Technical Investigation Part 2: Climate Profile

Climate Action Plan (CAP)

Clackamas County

Draft v2

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Prepared by SSG and whatIf

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1. Introduction

Clackamas County has committed to a net-zero GHG emissions target by 2050. Clackamas County's Climate Action Plan is being developed to provide a pathway to achieving this goal; energy and emissions modeling is informing the strategy. This report documents Clackamas County's energy use and emissions production for the baseline year of 2018 and estimates energy use and emissions production to the year 2050 under a Business as Planned (BAP) scenario. BAP assumes no additional policies, actions or strategies are implemented by 2050 beyond those that are currently underway. Two steps were taken to develop and quantify the BAP:

- Data collection: A data request was compiled, and data collected from various sources. Assumptions were identified to supplement any gaps in observed data. A data, methods and assumptions manual ensures transparency of data and assumptions used.

- Model calibration and baseline: The model is custom built for the Clackamas County context and includes data for population, population assignment to dwellings, jobs assignment to buildings, a surface model of buildings, transportation, waste, industry, and land-use. An energy and emissions inventory baseline year is established (2018) and at each modeling stage the model is calibrated against observed data.

Population and demographic information is presented in 5-year increments from 2018 to 2053 for consistency with census years.

2. About Modeling

Modeling for the 2018 baseline year and 2050 BAP scenario was completed using a comprehensive energy, emissions and finance model developed by Sustainability Solutions Group (SSG) and whatIf? Technologies Inc. The model uses the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC Protocol) framework—an international standard for greenhouse gas emissions accounting.

BAP scenario modeling accounts for population and demographics trends and estimates, and uses energy and emissions related information from local, State, and federal governments to inform modeling assumptions about buildings, transportation, energy use, and solid and liquid waste. Tables 1A, 1B and 1C lists the central assumptions. A more detailed description of all assumptions and modeling inputs is provided in the Data, Methods and Assumptions Manual (DMA), a separate document.

Table 1A: Central BAP assumptions 2018 and 2050.

Variable	2018	2050	Units
Population	416,065	582,678	people
Heating Degree Days	2326	1762	HDD
Cooling Degree Days	409	620	CDD
Increasing building efficiency	Improvements to building code every 5 years, beginning with 8.5% energy efficiency gains in 2024 over 2019, then an additional 5.7% in 2028, an additional 3.8 % in 2033, such that new code gains are 2/3 of previous code's baseline.		%
Retrofit rate	1.5% of the existing stock is retrofit each year, achieving a 15% improvement in energy use.		%
Annual vehicle miles travelled, external inbound	807,653,889	1,085,493,820	miles
Annual vehicle miles travelled, internal outbound	1,450,454,895	2,060,143,909	miles
Annual vehicle miles travelled, internal	971,756,825	1,263,151,157	miles
Electric vehicle uptake	14	23	% of new sales
Electricity Emissions factor	771	176	lbs. CO2e per MWh

Table 1B: Central Waste and Wastewater Assumptions 2018 and BAP 2050.

Waste sector	Assumption
Solid Waste	Landfill emissions are calculated from first order decay of degradable organic carbon deposited in landfill. Derived emission factor in 2018 to be determined based on percent recovery of landfill methane and waste composition.
Wastewater	CH4: 0.48 kg CH4/kg BOD N2O: 3.2 g / (person * year) from advanced treatment 0.005 g /g N from wastewater discharge

Table 1C: Central Fuel Emissions Factors Assumptions 2018 and 2050.

Fuels	CO2	CH4	N20
Gasoline	0.07024 MT/MMBtu	0.000000017343 MT/mile	0.000000009825 MT/mile
Natural Gas	53.02 kg/MMBtu	0.005 kg/MMBtu	0.0001kg/MMBtu
Diesel	0.073934483 MT/MMBtu	0.000000001 MT/vehicle mile	0.0000000015 MT/vehicle mile
Fuel Oil	73.9 kg per MMBtu	0.003 kg per MMBtu	0.0006 kg per MMBtu
Wood	93.80 kg per MMBtu	0.0072 kg per MMBtu	0.0036 kg per MMBtu
Propane	62.87 kg per MMBtu For mobile combustion: 5.7 kg per gallon	0.003 kg per MMBtu	0.0006 kg per MMBtu

3. Population and Demographics

Demographics provide important information in establishing a community's energy and emissions baseline. For the baseline year (2018) the US Census provides this information. In the BAP scenario projections for population, employment growth, number of households, and number of vehicles are critical dimensions in determining the change in energy consumption and GHG emissions.

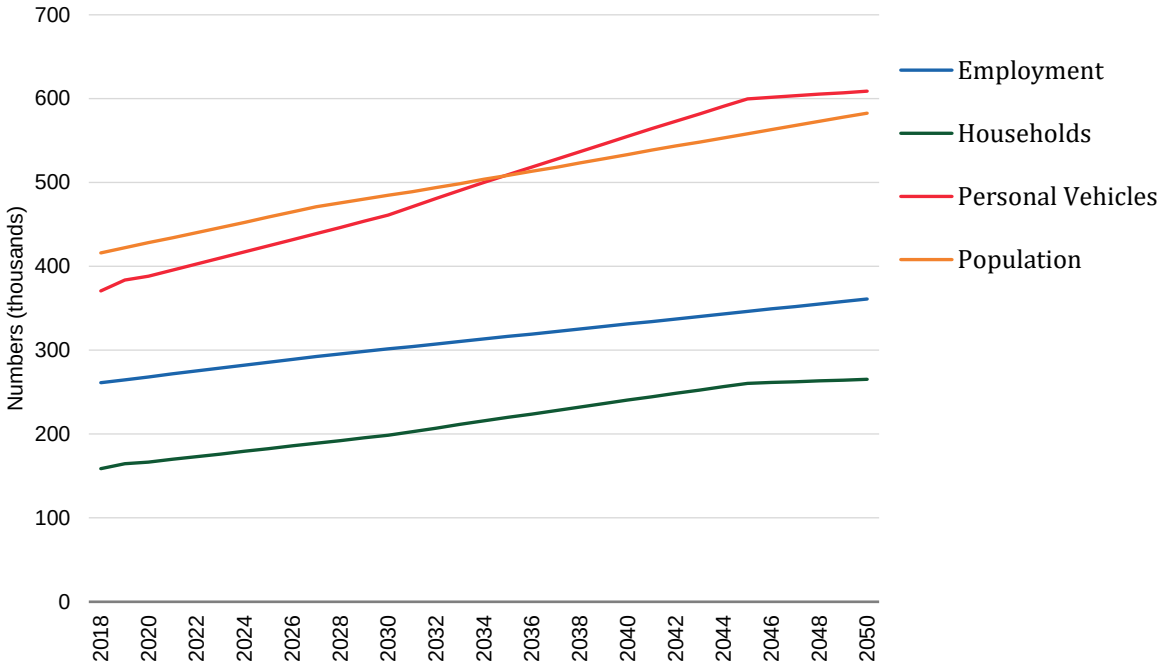

Figure 1: Clackamas Projected Population, Employment and Households, 2018-2050.

Projections indicate that Clackamas County's population is expected to increase by 40% or approximately 160,000 people by 2050 (Figure 2 illustrates where growth occurs). Employment is expected to scale with population, with nearly 100,000 jobs added between 2018 and 2050 (~40%). Households are expected to grow 67% and anticipate increased growth of non-primary homes being constructed.

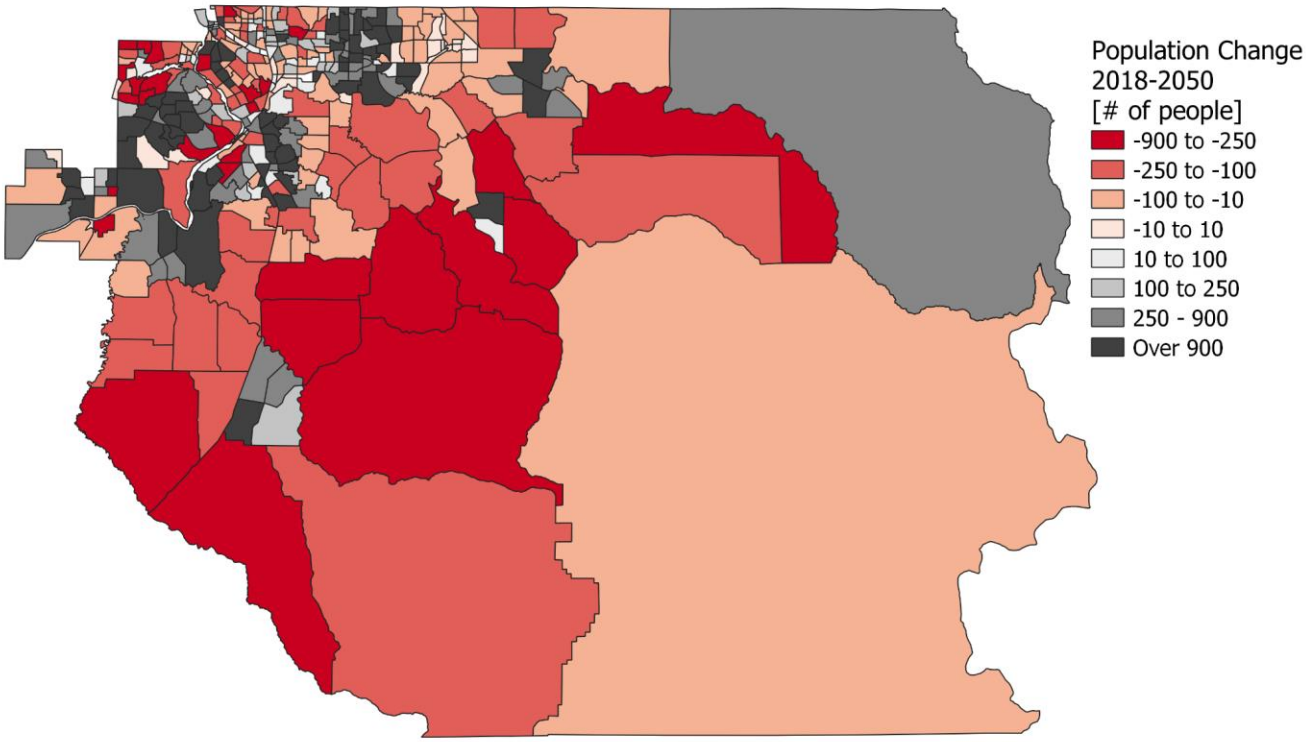

Figure 2: Change in Population across the County, 2018-2050.

4. Projected Total Energy Use and Emissions

Total and Per Capita

Figure 3 shows the total community energy use in 2018, and the energy use projection to 2050. Energy use is expected to increase by 3,000,000 MMBTU or +6%.

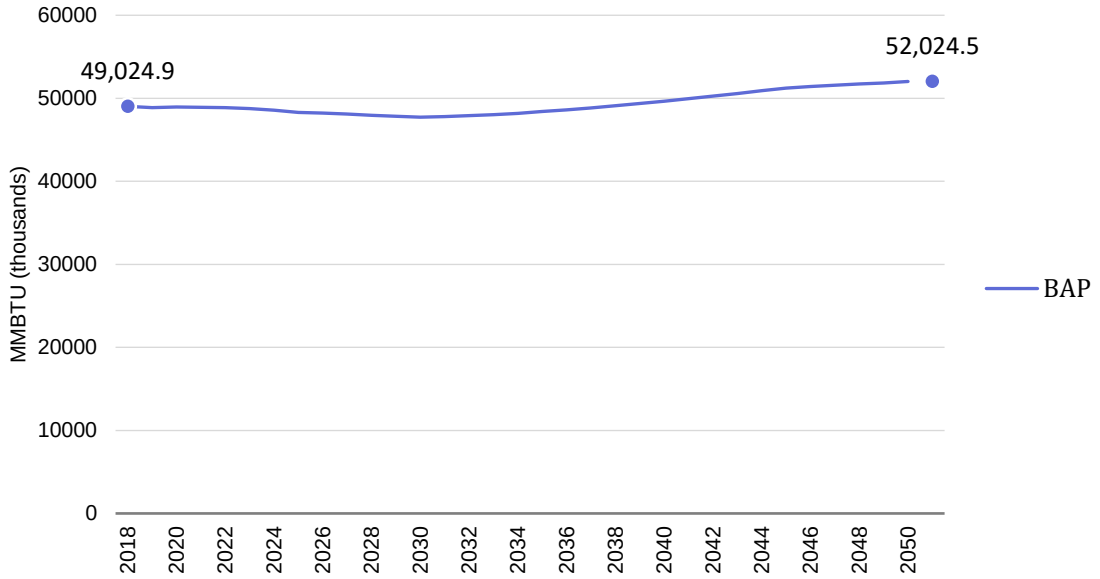

Figure 3: Projected Total Community Energy Use, 2018-2050.

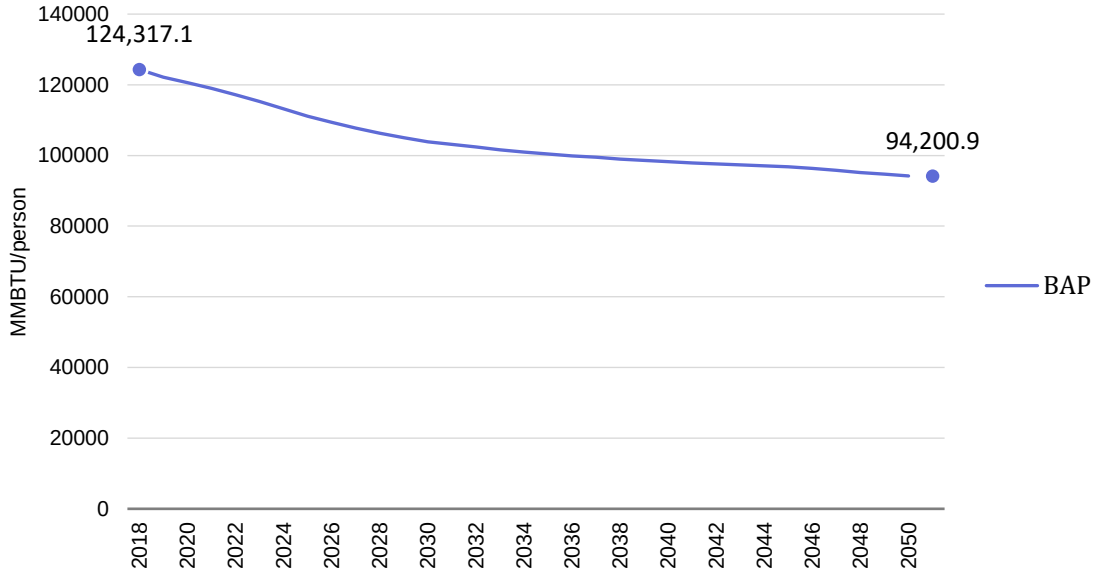

Figure 4: Projected per Capita Energy Use, 2018-2050.

Although Clackamas County's total energy use is projected to increase by 2050, per capita energy use decreases by about 30,000 MMBTU/person (Figure 4). The population is increasing,

however there is overall reduced space heating/cooling and water heating demands, due in part to smaller homes, increased energy efficiency, and decreased winter heating demand as the climate warms.

Clackamas County's total emissions for the 2018 baseline year are 7,218,000 metric tons of carbon dioxide equivalent (MtCO2e). Total projected emissions rise to 7,991,000 MtCO2e by 2050 (+11%) (Figure 5). Per capita emissions decrease by 3.6 MtCO2e/person between 2018 and 2050 (-21%) (Figure 6). Both of these numbers include energy-related emissions from buildings, transportation fuels, and industrial and agricultural practices as well as direct emissions from waste, livestock and fugitive emissions, and consumption-based emissions.

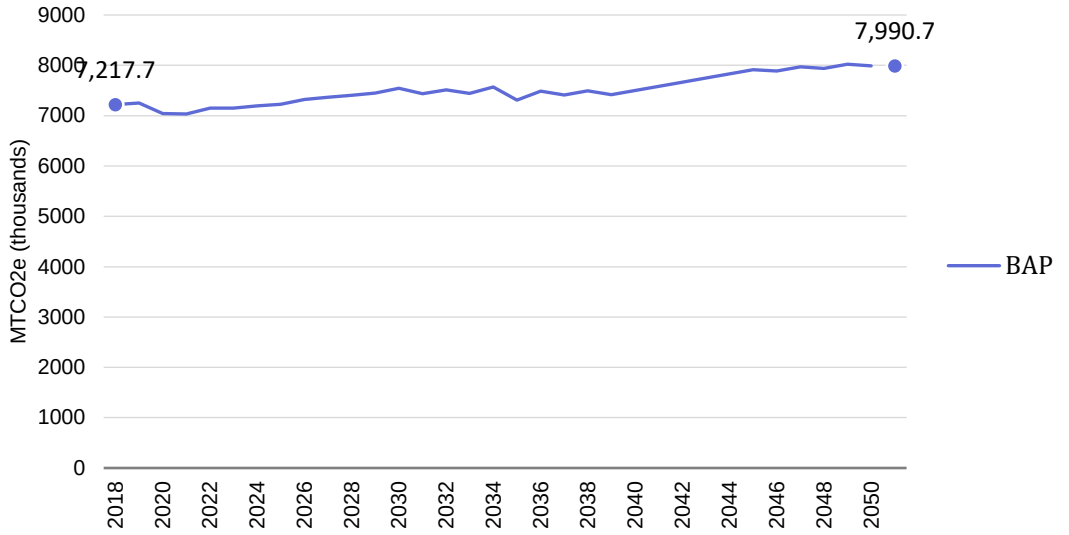

Figure 5: Projected Total Clackamas County Emissions, 2018-2050.

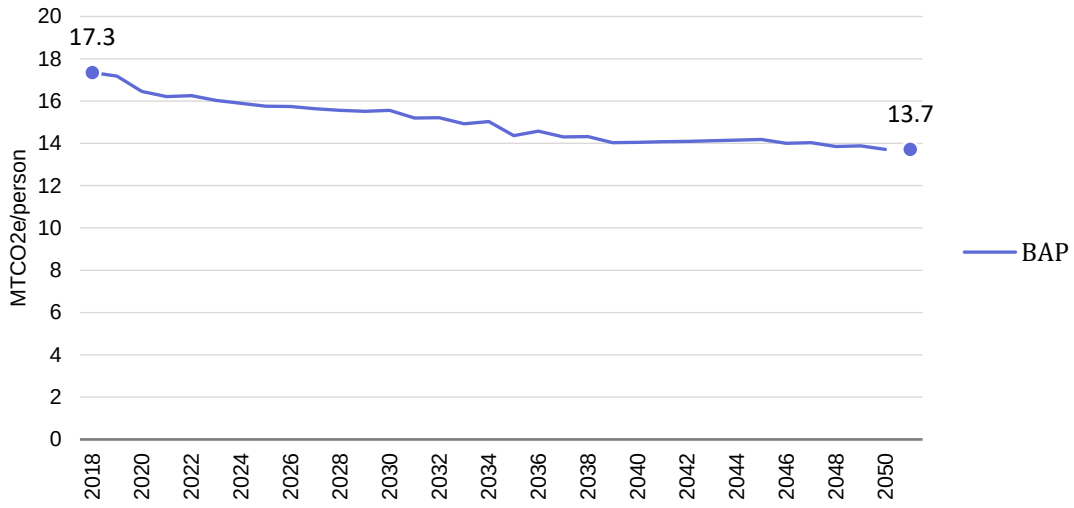

Figure 6: Projected per Capita Clackamas County Emissions, 2018-2050.

Energy Use and Emissions By Sector

In 2018, the transportation sector accounted for 45% of all energy use, residential for 30%, and commercial and industrial sectors for most of the remaining share (Figure 7). Due to the projected increase in dwelling units by 2050, residential sector energy use is expected to rise the most, by 26%, accounting for the largest share of Clackamas County's total projected energy use in 2050. Transportation is expected to use 18% less energy in total as vehicle efficiency standards increase and new vehicle purchases are increasingly electric models. There are also increases of 38% in industrial energy and 17% in the commercial sector. Together these sectors continue to contribute approximately one third of the total energy consumption split evenly between them. For more details, see Appendix Table A1.

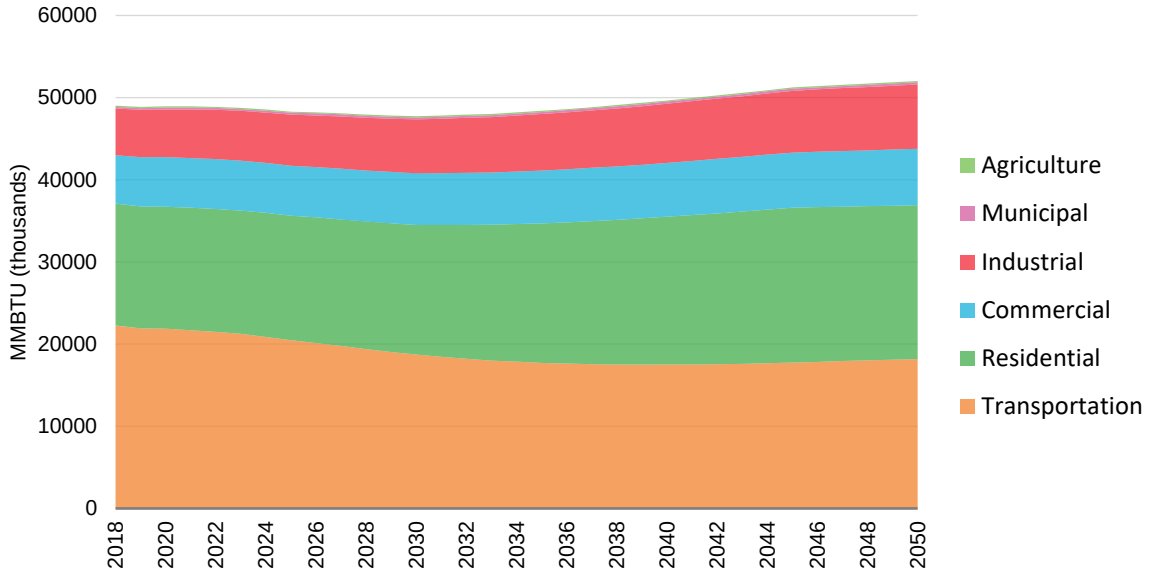

Figure 7: Projected Total Energy Use by Sector, 2018-2050.

Consumption-based emissions accounted for 34% of all emissions in 2018 and increases in step with the number of households, up 67% in the BAP scenario (Figure 8). The transportation sector and residential buildings together are responsible for over half of Clackamas County's emissions, with 37% and 21% of all non-consumption-based 2018 emissions, respectively.

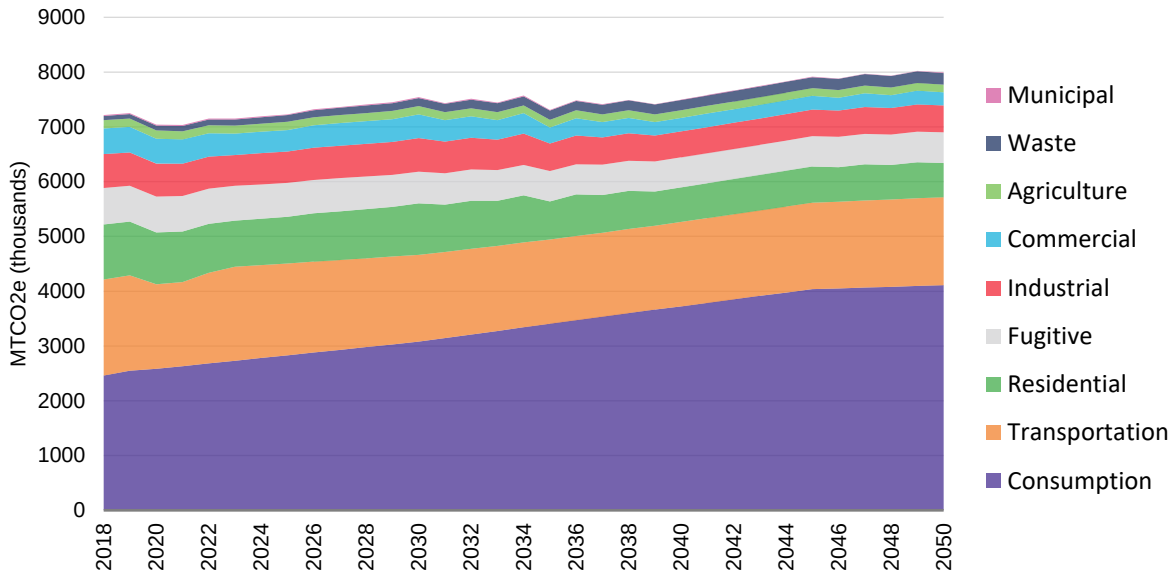

Figure 8: Projected Total Emissions by Sector, 2018-2050.

By 2050, most sectors except for consumption and waste are projected to decrease. Fugitive emissions from natural gas systems (unintentional emissions from transportation and distribution) amount to 661,700 Mt CO2e in 2018, decreasing 15% by 2050. The building sectors see the largest decreases driven by improvements to the building code, retrofits, space heating/cooling efficiency gains, and lower electricity grid emissions. In the case of transportation, decreases are driven by efficiency and electrification. For details on exact values and shares of emissions, see Appendix Table A2.

Energy and Emissions By End Use

In 2018, the dominant end use energy users are transportation (45%) and space heating (19%) (Figure 9). The remaining 36% is distributed, in descending order, among Industrial processes, water heating, plug loads, lighting, major appliances, and space cooling.

In the BAP scenario, there is a net energy demand increase of 6%; however, the top two end uses both decrease between 2018 and 2050. In 2050, transportation accounts for 35% of total energy use, while space heating accounts for 18%. The other end uses increase energy demand, with the largest increase coming from space cooling (79%) because of the warming weather trend. However, it still makes up only 1% of the energy use overall. For details see Appendix Table A3.

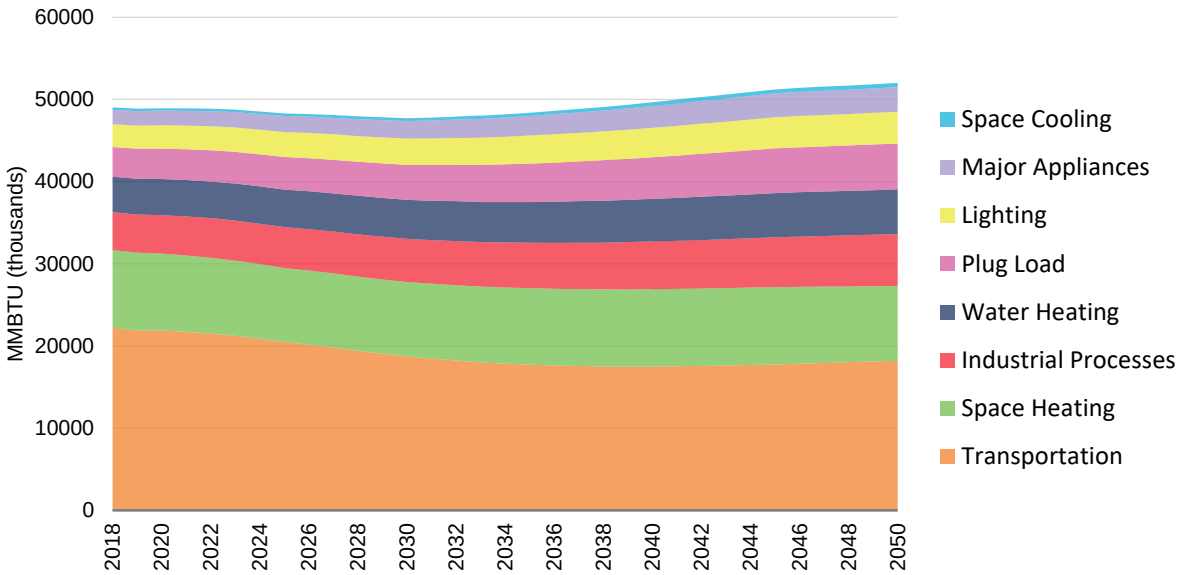

Figure 9: Projected Total Energy Use by End Use, 2018-2050.

Energy and Emissions By Fuel Type

Figure 10 shows the projected emissions by fuel type over time between 2018 and 2050 under the BAP scenario. Here 'Non Energy' emissions include consumption emissions and fugitive emissions.

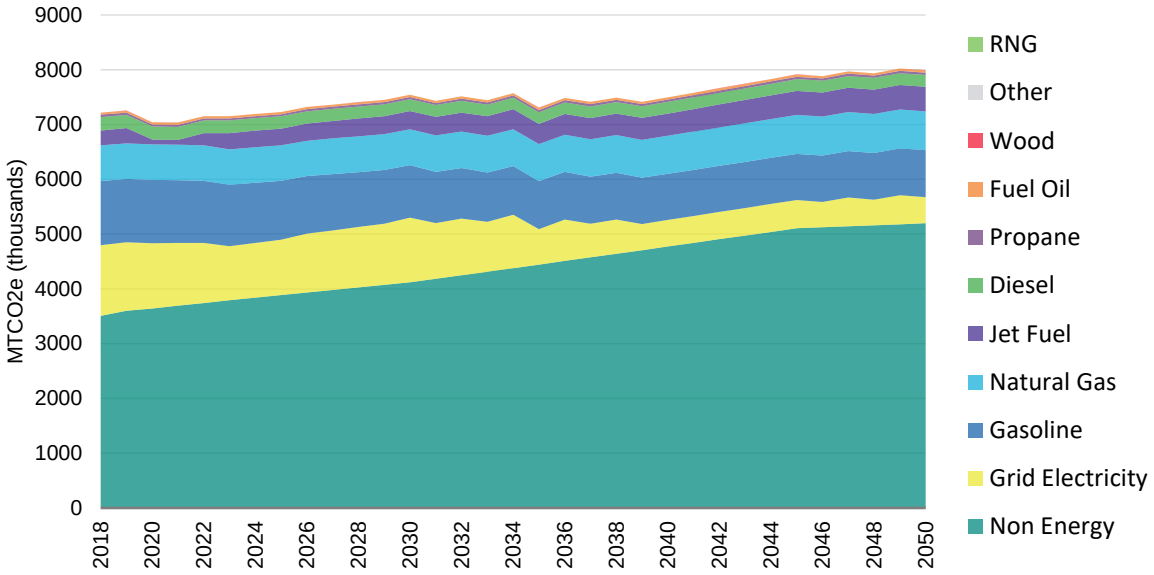

Figure 10: Projected Total Emissions by Fuel Source, 2018 - 2050.

In 2018 gasoline accounted for roughly one third of all non-consumption energy use (35%) and emissions (31%). By 2050 it is expected to decrease by 26% (Table 2). In 2018, grid electricity

and natural gas made up nearly 50% of non-consumption energy use, each approximately 12,729,700 MMBTU. However, they have different emissions factors, and moreover the emissions intensity of grid electricity is expected to decrease substantially as fossil fuel electricity production is phased out and more renewables come online. Thus, by 2050 although grid electricity energy use increases by 54%, its emissions decrease by 63%. Natural gas increases in energy use and emissions by 8%. Detailed energy use and emissions by fuel type data are summarized in Appendix Tables A4 and A5.

Table 2: Changes in shares of energy and emissions by fuel type, 2018 and 2050.

	2018		2050		% change 2018-2050	
Fuel Type	**Share of Energy**	**Share of Energy Emissions**	**Share of Energy**	**Share of Energy Emissions**	**Energy**	**Emissions**
Gasoline	35%	31%	24%	31%	-26%	-26%
Grid Electricity	26%	35%	38%	17%	54%	-63%
Natural Gas	26%	18%	26%	25%	8%	8%
Diesel	7%	7%	6%	8%	-14%	-13%
Wood	2%	0%	2%	0%	-10%	-10%
Other	2%	0%	2%	0%	18%	-14%
Propane	1%	1%	1%	2%	6%	6%
Fuel Oil	1%	1%	1%	1%	10%	10%
Local Electricity	0%	0%	0%	0%	21%	0%
District Energy	0%	0%	0%	0%	0%	0%
Jet Fuel	n/a	7%	n/a	16%	n/a	67%

Energy Flow and Conversion

Before energy is used for its ultimate purpose, it is frequently distributed over distances and/ or converted to different forms. These distributions and conversions often result in a loss of energy.

The Sankey diagrams in Figure 11 and Figure 12 depict Clackamas County's energy flow by fuel and sector in 2018 and 2050 under the BAP. The diagrams show energy sources on the left portion of the figure, and sectoral uses in the middle. Wider lines depict greater uses of energy. The final two bars on the right side summarize the amount of energy that is ultimately used and the amount that is lost along the way. Note that "Electricity" refers to electricity provided by the grid; "Solar" refers to that provided by solar installations that are not part of the grid; and "Elec Gen" refers to electricity that is generated from excess heat produced from the combustion of fuel.

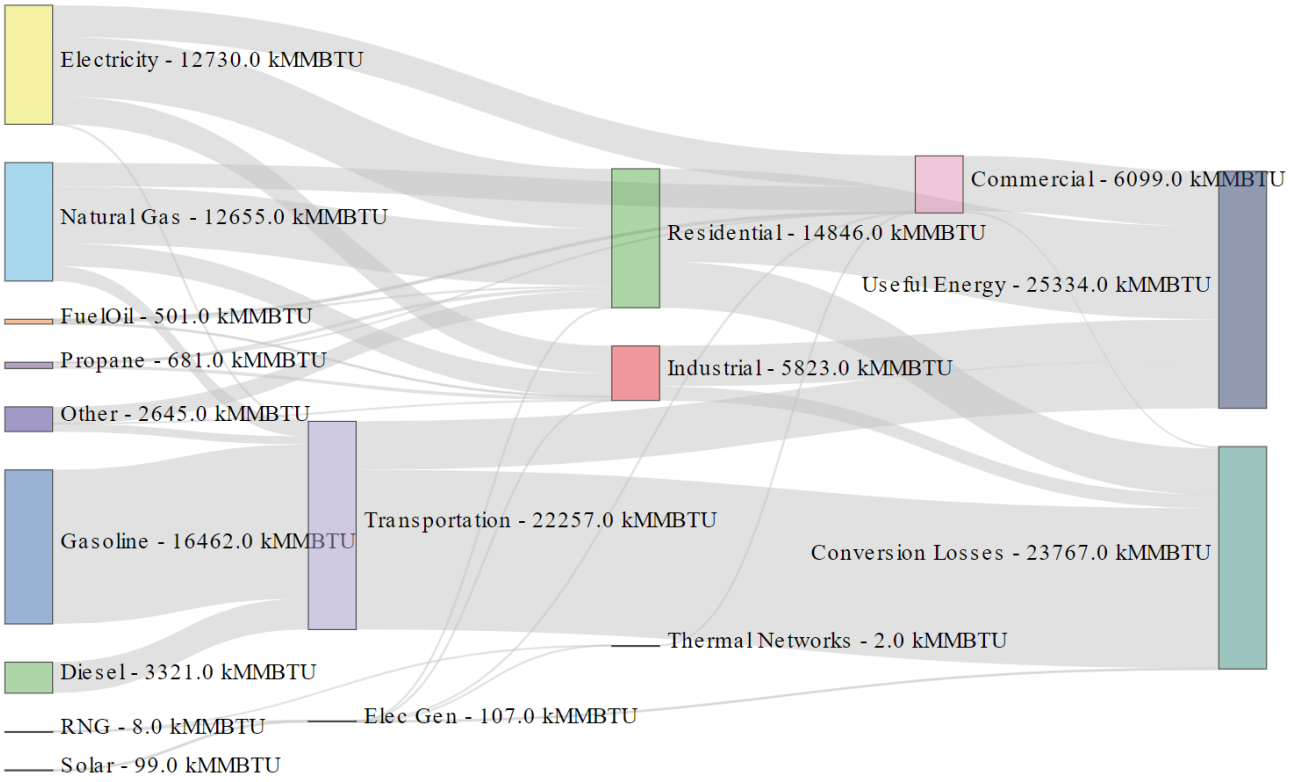

Figure 11: Energy Flow and Conversion by Sector, 2018.

In 2018, the ratio of useful energy to conversion losses is approximately 1.06:1. Transportation represents the largest source of conversion loss due primarily to the inefficiency of internal combustion engines.

In 2018, approximately 107,000 MMBtu of local energy was produced through renewable natural gas (RNG) and solar PV. The RNG is used primarily for district energy uses in the commercial sector, while solar PV is used for electricity in most building types.

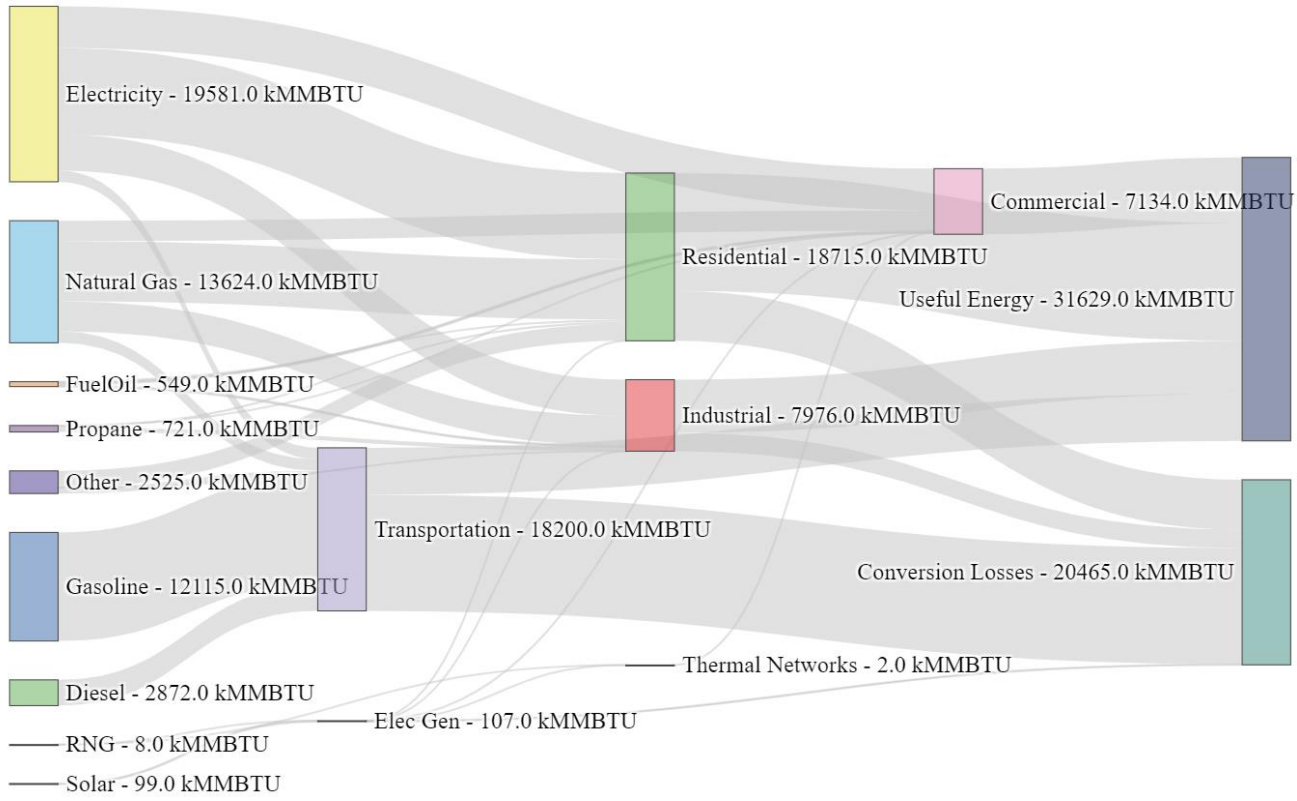

Figure 12: Modeled Energy Flow and Conversion by Sector, 2050 BAP.

Overall, modeled energy demand remains fairly linear in growth in 2050 compared to 2018, matching population and employment growth trends. The ratio of useful energy to conversion losses improves by 2050 with a ratio of 1:1.5. This assumes improvements in vehicle engine efficiency and building code improvements (detailed in Table 1). No further local energy is assumed to be generated by 2050.

5. Buildings Energy and Emissions

Building Area Projections

As Clackamas County's population increases, its building stock is also expected to increase to accommodate people in homes, office spaces, and commercial/retail spaces. Total building area is expected to increase by 63% for homes and 32% for all other building types across the county by 2050.

The residential sector is expected to have the largest increase by 2050, with almost 103,000 new units, primarily as single-family homes (Table 3). While single detached homes have the largest absolute increase, newly built apartments are outpacing all other new dwelling types in relative terms (increasing by 147%).

Table 3: Clackamas County residential buildings: increases in number of units.

Building Type	2018 (# units)	Share of total 2018	2050 (# units)	Share of total 2050	Increase in dwelling units
Single Detached	132,180	81%	198,182	75%	50%
Apartment	23,680	15%	58,606	22%	147%
Row/Townhouse	6,672	4%	8,574	3%	29%
Total Residential	162,532	100%	265,361	100%	63%

The acceleration of construction of new dwellings is not uniformly distributed across the County (Figure 13). The density of new dwellings is a measure of the current building rate for a given region, and the difference between current new buildings in 2018 and new building density (units per hectare) in 2050 increases mostly in the areas surrounding Shadowood, Stafford, the outskirts of Mount Pleasant, and the areas surrounding Happy Valley. These forecasts are based on data received from the Oregon Metro Data Research Center.

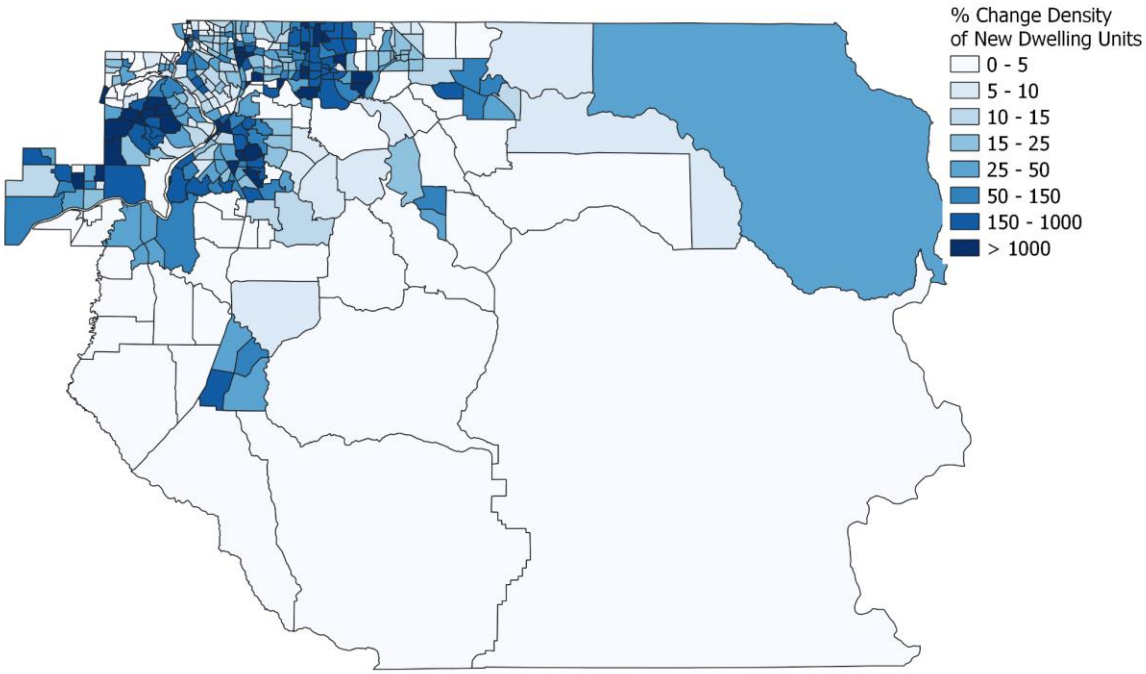

Figure 13: Percentage Expected Change in the Density of Newly built Residential Units.

It is expected that Clackamas County will also see steady and uniform increases in all of its non-residential building stock except for buildings in the "Primary" building type (industries that extract or produce natural materials such as forestry and agriculture), totaling nearly 10,645,000 ft^2 (Table 4).

Table 4: Clackamas County increase in non-residential floor space.

Building Type	2018 (ft^2)	Share of total 2018	2050 (ft^2)	Share of total 2050	Increase in floor space
Office	13,603,692	41%	18,762,813	43%	38%
Warehouse	6,448,403	19%	8,893,923	20%	38%
Primary	5,339,807	16%	5,339,807	12%	0%
Industrial	3,833,622	11%	5,287,501	12%	38%
Retail	2,546,729	8%	3,512,561	8%	38%
Municipal	796,223	2%	1,098,186	2%	38%
Education	635,310	2%	876,247	2%	38%
Service	208,519	1%	286,069	1%	37%
Total Non-Residential	33,412,305	100%	44,057,107	100%	32%

In absolute terms this is primarily as office buildings, which are the most common non-residential buildings (gaining 5,159,121 ft2). Commercial sector buildings (which includes offices, retail, service) are rapidly increasing in the regions closest to Lake Oswego, Milwaukie, Oatfield, Happy Valley, Wilsonville, and Canby (Figure 14).

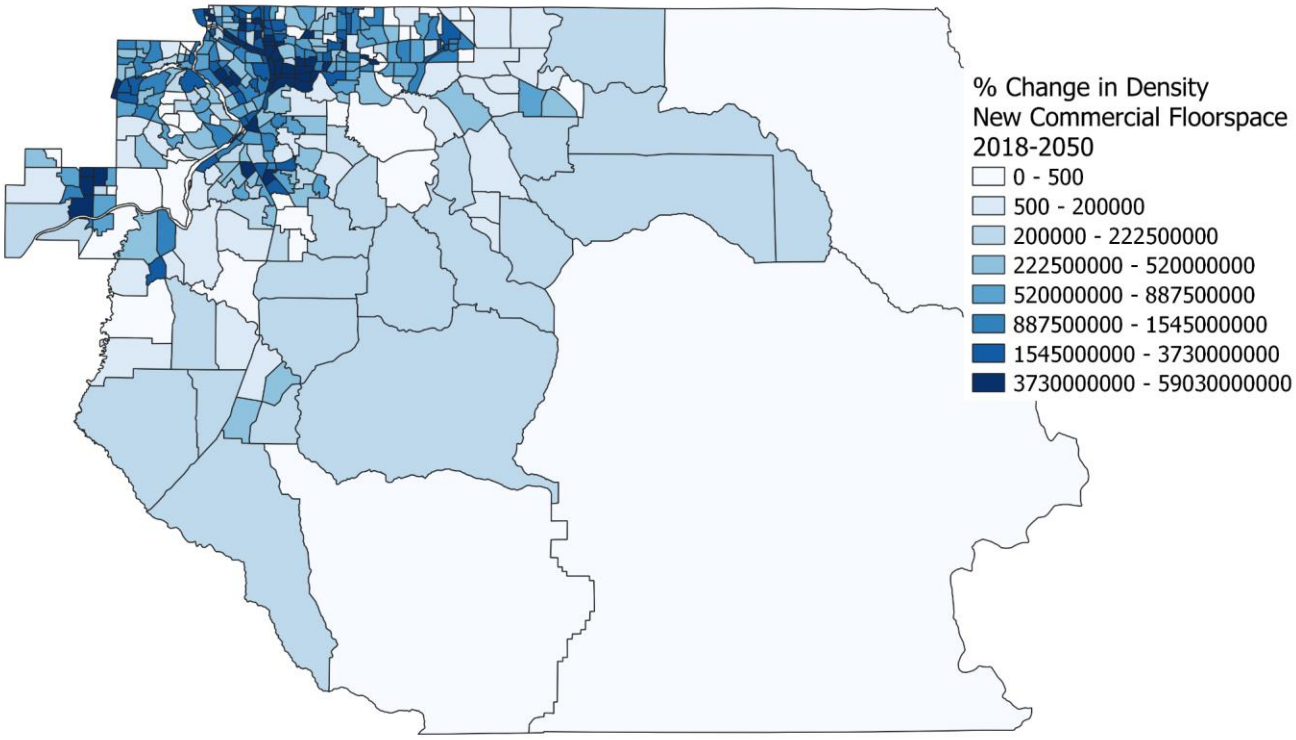

Figure 14: Percentage Expected Change in the Density (Square Feet Per Hectare) of New Commercial Floor space Between 2018 And 2050.

Total Building Sector Energy Use and Emissions

In 2018 buildings used 26,768,000 MMBTU of energy, and that number will increase by 25% in 2050 under the BAP scenario (Figure 15). All sectors except agriculture are increasing in energy use. The top three consumers are residential, followed by commercial and industrial.

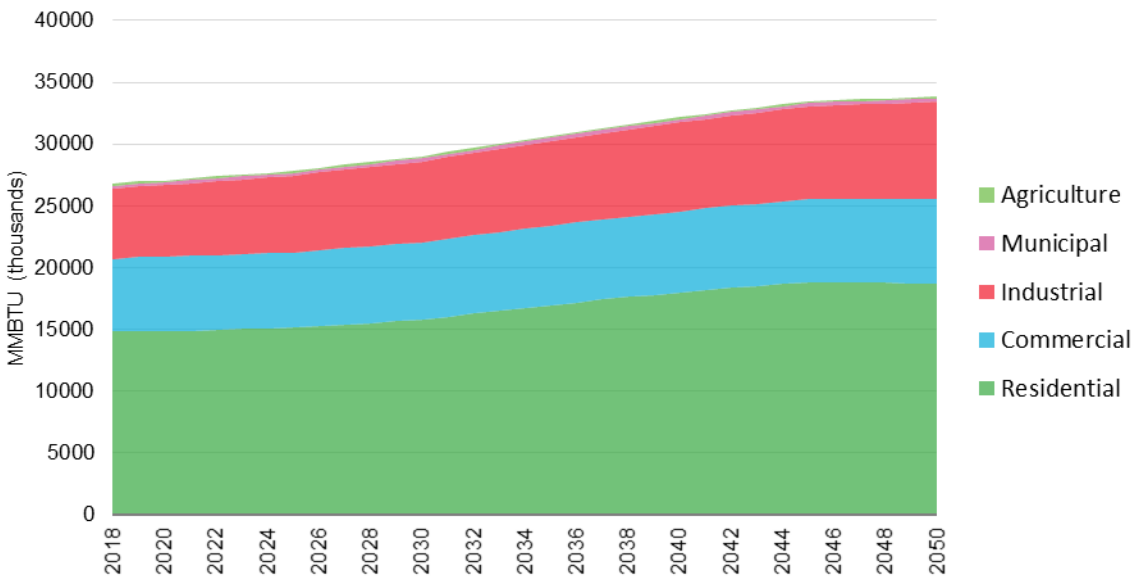

Figure 15: Projected Clackamas County Building Energy Use by Sector, 2018-2050.

A sector-by-sector comparison of energy use in 2018 and 2050, along with relative share, are provided in Table 5. The agricultural buildings sector[1] is the only sector with flat energy use over this time period.

Table 5: Clackamas County Building Energy Use Shares and Percent Change by Building Type.

Sector	2018 (MMBTU)	2018 Share	2050 (MMBTU)	2050 Share	% change 2018-2050
Residential	14,845,934	55%	18,714,775	55%	26%
Commercial	5,877,539	22%	6,858,546	20%	17%
Industrial	5,678,199	21%	7,831,623	23%	38%
Municipal	221,766	1%	274,988	1%	24%
Agriculture	144,830	1%	144,830	<1%	<1%
Total	26,768,268	100%	33,824,761	100%	26%

The industrial sector sees the largest increase (38%), which is proportional to the increase in floor area. Unlike other municipal, residential and commercial sectors, the industrial sector does not see the same level of energy efficiency improvements.

[1] Note: this sector accounts for buildings-related energy within the agricultural sector, not the other activities e.g., emissions from livestock or off-road farming vehicles, which are accounted for separately in subsequent sections.

The building sectors that consume the most energy are also, unsurprisingly, the largest emitters (Table 6). However, while total energy use is expected to increase, the emissions under the BAP scenario are decreasing by 40% overall. The largest share of emissions come from residential buildings: 1,010,500 MT CO2e in 2018. This sector is projected to emit 624,300 MT CO2e (38% fewer emissions) in 2050.

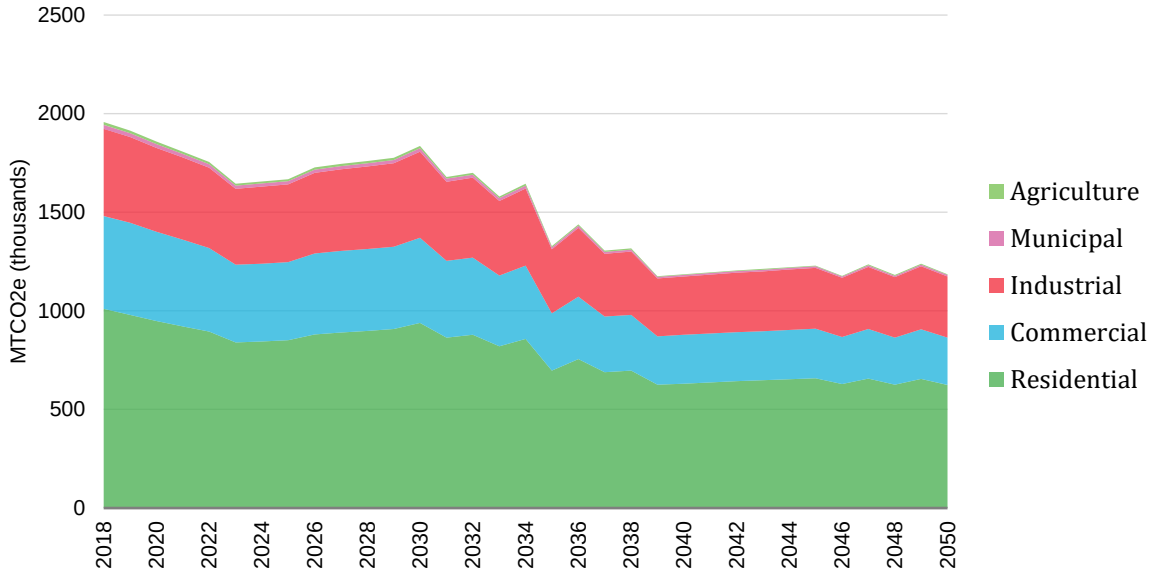

Figure 16: Projected Clackamas County Emissions from the Buildings Sectors, 2018- 2050.

The overall trend is a reduction in emissions, albeit not in a smooth continuous curve (Figure 16); an important factor for emissions is the electricity-grid-associated emissions. These can vary each year, as the mix of inputs to the generation of electricity vary each year. Overall, the electricity grid emissions per unit of energy are decreasing. In 2018, the average emissions factor was 771 lbs. CO2e per MWh, based on the average from Portland General Electric. In 2050, this is expected to decrease to 176 lbs. CO2e per MWh. More generally, emissions per unit of energy are decreasing faster than energy use is increasing due to grid decarbonization alongside decreasing reliance on fossil fuels.

Table 6: Clackamas County Building Emissions Shares and Percent Change by Building Sector.

Sector	2018 Emissions (MTCO2e)	2018 Share	2050 Emissions (MTCO2e)	2050 Share	% change 2018-2050
Residential	1,010,488	52%	624,324	53%	-38%
Commercial	470,025	24%	239,975	20%	-49%
Industrial	442,392	23%	310,530	26%	-30%

Municipal	20,124	1%	7,671	1%	-62%
Agriculture	14,695	1%	3,509	0%	-76%
Total	1,957,725	100%	1,186,010	100%	-40%

Combining the floor area projections and the emissions yields emissions per 'fixed' unit of floor area, allowing comparison across building sectors in terms of emissions intensities. In the BAP scenario, all buildings are reducing their emissions per floor area, by becoming more efficient and benefiting from less carbon in the electricity grid (Table 7). The municipal buildings in Clackamas County have the greatest reductions in emissions (72% per unit of floor area).

Table 7: Clackamas County Building Emissions per Floor Area, and Percent Change between 2018 and 2050.

Building Sector	2018 Emissions/ Floor Area (MTCO2e / ft^2)	2050 Emissions/ Floor Area (MTCO2e / ft^2)	% change 2018-2050
Residential	0.002168723	0.000805934	-63%
Commercial	0.02166138	0.008600882	-61%
Industrial	0.115397982	0.058729146	-49%
Municipal	0.025274798	0.006985327	-72%

By End Use

At 35% of the total energy used in buildings in 2018, space heating is by far the greatest building energy end use (Figure 17). This demand is driven by the residential and commercial building sectors. As buildings become more efficient and homes become smaller on average, space heating energy demand decreases to 27% of total energy consumption by 2050. However, the other end uses each increase. On the residential side, increases in population bring an increased demand for water heating, plug loads, and lighting, whose energy uses are projected to experience a 26%, 55% and 39% change (increase), respectively. Although projected to be only 9% and 2% of the total energy used in 2050, major appliances and space cooling energy demand increases significantly from 2018. Whereas space heating is driven by the residential and commercial sectors, the second highest energy end use category overall is industrial processes, which are entirely from industrial buildings. Energy for industrial processes is expected to increase by 38%. For a complete overview of energy and shares, see Appendix Table A6.

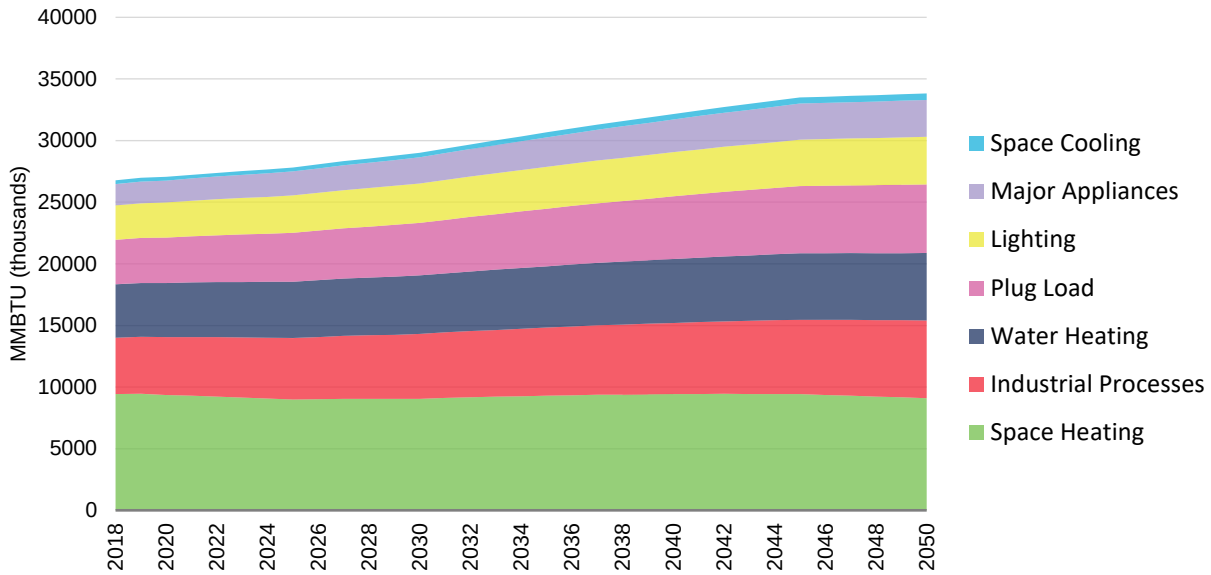

Figure 17: Projected Clackamas County Building Energy by End Use 2018-2050.

Because much of Clackamas County's building space heating (primary energy user) is supplied by fossil fuels, space heating's share of total buildings emissions makes up 25% of total emissions in 2018 and 30% in 2050 (Table 8). Its overall share of the total emissions is increasing because of the relative decarbonization of other end uses such as plug loads and lighting. The latter decrease their emissions by 63% and 67% respectively. Although cooling degree days increase between 2018-2050, space cooling remains a small share of emissions overall under the BAP scenario.

Table 8: Clackamas County Building Emissions by End Use.

End Use	2018 Emissions (MTCO2e)	2018 Share	2050 Emissions (MTCO2e)	2050 Share	% change 2018-2050
Space Heating	481,306	25%	356,848	30%	-26%
Plug Load	364,711	19%	134,887	11%	-63%
Industrial Processes	337,239	17%	266,212	22%	-21%
Water Heating	294,270	15%	242,029	20%	-18%
Lighting	282,099	14%	93,479	8%	-67%
Major Appliances	168,394	9%	79,410	7%	-53%
Space Cooling	29,706	2%	13,145	1%	-56%
Total	1,957,725		1,186,010		-39%

Parsing the above information, by sector and by end use (Figure 18), shows the distinct patterns of emissions within building sectors, largely because of the sectors' different end use shares. Residential, commercial and municipal see changes tied to the electricity-based end uses (especially plug loads, lighting, and space cooling).

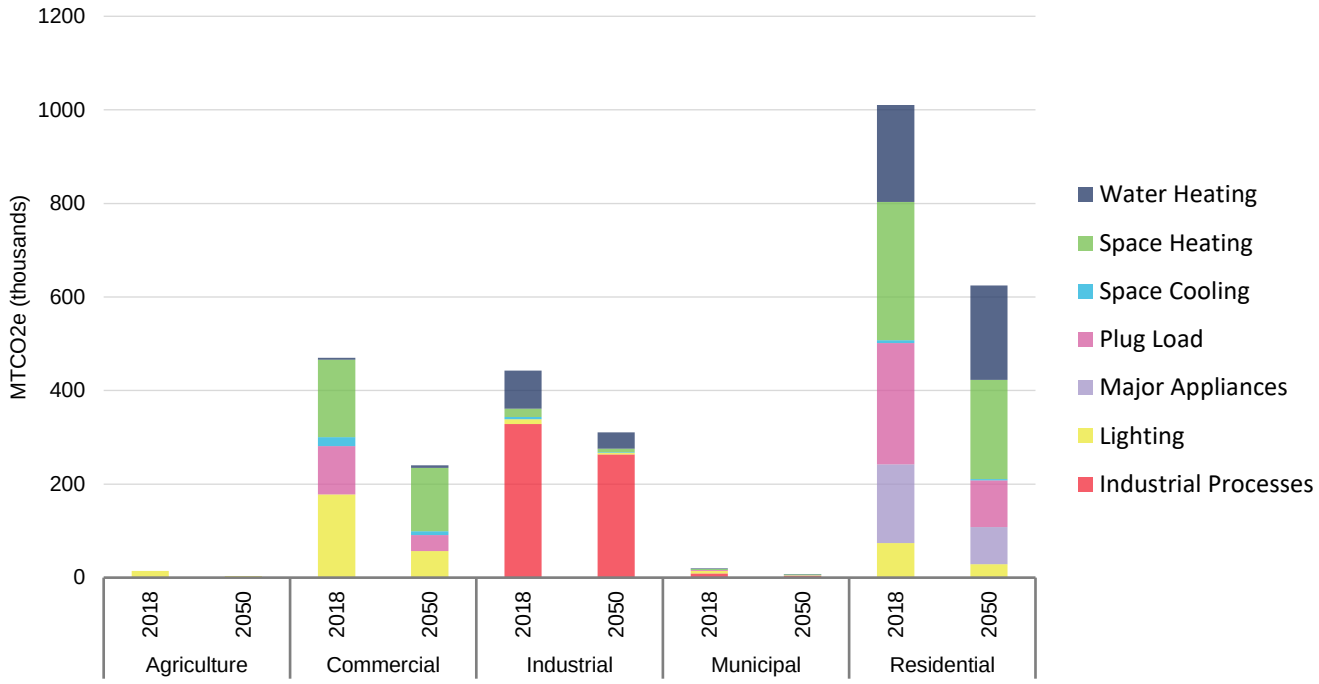

Figure 18: Clackamas County Building Emissions by Sector by End Use 2018 and 2050.

By Fuel Type

In 2018 electricity provided most of the energy used in buildings (47%). Building consumption of electricity is expected to increase by 44% by 2050 (Figure 19). Natural gas use is also expected to increase in buildings from 2018 to 2050, by 11%, although it will decrease in its relative share as more buildings switch to electricity. Together, grid electricity and natural gas account for 88% of all energy use. The remaining energy is provided by fuels such as wood, propane, and furnace oil. For detailed energy use, see Appendix Table A7.

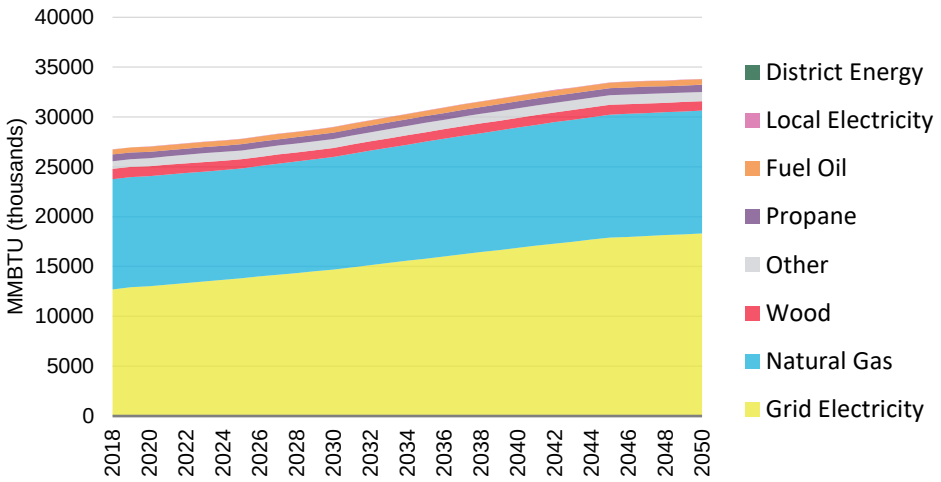

Figure 19: Projected Clackamas County Building Energy Use by Fuel Type 2018 to 2050.

Although natural gas accounted for 41% of the energy used by buildings in 2018, it was responsible for only 30% of emissions associated with buildings. Electricity use was responsible for the majority (66%) of 2018 building emissions. Propane stoves, fuel oil furnaces, and wood stoves were responsible for the remainder of 2018 building emissions.

In 2050, by contrast, electricity and natural gas have swapped positions: with the lowering of grid emissions, and despite increasing in energy use by 44% over the same time period, the emissions from electricity decrease by 66% and make up only 37% of the share of all building-related emissions. Total emissions associated with natural gas, propane, fuel oil increase. Thanks mostly to lowering of the grid emissions factors, overall emissions from buildings will decrease 39% by 2050. Fuel types are projected to have a relatively consistent pattern across all the building types (Figure 20).

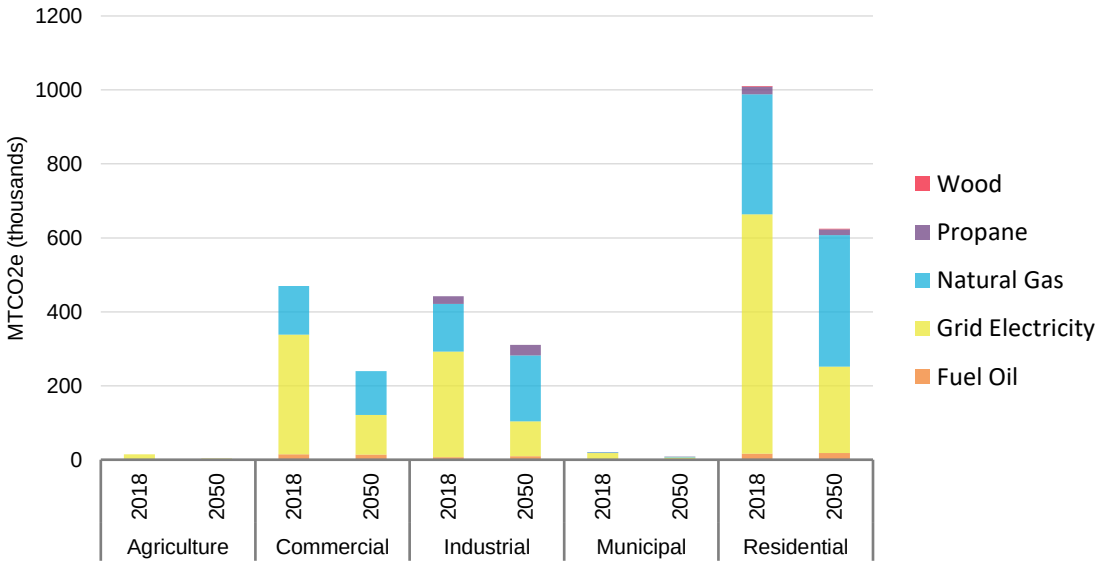

Figure 20: Clackamas County Building Emissions by Sector and Fuel Type 2018 and 2050.

6. Transportation Energy & Emissions

Energy and Emissions By Vehicle Type

At over 22,256,000 MMBTU, Clackamas County's transportation sector accounted for 45% of the total energy use in 2018. This share will decrease to 35% of total energy by 2050 (Figure 21). The transportation sector emitted 1,751,600 MTCO2e in 2018. This is expected to decrease slightly (by 8%) by 2050.

As transportation needs grow in step with population growth, there is an increase in the number of cars and light trucks. Light truck (and SUV) ownership starts to outpace cars by 2029.

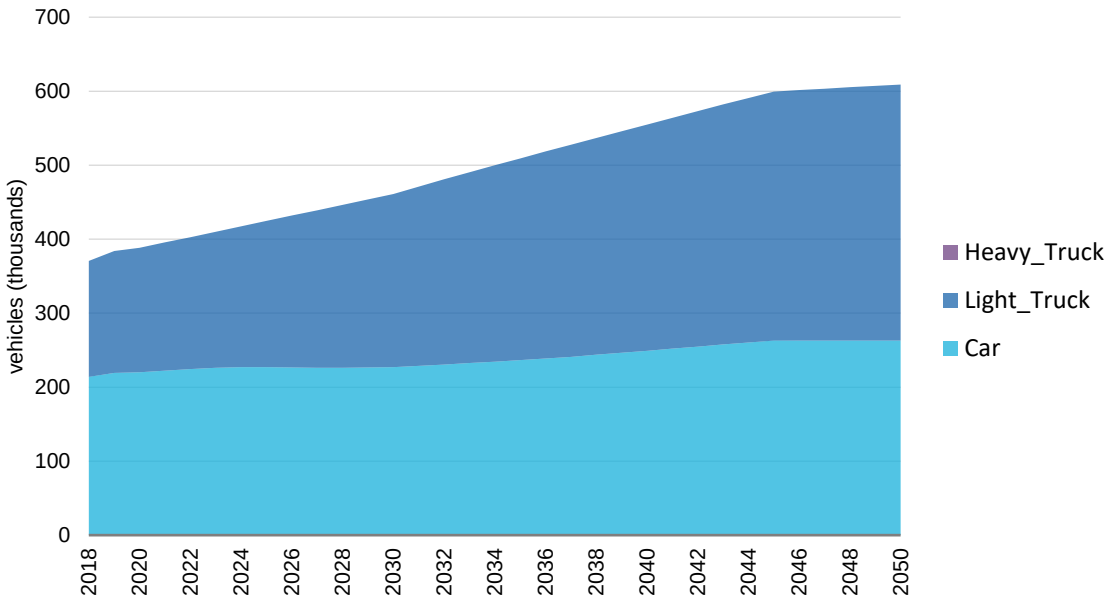

Figure 21: Vehicle Ownership, Between 2018 and 2050.

Cars and light trucks accounted for almost 75% of transportation energy use in 2018 (Figure 22). Commercial (heavy) trucks used almost 19% of total energy, and Clackamas County's transit system (LRT, rail, and buses) used a little over 2%.

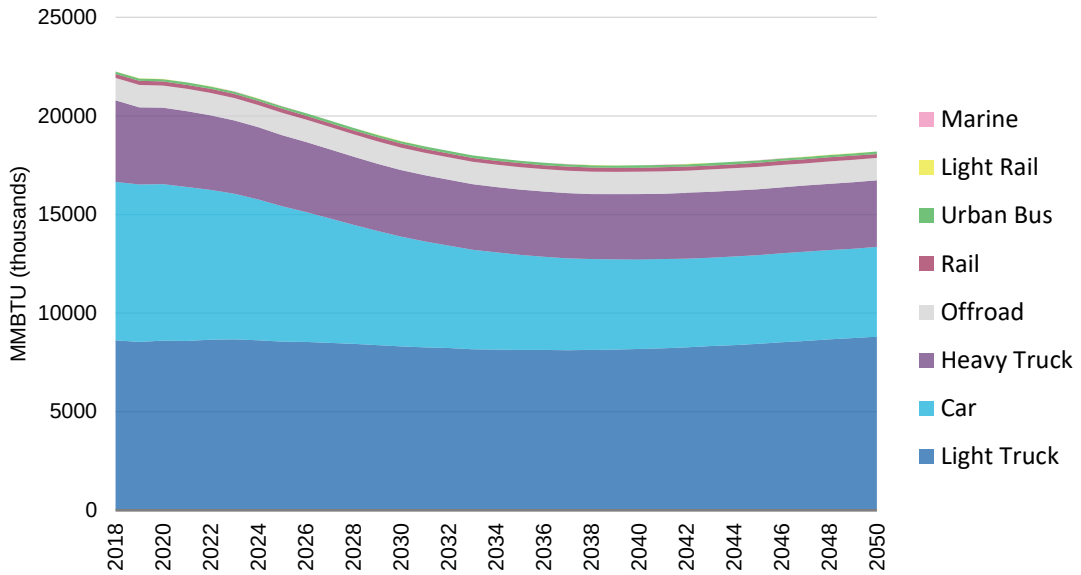

Figure 22: Transportation Energy by Vehicle Type, between 2018 and 2050.

As personal vehicles (mainly cars) electrify and become more fuel efficient, their energy use decreases. For cars, there is a 43% energy use reduction from 2018 to 2050 (Table 9).

Table 9: Transportation Energy and Share by Vehicle Type, 2018 and 2050.

Vehicle Type	2018 (MMBTU)	2018 Share	2050 (MMBTU)	2050 Share	% change 2018-2050
Light Truck	8,615,644	39%	8,806,171	48%	2%
Car	8,041,459	36%	4,548,108	25%	-43%
Heavy Truck	4,133,780	19%	3,379,742	19%	-18%
Off-road	1,132,053	5%	1,132,053	6%	0%
Rail	204,791	1%	204,791	1%	0%
Urban Bus	120,542	1%	120,542	1%	0%
Light Rail	6,044	0%	6,044	0%	0%
Marine	2,279	0%	2,279	0%	0%
Total	22,256,592	100%	18,199,730	100%	-18%

Emissions shares by vehicle type align almost precisely with their energy use (Figure 23).

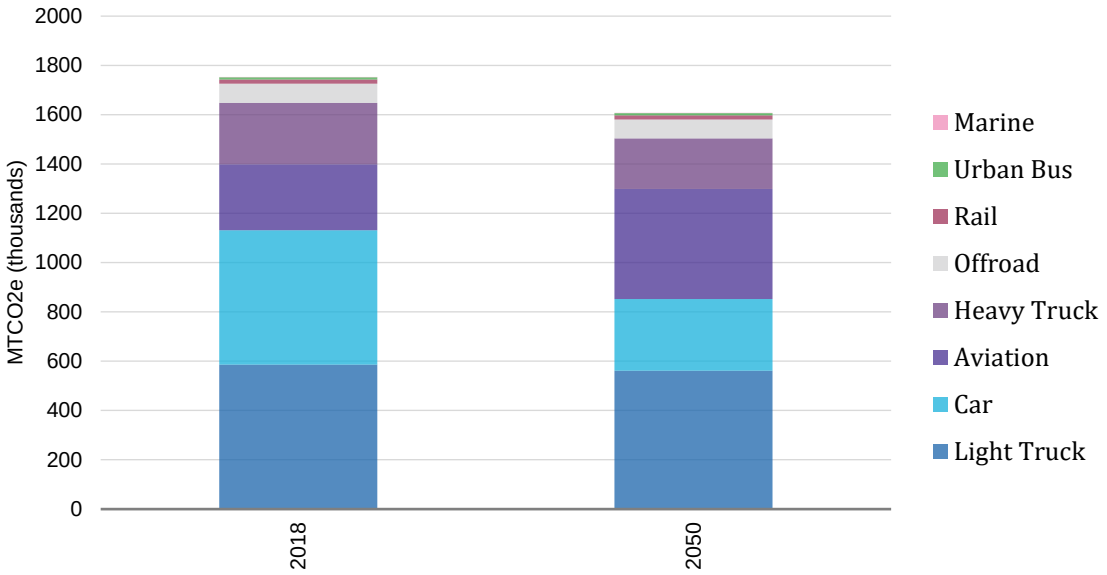

Figure 23: Transportation Emissions by Vehicle Type, 2018 and 2050.

In 2018, cars and light trucks accounted for about 85% of Clackamas County's total transportation emissions, while heavy trucks and buses accounted for about 15%. As cars electrify and use cleaner energy from the electricity grid, personal vehicle emissions decrease substantially by 2050. Light trucks are increasing in number and slower to electrify, which means they have only a slight decrease in emissions (4%) by 2050. For detail on emissions by vehicle type and shares see Table A8 in the Appendix.

Overall energy efficiency emissions savings outpace vehicle ownership and VMT, resulting in an overall 8% decrease in transportation emissions by 2050.

Energy and Emissions By Fuel Type

As the primary vehicle fuel source in 2018, gasoline consumption was responsible for the vast majority of transportation emissions at 74% (Table 10). Despite the countervailing factors of increased vehicle ownership and VMT increase by 2050, gasoline use declines by a net -26% by 2050 due to efficiency standards and electrification. By 2050, the total electricity used by vehicles increases by over 4600%, although as a share of total energy used, this electricity use is minuscule. Gas and diesel still make up over 83% of transportation energy use in 2050.

Table 10: Transportation Energy Use and Shares by Fuel Type, 2018 and 2050.

Fuel Type	2018 Energy (MMBTU)	2018 Share	2050 Energy (MMBTU)	2050 Share	% change 2018-2050
Gas	16,461,657	74%	12,115,198	67%	-26%
Diesel	3,320,934	15%	2,872,036	16%	-14%
Natural Gas	1,594,501	7%	1,292,868	7%	-19%
Ethanol	706,684	3%	529,585	3%	-25%
Biodiesel	146,100	1%	125,149	1%	-14%
Grid Electricity	26,716	0%	1,264,894	7%	4635%
Total	22,258,610	100%	18,201,780	100%	-18%

Plotting fuel type for each vehicle type (Figure 24) shows the potential for reducing emissions from cars and light trucks, which represent the highest shares of emissions and the highest shares of gasoline consumption in the BAP scenario.

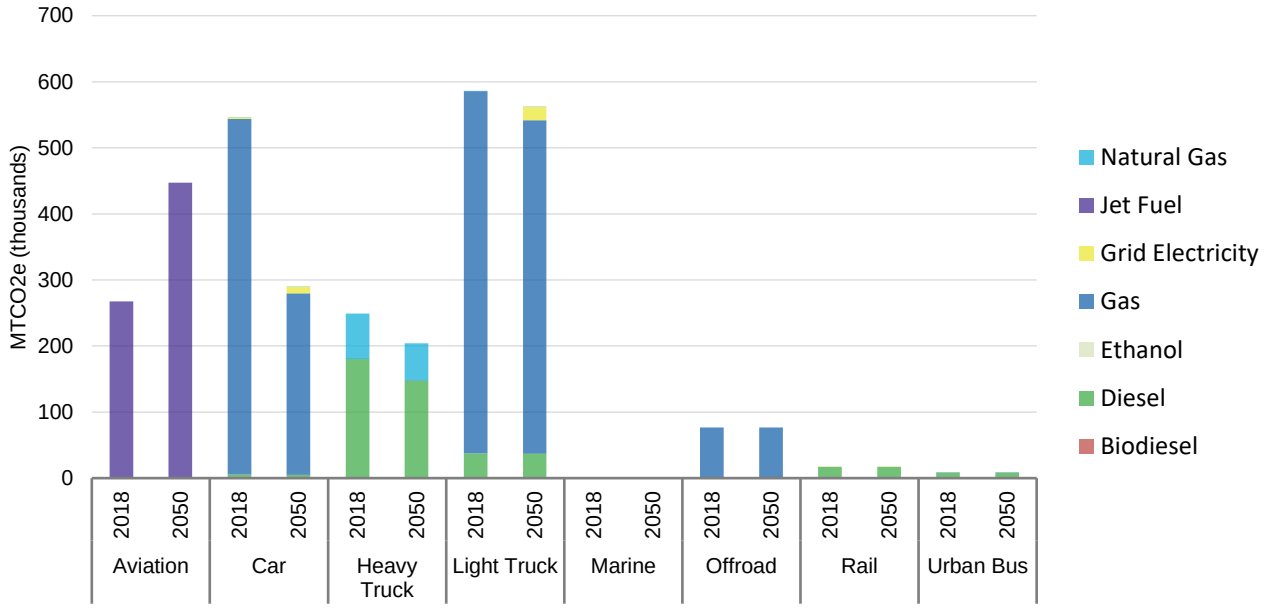

Figure 24: Transportation Emissions by Vehicle Type by Fuel Type 2018 and 2050.

Trips and Mode Share

Most vehicle miles travelled in the county in 2018 (45%) are people travelling outbound (originating in Clackamas County and terminating outside Clackamas County), followed by

internal trips (originating and terminating within Clackamas County) and the remainder constituting inbound travel (Table 11). The pattern is consistent through 2050.

Table 11: Personal Use Vehicle Miles Travelled in 2018 and 2050.

Origin-Destination	2018 VMT	2018 Share	2050 VMT	2050 Share	% change 2018-2050
Outbound	1,450,454,895	45%	2,060,143,909	47%	42%
Internal	971,756,825	30%	1,263,151,157	29%	30%
External Inbound	807,653,889	25%	1,085,493,820	25%	34%

For all three trip types (outbound, internal, and inbound), personal vehicle trips are most of the trips made in Clackamas County (Table 12). Fewer than 10% of internal trips were made by transit and active transportation in 2018. This is expected to change slightly by 2050, with more walking and biking and a doubling of transit trips.

Table 12: All Annual Person-Trips by Mode, 2018 and 2050.

Trip Mode	2018 Person-Trips	2018 Share	2050 Person-Trips	2050 Share	% change 2018-2050
Personal Vehicle	406,428,433	91%	552,670,645	84%	36%
Transit	27,681,811	6%	82,103,459	12%	197%
Bike	8,027,707	2%	13,995,286	2%	74%
Walk	6,812,139	2%	10,282,677	2%	51%

On average, 91% of trips are by personal vehicle. For internal trips, the mode of personal vehicle remains dominant, but decreases in share slightly over time as mode choices shift to transit, as seen in Figure 25.

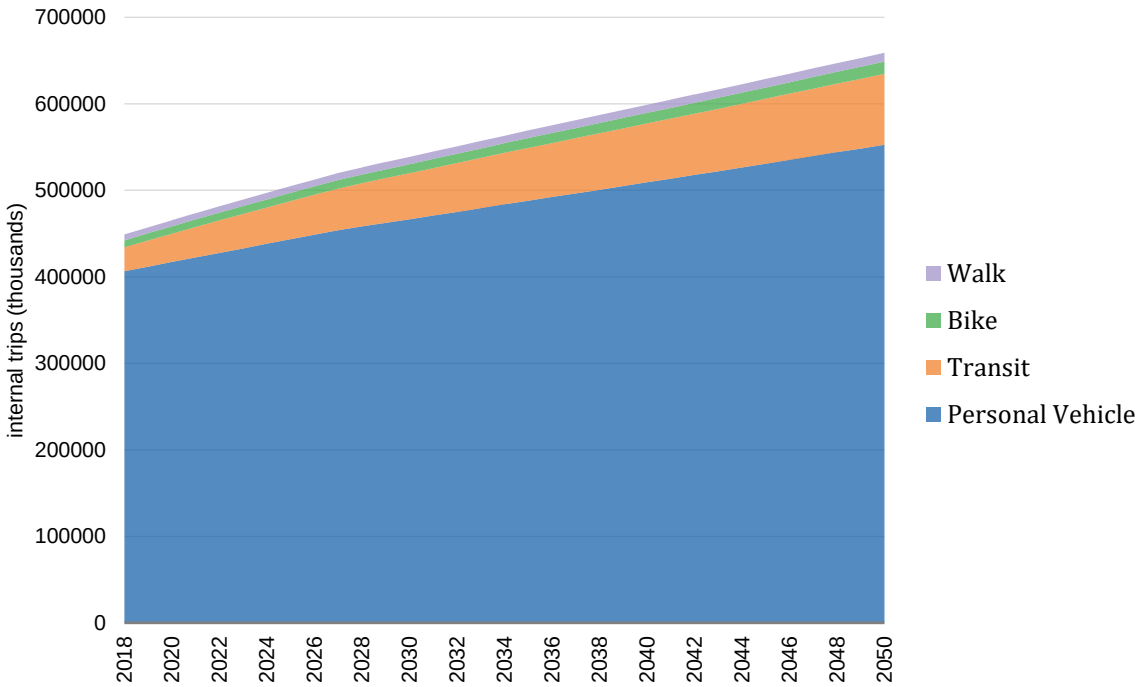

Figure 25: Annual Person Internal Trips by Mode 2018 and 2050.

7. Waste

Waste and wastewater quantities

Clackamas County produced over 282,000 tons of solid waste in 2018 (Figure 26)[2]. Waste is expected to increase almost 40% by 2050 because waste generation grows proportionally to population in the BAP scenario, based on baseline year per capita waste generation rates. For detailed information on solid waste tonnage by type and shares of total, see Appendix Table A9.

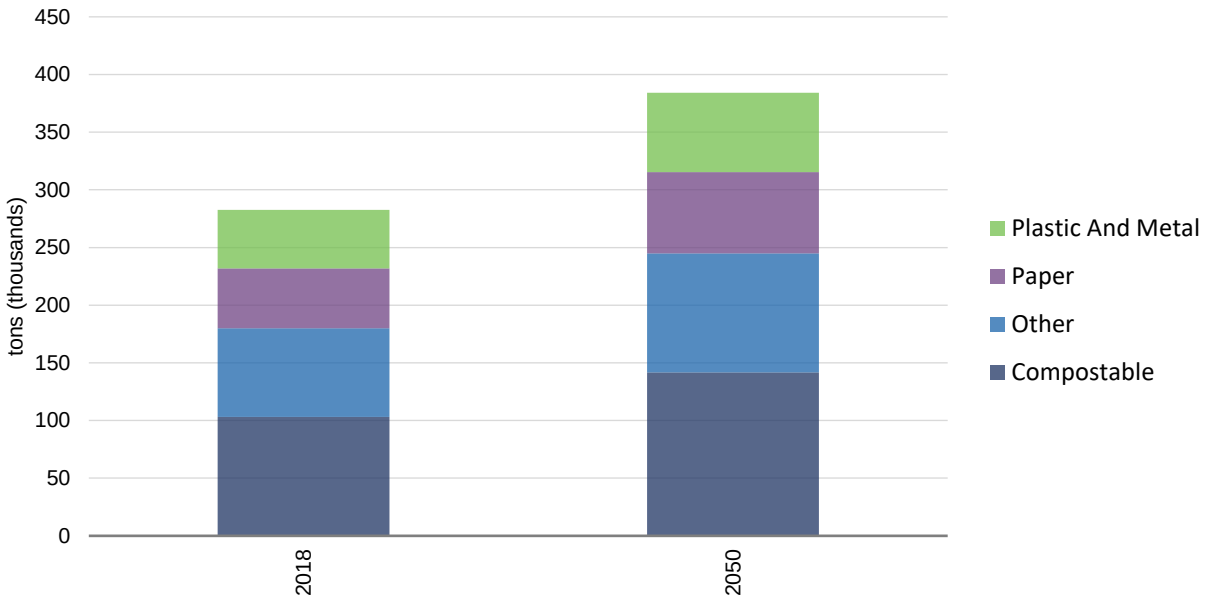

Figure 26: Solid waste tonnage by type, 2018 and 2050.

In 2050, waste tonnage by type and treatment type are expected to have roughly the same ratios as 2018 levels because diversion rates are kept constant in the BAP scenario (Table 13). Almost 88% of it was disposed of in landfills while 12% was biologically treated (through sorting facility composting and/or anaerobic digestion).

[2] This does not include recycled materials.

Table 13: Clackamas County Waste by Type and Treatment in 2018 and 2050.

Category of Waste Treatment	2018 (Kilotons)	2018 Share	2050 (Kilotons)	2050 Share	% change 2018-2050
Biotreatment	34,243	12%	47,026	12%	37%
Landfill	248,363	88%	337,193	88%	36%
Total	282,606	100%	384,220	100%	36%

Wastewater volume similarly increases in step with population: In 2018, 38,200,000 gallons of wastewater were produced, the majority of which was treated by central treatment facilities. The remainder (24%) was treated by septic fields. Wastewater production is expected to increase in step with population, rising to 52,300,000 gallons by 2050.

Emissions by waste sector

Over 85% of Clackamas County's waste emissions are attributable to its landfilled waste in 2018. Emissions associated with solid waste and wastewater are expected to increase in step with population, rising over 37% by 2050 (Figure 27).

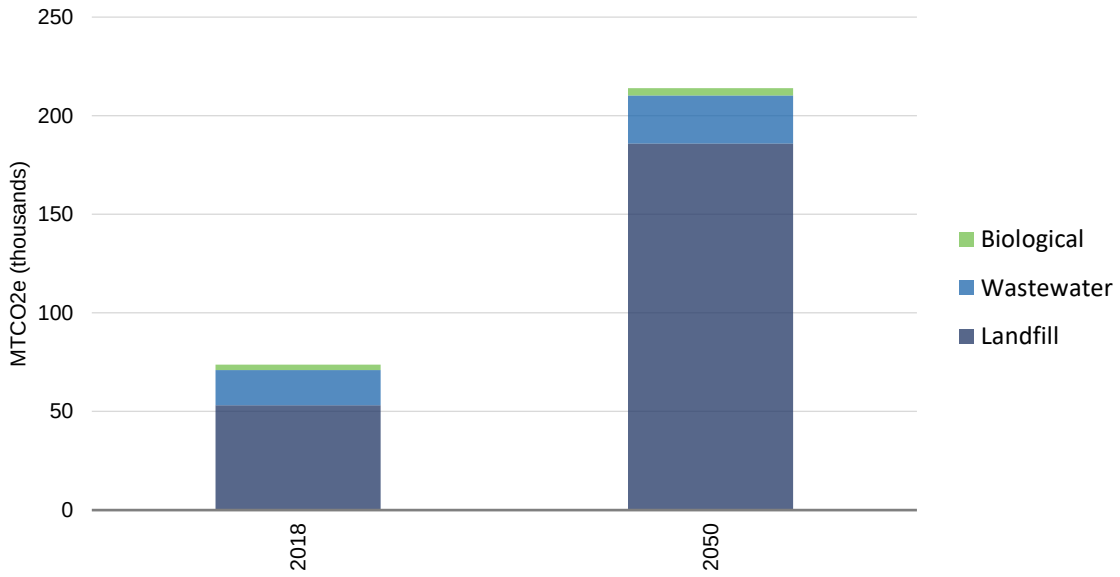

Figure 27: Waste Emissions by Sector in 2018 and 2050.

The recycling of solid waste is assumed to result in zero waste emissions. Emissions associated with the energy used at recycling facilities is accounted for in the buildings energy use sector. Similarly, emissions associated with the transportation of waste are accounted for under the transportation sector. Landfill emissions are mostly methane, a potent GHG. These emissions occur despite attempts to capture and burn the methane being produced. Landfill emissions include those from active and closed landfills.

8. Conclusion

Clackamas County's current energy use and emissions production is typical of a mostly dispersed, vehicle-centric, and fossil fuel dependent society. At over 17 MT CO2e, the county's per capita emissions are high, although aligned with similar jurisdictions (before net-zero emissions targets, 5 MTCO2e per person was a common target).

The modeled BAP scenario accounts for current plans and trends that affect energy efficiency and emissions production. Total energy use and emissions rise as more people and homes are added across the county, but more efficient homes, improved fuel standards, EV uptake, and decreased heating demand in a warming climate result in decreasing per capita emissions.

The BAP trend of slight emissions reductions is good, but it is far from achieving the County's net-zero by 2050 target.

BAP modeling shows us the areas requiring focus for emissions reductions:

- **Product consumption,**
- **Residential space and water heating,**
- **Gas and diesel powered vehicles, and**
- **Industrial processes top the list.**

It shows us that grid electricity is getting cleaner, but not fast enough. It shows us that there is no sufficient solution in motion to replace natural gas use whose use and fugitive emissions will continue to generate powerful greenhouse gases for decades to come. Waste and wastewater emissions will continue to grow with population and homes in the absence of concerted efforts to curb waste and improve treatment.

In many ways, the BAP modeling confirms what we already know: where energy is being used, what is producing emissions, and where trends are intuitively headed. This is good - it means we have the right notions about energy use and emissions production across the county. The modeling outputs' power is in their precision. They provide detailed breakdowns that allow energy efficiency and emissions reductions actions to pinpoint solutions. Maps show where efforts are most needed. With this information, Clackamas County will be able to develop energy and emissions policies and actions with confidence - with the knowledge that their implementation can achieve our goals.

Appendix: Additional Tables

Table A1: Total Energy by Sector, 2018 and 2050.

Sector	2018 Energy (MMBTU)	2018 Share	2050 Energy (MMBTU)	2050 Share	% change 2018-2050
Transportation	22,256,591	45%	18,199,727	35%	-18%
Residential	14,845,935	30%	18,714,775	36%	26%
Commercial	5,877,539	12%	6,858,546	13%	17%
Industrial	5,678,199	12%	7,831,623	15%	38%
Municipal	221,766	0%	274,988	1%	24%
Agriculture	144,830	0%	144,830	0%	0%
Total	49,024,860		52,024,488		6%

Table A2: Total emissions by sector, 2018 and 2050.

Category	2018 Emissions (MTCO2e)	2018 Share	2018 Share excluding consumption	2050 Emissions (MTCO2e)	2050 Share	2050 Share Excluding Consumption	% change 2018-2050
Consumption Emissions	2,459,197	34%	-	4,110,735	51%	-	67%
Transportation	1,751,605	24%	37%	1,606,315	20%	41%	-8%
Residential	1,010,488	14%	21%	624,324	8%	16%	-38%
Fugitive	661,723	9%	14%	559,944	7%	14%	-15%
Industrial	619,564	9%	13%	487,702	6%	13%	-21%
Commercial	470,025	7%	10%	239,976	3%	6%	-49%
Agriculture	151,229	2%	3%	140,042	2%	4%	-7%
Waste	73,772	1%	2%	213,995	3%	6%	190%
Municipal	20,124	0%	0%	7,671	0%	0%	-62%
Total	7,217,727	100%	100%	7,990,704	100%	100%	11%

Table A3: Energy by End Use, 2018 and 2050.

End Use	2018	2018 Share	2050	2050 Share	% change 2018-2050
Transportation	22,256,591	45%	18,199,727	35%	-18%
Space Heating	9,428,178	19%	9,106,523	18%	-3%
Industrial Processes	4,570,544	9%	6,303,247	12%	38%
Water Heating	4,346,228	9%	5,460,060	10%	26%
Plug Load	3,605,495	7%	5,571,320	11%	55%
Lighting	2,788,338	6%	3,868,805	7%	39%
Major Appliances	1,732,314	4%	2,981,966	6%	72%
Space Cooling	297,171	1%	532,841	1%	79%
Total	49,024,860	100%	52,024,488	100%	6%

Table A4: Total Energy by Fuel Type, 2018 and 2050.

Fuel Type	2018 Energy (MMBTU)	2018 Share	2050 Energy (MMBTU)	2050 Share	% change 2018-2050
Gasoline	17,168,340	35%	12,644,780	24%	-26%
Grid Electricity	12,729,731	26%	19,581,212	38%	54%
Natural Gas	12,654,794	26%	13,624,154	26%	8%
Diesel	3,320,934	7%	2,872,036	6%	-14%
Wood	1,042,023	2%	939,888	2%	-10%
Other	896,197	2%	1,055,335	2%	18%
Propane	681,136	1%	721,500	1%	6%
Fuel Oil	501,378	1%	549,327	1%	10%
Local Electricity	28,121	0%	34,051	0%	21%
District Energy	2,205	0%	2,205	0%	0%

Table A5: Total Emissions by Fuel Type, 2018 and 2050.

Fuel Type	2018 Emissions (MTCO2e)	2018 Share	2050 Emissions (MTCO2e)	2050 Share	% change 2018-2050
Non Energy	3,508,396	49%	5,198,379	65%	48%
Grid Electricity	1,291,649	18%	474,375	6%	-63%
Gasoline	1,163,791	16%	857,205	11%	-26%
Natural Gas	656,540	9%	711,012	9%	8%
Jet Fuel	267,650	4%	447,397	6%	67%
Diesel	248,470	3%	215,135	3%	-13%
Propane	42,054	1%	44,546	1%	6%
Fuel Oil	37,794	1%	41,409	1%	10%
Wood	1,373	0%	1,238	0%	-10%
Other	9	0%	8	0%	-14%
RNG	0	0%	0	0%	0%

Table A6: Clackamas County building energy by end use, 2018-2050.

End Use	2018 (MMBTU)	2018 Share	2050 (MMBTU)	2050 Share	% change 2018-2050
Space Heating	9,428,178	35%	9,106,523	27%	-3%
Industrial Processes	4,570,544	17%	6,303,247	19%	38%
Water Heating	4,346,228	16%	5,460,060	16%	26%
Plug Load	3,605,495	13%	5,571,320	16%	55%
Lighting	2,788,338	10%	3,868,805	11%	39%
Major Appliances	1,732,314	6%	2,981,966	9%	72%
Space Cooling	297,171	1%	532,841	2%	79%
Total	26,768,268	100%	33,824,761	100%	26%

Table A7: Clackamas County Building Emissions by Fuel Type.

Fuel Type	2018 Emissions (MMBTU)	2018 Share	2050 Emissions (MMBTU)	2050 Share	% change 2018-2050
Grid Electricity	1,288,938	66%	443,732	37%	-66%
Natural Gas	587,565	30%	655,085	55%	11%
Propane	42,054	2%	44,546	4%	6%
Fuel Oil	37,794	2%	41,409	3%	10%
Wood	1,373	0%	1,238	0%	-10%
Total	1,957,725	100%	1,186,010	100%	-39%

Table A8: Transportation Emissions and share by Vehicle Type, 2018 and 2050.

Vehicle Type	2018 (MTCO2e)	2018 Share	2050 (MTCO2e)	2050 Share	% change 2018-2050
Light Truck	585,593	33%	561,988	35%	-4%
Car	545,997	31%	290,084	18%	-47%
Aviation	267,650	15%	447,397	28%	67%
Heavy Truck	249,152	14%	204,003	13%	-18%
Off-road	76,936	4%	76,936	5%	0%
Rail	17,632	1%	17,285	1%	-2%
Urban Bus	8,472	0%	8,472	1%	0%
Marine	174	0%	149	0%	-14%
Total	1,751,605	100%	1,606,315	100%	-8%

Table A9: Clackamas County Waste Tonnage in 2018 and 2050.

Category of Solid Waste	2018 (Kilotons)	2018 Share	2050 (Kilotons)	2050 Share	% change 2018-2050
Compostable	103,235	37%	141,774	37%	37%
Other	76,671	27%	103,055	27%	34%
Paper	52,057	18%	70,541	18%	36%
Plastic and Metal	50,643	18%	68,850	18%	36%