Sustainable Energy Inventory and Action Matrix

for the City of Arvada, Colorado

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Because we don't think about future generations, they will never forget us.

~Henrik Tikkanen

i. Executive Summary

The City of Arvada, in collaboration with the University of Colorado Denver (UCDenver), seeks to enhance the sustainability of the community by developing a Climate Action Plan. The development of this plan involves:

1. Conducting a comprehensive *Greenhouse Gas (GHG) Inventory* for the community of Arvada, in order to establish baseline data on energy use;
2. Developing a *Sustainable Energy Action matrix* based on the GHG inventory, in order to analyze the degree of GHG mitigation achievable and prioritize the available options based on local economics, culture, civic engagement and political support;
3. Conducting *Focus Groups* in order to:
    a) identify baseline community-perceived definitions of (and barriers to) sustainability;
    b) gauge responses to potential actions/options, evaluate strategies for implementation, and identify regulatory thresholds.

GHG Inventory Results

This inventory covers calendar year 2006 and includes:
In-boundary activities:

- Energy use in buildings and facilities, including electricity, natural gas, and steam., and,
- Tailpipe emissions from vehicles used for personal and commercial transport (including public transportation and air travel).

And *Out-of-boundary* activities:

- Airline travel and embodied energy of key materials used by Arvada, including: water, production of transport fuels, waste/recycling, food, and concrete.

GHG accounting results are shown in Figure 1 and Table 1. The main results are:

- The *building sector* contributes to nearly half (48%) of Arvada's GHG footprint
- The *key urban materials* sector contributes about one-third (34%)
- The *surface transport* sector contributes nearly one-fifth (18%)
- The largest single contributor was Arvada's homes, contributing 30%, suggesting the largest opportunity for mitigation
- Arvada's community-wide GHG footprint was 1,463,677 mt-CO_2e in 2006
- To understand the magnitude of Arvada's emissions, Arvada's per-capita GHG footprint was calculated, and found to be 13.

Figure 1: GHG Emissions by sector in Metric tons of CO2e

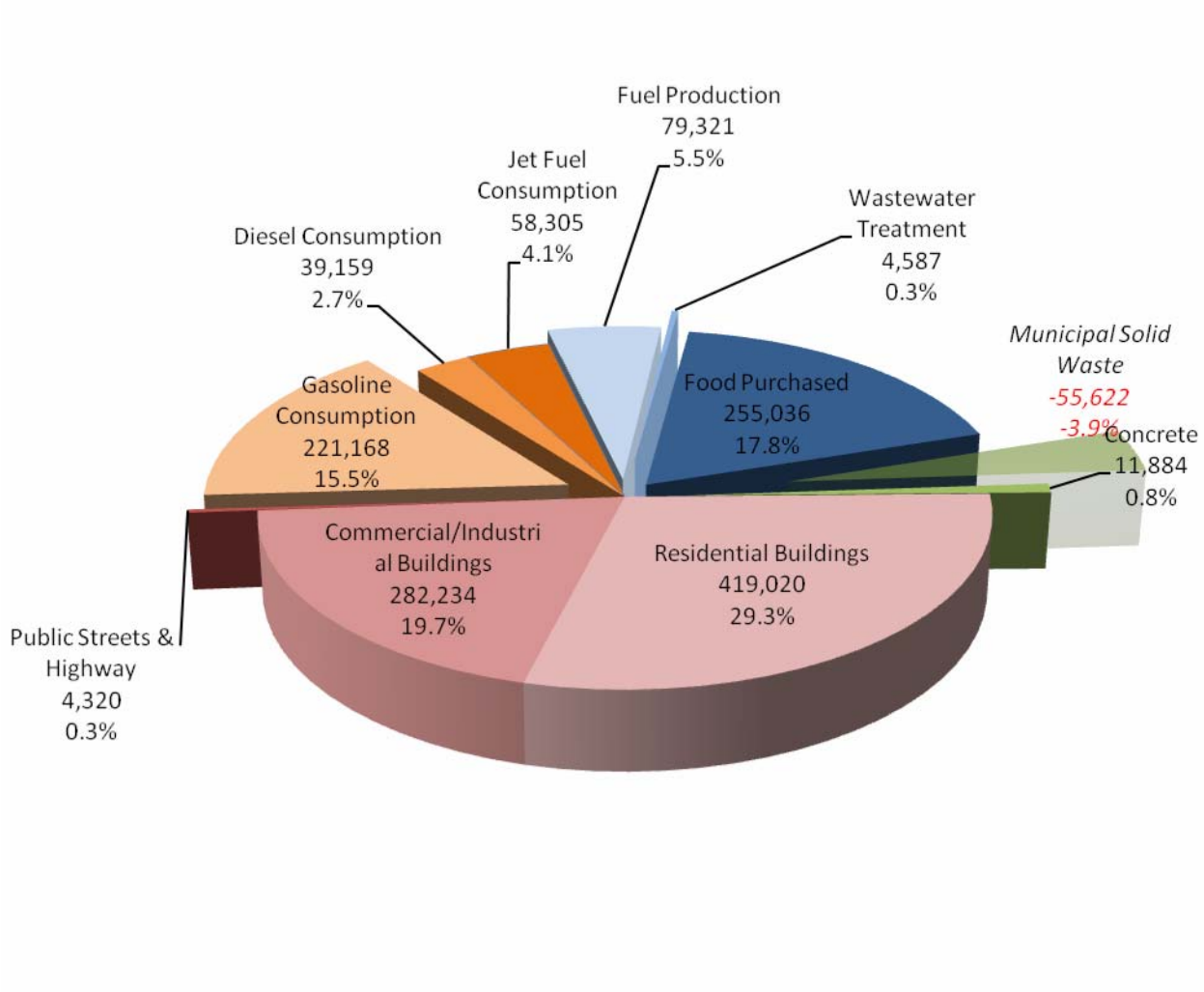


Table 1: Summary of Arvada's GHG Accounting

Scopes	Inclusions	2006 Community-wide GHG Emissions (mt-CO_2e)
Scope 1+2+Waste ***(ICLEI inventory)***	**Building Sector (electricity, natural gas)** **Surface transport (tailpipe emissions)** **Waste/Recycling** ***(Inventory= 910,279)***	**705,574 (48%)** **260,327 (18%)** **-55,622 (-4%)**
Scope 1+2+3 (WRI, Ramaswami, et al.) City-scale Footprint	**All the above *plus* Scope 3:** **Airline transport** **Key Urban Materials**	 **58,305 (4%)** **495,093 (34%)**
	Footprint: ***Per Capita Footprint:***	***1,463,677 (100%)*** ***13.6 mt-CO_2e/person***

Focus Groups Results

UCD conducted four focus groups, two representing Arvada's commercial sector and two representing Arvada's residential sector. Each of the four groups consisted of eight to twelve participants from the Arvada community, one facilitator, and one note taker.

Emerging themes from the commercial focus group discussions include:

- The reasons for working or conducting business in Arvada go beyond economics; the small town sense of community is valued.
- The meaning of sustainability is difficult to distinguish from 'staying in business.'
- A sustainable community is most often equated with responsibly managed growth and parks/open space.
- Education on sustainable issues is needed for sustainable practices to be implemented.
- The City should provide a comprehensive source of information about sustainable practices.
- The City should provide incentives or tax breaks for business that implements sustainable practices.
- The City should not mandate sustainable practices.

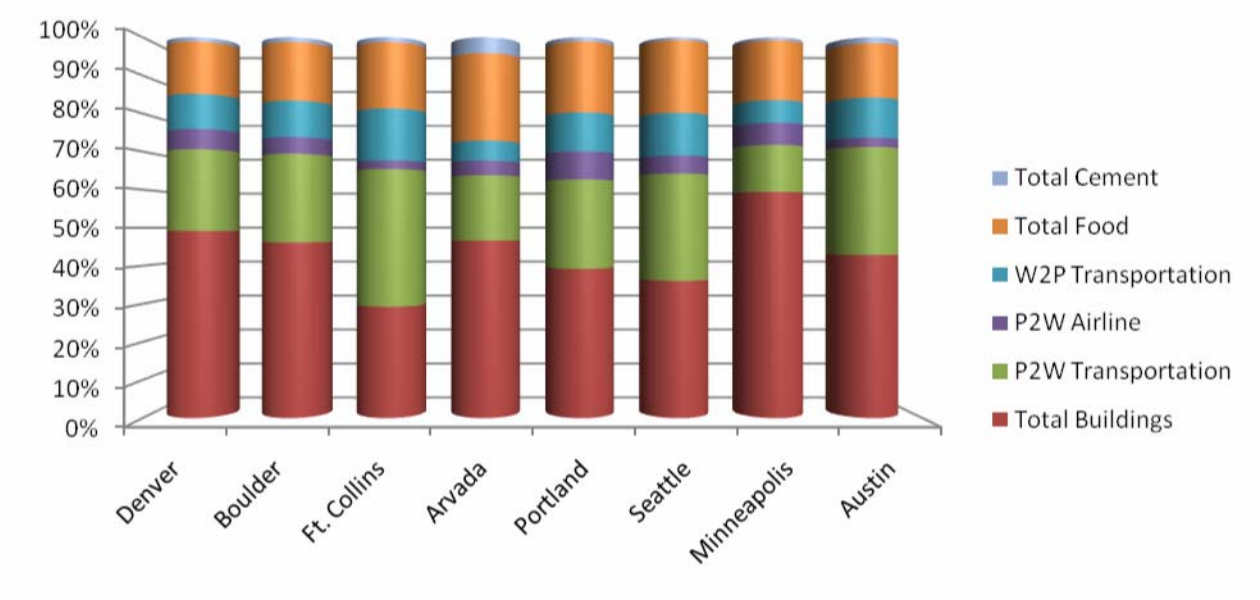
From the two residential focus groups, the following key themes emerged:

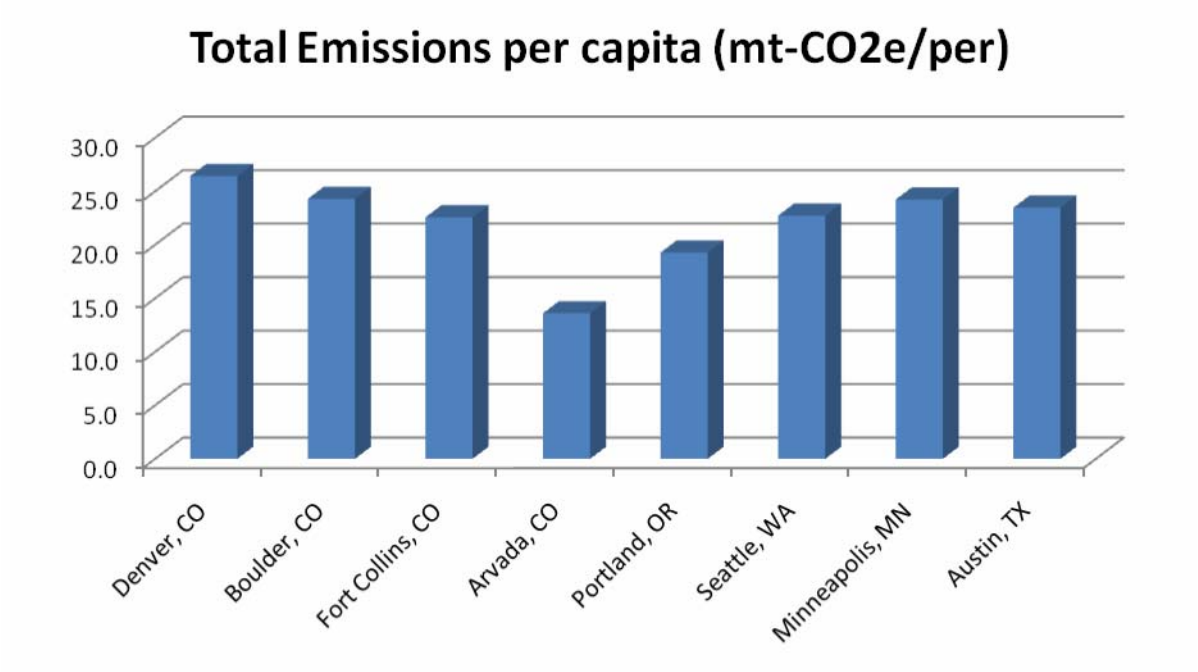
- Natural spaces and trails were a huge draw and benefit for the citizens and many wanted to preserve these spaces and set aside more.
- The small town feel was important to citizens as well as increasing local business.
- More communication is needed, in terms of the City communicating with the citizens, the City communicating better within different departments, and citizens communicating with each other.
- Educating the young people on sustainability is important.
- Citizens want smart growth and development to prevent sprawl.
- The City should decrease its carbon footprint with better use of energy in government buildings to set an example.
- The City should be responsible for coordinating different trash hauling and recycling programs to be improve efficiency.

Conclusions / Recommendations / Next Steps

Arvada community residents support the notion of sustainability. Businesses feel connected to the community and are motivated by practices that enhance their business longevity, as well as promote a sustainable community environment. More outreach and assistance, as well as a better understanding of what the City itself is doing, would be welcome. Residents value natural spaces and smart growth strategies, and also support more outreach and education, particularly for youth.

As next steps, Arvada can consider additional focus groups, community-wide surveys targeted to specific target groups, and City programs to better liaison with businesses and residents on sustainable practices. Also, the City should consider identifying baseline data for all sectors that can be used for future GHG Inventory updates. More specific conclusions and recommendations are included in the body of the report.





1. Introduction to Sustainable Energy Futures

Sustainability is widely understood to encompass the three E's: Economics, Environment and

Equity (Wheeler and Bijur 2000). In the context of the environment, sustainability refers to more efficient use of scarce natural resources such as water, energy and minerals, as well as reducing or avoiding emissions of toxic pollutants such as heavy metals, harmful pesticides, carcinogens, etc. Sustainability entails facilitating human activities that simultaneously promote economic development, environmental protection, and social equity.

The Business Case for Sustainable Energy:

There has been much interest nationally, in the State of Colorado, and in several Colorado cities in developing sustainable energy plans. These plans are motivated by the projected increase in global demand for limited oil and gas resources, the increasing world-wide cost of fossil fuels, our dependence on foreign oil which impacts national energy security, and our understanding of the global and local environmental impacts of using fossil energy. These impacts include: local-scale air pollution from petroleum use in automobiles contributing to smog; local scale air pollution from coal-fired power plants; and global impacts of greenhouse gas (GHG) emissions that are projected to impact regional snow pack, water supplies and agriculture. Looking toward a future with increased cost and reduced availability of fossil energy, cities are embarking on sustainable energy plans. These plans can save money through energy and resource conservation, generate jobs in a new "green" economy focused on energy efficiency and renewables, while promoting community-wide economic development.

Sustainable Energy Planning and Greenhouse Gas Accounting:

Because we use fossil fuel for almost all human activities – for cooling and heating our buildings, for transportation, and for industrial production - an accounting of CO2 emissions from burning fossil fuel promotes a comprehensive understanding of our fossil energy use community-wide. In addition, such Greenhouse gas accounting is also useful to represent human impact on climate.

Greenhouse Gases (GHGs):

GHGs include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6).The first three GHGs are

dominant and account for more than 98% of GHGs emitted nationally (EPA 2006). Carbon dioxide is produced primarily from burning of fossil fuels and is the largest contributor to global warming. Methane is produced largely from waste decomposition (naturally or in landfills) and from fugitive emission in natural gas pipelines. Nitrogen oxides (NO_x) are generated from all combustion operations that involve nitrogen and oxygen coming into contact at high temperatures (Ramaswami, et al. 2007). The remaining three GHGs may be omitted unless significant industrial production of these chemicals is occurring in the region of interest.
In an effort for consistency, all of these gases are measured in carbon dioxide-equivalents (CO_2e). CO_2e calculates the impact of the other GHGs by their Global Warming Potential (GWP) compared to that of the reference gas CO_2. The Global Warming Potential is the "ratio of the time-integrated radiative force from the instantaneous release of 1 kg of a trace substance relative to that of 1 kg of a reference gas" (*EPA GHG Inventory 2007*). For example, one metric ton (1000 kilograms) of CO_2 has the GWP of one metric ton of CO_2e; however, one metric ton of methane (CH_4) has the GWP of 21 metric tons of CO_2e.

Developing a sustainable energy plan

The City of Arvada has teamed up with the IGERT Program on Sustainable Urban Infrastructure at the University of Colorado Denver to assist in developing a sustainability plan for Arvada, based on the business case of advancing the three E's of sustainability. Again, the objectives of this study were to:

1. Conduct a comprehensive *Greenhouse Gas (GHG) Inventory* for the community of Arvada, in order to establish baseline data on energy use;
2. Develop a *Sustainable Energy Action matrix* based on the GHG inventory, in order to analyze the degree of GHG mitigation achievable and prioritize the available options based on local economics, culture, civic engagement and political support;
3. Conduct *Focus Groups* in order to:
    a) identify baseline community-perceived definitions of (and barriers to) sustainability;
    b) gauge responses to potential actions/options, evaluate strategies for implementation, and identify regulatory thresholds.

In the following section, we present background information about the City of Arvada, after which Section 3 develops the GHG inventory for Arvada. A Sustainable Energy Action matrix is developed in Section 4. Section 5 will highlight the results of the focus groups, and their

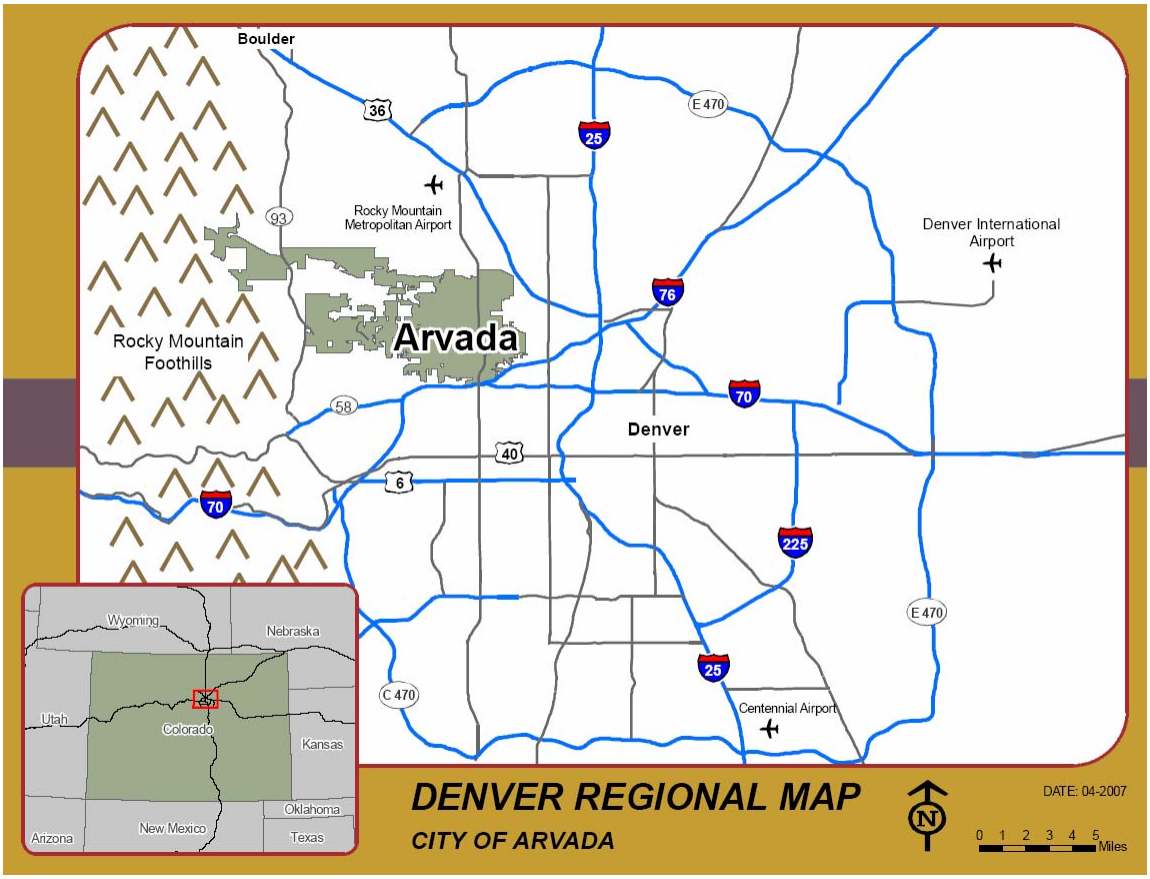
implications on the “best practices” being pursued.

Community of Arvada

The community of Arvada, located just west of Denver, Colorado (Fig. 2), strives to maintain a high quality of life for residents. It has evolved as a community that maintains the best elements of its history, such as Olde Town Arvada, while also looking to the future in projects such as the development of the GEOS sustainable community and the future Gold Line light rail stations. In addition to placing a high value on community amenities, such as the Nature Center and the Center for Arts and Humanities, the city government also strives to provide a positive climate for business. Key population statistics for Arvada are provided below:

- Population: 107,500 (City of Arvada)
- Median Age: 37.2 (11% over age 65) (City of Arvada)
- Percent Residents Working in Arvada: 20% (U.S. Census, 2000)
- Households: 43,456 (DRCOG, 2006)
- Square Miles: 35.6 (DRCOG)

Figure 2: City of Arvada in respect to the Front Range



Household Profile: Those identifying themselves as "White" currently make up 83% of the population, "Hispanic or Latino" nearly 12% (the fastest growing population), "Asian" over 2%, "Black" over 1%, with over 1% identifying themselves as being of two or more races. 51% of Arvada residents are female, and roughly 1 in 3 residents have at least a bachelor's degree (U.S. Census Bureau 2006).

The average household size in Arvada is estimated at 2.56, compared with the national average of 2.61. Approximately 43,456 households occupy an average of 1,622 square feet each, residing in a total of 59,267,672 square feet (DRCOG 2006).

Business Profile: In Arvada, 2,708 employers employed 33,367 people in 2006. Personal services, business services and retail trade were the top three industries employing workers in Arvada. Some of the largest employers included Sorin Group USA, Inc., Sundyne Corporation, Jefferson County Public Schools, Dillon Companies, Inc., and the City of Arvada (DRCOG 2006) (Arvada Economic Development Association 2008).

City Government seeks to maintain and enhance the "sustainability" and "vitality" of the community. The City describes sustainability as improving and enhancing the long-term social, economic, and environmental health of the community, allowing current and future community members to lead healthy, productive, and balanced lives. Similarly, "vitality" is described as the intangible elements that make a community strong, including: walkable neighborhoods; community amenities; citizen involvement; ability to live, work, and play without leaving Arvada; health, wellness, and education access; housing diversity; and multi-generational living opportunities.

To help achieve sustainability, City Government developed a Sustainability plan to articulate Arvada municipal government's corporate identity as a sustainable organization and to raise City government actions to a "best practices" level. The Plan is focused on internal City practices, but also includes some outreach activities. The City is also in the process of developing a Community Action Plan and in doing so is trying to define how the City should use its regulatory authority to encourage development of a "Sustainable Arvada". The concept of sustainability appears to enjoy strong support from the community. Several general proposals concerning sustainable measures related to energy, recycling, public transit, and green building were included in the Arvada, Colorado 2007 Citizen Survey and were strongly or somewhat supported by more than 75% of the respondents.

2. GHG Inventory Method

Method and Scopes: The GHG inventory is conducted using the advanced method developed by Ramaswami et al (2008). The method uses the standardized ICLEI protocol to report GHG emissions from in-boundary activities. Out-of-boundary activities critical for a community – such as the provision of food, water, fuels and shelter – are added on to the in-boundary activities to yield a more holistic GHG footprint. These inclusions of additional out-of-boundary (WRI Scope 3) activities are highly recommended by EPA's Climate Leaders Program . The Ramaswami et al (2008) inventory-footprint method for GHG accounting was first pioneered by UCD with the City of Denver, and has since been used by other cities such as Portland, OR, Seattle, WA, Central City, CO, Austin, TX, and Minneapolis, MN.

***In-boundary* activities** include the following energy uses and are required to be reported by all cities as per ICLEI and WRI guidelines (World Resources Institute 2004).

- BUILDINGS ENERGY USE – Use of electricity, natural gas, and steam in residential, commercial and industrial sectors in a community
- TRANSPORT OPERATIONS ENERGY USE – Includes tailpipe emissions from operating personal and commercial vehicles associated with a community
- EMISSIONS FROM WASTE DISPOSAL: In ICLEI protocol, emissions from waste disposal by residential and commercial sectors are also included in the in-boundary accounting.

Formally, the GHGs emitted directly from burning natural gas in buildings and gasoline/diesel in vehicles are termed Scope 1 emissions by WRI, while CO2e emissions from power plants to produce electricity used within our community is termed Scope 2 emissions. Scope 1-2 plus Waste emissions are included in the "In-boundary" activities and are required to be reported in a city's GHG inventory as per ICLEI protocols.

***Out-of-boundary* activities** designated by the WRI as Scope 3 are optional, but are highly recommended by the EPA as they can lead to win-win strategies for GHG mitigation. The following out-of-boundary activities, when added to in-boundary activities, yield a more holistic account of a community's CO_2e footprint:

- EMBODIED ENERGY OF CRITICAL URBAN MATERIALS: This includes energy use and associated GHG emissions from producing key urban materials such as water, transport fuels, food, and shelter (cement for concrete), necessary to support life in cities.
- AIRLINE TRAVEL: Energy use for airline travel is important as it appears in national and state-wide GHG inventories and in personal calculators. At the city-scale, these appear as out-of-boundary emissions, particularly when the airport is outside city boundaries (as is the case with the City of Arvada).

Energy Use Sectors and Data: To better communicate a community's overall energy use and GHG emissions, classifying end-use of energy in three different sectors is more useful. In this report, we consistently report energy use and GHG emissions in the following three sectors:

- Buildings Sector – Energy use in residential and commercial buildings and industrial facilities.
- Transport Sector (P2W) – Energy use to operate personal vehicles, commercial trucks and airplanes, termed Pump-to-Wheels (P2W) energy use.
- Materials Sector: Energy Use and associated GHG emission from producing critical urban materials (food, fuels, water, cement) and from waste disposal.

For energy (or materials use) in each sector, the following data was gathered:

- Annual Materials of Energy Consumption Data, e.g., total kWh of electricity consumed annually, total water consumed annually, total natural gas use, etc. The annual Material/Energy Flow Analysis tells us how much we consume as a community. By benchmarking these consumption data on a per-person, per-household, per-square-foot, etc. basis, we can represent how efficient the community is in its consumption patterns.
- GHG Emission Factors: GHG emissions factors tell us how clean our energy or materials are in terms of how much CO2e is emitted per unit of the product consumed. For example, kg-CO_2e emitted per unit kWh of electricity consumed.

Annual CO_2e emissions are calculated by multiplying the Material Flow Analysis (MFA) by that material's Emission Factor (EF) from its Life Cycle Assessment (LCA):

$$Total\ CO_2e\ emissions = MFA * EF_{LCA}$$

where MFA represents the number of units of a material consumed annually (i.e. total kilowatt hours used) and EF_{LCA} represents the amount of CO_2e attributable to each (kilograms of CO_2e per kilowatt hour).

In the next section, consumption data and emission factors for all three sectors are reported and overall community-wide GHG inventory and footprint is developed.

3. Community-wide Energy and GHG Analysis

Reporting year: This section reports energy (or materials) consumption data and associated GHG emissions factors of three main sectors in 2006:

- Buildings
- Transportation (Tailpipe emissions)
- Materials and Waste

For each sector, raw consumption data are presented first, the data are then normalized and compared with benchmarking metrics after which emission factors are quantified. The total GHG emissions from each sector are consolidated and reported in an overall community-wide summary table. GHG emissions are reported in terms of metric tons (mt) of carbon-dioxide equivalents, shown as CO2e.

4.1 Buildings Sector

Buildings Energy Consumption and Energy Intensity: The buildings sector energy use reports electricity and natural gas consumed in residential, commercial, and industrial facilities. Data were obtained from Xcel Energy (Xcel) for 2006. Based on the number of households and the square footage of commercial spaces in Arvada, energy use intensity can be computed in terms of electricity and natural gas use per home, and kBTU used per commercial square foot. These intensity numbers for buildings in Arvada can then be bench-marked with similar energy intensity metrics reported by the Energy Information Agency for homes and commercial spaces in the Rocky Mountain region. The data shows:

- Arvada residences consumed 665 kWh per household per month, compared to 674 kWh/hh/month in Colorado, 916 kWh/hh/month in the Rocky Mountain region, and 964 kWh/hh/month nationwide (EIA 2005) (SWEEP 2008).
- Arvada residences also consumed 54 therms per household per month, compared to 47 therms/hh/month in Colorado, 50 therms/hh/month in the Rocky Mountain region, and 56 therms/hh/month nationwide (EIA 2005) (SWEEP 2008).
- Arvada's businesses consumed only 84 kBTUs per square foot per year, compared to 104 kBTU/ft^2/year in the Rocky Mountain region, and 90 kBTU/ft^2/year nationwide (EIA 2003).

- % Green Electricity Purchased

Emission Factors for Electricity & Natural Gas: In Colorado, coal and natural gas make up 57% and 37%, respectively. Renewable energy makes up 5% with wind generation and 1% with hydro (Xcel Energy 2007). The emissions factor for electricity in Colorado, given this mix, accounts for 0.8 kg of CO_2e/kWh. Colorado's emission factor is higher than the national average of 0.6 kg of CO_2e/kWh because of the lack of nuclear and hydroelectric power sources (EIA 2003). Natural gas emissions do not vary greatly from region to region and has been calculated as 5.4 kg of CO_2e/therm (ICLEI 2003).

Together, the EF and the Annual Energy Use data yield a total of 419,020 mtCO2e from the residential sector as shown in

Table 2.

Figure 3: Total Buildings Emissions by Source (mt-CO_2e)

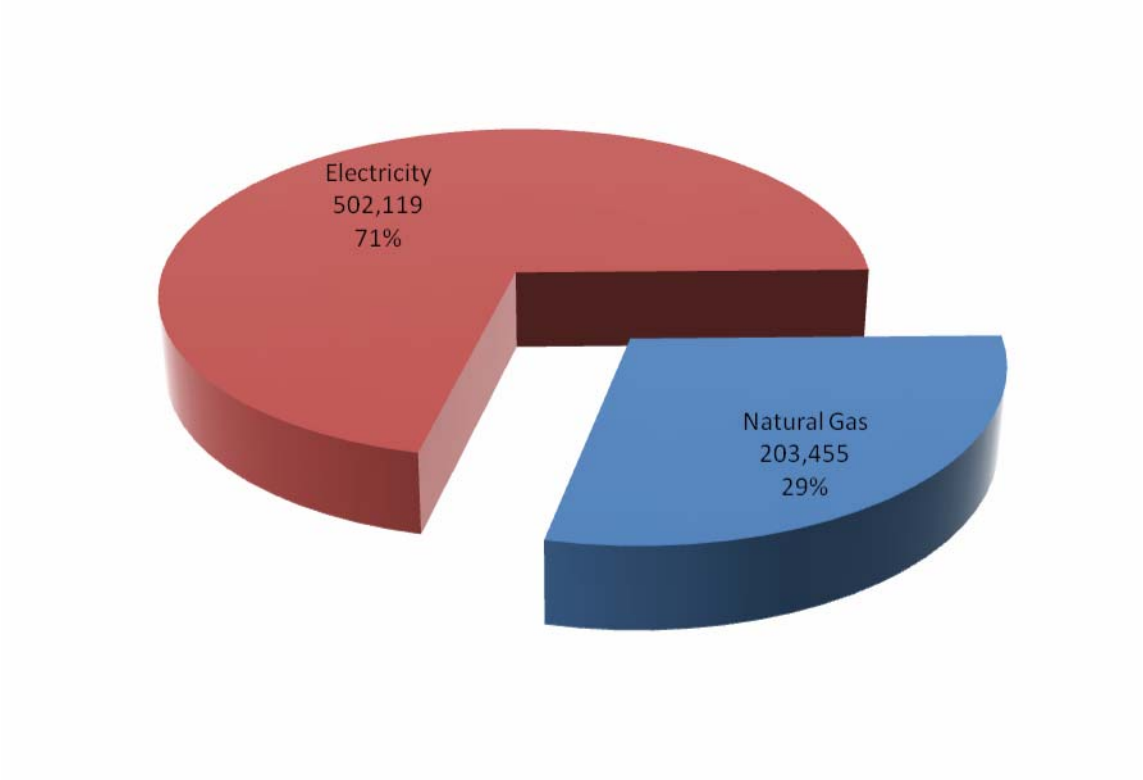


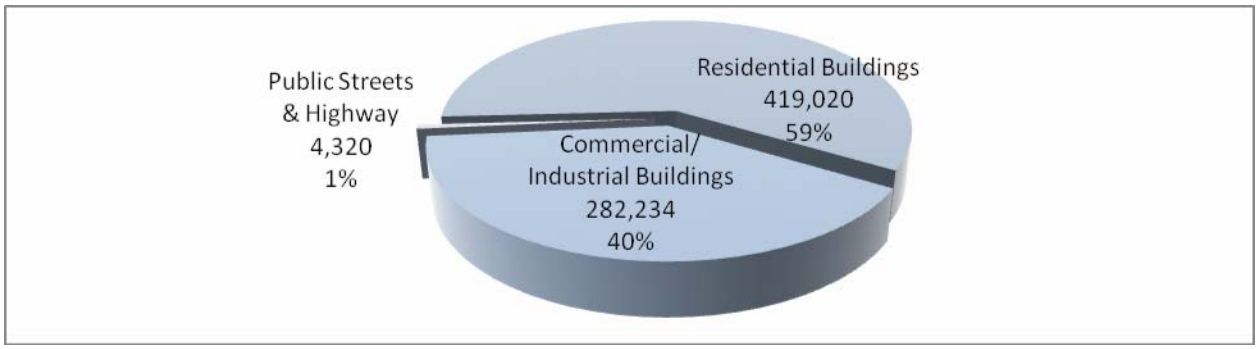
Table 2: Summary of energy use and GHG emissions from residential buildings and industrial and commercial facilities in Arvada (numbers may not add due to rounding).

A. Residential Energy	Arvada 2006
Total Number of Customers (premises)	42,506
Total Grid Electricity Used (MWh)	339,147
Electricity/household/month (kWh/hh/mo)	665
Total Natural Gas Used (million therms)	27.3
Natural Gas/household/month (therms/hh/mo)	54
Total Residential GHG emissions (mt-CO_2e)	419,020
Total Residential Per Capita GHG emissions (mtCO_2e per person)	3.9
B. Commercial-Industrial Energy	**Arvada**
Total Number of Customers (premises)	3,898
Total Commercial-Industrial Area (million sf)	23.7
Total Electricity Used (MWh)	283,103
Total Natural Gas (million therms)	10.3
Total energy use per square foot (kBtu/sf)	84.3

Total commercial–industrial GHG emissions (mt-CO_2e)	282,234
Public Street & Highway (MWh)	5,400
Total PS&H GHG emissions (mt-CO_2e)	4,320
C. Total Buildings and Facilities GHG Emissions ($mtCO_2e$)	705,574

Data Source: All energy data from Xcel Energy. Steam generation and chilled water are included in natural gas and electricity consumption, respectively. GWh = Giga Watt-hours of electricity = 1 million kWh. Both electricity and natural gas use can be combined and represented as kBtu (1 kWh = 3.412 kBtu; 1 therm = 100 kBtu).
Energy use was converted to CO_2e emissions using an emission factor of 1.19 lb-CO_2e/kWh provided by Xcel Energy for the local area (Personal Communication, Pete West)

Figure 4: Total Buildings Emissions by Use (mt-CO_2e)

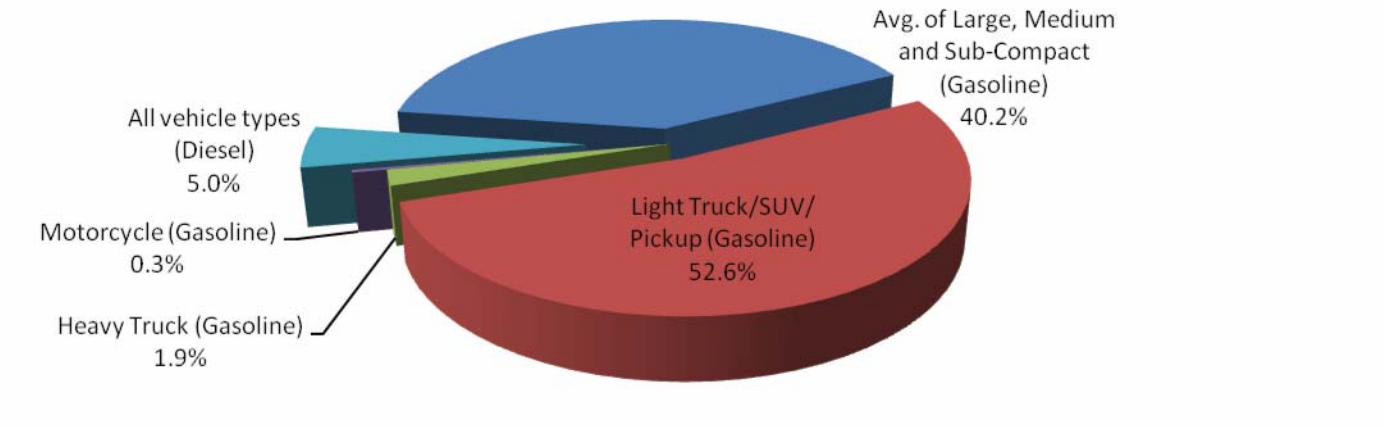


4.2 Transportation Sector

Surface Travel Miles and Travel Intensity: Annual Vehicle Miles Traveled (VMT) for the City of Arvada was computed by the demand-method (Ramaswami et al., 2008), i.e., surface travel demand created by Arvada's residents and businesses was accounted for. The VMT data was obtained from DRCOG for the 2006 model run. Fuel use (gasoline and diesel) was computed by allocating the annual VMT to an average State of Colorado Vehicle mix as reported by the CDPHE (Figure 4), with a weighted average fuel economy of 19.85 miles per gallon was reported in ICLEI CACP program (ICLEI 2003).

The VMT intensity is the total annual VMT allocated to Arvada (481 million) per resident (107,500). The Travel VMT intensity for Arvada is 12.26 VMT per person per day, or nearly half of the State of Colorado average of 25 VMT per person per day. This is likely related to lower employment intensity in Arvada

Figure 5: Vehicle Miles traveled (VMT) distribution by vehicle in 2006



Airline trips for Arvada residents were approximated from the jet fuel consumption allocated to each city in the DRCOG region. This is based on the proportion of vehicle trips bound for Denver International Airport (DIA) from a specific city, to the total number of vehicle trips to DIA. The DRCOG transportation model (Ramaswami and Hillman Transportation Model, 2005) allots 1.5% all vehicle trips to DIA to originate in Arvada. As a result, the 1.5% of all jet fuel purchased at DIA is allocated as consumed by Arvada.

Emission Factors for Diesel, Gasoline and Jet Fuel were obtained from GREET for pump-to-wheels analysis, appropriate for vehicle operations. The emissions factors of 9.13, 10.15 and 9.87 kg-CO_2e/gallon for gasoline, diesel, and jet fuel, respectively, are in line with those in ICLEI, IPCC. The emissions factor for transportation fuels was combined with the total demand for transport to compute the total transport sector tailpipe emissions of 318,631 mt-CO_2e. Details are provided in Table 3 below.

Table 3 ***Transport distances, fuel use and Tailpipe (P2W) GHG emissions by modes of transport in Arvada. GHG emissions include tailpipe emissions (pump-to-wheels).***

A. Personal & Commercial Motor Vehicles	2006
Annual Vehicle Miles Traveled (million VMT)	481
VMT/person/day*	12
Annual Fuel Use	
Gasoline (million gallons)	24.23
Diesel (million gallons)	3.86
Total GHG Emissions from Personal and Commercial Motor Vehicle Transport (mtCO_2e)	260,327
B. Airline Travel (allocated to Arvada – 1.5%)	**2006**
Annual Fuel Use	

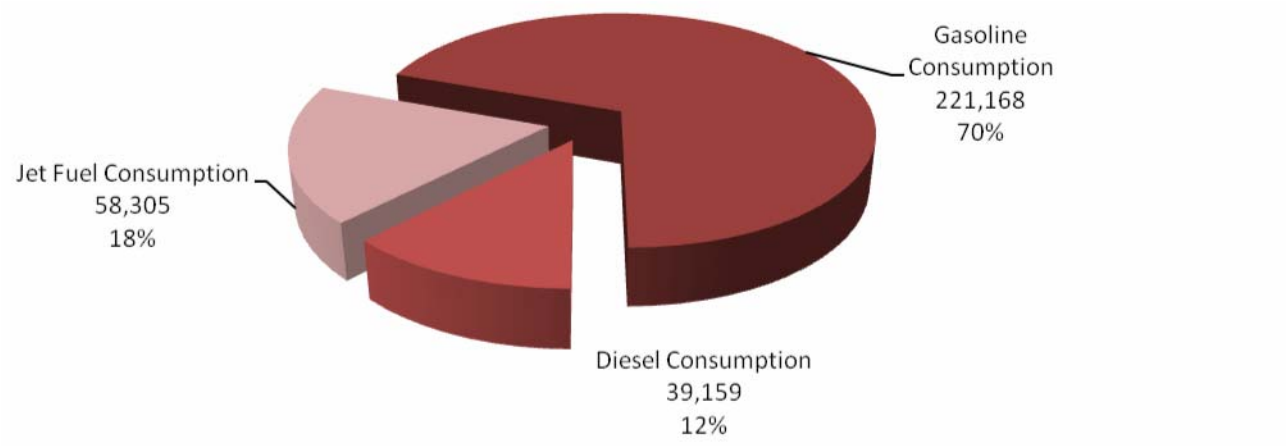
Jet Fuel (million gallons)	5.91
Total GHG Emissions from Airline Travel Allocated to Arvada ($mtCO_2e$)	58,305
C. Total GHG Emissions form Transportation Sector (million $mtCO_2e$)	**318,631**

A. Data Source: VMT for personal-commercial vehicles obtained from DRCOG transportation model with Arvada as a demand center. Vehicle loading and fuel economy data from CDPHE to calculate Fuel use.

B. Data Source: Fuel data for Airport operations provided by DIA for 2005. Aircraft loading and miles traveled per gallon of fuel from National Bureau of Transportation Statistics (BTS, 2006). 1.5% of all airline travel at Denver's Airport was allocated to Arvada as the Airport serves the whole Front Range DRCOG region and beyond.

C. GHG Emission Factors: Fuel use was converted to CO_2e using ICLEI's CACP for tailpipe emissions and DOE's GREET model for wells-to-pump GHG emissions for fuel refining. EIA's tailpipe emissions factors for jet fuel were applied for airline travel (EIA).
*Miles traveled are normalized to Arvada's entire population, including children, and therefore do not reflect actual average travel distances per driver.

Figure 6: Tailpipe Emission (P2W) by Fuel type (mt-CO_2e)



4.3 Materials and Waste Sector

Annual Consumption of Key Materials: Consumption of transportation fuels was determined from travel demand computations as summarized in Table 2. The consumption of food was tracked in terms of money spent on food expenditures as reported in the Consumer Expenditure Surveys for residents $3,886 per household per year (in 1997 $'s), compared to $4,018/hh/year in the western U.S., and $3,417/hh/year nationwide. Cement use per person was also obtained for the Denver region from Consumer Expenditure Surveys for the Denver-Boulder MSA (BLS 2005). Water use data was obtained from the City of Arvada at 6.2 billion gallons treated in the city limits in 2006. Wastewater treatment is handled by Metro Wastewater Reclamation District, which treated 3.3 billion gallons of wastewater from Arvada.

Annual Municipal Waste and Recycling: Very little data was available from trash

haulers on volumes or tonnage of waste generated from Arvada. Hence the waste generated in the residential sector was estimated based on national average of 4 lb per person per day, and at present, waste is hauled to landfills in Boulder and Commerce City, CO (Simmons, et al. 2006).

Data obtained from Allied Waste for over 5,000 households in the City of Arvada (~12%) yielded a similar per-person waste generation rate of 3.92 pounds per person per day. Allied Waste also reported 14% of all collections were of recyclables, compared to the Colorado average of 12.5%, and 28.5% nationwide.

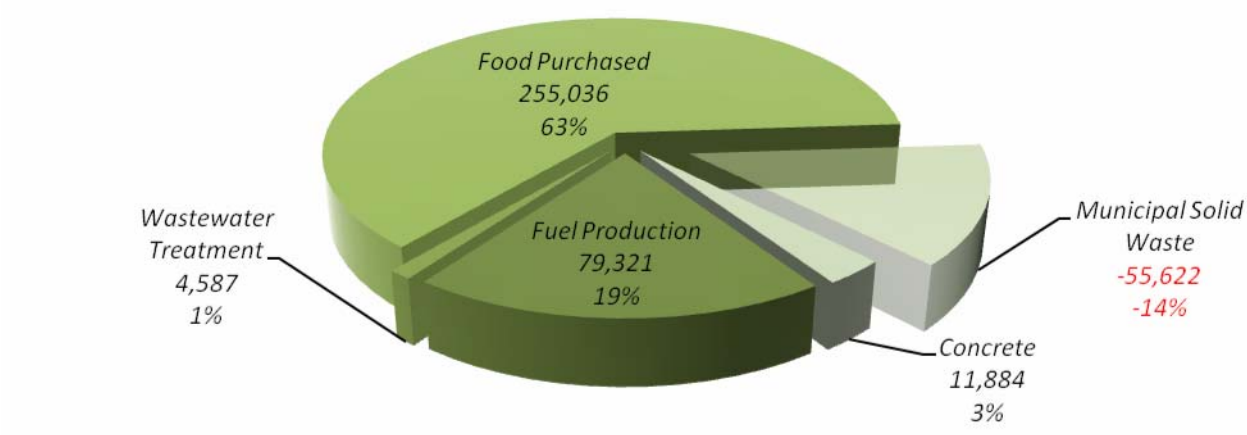
Emission Factors for Materials and Waste: The GHG emission factors for producing transport fuels were obtained from GREET Well-To-Pump analysis as 2.4 kg-CO_2e/gallon for gasoline and 2.3 kg-CO_2e/gallon for diesel and jet fuel, respectively. The emission factors for cement and food were obtained from EIO-LCA and are 1 mt-CO_2e/mt and 1.5 kg-CO_2e/$ (in 1997 dollars), respectively. The emission factor for waste was derived using the Environmental Protection Agency's (EPA) Waste Reduction Model (WARM), and they account for approximately -0.3 and -2.9 kg-CO_2e/ton for solid waste and recyclables, respectively (EPA 2006). Applying these emission factors to the consumption data, the total GHG emissions from the waste sector are as shown in Table 3.

Table 4 ***GHG emissions from manufacture of key urban materials used and waste disposal and recycling in Arvada.***

Material	Annual Material Flow	GHG Emissions in mtCO_2e
Fuel (gasoline, diesel, jet fuel)	24.2, 3.8 and 5.9 million gallons of gasoline, diesel and jet fuel, respectively	79,321
Water/Wastewater	6.2 billion gal. water & 3.3 billion gal. wastewater treated	7,315*
Cement in Urban Concrete	62,870 metric tons	62,870
Municipal Solid Waste	78,475 tons	*-23,950*
Recycling	10,987 tons	*-31,672*
Food & Packaging	$232.2 million (in 1997-$)	348,315
Total GHG Emissions for Producing Key Urban Materials		**442,199**

*GHG emissions from water (2,728 mt-CO_2e) are already counted under building energy use

Figure 7: Total Emissions by Key Urban Material (mt-CO_2e)



Community-Wide and Per Capita GHG Footprint

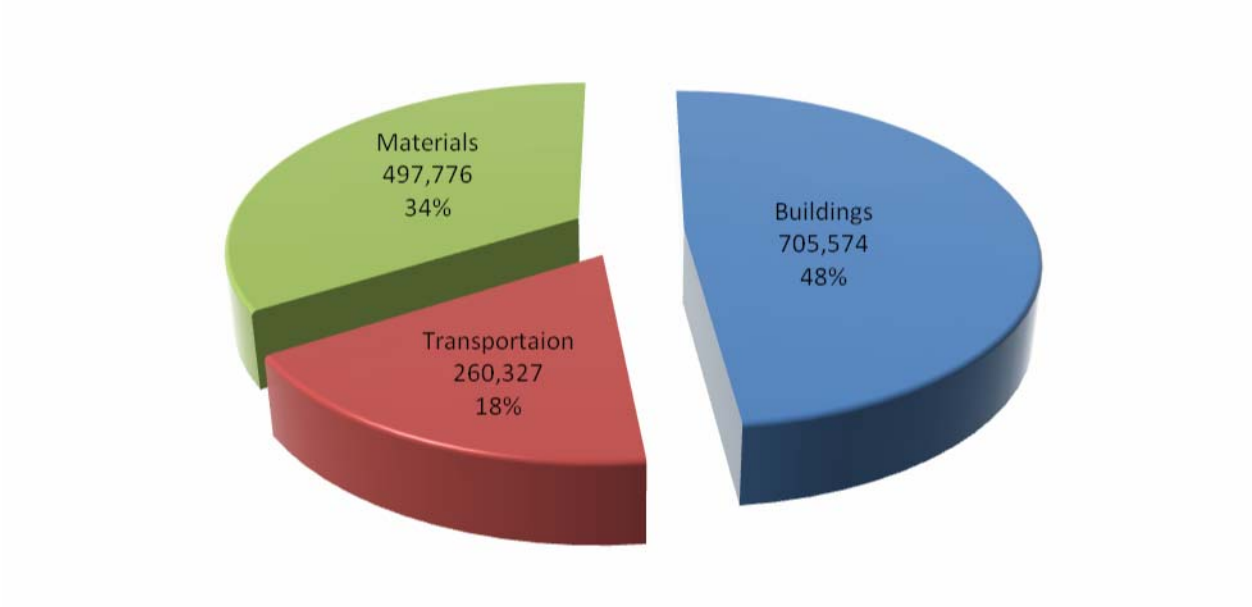
All three sectors described previously in sections 4.1-4.3 are added together in Table 4, to yield the total community-wide GHG footprint shown by sector in Figure 8.

Table 5:Expanded Scope 1-2-3 inventory-footprint computations for Arvada, CO. Annual community-wide material and energy flows (MFA) are shown with associated GHG emission factors (EF) for various sectors in the City of Arvada, CO. GHG emissions are reported in metric tons CO_2 equivalents (mt-CO_2e)[a]. Table is adapted from Ramaswami et al, ES&T, 2008.

GHG inventory items by WRI Scopes	Sector/use	Community-wide annual urban material/energy flows (MFA)	Data source for MFA	GHG emission factor (EF)	EF data source	Total GHG emitted = MFA x EF
In-boundary Activities (Scopes 1 & 2 & Waste)	Buildings Natural Gas Use	Residential 2,730, 654 MMBTU Commercial 1,030,700 MMBTU Industrial Public St. 3,761,354 MMBTU	Xcel	54 kg-CO_2e /MMBTU	Xcel	203,455 mt-CO_2e
	Buildings Electricity Use	Residential 339,147,000 kWh Commercial 276,347,000 kWh Industrial 6,757,000 kWh Public St. 5,400,000 kWh 627,651,000 kWh	Xcel	0.8 kg-CO_2e/kWh	Xcel	502,119 mt-CO_2e
	Fuel Use (P2W)	Gasoline 24,232,868 gallons Diesel 3,858,301 gallons	DRCOG Model & CDPHE	Gasoline 9.1 kg-CO_2e/gallon Diesel 10.2 kg-CO_2e/gallon	GREET	260,327 mt-CO_2e
	Waste/ Recycling	78,475 tons 10,987 tons	CDPHE & EPA	-0.3 kg-CO_2e/ton -2.8 kg-CO_2e/ton	WARM	-55,622 mt-CO_2e
Out-of-boundary Activities (Scope 3)	Airline Travel (P2W)	Jet Fuel 5,906,250 gallons	DIA & BTS	Jet Fuel 9.9 kg-CO_2e/gal	EIA	58,305 mt-CO_2e
	Fuel Production (W2P)	Gasoline 24,232,868 gallons Diesel 3,858,301 gallons Jet Fuel 5,906,250 gallons	ICLEI	Gasoline 2.4 kg-CO_2e/gal Diesel/Jet Fuel 2.3 kg-CO2e/gal	GREET	79,321 mt-CO_2e
	Cement Use	62,870 metric tons	United States Census Bureau	1 mt-CO2e/metric ton	EIO-LCA	62,870 mt-CO_2e
	Food Purchases	$127,518,000 (1997-$)	Denver-Aurora Economic Census	1.5 kg-CO_2e/$ (1997-$)	EIO-LCA	348,315 mt-CO_2e
	Wastewater Treatment	3.3 billion gallons	City of Arvada	0.00139 kg-CO_2e/gallon	Denver water	4,543 mt-CO_2e
Arvada's Community-Wide Total GHG Emissions [b]						**1,463,677 mt-CO_2e**

P2W = Pump to Wheels (tailpipe) GHG emissions. W2P = Wells-to-Pump GHG emissions
* Water already counted under *Building Electricity Use*

Figure 8: Emissions by Sector in mt-CO_2e



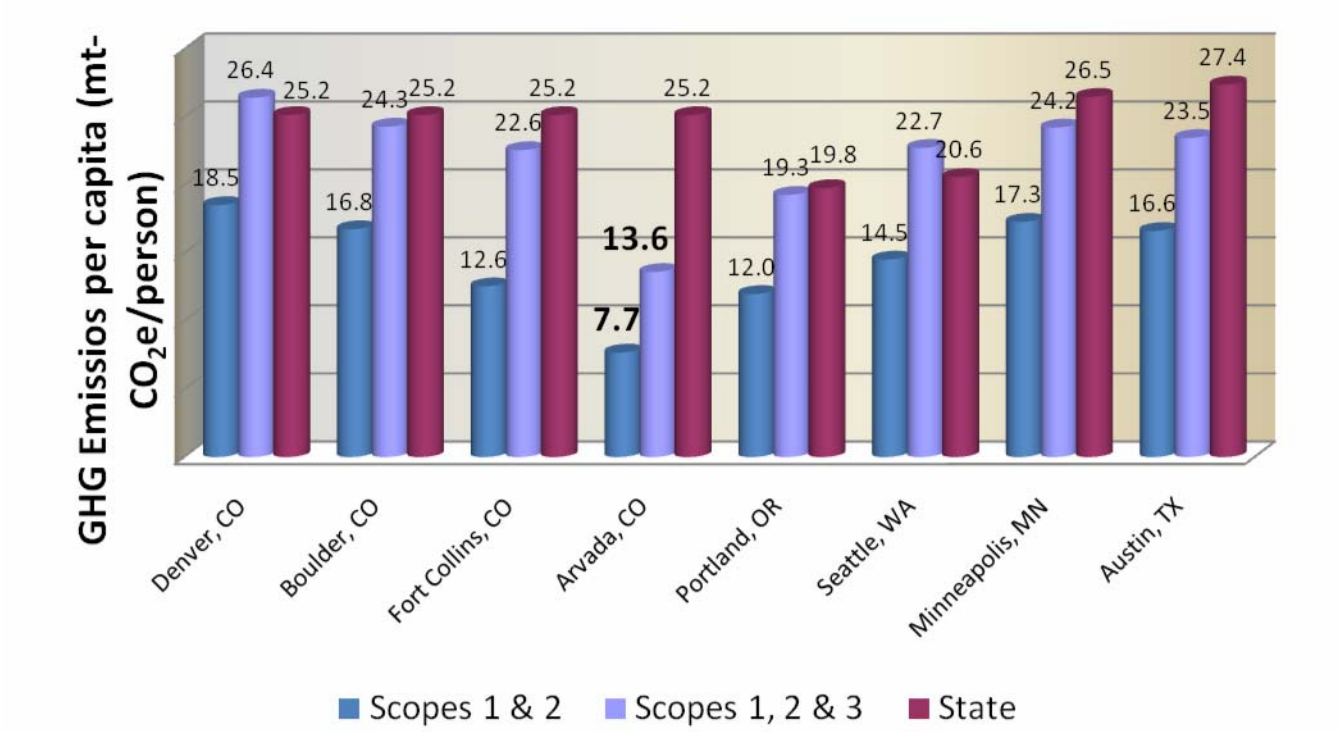
Benchmarking: To assist Arvada in tracking future changes in energy consumption, the following benchmark table is created comparing consumption parameters in Arvada versus Statewide or regional benchmarks.

Table 3: Proposed metrics for cities to include in their GHG reporting and climate action outcomes assessment, in addition to communitywide GHG and per capita GHG benchmarks.

Description of Benchmark	Arvada, CO	Regional Benchmarks		
Residential Energy Use per Home per month (Average Home Square Footage)	665 kWh/hh/mo 54 therms/hh/mo 1,622 sqft	*Colo.* 674 kWh 47 therms	*Mountain* 916 kWh 50 therms	*U.S.* 964 kWh 56 therms
Commercial Buildings Energy Use Per Square foot (sf) Total Commercial Square Footage	84.3 kBTU/sqft 23,682,048 sqft	*Mountain* 104 kBTU/sqft		*U.S.* 90 kBTU/sqft
Amount of Purchase of Renewable Electricity (% of total kWh)	Res: ? % Commercial: ?%			
Number of Customers Purchasing Renewable Electricity (% Total)	Res: ?% Commercial: ?%			
Vehicle Miles per person per day Average Fleet Fuel Economy	12 VMT/person/day 19.85 mpg	*Colorado:* 24.5 VMT/person/day *U.S.:* 27.5 VMT/person/day Average Fuel Economy [21 mpg]		
Cement Use	0.58 metric tons/capita	*U.S.:* 0.36 metric tons/capita		
Water and Wastewater	88,372 gallons/person/year	(Water & WW): [gallons/person/year]		

Municipal Solid Waste/ Recycling	0.73 tons/person/year 14% diversion rate	*Colo.* 1.14% *U.S.:* 0.84 tons *Colo.* 12.5% *U.S.:* 28.5%	
Food Purchases at Home	$3,000/hh/year (1997-$)	*Western Region* $4,018/hh/year	*U.S.:* $3,417/hh/year
GHG Emissions	13.6 mt-CO_2e/person	*Colo.:* 25.2 mt-CO_2e/ person	*U.S.:* 24.5 mt-CO_2e/ person

Figure 9: Per capita emissions compared to other cities



The next Chapter will discuss actions that can be taken in each of the energy use sectors to increase energy efficiency, shift to renewable energy supplies and increase economic benefits while reducing potential costs.

2. Sustainable Energy Action Matrix

Build solar-powered water treatment plant – CHECK

3. Focus Groups