MEMO

To: Mayor Haila and Ames City Council

From: Deb Schildroth, Assistant City Manager

Date: August 27, 2021

Subject: Climate Action Plan Data, Methods, and Assumptions Manual

The Data, Methods, and Assumptions (DMA) manual is one of the Climate Action Planning (CAP) documents being provided to you for reference purposes. The DMA is technically written to outline the details of the modeling approach that the CAP consultant, SSG, will use to determine community energy and emissions benchmarks and projections.

Because the DMA primarily serves as a technical guide and reference tool, it won't be reviewed during the CAP workshop. However, it will be referred to at points during the CAP project, so it is important to ensure you have access to it.

Thank you

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Ames Climate Action Plan and Target Setting

Engagement Plan

Draft

August 2021

Purpose of this Document

The purpose of this Engagement Plan is to outline the objectives, desired outcomes, approach, and roles and responsibilities of the engagement portion of Ames' Climate Action Plan and Target Setting.

Contents

Background

Context

The City of Ames is embarking on a process to set a community greenhouse gas emissions (GHG) reduction target and develop an associated Climate Action Plan (CAP).

Supporting Strategic Documentation

The City of Ames' strategic documents and planning initiatives were analyzed in a "Situational Analysis" and provided to the City. This background research provides useful information for engagement activities such as focus groups and surveys. Drawing examples, principles, and approaches from these documents will increase the CAP's alignment with these other plans, and help to integrate all of these different but related initiatives. This in turn will improve the chances of success for all of them.

The following documentation are the primary strategic documents that will inform both the engagement and technical modelling:

- City of Ames' Promise/Vision;
- City of Ames' 2020-2021 City Council Goals, especially those related to engagement, equity, and environmental sustainability;
- The City's 2016 Resolution Reaffirming The City's Commitment to the Values of Equity, Fairness, Inclusion, and Justice;
- Ames 2040 Plan; and
- Iowa State University's Strategic Plan for Sustainability in Operations 2021-2025.

What is Being Decided and How

The City of Ames wants to foster a forward-thinking, innovative, and sustainable community. An effective GHG reduction target and CAP can help achieve these goals. This will require factual information about the City's infrastructure and standards for the technical modelling, as well as an understanding of the city's context. It will also require decisions be made about an appropriate GHG reduction target and what actions the City of Ames will need to take to reduce its GHGs, on what timeline, and how those actions should be implemented. The CAP will contain the recommended answers to these questions, based on the technical modelling and engagement input.

The City of Ames expects the CAP will be ready to be recommended for approval by Council by September 2022. This plan will achieve the City's emission reduction targets and reflect the inputs and ideas of the community.

Engagement Strategy

The Engagement Strategy is the framework that will ensure internal (City) and external stakeholders are given opportunities to provide feedback that will be used to create the most effective CAP possible, and to establish a community that will support the implementation of the plan through to its completion.

Givens

Givens are facts that are outside the scope of engagement, which means they are not negotiable. The givens for this engagement will include the following:

- Climate change is real and primarily driven by human activity.
- The City of Ames will set a GHG emissions reduction target and develop a Climate Action Plan.
- This project is not an opportunity to debate ongoing flood mitigation work, or other ongoing city projects.

Stakeholders

In addition to providing broad feedback opportunities to the public, the City will engage stakeholders through four groups:

1. the Supplemental Input Committee, consisting of community stakeholders from various sectors, chosen by the City;
2. the City Steering Committee, consisting of the Mayor and Council;
3. the City Project Team consisting of the Assistant City Manager, Public Relations Officer, Energy Services Coordinator, and the Sustainability Coordinator;
4. the City Technical Advisory Committee, consisting representatives from across City departments.

Interviewees from the pre-engagement process suggested the plan incorporate feedback from the broader community. To maximize resources, the Supplemental Input Committee, which will be engaged in the CAP development and target setting process, will be tasked with:

- providing representative feedback from their sectors,

- looking for opportunities to educate their networks, and
- sharing concerns from their networks.

Guiding Principles

The following principles, derived primarily from the Pre-Engagement Report and the project Proposal, will guide the design and execution of all engagement activities,

- A commitment to:
    - Informing the public about complexity before and during the active engagement period, in order to raise the general level of understanding of global warming and climate action planning;
    - Involving stakeholders in a variety of ways for information collection to demonstrate process integrity and build credibility for recommendations;
    - Communicating background information and engagement opportunities (times, dates, online venues) in a reasonable time prior to engagement;
    - Providing stakeholders with various opportunities to provide input throughout the active engagement period; and
    - Although decision-making will be focused on building consensus, the decision-making body is the Steering Committee, which is composed of the Ames City Council. The Council will consider the information received during the engagements as much as possible in making its decisions.

Objectives

The following are the main objectives of this Engagement Plan described according to the IAP2 (International Association of Public Participation) Spectrum of Engagement (i.e., inform, consult, involve, or collaborate), which is included as **Appendix A**. As with the Guiding Principles, these Objectives are based on information available in the project proposal, the Pre-Engagement Report, as well as City Technical Advisory Committee input to date. The **outputs** (i.e. tangible things) and **outcomes** (i.e. intangible things) that will help achieve each objective are also described below.

The outputs and outcomes drive the techniques selected to achieve these objectives. The techniques selected are described in the **Engagement Technique** section, further below.

Objective 1

To inform and educate the community of the specific targets and actions required to create meaningful and feasible greenhouse gas emission reductions, while engendering a sense of responsibility for continuing this work through to its long-term completion.

- *Outputs:*
  - A community-based input committee, with internal (i.e., City) and external members, is established.
  - Communications materials are created to educate and inform stakeholders about the strategy process and opportunities for input.
- *Outcomes:*
  - Stakeholders understand the process of science-based GHG reduction target setting, and best practices from other communities.
  - Stakeholders understand the level of action and investment required from a climate action plan in order to meet their chosen GHG reduction target, and best practices from other communities.
  - Stakeholders understand the increasing costs of inaction, and the benefits of action.

Objective 2

To involve stakeholders in the development of the engagement process and facilitate inclusive conversations among stakeholders in order to document community concerns and aspirations.

- *Outputs:*
  - Interviews with selected community members from the pre-engagement process, which results in a pre-engagement report containing a set of engagement plan recommendations.
  - An interactive website serves as a one-stop shop for members of the public to learn about ways to provide feedback and learn more about relevant background information.
- *Outcomes:*
  - Stakeholders say they have been meaningfully involved in the development of the engagement plan for the CAP.
  - Community participants know how to get engaged, are motivated to identify opportunities, and become partners in the realization of the CAP.

Objective 3

To involve the community and City staff in gathering feedback that will inform: 1) the community's GHG reduction target, 2) the selected low-carbon actions, and 3) the CAP's near-term implementation strategy.

- *Outputs:*
  - A series of assumptions to be used in the creation of low-carbon scenarios.
  - City Steering Committee and Supplemental Input Committee sessions on:
    - Target-setting and climate action planning 101;
    - BAU and low-carbon scenario results; and
    - CAP implementation planning.
  - Regular updates (e.g., bi-monthly) to the website on project progress.
  - Community-wide feedback on effective CAP implementation planning.
  - A draft implementation plan.
  - Contact lists of stakeholders who wish to continue the dialogue on CAP implementation.
- *Outcomes:*
  - A revised list of low-carbon actions, adjusted based on City and stakeholder feedback.
  - The City of Ames identifies and collaborates with its implementation partners to maximize the impact of the CAP and to benefit all participants justly and equitably.

Objective 4

To inform stakeholders of how their involvement shaped the plan.

- *Outputs:*
  - The City of Ames will provide regular and clear information on the progress of the CAP on the project's interactive website (during the course of the CAP development) and then on the City of Ames' website. These updates will summarize input received and how it influenced plan decisions.
  - Final presentation to the City Council.
- *Outcomes:*
  - Community members can see they have impacted decision-making.
  - Community members will understand the impact of their participation in shaping the CAP, and in acting as champions for the implementation of the plan.

Communications

Comprehensive communications and education efforts are critical to the engagement's overall success. Working with the City of Ames' communications staff and the project team, we will communicate the following key messages through the channels outlined below.

Key Messages

The following key messages have been developed for the project, which have been informed by the pre-engagement interview process:

- The City of Ames is committed to creating a climate-friendly future by partnering with the community.
- The City of Ames is prepared to pursue policy changes that encourage and require carbon reduction behaviors.
- Investment in climate action contributes to Ames' economic development, in addition to generating co-benefits related to health, improved environment, equity, and economic growth.

Timeline

The timeline of engagement will be integrated with the project's technical modelling activities. Between the stages of modelling, engagement input will be gathered; and when the modelled results are completed, results will be presented.
The engagement will feed into the overall Plan completion as shown in the image below.

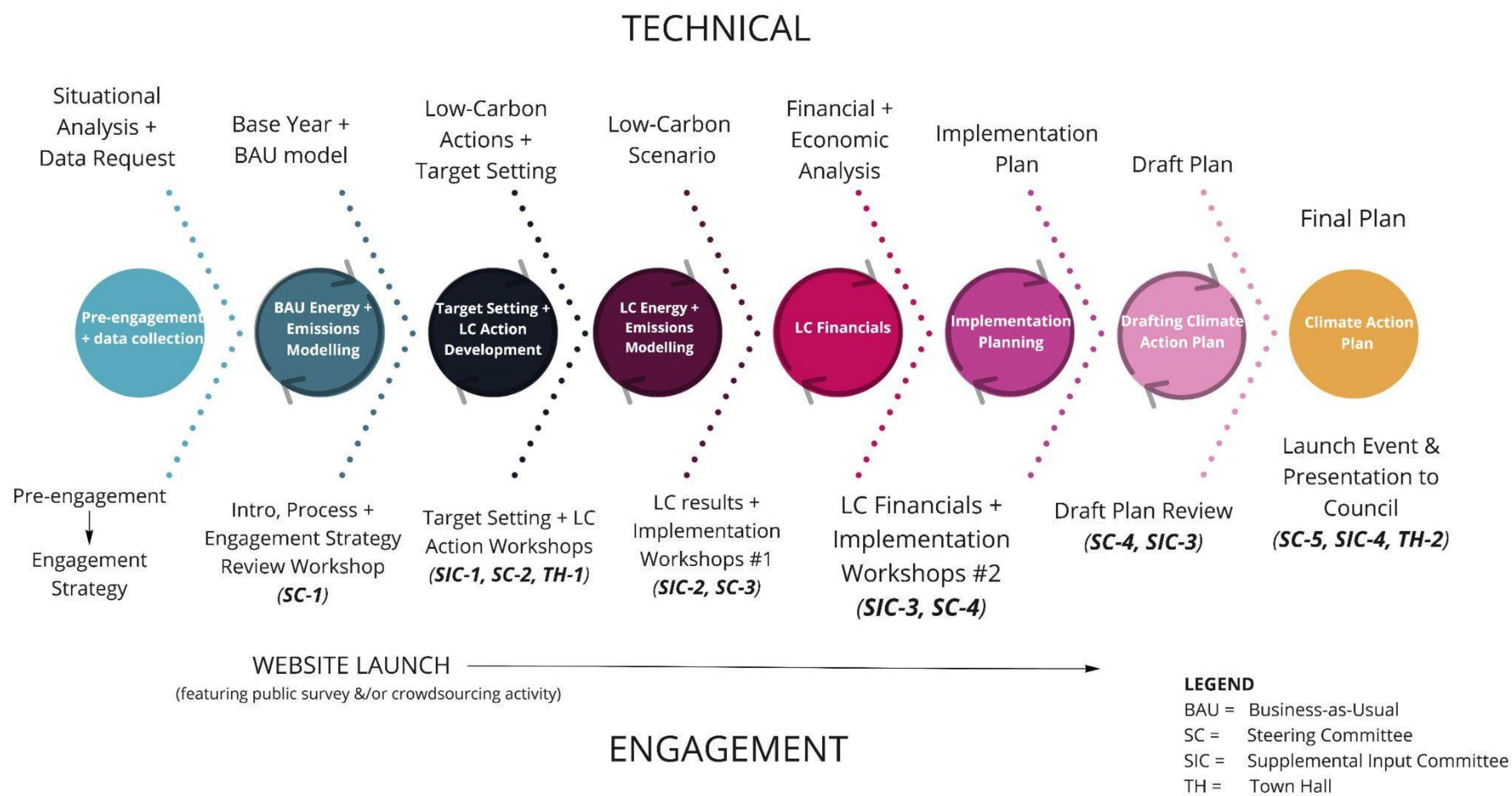

Figure 1. Energy and emissions modelling with data and engagement milestones.

Engagement Techniques

Phase 1: Pre-engagement Interviews + Engagement Design

Project initiation - September 2021

Activity	**SSG role**	**City role**	**Objectives**	**Timeframe**
Pre-Engagement Interviews and Summary Report	• Conduct interviews of individuals identified by city (30-minute to 1-hour phone or video call. • Analyze interviews.	• Identify participant pool and advise them about being contacted to gather engagement data.	Objective 1	June - July
Engagement Plan design	• Draft Engagement Plan.	• Refine and approve	All	August-September

Phase 2: Active Engagement Period (prior to plan completion)

July 2021 - July 2022

Activity	IAP2 Spectrum Level	SSG role	City role	Objectives	Timeframe
Focus groups with stakeholders As identified by the Technical Advisory Committee, hold discussions with stakeholders to discuss the city's current energy and emissions profile, potential low-carbon actions, and implementation plan design	**Involve.** Although decision-making will be focused on building consensus, the decision-making body is the Steering Committee, which is composed of the Ames City Council. The Council will consider the information received during the engagements as much as possible in making the required decisions.	• Lead discussion, provide key background material, and take notes • Incorporate key information into CAP	• Support in coordinating meeting timing and hosting.	All	July 2021 - July 2022

CAP interactive website	**Inform.** Promise to the public: We will provide you with resources and opportunities to stay informed.	• Design website and draft content that ensures the public is informed about: ○ engagement opportunities, ○ key background information, and ○ how their feedback is used to shape the final CAP. • Website will host the community survey described	• Provide support and guidance.	Objectives 1, 3, 4	Ongoing
City Steering Committee (CSC) Workshop 1: The Process Steering Committee members will become acquainted with the project goals and process, including the scenario modelling method. Target setting and climate action planning best practices will be introduced and discussed. Finally, the	**Involve.** Although decision-making will be focused on building consensus, the decision-making body is the Steering Committee, which is composed of the Ames City Council. The Council will consider the information received during the engagements as much	• Prepare an energy and emissions planning and target setting 101 presentation. • Prepare an overview of the project process and milestones. • Prepare an overview of the engagement plan.	• Coordinate meeting timing and hosting. • Review presentation materials prior to the workshop. • Respond to questions about the City's role, jurisdiction.	All	August/ September

project's engagement strategy will be reviewed and discussed. In particular, the process for seeking and integrating community and CSC input into the CAP and in setting the community GHG target will be reviewed, and feedback sought from the CSC.	as possible in making the required decisions.				
Supplemental Input Committee (Committee) Workshop 1: Base Year and BAU Results and Target-Setting Workshop Committee members will become acquainted with each other and the project goals and process. Committee members will be asked to watch the CSC workshop as preparation for the workshop. Base year energy and emissions inventory data	**Involve.** Although decision-making will be focused on building consensus, the decision-making body is the Steering Committee, which is composed of the Ames City Council. The Council will consider the information received during the engagements as much as possible in making the required decisions.	• Prepare an energy and emissions planning and target setting 101 presentation. • Prepare an overview of the project process and milestones. • Provide digital framework/exercise tools. • Prepare a take-home survey or worksheets after the workshop. To finalize ideas.	• Recruit committee members. • Coordinate meeting timing and hosting. • Provide presentation background material on the CAP, indicating how it fits with other City plans/strategies. • Review presentation materials prior to the workshop. • Respond to questions about the City's role, jurisdiction.	Objectives 1, 3, 4	September/ October

and business as usual (BAU) scenario modelling results will be reviewed. Emissions reduction challenges and opportunities will be discussed Participatory workshop exercises will be hosted to build relationships and develop a CAP vision. Varying emissions reduction targets will be debated, and preferred targets will be documented.					
Launch Event: Town Hall - CAP Inventory and BAU: The first public event, the Town Hall will introduce the community to the CAP process, share information about public input opportunities, and enable participants to share their vision for Ames' future.	**Involve.** Although decision-making will be focused on building consensus, the decision-making body is the Steering Committee, which is composed of the Ames City Council. The Council will consider the information	● Assist with the logistics and coordination of the event. ● Prepare an energy and emissions planning and target setting 101 presentation. ● Prepare a presentation on community GHG	● Set the program/agenda. ● Advise on guest speakers. ● Provide a host for the event. ● Invite the Mayor and/or Council to give some brief remarks.	Objectives 1, 3, 4	October

	received during the engagements as much as possible in making the required decisions.	inventory, BAU modelling results, and public input opportunities. ● Design an activity to allow participants to express their vision for Ames' low-carbon future. ● Co-host, if required.			
Committee Workshop 2: Low-Carbon Action Workshop Ames' energy and emissions outlook will be presented to provide the scale of the emissions reductions challenge. The Committee will identify emissions areas on which to focus and present emissions reduction opportunities in each emissions sector for consideration in CAP development.	**Involve.** Although decision-making will be focused on building consensus, the decision-making body is the Steering Committee, which is composed of the Ames City Council. The Council will consider the information received during the engagements as much as possible in making the required decisions.	● Lead the workshop, prepare and provide materials. ● Provide digital framework/exercise tools. ● Prepare a list of low-carbon actions. ● Prepare a take-home survey or worksheets after the workshop. To finalize ideas.	● Review presentation materials prior to the workshop. ● Coordinate meeting timing and hosting.	Objectives 1, 3, 4	November

CSC Workshop 2: Review of feedback to date on target setting and low-carbon actions, and low-carbon action workshop. For context, base year energy and emissions inventory data and business as usual (BAU) scenario modelling results will be reviewed. Emissions reduction challenges and opportunities will be discussed with regard to which items are under City jurisdiction. Inputs for the workshop will come from SSG's technical analysis and the Committee. Proposed Attendees: ● Directors or senior representatives from building approvals,	**Involve.** Although decision-making will be focused on building consensus, the decision-making body is the Steering Committee, which is composed of the Ames City Council. The Council will consider the information received during the engagements as much as possible in making the required decisions.	● Provide modelling outputs presentation materials. ● Prepare a summary of what we've heard to date. ● Prepare discussion topics and exercises. ● Prepare a preliminary list of low-carbon actions. ● Lead workshop.	● Identify and convene group members ● Review presentation materials prior to the workshop. ● Coordinate meeting timing and hosting.	Objectives 1, 3, 4	November 16

community planning/short-term planning, transportation, environmental services					
CSC & Committee Workshop : Low-carbon scenario modelling results & introduction to implementation Low-carbon scenario modelling results Proposed Attendees: ● Directors or senior representatives from building approvals, community planning/short-term planning, transportation, environmental services	**Involve.** Although decision-making will be focused on building consensus, the decision-making body is the Steering Committee, which is composed of the Ames City Council. The Council will consider the information received during the engagements as much as possible in making the required decisions.	● Provide modelling outputs presentation materials. ● Prepare discussion topics and exercises. ● Lead workshop. ● Provide digital framework/exercise tools.	● Review presentation materials prior to the workshop. ● Coordinate meeting timing and hosting	Objective 4	February

Community survey: Online survey to give community members a chance to provide their input on the CAP implementation plan.	**Consult.** Promise to the public: We will seek your advice on the variety of options presented.	• Draft survey. • Set survey up on selected online platform. • Analyze feedback.	• Review draft survey. • Promote to the community. • Logistical support.	Objectives 1,3, 4	March-June
CSC & Committee Workshop: Low-carbon financial results & implementation part 2 Low-carbon financial modelling results Proposed Attendees: • Directors or senior representatives from building approvals, community planning/short-term planning, transportation, environmental services	**Involve.** Although decision-making will be focused on building consensus, the decision-making body is the Steering Committee, which is composed of the Ames City Council. The Council will consider the information received during the engagements as much as possible in making the required decisions.	• Provide modelling outputs presentation materials. • Prepare discussion topics and exercises. • Lead workshop. • Provide digital framework/exercise tools.	• Review presentation materials prior to the workshop. • Coordinate meeting timing and hosting	Objective 4	March/April

Online Implementation Plan review: CSC + Committee	**Consult.** Promise to the public: We will seek your advice on the variety of options presented.	• Prepare draft. • Set up a feedback mechanism to gather input.	• Provide logistical support.	Objectives 1, 3, 7	May-June
Town Hall + Kitchen Workbook The team will prepare guided workbooks that households can work through around the kitchen table to review the draft CAP and explore how they can contribute to the CAP in their household and place of work, and identify how the City and other stakeholders can be a resource.	**Consult.** Promise to the public: We will seek your advice on the variety of options presented.	• Prepare workbook • Co-host if required • Analyze results	• Set the program/agenda. • Advise on guest speakers. • Provide a host for the event. • Invite the Mayor and/or Council to give some brief remarks. Promote to the community. • Provide logistical support.	Objectives 3, 4	June - July
Online Draft CAP review (TAC +CSC)	**Consult.** Promise to the public: We will seek your advice on the variety of options presented.	• Prepare and deliver a presentation on an updated version of the CAP. • Gather and analyze feedback.	• Provide logistical support.	Objectives 1, 3, 7	July - August

Phase 3: Final Report + Presentation

By September 2022

Activity	SSG's Role	City of Ames' Role	Objectives	Timeframe
Presentation to Council	• Draft presentation • Deliver presentation to Council and answer questions.	• Edit presentation. • Co-deliver presentation.	Objective 4	September 2022

Appendix A: IAP2 Public Participation Spectrum

IAP2 Spectrum of Public Participation

International Association for Public Participation

Increasing Level of Public Impact →

	Inform	Consult	Involve	Collaborate	Empower
Public participation goal	To provide the public with balanced and objective information to assist them in understanding the problem, alternatives, opportunities and/or solutions.	To obtain public feedback on analysis, alternatives and/or decisions.	To work directly with the public throughout the process to ensure that public concerns and aspirations are consistently understood and considered.	To partner with the public in each aspect of the decision including the development of alternatives and the identification of the preferred solution.	To place final decision-making in the hands of the public.
Promise to the public	We will keep you informed.	We will keep you informed, listen to and acknowledge concerns and aspirations, and provide feedback on how public input influenced the decision.	We will work with you to ensure that your concerns and aspirations are directly reflected in the alternatives developed and provide feedback on how public input influenced the decision.	We will look to you for advice and innovation in formulating solutions and incorporate your advice and recommendations into the decisions to the maximum extent possible.	We will implement what you decide.
Example techniques	▪ Fact sheets ▪ Web sites ▪ Open houses	▪ Public comment ▪ Focus groups ▪ Surveys ▪ Public meetings	▪ Workshops ▪ Deliberative polling	▪ Citizen advisory committees ▪ Consensus-building ▪ Participatory decision-making	▪ Citizen juries ▪ Ballots ▪ Delegated decision

Ames Climate Action Plan and Target Setting

Data, Methods, and Assumptions (DMA) Manual

July 2021

Purpose of this Document

This Data, Methods, and Assumptions (DMA) manual details the modeling approach used to provide community energy and emissions benchmarks and projections while providing a summary of the data and assumptions used in scenario modeling. The DMA makes the modeling elements fully transparent and illustrates the scope of data required for future modeling efforts.

CONTENTS

Glossary

BAU	Business as usual
CBECS	Commercial Buildings Energy Consumption Survey
CHP	Combined heat and power
DMA	Data, methods, and assumptions manual
GHG	Greenhouse gases
GIS	Geographic information systems
GPC	Global Protocol on Community-Scale GHG Emissions Inventories
IPCC	Intergovernmental Panel on Climate Change
VMT	Vehicle Miles Travelled

Accounting and Reporting Principles

The municipal greenhouse gas (GHG) inventory base year development and scenario modeling approach correlate with the Global Protocol for Community-Scale GHG Emissions Inventories (GPC).[1] The GPC provides a fair and true account of emissions via the following principles:

Relevance: The reported GHG emissions appropriately reflect emissions occurring as a result of activities and consumption within the City boundary. The inventory will also serve the decision-making needs of the City, taking into consideration relevant local, state, and national regulations. Relevance applies when selecting data sources and determining and prioritizing data collection improvements.

Completeness: All emissions sources within the inventory boundary shall be accounted for and any exclusions of sources shall be justified and explained.

Consistency: Emissions calculations shall be consistent in approach, boundary, and methodology.

Transparency: Activity data, emissions sources, emissions factors and accounting methodologies require adequate documentation and disclosure to enable verification.

Accuracy: The calculation of GHG emissions should not systematically overstate or understate actual GHG emissions. Accuracy should be enough to give decision makers and the public reasonable assurance of the integrity of the reported information. Uncertainties in the quantification process should be reduced to the extent possible and practical.

[1] WRI, C40 and ICLEI (2014). Global Protocol for Community-Scale Greenhouse Gas Emissions Inventories. Retrieved from: https://ghgprotocol.org/sites/default/files/standards/GHGP_GPC_0.pdf.

Scope

Geographic Boundary

Energy and emissions inventories and modeling for the project will be done in relation to the geographical boundary shown in Figure 1.

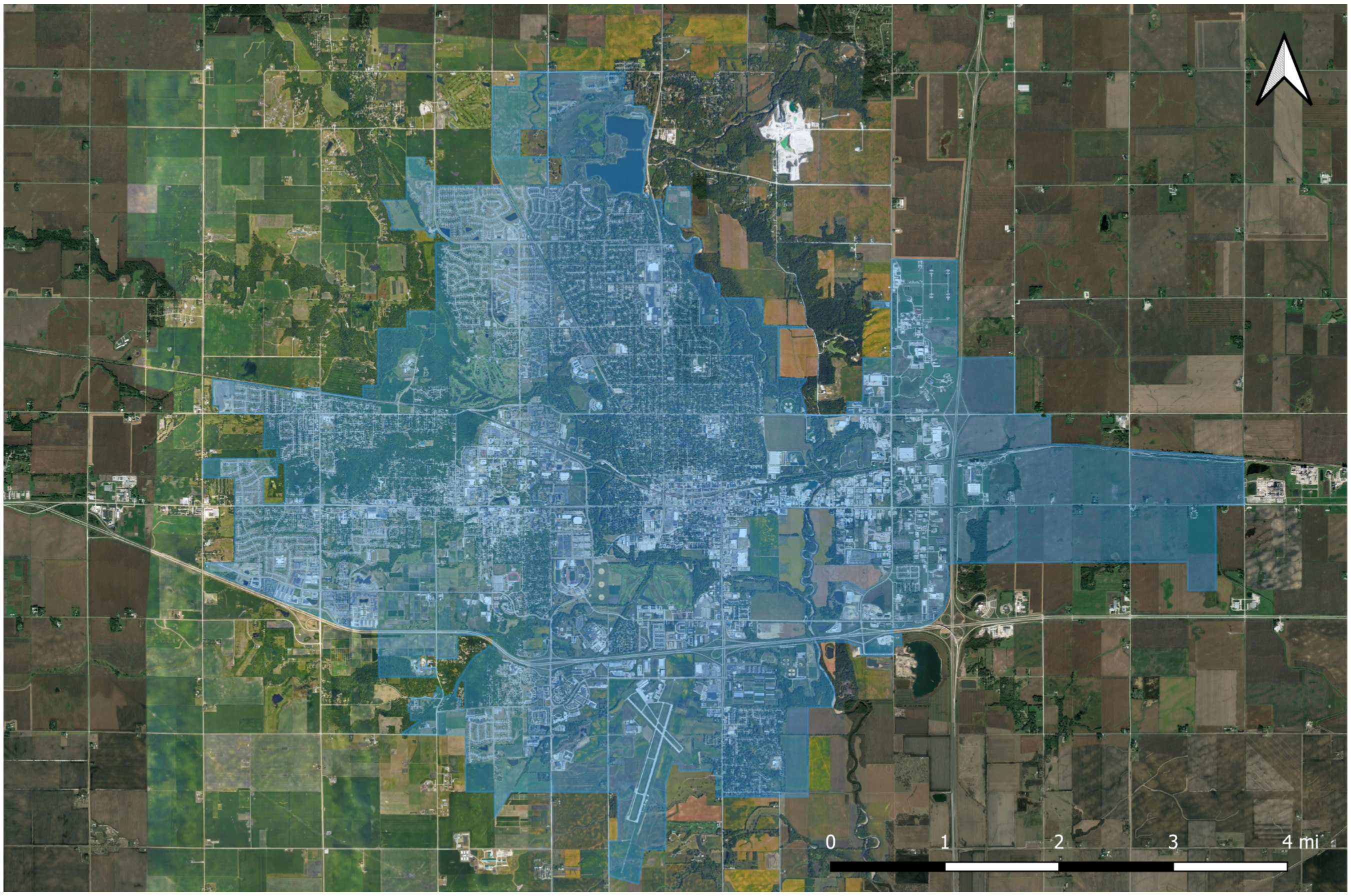

Figure 1. Geographical boundary considered for the project.

Time Frame of Assessment

The modeling time frame will include years 2018-2050. The year 2018 will be used as the base year since it aligns with the City's existing inventory, and 2050 is the relevant target year. Model calibration for the base year uses as much locally observed data as possible.

Energy and Emissions Structure

The total energy for a community is defined as the sum of the energy from each of the aspects:

$$Energy_{City} = Energy_{transport} + Energy_{buildings} + Energy_{waste\&wastewater}$$

Where:

$Energy_{transport}$ is the movement of goods and people.

$Energy_{buildings}$ is the generation of heating, cooling and electricity.

$Energy_{wastegen}$ is energy generated from waste.

The total GHG emissions for a community is defined as the sum from all in-scope emissions sources:

$$GHG_{landuse} = GHG_{transport} + GHG_{energygen} + GHG_{waste\&wastewater} + GHG_{agriculture} + GHG_{forest} + GHG_{landconvert}$$

Where:

$GHG_{transport}$ is emissions generated by the movement of goods and people.

$GHG_{energygen}$ is emissions generated by the generation of heat and electricity.

$GHG_{waste\&wastewater}$ is emissions generated by solid and liquid waste produced.

$GHG_{agriculture}$ is emissions generated by food production.

GHG_{forest} is emissions generated by forested land.

$GHG_{landconvert}$ is emissions generated by the lands converted from natural to modified conditions.

Emissions Scope

The inventory will include emissions Scopes 1 and 2, and some aspects of Scope 3, as defined by GPC (Table 1 and Figure 2). Refer to Appendix 1 of this DMA for a list of included GHG emissions sources by scope.

Table 1. GPC scope definitions.

Scope	Definition
1	All GHG emissions from sources located within the municipal boundary.
2	All GHG emissions occurring from the use of grid-supplied electricity, heat, steam and/or cooling within the municipal boundary.
3	All other GHG emissions that occur outside the municipal boundary as a result of activities taking place within the boundary.

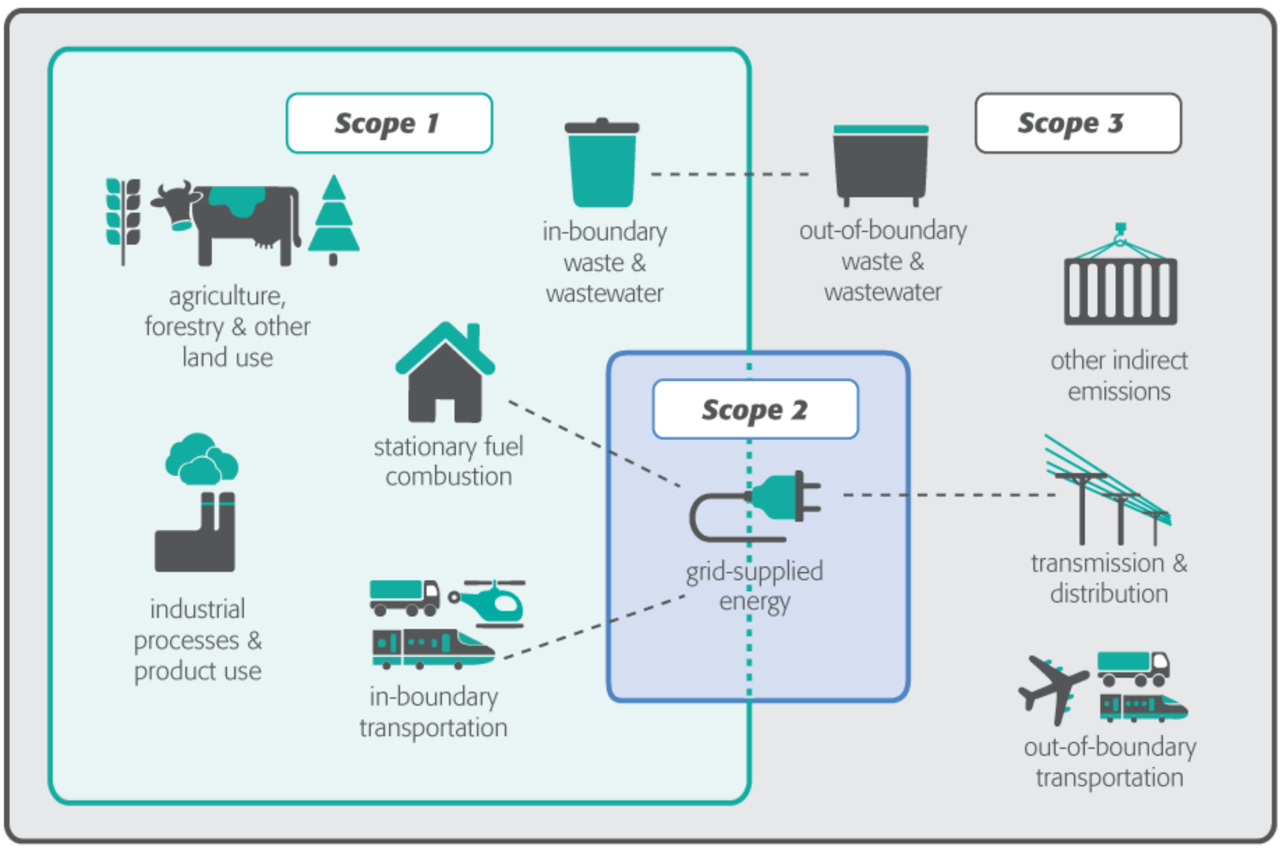

Figure 2. Diagram of GPC emissions scopes.

The Model

The model is an energy, emissions, and finance tool developed by Sustainability Solutions Group and whatIf? Technologies. The model integrates fuels, sectors, and land-use in order to enable bottom-up accounting for energy supply and demand, including:

- renewable resources,
- conventional fuels,
- energy consuming technology stocks (e.g., vehicles, appliances, dwellings, buildings), and
- all intermediate energy flows (e.g., electricity and heat).

Energy and GHG emissions values are derived from a series of connected stock and flow models, evolving based on current and future geographic and technology decisions/assumptions (e.g., EV uptake rates). The model accounts for physical flows (e.g., energy use, new vehicles by technology, VMT) as determined by stocks (buildings, vehicles, heating equipment, etc.).

The model applies a system dynamics approach. For any given year, the model traces the flows and transformations of energy from sources through energy currencies (e.g., gasoline, electricity, hydrogen) to end uses (e.g., personal vehicle use, space heating) to energy costs and to GHG emissions. An energy balance is achieved by accounting for efficiencies, technology conversion, and trade and losses at each stage in the journey from source to end use.

Table 2. Model characteristics.

Characteristic	Rationale
Integrated	The tool models and accounts for all city-scale energy and emissions in relevant sectors and captures relationships between sectors. The demand for energy services is modelled independently of the fuels and technologies that provide the energy services. This decoupling enables exploration of fuel switching scenarios. Feasible scenarios are established when energy demand and supply are balanced.
Scenario-based	Once calibrated with historical data, the model enables the creation of dozens of scenarios to explore different possible futures. Each scenario can consist of either one or a combination of policies, actions, and strategies. Historical calibration ensures that scenario projections are rooted in observed data.
Spatial	Built environment configuration determines walkability and cyclability, accessibility to transit, feasibility of district energy, and other aspects. The model therefore includes spatial dimensions that can include as many zones (the smallest areas of geographic analysis) as deemed appropriate. The spatial components can be integrated with GIS systems, land-use projections, and transportation modeling.
GPC-compliant	The model is designed to report emissions according to the GHG Protocol for Cities (GPC) framework and principles.

Economic impacts	The model incorporates a high-level financial analysis of costs related to energy (expenditures on energy) and emissions (carbon pricing, social cost of carbon), as well as operating and capital costs for policies, strategies, and actions. This allows for the generation of marginal abatement costs.

Model Structure

The major components of the model and the first level of their modelled relationships (influences) are represented by the blue arrows in Figure 3. Additional relationships may be modelled by modifying inputs and assumptions—specified directly by users, or in an automated fashion by code or scripts running “on top of” the base model structure. Feedback relationships are also possible, such as increasing the adoption rate of non-emitting vehicles in order to meet a GHG emissions constraint.

The model is spatially explicit. All buildings, transportation, and land-use data are tracked within the model through a GIS platform, and by varying degrees of spatial resolution. A zone type system is applied to divide the City into smaller configurations, based on the City’s existing traffic zones (or another agreeable zone system). This enables consideration of the impact of land-use patterns and urban form on energy use and emissions production from a base year to future dates using GIS-based platforms. The model’s GIS outputs will be integrated with the City’s mapping systems.

For any given year various factors shape the picture of energy and emissions flows, including: the population and the energy services it requires; commercial floorspace; energy production and trade; the deployed technologies which deliver energy services (service technologies); and the deployed technologies which transform energy sources to currencies (harvesting technologies). The model is based on an explicit mathematical relationship between these factors—some contextual and some part of the energy consuming or producing infrastructure—and the energy flow picture.

Some factors are modelled as stocks—counts of similar things, classified by various properties. For example, population is modelled as a stock of people classified by age and gender. Population change over time is projected by accounting for: the natural aging process, inflows (births, immigration), and outflows (deaths, emigration). The fleet of personal use vehicles, an example of a service technology, is modelled as a stock of vehicles classified by size, engine type and model year, with a similarly classified fuel consumption intensity. As with population, projecting change in the vehicle stock involves aging vehicles and accounting for major inflows (new vehicle sales) and major outflows (vehicle discards). This stock-turnover approach is applied to other service technologies (e.g., furnaces, water heaters) and harvesting technologies (e.g., electricity generating capacity).

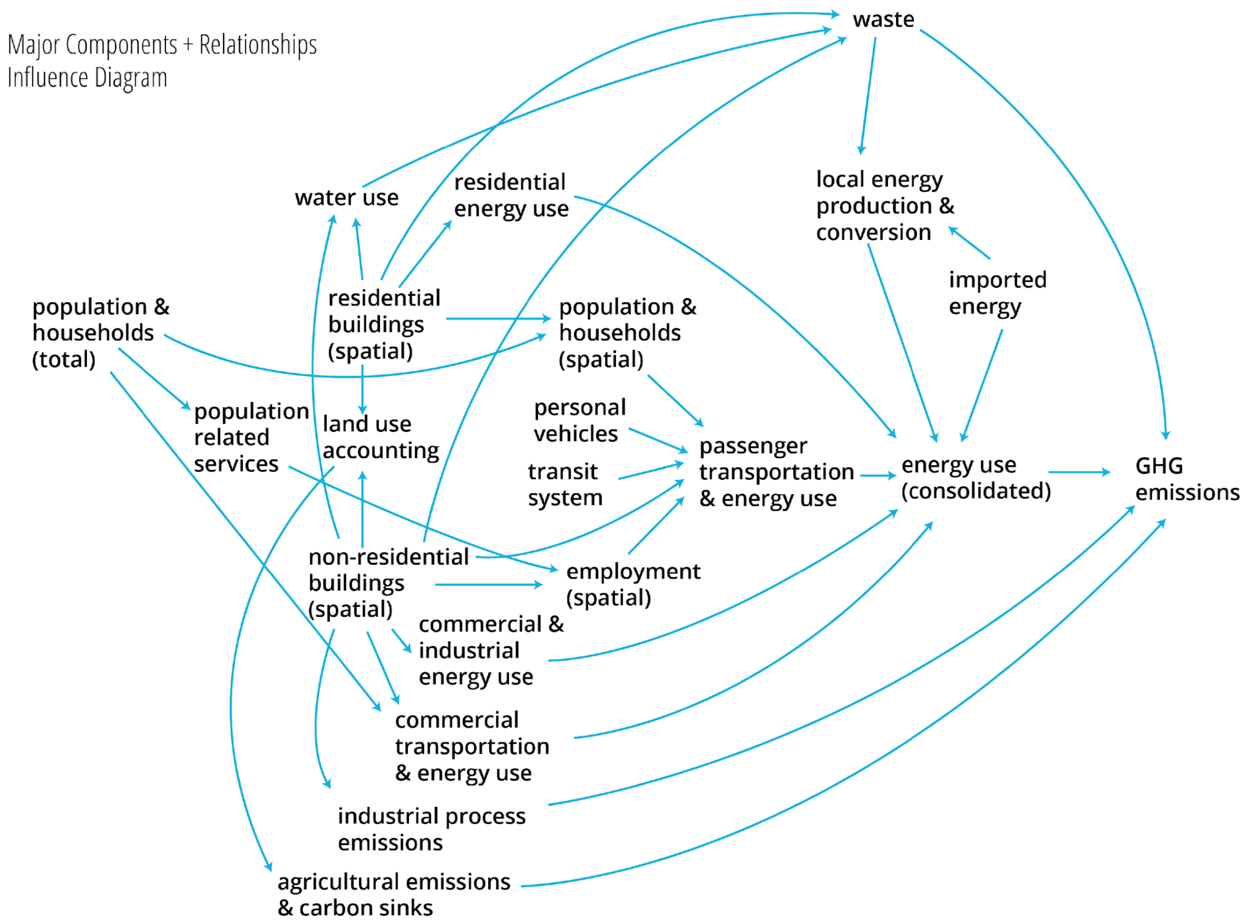

Figure 3. Representation of the CiS model structure.

Sub-Models

Population and Demographics

City-wide population is modelled using the standard population cohort-survival method, disaggregated by single year of age and gender. It accounts for typical components of change: births, deaths, immigration and emigration. The age-structured population is important for analysis of demographic trends, generational differences and implications for shifting energy use patterns. These numbers are calibrated against existing projections.

Residential Buildings

Residential buildings are spatially located and classified using a detailed set of 30+ building archetypes capturing footprint, height and type (single, double, row, apt. high, apt. low), and year of construction. This enables a "box" model of buildings that helps to estimate the surface area, and model energy use and simulate the impact of energy efficiency measures based on what we know about the characteristics of the building. Coupled with thermal envelope performance and degree-days the model calculates space conditioning energy demand independent of any space heating or cooling technology and fuel. Energy service demand then drives stock levels of key service technologies including heating systems, air conditioners, water heaters. These stocks are modelled with a stock-turnover approach capturing equipment age, retirements, and additions—exposing opportunities for efficiency gains and fuel switching, but also showing the rate limits to new technology adoption and the effects of lock-in (obligation to use equipment/infrastructure/fuel type due to longevity of system implemented). Residential building archetypes are also characterized by the number of contained dwelling units, allowing the model to capture the energy effects of shared walls but also the urban form and transportation implications of population density.

Non-Residential Buildings

These are spatially located and classified by a detailed use/purpose-based set of 50+ archetypes. The floorspace of these archetypes can vary by location. Non-residential floorspace produces waste and demand for energy and water, and provides an anchor point for locating employment of various types.

Spatial Population and Employment

City-wide population is made spatial through allocation to dwellings, using assumptions about persons-per-unit by dwelling type. Spatial employment is projected via two separate mechanisms:

- population-related services and employment, which is allocated to corresponding building floorspace (e.g., teachers to school floorspace), and
- floorspace-driven employment (e.g., retail employees per square foot).

Passenger Transportation

The model includes a spatially explicit passenger transportation sub-model that responds to changes in land-use, transit infrastructure, vehicle technology, travel behaviour change, and other factors. Trips are divided into four types (home-work, home-school, home-other, and non-home-based), each produced and attracted by different combinations of spatial drivers (population, employment, classrooms, non-residential floorspace). Trips are distributed and trip volumes are specified for each zone of origin and zone of destination pair. For each origin-destination pair, trips are shared over walk/bike (for trips within the walkable distance threshold), public transit (for trips whose origin and destination are serviced by transit), and automobile. A projection of total personal vehicles miles travelled (VMT) and a network distance matrix are produced following the mode share calculation. The energy use and emissions associated with personal vehicles is calculated by assigning VMT to a stock-turnover personal vehicle model. The induced approach is used to track emissions. All internal trips (trips within the boundary) are accounted for, as well as half of the trips that terminate or originate within the municipal boundary. Figure 4 displays trip destination matrix conceptualization.

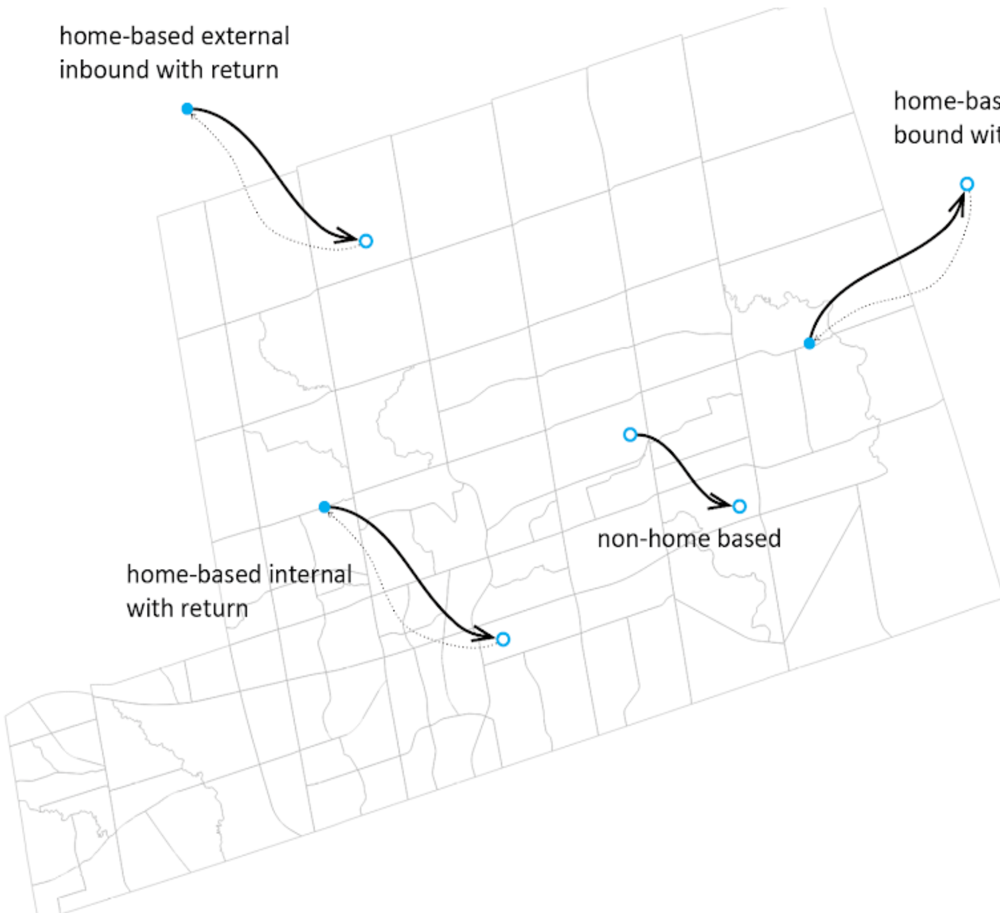

Figure 4. Conceptual diagram of trip categories.

Waste and Wastewater

Households and non-residential buildings generate solid waste and wastewater. The model traces various pathways to disposal, compost, and sludge including those which capture energy from incineration and recovered gas. Emissions accounting is performed throughout the waste sub-model.

Energy Flow and Local Energy Production

Energy produced from primary sources (e.g., solar, wind) is modelled alongside energy converted from imported fuels (e.g., electricity generation, district energy, CHP). As with the transportation sub-model, the district energy supply model has an explicit spatial dimension and can represent areas served by district energy networks.

Finance and Employment

Energy related financial flows and employment impacts are captured through an additional layer of model logic (not shown explicitly in Figure 2). Calculated financial flows include the capital, operating, and maintenance cost of energy consuming stocks and energy producing stocks, including fuel costs. Employment related to the construction of new buildings, retrofit activities and energy infrastructure is modelled. The financial impact on businesses and households of implementing the strategies is assessed. Local economic multipliers are also applied to investments.

Consumption Emissions

Emissions attributable to the production of some items produced outside, but consumed in, Ames are estimated and included in the emissions inventory and modeling (e.g., those for electronics, food, and clothing). These are estimated based on the number of households and a weighted average consumption per household across all income levels. A total base year emissions value is derived by multiplying the weighted average emissions per household intensity by number of households. This methodology enables accurate comparison to previous Ames inventories.

Model Calibration for Local Context

Data Request and Collection

Local data was supplied by the municipality. Assumptions were identified to supplement any gaps in observed data. The data and assumptions were applied in modeling per the process described below.

Zone System

The model is spatially explicit: population, employment, residential, and non-residential floorspace are allocated and tracked spatially within the City’s zone system (see Figure 5). These elements drive stationary energy demand. The passenger transportation sub-model, which drives transportation energy demand, also operates within the same zone system.

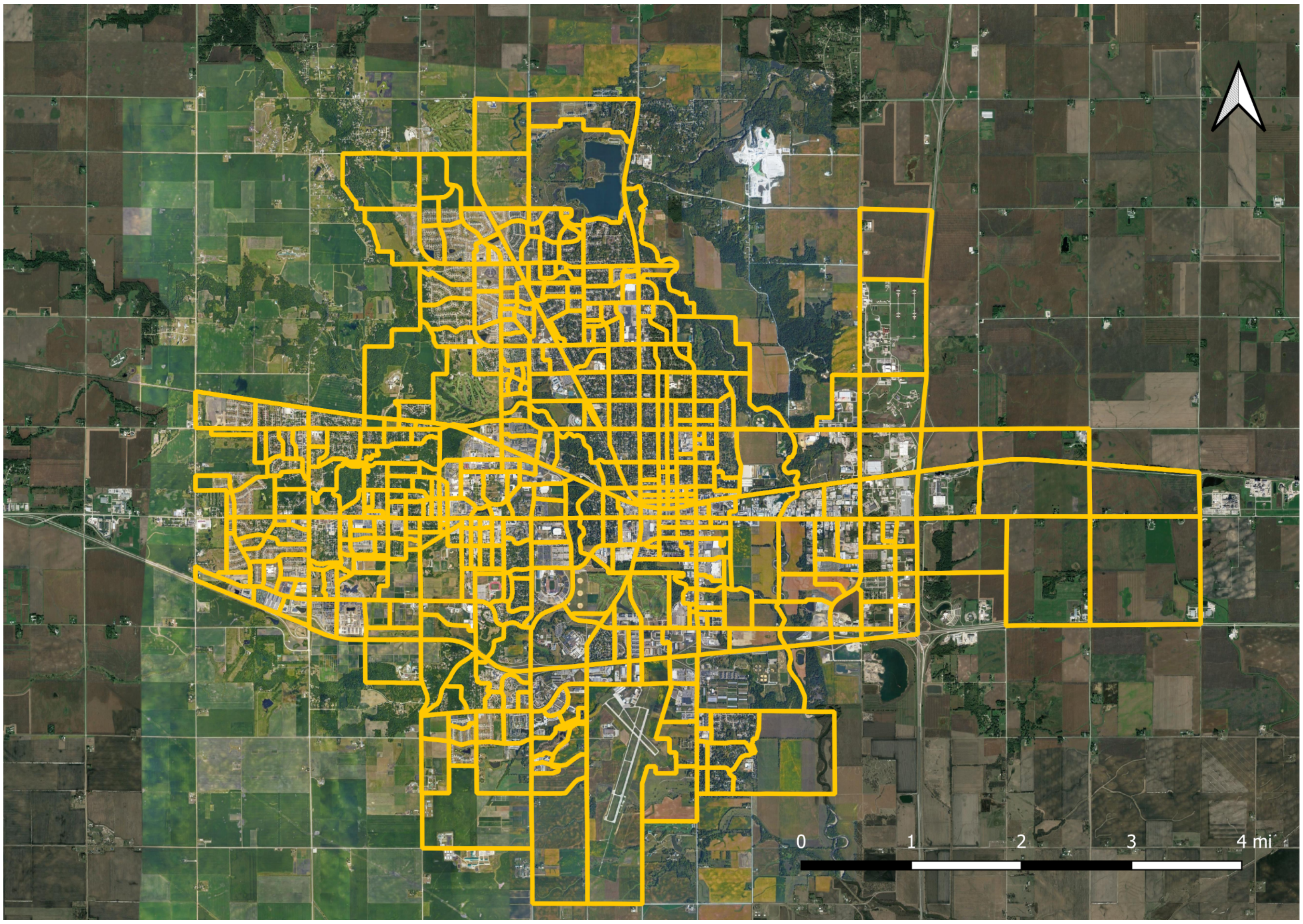

Figure 5. Zone system used in modelling.

Buildings

Buildings data, including building type, building footprint area, number of stories, total floorspace area, number of units, and year built was sourced from City property assessment data. Buildings were allocated to specific zones using their spatial attributes, based on the zone system. Buildings are classified using a detailed set of building archetypes (see Appendix 2). These archetypes capture footprint, height and type (e.g., single-family home, semi-attached home, etc.), enabling the creation of a "box" model of buildings, and an estimation of surface area for all buildings.

Residential Buildings

The model multiplies the residential building surface area by an estimated thermal conductance (heat flow per unit surface area per degree day) and the number of degree days (heating and cooling) to derive the energy transferred out of the building during winter months and into the building during summer months. The energy transferred through the building envelope, the solar gain through the building windows, and the heat gains from equipment inside the building constitute the space conditioning load to be provided by the heat systems and the air conditioning. The initial thermal conductance estimate is a regional average by dwelling type from a North American energy system simulator, calibrated for the Midwest. This initial estimate is adjusted through the calibration process as the modelled energy consumption from the market profile in the 2015 Residential Energy Consumption Survey (RECS) and City property assessment data.

Non-Residential Buildings

The model calculates the space conditioning load as it does for residential buildings with two distinctions: the thermal conductance parameter for non-residential buildings is based on floor space area instead of surface area, and incorporates data from Ames.

Starting values for output energy intensities and equipment efficiencies for non-residential end uses are taken from the 2012 Commercial Buildings Energy Consumption Survey (CBECS). All parameter estimates are further adjusted during the calibration process. The calibration target for non-residential building energy use is the observed commercial and industrial fuel consumption in the base year.

Using assumptions for thermal envelope performance for each building type, the model calculates total energy demand for all buildings, independent of any space heating or cooling technology and fuel.

Population and Employment

Federal census population and employment data was spatially allocated to residential (population) and non-residential (employment) buildings. This enables indicators to be derived from the model, such as emissions per household, and drives the BAU energy and emissions projections for buildings, transportation, waste.

Population for 2018 was spatially allocated to residential buildings using initial assumptions about persons-per-unit (PPU) by dwelling type. These initial PPUs are then adjusted so that the total population in the model (which is driven by the number of residential units by type multiplied by PPU by type) matches the total population from census/regional data.

Employment for 2018 was spatially allocated to non-residential buildings using initial assumptions for two main categories: population-related services and employment, allocated to corresponding building floorspace (e.g., teachers to school floorspace); and floorspace-driven employment (e.g., retail employees per square foot). Like population, these initial ratios are adjusted within the model so that the total employment derived by the model matches total employment from census/regional data.

Transportation

The model includes a spatially explicit passenger transportation sub-model that responds to changes in land-use, transit infrastructure, vehicle technology, travel behaviour change, and other factors. Trips are divided into four types (home-work, home-school, home-other, and non-home-based), each produced and attracted by a different combination of spatial drivers (population, employment, classrooms, non-residential floorspace). Trip volumes are distributed as pairs for each zone of origin and zone of destination. For each origin-destination pair, trips are shared over walk/bike (for trips within the walkable distance threshold), public transit (for trips whose origin and destination are serviced by transit), and automobile. Total personal vehicle miles travelled (VMT) is produced when modeling mode shares and distances. The energy use and emissions associated with personal vehicles is calculated by assigning VMT to model personal vehicle ownership.

The passenger transportation model is anchored with origin-destination trip matrices by trip mode and purpose, generated by the City's transportation department. The results are cross-checked against indicators such as average annual VMT per vehicle. For medium-heavy duty commercial vehicle transportation, the ratio of local retail diesel fuel sales to State retail diesel fuel sales was applied to estimate non-retail diesel use.

The modelled stock of personal vehicles by size, fuel type, efficiency, and vintage was informed by regional vehicle registration statistics. The total number of personal-use and corporate vehicles is proportional to the projected number of households in the BAU.

The GPC induced activity approach is used to account for emissions. Using this approach, all internal trips (within boundary) as well as half of the trips that terminate or originate within the municipal boundary are accounted for. This approach allows the municipality to understand its transportation impacts on its peripheries and the region.

Transit VMT and fuel consumption was modelled based on data provided by Ames in the 2018 emissions inventory data.

Waste

Solid waste stream composition and routing data (landfill, composting, recycling) was sourced from local data sources. The base carbon content in the landfill was estimated based on historical waste production data. Total methane emissions were estimated for landfills using the first order decay model, with the methane generation constant and methane correction factor set to default, as recommended by, and based on values from, IPCC Guidelines for landfill emissions. Data on methane removed via recovery was provided by the landfills.

Data and Assumptions

Scenario Development

The model supports the use of scenarios as a mechanism to evaluate potential futures for communities. A scenario is an internally consistent view of what the future might turn out to be—not a forecast, but one possible future outcome. Scenarios must represent serious considerations defined by planning staff and community members. They are generated by identifying population projections into the future, identifying how many additional households are required, and then applying those additional households according to existing land-use plans and/or alternative scenarios. A simplified transportation model evaluates the impact of the new development on transportation behaviour, building types, agricultural and forest land, and other variables.

Business-As-Usual Scenario

The Business-As-Usual (BAU) scenario estimates energy use and emissions volumes from the base year (2018) to the target year (2050). It assumes an absence of substantially different policy measures from those currently in place.

Methodology

1. Calibrate model and develop 2018 base year using observed data and filling in gaps with assumptions where necessary.
2. Input existing projected quantitative data to 2050 where available:
    - Population, employment and housing projections by transport zone
    - Build out (buildings) projections by transport zone
    - Transportation modeling from the municipality
3. Where quantitative projections are not carried through to 2050, extrapolate the projected trend to 2050.
4. Where specific quantitative projections are not available, develop projections through:
    - Analyzing current on the ground action (reviewing action plans, engagement with staff, etc.), and where possible, quantifying the action.
    - Analyzing existing policy that has potential impact and, where possible, quantifying the potential impact.

Low-Carbon Scenario

The model projects how energy flow and emissions profiles will change in the long-term by modeling potential changes in the context (e.g., population, development patterns), projecting energy services demand intensities, waste production and diversion rates, industrial processes, and projecting the composition of energy system infrastructure.

Policies, Actions, and Strategies

Alternative behaviours of various energy system actors (e.g., households, various levels of government, industry, etc.) can be mimicked in the model by changing the values of the model's user input variables. Varying their values creates "what if" type scenarios, enabling a flexible mix-and-match approach to behavioral models which connect to the physical model. The model can explore a wide variety of policies, actions and strategies via these variables. The resolution of the model enables the user to apply scenarios to specific neighbourhoods, technologies, building or vehicle types or eras, and configurations of the built environment.

Methodology

1. Develop a list of potential actions and strategies;
2. Identify the technological potential of each action or group of actions to reduce energy and emissions by quantifying the actions:
    a. If the action or strategy specifically incorporates a projection or target; or,
    b. If there is a stated intention or goal, review best practices and literature to quantify that goal; and
    c. Identify any actions that are overlapping and/or include dependencies on other actions.
3. Translate the actions into quantified assumptions over time;
4. Apply the assumptions to relevant sectors in the model to develop a low-carbon scenario (i.e., apply the technological potential of the actions to the model);
5. Analyze results of the low-carbon scenario against the overall target;
6. If the target is not achieved, identify variables to scale up and provide a rationale for doing so;
7. Iteratively adjust variables to identify a pathway to the target; and
8. Develop a marginal abatement cost curve for the low-carbon scenario.

Addressing Uncertainty

There is extensive discussion of the uncertainty in models and modeling results. The assumptions underlying a model can be from other locations or large data sets and do not reflect local conditions or behaviours, and even if they did accurately reflect local conditions, it is exceptionally difficult to predict how those conditions and behaviours will respond to broader societal changes and what those broader societal changes will be.

The WhatIf?/SSG modeling approach uses four strategies for managing uncertainty applicable to community energy and emissions modeling:

1. **Sensitivity analysis:** One of the most basic ways of studying complex models is sensitivity analysis, which helps quantify uncertainty in a model's output. To perform this assessment, each of the model's input parameters is drawn from a statistical distribution in order to capture the uncertainty in the parameter's true value (Keirstead, Jennings, & Sivakumar, 2012).

Approach: Selected variables are modified by ±10-20% to illustrate the impact that an error of that magnitude has on the overall total.

2. **Calibration:** One way to challenge untested assumptions is the use of 'back-casting' to ensure the model can 'forecast the past' accurately. The model can then be calibrated to generate historical outcomes, calibrating the model to better replicate observed data.

Approach: Variables are calibrated in the model using two independent sources of data. For example, the model calibrates building energy use (derived from buildings data) against actual electricity data from the electricity distributor.

3. **Scenario analysis:** Scenarios are used to demonstrate that a range of future outcomes are possible given the current conditions and that no one scenario is more likely than another.

Approach: The model will develop a reference scenario.

4. **Transparency:** The provision of detailed sources for all assumptions is critical to enabling policy-makers to understand the uncertainty intrinsic in a model.

Approach: Modeling assumptions and inputs are presented in this document.

Appendix 1: GPC Emissions Scope Table for Detailed Model

Green rows = Sources required for GPC BASIC inventory
Blue rows = Sources required GPC BASIC+ inventory
Red rows = Sources required for territorial total but not for BASIC/BASIC+ reporting

Exclusion Rationale Legend

N/A	Not Applicable, or not included in scope
ID	Insufficient Data
NR	No Relevance, or limited activities identified
Other	Reason provided in other comments

GPC ref No.	Scope	GHG Emissions Source	Inclusion	Exclusion rationale
I	STATIONARY ENERGY SOURCES			
I.1	Residential buildings			
I.1.1	1	Emissions from fuel combustion within the city boundary	Yes	
I.1.2	2	Emissions from grid-supplied energy consumed within the city boundary	Yes	
I.1.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	Yes	
I.2	Commercial and institutional buildings/facilities			
I.2.1	1	Emissions from fuel combustion within the city boundary	Yes	
I.2.2	2	Emissions from grid-supplied energy consumed within the city boundary	Yes	
I.2.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	Yes	
I.3	Manufacturing industry and construction			
I.3.1	1	Emissions from fuel combustion within the city boundary	Yes	
I.3.2	2	Emissions from grid-supplied energy consumed within the city boundary	Yes	
I.3.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	Yes	
I.4	Energy industries			
I.4.1	1	Emissions from energy used in power plant auxiliary operations within the city boundary	Yes	
I.4.2	2	Emissions from grid-supplied energy consumed in power plant auxiliary operations within the city boundary	Yes	
I.4.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption in power plant auxiliary operations	Yes	

I.4.4	1	Emissions from energy generation supplied to the grid	No	NR
I.5	Agriculture, forestry and fishing activities			
I.5.1	1	Emissions from fuel combustion within the city boundary	Yes	
I.5.2	2	Emissions from grid-supplied energy consumed within the city boundary	Yes	
I.5.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	Yes	
I.6	Non-specified sources			
I.6.1	1	Emissions from fuel combustion within the city boundary	No	NR
I.6.2	2	Emissions from grid-supplied energy consumed within the city boundary	No	NR
I.6.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	No	NR
I.7	Fugitive emissions from mining, processing, storage, and transportation of coal			
I.7.1	1	Emissions from fugitive emissions within the city boundary	No	NR
I.8	Fugitive emissions from oil and natural gas systems			
I.8.1	1	Emissions from fugitive emissions within the city boundary	Yes	
II	TRANSPORTATION			
II.1	On-road transportation			
II.1.1	1	Emissions from fuel combustion for on-road transportation occurring within the city boundary	Yes	
II.1.2	2	Emissions from grid-supplied energy consumed within the city boundary for on-road transportation	Yes	
II.1.3	3	Emissions from portion of transboundary journeys occurring outside the city boundary, and transmission and distribution losses from grid-supplied energy consumption	Yes	
II.2	Railways			
II.2.1	1	Emissions from fuel combustion for railway transportation occurring within the city boundary	No	N/A
II.2.2	2	Emissions from grid-supplied energy consumed within the city boundary for railways	No	N/A
II.2.3	3	Emissions from portion of transboundary journeys occurring outside the city boundary, and transmission and distribution losses from grid-supplied energy consumption	No	N/A
II.3	Water-borne navigation			
II.3.1	1	Emissions from fuel combustion for waterborne navigation occurring within the city boundary	No	NR
II.3.2	2	Emissions from grid-supplied energy consumed within the city boundary for waterborne navigation	No	NR

II.3.3	3	Emissions from portion of transboundary journeys occurring outside the city boundary, and transmission and distribution losses from grid-supplied energy consumption	No	NR
II.4	Aviation			
II.4.1	1	Emissions from fuel combustion for aviation occurring within the city boundary	Yes	
II.4.2	2	Emissions from grid-supplied energy consumed within the city boundary for aviation	Yes	
II.4.3	3	Emissions from portion of transboundary journeys occurring outside the city boundary, and transmission and distribution losses from grid-supplied energy consumption	No	ID
II.5	Off-road			
II.5.1	1	Emissions from fuel combustion for off-road transportation occurring within the city boundary	Yes	
II.5.2	2	Emissions from grid-supplied energy consumed within the city boundary for off-road transportation	No	ID
III	WASTE			
III.1	Solid waste disposal			
III.1.1	1	Emissions from solid waste generated within the city boundary and disposed in landfills or open dumps within the city boundary	No	NR
III.1.2	3	Emissions from solid waste generated within the city boundary but disposed in landfills or open dumps outside the city boundary	Yes	
III.1.3	1	Emissions from waste generated outside the city boundary and disposed in landfills or open dumps within the city boundary	No	N/A
III.2	Biological treatment of waste			
III.2.1	1	Emissions from solid waste generated within the city boundary that is treated biologically within the city boundary	Yes	
III.2.2	3	Emissions from solid waste generated within the city boundary but treated biologically outside of the city boundary	No	ID
III.2.3	1	Emissions from waste generated outside the city boundary but treated biologically within the city boundary	No	N/A
III.3	Incineration and open burning			
III.3.1	1	Emissions from solid waste generated and treated within the city boundary	Yes	
III.3.2	3	Emissions from solid waste generated within the city boundary but treated outside of the city boundary	No	N/A
III.3.3	1	Emissions from waste generated outside the city boundary but treated within the city boundary	No	N/A
III.4	Wastewater treatment and discharge			
III.4.1	1	Emissions from wastewater generated and treated within the city boundary	Yes	

III.4.2	3	Emissions from wastewater generated within the city boundary but treated outside of the city boundary	No	NR
III.4.3	1	Emissions from wastewater generated outside the city boundary	No	N/A
IV	INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU)			
IV.1	1	Emissions from industrial processes occurring within the city boundary	No	ID
IV.2	1	Emissions from product use occurring within the city boundary	No	ID
V	AGRICULTURE, FORESTRY AND LAND USE (AFOLU)			
V.1	1	Emissions from livestock within the city boundary	Yes	
V.2	1	Emissions from land within the city boundary	No	NR
V.3	1	Emissions from aggregate sources and non-CO2 emission sources on land within the city boundary	No	ID
VI	OTHER SCOPE 3			
VI.1	3	Other Scope 3	Yes	
TOTAL				

Appendix 2: Building Types in the model

Residential Building Types	Non-residential Building Types	
Single_detached_1Storey_tiny	college_university	commercial_retail
Single_detached_2Storey_tiny	school	commercial
Single_detached_3Storey_tiny	retirement_or_nursing_home	commercial_residential
Single_detached_1Storey_small	special_care_home	retail_residential
Single_detached_2Storey_small	hospital	warehouse_commercial
Single_detached_3Storey_small	municipal_building	warehouse
Single_detached_1Storey_medium	fire_station	religious_institution
Single_detached_2Storey_medium	penal_institution	surface_infrastructure
Single_detached_3Storey_medium	police_station	energy_utility
Single_detached_1Storey_large	military_base_or_camp	water_pumping_or_treatment_station
Single_detached_2Storey_large	transit_terminal_or_station	industrial_generic
Single_detached_3Storey_large	airport	food_processing_plants
Double_detached_1Storey_small	parking	textile_manufacturing_plants
Double_detached_2Storey_small	hotel_motel_inn	furniture_manufacturing_plants
Double_detached_3Storey_small	greenhouse	refineries_all_types
Double_detached_1Storey_large	greenspace	chemical_manufacturing_plants
Double_detached_2Storey_large	recreation	printing_and_publishing_plants
Double_detached_3Storey_large	community_centre	fabricated_metal_product_plants
Row_house_1Storey_small	golf_course	manufacturing_plants_miscellaneous
Row_house_2Storey_small	museums_art_gallery	_processing_plants
Row_house_3Storey_small	retail	asphalt_manufacturing_plants
Row_house_1Storey_large	vehicle_and_heavy_equiptment_service	concrete_manufacturing_plants
Row_house_2Storey_large	warehouse_retail	industrial_farm
Row_house_3Storey_large	restaurant	barn
Apartment_1To4Storey_small		
Apartment_1To4Storey_large		
Apartment_5To14Storey_small		
Apartment_5To14Storey_large		
Apartment_15To24Storey_small		
Apartment_15To24Storey_large		
Apartment_25AndUpStorey_small		
Apartment_25AndUpStorey_large		
inMultiUseBldg		

Appendix 3: Emissions Factors Used

Category	Value	Comment
Natural gas	CO_2: 53.02 kg/MMBtu CH_4: 0.005 kg/MMBtu N_2O: 0.0001kg/MMBtu	ICLEI–Local Governments for Sustainability USA. "US community protocol for accounting and reporting of greenhouse gas emissions." (2012).
Electricity	2018 CO_2e: 1,098 lbs CO_2e per MWh	MROW average emissions factor per US EPA eGRID (www.epa.gov/egrid/data-explorer)
Gasoline	CO_2: 0.07024 MT/MMBtu CH_4: 0.000000017343 MT/mile N_2O: 0.000000009825 MT/mile	ICLEI–Local Governments for Sustainability USA. "US community protocol for accounting and reporting of greenhouse gas emissions." (2012).
Diesel	CO_2: 0.073934483 MT/MMBtu CH_4: 0.000000001 MT/vehicle mile N_2O: 0.0000000015 MT/vehicle mile	ICLEI–Local Governments for Sustainability USA. "US community protocol for accounting and reporting of greenhouse gas emissions." (2012).
Fuel oil	CO_2: 73.9 kg per mmBtu CH_4: 0.003 kg per mmBtu N_2O: 0.0006 kg per mmBtu	Environmental Protection Agency. "Emission factors for greenhouse gas inventories." *Stationary Combustion Emission Factors," US Environmental Protection Agency2014, Available:* *https://www.epa.gov/sites/production/files/2015-07/documents/emission-factors_2014.pdf* (2014). Table 1 Stationary Combustion Emission Factor, Fuel Oil No. 2
Wood	CO_2: 93.80 kg per mmBtu CH_4: 0.0072 kg per mmBtu N_2O: 0.0036 kg per mmBtu	Environmental Protection Agency. "Emission factors for greenhouse gas inventories." *Stationary Combustion Emission Factors," US Environmental Protection Agency2014, Available:* *https://www.epa.gov/sites/production/files/2015-07/documents/emission-factors_2014.pdf* (2014). Table 1 Stationary Combustion Emission Factor, Biomass fuels: Wood and Wood Residuals
Propane	CO_2: 62.87 kg per mmBtu CH_4 : 0.003 kg per mmBtu N_2O: 0.0006 kg per mmBtu For mobile combustion: CO_2: 5.7 kg per gallon	Environmental Protection Agency. "Emission factors for greenhouse gas inventories." *Stationary Combustion Emission Factors," US Environmental Protection Agency2014, Available:* *https://www.epa.gov/sites/production/files/2015-07/documents/emission-factors_2014.pdf* (2014). Table 1 Stationary Combustion Emission Factor, Petroleum Products: Propane Table 2 Mobile Combustion CO_2 Emission Factors: Propane
Waste	Landfill emissions are calculated from first order decay of degradable organic carbon deposited in landfill. Derived emission factor in 2018 to be determined based on % recovery of	Landfill emissions: IPCC Guidelines Vol 5. Ch 3, Equation 3.1

	landfill methane and waste composition.	
Wastewater	CH_4: 0.48 kg CH_4/kg BOD N_2O: 3.2 g / (person * year) from advanced treatment 0.005 g /g N from wastewater discharge	CH_4 wastewater: IPCC Guidelines Vol 5. Ch 6, Tables 6.2 and 6.3; MCF value for anaerobic digester N_2O from advanced treatment: IPCC Guidelines Vol 5. Ch 6, Box 6.1 N_2O from wastewater discharge: IPCC Guidelines Vol 5. Ch 6, Section 6.3.1.2

Greenhouse gases	Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N20) are included. Global Warming Potential CO_2 = 1 CH_4 = 34 N_2O = 298	Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3) are not included.