establishes the hierarchy as:

a. Volume reduction at the source.
b. Recycling and reuse.
c. Combustion with energy recovery.
d. Other approved techniques of solid waste management including but not limited to combustion for waste disposal and disposal in sanitary landfills.

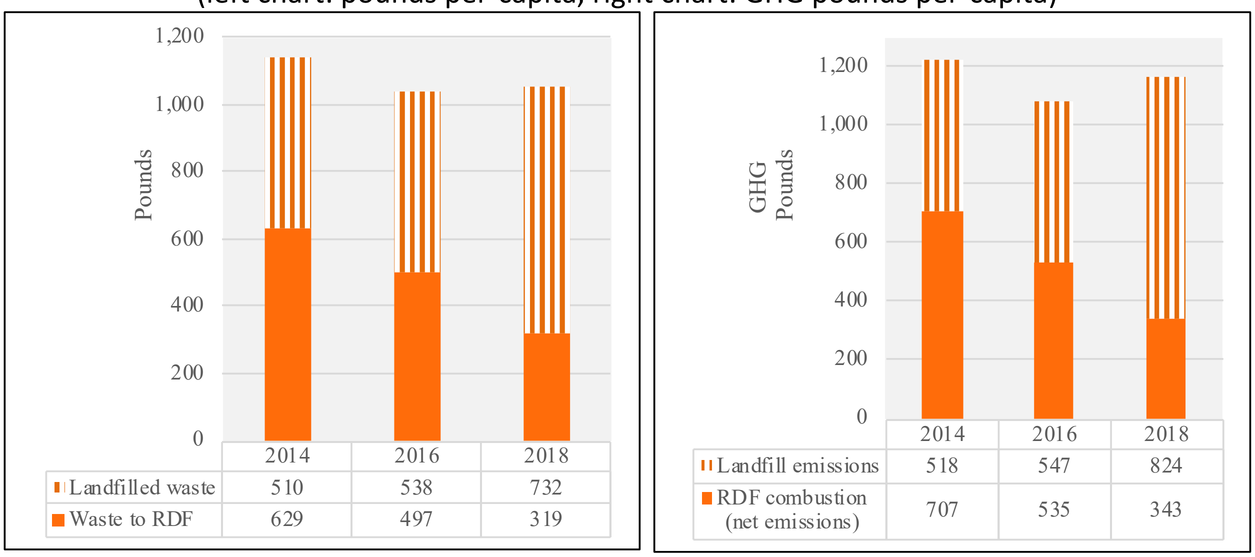
[19] The Iowa Department of Natural Resources tracks waste tonnages dumped at the state's landfills but not the amounts of recycled materials. Emission associated with recycled waste are captured via the energy consumption at recycling facilities and the transportation-related sources.

Emissions from RDF production and combustion comprised 29% of the total emissions in 2018 for the waste management category.

3.6.3.2. Landfill amounts and emissions: In 2018, 730 pounds of municipal solid waste per-capita were landfilled, which was a 43% increase over 2014 (Figure 13, left chart). Landfilling comprised 70% of the total waste stream in 2018. Per-capita, landfill emissions from citywide waste in 2018 were 820 tonnes, which were 59% higher than in 2014, again due to the downtime at the power plant (Figure 13, right chart). Emissions from landfilled waste comprised 71% of the total emissions in 2018 for the waste management category.

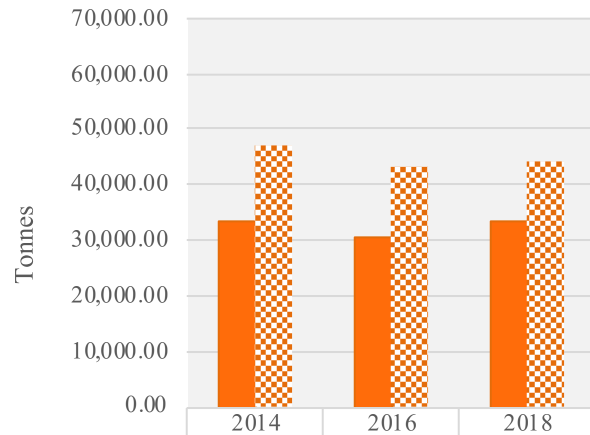
Figure 13: Citywide Solid Waste Management

(left chart: pounds per-capita, right chart: GHG pounds per-capita)



3.6.4. Emissions from RDF versus landfilling: It is useful to compare *theoretical* GHG emissions from the production and combustion of RDF versus landfilling MSW. To permit a more "apples-to-apples" comparison, emissions from RDF combustion should be reduced by the emissions that, had the AMES not burned the RDF, other fuels would have had to replace the RDF. On an average over the 3 Study Years, the per-ton, GHG emission rate for landfilling was 48% higher than the net rate for RDF production and combustion (as mentioned above). The theoretical landfill-only scenario would have resulted in an additional 12,400 tonnes of emissions on average annually, a 38% increase. This would have nearly doubled the actual total waste management emissions. The above chart on the bottom in Figure 14 compares the actual citywide tonnes of GHG emissions to the theoretical emissions had 100% of the waste been landfilled.

Figure 14: Citywide Solid Waste Management, Theoretical Avoided Emissions



	2014	2016	2018
Actual emissions	33,182	30,499	33,434
Theoretical 100% landfilling	46,865	43,337	44,050

Key Findings, Solid Waste Management:

- **RDF emissions:** Emissions associated with the combustion of the RDF result in an average of 0.86 tonnes of GHG per ton of RDF.
- **Landfilled waste:** Landfilled waste, which includes waste sent directly to the landfill and rejects from the RDF process, were 6% higher in 2018 compared to 2014. This was due to boiler repairs at the AMES power plant.
- **Landfill emissions:** The landfill does not have a methane recapture system so the associated GHG emissions are higher than if it did. Landfill emissions are 1.27 tonnes per ton, which is 48% higher than the average for processing waste into RDF and combusting it for electricity.
- **Emissions from RDF versus landfilling:** A theoretical landfill-only scenario would have resulted in an additional 12,400 tonnes of emissions in 2018, which would have been a 38% increase over the actual emission average over the 3 Study Years.

3.7. Wastewater and Infiltration

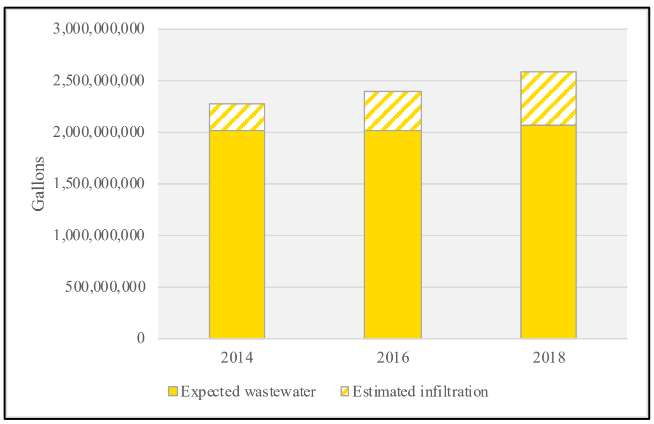
The City's Water Pollution Control plant provides wastewater treatment to over 25,000 homes and businesses within Ames.[20] Per-household wastewater flows have remained fairly steady. The 2018 amount is only 4% higher than the 2014 amount. In 2018, wastewater treatment resulted in 2,800 tonnes of GHG emissions, which equaled only 4% of total city operations emissions. Emissions in 2018 were -2% lower than in 2014, due primarily to the decrease in electricity emission factors.

[20] The facility is located outside City boundary with electrical service from Consumers Energy. The City provides service to the National Centers for Animal Health located within the City, the National Animal Disease Center and National Veterinary Services Laboratories, and the Iowa State University campus. It also services the City of Kelley but the flows are extremely minor and the calculations do not segregate these flows.

In addition to GHG emissions from energy consumption, the management of digester gas (methane) from the treatment process is another small source of emissions, less than 2 tonnes, because the equipment is covered. The City uses the methane to power dual-fuel generators that generate electricity for the plant and heat for the anaerobic digesters. When the process produces more methane than can be used (e.g., construction projects may limit operational abilities), the methane is flared.

Significant amounts of inflow and infiltration (I & I) are occurring in the system. The difference between water pumped and the wastewater flows represents some of this I & I water. Adding in the estimated exterior use of water indicates 252 million gallons of infiltration in 2014, 380 million in 2016, and 515 million in 2018 (Figure 15). According to staff, sump pump connections to the sanitary sewer system, known as inflow, produce a significant amount of flowage. This type of connection is not allowed but it still exists in older parts of the City. The City completed an I & I study in 2014 and has been addressing this issue.

Figure 15: Estimate of Groundwater Infiltration to Wastewater System



Inlow and infiltration estimates comprise significant portions of the total wastewater flows, and they are increasing: 11% in 2014, 16% in 2016, and 20% in 2018. According to City staff, the pipes are in a continuous state of deterioration, but there are also projects in place each year to reduce this deterioration and to replace pipes beyond repair.

Part 4: City Operations Assessment

4.1. Overview of Greenhouse Gas Emissions and Energy Consumption

This part of the Technical Report examines GHG emissions associated with City-owned facilities. The City owns and operates 15 buildings, 10 park and recreation facilities with electric and sometimes gas meters, 6 facilities for producing potable water and 20 wells, and numerous streetlights. Furthermore, the City owns and operates 4 other major public facilities: the Ames Municipal Electric System, the Chantland Resource Recovery plant, the Water Pollution Control facility (wastewater treatment), and the Ames Municipal Airport.

4.1.1. City operations greenhouse gas emissions and energy consumption: Figure 16 lists the GHG emissions for City operations for the 3 Study Years and percent changes from the 2014 base Study Year. Figure 17 does the same for energy consumption. Total GHG emissions in 2018 were -53% lower than in 2014, a total reduction of -89,100 GHG tonnes, and energy consumption was -30% lower than in 2014.

Figure 16: City Operations, Greenhouse Gas Emissions (tonnes)

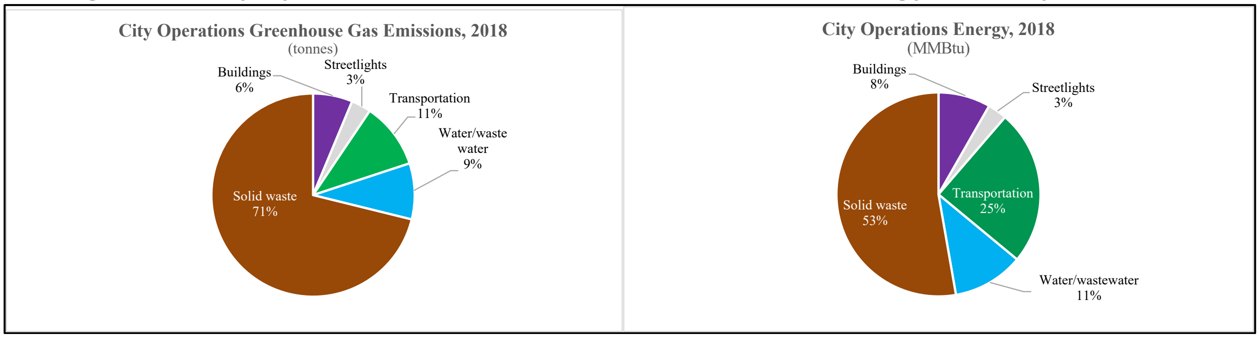
Category	2014	2016	Change	2018	Change	Change from 2014
Buildings and facilities	6,164	4,880	-21%	4,528	-7%	-27%
Streetlights and signals	3,956	3,077	-22%	2,269	-26%	-43%
Transportation	6,401	6,580	3%	7,570	15%	18%
Water	4,079	3,214	-21%	3,584	12%	-12%
Wastewater	2,883	2,539	-12%	2,836	12%	-2%
Solid waste	52,535	47,056	-10%	51,268	9%	-2%
Subtotal	**76,018**	**67,346**	**-11%**	**72,056**	**7%**	**-5%**
Per-capita	1.17	1.02	-13%	1.09	7%	-7%
Per-household	3.23	2.67	-17%	2.83	6%	-12%
Ames Municipal Electric System	313,692	206,717	-34%	112,873	-45%	-43%
Grand total	**389,710**	**274,063**	**-30%**	**184,929**	**-33%**	**-53%**

Figure 17: City Operations Energy Consumption (MMBtu)

Category	2014	2016	Change	2018	Change	Change from 2014
Buildings and facilities	33,783	31,284	-7%	34,601	11%	2%
Streetlights and signals	14,709	15,248	4%	12,743	-16%	-13%
Transportation	87,065	89,393	3%	103,257	16%	19%
Water	17,317	17,730	2%	24,471	38%	41%
Wastewater	22,500	23,203	3%	22,567	-3%	0.3%
Solid waste	318,702	306,711	-4%	220,603	-28%	-31%
Subtotal	**494,076**	**483,570**	**-2%**	**418,242**	**-14%**	**-15%**
Per-capita	7.63	7.34	-4%	6.34	-14%	-17%
Per-household	21.0	19.2	-8%	16.4	-14%	-22%
Ames Municipal Electric System	3,180,022	3,253,788	2%	2,169,795	-33%	-32%
Grand total	**3,674,099**	**3,737,357**	**2%**	**2,588,036**	**-31%**	**-30%**

Figure 18 illustrates the shares of emissions and energy consumption for the city operations categories. Notable is the large role of the Solid Waste category. While consisting of only 3% of the citywide emissions (refer to Figure 7), it represents 71% of city operations GHG emissions and 53% of the energy consumption.

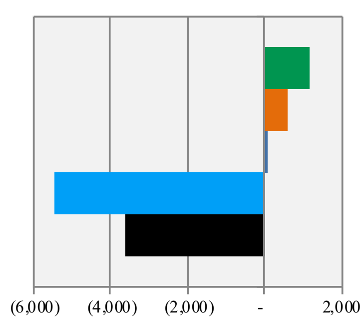
Figure 18: City Operations Greenhouse Gas Emissions and Energy Consumption, 2018



4.1.2. **Primary reasons for the change in emissions:** Figure 19 shows increased emissions for the Transportation, Solid Waste, and Natural gas categories. However, the emissions reductions below resulted in the large decrease in overall city operations emissions:

- The largest factor, which accounted for 94% of the reduction, was replacing coal with natural gas at the AMES. The AMES was responsible for 313,700 GHG tonnes in 2014 and 112,900 tonnes in 2018, a -64% decrease.
- Secondly, the AMES produced less electricity, which accounted for 6% of the total reduction.

Figure 19: City Operations, Primary Causes for Emission Change, 2014-2018

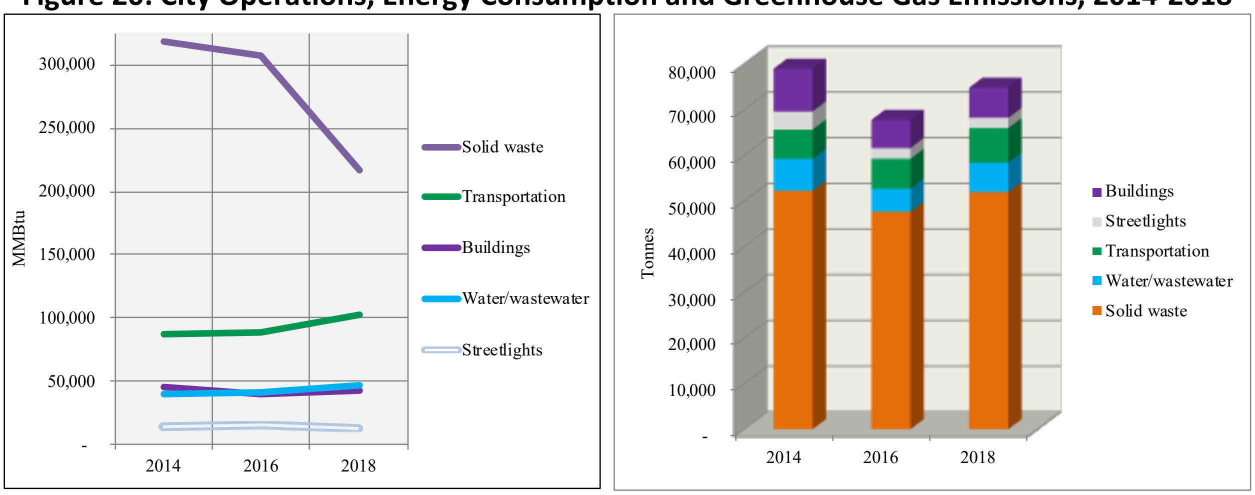


	Tonnes
Transportation	1,169
Solid waste	587
Natural gas	123
Gas replaced coal at AMES	(5,451)
Total	(3,571)

4.1.3. Excluding the Ames Municipal Electric System:[21] The ICLEI protocol classifies the emissions for the AMES as Scope 1 for city operations emissions even though the plant serves the entire City. [22] Since GHG emissions from the AMES were about 3 times larger than for the rest of the City's facilities combined, it helps to compare changes with the AMES excluded. Excluding the AMES, Figures 17 and 18 show that energy consumption for City facilities totaled 418,200 MMBtu in 2018, which was -15% lower than in 2014. Greenhouse gas emissions totaled 72,100 tonnes in 2018, which was -5% lower than in 2014.

In most cases in this analysis when energy consumption data that include electricity is lower than in the 2014 Base Study Year, the associated GHG emissions are lower still because of reductions in the electricity emission factors. However, this is not the case with the City Operations Assessment (when the AMES is excluded) due to changes in the management of solid waste. The shift in 2018 of more waste to landfilling instead of processing it into RDF and burning it (as described in sections 3.6 ad 4.6) resulted in a large decrease in energy consumption (-31% lower than in 2014) but only a -2% decrease in GHG emissions. Since solid waste management accounts for an average of 70% of total city operations emissions, this change in management methods had a major effect.

Figure 20: City Operations, Energy Consumption and Greenhouse Gas Emissions, 2014-2018



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[21] Some of the comparisons are not included in the summary tables in Figures 16 and 17. They can be found in the "CO Summary" and "Takeaways" sheets in the accompanying spreadsheet analysis.

[22] The calculation for the energy and GHG emissions for the AMES are somewhat involved to avoid double counting: 1) Purchased power from the electrical grid is not included. 2) The electricity consumed by City-owned facilities must be subtracted from the total electricity produced on site; but only the portion of the entire output of plant. For example, 43% of the total electricity distributed by the system in 2014 was produced on site. To avoid double counting, 43% of the emissions from City facilities (about 3,200 tonnes) must be subtracted from on-site produced power. Since Consumers Energy and Alliant Energy provide power to 2 City facilities, their consumption can't be included in this subtraction. 3) The emissions associated with RDF combustion are counted in the solid waste category (13,200 tonnes) so they must be subtracted.

The 2 charts in Figure 20 depict energy consumption and GHG emissions over the 3 Study Years. The AMES is excluded on both charts because its emissions would swamp any detail of the other emissions. The section below provides details. Wastewater treatment is addressed in the above Citywide Inventory portion of this analysis, Section 3.7.

4.1.4. Per-capita and normalized comparisons: It is valuable to examine per-capita data since many City services are dependent on the size of the City's population. Per-capita GHG emissions (excluding the AMES) were 1.17 tonnes in 2014 and 1.09 tonnes in 2018, a -7% decrease. As with citywide emissions, the decreases in the blended electricity emission factor reduced GHG emissions for the City Operations Assessment. Had the emission factors remained at the 2014 levels, there would have been an additional 5,700 tonnes emitted in 2018, and the per-capita emission rate would have been 1.18 tonnes. Furthermore, the per-capita decrease would have been virtually unchanged, instead of the actual -7% difference with 2014 levels.

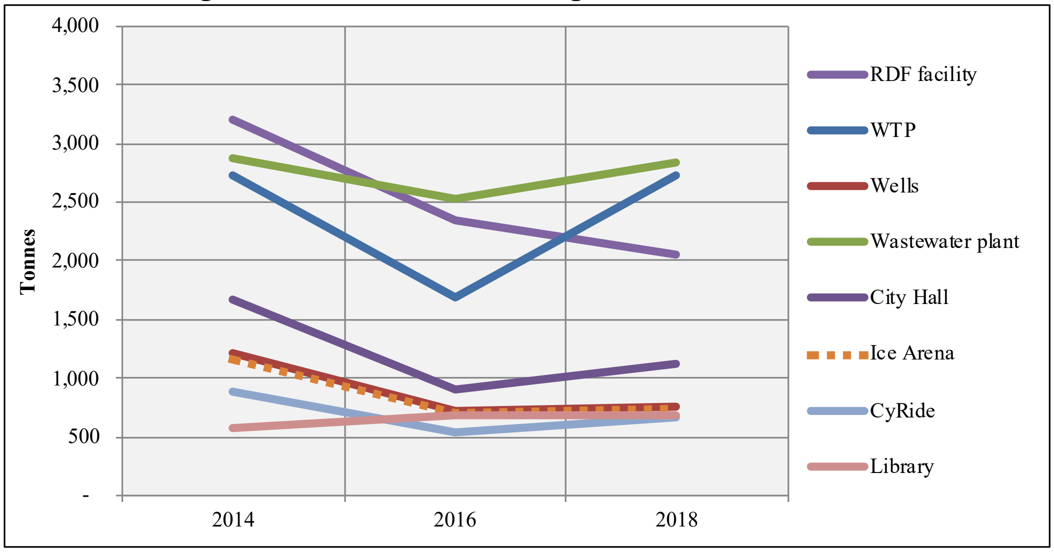
4.2. Buildings and Facilities

In 2018, the Building and Facilities category (including park buildings and facilities) were the source of 4,500 tonnes of GHG emissions, which equaled 6% of total city operations emissions. Emissions were -27% lower than in 2014. In 2018, energy consumption for the category was 34,600 MMBtu, which was 2% higher than in 2014. The reduced electricity emission factors account for the significant decline in GHG emissions in spite of the slight increase in consumption.

The analysis examined monthly energy consumption data for 20 facilities that are relatively large energy consumers. The examination did not reveal any substantive changes or anomalies over the 3 Study Years for the City's Buildings Facilities category.

Figure 21 illustrates the changes in emissions for 8 of the City's largest facilities. It ignores the Ames Municipal Electric System because its emissions are out of scale with these included facilities.

Figure 21: Emissions From Large Facilities, 2014-2018



4.3. Streetlights and Signals

In 2018, the streetlights and signals category resulted in 2,300 tonnes of GHG emissions, which equaled 3% of total city operations emissions. Emission were -43% lower than in 2014, again, largely due to the reduced electricity emission factor and conversions to LED fixtures.

4.4. City Operations Transportation

The transportation category includes 4 subsections: Liquid fuels (operations in the Public Works Department and vehicle use by the Police, Fire, and other departments), CyRide, contracted services, and airport emissions. These activities resulted in 7,600 tonnes of GHG emissions in 2018, which equaled 11% of total city operations emissions (excluding the AMES). Emission were 18% higher than in 2014 (Figure 22). The large increase in transportation emissions is almost exclusive due to increased emissions at the Ames Municipal Airport. As mentioned above in the Citywide Inventory portion of this report (Section 3.5.2.), the increase is due to the dramatic increase in jet fuel consumption in 2017 and again in 2018. Consumption in 2018 was twice as large than in 2016.

The City has contracts with private firms to complete projects that are normally a part of city operations (e.g., road-resurfacing, plowing, and street sweeping). According to the ICLEI Protocol, these are Scope 3 emissions, which are normally not grouped with Scope and 1 and 2 emissions. However, the Protocol provides flexibility regarding these matters. The key principle is whether the City has substantive control over an emission source and whether inclusion in the assessment will be useful to the City. Including contractor services is consistent with both of these principles. While the City may not require the private contractors it hires to reduce their emissions, it does control the degree it relies on contracts rather than in-house resources.

Figure 22: City Operations, Transportation Emissions

Category (tonnes)	2014	2016	Change	2018	Change	Change from 2014
Liquid fuels	1,566	1,433	-8%	1,506	5%	-4%
CyRide	3,744	4,009	7%	3,899	-3%	4%
Contractor services	39	94	144%	91	-4%	135%
Ames Municipal Airport	1,052	1,044	-1%	2,074	99%	97%
Total	**6,401**	**6,580**	**3%**	**7,570**	**15%**	**18%**

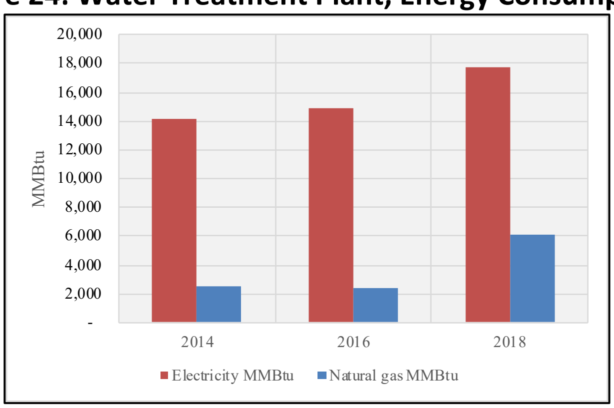
4.5. Potable Water

4.5.1. System-wide energy consumption and the new Water Treatment Plant: The City brought a new water treatment plant on line in 2017. It is much larger than the former facility, which affects energy consumption, especially for space heating and ventilation. Compared to 2014, electricity consumption for the entire potable water system (including wells, water towers, and pump stations) was slightly higher in 2016 (4%). However, consumption jumped an additional 974,000 kWh higher in 2018, a 20% increase over the 2016 level (Figure 23). The opening of the new Water Treatment plant accounted for the increase.

Figure 23: Water Treatment System, Energy Consumption and Energy Efficiency[23]

Category	2014	2016	% Change	2018	% Change	Change Since 2014
Water Treatment Plant (MMBtu)	0	326		9,578		
Water Meter Division (MMBtu)	12,196	12,230	0.3%	10,027	-18%	-18%
Wells, towers, and other facilities (MMBtu)	5,084	5,138	1%	4,833	-6%	-5%
Total MMBtu	17,280	17,694	2%	24,438	38%	41%
Electricity	14,640	15,275	4%	18,274	20%	25%
Natural gas	2,640	2,420	-8%	6,164	155%	134%
Gallons (millions)	2,069	2,197	6%	2,192	-0.2%	6%
Btu per gal.	8.35	8.05	-4%	11.15	38%	33%

Figure 24: Water Treatment Plant, Energy Consumption



Compared to 2014, natural gas consumption for the potable water system was slightly lower in 2016 (-8%), but, like the jump in electricity consumption, the

[23] Excludes minor volumes of diesel consumption for back-up generators.

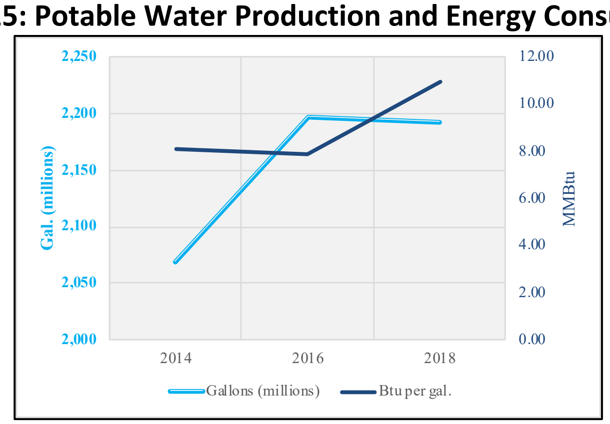
new Water Treatment Plant with it's much larger HVAC needs resulted in significantly higher gas consumption in 2018, an increase of 35,200 therms, which was a 155% increase over the 2016 level (Figure 24). Another reason for the increased energy consumption at the new facility is that the water clarifiers for the old facility were located outside and they are inside the new plant. These are large, open-topped tanks that hold well water that enters at 50-55 degrees. Having them inside may be causing an increased heating demand as the system continuously loses heat to the water throughout the heating season.

Looking at overall changes in the system showed that electricity usage in 2018 was 25% higher than in 2014 and natural gas consumption was 134% higher (refer to Figure 23 and 24). Figure 23 also shows that it took more energy per gallon in 2018 compared to 2014, 33% more.

4.5.2. Per-capita and per-household water consumption: Water consumption directly affects the energy needed to produce it. However, GHG assessments rarely go beyond analyzing that energy. Nonetheless, water consumption is an important environmental indicator for sustainable drawdowns of ground water.

In 2018, the production of potable water resulted in 3,600 tonnes of GHG emissions, which equaled 5% of total city operations emissions (excluding AMES). Emission were -12% lower than in 2014. Potable water production and per-capita consumption was very stable over the 3 Study Years. Per-capita consumption in 2018 was only 4% larger than in 2014. Although total water production was stable, the energy needed to produce the water increased over time (Btu per gallon). The efficiency was about 8.2 Btu per gal. in 2014 and 2016, but jumped to 11.1 in 2018, a 36% increase. The larger energy demands of the new Water Treatment Plant are essentially responsible for these increases.

Figure 25: Potable Water Production and Energy Consumption

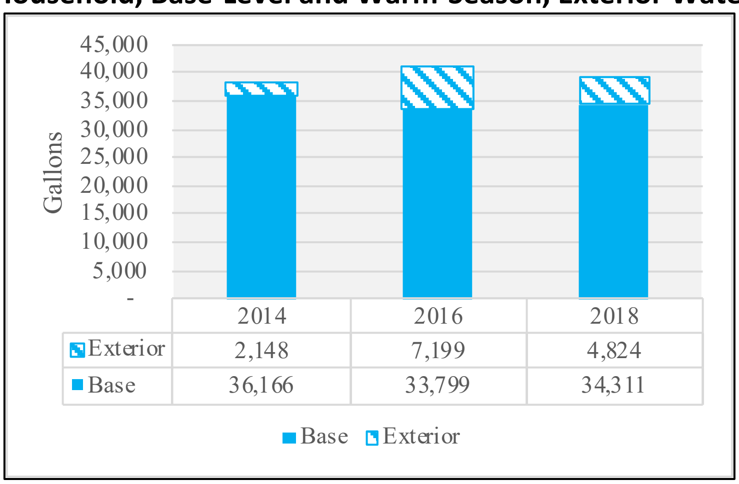


Even though natural gas consumption for the main facilities was 138% higher in 2018 than in 2014, gas provides only a small portion of the total energy. This relatively large increase was dwarfed by electricity consumption, which comprised 69% of total consumption in 2018.

4.5.3. Warm season water consumption: Warm season consumption (May through Sep., 154 days) includes exterior water use for irrigation primarily, as well as car washing, swimming pools, etc. The monthly water data provided total consumption during the warm season and the rest of the year when virtually all water consumption eventually drains to the sanitary sewer system (i.e. the "cold season"). The daily, per-capita consumption during the cold season is a predictor of year-round base-level consumption. The difference between this year-round base level and the total warm-season consumption provides an estimate of exterior water use during the warm season. On a per-capita basis during the warm season, exterior daily consumption was 5.1 gal. in 2014, jumped to 17.8 gal. in 2016, and settled to a midpoint of 12.1 gal. in 2018.

The changes in per-capita exterior consumption are dramatic. Compared to 2014, the amount in 2016 was 252% higher and the 2018 amount was 138% higher (Figure 26). The City provides meters to customers who only use the water for exterior purposes (such as irrigation). The changes to those amounts paralleled the changes in the total exterior amounts.

Figure 26: Per-Household, Base-Level and Warm-Season, Exterior Water Consumption



4.5.4. Irrigation and weather: Warm season precipitation was virtually identical in 2014 and 2016; however, cooling degree days in 2016 were 36% higher than in 2014, which helps explain the greater need for irrigation in that year. Compared to 2014 and 2016, cooling degree days were much higher in 2018 (54% above the 30-year average) but so was precipitation (28% higher than average), which tempered the need for additional irrigation.

Figure 27: Per-Household, Daily, Exterior Consumption Versus Rain and Heat Score

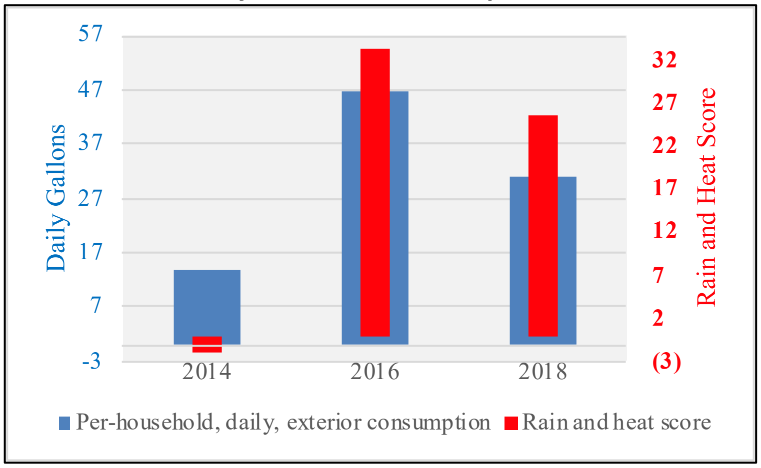


Figure 27 uses a “Rain and Heat Score” to compare the demand for irrigation with exterior water consumption. The score combines the percentage variation from 30-year *normals* for warm season precipitation and temperature. The hotter and dryer the summer, the higher the score, and vice versa. The very high score for 2016 corresponds to the very high per-household consumption. As the score dropped in 2018, so did the exterior consumption.

Key findings, Potable Water:

- The opening of the new Water Treatment plant accounted for substantial increases in energy consumption. An analysis of the changes from 2016 to 2018 for the potable water system showed that electricity usage was 20% higher than in 2016 and natural gas consumption in 2018 was 155% higher than in 2016.
- Although total water production was stable, the energy needed to produce the water increased over time (33% larger in 2018 than in 2014). The larger energy demands of the new Water Treatment Plant are essentially responsible for these increases.
- In spite of the large increase in energy consumption, emissions from potable water production were stable over the 3 Study Years, again, primarily due to the -31% reduction in the blended electricity emission factors in 2018 compared to 2014.
- The changes in per-capita exterior water consumption are dramatic. Compared to 2014, the amount in 2016 was 252% higher and the 2018 amount was 138% higher than in 2014. The summer of 2016 was much hotter than in 2014, which helps explain the very high rate in 2016.

4.6. Solid Waste Management

As noted above, emissions associated with solid waste management in the Citywide Inventory (Section 3.6.) are restricted to those generated within the City’s geographic boundary. It’s not the same for the City Operations Assessment. Since the City is essentially in the solid waste management business (for nearly all of Story County), all associated emissions are Scope 1 emissions.

In 2018, emissions from operating the Chantland RDF plant, plus those from combusting the RDF and the fugitive landfill emissions from RDF rejects and non-processes waste, totaled 52,300 tonnes. This amount was slightly lower than in 2014 for the same main reason explained in the Citywide Inventory: the boiler upgrade at the AMES, which reduced the available capacity for burning RDF.

Appendix A
Primary Sources

City data: City staff
ICLEI protocols: https://icleiusa.org
Demographics:

- **Population:** Census Bureau, Annual Estimates of the Resident Population for Incorporated Places in Iowa: April 1, 2010 to July 1, 2019 (https://www.census.gov/data/tables/time-series/demo/popest/2010s-total-cities-and-towns.html).
- **Employment:** U.S. Census Bureau, 2006-2010 American Community Survey; U.S. Census Bureau, 2007-2011 American Community Survey; U.S. Census Bureau, 2008-2012 American Community Survey; U.S. Census Bureau, 2009-2013 5-Year American Community Surveys

Weather:

- **Heating and cooling degree days:** https://www.cityofames.org/government/departments-divisions-a-h/electric/the-energy-guy/degree-day
- Source: https://www.usclimatedata.com/climate/ames/iowa/united-states/usia0026/2019/12
- **Precipitation**: https://www.usclimatedata.com/climate/ames/iowa/united-states/usia0026/2019/12

Electricity and natural gas:

- **eGRID:** http://www.epa.gov/cleanenergy/energy-resources/eGRID/index.html
- **Ames Municipal Electric System:** City of Ames.
- **Alliant Energy:** Mason Adams, Key Account Manager, 1284 XE Place | Ames, IA 50014, Office: (515) 268-3430 | Cell: (515) 689-0679, masonadams@alliantenergy.com
- **Consumers Energy:** Gail Hull, Member Services Manager, 641-754-1651 / 800-696-6552 extension 104, Fax: 641-752-5738, ghull@consumersenergy.coop.
- **Midland Power Cooperative:** Norm Fandel, Senior V.P. of Business Operations, nfandel@ENOVUS.coop, o. 515-386-4111, c. 515-370-0992
- **Global warming potentials:** https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator-revision-history

Transportation:

- **Vehicle miles traveled:** Iowa Department of Transportation. https://iowadot.gov/maps/data/vehicle-miles-traveled
- **Converting VMT to GHG emissions:** Federal Highway Administration, https://www.fhwa.dot.gov/policyinformation/statistics/ (insert year)

Municipal solid waste:

- **Waste characterization:** 2017 Iowa Statewide Waste Characterization Study, Iowa Dept. of Natural Resources, 12/28/207
- **Emission factors:** Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM), Organic Materials Chapters, Exhibit 1-10, U.S.

Environmental Protection Agency Office of Resource Conservation and Recovery, February 2016

- **MSW combustion emission factors:** EPA, "Emission Factors for Greenhouse Gas Inventories," https://www.epa.gov/sites/production/files/2018-03/documents/emission-factors_mar_2018_0.pdf

Conversion factors:

- **Greenhouse Gases Equivalencies Calculator - Calculations and References:** https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references
- **Emission factors:** US EPA Center for Corporate Climate Leadership, https://www.epa.gov/sites/production/files/2018-03/documents/emission-factors_mar_2018_0.pdf.
- **Emission factor for coal:** https://www3.epa.gov/ttnchie1/ap42/ch01/final/c01s01.pdf

Iowa State University: All consumption and emission data is from the Iowa State University GHG Emission Factors report. Provided in December 2019 by Jeffrey Witt (retired), former Dir. of Utility Services, jwitt@iastate.edu.

Appendix B

City of Ames Citywide Inventory, Energy Consumption and Greenhouse Gas Emissions

Categories	2014			2016			GHG Change from Prior Study Year	2018			GHG Change from Prior Study Year	MMBtu Change Since 2014	GHG Change Since 2014
	Amount [1]	MMBtu	GHG (tonnes)	Amount [1]	MMBtu	GHG (tonnes)		Amount [1]	MMBtu	GHG (tonnes)			
Electricity (MWh):													
Residential	179,881	613,754	162,831	187,064	638,261	127,490	-22%	197,736	674,675	119,079	-7%	10%	-27%
Commercial and institutional	296,453	1,011,499	271,006	311,114	1,061,521	213,721	-21%	292,820	999,100	177,347	-17%	-1%	-35%
Industrial	148,417	506,397	133,504	149,875	511,373	101,961	-24%	158,892	542,141	95,482	-6%	7%	-28%
ISU purchase of power from MISO	44,268	151,042	40,019	50,919	173,736	46,031	15%	48,370	165,038	43,455	-6%	9%	9%
ISU campus wind and solar	99	338	-	100	341	-		-	-	(0)			
Industrial subtractions (MWh): [2]	(28,102)	(249,491)	(27,388)	(26,463)	(238,730)	(20,793)		(22,599)	(182,952)	(15,563)			
MSW managed via RDF combustion	(16,885)	(211,218)	(18,740)	(15,791)	(202,319)	(14,406)		(10,973)	(143,284)	(8,899)			
Electricity for RDF production	(2,410)	(8,221)	(2,211)	(1,732)	(5,909)	(1,193)		(1,503)	(5,128)	(913)			
Electricity for wastewater treatment	(4,517)	(15,411)	(2,500)	(4,463)	(15,227)	(2,111)		(4,767)	(16,265)	(2,496)			
Electricity for potable water	(4,291)	(14,640)	(3,937)	(4,477)	(15,275)	(3,083)		(5,356)	(18,274)	(3,254)			
Net industrial	164,682	408,287	146,135	174,431	446,720	127,200	-13%	184,664	524,228	123,374	-3%	28%	-16%
Streetlights and signals	4,368	14,902	3,987	4,554	15,537	3,118	-22%	3,836	13,089	2,323	-26%	-12%	-42%
Net electricity totals	**645,384**	**2,048,442**	**583,958**	**677,163**	**2,162,039**	**471,528**	**-19%**	**679,055**	**2,211,092**	**422,123**	**-10%**	**8%**	**-28%**
Blended emission factor (tonnes per MWh)			0.905			0.696	**-23%**			0.622	**-11%**		**-31%**
Electricity as a % of total citywide amounts		19%	45%		20%	40%			21%	39%			
Added emissions with unchanged emission factors [3]			-			141,184				192,302			
Natural gas (therms):													
Residential	13,742,888	1,374,289	72,837	10,701,950	1,070,195	56,720	-22%	13,455,788	1,345,579	71,316	26%	-2%	-2%
Commercial and institutional	12,623,536	1,262,354	66,905	11,212,728	1,121,273	59,427	-11%	12,714,322	1,271,432	67,386	13%	1%	1%
Industrial	14,788,564	1,478,856	78,379	44,929,157	4,492,916	238,125	204%	44,466,217	4,446,622	235,671	-1%	201%	201%
Subtractions: [2]	(94,568)	(9,457)	(501)	(24,781,691)	(2,478,169)	(131,343)		(21,939,741)	(2,193,974)	(116,281)			
Natural gas already accounted for via electricity production at Ames Municipal Electric System	-	-	-	(24,679,410)	(2,467,941)	(130,801)		(21,817,300)	(2,181,730)	(115,632)			
Natural gas for RDF production	-	-	-	-	-	-		-	-	-			
Natural gas for wastewater treatment	(68,171)	(6,817)	(361)	(78,086)	(7,809)	(414)		(60,801)	(6,080)	(322)			
Natural gas for potable water	(26,397)	(2,640)	(140)	(24,195)	(2,420)	(128)		(61,640)	(6,164)	(327)			
Net industrial	14,693,996	1,469,400	77,878	20,147,466	2,014,747	106,782		22,526,476	2,252,648	119,390	12%	53%	53%
Net natural gas totals	**41,060,420**	**4,106,042**	**217,620**	**42,062,144**	**4,206,214**	**222,929**	**2%**	**48,696,586**	**4,869,659**	**258,092**	**16%**	**19%**	**19%**
Natural gas as a percent of total citywide amounts		39%	17%		40%	19%			45%	24%			
Coal:													
ISU coal consumption (tons)	**104,046**	**2,393,058**	**334,019**	**91,554**	**2,105,742**	**293,916**	**-12%**	**68,912**	**1,584,976**	**221,228**	**-25%**	-34%	-34%
Coal as a percent of total citywide amounts		23%	25%		20%	25%			15%	20%			
Totals for energy (electricity, natural gas, and coal)		**8,547,542**	**1,135,597**		**8,473,996**	**988,373**	**-13%**		**8,665,727**	**901,443**	**-9%**	**1%**	**-21%**
GHG totals for electricity, normalized for unchanged emission factor. [3]							-100%				-100%		-100%
Per-capita rates:													
Net electricity (MWh)	10.0	31.6	9.0	10.3	32.8	7.2	-21%	10.3	33.5	6.4	-11%	6%	-29%
Net natural gas (therms)	634	63.4	3.4	638	63.8	3.4	1%	738	73.8	3.9	16%	16%	16%
Combined electricity, natural gas, and coal (net amounts)		132.0	17.5		128.6	15.0	-14%		131.3	13.7	-9%	-1%	-22%
Total normalized for unchanged electricity rate. [2]			17.5			15.0	-14%			13.7	-9%		-22%
Energy as a percent of total citywide amounts		81%	87%		80%	85%			81%	83%			
Transportation:													
Vehicle miles traveled (thousands of miles)	249,746	1,729,239	132,096	271,255	1,825,900	139,537	6%	283,397	1,840,750	145,234	4%	6%	10%
Ames Municipal Airport		14,640	1,052		14,528	1,044	-1%		28,848	2,074	99%	97%	97%
Subtotals		**1,743,879**	**133,148**		**1,840,428**	**140,581**	**6%**		**1,869,598**	**147,308**	**4.8%**	**7%**	**11%**
Per-capita amounts (miles)	3,856	26.9	2.1	4,115	27.9	2.1	3.8%	4,294	28.3	2.2	5%	5%	9%
Transportation as a % of total citywide amounts		17%	10%		17%	12%			17%	14%			
Solid Waste:													
Electricity for RDF production (MWh)	2,410	8,221	2,211	1,732	5,909	1,193	-3%	1,503	5,128	913	-8%	-38%	-59%
Natural gas (therms)	-	-	-	-	-	-							
MSW managed as RDF (tons)	20,377	211,218	18,740	16,385	202,319	14,406	-23%	10,533	143,284	8,899	-38%	-32%	-53%
Landfill (tons)	16,524		15,222	17,738		16,348	7%	24,153		24,679	51%		62%
Subtotals		**219,439**	**36,172**		**208,228**	**31,947**	**-12%**		**148,412**	**34,491**	**8%**	**-32%**	**-5%**
Per-capita amounts (tons)	1,139	3.4	0.6	1,035	3.2	0.5	-13%	1,051	2.2	0.5	8%	-34%	-6%
Solid waste as a % of total citywide amounts		2%	3%		2%	3%			1%	3%			
Wastewater:													
Electricity (MWh)	4,517	15,411	2,500	4,463	15,227	2,111	-16%	4,767	16,265	2,496	18%	6%	0%
Natural gas (therms)	68,171	6,817	361	78,086	7,809	414	15%	60,801	6,080	322	-22%	-11%	-11%
Diesel (gal.)	2,009	272	20	1,236	167	12	-38%	1,639	222	16	33%	-18%	-18%
Emissions from combustion of digester gas (tonnes)			1.3			1.4	6%			1.5	5%		12%
Subtotals		**22,500**	**2,883**		**23,203**	**2,539**	**-12%**		**22,567**	**2,836**	**12%**	**0.3%**	**-2%**
Per-capita amounts (gal.)	34,892	0.3	0.04	36,158	0.4	0.04	-13%	38,988	0.3	0.04	12%	-2%	-3%
Wastewater as a % of total citywide amounts		0.2%	0.2%		0.2%	0.2%			0.2%	0.3%			
Potable Water:													
Electricity (MWh)	4,291	14,640	3,937	4,477	15,275	3,083	-22%	5,356	18,274	3,254	6%	25%	-17%
Natural gas (therms)	26,397	2,640	140	24,195	2,420	128	-8%	61,640	6,164	327	155%	134%	134%
Diesel (gal.)	275	37	3	267	36	3	-3%	245	33	2	12%	-11%	-11%
Subtotals		**17,317**	**4,079**		**17,730**	**3,214**	**-21%**		**24,471**	**3,584**	**12%**	**41%**	**-12%**
Per-capita daily consumption (gal.)	87			91				91					
Per-household daily consumption (gal.)	240			239				232					
Potable water as a % of total citywide amounts		0.2%	0.3%		0.2%	0.3%			0.2%	0.3%			
Citywide Totals:		**10,550,678**	**1,311,879**		**10,563,585**	**1,166,654**	**-11%**		**10,730,775**	**1,089,662**	**-7%**	**1.7%**	**-17%**
Per-capita amounts		163	20.3		160	17.7	-13%		163	16.5	-7%	0%	-18%
Per-household amounts		448	56		419	46	-17%		421	43	-8%	-6%	-23%
Normalizing Factors:													
Normalized for change in utility emission factor			1,311,879			1,307,838	-0.3%			1,281,964	-2%		-2%
Per-capita emissions normalized for unchanged utility emission factors			20.3			19.8	-2%			19.4	-2%		-4%
Other factors:													
City population	64,773			65,915			2%	66,001		0	0%		2%
Households	23,566			25,185			7%	25,470			1%		8%
Full-time-equivalent employees	33,655			34,978			4%	35,200			1%		5%
Water consumption:													
Per-capita, daily water consumption (gal.)	87			91			4%	91			0%		4%
Daily, per-household, consumption for irrigation/outdoor uses (gal.)	5.1			17.8			252%	12.1			-32%		138%
Weather:													
Precipitation variation from 6-year average	9%			9%				28%					
Percent cooling degree-days varied from 30-year "normal"	7%	Normal winter and summer temps, wetter summer, normal snowfall.		43%	Warm winter with light snowfall, very hot summer and slightly wetter.			54%	Normal winter with light snowfall, very hot and wet summer.				
Percent heating degree-days varied from 30-year "normal"	7%			-19%				2%					

Notes:

1 Electricity in MWh, natural gas in therms. Carbon dioxide equivalents (GHG) are expressed in metric tonnes, which equal 1,000 kilograms, 2,204.6 pounds, or 1.102 US tons.

2 To avoid double-counting, energy consumption and emissions associated with wastewater treatment and solid waste management are subtracted from the commercial, institutional, and industrial category.

3 Many electric utilities have reduced their emission rates (GHG per MWh). The figures show the emissions that would have been emitted had the utility emission rates stayed the same as in the first study year. ISU is not included for the reasons explained in footnote 2 on the ISU Emissions sheet.

Appendix C

Categories	2014 MMBtu	2014 GHG (tonnes)	2016 MMBtu	2016 GHG (tonnes)	GHG Change from Prior Study Year	2018 MMBtu	2018 GHG (tonnes)	GHG Change from Prior Study Year	MMBtu Change from 2014	GHG Change from 2014
	City of Ames City Operations Assessment, Energy Consumption and Greenhouse Gas Emissions									
Buildings and facilities:										
Buildings	29,591	5,624	28,339	4,500	-20%	31,352	4,154	-8%	6%	-26%
Park and recreation facilities	4,192	540	2,945	380	-30%	3,249	373	-2%	-23%	-31%
Subtotal Buildings and Facilities	**33,783**	**6,164**	**31,284**	**4,880**	**-21%**	**34,601**	**4,528**	**-7%**	**2%**	**-27%**
Percent of total (excluding AMES)	7%	8%	6%	7%		8%	6%			
Streetlights and signals:	**14,709**	**3,956**	**15,248**	**3,077**	**-22%**	**12,743**	**2,269**	**-26%**	**-13%**	**-43%**
Percent of total (excluding AMES)	3%	5%	3%	5%		3%	3%			
Transportation:										
Fleet vehicles	22,021	1,566	20,243	1,433	-8%	21,261	1,506	5%	-3%	-4%
CyRide	49,890	3,744	53,369	4,009	7%	51,940	3,899	-3%	4%	4%
Contracted services	514	39	1,253	94	144%	1,208	91	-4%	135%	135%
Ames Municipal Airport	14,640	1,052	14,528	1,044	-1%	28,848	2,074	99%	97%	97%
Subtotal transportation	**87,065**	**6,401**	**89,393**	**6,580**	**3%**	**103,257**	**7,570**	**15%**	**19%**	**18%**
Percent of total (excluding AMES)	18%	8%	18%	10%		25%	11%			
Water and wastewater:										
Potable water production (incl. diesel)	17,317	4,079	17,730	3,214	-21%	24,471	3,584	12%	41%	-12%
Wastewater treatment, energy (incl. diesel)	22,500	2,882	23,203	2,538	-12%	22,567	2,835	12%	0.3%	-2%
Emissions from combustion of digester gas (tonnes)		1.3		1.4	6%		1.5	5%		12%
Subtotal water and wastewater	**39,817**	**6,962**	**40,933**	**5,753**	**-17%**	**47,038**	**6,420**	**12%**	**18%**	**-8%**
Percent of total (excluding AMES)	8%	9%	8%	9%		11%	9%			
Solid waste management:										
Electricity	11,940	3,211	8,704	1,757	-45%	7,622	1,357	-23%		
RDF combustion	306,762	27,216	298,007	21,220	-22%	212,980	13,228	-38%	-31%	-51%
Fugitive landfill emissions		22,107		24,080	9%		36,683	52%		66%
Subtotal waste management	**318,702**	**52,535**	**306,711**	**47,056**	**-10%**	**220,603**	**51,268**	**9%**	**-31%**	**-2%**
Percent of total (excluding AMES)	65%	69%	63%	70%		53%	71%			
Subtotal (excluding the Ames Municipal Electric System):										
Totals	**494,076**	**76,018**	**483,570**	**67,346**	**-11%**	**418,242**	**72,056**	**7%**	**-15%**	**-5%**
Per-capita totals	7.6	1.17	7.3	1.02	-13%	6.3	1.09	7%	-17%	-7%
Per-household totals	21.0	3.2	19.2	2.7	-17%	16.4	2.8	6%	-22%	-12%
Emissions with an unchanged electricity emission factor		76,018		71,787	-6%		77,763	8%		2%
Per-capita with normalized emission factors		1.17		1.09			1.18			0%
City emissions as a % of citywide emissions	35%	30%	35%	23%		24%	17%			
Totals by fuels:										
Electricity	76,951	19,048	76,096	14,395	-24%	76,425	13,210	-8%	-1%	-31%
Natural gas	22,990	1,221	19,871	1,055	-14%	25,325	1,344	27%	10%	10%
Liquid fuels	87,065									
Ames Municipal Electric System (AMES)										
Scope 1 energy and emissions	3,516,056	348,781	3,579,463	233,521	-33%	2,400,812	129,313	-45%	-32%	-63%
Subtractions:										
Scope 2 electricity and emissions	-29,272	-7,872	-27,668	-5,584		-18,037	-3,212			
Subtraction of RDF combustion	-306,762	-27,216	-298,007	-21,220		-212,980	-13,228			
Total net energy and emissions	**3,180,022**	**313,692**	**3,253,788**	**206,717**	**-34%**	**2,169,795**	**112,873**	**-45%**	**-32%**	**-64%**
Percent of Grand Total	87%	80%	87%	75%		84%	61%			
Grand totals:	**3,674,099**	**389,710**	**3,737,357**	**274,063**	**-30%**	**2,588,036**	**184,929**	**-33%**	**-30%**	**-53%**
Per-capita totals	56.7	6.0	56.7	4.2	-31%	39.2	2.8	-33%	-31%	-53%
Per-household totals	155.9	16.5	148.4	10.9	-34%	101.6	7.3	-33%	-35%	-56%
Other Factors:										
City population		64,773		65,915	2%		66,001	0%		2%
Households		23,566		25,185	7%		25,470	1%		8%
FTE		597		615	3%		620	1%		4%
Weather:	Normal winter and summer temps, wetter summer, normal snowfall.		Warm winter with light snowfall, very hot summer and slightly wetter.			Normal winter with light snowfall, very hot and wet summer.				

Appendix D

Takeaways	X	Y	Z	Section [1]	Spradsheet File
The Big Story, Chapter 1: Citywide Inventory					
The picture in 2018: Electricity and natural gas consumption were the largest sources of emissions (X% and Y% of the total respectively) with coal being the next largest, Z% of the total.	39%	24%	20%	1.4.1	TC 1
The transportation sector resulted in X% of total citywide emissions, and solid waste, water production, and wastewater treatment accounted for the remaining emissions of less than Y% of the total. ISU accounted for Z% of the total citywide emissions.	14%	4%	36%	1.4.1	TC 1
The change in 2018 compared to 2014:					
Citywide GHG emissions in 2018 were X% lower than in 2014. For the Electricity category, the 2018 amount was less than in 2014 by Y%, and Natural Gas was Z% larger.	-17%	-28%	19%	1.4.1	CW 1
Compared to 2014, citywide GHG emissions in 2018 for the Transportation category were X% higher, and emissions for the Solid Waste category were Y% lower.	11%	-5%	NA	1.4.1	CW 1
The role of coal: ISU emissions were X% lower in 2018 than in 2014. Virtually all of the reduction was due to reduced emissions from its combined heat and power (CHP) plant because it replaced a lot of its coal with natural gas. The AMES replaced coal with natural gas in 2016. That resulted in an emissions factor for produced electricity that was Y% lower than in 2014. The blended emission factor for the AMES (including produced and purchased power) was Z% lower than in 2014.	-14%	-43%	-34%	1.4.2	CW 14 & CO 3
Preference for on-site power: The AMES bought 42% to 54% of the power it distributed from the electricity grid between 2014 and 2018. The grid's emissions factor was X% lower in 2018 than in 2014. Because the electricity emission factor for on-site production at the AMES is significantly lower than that for the grid electricity the plant purchases, producing (rather than purchasing) more power will lower citywide and city operations GHG emissions. The AMES was the largest but not the only source of citywide power. The calculated emission factor for the Electricity category was Y% lower in 2018 compared to 2014.	-9%	-31%	NA	1.4.2	D 1 & CW 1
Transportation: Increased VMT (X% higher) and use of jet fuel instead of aviation gas increased emissions by Y%. Transportation accounted for Z% of total emissions in 2018.	10%	11%	11%	1.4.3	CW 7 & CO 1
Emissions in sum, 2018 versus 2014 in 6 numbers: The University reduced its emissions by X%. Since electricity is of prime importance, replacing coal with natural gas had the largest impact at both the University's CHP plant and AMES because it significantly reduced the electricity emissions factors. The overall blended emission factor for the Electricity category Y% lower than in 2014. Consumption for the Electricity category (excluding consumption for the categories of solid waste, wastewater treatment, and potable water) was Z% higher in 2018 compared to 2014.	-14%	-31%	8%	1.4.4	TC 1 & CW 1
The increase in consumption in the Electricity category and the significantly decreased blended emissions factors resulted in an X% decrease in electricity emissions. Citywide, this reduction from electricity was offset somewhat by increased emissions from natural gas consumption and transportation (on-road travel and jet fuel consumption). The net result was the Y% overall reduction. On a per-capita basis, overall GHG emissions were Z% lower in 2018 than in 2014.	-28%	-17%	-18%	1.4.4	CW 1
The Big Story, Chapter 2: City Operations Assessment					
The AMES impact on emissions: The electricity produced (not purchased) by the Ames Municipal Electric System accounted for X% of total City operations emissions in 2018, and its emissions were Y% lower than in 2014. Also, the AMES produced Z% less electricity in 2018 compared to 2014. It made up the difference with purchased power from the electric grid.	61%	-43%	-32%	1.5.1	CO 1 & CO 3
The big changes:					
Solid Waste: The ICLEI Protocol requires the emissions associated with the combustion of the waste that the City processes into refuse derived fuel (RDF) be allocated to the solid waste category. These emissions are significant considering every ton of RDF resulted close to 1 tonnes of GHG emissions. The City's Chantland RDF plant sent fewer tons of RDF to the AMES power plant in 2018 due to extended down time of one of the plant's boilers that year. Thus, emissions associated with RDF combustion were -X% lower in 2018 compared to 2014. More waste was landfilled and the emission rate for the landfill is Y% higher than for RDF processing. As a result, solid waste emissions were Y% higher in 208 than in 2014. The emissions for the Solid Waste category equal Z% of total city operations emissions in 2018.	-2%	48%	NA	1.5.1	CO 1 & CW 13
Buildings and facilities accounted for X% of total emissions (excluding the AMES) in 2018. Energy consumption (Btus of electricity and natural gas) was Y% higher in 2018 compared to 2014. Electricity consumption for streetlights and signals was Z% lower due to conversions to LED fixtures.	6%	2%	-13%	1.5.2	CO 1 & CO 3

Offsetting factors: Emissions from the Transportation category, which comprise X% of total emissions in 2018 (excluding AMES), were Y% higher in 2018 than in 2014.	11%	18%		1.5.3	CO 1 & CO 3

Takeaways	X	Y	Z	Section [1]	Spradsheet File
Net effects: Changes in the water and wastewater categories did not have substantive effects on overall emissions. Excluding the AMES, total energy consumption (electricity, natural gas, liquid fuels) was X% lower in 2018 than in 2014 and total emissions were Y% lower. This is a rare instance where reductions in energy consumption were greater than in emission reductions. The reason is that the significant drop in RDF combustion decreased the associated energy. Although landfill emissions increased, they have no effect on the energy consumption calculation. If the AMES is included, emission were Z% lower in 2018 compared to 2014.	-15%	-5%	-53%	1.5.4	CO 1 & CO 3
Citywide GHG emissions and energy consumption:					
Citywide emissions: Citywide emissions totaled X tonnes in 2014 and Y tonnes in 2018, a Z tonne decrease.	1,311,879	1,089,662	(222,218)	3.1	CW 1
The X% decrease citywide emissions was exceeded on a per-capita and per-household basis, Y% lower and Z% lower respectively.	-17%	-18%	-23%	3.1	CW 1
Energy consumption: Citywide energy consumption (electricity, natural, and liquid fuels) totaled X MMBtu in 2018, Y MMBtu per-capita. Per-capita consumption was Z% lower in 2018 than in 2014.	10,730,775	163	-0.2%	3.1	CW 1
Primary factors for changes in GHG emissions: Three factors had the greatest effect on reducing GHG emissions in 2018 compared to 2014: Most importantly, replacing coal at the AMES accounted for X% of the net reduction. Reduced coal consumption at the University's CHP plant avoided Y% of the net total, and finally, reduced electricity consumption saved Z% of the net total reduction. Combined, the percentages exceed 100% because emissions in 2018 for other categories (i.e., natural gas and transportation) had higher emissions.	87%	51%	-9%	3.2	TC 1
Natural gas consumption and change in emissions: These lowered GHG emissions from reduced use of coal were offset somewhat by the increase in emissions associated with natural gas consumption (X% higher in 2018 compared with 2014). Taken together, these changes (and some minor changes in other categories) yielded the citywide, total GHG emissions in 2018 that were Y tonnes lower than in 2014.	19%	(222,218)	NA	3.2	CW 1
Citywide electricity and emission factors:					
Electric utilities: Four utilities provide electricity within the City. In 2018, Ames Municipal Electric System (AMES) provided X% of the power and Alliant Energy, plus very small amounts from Consumers Energy and Midland Power Cooperative, provided Y%. These percentages do not include the power generated by the University's combined heat and power (CHP) plant, but they do include the power the University purchased from the Midcontinent Independent System Operator (MISO) via the City. This MISO power equaled Z% of the total in 2018.	88%	5%	7%	3.3.1	CW 2
Electricity consumption: Citywide electricity consumption totaled X MWh in 2014 and Y MWh in 2018, a Z% decrease (on a Btu basis).	645,384	679,055	8%	3.3.2	CW 1
Per-capita electricity consumption was X and Y kWh in 2014 and 2018 respectively. The per-capita rate in 2018 was Z% higher than in 2014.,	9,964	10,289	3%	3.3.1	CW 1
GHG emissions from electricity: GHG emissions from electricity consumption were X tonnes in 2014 and Y tonnes in 2018, a Z% decrease.	583,958	422,123	-28%	3.3.2	CW 1
Per-capita electricity emissions were X and Y tonnes in 2014 and 2018 respectively. The rate in 2018 was Z% lower than in 2014.	9.0	6.4	-29%	3.3.2	CW 1
The reason that the percentage decrease in GHG emissions from electricity was more than the consumption decrease was the reduced electricity emission factors, especially that of the AMES. The blended emission factor in 2018 was X% lower than in 2014. Had the emission factors not decreased, the electricity consumption would have resulted in an additional Y GHG tonnes in 2018. This represents Z% of the total electricity emissions in 2018.	-31%	192,302	46%	3.3.2	CW 1
Ames Municipal Electric System: The AMES electricity emission factors have declined significantly since 2014 (X tonnes per MWh in 2014 and Y tonnes in 2018), a decline of Z% by 2018.	1.241	0.703	-43%	3.3.3	CO 3
AMES purchases and redistributes significant amounts of power from MISO (X% of total power distributed in 2018). The MISO GHG emission factor (eGRID for this analysis) was Y% lower in 2018 than in 2014. The blended emission factor for the entire AMES electrical system was Z% lower than in 2014.	60%	-9%	-34%	3.3.3	CO 6 $ CO 3
Alliant Energy: Alliant Energy's emission factor was X tonnes per MWh in 2014 and was Y% lower in 2018. The overall blended emission factor for the Electricity category was Z% lower in 2018 than in 2014.	0.756	-29%	-31%	3.3.3	CW 2
Iowa State University electricity emissions:					

The University operates a combined heat and power (CHP) plant that provides heat (50% of output), chilled water (28% of output), and electricity (27% of output) for the campus (2019 data). The University prepared a GHG assessment that showed emission in 2014 at X tonnes and Y tonnes in 2018, which was Z% lower than in 2014.	452,220	387,029	-14%	3.3.4	CW 14 & CO 3
Citywide natural gas and coal consumption:					
Alliant Energy provides natural gas service to the University, the City, and the AMES. The associated GHG emissions in 2018 were X tonnes, Y tonnes per-capita. The per-capita emissions were Z% higher in 2018 than in 2014. The increase is due to the complete replacement of coal with gas at the AMES and the partial replacement at the University's CHP plant.	258,092	3.9	19%	3.3.4	CW 1

Takeaways	X	Y	Z	Section [1]	Spradsheet File
Major new natural gas consumers: Compared to 2014, natural gas consumption increased in 2018 to replace coal at the AMES (X therms) and the University's CHP plant (Y therms). Also, the new Water Treatment Plant required more natural gas than the old facility (Z therms); however, the amount was dwarfed by the other 2 facilities.	21,817,300	6,944,933	35,412	3.3.4	CO 3
The combined impact of replacing coal with natural gas also had a profound effect on decreasing citywide emissions. Focusing on the 2 coal users, emissions from the AMES and the University's CHP plant were X and Y% lower in 2018 than in 2014 respectively. These reduced GHG tonnes equal Z% of all of the GHG reductions in the 2018 Study They more than offset the increased emissions from other categories. Continued reduction of coal use at the University’s combined heat and power plant would have a net positive effect, even if it were to increase natural gas usage.	-43%	-15%	106%	3.3.4	CO 3 & CO 2
Examining these important improvements on a per-capita basis makes the effects even more compelling. Percapita emissions for the 2 facilities in 2018 were X% lower than in the Base Year, 2014.	-26%	NA	NA	3.4	CO 2
Key findings, Electricity and Natural Gas:					
To summarize, 2018 vs. 2014: Consumption for the Electricity category was X% higher, the blended emission factor was Y% lower, and the resultant emissions were Z% lower.	8%	-31%	-28%	Key Findings	CW 1
Overall, per-capita electricity consumption was X% higher and emissions were Y% lower than in 2014. Electricity emissions in 2018 were Z% of the City’s total.	3%	-29%	39%	Key Findings	CW 1
Using a *normalized* emissions factor (i.e., assuming the rate was unchanged in 2018 from the 2014 rate), percapita GHG emissions would have increased to X tonnes in 2018 instead of the actual Y tonnes. Had the emission factors not decreased, the electricity consumption would have resulted in an additional Z GHG tonnes in 2018.	9.3	6.4	192,302	Key Findings	CW 1
Replacing coal with natural gas resulted in emissions from consumption for the Natural Gas category that were X% higher in 2018 than in 2014.	19%	NA	NA	Key Findings	CW 1
Citywide transportation:					
VMT: Total vehicle miles traveled (VMT) within the City in 2018 was X million miles, Y miles per-capita. The per-capita amount was Z% higher than in 2014.	283.4	4,294	11%	3.5.1	CW 8
GHG emissions: Since 2008, VMT has increased by X% but the associated GHG emissions only increased by Y%. The primary reason for the difference is that the GHG emission rate declined by Z%. This improvement is the result of increased vehicle efficiency--more miles per gallon.	8%	4%	-3%	3.5.1	CW 8
The GHG emissions associated with VMT in 2018 were X tonnes, Y tonnes per-capita. The per-capita amount in 2018 was unchanged from the 2014 level but Z% lower than in 2008.	145,234	0.0	-11%	3.5.1	CW 8
Municipal Airport: Emissions associated with operations at the Ames Municipal Airport totaled X tonnes in 2018, which were X% higher than in 2014 due to a large increase in the use of jet fuel instead of aviation gas. Total emissions in the transportation category were Z% higher than in 2014.	2,074	97%	11%	3.5.2	CW 7 & CO 1
The transportation category accounted for X% of total citywide emissions in 2018. Emissions in 2018 were Y% higher than in 2014; however, on the per-capita basis, they were only Z% higher than in 2014.	14%	11%	9%	3.5.2	CW 1
Solid waste management: Data for City Operations Inventory					
Scopes for solid waste management: The City processes burnable municipal solid waste (MSW) into refuse derived fuel (RDF) and burns the fuel at the AMES main plant to generate electricity. The ICLEI Protocol directs cities to account for emissions associated with solid waste management within the solid waste category even when emissions are associated with the combustion of RDF. Consistent with the ICLEI Protocol, 100% of the emissions associated with waste management are attributed to the City in the city operations assessment. The Chantland Resource Recovery plant serves all of Story County. Consistent with the ICLEI Protocol, only energy and emissions attributable to waste generated within the City are within the scope of the Citywide Inventory (which is about 2/3 as calculated on a per-capita basis).	NA	NA	NA	3.6	NA

RDF emission rates: The energy to run the Chantland Resource Recovery Plant is not large. However, the ICLEI Protocol requires the emissions associated with the combustion of the RDF be allocated to the solid waste category. These emissions are significant considering every ton of RDF resulted in X tonnes of GHG emissions in 2014. The emission rate has been declining; it was Y tonnes per ton in 2018, a Z% decline.	0.92	0.84	-8%	3.6.1	CW 1
Refuse derived fuel: The Chantland RDF plant sent fewer tons of RDF to the AMES power plant in January of 2016 (and consumed less electricity) when the power plant converted from coal to natural gas. The same is true in the Fall of 2018 due to extended down time at the power plant that year. Thus, total emissions associated with RDF combustion were X% lower in 2018 compared to 2014. When the power plant is fully operational, staff anticipate RDF combustion to be closer to the 2014 amounts.	-47%	NA	NA	3.6.1	CW 13
GHG emissions from RDF production and combustion: Primarily as a result of the decrease in the waste combusted, GHG emissions associated with RDF production and combustion decreased from X tonnes in 2014 to Y tonnes in 2018, a Z% decrease.	18,740	8,899	-53%	3.6.1	CW 13

Takeaways	X	Y	Z	Section [1]	Spradsheet File
Waste streams: On average over the 3 Study Years, X% of the waste collected from Story County was processed into RDF and Y% was recovered metals for recycling. The rest (Z%) included waste that was sent directly to the Boone County landfill plus the rejects from RDF processing.	43%	4%	53%	3.6	CW 13
Landfilled waste: After converting the burnable portion of the MSW into RDF at the Chantland Resource Recovery facility, the City sends the remainders to the Boone County landfill. Due to the down time in 2018 at the power plant, rejects were X% higher in 2018 than in 2014. The City landfills waste that is inappropriate for processing into RDF. This waste stream was Y% higher in 2018 than in 2014. The combined landfilled streams (RDF rejects plus direct to landfilled waste) were Z% higher in 2018 than in 2014.	6%	133%	66%	3.6.2	CW 13
Landfill emissions: The landfill does not have a methane recapture system so the associated GHG emissions are higher than if it did. Per-capita, landfill emissions from citywide waste in 2018 were X pounds, which were Y% higher than in 2014, again due to the downtime at the power plant. Emissions from landfilled waste comprised Z% of the total emissions in 2018 for the waste management category.	824	59%	72%	3.6.2 and 3.6.3	CW 13
Per-capita amounts of waste (for the Citywide Assessment):					
Total per-capita waste: The following calculations do not account for recycled materials because citywide and countywide data on amounts were not available. According to the ICLEI Protocol, no GHG emissions are associated with recycled waste. Total per-capita waste processed (excluding recycled waste) was X pounds in 2018, Y% less than in 2014.	1,051	-8%	NA	3.6.3	CW 13
Per-capita amounts: Per-capita emissions from overall waste management were X pounds in 2018, Y% lower than in 2018 than in 2014. The decrease in emissions was not as large as the decrease in the amount of waste managed. This is because more waste was landfilled and the emission rate for landfilling (GHG tonnes per ton of waste) is Z% higher on average than for RDF combustion over the 3 Study Years.	1,152	-6%	48%	3.6.3 & 3.6.4	CW 13
RDF: In 2018, X lbs. per-capita were converted to RDF, Y% change from 2014. RDF comprised Z% of the total waste stream in 2018.	319	-49%	30%	3.6.3	CW 13
RDF emissions: Per-capita, RDF emissions from citywide waste in 2018 were X pounds, which were Y% higher than in 2014, again due to the downtime at the power plant. Emissions from RDF production and combustion waste comprised Z% of the total emissions in 2018 for the waste management category.	328	-54%	28%	3.6.3	CW 13
Landfilling: In 2018, X lbs. per-capita were landfilled, Y% change from 2014. Landfilled waste comprised Y% of the total waste stream in 2018.	732	43%	70%	3.6.3	CW 13
Emissions from RDF versus landfilling: It is useful to compare theoretical, citywide emissions from the production and combustion of RDF versus landfilling MSW. To permit a more "apples-to-apples" comparison, emissions from RDF combustion should be reduced by the emissions that, had the AMES not burned the RDF, other fuels would have had to replace the RDF. On an average, per-ton basis for MSW over the 3 Study Years, the emission rate for landfilling is X% higher than for RDF combustion. The theoretical landfill-only scenario would have resulted in an additional Y tonnes of emissions on average over the 3 Study Years, which would have been a Z% increase over the actual emission average.	48%	(12,379)	38%	3.6.4	CW 13
Key Findings, Solid Waste:					
RDF emissions: Emissions associated with the combustion of the RDF result in an average of X tonnes of GHG per ton of RDF.	0.86	NA	NA	Key Findings	NA
Landfilled waste: Landfilled waste, which includes waste sent directly to the landfill and rejects from the RDF process, were X% higher in 2018 compared to 2014. This was due to boiler repairs at the AMES power plant.	6%	NA	NA	Key Findings	NA

Landfill emissions: The landfill does not have a methane recapture system so the associated GHG emissions are higher than if it did. Landfill emissions are X tonnes per ton, which is Y% higher than the average for processing waste into RDF and combusting it for electricity.	1.27	48%	NA	Key Findings	NA
Emissions from RDF versus landfilling: A theoretical landfill-only scenario would have resulted in an additional X tonnes of emissions in 2018, which would have been an Y% increase over the actual emission average over the 3 Study Years.	(12,379)	38%	NA	Key Findings	NA
Wastewater:					
Wastewater flows: Per-household wastewater flows have remained fairly steady. The 2018 amount is only X% higher than the 2014 amount.	4%	NA	NA	3.7	CW 12
In 2018, wastewater treatment resulted in X tonnes of GHG emissions, which equaled Y% of total city operations emissions. Emission were Z% lower than in 2014. The combustion of digester gas from the wastewater treatment facility results in a very small amount of GHG emissions.	2,835	4%	-2%	3.7	CO 1
Inflow and infiltration: Significant amounts of inflow and infiltration (I & I) are occurring in the system. The difference between water pumped and the wastewater flows represents some of this I & I water.. Adding in the estimated exterior use of water indicates X million gallons of infiltration in 2014, Y million in 2016, and Z million in 2018. According to staff, sump pump connections to the sanitary sewer system, known as inflow, produce a significant amount of flowage. This type of connection is not allowed but it still exists in older parts of the City. The City completed an I & I study in 2014 and has been addressing this issue.	251.8	379.5	514.5	3.7	CW 12

Takeaways	X	Y	Z	Section [1]	Spradsheet File
Inlow and infiltration estimates comprise significant portions of the total wastewater flows, and they are increasing: X% in 2014, Y% in 2016, and Z% in 2018. According to City staff, the pipes are in a continuous state of deterioration, but there are also projects in place each year to reduce this deterioration and to replace pipes beyond repair.	11%	16%	20%	3.7	CW 12
City operations GHG emissions and energy consumption:					
Total energy and emissions: Total energy consumption and associated GHG emissions in 2018 were X% and Y% lower than in 2014 respectively, a total reduction of Z tonnes.	-30%	-53%	-89,135	4.1.1	CO 1
Ames Municipal Electricity System (AMES): The AMES was responsible for X GHG tonnes in 2014 and Y tonnes in 2018, a Z% decrease.	313,692	112,873	-64%	4.1.2	CO 1
There are 3 primary reasons for this large decrease in emissions: The largest factor, which accounted for X% of the reduction, was replacing coal with natural gas at the AMES. The AMES burned less RDF fuel and produced Y% less electricity, which accounted for the remaining Z% of the total reduction.	94%	-35%	6%	4.1.2	CO 3
Avoiding double counting at the AMES: The calculation for the energy and GHG emissions for the AMES are somewhat involved to avoid double counting: 1) Purchased power from the electrical grid is not included. 2) The electricity consumed by City-owned facilities must be subtracted from the total electricity produced on site; but only the portion of the entire output of the AMES. For example, X% of the total electricity distributed by the system in 2014 was produced on site. To avoid double counting, X% of the emissions from City facilities (Y tonnes) must be subtracted from on-site produced power. Since Consumers Energy and Alliant Energy provide power to 2 City facilities, their consumption can't be included in this subtraction. 3) The emissions associated with RDF combustion are counted in the solid waste category so they must be subtracted (Z tonnes).	43%	(3,212)	(13,228)	Footnote in Section 4.1.3	CO 1 & CO 4
City operations GHG emissions and energy consumption (excluding the AMES):					
Overall energy consumption and GHG emissions: The energy consumption and associated GHG emissions from he AMES are of an entirely different scale than those from the other City facilities. The ICLEI protocol classifies the emissions from AMES as Scope 1 for city operations even though the AMES serves the entire City. However, it's helpful to exclude the AMES for analysis purposes. Unless otherwise noted, the emission from the AMES are excluded from the figures.	NA	NA	NA	4.1.3	NA
Total energy consumption in 2014 was X MMBtu and Y MMBtu in 2018, a Z% decrease.	494,076	418,242	-15%	4.1.3	CO 1
Total GHG emissions in 2018 were X tonnes and Y tonnes in 2018, Z% lower than in 2014.	76,018	72,056	-5%	4.1.3	CO 1
Unusual reversal of relative changes in GHG verses energy consumption: In most cases in this analysis when energy consumption data that include electricity is lower than in the 2014 Base Study Year, the associated GHG emissions are lower still because of reductions in the electricity emission factors. However, this is not the case with the City Operations Assessment (when the AMES is excluded) due to changes in the management of solid waste. The shift in 2018 of more waste to landfilling instead of processing it into RDF and burning it resulted in a large decrease in energy consumption (X% lower than in 2014) but only a Y% decrease in GHG emissions. Since solid waste management accounts for an average of Z% of total city operations emissions, this change in management methods had a major effect.	-31%	-2%	70%	4.1.3	CO 1

Per-capita GHG emissions: Per-capita GHG emissions were X tonnes in 2014 and Y tonnes in 2018, a Z% decrease.	1.17	1.09	-7%	4.1.4	CO 1
Emissions with normalized electricity emission factor: The decreases in the blended electricity emission factors reduced GHG emissions from electricity consumption. Had the emission factors remained at the 2014 levels, there would have been X additional tonnes in 2018, per-capita emission rate would have been Y tonnes, and the per-capita decrease would have been Z%.	5,708	1.18	0.4%	4.1.4	CO 1 & CO 2
Buildings and facilities:					
In 2018, the building and facilities category (including park buildings and facilities) had X tonnes of GHG emissions, which equaled Y% of total city operations emissions. Emission were Z% lower than in 2014.	4,528	6%	-27%	4.2	CO 1
In 2018, energy consumption for the category was X MMBtu. Energy consumption was Y% higher than in 2014. The decline in energy consumption was less than that for GHG emissions because of the reduced electric emission factor.	34,601	2%		4.2	CO 1
Large facilities:					
Description: The analysis examined monthly energy consumption data for 20 facilities that are relatively large energy consumers (refer to the "Large Energy Consumers" sheet).	NA	NA	NA	4.2	NA
Streetlights and signals:					
In 2018, the streetlights and signals category had X tonnes of GHG emissions, which equaled Y% of total city operations emissions. Emission were Z% lower than in 2014.	2,269	3%	-43%	4.3	CO 1
City Operations Transportation					
In 2018, the transportation category had X tonnes of GHG emissions, which equaled Y% of total city operations emissions. Emission were Z% higher than in 2014.	7,570	11%	18%	4.4	CO 1

Takeaways	X	Y	Z	Section [1]	Spradsheet File
The large increase in transportation emissions is almost exclusive due to increased emissions at the Ames Municipal Airport. The airport was responsible for the largest part of the category's GHG emissions (X%) and they were Y% larger in 2018 than in 2014. The increase is due to the dramatic increase in jet fuel consumption in 2017 and again in 2018. Consumption in 2018 was Z% larger than in 2016.	27%	97%	101%	4.4	CO 1 & CW 11
Potable water:					
System-wide energy consumption, electricity: The City brought a new water treatment plant on line in 2017. It is a much larger facility than the former facility, which affected energy consumption, especially for space heating. Compared to 2014, electricity consumption for the entire potable water system (including wells and water towers) was slightly higher in 2016 (X%). Consumption jumped an additional Y kWh higher in 2018, a Z% increase over the 2016 level. The opening of the new Water Treatment plant accounts for the increase.	4%	973,910	20%	4.5.1	CO 2
System-wide natural gas consumption: Compared to 2014, natural gas consumption for the potable water system was slightly lower in 2016 (X%), but significantly higher in 2018, an increase of Y therms, a Z% increase compared to 2014. The new Water Treatment Plant with it's much larger HVAC needs was responsible for virtually all of this additional consumption.	-8%	35,243	155%	4.5.1	CO 2 & CO 6
Change in the primary potable water facilities: Focusing on the primary facilities (excluding the wells, pump stations, and water towers), energy consumption was X% larger in 2018 than in 2014 but GHG emissions were only Y% larger. The main reason is due to the system's reliance primarily on electricity and the reduced electricity emission factor.	61%	0.1%	NA	NA	CO 4
GHG emissions and energy: In 2018, the production of potable water resulted in X tonnes of GHG emissions, which equaled Y% of total city operations emissions. Emission were Z% lower than in 2014 due to decreases in the electricity emission factors.	3,584	5%	-12%	4.5.2	CO 1
Per-capita and per-household water consumption: Potable water production was X% higher in 2016 compared to 2014, and stable in 2018. On a per-capita basis, water consumption was relatively stable. There was a small increase in 2018 compared to 2014, a Y% increase.	6%	4%		4.5.2	CO 6
Energy efficiency: Although total water production increased only slightly in 2016 compared to 2014 and remained at that level in 2018, the energy needed to produce the water increased over time (Btu per gallon). The efficiency was about X Btu per gal. in 2014 and 2016 but jumped to Y in 2018, a Z% increase. The larger energy demands of the new WTP are essentially responsible for these increases.	8.2	11.1	36%	4.5.2	CO 6
Even though natural gas consumption for the main facilities was X% higher in 2018 than in 2014, gas provides only a small portion of the total energy. This relatively large increase was dwarfed by electricity consumption, which comprised Y% of total consumption in 2018.	138%	69%	NA	4.5.2	CO 4

Warm season water consumption: Warm season consumption (May through Sep., 154 days) includes exterior water use for irrigation, primarily, as well as car washing, swimming pools, etc. The monthly water data provided total consumption during the warm season and the rest of the year when virtually all water consumption eventually drains to the sanitary sewer system (i.e. the cold season). The daily, per-capita consumption during the cold season is a predictor of year-round base-level consumption. The difference between this base level and the total warm-season consumption provides an estimate of exterior water use. On a per-capita basis during the warm season, daily exterior consumption was X gal. in 2014, jumped to Y gal. in 2016, and settled to a midpoint of Z gal. in 2018.	5.1	17.8	12.1	4.5.3	CO 6
The changes in per-capita exterior consumption are dramatic. Compared to 2014, the amount in 2016 was X% higher and the 2018 amount was Y% higher. The City provides meters to customers who only use the water for exterior purposes (such as irrigation). The changes to those amounts paralleled the changes in the total exterior amounts.	252%	138%	NA	4.5.3	CO 6
Irrigation and weather: Warm season precipitation was virtually identical in 2014 and 2016; however, cooling degree days in 2016 were 36% higher than in 2014, which helps explain the greater need for irrigation in that year. Compared to 2014 and 2016, cooling degree days were much higher in 2018 (X% above the 30-year average) but so was precipitation (Y% higher than average), which tempered the need for additional irrigation.	54%	28%	NA	4.5.4	CO 6
Total waste management emissions for City operations: Total emissions were X tonnes in 2014. Emissions dropped in 2016 (a Y% drop), but climbed again in 2018 close to the 2014 level due to the diversion of waste to landfilling instead of RDF combustion (Z tonnes).	52,535	-10%	51,268	4.6	CO 13
The above figures apply to the City Operations Inventory. Since the Citywide Assessment is based on waste generated only within the City boundaries, the above waste and emission amounts are about 2/3 of these amounts for the Citywide Assessment. The change in percentages would be the same in both analyses.	NA	NA	NA	4.6	NA

Section A2

GHG Forecast Assumptions

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City of Ames
GHG Forecast Assumptions:

Demographics:

- Population: Total Population projections through 2040 are projected based on the ongoing 2020 City of Ames comprehensive plan data with an assumed 0.75% annual growth rate in non-student population between years 2040 and 2050.
- Households: Total household counts through 2040 are projected based on the ongoing 2020 City of Ames comprehensive plan data with an assumed simple 5% growth rate between years 2040 and 2050.
- Commercial and Industrial: Total commercial and industrial building area through 2040 is projected based on the ongoing 2020 City of Ames comprehensive plan data with an assumed simple 5% growth rate between years 2040 and 2050.
- Jobs: Total commercial and industrial jobs are calculated based on maintaining the existing jobs-per-square footage factors applied to projected commercial and industrial building stock.

Climate Data

- Cooling Degree Days (CCD): Projected climate changes for the region will include increased summer temperatures. The increase in temperatures will result in an increase, or variability, in air conditioning demand. The forecast calculates annual changes in air conditioning demand based on weighted mean average projections of the RCP 8.5 climate model provided by the "Climate Explorer" tool developed by US NOAA in support of the National Climate Assessment work.* https://crt-climate-explorer.nemac.org/
- Heating Degree Days (HDD): Projected climate changes for the region will include increased winter temperatures. The increase in temperatures will result in a decrease, or variability, in building heating demand. The forecast calculates annual changes in heating demand based on weighted mean average projections of the RCP 8.5 climate model provided by the "Climate Explorer" tool developed by US NOAA in support of the National Climate Assessment work.* https://crt-climate-explorer.nemac.org/

Electricity:

- Residential: Demand is based on a per household basis and modified based on the projected Cooling Degree Days for each year, assuming 15% of electricity is used for cooling (RCP 8.5 model*). 50% of projected increased electrical vehicle usage is attributed to residential EV charging.
- Commercial and Industrial: Demand is based on a per job basis and modified based on projected cooling degree days for each year, assuming that 15% of commercial and 7.5% of industrial electricity is used for cooling. (RCP 8.5 model*). 50% of projected increased electrical vehicle usage is attributed to commercial EV charging
- All electricity emission factors are calculated using estimated emissions factors for 2030, 2040, and 2050 based on current, known, supplier commitments (Alliant Energy 80 carbon reduction by 2050 and MISO grid providers). For electrical suppliers with unknown or unestablished emission commitments, and for electricity purchased from the MISO grid, electricity emission factors are calculated based on EPA forecasts (https://fas.org/sgp/crs/misc/R45453.pdf). Estimated emissions factors are reduced 5% by 2030, 10% by 2040, and 15% by 2050.

Natural Gas:

- Residential: Demand is based on a per household basis and modified based on the projected Heating Degree Days for each year, assuming 75% of natural gas is used for heating (RCP 8.5 model*).

- Commercial and Industrial: Demand is based on a per job basis and modified based on projected heating degree days for each year, assuming that 40% of commercial and 20% of industrial natural gas is used for heating (RCP 8.5 model*).
- Natural Gas emissions factors are projected to be unchanged.

Coal:

- The University is proceeding with planning to convert the remaining coal-fired boilers at the power plant to burn natural gas, which will result in a positive effect on future emissions. The proposed project is subject to final University and Board of Regents approvals. As of the writing of this report, approvals have not yet been granted, consequently, BAU projections include maintaining current coal usage levels.

Transportation:

- Vehicle Miles Traveled is based on US Department of Transportation VMT per capita projections through 2050 (1.1% annual growth rate through 2037 and 0.8% annual growth rate from 2038 through 2050)
- https://www.fhwa.dot.gov/policyinformation/tables/vmt/vmt_forecast_sum.cfm
  Vehicle fuel use is calculated based on US Energy Information Agency projected rolling stock average fuel efficiency projections, modified to 75% projected MPG to account for heavy duty vehicle MPG share (based on US Department of Transportation data on current light duty to average all vehicle MPG ratios) https://www.eia.gov/todayinenergy/detail.php?id=31332
- Total vehicle stock is based on per household projections maintaining existing average number of vehicles per household through 2030 (2.556) and then reducing the average vehicle per household 10% through 2050 (2.3).
- Electric Vehicle Adoption: Transportation emissions assume a reduction in fossil fuel based VMT emissions based on estimated adoption rates. Adoption rates are based on State of Iowa Economic Development "Advancing Iowa's Electric Vehicle Market" report, medium scenario. Existing vehicle stock is assumed to be replaced based on an average replacement lifespan of 15 years.
  (https://www.iowaeconomicdevelopment.com/our-agency-detail-resources/6620
  https://berla.co/average-us-vehicle-lifespan/).

Solid Waste:

- Total Solid Waste handled is based on total number of households and maintaining existing volume per household and emissions factors per ton handled.

Wastewater:

- Total Wastewater handled is based on total number of households and maintaining existing volume per household and emissions factors per household.
  https://www.eia.gov/tools/faqs/faq.php?id=1174&t=1

* In the RCP 8.5 emissions scenario the radiative forcing level reaches 8.5 W/m^2 characterized by increasing greenhouse gas emissions over time. This high-emissions scenario is frequently referred to as "business as usual", suggesting that is a likely outcome if society does not make concerted efforts to cut greenhouse gas emission.

Note:

GHG emissions forecasts are not predictions of what will happen, but rather modeled projections of what may happen given certain assumptions and methodologies. GHG forecasts in this report should be interpreted with a clear understanding of the assumptions that inform them and the limitations inherent in any modeling effort.

Section A3

The City of Ames GHG Inventory - Infographic

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The City of Ames GHG Inventory - Infographic

To the left is an image of The City of Ames Greenhouse Gas Inventory infographic created to summarize the findings of the inventory. Click on the link provided or scan the QR code to access the infographic.

https://cutt.ly/9iuiakG

Section A4

Ames Climate Change Infographics

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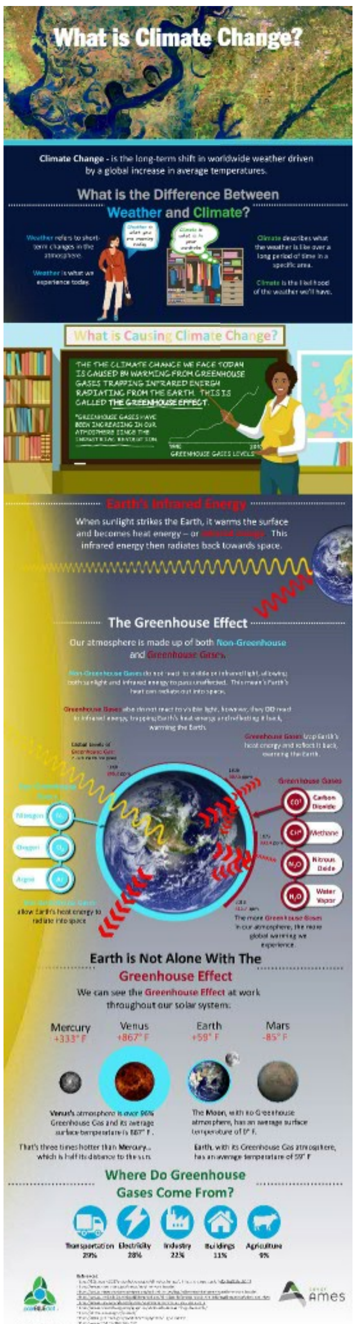
Ames Climate Change Infographics

Below are images of infographics created to support climate change communication in Ames. Click on the links provided or scan the QR code to access the infographic.

What is Climate Change?	The Climate Change Road Ahead for Ames	Climate Change Solutions for Ames
https://cutt.ly/kiudgZ7	https://cutt.ly/edYjyKK	https://cutt.ly/GiudPq4



Section A5

GHG Inventory Glossary of Terms

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GHG Inventory Glossary

A

Activity Data
Data on the magnitude of a human activity resulting in emissions or removals taking place during a given period of time. Data on energy use, metal production, land areas, management systems, lime and fertilizer use and waste arisings are examples of activity data. (IPCC)

Aerosols
A collection of airborne solid or liquid particles, with a typical size between 0.01 and 10 micrometer that reside in the atmosphere for at least several hours. Aerosols may be of either natural or anthropogenic origin. Aerosols may influence climate in several ways: directly through scattering and absorbing radiation, and indirectly by acting as cloud condensation nuclei or modifying the optical properties and lifetime of clouds. (IPCC2)

Afforestation
Planting of new forests on lands that historically have not contained forests. (IPCC2)

Air Pollutant
Any man-made and/or natural substance occurring in the atmosphere that may result in adverse effects to humans, animals, vegetation, and/or materials. (CARB)

Anthropogenic
The term "anthropogenic", in the context of greenhouse gas inventories, refers to greenhouse gas emissions and removals that are a direct result of human activities or are the result of natural processes that have been affected by human activities. (USEPA2)

Atmosphere
The gaseous envelope surrounding the Earth. The dry atmosphere consists almost entirely of nitrogen (78.1% volume mixing ratio) and oxygen (20.9% volume mixing ratio), together with a number of trace gases, such as argon (0.93% volume mixing ratio), helium and radiatively active greenhouse gases such as carbon dioxide (0.035% volume mixing ratio) and ozone. In addition, the atmosphere contains the greenhouse gas water vapor, whose amounts are highly variable but typically around 1% volume mixing ratio. The atmosphere also contains clouds and aerosols. (IPCC2)

B

Baseline Emissions
A baseline is a measurement, calculation, or time used as a basis for comparison. Baseline emissions are the level of emissions that would occur without policy intervention or without implementation of a project. Baseline estimates are needed to determine the effectiveness of emission reduction programs (also called mitigation strategies).

Base Year
The starting year for the inventory. Targets for reducing GHG emissions are often defined in relation to the base year.

Biogenic
Produced by the biological processes of living organisms. Note that we use the term "biogenic" to refer only to recently produced (that is non-fossil) material of biological origin. IPCC guidelines recommend that peat be treated as a fossil carbon because it takes a long time to replace harvested peat.

Biogeochemical Cycle
Movements through the Earth system of key chemical constituents essential to life, such as carbon, nitrogen, oxygen, and phosphorus. (NASA)

Biomass
Either (1) the total mass of living organisms in a given area or of a given species usually expressed as dry weight; or (2) Organic matter consisting of or recently derived from living organisms (especially regarded as fuel) excluding peat. Includes products, by-products and waste derived from such material. (IPCC1)

Biomass Waste
Organic non-fossil material of biological origin that is a byproduct or a discarded product. "Biomass waste" includes municipal solid waste from biogenic sources, landfill gas, sludge waste, agricultural crop byproducts, straw, and other biomass solids, liquids, and gases; but excludes wood and wood-derived fuels (including black liquor), biofuels feedstock, biodiesel, and fuel ethanol. Note: EIA "biomass waste" data also include energy crops grown specifically for energy production, which would not normally constitute waste. (EIA)

Black Carbon
Operationally defined aerosol species based on measurement of light absorption and chemical reactivity and/or thermal stability; consists of soot, charcoal and/or possible light absorbing refractory organic matter (Charlson and Heintzenberg, 1995, p. 401). (IPCC2)

C
Carbon Cycle
All parts (reservoirs) and fluxes of carbon. The cycle is usually thought of as four main reservoirs of carbon interconnected by pathways of exchange. The reservoirs are the atmosphere, terrestrial biosphere (usually includes freshwater systems), oceans, and sediments (includes fossil fuels). The annual movements of carbon, the carbon exchanges between reservoirs, occur because of various chemical, physical, geological, and biological processes. The ocean contains the largest pool of carbon near the surface of the Earth, but most of that pool is not involved with rapid exchange with the atmosphere. (NASA)

Carbon Dioxide (CO_2)
A naturally occurring gas, and also a by-product of burning fossil fuels and biomass, as well as land-use changes and other industrial processes. It is the principal anthropogenic greenhouse gas that affects the Earth's radiative balance. It is the reference gas against which other greenhouse gases are measured and therefore has a Global Warming Potential of 1. (IPCC2)\

Carbon Dioxide Equivalent (CO_2e)
A metric used to compare emissions of various greenhouse gases. It is the mass of carbon dioxide that would produce the same estimated radiative forcing as a given mass of another greenhouse gas. Carbon dioxide equivalents are computed by multiplying the mass of the gas emitted by its global warming potential.

Carbon Equivalent (CE)
A metric measure used to compare the emissions of the different greenhouse gases based upon their global warming potential. Carbon equivalents can be calculated from to carbon dioxide equivalents by multiplying the carbon dioxide equivalents by 12/44 (the ratio of the molecular weight of carbon to that of carbon dioxide). The use of carbon equivalent is declining in GHG inventories.

Carbon Intensity
The amount of carbon by weight emitted per unit of energy consumed. A common measure of carbon intensity is weight of carbon per British thermal unit (Btu) of energy. When there is only one fossil fuel under consideration, the carbon intensity and the emissions coefficient are identical. When there are several fuels, carbon intensity is based on their combined emissions coefficients weighted by their energy consumption levels. (EIA)

Carbon Sequestration
This refers to the capture of CO_2 from the atmosphere and its long term storage in oceans (oceanic carbon

sequestration), in biomass and soils (terrestrial carbon sequestration) or in underground reservoirs (geologic carbon sequestration).

Chlorofluorocarbons (CFCs)
Greenhouse gases covered under the 1987 Montreal Protocol and used for refrigeration, air conditioning, packaging, insulation, solvents, or aerosol propellants. Because they are not destroyed in the lower atmosphere, CFCs drift into the upper atmosphere where, given suitable conditions, they break down ozone. These gases are being replaced by other compounds, including hydrochlorofluorocarbons and hydrofluorocarbons, which are greenhouse gases covered under the Kyoto Protocol. (IPCC3)

City of Ames
City of Ames (capitalized) refers to the municipal government entity, its facilities, and operations.

city of Ames
city of Ames (uncapitalized) refers to all residents, businesses, and organizations living and operating within the boundaries of the city of Ames.

Citywide
Citywide refers to all residents, businesses, and organizations living and operating within the boundaries of the city of Ames.

Climate
Climate in a narrow sense is usually defined as the "average weather" or more rigorously as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period is 30 years, as defined by the World Meteorological Organization (WMO). These relevant quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system. (IPCC2)

Climate Change
Climate change refers to a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use. (IPCC2)

Cogeneration
Cogeneration is an industrial structure, installation, plant, building, or self-generating facility that has sequential or simultaneous generation of multiple forms of useful energy (usually mechanical and thermal) in a single, integrated system. (CARB)

Combined Heat and Power (CHP)
Combined heat and power is the simultaneous production of both electricity and useful heat for application by the producer or to be sold to other users with the aim of better utilisation of the energy used. Public utilities may utilise part of the heat produced in power plants and sell it for public heating purposes. Industries as auto-producers may sell part of the excess electricity produced to other industries or to electric utilities. (IPCC)

Consistency
Consistency means that an inventory should be internally consistent in all its elements over a period of years. An inventory is consistent if the same methodologies are used for the base and all subsequent years and if consistent data sets are used to estimate emissions or removals from sources or sinks. (IPCC)

Continuous Emission Monitor (CEM)
A type of air emission monitoring system installed to operate continuously inside of a smokestack or other emission source. (CARB)

Criteria Air Pollutant
An air pollutant for which acceptable levels of exposure can be determined and for which an ambient air quality standard has been set. Examples include: ozone, carbon monoxide, nitrogen dioxide, sulfur dioxide, and PM10 and PM2.5. The term "criteria air pollutants" derives from the requirement that the U.S. EPA must describe the characteristics and potential health and welfare effects of these pollutants. The U.S. EPA and CARB periodically review new scientific data and may propose revisions to the standards as a result. (CARB)

D
Deforestation
Those practices or processes that result in the change of forested lands to non-forest uses. This is often cited as one of the major causes of the enhanced greenhouse effect for two reasons: 1) the burning or decomposition of the wood releases carbon dioxide; and 2) trees that once removed carbon dioxide from the atmosphere in the process of photosynthesis are no longer present and contributing to carbon storage. (UNFCC)

Distillate Fuel Oil
A general classification for one of the petroleum fractions produced in conventional distillation operations. It includes diesel fuels and fuel oils. Products known as No. 1, No. 2, and No. 4 diesel fuel are used in on-highway diesel engines, such as those in trucks and automobiles, as well as off-highway engines, such as those in railroad locomotives and agricultural machinery. Products known as No. 1, No. 2, and No. 4 fuel oils are used primarily for space heating and electric power generation. (EIA)

E
Emissions
The release of a substance (usually a gas when referring to the subject of climate change) into the atmosphere. (USEPA1)

Emission Factor
A coefficient that quantifies the emissions or removals of a gas per unit activity. Emission factors are often based on a sample of measurement data, averaged to develop a representative rate of emission for a given activity level under a given set of operating conditions. (IPCC)

Emission Inventory
An estimate of the amount of pollutants emitted into the atmosphere from major mobile, stationary, area-wide, and natural source categories over a specific period of time such as a day or a year. (CARB)

Emission Rate
The weight of a pollutant emitted per unit of time (e.g., tons / year). (CARB)

Estimation
Estimation is the assessment of the value of an unmeasurable quantity using available data and knowledge within stated computational formulas or mathematical models.

F
Fluorocarbons
Carbon-fluorine compounds that often contain other elements such as hydrogen, chlorine, or bromine. Common fluorocarbons include chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs). (UNFCC)

Flux
Either (1) Raw materials, such as limestone, dolomite, lime, and silica sand, which are used to reduce the heat or other energy requirements of thermal processing of minerals (such as the smelting of metals). Fluxes also may serve a dual function as a slagging agent. (2) The rate of flow of any liquid or gas, across a given area; the amount of this crossing a given area in a given time. (e.g., "Flux of CO2 absorbed by forests"). (IPCC)

Fossil Fuel
Geologic deposits of hydrocarbons from ancient biological origin, such as coal, petroleum and natural gas.

Fuel Combustion
Fuel combustion is the intentional oxidation of materials within an apparatus that is designed to provide heat or mechanical work to a process, or for use away from the apparatus. (IPCC)

Fugitive Emissions
Emissions that are not emitted through an intentional release through stack or vent. This can include leaks from industrial plant and pipelines. (IPCC)

G
Geologic Farbon Sequestration
It is the process of injecting CO_2 from a source, such as coal-fired electric generating power plant, through a well into the deep subsurface. With proper site selection and management, geologic sequestration could play a major role in reducing emissions of CO_2. Research efforts to evaluate the technical aspects of CO_2 geologic sequestration are underway. (USEPA4)

Global Warming
Global warming is an average increase in the temperature of the atmosphere near the Earth's surface and in the troposphere, which can contribute to changes in global climate patterns. Global warming can occur from a variety of causes, both natural and human induced. In common usage, "global warming" often refers to the warming that can occur as a result of increased emissions of greenhouse gases from human activities. Also see Climate Change (USEPA1)

Global Warming Potential (GWP)
An index, based upon radiative properties of well-mixed greenhouse gases, measuring the radiative forcing of a unit mass of a given well-mixed greenhouse gas in the present-day atmosphere integrated over a chosen time horizon, relative to that of carbon dioxide. The GWP represents the combined effect of the differing times these gases remain in the atmosphere and their relative effectiveness in absorbing outgoing thermal infrared radiation. The Kyoto Protocol is based on GWPs from pulse emissions over a 100-year time frame. (IPCC2)

GCOM Global Covenant of Mayors:
GCoM is the largest global alliance for city climate leadership, built upon the commitment of over 10,000 cities and local governments. The alliance's mission is to mobilize and support climate and energy action in communities across the world.

Greenhouse Effect
Trapping and build-up of heat in the atmosphere (troposphere) near the earth's surface. Some of the heat flowing back toward space from the earth's surface is absorbed by water vapor, carbon dioxide, ozone, and several other gases in the atmosphere and then reradiated back toward the earth's surface. If the atmospheric concentrations of these greenhouse gases rise, the average temperature of the lower atmosphere will gradually increase. (UNFCC)

Global Protocol for Community-Scale Greenhouse Gas Emissions Inventories:
A robust, transparent and globally-accepted framework that cities and local governments can use to consistently identify, calculate and report on city greenhouse gas emissions.

Greenhouse Gas
Any gas that absorbs infrared radiation in the atmosphere. Greenhouse gases include, but are not limited to, water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrochlorofluorocarbons (HCFCs), ozone (O_3), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). (UNFCC)

Gross Domestic Product (GDP)
The sum of gross value added, at purchasers' prices, by all resident and non-resident producers in the economy, plus any taxes and minus any subsidies not included in the value of the products in a country or a geographic region for a given period, normally one year. It is calculated without deducting for depreciation of fabricated assets or depletion and degradation of natural resources. (IPCC3)

H

Halocarbons
A collective term for the group of partially halogenated organic species, including the chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), halons, methyl chloride, methyl bromide, etc. Many of the halocarbons have large Global Warming Potentials. The chlorine and bromine-containing halocarbons are also involved in the depletion of the ozone layer. (IPCC2)

Hydrocarbons
Strictly defined as molecules containing only hydrogen and carbon. The term is often used more broadly to include any molecules in petroleum which also contains molecules with S, N, or O An unsaturated hydrocarbon is any hydrocarbon containing olefinic or aromatic structures. (IPCC)

Hydrofluorocarbons (HFCs)
Compounds containing only hydrogen, fluorine, and carbon atoms. They were introduced as alternatives to ozone depleting substances in serving many industrial, commercial, and personal needs. HFCs are emitted as by-products of industrial processes and are also used in manufacturing. They do not significantly deplete the stratospheric ozone layer, but they are powerful greenhouse gases with global warming potentials ranging from 140 (HFC-152a) to 11,700 (HFC-23). (USEPA1)

I

ICLEI Local Governments for Sustainability:
A membership organization for local governments to pursue reductions in carbon pollution and improvements in advancing sustainable urban development. ICLEI's members and team of experts work together through peer exchange, partnerships and capacity building to create systemic change for urban sustainability.

Intergovernmental Panel on Climate Change
The IPCC was established jointly by the United Nations Environment Programme and the World Meteorological Organization in 1988. The purpose of the IPCC is to assess information in the scientific and technical literature related to all significant components of the issue of climate change. The IPCC draws upon hundreds of the world's expert scientists as authors and thousands as expert reviewers. Leading experts on climate change and environmental, social, and economic sciences from some 60 nations have helped the IPCC to prepare periodic assessments of the scientific underpinnings for understanding global climate change and its consequences. With its capacity for reporting on climate change, its consequences, and the viability of adaptation and mitigation measures, the IPCC is also looked to as the official advisory body to the world's governments on the state of the science of the climate change issue. For example, the IPCC organized the development of internationally accepted methods for conducting national greenhouse gas emission inventories. (USEPA1)

K

Kilowatt Hour (kWh):
A measure of electrical energy equivalent to a power consumption of 1,000 watts for one hour.

Kyoto Protocol
The Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) was adopted in 1997 in Kyoto, Japan, at the Third Session of the Conference of the Parties (COP) to the UNFCCC. It contains legally binding commitments, in addition to those included in the UNFCCC. Countries included in Annex B of the Protocol (most Organisation for Economic Cooperation and Development countries and countries with economies in transition) agreed to reduce their anthropogenic greenhouse gas emissions (carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride) by at least 5% below 1990 levels in the commitment period 2008 to 2012. The Kyoto Protocol entered into force on 16 February 2005. (IPCC2)

L

Land Use and Land Use Change
Land use refers to the total of arrangements, activities and inputs undertaken in a certain land cover type (a set of human actions). The term land use is also used in the sense of the social and economic purposes for which land is managed (e.g., grazing, timber extraction and conservation). Land use change refers to a change in the use or management of land by humans, which may lead to a change in land cover. Land cover and land use change may have an impact on the surface albedo, evapotranspiration, sources and sinks of greenhouse gases, or other properties of the climate system and may thus have a radiative forcing and/or other impacts on climate, locally or globally. (IPCC2)

LULUCF
Acronym for "Land Use, Land Use Change and Forestry", a category of activities in GHG inventories.

M

Megawatt Hour (MWH):
A measure of electrical energy equivalent to a power consumption of 1,000,000 watts for one hour.

Methane (CH_4)
A hydrocarbon that is a greenhouse gas with a global warming potential most recently estimated at 25 times that of carbon dioxide (CO_2). Methane is produced through anaerobic (without oxygen) decomposition of waste in landfills, flooded rice fields, animal digestion, decomposition of animal wastes, production and distribution of natural gas and petroleum, coal production, and incomplete fossil fuel combustion. The GWP is from the IPCC's Fourth Assessment Report (AR4).

Metric Ton
The tonne (t) or metric ton, sometimes referred to as a metric tonne, is an international unit of mass. A metric ton is equal to a Megagram (Mg), 1000 kilograms, 2204.6 pounds, or 1.1023 short tons.

Million Metric Tons (MMT)
Common measurement used in GHG inventories. It is equal to a Teragram (Tg).

Mitigation:
Actions taken to limit the magnitude or rate of long-term global warming and its related effects. Climate change mitigation generally involves reductions in human emissions of greenhouse gases.

Mobile Sources
Sources of air pollution such as automobiles, motorcycles, trucks, off-road vehicles, boats, and airplanes. (CARB)

Model
A model is a quantitatively-based abstraction of a real-world situation which may simplify or neglect certain features to better focus on its more important elements. (IPCC)

Municipal Solid Waste (MSW)
Residential solid waste and some non-hazardous commercial, institutional, and industrial wastes. This material is generally sent to municipal landfills for disposal. (USEPA1)

N
Natural Sources
Non-manmade emission sources, including biological and geological sources, wildfires, and windblown dust. (CARB)

Nitrogen Fixation
Conversion of atmospheric nitrogen gas into forms useful to plants and other organisms by lightning, bacteria, and blue-green algae; it is part of the nitrogen cycle. (UNFCC)

Nitrogen Oxides (NO_x)
Gases consisting of one molecule of nitrogen and varying numbers of oxygen molecules. Nitrogen oxides are produced in the emissions of vehicle exhausts and from power stations. In the atmosphere, nitrogen oxides can contribute to formation of photochemical ozone (smog), can impair visibility, and have health consequences; they are thus considered pollutants. (NASA)

Nitrous Oxide (N_2O)
A powerful greenhouse gas with a global warming potential of 298 times that of carbon dioxide (CO_2). Major sources of nitrous oxide include soil cultivation practices, especially the use of commercial and organic fertilizers, manure management, fossil fuel combustion, nitric acid production, and biomass burning. The GWP is from the IPCC's Fourth Assessment Report (AR4).

O
Ozone (O_3)
Ozone, the triatomic form of oxygen (O_3), is a gaseous atmospheric constituent. In the troposphere, it is created both naturally and by photochemical reactions involving gases resulting from human activities (smog). Tropospheric ozone acts as a greenhouse gas. In the stratosphere, it is created by the interaction between solar ultraviolet radiation and molecular oxygen (O_2). Stratospheric ozone plays a dominant role in the stratospheric radiative balance. Its concentration is highest in the ozone layer. (IPCC2)

Ozone Depleting Substances (ODS)
A compound that contributes to stratospheric ozone depletion. Ozone-depleting substances (ODS) include CFCs, HCFCs, halons, methyl bromide, carbon tetrachloride, and methyl chloroform. ODS are generally very stable in the troposphere and only degrade under intense ultraviolet light in the stratosphere. When they break down, they release chlorine or bromine atoms, which then deplete ozone. (IPCC)

P
Perfluorocarbons (PFCs)
A group of human-made chemicals composed of carbon and fluorine only. These chemicals (predominantly CF_4 and C_2F_6) were introduced as alternatives, along with hydrofluorocarbons, to the ozone depleting substances. In addition, PFCs are emitted as by-products of industrial processes and are also used in manufacturing. PFCs do not harm the stratospheric ozone layer, but they are powerful greenhouse gases: CF_4 has a global warming potential (GWP) of 7,390 and C_2F_6 has a GWP of 12,200. The GWP is from the IPCC's Fourth Assessment Report (AR4).

Photosynthesis
The process by which plants take carbon dioxide from the air (or bicarbonate in water) to build carbohydrates, releasing oxygen in the process. There are several pathways of photosynthesis with different responses to atmospheric carbon dioxide concentrations. (IPCC2)

Point Sources
Specific points of origin where pollutants are emitted into the atmosphere such as factory smokestacks. (CARB)

Process Emissions
Emissions from industrial processes involving chemical transformations other than combustion. (IPCC)

R
Radiative Forcing
A change in the balance between incoming solar radiation and outgoing infrared (i.e., thermal) radiation. Without any radiative forcing, solar radiation coming to the Earth would continue to be approximately equal to the infrared radiation emitted from the Earth. The addition of greenhouse gases to the atmosphere traps an increased fraction of the infrared radiation, reradiating it back toward the surface of the Earth and thereby creates a warming influence. (UNFCC)

Reforestation
Planting of forests on lands that have previously contained forests but that have been converted to some other use. (IPCC2)

Regeneration
The act of renewing tree cover by establishing young trees, naturally or artificially - note regeneration usually maintains the same forest type and is done promptly after the previous stand or forest was removed. (CSU)

Residence Time
Average time spent in a reservoir by an individual atom or molecule. Also, this term is used to define the age of a molecule when it leaves the reservoir. With respect to greenhouse gases, residence time usually refers to how long a particular molecule remains in the atmosphere. (UNFCC)

Reservoir
Either (1) a component or components of the climate system where a greenhouse gas or a precursor of a greenhouse gas is stored; or (2) Water bodies regulated for human activities (energy production, irrigation, navigation, recreation etc.) where substantial changes in water area due to water level regulation may occur. (IPCC)

Respiration
The process whereby living organisms convert organic matter to carbon dioxide, releasing energy and consuming molecular oxygen. (IPCC2)

S
Scope 1:
Scope 1 includes emissions being released within the city limits resulting from combustion of fossil fuels and from waste decomposition in the landfill and wastewater treatment plant.

Scope 2:
Scope 2 includes emissions produced outside the city that are induced by consumption of electrical energy within the city limits.

Scope 3:
Scope 3 includes emissions of potential policy relevance to local government operations that can be measured and reported but do not qualify as Scope 1 or 2. This includes, but is not limited to, outsourced operations and employee commute.

Short Ton
Common measurement for a ton in the United States. A short ton is equal to 2,000 lbs or 0.907 metric tons. (USEPA1)

Sink
Any process, activity or mechanism that removes a greenhouse gas, an aerosol or a precursor of a greenhouse gas or aerosol from the atmosphere. (IPCC2)

Solar Radiation
Electromagnetic radiation emitted by the Sun. It is also referred to as shortwave radiation. Solar radiation has a distinctive range of wavelengths (spectrum) determined by the temperature of the Sun, peaking in visible wavelengths. (IPCC2)

Source
Any process, activity or mechanism that releases a greenhouse gas, an aerosol or a precursor of a greenhouse gas or aerosol into the atmosphere. (IPCC2)

Stationary Sources
Non-mobile sources such as power plants, refineries, and manufacturing facilities which emit air pollutants. (CARB)

Sulfur Dioxide (SO_2)
A compound composed of one sulfur and two oxygen molecules. Sulfur dioxide emitted into the atmosphere through natural and anthropogenic processes is changed in a complex series of chemical reactions in the atmosphere to sulfate aerosols. These aerosols are believed to result in negative radiative forcing (i.e., tending to cool the Earth's surface) and do result in acid deposition (e.g., acid rain). (UNFCC)

Sulfur Hexafluoride (SF_6)
A colorless gas soluble in alcohol and ether, slightly soluble in water. A very powerful greenhouse gas with a global warming potential most recently estimated at 22,800 times that of carbon dioxide (CO_2). SF_6 is used primarily in electrical transmission and distribution systems and as a dielectric in electronics. This GWP is from the IPCC's Fourth Assessment Report (AR4).

T
Terrestrial Carbon Sequestration
It is the process through which carbon dioxide (CO_2) from the atmosphere is absorbed by trees, plants and crops through photosynthesis, and stored as carbon in biomass (tree trunks, branches, foliage and roots) and soils. The term "sinks" is also used to refer to forests, croplands, and grazing lands, and their ability to sequester carbon. Agriculture and forestry activities can also release CO_2 to the atmosphere. Therefore, a carbon sink occurs when carbon sequestration is greater than carbon releases over some time period. (USEPA3)

Therm:
A unit of measure for energy that is equivalent to 100,000 British Thermal units, or roughly the energy in 100 cubic feet of natural gas. Often used for measuring natural gas usage for billing purposes.

Total Organic Gases (TOG)
Gaseous organic compounds, including reactive organic gases and the relatively unreactive organic gases such as methane. (CARB)

Transparency
Transparency means that the assumptions and methodologies used for an inventory should be clearly explained to facilitate replication and assessment of the inventory by users of the reported information. The transparency of inventories is fundamental to the success of the process for the communication and consideration of information. (IPCC)

Trend
The trend of a quantity measures its change over a time period, with a positive trend value indicating growth in the quantity, and a negative value indicating a decrease. It is defined as the ratio of the change in the quantity over the time period, divided by the initial value of the quantity, and is usually expressed either as a percentage or a fraction. (IPCC)

V
VMT Vehicle Miles Traveled:
A unit used to measure vehicle travel made by private vehicles, including passenger vehicles, truck, vans and motorcycles. Each mile traveled is counted as one vehicle mile regardless of the number of persons in the vehicle.

W
Water Vapor
The most abundant greenhouse gas; it is the water present in the atmosphere in gaseous form. Water vapor is an important part of the natural greenhouse effect. While humans are not significantly increasing its concentration, it contributes to the enhanced greenhouse effect because the warming influence of greenhouse gases leads to a positive water vapor feedback. In addition to its role as a natural greenhouse gas, water vapor plays an important role in regulating the temperature of the planet because clouds form when excess water vapor in the atmosphere condenses to form ice and water droplets and precipitation. (UNFCC)

Weather
Atmospheric condition at any given time or place. It is measured in terms of such things as wind, temperature, humidity, atmospheric pressure, cloudiness, and precipitation. In most places, weather can change from hour-to-hour, day-to-day, and season-to-season. Climate in a narrow sense is usually defined as the "average weather", or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period is 30 years, as defined by the World Meteorological Organization (WMO). These quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system. A simple way of remembering the difference is that climate is what you expect (e.g. cold winters) and 'weather' is what you get (e.g. a blizzard). (USEPA1)

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