Charleston County Climate Action Plan

Data, Methods, and Assumptions Manual

February 2024

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
BAP	Business-as-planned
CBECS	Commercial Buildings Energy Consumption Survey
CHP	Combined heat and power
DMA	Data, methods, and assumptions manual
GHG	Greenhouse gasses
GIS	Geographic information systems
GPC	Global Protocol on Community-Scale GHG Emissions Inventories
LC	Low-carbon
IPCC	Intergovernmental Panel on Climate Change
VMT	Vehicle Miles Traveled

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 County boundary. The inventory will also serve the decision-making needs of the County, 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 completed for Charleston County's current boundary (Figure 1). The land-use and density targets modeled will be in line with what is identified in Charleston County's Comprehensive Plan.

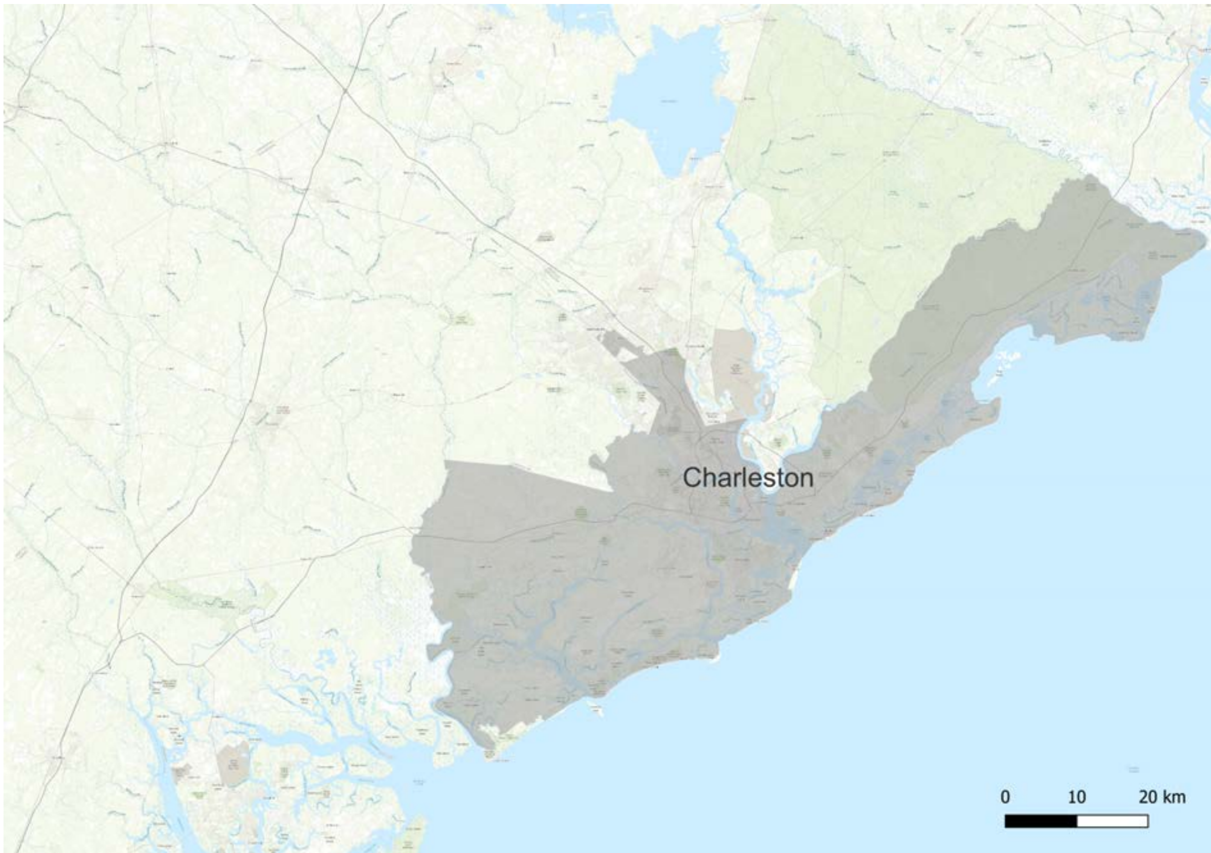

Figure 1. Geographical boundary for Charleston County

Time Frame of Assessment

The modeling time frame will include years 2020-2050. The year 2020 will be used as the base year since it aligns with the County's existing inventory, transportation modeling and the latest census, 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:

$$Energy_{County} = Energy_{transport} + Energy_{buildings}$$

Where:

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

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

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

$$GHG_{landuse} = GHG_{transport} + GHG_{energygen}$$

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.

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.

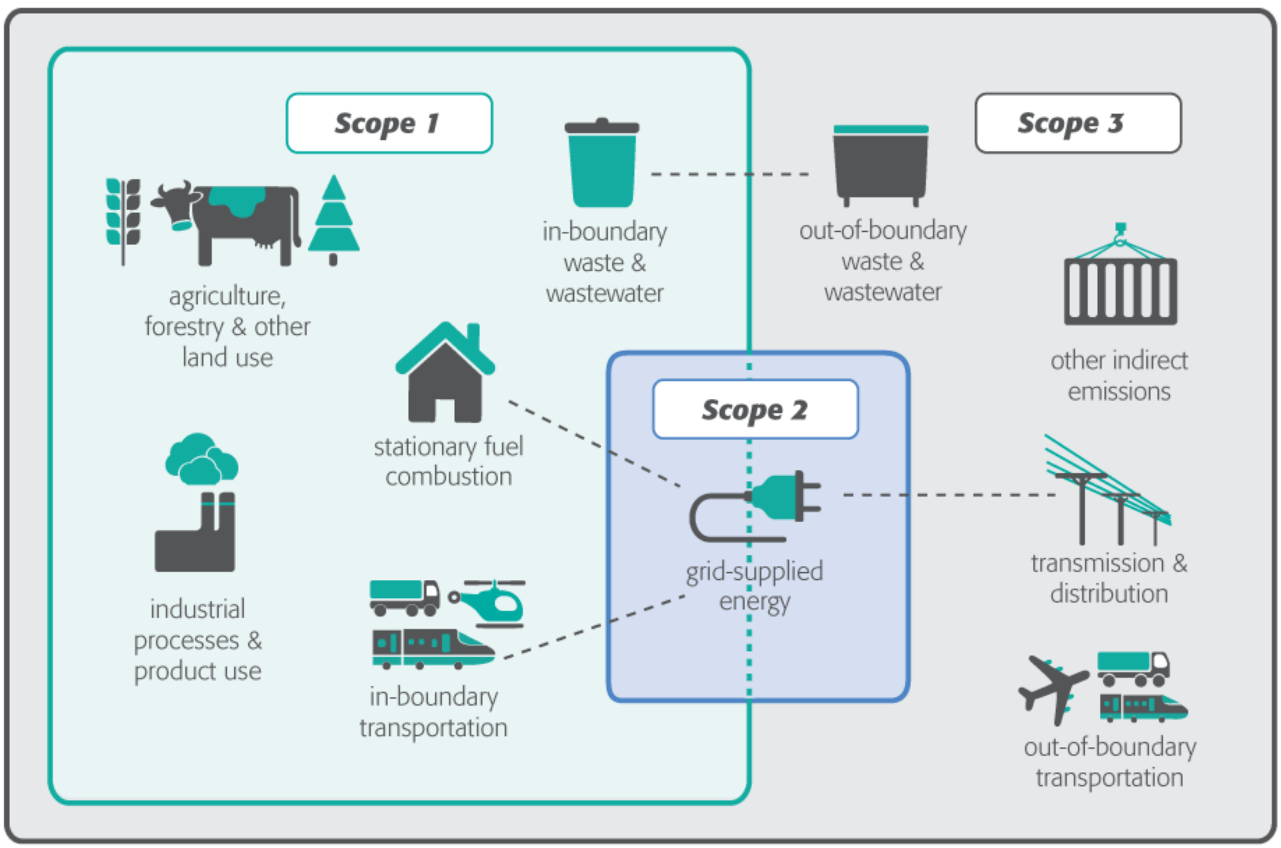

Figure 2. Diagram of GPC emissions scopes.

The Model

The model is an energy, emissions, and finance tool developed by Sustainability Solutions Group. 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 County-scale energy and emissions in relevant sectors and captures relationships between sectors. The demand for energy services is modeled 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 modeled relationships (influences) are represented by the blue arrows in Figure 3. Additional relationships may be modeled 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 County into smaller configurations, based on the County's existing traffic zones. 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 County'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 modeled as stocks—counts of similar things, classified by various properties. For example, population is modeled 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 modeled 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).

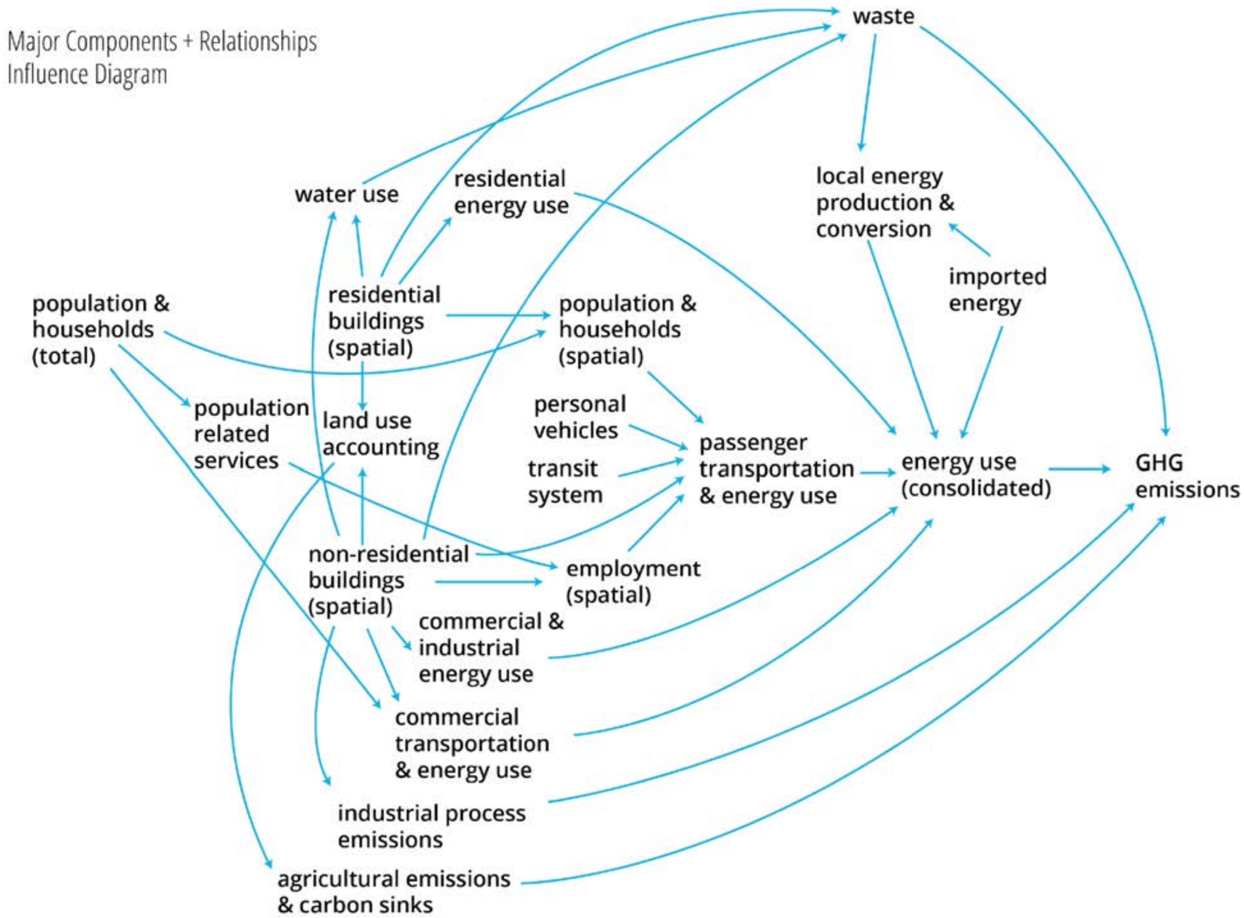

Figure 3. Representation of the Energy and Emission model structure.

Sub-Models

Population and Demographics

County-wide population is modeled 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 modeled 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 45+ archetypes. The floorspace of these archetypes can vary by location. Non-residential floorspace produces demand for energy, and provides an anchor point for locating employment of various types.

Spatial Population and Employment

County-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 behavior 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.

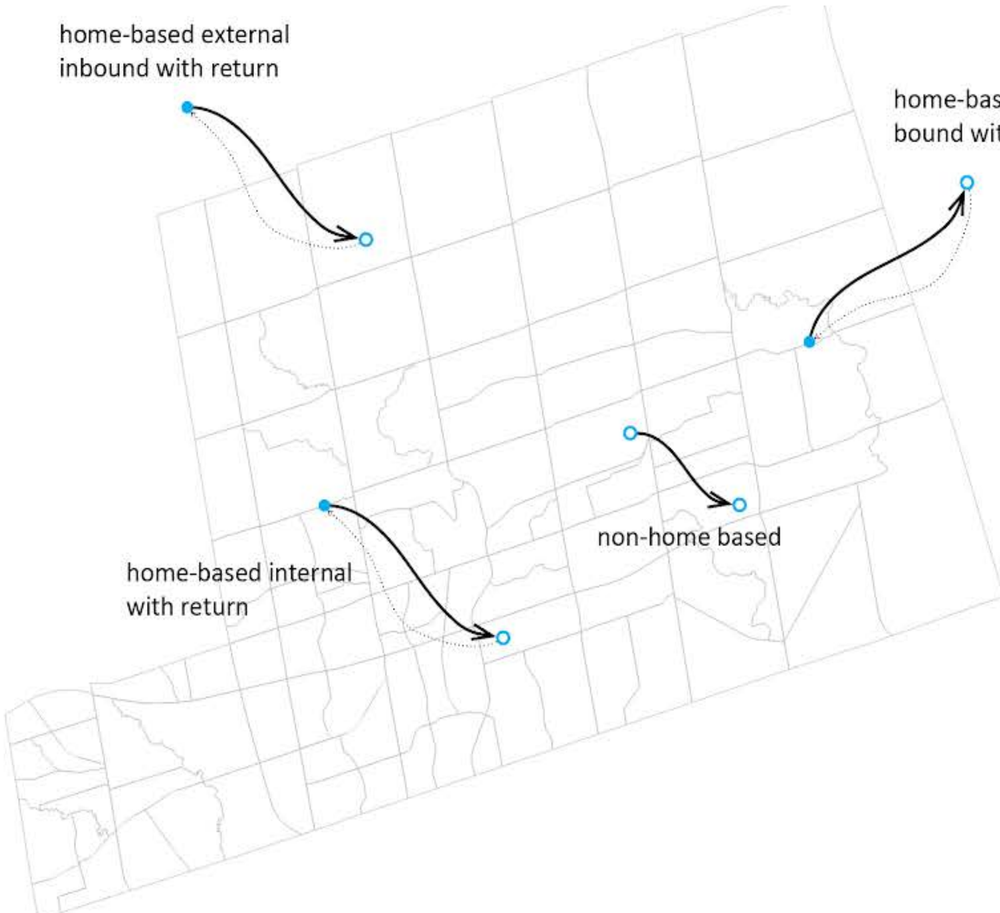

Figure 4. Conceptual diagram of trip categories.

Energy Flow and Local Energy Production

Energy produced from primary sources (e.g., solar, wind) is modeled 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 modeled. The financial impact on businesses and households of implementing the strategies is assessed. Local economic multipliers are also applied to investments.

Data Request and Collection

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

Zone Systems

The model is spatially explicit: population, employment, residential, and non-residential floorspace are allocated and tracked spatially within the County's municipal-based zone system (see green neighborhood boundaries in Figure 5). These elements drive stationary energy demand. The passenger transportation sub-model, which drives transportation energy demand, operates on another more detailed traffic zone system that was borrowed from Berkeley-Charleston-Dorchester Council of Governments (BCDCOG) transportation department (see green neighborhood boundaries in Figure 5).

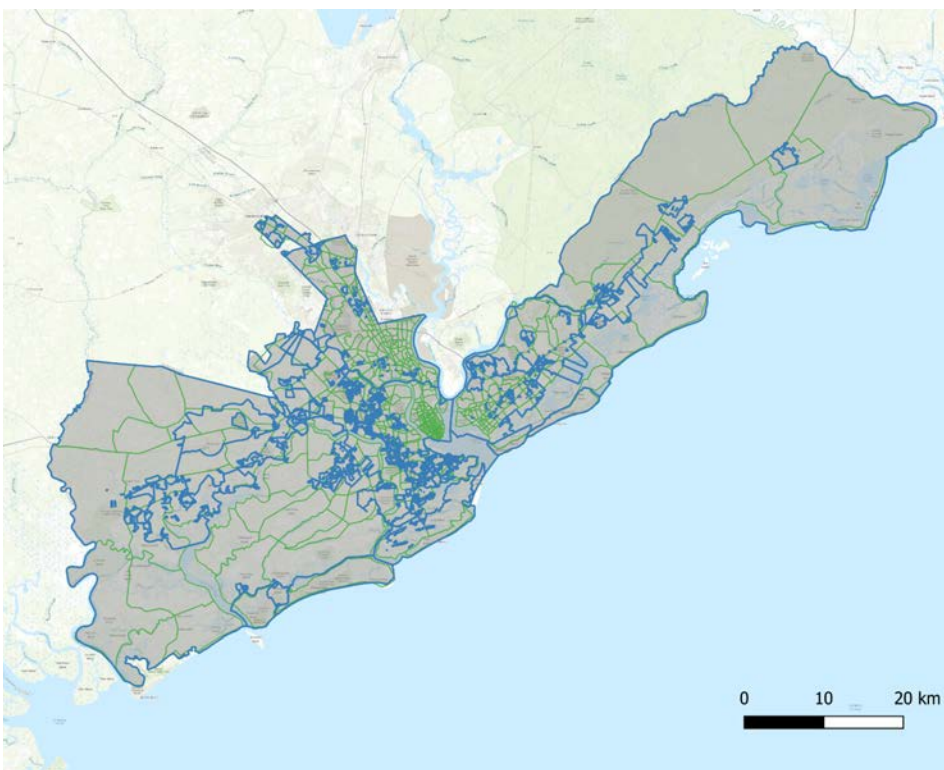

Figure 5. Zone systems used in modeling.

Buildings

Buildings data, including building type, building footprint area, number of stories, total floorspace area, number of units, and year built was sourced from County 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 South Atlantic. This initial estimate is adjusted through the calibration process such that the modeled energy consumption in the residential sector aligns with the target energy use . The calibration target for residential building energy use is the observed residential natural gas and electricity consumption in the base year.

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 Charleston County.

Starting values for output energy intensities and equipment efficiencies for non-residential end uses are taken from a North American energy system simulator, calibrated for the South Atlantic. 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, and transportation.

Population for 2020 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 2020 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 traveled (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 BCDCOG 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 modeled 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 modeled based on data provided by Whatcom Transportation Authority.

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 behavior, 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 (2020) 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 2020 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, 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 behaviors, and even if they did accurately reflect local conditions, it is exceptionally difficult to predict how those conditions and behaviors will respond to broader societal changes and what those broader societal changes will be.

The 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 county boundary	Yes	
I.1.2	2	Emissions from grid-supplied energy consumed within the county 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 county boundary	Yes	
I.2.2	2	Emissions from grid-supplied energy consumed within the county 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 county boundary	Yes	
I.3.2	2	Emissions from grid-supplied energy consumed within the county 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 county boundary	No	NR
I.4.2	2	Emissions from grid-supplied energy consumed in power plant auxiliary operations within the county boundary	No	NR
I.4.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption in power plant auxiliary operations	No	NR

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 county boundary	Yes	
I.5.2	2	Emissions from grid-supplied energy consumed within the county 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 county boundary	No	NR
I.6.2	2	Emissions from grid-supplied energy consumed within the county 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 county boundary	No	NR
I.8	Fugitive emissions from oil and natural gas systems			
I.8.1	1	Emissions from fugitive emissions within the county boundary	Yes	
II	TRANSPORTATION			
II.1	On-road transportation			
II.1.1	1	Emissions from fuel combustion for on-road transportation occurring within the county boundary	Yes	
II.1.2	2	Emissions from grid-supplied energy consumed within the county boundary for on-road transportation	Yes	
II.1.3	3	Emissions from portion of transboundary journeys occurring outside the county 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 county boundary	Yes	
II.2.2	2	Emissions from grid-supplied energy consumed within the county boundary for railways	No	ID
II.2.3	3	Emissions from portion of transboundary journeys occurring outside the county boundary, and transmission and distribution losses from grid-supplied energy consumption	Yes	NR
II.3	Water-borne navigation			
II.3.1	1	Emissions from fuel combustion for waterborne navigation occurring within the county boundary	No	ID
II.3.2	2	Emissions from grid-supplied energy consumed within the county boundary for waterborne navigation	No	ID

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

III.4.1	1	Emissions from wastewater generated and treated within the county boundary	Yes	
III.4.2	3	Emissions from wastewater generated within the county boundary but treated outside of the county boundary	No	N/A
III.4.3	1	Emissions from wastewater generated outside the county boundary	No	N/A
IV	INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU)			
IV.1	1	Emissions from industrial processes occurring within the county boundary	Yes	
IV.2	1	Emissions from product use occurring within the county boundary	No	N/A
V	AGRICULTURE, FORESTRY AND LAND USE (AFOLU)			
V.1	1	Emissions from livestock within the county boundary	Yes	
V.2	1	Emissions from land within the county boundary	Yes	
V.3	1	Emissions from aggregate sources and non-CO2 emission sources on land within the county boundary	No	NR
VI	OTHER SCOPE 3			
VI.1	3	Other Scope 3	No	N/A
TOTAL				

Appendix 2: Building Types in the model

Residential Building Types	Non-residential Building Types	
Single_detached_small	college_university	religious_institution
Single_detached_medium	school	energy_utility
Single_detached_large	retirement_or_nursing_home	municipal_office
Double_detached_small	hospital	municipal_fire_station
Double_detached__large	penal_institution	municipal_police_station
Row_house_small	military_base_or_camp	municipal_culture art
Row_house_large	transit_terminal_or_station	museums, cultural buildings
Apt_1To3Storey	airport	municipal_entertainment
Apt_4To6Storey	hotel_motel_inn	municipal_recreation
Apt_7To12Storey	greenhouse	municipal_community_centre
Apt_13AndUpStorey	greenspace	municipal_arena_pool
inMultiUseBldg	recreation	municipal_yards_maintenance
	community_centre	municipal_other
	golf_course	municipal_retirement_home
	museums_art_gallery	surface_infrastructure
	retail	water_pumping_or_treatment_station
	vehicle_and_heavy_equiptment_service	industrial_generic
	warehouse_retail	pulp_paper
	restaurant	cement
	commercial_retail	chemicals
	commercial	iron_steel_aluminum
	warehouse_commercial	mining
	warehouse	agriculture

Appendix 3: Emissions Factors Used

Category	Value	Comment
Natural gas	CO_2: 53.06 kg/MMBtu CH_4: 0.001 kg/MMBtu N_2O: 0.0001 g/MMBtu	Environmental Protection Agency. "Emission factors for greenhouse gas inventories." *Stationary Combustion Emission Factors," US Environmental Protection Agency 2020, Available: https://www.epa.gov/sites/default/files/2021-04/documents/emission-factors_mar2020.pdf* (2020). Table 1 Stationary Combustion Emission Factor, Natural Gas
Electricity	2021 CO_2: 807 lbs/MWh CH_4: 0.060 lbs/MWh N_2O: 0.009 lbs/MWh	US Environmental Protection Agency. "Emissions and Generation Resource Integrated Database" for South Carolina Available: https://www.epa.gov/egrid/download-data (2021)
Gasoline	CO_2: 70.22 kg/MMBtu CH_4: 0.003 kg/MMBtu N_2O: 0.0006 kg/MMBtu	Environmental Protection Agency. "Emission factors for greenhouse gas inventories." *Stationary Combustion Emission Factors," US Environmental Protection Agency 2020, Available: https://www.epa.gov/sites/default/files/2021-04/documents/emission-factors_mar2020.pdf* (2020). Table 1 Stationary Combustion Emission Factor, Motor Gasoline
Diesel	CO_2: 10.21 kg/gallon CH_4: 0.003 kg/MMBtu N_2O: 0.0006 kg/MMBtu	Environmental Protection Agency. "Emission factors for greenhouse gas inventories." *Stationary Combustion Emission Factors," US Environmental Protection Agency 2020, Available: https://www.epa.gov/sites/default/files/2021-04/documents/emission-factors_mar2020.pdf* (2020). Table 1 Stationary Combustion Emission Factor, LPG and Table 2 Mobile Combustion CO2
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 Agency 2020, Available: https://www.epa.gov/sites/default/files/2021-04/documents/emission-factors_mar2020.pdf* (2020). 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 Agency 2020, Available: https://www.epa.gov/sites/default/files/2021-04/documents/emission-factors_mar2020.pdf* (2020). 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 Agency 2020, Available: https://www.epa.gov/sites/default/files/2021-04/documents/emission-factors_mar2020.pdf* (2020). Table 1 Stationary Combustion Emission Factor, Petroleum Products: Propane Table 2 Mobile Combustion CO_2 Emission Factors: Propane
Waste and wastewater	**Wastewater emissions factors** CH_4: 0.6 kg CH_4/kg BOD for advanced treatment CH_4: 0.3 kg CH_4/kg BOD for septic N_2O: 5.60 kg / (person * year) from a combination of advanced treatment and septic 0.01 g /g N from wastewater discharge Landfill emissions are calculated from first-order decay of degradable organic carbon deposited in landfill derived emission factor in 2020 = 0.004 tonnes CH_4/tonnes solid waste	CH_4 wastewater: IPCC Guidelines Vol 5 Ch 6, Tables 6.2 and 6.3, we use the MCF value for Anaerobic reactor (e.g., upflow anaerobic sludge blanket digestion (UASB)) (MCF: 0.1) 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 Landfill emissions: IPCC Guidelines Vol 5 Ch 3, Equation 3.1
Natural Gas Fugitive Emissions	Natural gas mix CO_2: 0.000051 Gg / m3 CH_4: 0.0069 Gg/m3	CO_2: Table 4.2.4 from 2006 IPCC Guidelines, Volume 2, Chapter 4, Fugitive Emissions CH_4: Assumed 1% of NG throughput is unaccounted, and 0.964 fraction of methane in NG to determine emission factor
Aviation	Jet Fuel 9.57 kg/US Gallons Aviation Gasoline 8.32 kg/US Gallons	Gallons of Jet Fuel and Aviation Gasoline from US Energy Information Agency (EIA) for 2020 and scaled down to Charleston County using the number of travellers from Charleston compared to South Carolina

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.