Gunnison County
Energy, Materials, and Greenhouse Gas Emissions Inventory:
2015 Baseline
&
2030 Forecast

Center for Environment and Sustainability
Community Solutions Incubation+Innovation (CS2I) Lab
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Executive Summary

Gunnison County and Western State Colorado University's Center for Environment and Sustainability have partnered to complete 1) an energy use and GHG emissions baseline inventory and footprint for Gunnison County, and 2) forecast county GHG emissions to year 2030. The baseline inventory and footprint has been completed for 2015, applying latest and global best practices most recently published in the Global Protocol for Communities (GPC) standard. The inventory accounts for in-boundary activities stemming from residential buildings, commercial/industrial buildings, surface travel, air travel, and waste landfilling. Beyond the boundary limited inventory, the footprint additionally accounts for out-of-boundary energy uses and GHG emissions rooted in essential activities required for Gunnison County's continued operation; those activities are: fuel refining (for transportation), cement production (for built environment), and food production.

Described in this report includes the important difference between inventory and footprint. An inventory is boundary limited in that only activities from within the community are considered (i.e., Scopes 1+2). However, the reality is that communities are far more complex than their in-boundary activities and depend on a vast number of supply-chains. Thus, a footprint expands beyond the community boundary to consider a series of inexorably linked flows that are imperative for community and economic function (Scopes 1+2+3).

A forecast of Gunnison County's energy use and GHG emissions was also completed. Applying robust variables that included demographic, economic, and technical infrastructural changes, the forecast achieved a projection to 2030. This forecast is intended to be a tool for local governments to have a reference point for future actions, allowing for continued tracking over time. Note, the 2030 forecast is conducted for Gunnison County's five in-boundary inventory sectors (residential buildings, commercial/industrial buildings, surface travel, air travel, and waste landfilling).

Results – Energy and GHG Emissions Baseline

This assessment estimates GHG emissions associated with Gunnison County in 2015 amount to:

In-Boundary Inventory *(Scopes 1+2)* associated with residential + commercial/industrial buildings, surface travel, air travel, and waste landfilling = **273,165 mt CO_2e**

Essential Out-of-Boundary Flows *(Scope 3)* associated with fuel refining, cement production, and food production = **87,544 mt CO_2e**

TOTAL Gunnison County Footprint *(Scopes 1+2+3)* = **360,710 mt CO_2e**

Figure ES.1 shows the allocation of Gunnison County's GHG emissions footprint across sectors. One can observe that buildings energy use amounts to **47%** of the County's footprint, with electricity alone being **32%** of the footprint. Activities associated with transportation, both in- and out-of-boundary present another important dimension of the footprint. Transportation related energy use in the County (i.e., tailpipe) amount to **23%** of GHG emissions, or **28%** including fuel refining. Lastly, it is clear that the essential supply-chains emerging from out-of-boundary activities (fuel refining, cement, and food) yield an important consideration in future planning and community/economic development efforts.

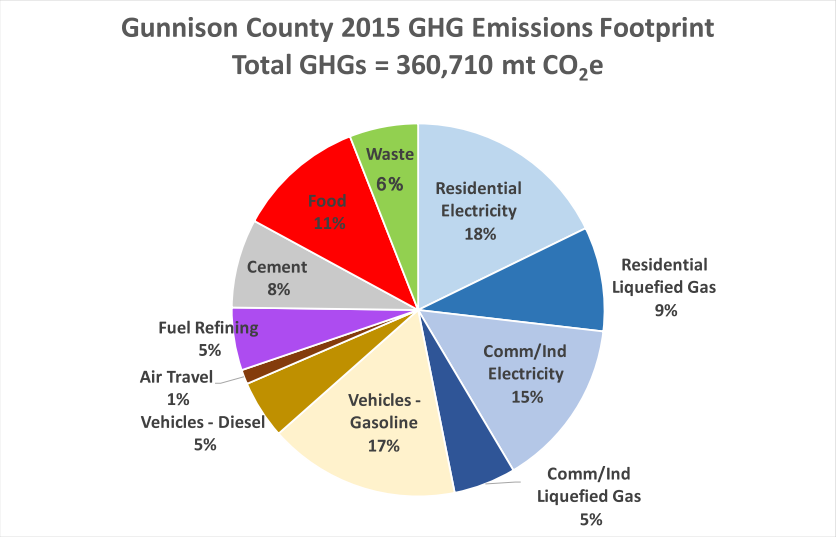

Figure ES.1: Gunnison County 2015 GHG Emissions Footprint.

Results – Energy and GHG Emissions 2030 Forecast:

The use of high-quality publicly available demographic, economic, and technological data were coupled with sound modeling and this 2015 inventory to create a 2030 forecast for Gunnison County. The forecast reveals that Gunnison County's in-boundary GHG emissions are projected to increase from 2015 levels of 273,165 mt CO_2e, by 11.9% to 305,577 mt CO_2e in 2030. During that same period (2015-2030), Surface Travel is projected to increase the most (25.5%). The sector is associated with private and commercial on-road transportation. See Figure ES.2.

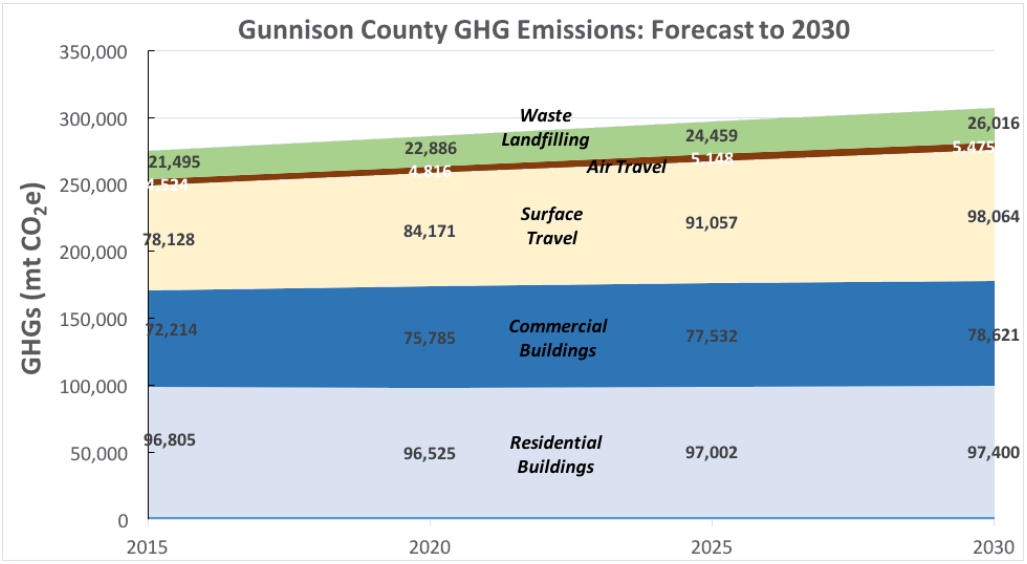

Figure ES.2: Gunnison County In-Boundary GHG Emissions 2030 Forecast.

The combination of the energy use and GHG emissions footprint, with 2030 forecast allows for several important opportunities. On one hand, local government personnel can track and measure the effects of community development efforts using a suite of dimensions. On the other hand, the possibilities for community engagement, reporting, and participation are vast.

1. Introduction and Background

Sustainability and resilience are two concepts that are becoming increasingly more familiar for and common parlance in local governments. Sustainability is often rooted in the "three E's" (Economics, Environment and Equity), and resilience is measured by the ability of a system to respond or return to functioning state post-shock. All the while, in order for maximum relevance, each concept ought to be placed and defined within the local community's context.

To this end, Dr. Abel Chávez and his Sustainable and Resilient Communities (SRC) team at Western State Colorado University (Western) partner with local governments and their constituents to develop their respective contexts and coupled narratives around energy, materials, and greenhouse gas (GHG) emissions. The SRC team also employs robust data processes to create energy and GHG emissions forecasts that are employed in long-term sustainability, resilience, and community planning.

The following report describes the results from energy and GHG emissions baselining and forecasting conducted through the partnership of Western and Gunnison County. First, a brief introduction into baselining guiding principles and global best practices are presented. Second, results from the energy and GHG emissions baselining are shared. Last, highlights from the energy and GHG emissions forecasting to year 2030.

The reader should note the important difference between inventory and footprint. An inventory is boundary limited in that only activities from within the community are considered. However, the reality is that communities are far more complex than their in-boundary activities and depend on a vast number of supply-chains. Thus, a footprint expands beyond the community boundary to consider a series of inexorably linked flows, that are imperative for community and economic function. Additionally, while the expansion from inventory to footprint will also yield a 'larger' estimate of a community's energy and GHG emissions, cost-effective actions may enhance efficiencies across out-of-boundary activities while preventing shifting of impacts, thus yielding a more holistic and realistic representation of the community.

1.1 Energy & GHG Emissions Baselining and Forecasting

As our economic system globalizes, the chains through which demand for energy and materials are provisioned are increasingly longer, more complex, and often more abstract. Thus, such energy and GHG emissions baselines are a useful mechanism for assessing a series of fundamental community questions including: "how much of particular energy type is used by vs. in the community and for what purposes?"; "how secure are the community's energy sources, and where are resilience opportunities?"; or, "can we continue growing our economy in a sustained manner?". A strong, robust, and community-driven baseline and forecast is a tool for all government-level departments in their respective and collective planning efforts, yielding an understanding of the possibilities towards building a strong local economy that generates jobs for its healthy residents, who are able to reap the benefits of energy efficient and renewable technologies.

In addition to the energy and GHG emissions baseline for year 2015, this report also summarizes a business-as-usual (BAU) forecast of Gunnison County's energy and GHG emissions to year 2030. Such a forecast allows for informed planning with innovative actions which can drive specific actions, all while being able to track the effects of actions in real-time, and long-term.

1.2 Greenhouse Gases (GHGs)

There are several greenhouse gases that are captured in a GHG emissions Baseline. GHGs include carbon dioxide ***(CO_2)***, methane ***(CH_4)***, nitrous oxide ***(N_2O)***, and three replacements for chlorofluorocarbons ***(CFC)*** (HFCs, PFCs, SF_6) that have mostly been phased out as a result of the 1989 Montreal Protocol. CFCs are typically small, unless significant industrial production of these chemicals occurs within the community.

Dominant GHGs: In the U.S., carbon dioxide ***(CO_2)***, methane ***(CH_4)***, and nitrous oxide ***(N_2O)*** emissions account for 97% of GHG emissions (EPA, 2016).

Sources of GHGs: There are a number of prominent GHG sources across communities. Carbon dioxide ***(CO_2)***, the largest contributor, is frequently produced from the combustion of fossil fuels in furnaces, power plants, and vehicular transportation. Methane ***(CH_4)*** is most often produced from waste decomposition (naturally or in landfills), enteric fermentation (cattle), and from fugitive emissions in natural gas pipelines. Nitrous oxide ***(N_2O)*** is most often emitted during wastewater treatment and agricultural soil and manure management.

GHGs Global Warming Potentials: GHGs are classified by their ability to trap heat in the atmosphere, and thus are assigned a value called Global Warming Potential (GWP). As a result, GHGs from different sources are then aggregated by their respective GWP and reported as a whole on a common basis known as metric tons of carbon dioxide equivalent (mt CO_2e). Table 1 shows the GWP for the top three greenhouse gases in the atmosphere. Note that methane has 28 times more potential to trap heat than carbon dioxide, and nitrous oxide has 265 times more potential.

Table 1: Global Warming Potentials

Greenhouse gas	Chemical Formula	Global Warming Potential
Carbon Dioxide	CO_2	1
Methane	CH_4	28
Nitrous Oxide	N_2O	265

1.3 Background: Energy and GHG in Gunnison

Gunnison County is located in southwest Colorado. The mostly rural county is home to about 80% public lands, with the City of Gunnison, Crested Butte and Mt. Crested Butte representing the semi-urban areas of the county. Total county population is estimated at 16,145 people, with about 50% of the population concentrated in the semi-urban areas and near 18% living below the poverty line (Census, 2016). With an average elevation of 7,700 feet above sea-level, Gunnison is also one of the coldest counties in the continental U.S. averaging 37°F. Gunnison County is a place with rich diversity, where its people are proud to call the county home. As the county continues adopting exemplary and novel paths that align its community development & planning needs, energy and GHG emissions analysis can bring insights into informing stakeholders about key critical paths, while creating new and novel opportunities for all.

Often, energy and GHG emissions analyses are placed under the nomenclature of *Energy Plan*, or *GHG Emissions Inventories*. The community has a precedent with the latter. In 2008, a group of community members released the Upper Gunnison River Watershed Greenhouse Gas Emissions Inventory (UGRW) applying 2005 activity data to a boundary that is defined by the watershed, and not the county (ORE, 2008). The current GHG emissions baseline and forecast,

this report, obtained new and current data, while applying present energy and GHG accounting methodologies as detailed in recently released global standards (i.e., ICLEI, 2012; PAS, 2013; GPC, 2014). Thus, the objectives of this study included:

- In partnership with the county, conduct a baseline inventory and footprint of county-wide energy use and GHG emissions;
- Understand key sources of use and opportunity across sectors in Gunnison County;
- Explore innovative actions that the county can promote to its policymakers and constituents in efforts of economic development, regional leadership & innovation, business opportunities, resource conversation, and energy efficiency;
- Track effects of actions using robust and current data and inventory techniques.

Following is a detailed description and findings of our analysis.

2. GHG Inventory Methodology

2.1 Method and Scopes

This Energy and GHG Inventory for Gunnison County is completed using latest community-based methods (ICLEI, 2012; PAS, 2013; GPC, 2014), which Dr. Abel Chávez helped inform and author. These latest methods delineate and describe many important community details around in-boundary (within jurisdictional boundary), and out-of-boundary activities – often reported using the Scope framework. Of the three scopes (Scope 1, 2, 3), Scope 1 are those from purely in-boundary activities, i.e., on-site combustion of fuels (natural gas combustion in furnaces, or vehicle fuel). Scope 2 emissions are usually out-of-boundary resulting from purchased electricity that is generated beyond the community boundary. Last, Scope 3 includes other "optional" out-of-boundary activities crucial for a community (e.g. water, food, fuels, and shelter).

In general, there are three types of approaches to community scale energy, material, and GHG emission accounting, each of which yields unique narratives and policy options. The three are:

- Purely Territorial *(Scope 1)*;
- Expanded Production *(Scope 1, 2, 3 as related to 'production')*; and
- Consumption-Based *(Scope 1, 2, 3 as related to 'consumption')*.

Figure 1 (adapted from Chavez et al., 2013) illustrates these flows in schematic form. And while the accounting completed in this effort mostly reflects a purely territorial (Scope 1), plus Scope 2, with minimal production Scope 3, we are committed to working with Gunnison County to complete a comprehensive accounting that will enhance the suite of production and consumption-based policy options available to the county.

2.2 In-Boundary Activities

In-boundary activities accounted include the following.

- **BUILDINGS:** Use of electricity, natural gas, and propane in residential, commercial and industrial sectors in the community. The uses of these fuels are converted to GHG emissions via each fuels' emissions factor.
- **SURFACE TRANSPORT:** Use of gasoline, diesel by personal and commercial vehicles in the community. Specifically captured as tailpipe GHG emissions from operating vehicles within a community.
- **WASTE LANDFILLING:** Amount of waste landfilled in the community by residential and commercial/industrial sectors. Best practices from EPA's WARM are used for estimating waste GHG emissions.

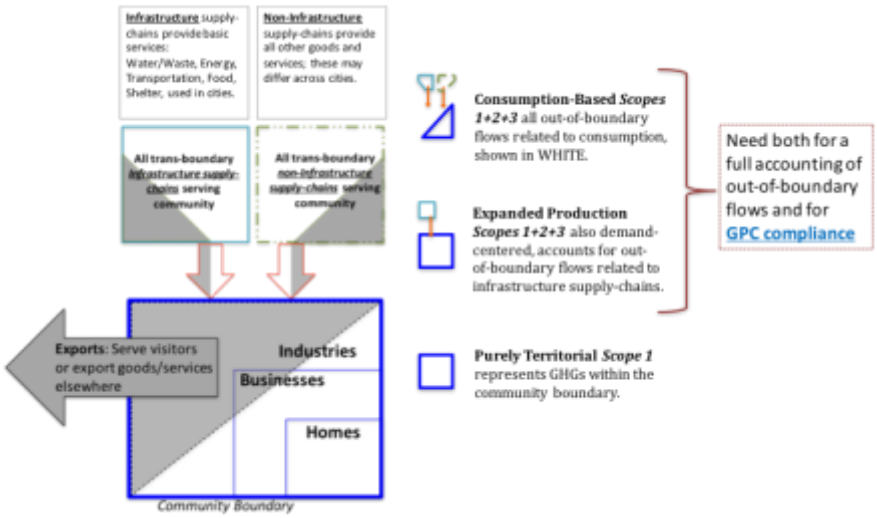

Figure 1: The three fundamental types of GHG accounting approaches for communities.

2.3 Out-of-Boundary Activities

Despite the fact that a community may report a larger GHG footprint upon including Scope 3 activities, either production or consumption, there may also be cost-effective actions that can be taken to enhance efficiencies across Scope 3 emissions. The following out-of-boundary activities, when added to in-boundary activities, yield a more holistic account of a community's GHG emissions footprint:

- **INFRASTRUCTURE SUPPLY-CHAINS:** This includes energy use and embodied GHG emissions from producing key materials such as water, energy, transport fuels, food, and shelter (cement for concrete), necessary to support life and economic development in the community.
- **NON-INFRASTRUCTURE SUPPLY-CHAINS:** These are associated with the provisioning of all other goods and services, such as financial, health, or educational type of services. Though not accounted for in this report, they can provide additional insights.

2.4 Assessed Sectors

To better communicate a community's overall energy use and GHG emissions, classifying energy end-use in three different sectors is most comprehensible in community-wide communications. Thus, noting that the adopted approach is a 'production' based approach, here we report energy use and GHG emissions in the following three sectors:

- **Buildings Sector:** Energy use (electricity, natural gas, and propane) in residential and commercial buildings, and industrial facilities.
- **Transportation Sector:** Energy (gasoline, diesel, and jet fuel) used in personal and commercial vehicles, and air travel. Often referred to as pump-to-wheels (P2W).
- **Materials and Waste Sector:** Energy use and associated GHG emissions from producing critical infrastructure materials (food, energy, water, cement) and waste landfilling.

2.5 Required Data and Benchmarks

In order to adequately complete the 2015 baseline for Gunnison County, the following data were gathered (see Table 2). In addition to these data, benchmarks were computed to validate and

identify possibly spurious data points, and determine the County's efficiencies.

Next, to convert energy and material use to GHG emissions, GHG Emissions Factors (EF) are employed. GHG EFs are based on latest technological understanding, and represent the amount of CO_2e (carbon dioxide equivalents) emitted per unit of the unit used. For example, kg CO_2e emitted per unit kWh of electricity consumed (or kg CO_2e/kWh).

Last, total **GHG** emissions are computed as the product of how much is consumed (**MFA**) and the GHG emissions per unit of the product consumed (**LCA**), or **GHG** = **MFA** X **LCA**. Thus, each sector's CO_2e emissions can be summed to find the total community-wide emissions.

Table 2: Required Energy Data and Computed Benchmarks for completing a community's baseline energy and material 'in-boundary' inventory.

Sector	Required Energy Data	Computed Benchmarks
Buildings ***(Residential, Commercial, and Industrial)***	• Electricity: total kWh • Natural gas: total therms (or BTU) • Propane: total gallons (or BTU) • Other Fuels, as applicable	Residential Intensity: kWh/HH/mo therms/HH/mo gallons/HH/mo kBTU/HH/mo Commercial/Industrial Intensity: kWh/job/mo therms/job/mo gallons/job/mo kBTU/job/mo
Surface Transport	• Gasoline: gallons used/purchased • Diesel: gallons used/purchased • Vehicle Miles Traveled (VMT)	VMT/person/day gallons-gasoline/cap/yr gallons-diesel/cap/yr
Air Transport	• Jet Fuel loaded at airport: gallons used/purchased • Enplaned passengers	Enplaned passengers/capita gallons-jet fuel/capita
Landfilling	• Waste landfilled • Characterized waste landfilled	tons-waste landfilled tons-waste landfilled/capita

3. 2015 Gunnison County Energy and GHG Emissions Baseline Inventory

This GHG Emissions Inventory and Footprint summary report is intended to serve as a baseline of energy use and GHG emissions for Gunnison County in 2015. It is Dr. Chávez's intent that Gunnison County have the necessary information for informed economic and environmental innovation across the county. As Gunnison County continues to embark on triple-bottom line actions, by sector, Western's Sustainable and Resilient Communities (SRC) team led by Dr. Chávez, will be able to assist the county in tracking the progress towards integrating infrastructure efficiencies, reducing environmental impacts, and the economic and social benefits that come as a result of such actions.

3.1 Reporting year

Based on most recent available data, the selected year for the Gunnison County baseline is 2015. Following are the summarized results for energy and GHG emissions relating to the sectors of:

- Buildings
- Transportation

- Waste and *selected* Materials

This baseline can be referenced, and the effects of local actions can be tracked, in assessing Gunnison County's goals progress in the coming years. For each sector, raw activity/use data are presented, GHGs are computed and reported in metric tons of carbon-dioxide equivalent (mt CO_2e), and data benchmarks are quantified and compared to relevant State of Colorado metrics.

3.2 Buildings Sector

3.2.1 Buildings MFA: Energy Use

The buildings sector energy use reports electricity, natural gas, and propane used by residential, commercial, and industrial facilities. These data were obtained from the following: Electricity from the City of Gunnison utility (CoG), and Gunnison County Electric Association (GCEA) for 2015. Liquefied gas consisted of Natural Gas from Atmos Energy, and Propane from both Ferrell Gas and AmeriGas. As 2015 data from Ferrell Gas was inaccessible, 2014 sales data for Gunnison County was applied.

Next, using socio-demographic data pertaining to population, households, and employment retrieved from Colorado's Department of Local Affairs (DOLA), building energy use intensities were computed as noted in Table 2. Thus, calculated building energy use intensities for Gunnison County were benchmarked with parallel State of Colorado metrics reported by the Energy Information Administration (EIA) State Energy Data System (SEDS). The resulting metrics for both Gunnison County and the State of Colorado are shown in Table 7, resulting in acceptable alignment – confirming data validity.

3.2.2 Buildings LCA: GHG Emissions

CoG electricity EF was obtained directly from the utility and reported as 0.51 kg CO_2e/kWh; GCEA's EF was retrieved from Tri-State Generation and Transmission Association (Tri-State) – GCEA's sole supplier – and reported as 0.74 kg CO_2e/kWh (Tri-State, 2015). For natural gas and propane, the EF values applied were 5.3 kg CO_2e/therm and 5.7 kg CO_2e/gallon (EPA, 2014) corresponding to the national default values, which does not generally change according to region. Therefore, total energy use (or MFA), is multiplied by that fuel's respective emissions factors (or LCA), to compute the total GHG emissions, resulting in **169,019 mt CO_2e** for the buildings sector. See Table 3, Figure 2, and Figure 3 for added details.

Table 3: 2015 Buildings Energy Use and GHG Emissions – Gunnison County.

Residential Energy	**2015**
Total Population	16,145
Households	6,870
CoG Grid Electricity use (kWh)	24,437,142
GCEA Grid Electricity use (kWh)	70,311,978
Natural Gas use (therms)	4,309,512
Propane use (gallons)	1,707,786
Total Residential GHG emissions (mt CO_2e)	**96,805**
Commercial/Industrial Energy	**2015**
Jobs	10,797
CoG Grid Electricity use (kWh)	41,565,894
GCEA Grid Electricity use (kWh)	42,953,468
Natural Gas use (therms)	3,538,905
Propane use (gallons)	116,966
Total Comm/Ind GHG emissions (mt CO_2e)	**72,214**
Total Buildings GHG Emissions (mt CO_2e)	**169,019**

Figure 2: (A) Buildings Energy Use, and (B) GHG Emissions, by sector.

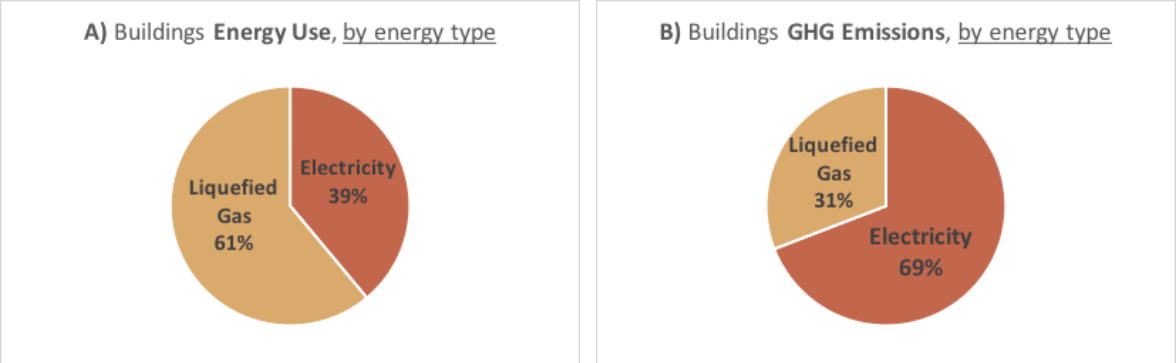

Figure 3: (A) Buildings Energy Use, and (B) GHG Emissions, by energy type.

3.3 Transportation Sector

Transportation energy use in Gunnison County are from two principal sources:

1. **Personal and Commercial Vehicles (Surface Travel)**
2. **Airline Transport (Air Travel)**

Summary statistics for Gunnison County's transportation sector are presented in Table 4 below.

3.3.1 Surface Travel and Vehicle Intensity

Estimating surface travel energy use for Gunnison County employed the following 2015 data. First, annual vehicle miles traveled (VMT) were retrieved from the Colorado Department of Transportation (CDOT) county-level VMT tool (CDOT, 2015), amounting to a county-wide estimate of 153.9 million VMT. Next, using percentage of national VMTs by vehicle type (e.g., light duty vehicles, trucks, bus, etc.), county VMTs were allocated to the same vehicle type classification, resulting in estimated VMTs by vehicle type for Gunnison County. Lastly, for each vehicle type, the ratio of VMT (miles) to fuel economy (miles per gallon) was used to compute total fuel usage, in gallons, of gasoline and diesel. See Table 4 for fuel estimates.

The above approach was validated in the following manner.

a. CDOT VMTs were compared to similar statistics reported by HPMS and EPA which uses average roadway vehicle-miles in both urban and rural U.S. counties. Our approach produced no computable differences. 27.2 miles/cap/day from HPMS, compared to 26.3 miles/cap/day our estimate.

b. Fuel use, per capita gallons of gasoline and diesel, respectively, were benchmarked to State metrics; acceptable and minor differences noted. See benchmarking table, Table 7.

3.3.2 Air Travel

For this Gunnison County GHG emissions baseline, we retrieved 2015 commercial passenger enplanement statistics at Gunnison-Crested Butte Regional Airport (GUC) from the Federal Aviation Administration (FAA, 2016), reported at 34,412 passengers. Next, using publicly reported national statistics on jet-fuel loaded from the Bureau of Transportation Statistics (BTS, 2016) and total enplanements from the FAA, a national average of jet-fuel loaded per passenger (13.4 gallons per passenger) was applied to total enplanements at GUC to estimate commercial fuel use for Gunnison County. Note, private jet fuel at GUC may represent a respectable amount of additional jet fuel use potentially not captured here.

3.3.3 Emissions from Gasoline, Diesel, and Jet Fuel

Transportation fuel (gasoline, diesel, and jet fuel) combustion emissions factors were obtained from EPA (2014) – the following factors were used in this baseline inventory: gasoline = 8.87 kg CO_2e/gallon, diesel = 10.22 kg CO_2e/gallon, and jet fuel = 9.78 kg CO_2e/gallon. Upon multiplying fuel used by type (MFA) by the respective EF (LCA), the following estimates of GHG emissions were computed for Gunnison County.

Gasoline = 59,896 mt CO_2e; Diesel = 18,232 mt CO_2e; Jet Fuel = 4,524 mt CO_2e. For total transportation GHG emissions of **82,651 mt CO_2e**. Table 4 provides additional details.

Table 4: Transportation sector energy use and GHG emissions.

Surface Travel	**2015**
Annual Vehicle Miles Traveled (VMT)	153,957,372
VMT/person/day	26.3
Annual Fuel Use	
Gasoline (gallons)	6,754,160
Diesel (gallons)	1,784,098
Total Surface Travel GHG emissions (mt CO_2e)	**78,128**
Air Travel	**2015**
Passenger Enplanements at GUC (passengers)	34,412
U.S. Passenger Fuel Intensity (gallons per passenger)	13.4
Annual Jet Fuel loaded at GUC (commercial gallons)	462,431
Total Air Travel GHG emissions (mt CO_2e)	**4,524**
Total Transportation Sector GHG Emissions (mt CO_2e)	**82,651**

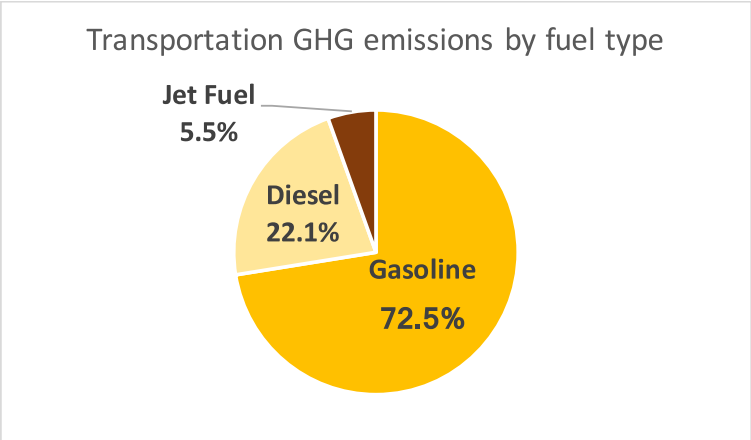

Figure 4: Transportation sector GHG emissions, by fuel type.

3.4 Materials and Waste Sector

Per protocol, an expanded production footprint must account for materials from several key sources of GHG emissions including: fuel refining, food production, cement, water & wastewater, and municipal solid waste (MSW). In this study however, incomplete data did not allow for a full accounting of the above material sectors. Thus, as described below, fuel refining, waste landfilling, cement production, and food production sectors were included in this assessment, enabling the team to approach a GHG emissions footprint as described in global protocols.

3.4.1 Fuel Refining

GHG emissions factors for fuel refining, or Wells-to-Pump (WTP), were retrieved from Argonne National Laboratory's GREET (Greenhouse gases, Regulated Emissions, and Energy use in Transportation) model (ANL, 2016). The corresponding values are: gasoline = 2.0 kg CO_2e/gallon, diesel = 2.65 kg CO_2e/gallon, and jet fuel = 2.65 kg CO_2e/gallon. As a result, fuel refining associated with Gunnison County's transportation fuel use emitted: gasoline = 13,639 mt CO_2e, diesel = 4,736 mt CO_2e, and jet fuel = 1,228 mt CO_2e from the fuel refining process, for a total of **19,603 mt CO_2e**.

3.4.2 Municipal Solid Waste

Municipal Solid Waste landfilled in Gunnison County at the Six Mile Landfill were retrieved from Colorado's Department of Public Health & Environment, which reported 16,916 tonnes of MSW in 2015 (CDPHE, 2016). Recycling information was not available at the time of this assessment. Next, leveraging the EPA's WAste Reduction Model (WARM) to estimate GHG emissions from solid waste as a result of anaerobic breakdown of biodegradable material, and selecting mixed MSW with no flaring in WARM, we arrived at an estimated **21,495 mt CO_2e** from waste landfilling in Gunnison County (WARM, 2016).

3.4.3 Cement in Concrete

Though a community uses a number of construction materials throughout its built environment, cement is recognized as a material used in high amounts, and one with high energy and GHG intensities. National Renewable Energy Laboratory's (NREL) Life Cycle Inventory Database reports that Portland cement production emits 0.93 kg CO_2e/kg cement (NREL, 2016). Cement flows in Gunnison County were estimated by first coupling State financial data for the cement sector (NAICS 3273) from Census (2016), where total sales are estimated as $912.6 million, with the average cost of cement ($90/mt cement). Last, the State's use of cement were allocated to Gunnison County via the proportion of County-to-State population, and thus finally arriving at **27,815 mt CO_2e** for cement GHG emissions attributed to Gunnison County.

3.4.4 Food Consumption

Food is yet another essential flow that should be captured in community footprints. Like the other materials sectors, food is not usually produced in large amounts within County limits; on the contrary, there are many miles between food's point of production and its consumption. Thus, the embodied energy from food and food packaging is determined in the following manner. The Consumer Expenditure Survey provides average annual household food expenditures, estimated at $3,245/HH/yr for Gunnison in 2015, after adjusting for inflation (BLS, 2015). The emissions factor for food production is estimated at 1.8 kg CO_2e/$\$_{2002}$ (CMU, 2015). As a result, applying the inflation adjusted food expenditures, the estimated GHG emissions associated with food in Gunnison are **40,126 mt CO_2e**.

3.4.5 Total Materials and Waste Emissions

Total emissions associated with fuel production, waste landfilling, cement production, and food production are summarized in Table 5 below.

Table 5: GHG emissions associated with materials and waste in Gunnison County.

Material	Material Flow	GHG Emissions (mt CO_2e)
Fuel Refining		
Gasoline (gallons)	6,754,160	13,639
Diesel (gallons)	1,784,098	4,736
Jet Fuel (gallons)	462,431	1,228
Waste Landfilling (tons)	18,647	21,495
Cement Production (tonnes)	29,909	27,815
Food Production ($/HH)	$3,245	40,126
Total Materials and Waste GHG Emissions (mt CO_2e)		**109,039**

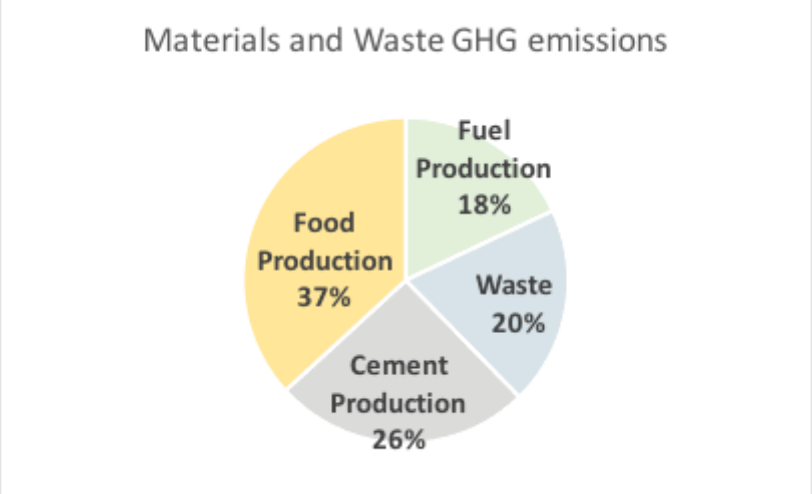

Figure 5: Materials and Waste GHG Emissions

3.5 County-Wide GHG Emissions Inventory and Footprint

This effort has allowed Gunnison County to have both, baseline energy and GHG emissions inventory, and footprint. An inventory accounts for in-boundary flows (Scope 1) plus out-of-boundary flows associated with purchased electricity generation (Scope 2). However, communities are greatly dependent on robust sets of infrastructure supply-chains for sustaining local economic development, that considering footprints, which include Scope 3 energy and GHG emissions, are a practical for continued planning. As a result, Gunnison County's GHG emissions inventory (Scope 1 + 2, less waste) totaled 251,670 mt CO_2e, or 16.9 mt CO_2e/capita. Upon aggregating infrastructure supply-chains associated with key materials in Gunnison County

(Scope 3), the County's GHG emissions footprint totals 360,710 mt CO_2e, or 22.3 mt CO_2e/capita. These data are summarized in Table 6 below. Lastly, Scope 1 emissions = 42%, Scope 2 emissions = 32%, and Scope 3 emissions = 26%.

Table 6: Summary of 2015 GHG emissions for Gunnison County

Sector		(A) Material/Energy Flow	(B) Emissions Factor	(A x B) = GHG Emissions (mt CO_2e)
Residential Buildings	Electricity	CoG: 24,437,142 kWh	0.51 kg CO_2e/kWh	12,463
		GCEA: 70,311,978 kWh	0.74 kg CO_2e/kWh	51,667
	Natural Gas	4,309,512 therms	5.3 kg CO_2e/therm	22,871
	Propane	1,707,786 gallons	5.7 kg CO_2e/gallon	9,804
Commercial/Industrial Buildings	Electricity	CoG: 41,565,894 kWh	0.51 kg CO_2e/kWh	21,199
		GCEA: 42,953,468 kWh	0.74 kg CO_2e/kWh	31,563
	Natural Gas	3,538,905 therms	5.3 kg CO_2e/therm	18,781
	Propane	116,966 gallons	5.7 kg CO_2e/gallon	671
Surface Travel	Gasoline	6,754,160 gallons	8.87 kg CO_2e/gallon	59,896
	Diesel	1,784,098 gallons	10.22 kg CO_2e/gallon	18,232
Air Travel	Jet Fuel	462,431 gallons	9.78 kg CO_2e/gallon	4,524
Waste Landfilling	Waste Landfilled	18,647 tons	1.15 mt CO_2e/ton	21,495
Fuel Refining	Gasoline	6,754,160 gallons	2.0 kg CO_2e/gallon	13,639
	Diesel	1,784,098 gallons	2.65 kg CO_2e/gallon	4,736
	Jet Fuel	462,431 gallons	2.65 kg CO_2e/gallon	1,228
Cement Production	Cement	29,909 tonnes	0.93 mt CO_2e/mt cement	27,815
Food Production	Food	$3,245/HH (2002$)	1.8 kg CO_2e/$\$_{2002}$	40,126
Total GHG Emissions Footprint (Scopes 1+2+3)				**360,710**
Per Capita GHG Emissions				**22.3 mt CO_2e/capita**

CoG: City of Gunnison Utility
GCEA: Gunnison County Electric Association

3.6 Benchmarking

Computing total emissions for a community is indeed an essential step towards measuring and continually tracking progress. In order for data to withstand the highest levels of scrutiny however, it must be validated. Therefore, Dr. Chávez employs rigorous levels of data benchmarking to illustrate the alignment of adopted data with what might be expected. The following table, Table 7, shows the results of the data benchmarking process comparing Gunnison County's energy and GHG emissions data against high-quality State data from the EIA-SEDS, and other sources. As a result, this ensures the data can be trusted and used for actionable local planning & engagement.

Table 7: Energy use and GHG Emissions benchmarks. Gunnison County vs. State of Colorado.

Gunnison County Building Energy Benchmarks				
	Metric	Unit	2015	Colorado (2014)
Residential	Population	people	16,145	5,355,588
	Households	households	6,870	2,116,833
	Electricity	kWh	94,749,120	18,093
	Natural Gas	therms	4,309,512	1,320,315,173
	Propane	gallons	1,707,786	124,191,112
	household electricity use	kWh/HH/mo	1,149	712
	household natural gas use	therms/HH/mo	52.3	52.0
	household propane gas use	gallons/HH/mo	20.7	4.9
	Electricity Intensity	kBTU/HH/mo	3,921	2,430
	Stationary Fuel Intensity	kBTU/HH/mo	7,119	5,644
	TOTAL Residential Building Intensity	kBTU/HH/mo	11,041	8,074

	Metric	Unit	2015	Colorado (2014)
Commercial + Industrial	Employment	jobs	10,797	3,068,394
	Electricity	kWh	84,519,362	35,239
	Natural Gas	therms	3,538,905	2,420,577,817
	Propane	gallons	116,966	46,267,277
	Annual electricity use	kWh/job/mo	652	957
	Annual natural gas use	therms/job/mo	27.3	65.7
	Annual propane use	gallons/job/mo	0.9	1.3
	Electricity Intensity	kBTU/job/mo	2,226	3,265
	Stationary Fuel Intensity	kBTU/job/mo	2,814	6,689
	TOTAL Comm+Ind Building Intensity	kBTU/job/mo	5,040	9,954

Gunnison County Travel Energy Benchmarks				
	Metric	Unit	2015	Colorado (2014)
Surface Travel	VMT	vehicle miles	153,957,372	47 billion miles
	VMT	miles/person/day	26.13	24.04
	Gasoline	gallons of gasoline	6,754,160	2,152,122,000
	Diesel	gallons of diesel	1,784,098	623,952,000
	Gasoline per capita	gallons-gasoline/cap	418.3	401.8
	Diesel per capita	gallons-diesel/cap	110.5	116.5

	Metric	Unit	2015	Colorado (2014)
Air Travel	enplanements	passengers	34,412	27,643,040
	jet fuel loaded	gallons-jet fuel	462,431	389,970,000
	normalized enplanements	passengers/cap	2.1	5.2
	normalized jet fuel loaded	gallons-jet fuel/cap	28.6	72.8

Gunnison County Waste Landfilling Benchmarks				
	Metric	Unit	2015	Colorado (2015)
Landfill	waste landfilled	tons-waste	18,647	7,578,280
	normalized waste landfilled	tons-waste/cap	1.15	1.39

4. 2030 GHG Emissions Forecast

This section summarizes the results from the energy and GHG emissions forecast for Gunnison County to year 2030. Such a forecast is a projection of activities, namely energy use, and the

resulting GHG emissions. The forecast is driven by a number of variables, including anticipated demographic changes (e.g., population), economic (e.g., jobs), and technical infrastructural dynamics (e.g., electricity emissions factors). While the 2030 energy and GHG emissions forecast is not intended to be a prediction, it is a tool for local governments to have a reference point to be able to visualize and track the effects stemming from a series of local actions over time.

In this forecast, the sectors defined by the inventory portion of this assessment (see Section 3) have been analyzed. The sectors are: residential buildings, commercial/industrial buildings, surface travel, air travel, and waste. These five sectors represent the majority of Gunnison County's footprint, but the foundation of these five sectors is such that they offer strong and relatively high-quality local data which allows for energy and GHG emissions forecasting. It is noteworthy to reiterate that this 2030 forecast is for Gunnison County's in-boundary activities (Scopes 1+2), including air travel and waste landfilling, only, and does not account for out-of-boundary (Scope 3) activities. Recall, said Scope 3 activities from the footprint are: fuel refining, cement production, and food production; these are not forecasted to 2030.

The following sections illustrate the highlights from Gunnison County's 2030 forecast.

4.1 Buildings: Residential and Commercial/Industrial

As previously noted, electricity is supplied to Gunnison County by two utilities: City of Gunnison Utility (CoG) and Gunnison County Electric Association (GCEA). Each has distinct grid emissions factors; at the time of this report CoG's EF is reported at 0.51 kg CO_2e/kWh, and GCEA's EF is 0.74 kg CO_2e/kWh. As each utility leads its own resource planning, helping establish the rate at which renewable targets are met, the following EF assumptions were made:

CoG – with the relatively higher levels of renewables currently integrated in CoG's grid, this forecast maintained a constant EF for CoG electricity through 2030.

GCEA – electricity is supplied to GCEA by Tri-State. A recent annual report indicated Tri-State's regional EF 2030 goals were 0.503 kg CO_2e/kWh (Tri-State, 2015). Thus, this forecast applied an annual linear reduction between current 2015 EF to 2030 goal.

As explained in the next two sub-sections, residential and commercial/industrial energy use forecast assumed that the respective energy use intensities remained unchanged from 2015 levels.

4.1.1 Residential Buildings

The residential buildings sector assumed that energy use per capita remained constant from 2015 levels throughout the forecast to 2030. This assumption applied to electricity use (5,869 kWh/cap/yr), natural gas use (266.9 therms/cap/yr), and propane use (105.8 gallons/cap/yr). Population growth statistics for Gunnison County were retrieved from Colorado's State Demography Office (DOLA, 2016), which reported the County's 2030 population at 19,540; a compound annual growth rate (CAGR) of 1.3% between 2015 and 2030.

As a result of these collective assumptions, residential building energy use (Figure 6) and GHG emissions (Figure 7) for Gunnison County are project to experience some growth. Residential energy use is forecasted to increase a total 21%, from 268,852 MWh in 2015 to 325,395 MWh in 2030. Meanwhile, largely due to a reported decrease in GCEA's EF, residential GHG emissions are forecasted to increase 0.6%, from 96,805 mt CO_2e in 2015 to 97,400 mt CO_2e in 2030. See Table 8. Additionally, appendix B reports residential building energy use and prices to 2030.

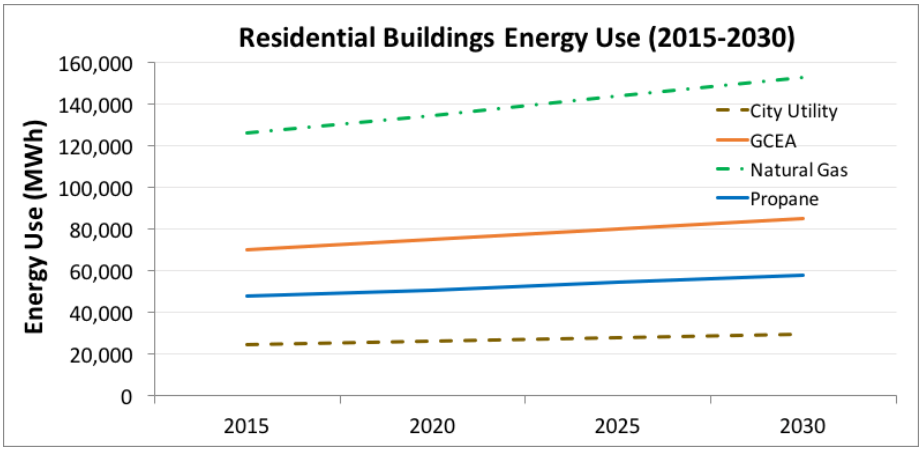

Figure 6: Residential building energy use thru 2030. *in MWh.*

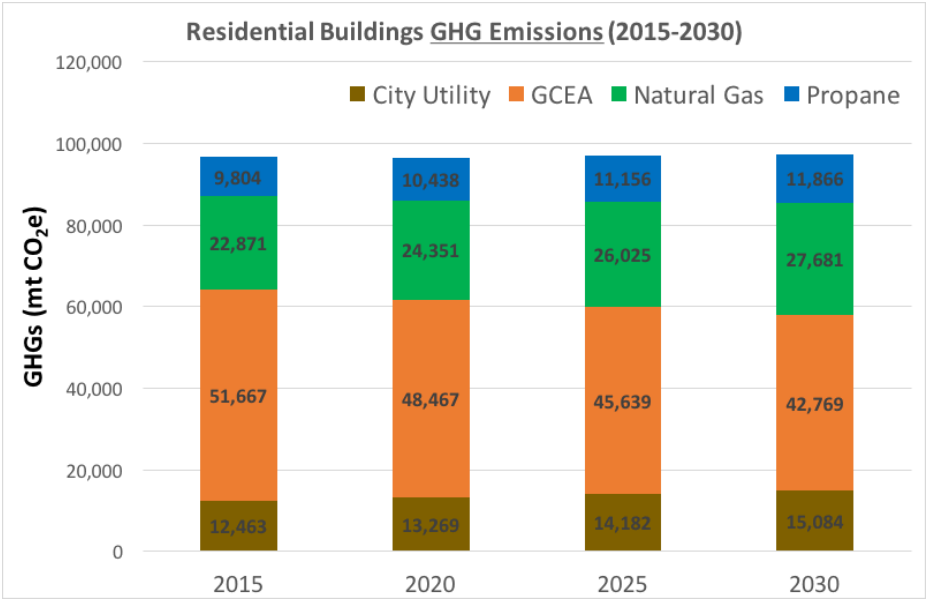

Figure 7: Residential building GHG emissions thru 2030. *in mt CO_2e.*

Table 8: Residential energy use and GHG emissions forecast in five-year increments.

	2015	**2020**	**2025**	**2030**	***% total change (2015 – 2030)***
Residential Energy Use *(MWh)*	268,852	286,244	305,930	325,395	***21%***
Residential GHG Emissions *(mt CO_2e)*	96,805	96,525	97,002	97,400	***0.6%***

4.1.2 Commercial/Industrial Buildings

The commercial/industrial buildings sector also assumed that energy use intensity remained constant from 2015 levels throughout the forecast to 2030. This assumption applied to electricity use (7,828 kWh/job/yr), natural gas use (327.8 therms/job/yr), and propane use (10.8 gallons/job/yr). Employment statistics for Gunnison County were retrieved from Colorado's State Demography Office (DOLA, 2016), which reported the County's 2030 employment at 13,639; a CAGR of 1.6% between 2015 and 2030.

As a result, commercial/industrial building energy use (Figure 8) and GHG emissions (Figure 9) for Gunnison County are projected to increase. Commercial/industrial energy use is forecasted to increase a total 26.3%, from 191,512 MWh in 2015 to 241,921 MWh in 2030. Meanwhile, commercial/industrial building GHGs will see a growth of 8.9%, from 72,214 mt CO_2e in 2015 to 78,621 mt CO_2e in 2030. Appendix C reports commercial/industrial building energy use and prices to 2030.

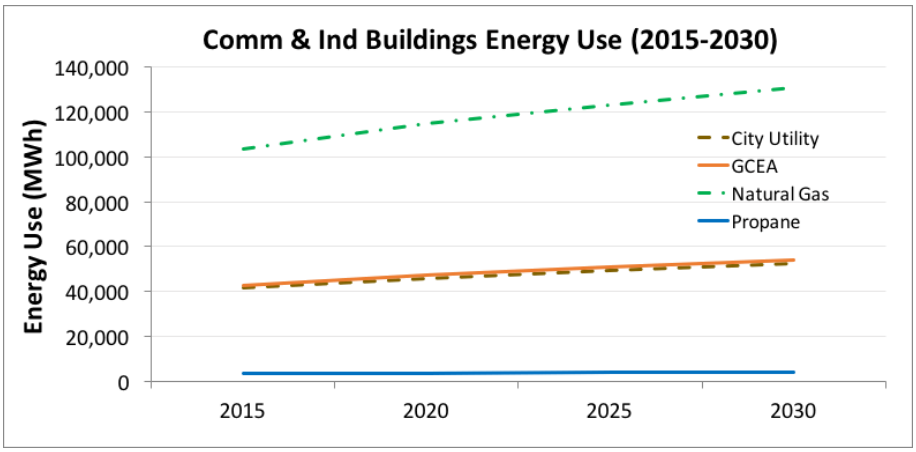

Figure 8: Commercial/Industrial building energy use thru 2030. *in MWh*.

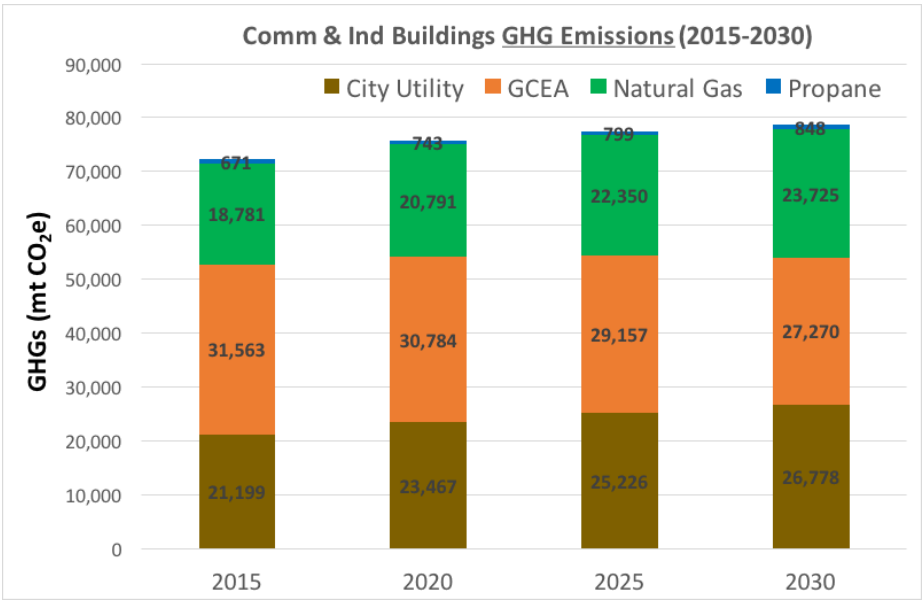

Figure 9: Commercial/Industrial building GHG emissions thru 2030. *in mt CO_2e*.

Table 9: Commercial/Industrial energy use and GHG emissions forecast in five-year increments.

	2015	2020	2025	2030	*% total change (2015 – 2030)*
Comm/Ind Energy Use *(MWh)*	191,512	212,003	227,900	241,921	***26.3%***
Comm/Ind GHG Emissions *(mt CO_2e)*	72,214	75,785	77,532	78,621	***8.9%***

4.2 Surface Travel

Surface travel is comprised of private and commercial vehicles, predominantly either users of gasoline or diesel. Emerging from the baseline assessment (described previously) were both VMT/capita and VMT by fuel type for Gunnison County. Meanwhile, national statistics from the U.S. Federal Highway Administration were used to derive growth estimates for gasoline and diesel VMT/capita, respectively, for communities that are both urban and rural – a reasonable depiction of Gunnison County (FHWA, 2015). From these data, a CAGR for VMT/cap of 0.04% (gasoline) and 0.87% (diesel) were derived, coupled with County population projections, and used for forecasting both gasoline VMT and diesel VMT. Then, after applying fuel efficiencies by vehicle type, forecasted GHG emissions were estimated as reported in Figure 10.

Gasoline GHG emissions are forecasted to increase by 21.8%, from 59,896 mt CO_2e in 2015 to 72,928 mt CO_2e in 2030. Diesel GHG emissions are forecasted to increase by 37.9%, from 18,232 mt CO_2e in 2015 to 25,137 mt CO_2e in 2030.

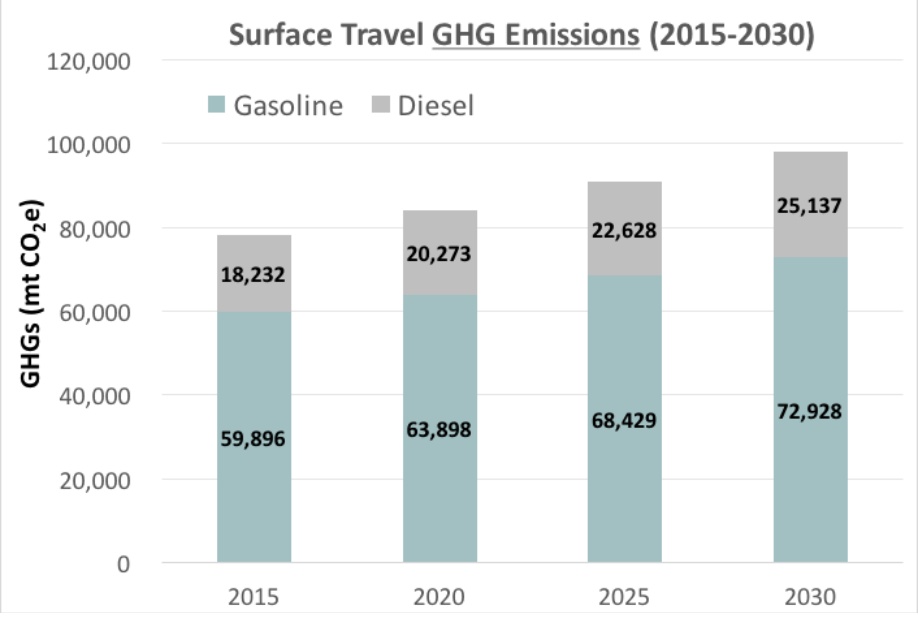

Figure 10: Surface travel GHG emissions thru 2030. *in mt CO_2e*.

4.3 Air Travel

The principal driver of the air travel energy use and GHG emissions forecast is population, as the number of county enplanements was held constant at 2.1 passengers/capita. Therefore,

doing so resulted in a forecast that amounted to 559,686 gallons of jet fuel loaded at GUC in 2030, emitting 5,475 mt CO_2e. See Figure 11.

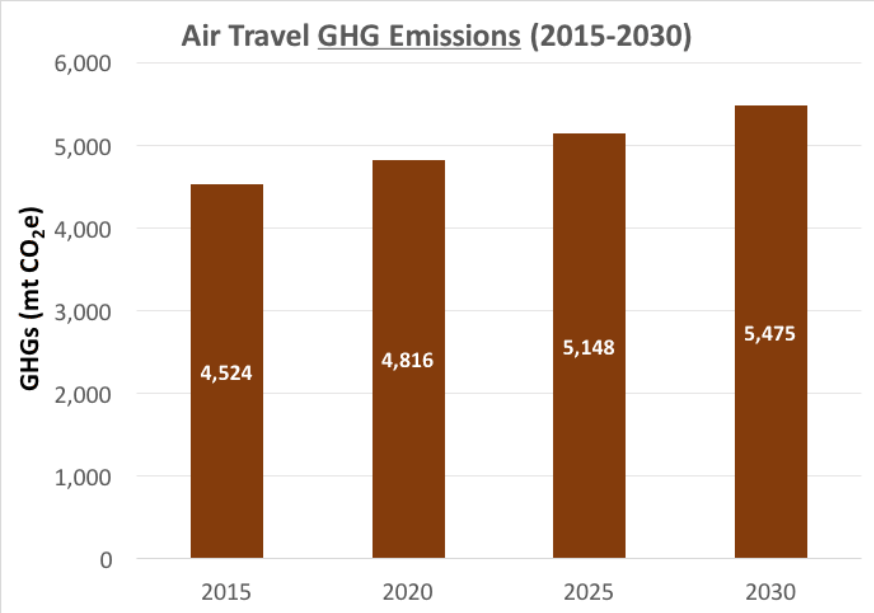

Figure 11: Air travel GHG emissions thru 2030. *in mt CO_2e*.

4.4 Waste Landfilling

Holding the amount of waste per capita constant, population is used to forecast GHG emissions from waste landfilling in Gunnison County. It is estimated that waste landfilling GHG emissions would total 26,016 mt CO_2e in 2030, an increase of 21% from 2015. See Figure 12.

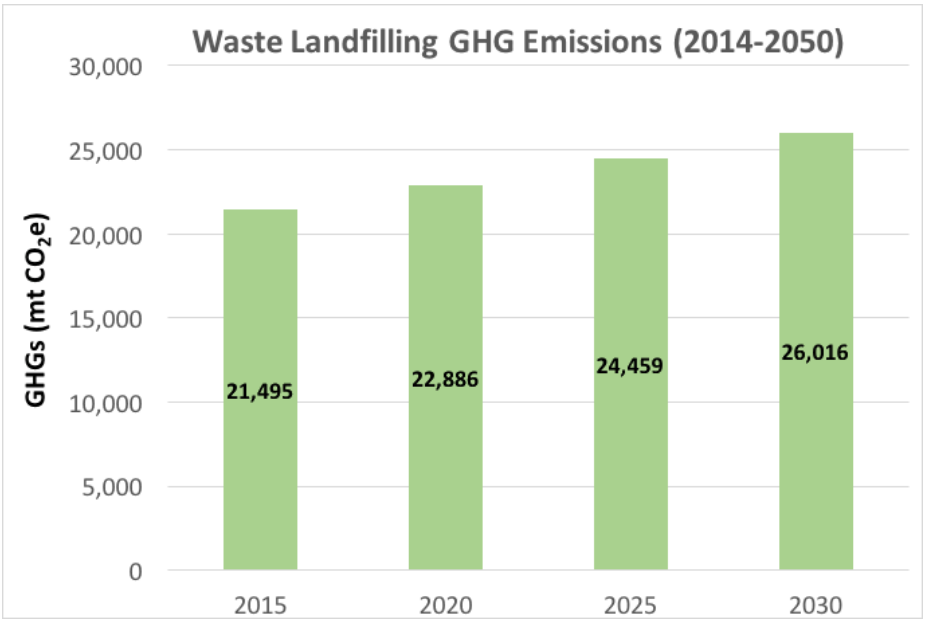

Figure 12: Waste landfilling GHG emissions thru 2030. *in mt CO_2e*.

4.5 Totals and Conclusions

In accordance with the procedures described in this section, the aggregate yields an energy and GHG emissions forecast for Gunnison County's in-boundary activities (Scopes 1+2), plus waste landfilling, to the year 2030. It is important to reiterate that this forecast does not account for out-of-boundary (Scope 3) activities. As result, this forecast estimates that the County's in-boundary GHG emissions will increase a total of 11.9% from the 2015 baseline of 273,165 mt CO_2e, and thus reaching 305,577 mt CO_2e by 2030. In the interim years, GHG emissions are projected to reach 284,183 mt CO_2e in 2020, and 295,199 mt CO_2e by 2025. The following table, Table 10, summarizes these projections, and Figure 13 illustrates the same in visual form.

With this 2030 forecast, the County can assess and track a series of actions and their effects over time. While the foundation of this forecast is energy use and GHG emissions associated with Gunnison County, the suite of possibilities extends well beyond energy use and into community development, economic development, social well-being, and many other key dimensions.

Table 10: GHG Emissions Forecast – Summary.

in mt CO2e	2015	2020	2025	2030	*% total change (2015 – 2030)*
Residential GHG Emissions	96,805	96,525	97,002	97,400	***0.6%***
Comm/Ind GHG Emissions	72,214	75,785	77,532	78,621	***8.9%***
Surface Travel GHG Emissions	78,128	84,171	91,057	98,064	***25.5%***
Air Travel GHG Emissions	4,524	4,816	5,148	5,475	***21%***
Waste Landfilling GHG Emissions	21,495	22,886	24,459	26,016	***21%***
TOTAL <u>In-Boundary</u> GHG Emissions	**273,165**	**284,183**	**295,199**	**305,577**	***11.9%***

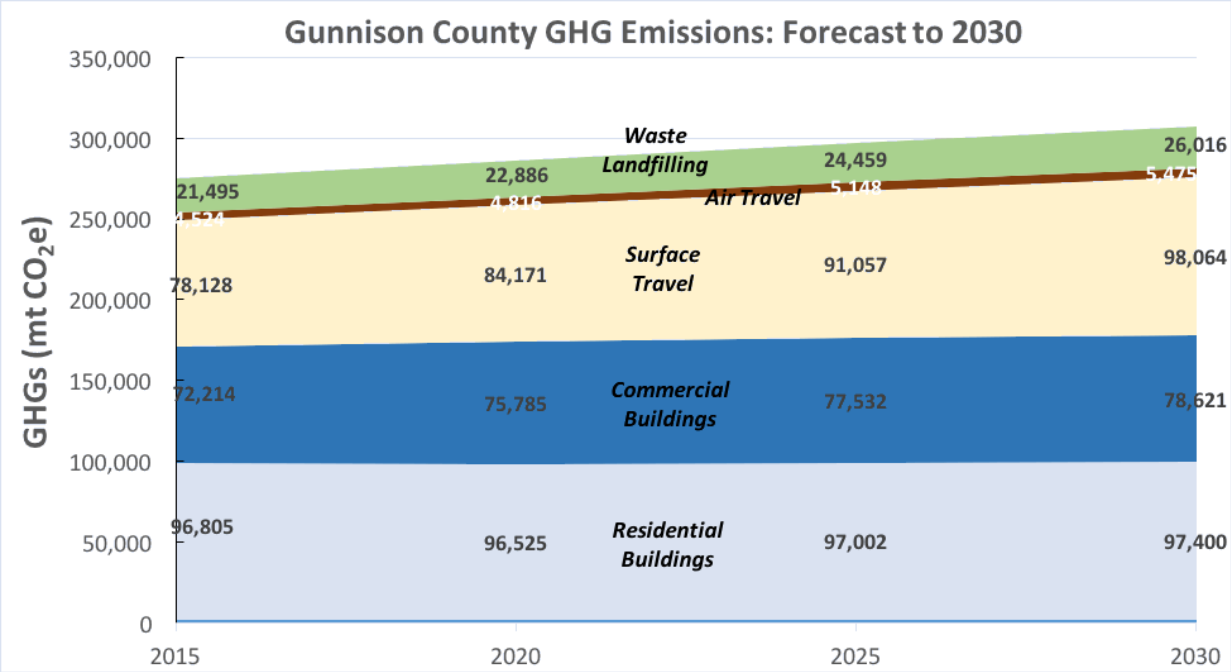

Figure 13: Gunnison County In-Boundary GHG Emissions 2030 Forecast.

Appendix

The suite of analyses completed under this 2015 Baseline & 2030 Forecast extend beyond the data presented in this summary report. Much of the additional analyses relates to Gunnison County's largest energy user – the buildings sector. The following appendices illustrate some of the additional discoveries made under this study.

Appendix A: Total Buildings Energy Use

Figure 14 presents total energy use (electricity, natural gas, and propane), in MWh, from all buildings (residential, commercial, and industrial) in Gunnison County for each of the following years: 2015, 2020, 2025, and 2030. It is noted that electricity use makes up 39%, natural gas 50%, and propane 11% of Gunnison County's buildings energy use.

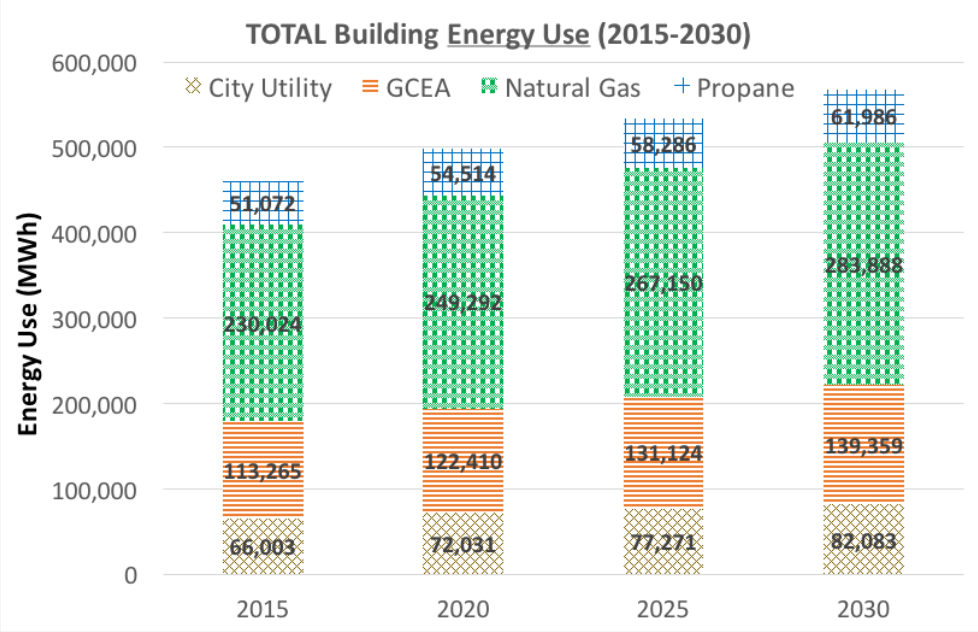

Figure 14: Total Buildings Energy Use in Gunnison County.

Appendix B: Residential Buildings Energy Use and Prices

Energy prices and projected volatilities can present communities with unique perspectives allowing for target strategies which may maximize local economic development opportunities. Figure 15 shows such projected changes in residential energy use, as reported by the U.S. Energy Information Administration (EIA) for the State of Colorado. It is observed that prices of both liquefied fuels (natural gas and propane) will witness modest or flat growth between 2015 and 2030, while electricity, already the highest in terms of price per unit ($/MWh) today, is projected to increase by 15% from $121/MWh (in 2015) to $139/MWh (in 2030).

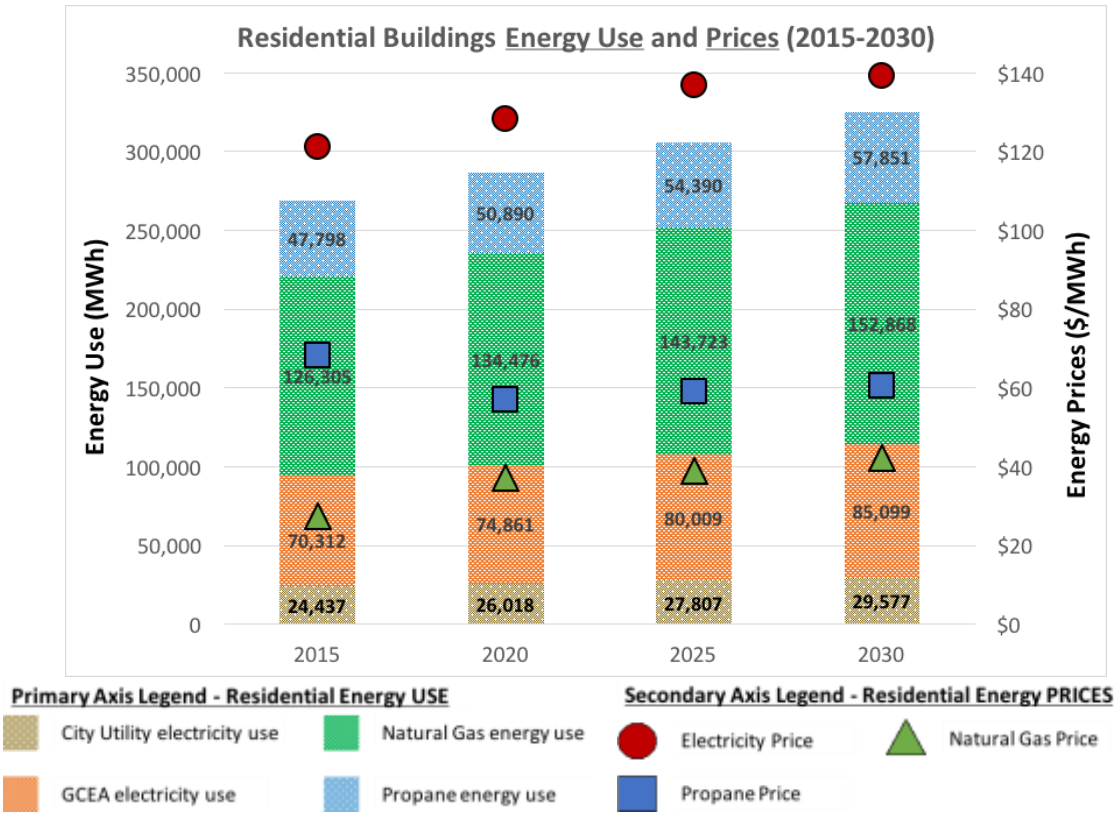

Figure 15: Residential Buildings Energy Use *(left y-axis)* and Prices *(right y-axis)*.

Appendix C: Commercial/Industrial Buildings Energy Use and Prices

Similarly, using EIA data for the State of Colorado, Figure 16 confirms that commercial & industrial electricity prices are significantly higher than prices of liquefied fuels. Moreover, between 2015 and 2030, electricity prices will remain high and increase from their 2015 prices of $88/MWh to 2030 projected price of $97/MWh.

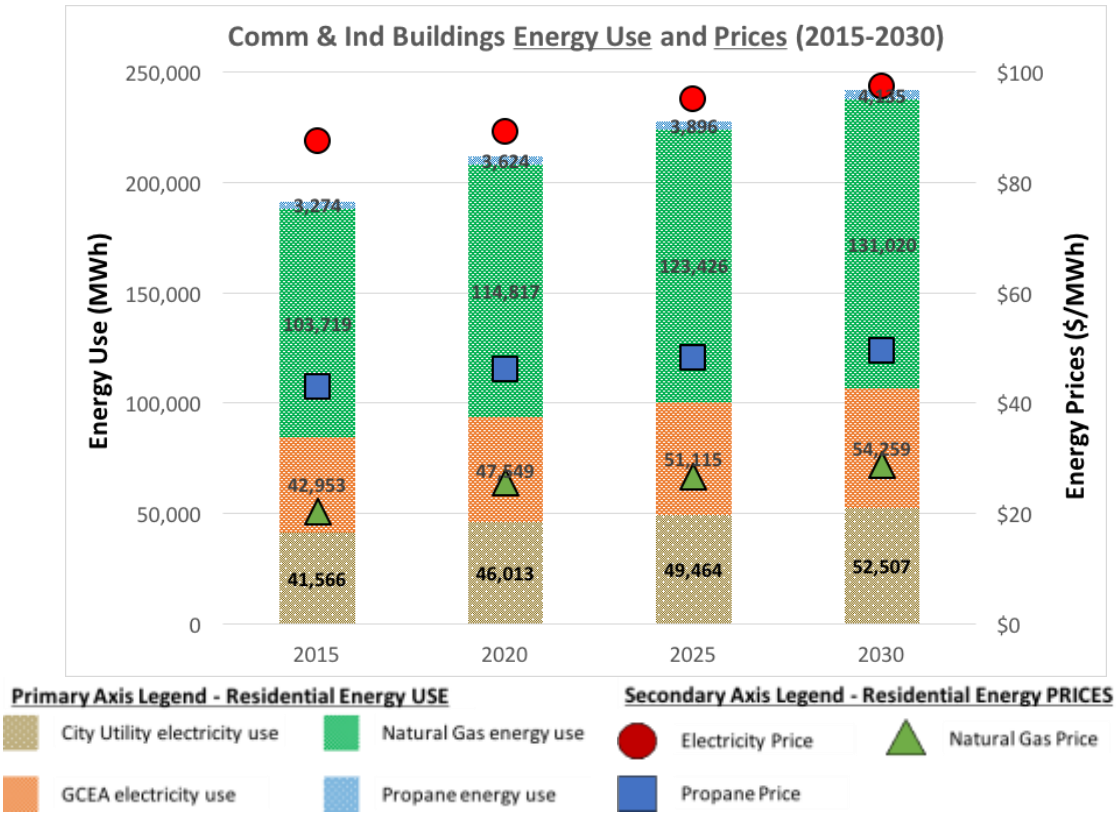

Figure 16: Commercial & Industrial Buildings Energy Use *(left y-axis)* and Prices *(right y-axis)*.

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