Appendix 6. Data, Methods and Assumptions Manual

SUSTAINABILITY SOLUTIONS GROUP

State of Oregon Resilient Efficient Buildings Taskforce

Data, Methods, and Assumptions Manual

September 2022

Purpose of this Document

This Data, Methods, and Assumptions (DMA) manual presents the modeling approach used to provide energy and emission benchmarks and projections, as well as a summary of the data and assumptions used in scenario modeling. The DMA makes the modeling elements fully transparent and illustrates the scope of data required for future modeling efforts using the same methodology.

CONTENTS

Glossary

Base Year: the starting year for energy or emissions projections.

Business as usual (BAU): a scenario illustrating energy use and GHG emissions if no additional plans, policies, programs, or projects are implemented.

Business as planned (BAP): a scenario illustrating energy use and GHG emissions if additional plans, policies, programs, and projects which have already been passed or are currently underway continue to be implemented.

Carbon sequestration: The process of storing carbon in a carbon pool.

Commercial Buildings Energy Consumption Survey (CBECS): Developed by the EIA, the CBECS provides information on the estimated 5.9 million commercial buildings in the U.S., including the number of workers, ownership and occupancy, structural characteristics, energy sources and uses, and other energy-related features (2018 data at the time of writing).

Combined heat and power (CHP): the simultaneous production of two or more useful forms of energy, typically electricity and heat, by a single device (also known as co-generation).

Energy Demand and Supply Simulator for the U.S. (EDSSUS): A model and data dictionary developed by SSG and whatIf? Technologies that can be used to simulate energy demand and supply for states, regions, and municipalities within the United States.

Energy Information Administration (EIA): An agency of the U.S. Federal Government that collects, analyzes, and disseminates information on energy and its interaction with the economy and the environment, including production, stocks, demand, imports, exports, and prices.

Environmental Protection Agency (EPA): An agency of the U.S. Federal Government that studies environmental issues, develops and enforces regulations to protect the environment, and provides grants to various entities to promote environmental conservation and human health.

Greenhouse gases (GHG): gases that trap heat in the atmosphere by absorbing and emitting solar radiation, causing a greenhouse effect. The main GHGs are water vapor, carbon dioxide, methane, nitrous oxide, and ozone.

Geographic information system (GIS): a type of a computer program or system that analyzes and displays geographically referenced data.

Heating Degree Day (HDD): a measurement designed to quantify the demand for energy needed to heat a building, consisting of the number of degrees that a given day's average temperature is below 18°C, thus requiring heating.

High Global Warming Potential (HGWP): Chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs), hydrochlorofluorocarbons (HCFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6) are sometimes called high global warming potential gasses because, for a given amount of mass, they trap substantially more heat than CO2.

National Renewable Energy Laboratory (NREL): The National Renewable Energy Laboratory is a federally funded research and development center sponsored by the Department of Energy and operated by the Alliance for Sustainable Energy, specializing in the research and development of renewable energy, energy efficiency, energy systems integration, and sustainable transportation.

Marginal abatement cost curves (MACC): MACCs show the relative economic costs or savings of emission abatement actions, in units of US$/t$CO_2$e over time.

Oregon Department of Energy (ODOE): A department of the State of Oregon that provides a central repository for energy data, information, and analysis, as well as energy education, technical assistance, regulation, oversight, programs and convenings regarding Oregon's energy landscape.

Oregon Department of Environmental Quality (ODEQ): A department of the State of Oregon with a mission to restore, maintain, and enhance the quality of Oregon's air, land, and water resources.

Oregon Department of Transportation (ODOT): A department of the State of Oregon that develops programs related to Oregon's systems of transportation, including highways, roads, bridges, railways, and public transit, as well as services related to transportation safety programs, driver and vehicle licensing, and motor carrier regulation.

Oregon Global Warming Commission (OGWC): Supported by the ODOE, this Commission is responsible for tracking trends in GHG emissions and recommending ways to co-ordinate state and local efforts to reduce emissions in Oregon.

Residential Energy Consumption Survey (RECS): Developed by the EIA, the RECS provides an estimate of residential energy costs and usage for heating, cooling, appliances, and other end uses, developed using a nationally representative sample of housing units and their energy characteristics combined with data from energy suppliers.

State Energy Data System (SEDS): Developed by the EIA, it provides comprehensive statistics regarding the consumption, production, prices, and expenditures of energy for each state and for the country as a whole.

Intergovernmental Panel on Climate Change (IPCC): a United Nations body that assesses the science related to climate change via regular reports and analyses about the state of scientific, technical and socio-economic knowledge on climate change, its impacts and future risks, and options for reducing the rate at which climate change is taking place.

Scenario: A plausible description of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces (e.g., rate of technological change, prices) and relationships. Note that scenarios are neither predictions nor forecasts, but are used to provide a view of the implications of developments and actions.

Vehicle Miles Traveled (VMT): distance traveled by vehicles within a defined region over a specified time period.

Accounting and Reporting Principles

SSG's greenhouse gas (GHG) inventory development and scenario modeling approach correlate with IPCC-derived accounting methods for developing fair and true accounts of national and state-level emissions, with a focus on alignment with the emission inventory compiled by the Oregon Department of Environmental Quality (DEQ). The GHG inventory includes detailed calculations of emissions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) in detail, and high-level calculations of perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3) for each of the following sectors: transportation, energy, residential, commercial, industry, natural and working lands, construction, and solid waste and wastewater. The GHG emission and removal estimates contained in Oregon's GHG inventory are developed using methodologies consistent with the 2019 Guidelines for National Greenhouse Gas Inventories developed by the Intergovernmental Panel on Climate Change (IPCC).

SSG and whatIf? have developed the following principles for GHG accounting and reporting, based on decades of research and experience working with municipal, state, and national government clients:

- **Relevance:** The reported GHG emissions appropriately reflect emissions occurring as a result of activities and consumption within the state. The inventory is meant to serve the decision-making needs of the State's Agencies, Commissions, and Offices, taking into consideration relevant local, state, and national regulations. Relevance applies when selecting data sources and determining and prioritizing data collection improvements.
- **Completeness:** All emission sources within the inventory boundary are accounted for, and any exclusions of sources (for example electricity generation destined for export) are justified and explained.
- **Consistency:** Emissions calculations are consistent in their approach, boundaries, and methodology.
- **Transparency:** Activity data, emissions sources, emissions factors and accounting methodologies require adequate documentation and disclosure to enable verification.

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

Scope

Geographic Boundary

Energy and emissions inventories and modeling for the project will be completed for the entire state of Oregon and broken down by county (Figure 1). The modeled land-use and density targets will be in line with the State's plans for climate action.

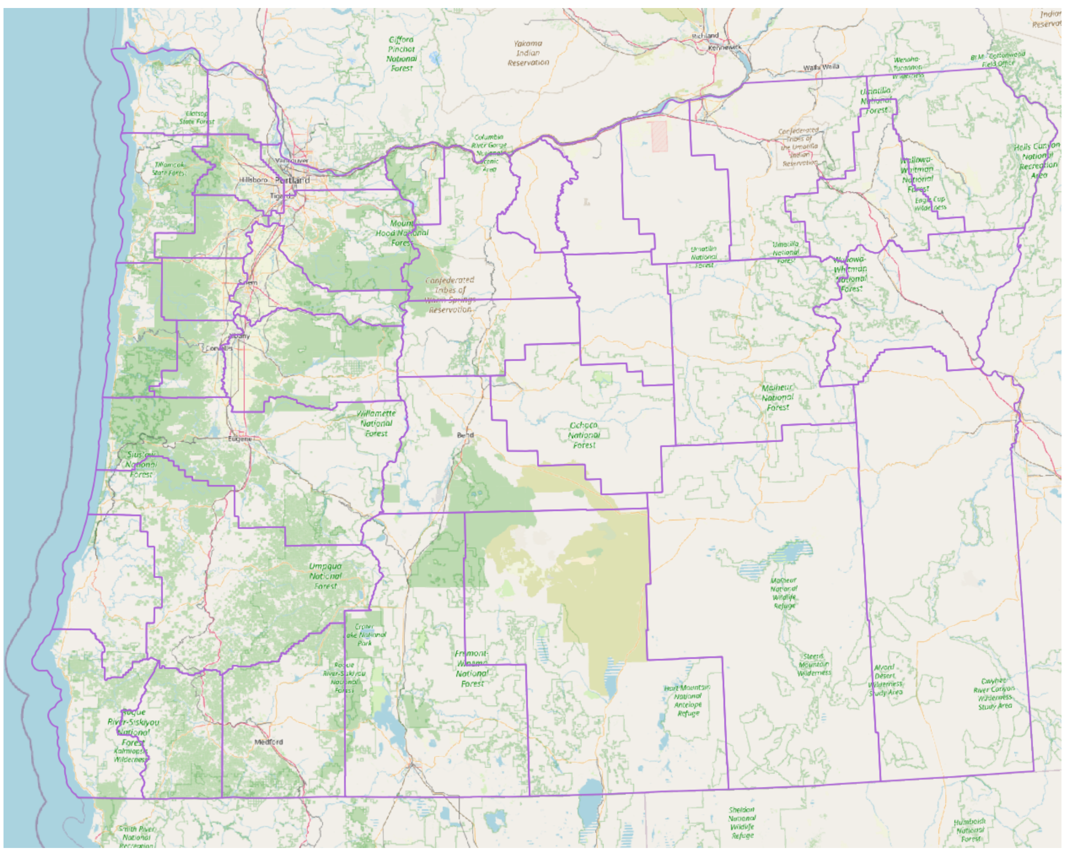

Figure 1. Geographic scope and sub-scopes (counties, in purple) of this study.

Time Frame of Assessment

The modeling time frame includes the time period from 2019 to 2050. The year 2019 is used as the base year, since it aligns with the most recent year for which an Oregon GHG inventory exists. Data from the 2019 American Community Survey (5-year) and the 2020 Census is used to support the calibration. Model calibration for the base year uses as much locally observed data as possible, including data for Oregon, reported by Federal agencies.

Emissions Scope

The scope of GHG emissions included in the model is derived from activities occurring in various sectors, as shown in Table 1. GHG emissions included for each sector come from sources located within the state boundary, including those occurring from the use of grid-supplied electricity, heat, steam, and cooling, as well as GHG emissions that occur outside the state boundary as a result of activities taking place within the boundary.

Refer to Appendix 1 for a detailed list of included GHG emissions sources by scope.

Table 1. Sectors included in the GHG Emissions scope and their definitions.

Emissions from Energy Use	
Sector	**Definition**
Residential	Emissions from the use of lighting, appliances, heating, and cooling in buildings used as dwellings
Commercial	Emissions from the use of lighting, appliances, heating, and cooling in buildings not used as dwellings

Energy Systems Simulator

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

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

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

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

Table 2. Model characteristics.

Characteristic	Rationale
Integrated	The tool models and accounts for all energy and emissions in relevant sectors and captures relationships between sectors. The demand for energy services is modeled independently of the fuels and technologies that provide the energy services. This decoupling enables exploration of fuel-switching scenarios. Viable scenarios are established when energy demand and supply are balanced.
Scenario-based	Once calibrated with historical data, the model enables the creation of scenarios to explore different possible futures. Each scenario can consist of either one or a combination of policies, actions, and strategies. Historical calibration ensures that scenario projections are rooted in observed data.
Spatial	The model includes spatial dimensions that can include as many zones (the smallest areas of geographic analysis) as deemed appropriate; in this case, they are Oregon counties. The spatial components can be integrated with Geographic Information Systems (GIS), land-use projections, and transportation modeling.

Characteristic	Rationale
Sector-based	The model is designed to report emissions according to categories based on sectors (residential, commercial, industry, etc.).
Economic impacts	The model incorporates a high-level financial analysis of costs related to energy (expenditures on energy) and emissions (carbon pricing, social cost of carbon), as well as operating and capital costs for policies, strategies, and actions. This allows for the generation of marginal abatement costs.

Model Structure

The major components of the model and the first level of their modeled relationships (or influences) are represented by the blue arrows in Figure 2. Additional relationships may be modeled by modifying inputs and assumptions—specified either directly by users, or in an automated fashion by code or scripts running "on top of" the base model structure. Integrated modeling generates a total picture of the overall impact of inputs and assumptions, including the emissions or sequestration intensity of other inputs within the model.

The model is spatially explicit. All buildings, transportation, and land-use data are tracked within the model through a GIS platform, and by varying degrees of spatial resolution. To divide the State into smaller configurations, we use data at the level of Oregon's 36 counties. This enables more accurate modeling of energy use for each of the counties, as there are significant differences between, for example, rural counties in the continental climate in the East and highly urbanized counties in the moderate climate in the West.

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

Some factors are modeled as stocks—counts of similar things, classified by various properties. For example, population is modeled as a stock of people classified by age and gender. Population change over time is projected by accounting for: the natural aging process, inflows (births, immigration), and outflows (deaths, emigration). The residential heating systems—an example of a service technology—is modeled as a stock of heat systems classified by technology, fuel and age, with a similarly classified efficiency. As with population, projecting change in the heat system stock involves aging equipment and accounting for major inflows (new heat system sales) and outflows (heat system discards). This stock-turnover approach is applied to other service technologies (e.g. furnaces, water heaters) and harvesting technologies (e.g. electricity generating capacity).

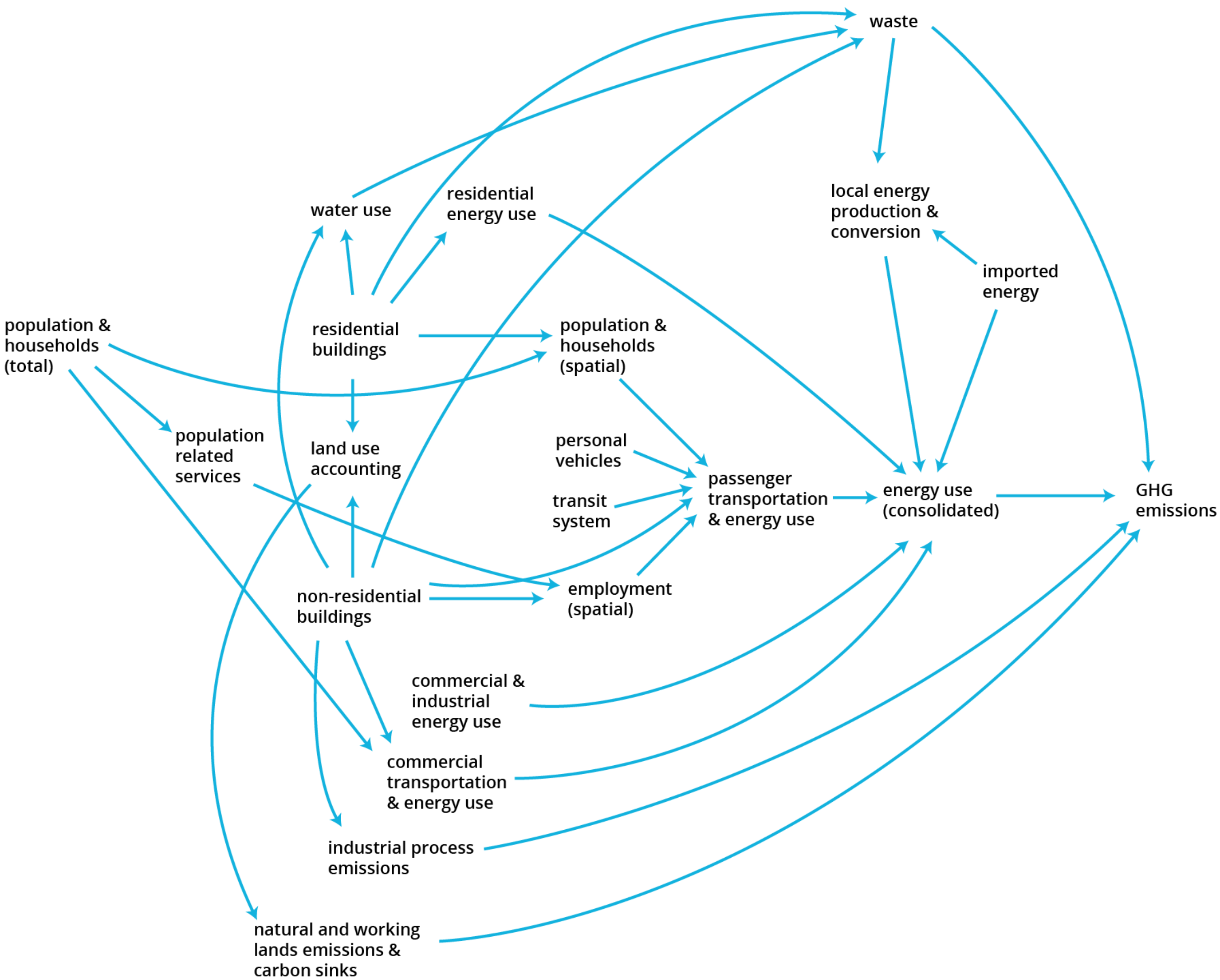

Figure 3. Representation of the model structure.

Sub-Models and Local Context Calibration

The overall model operates based on the interactions within and between factors of various sub-models, as described in this section. To develop the business-as-usual, business-as-planned, and low-carbon scenarios, we calibrate the model with local data, building the model from the ground up.

Data Request and Collection

Most data used to calibrate the model was supplied by Oregon state agencies, such as the Oregon Department of Energy (ODOE) and the Oregon Department of Environmental Quality (ODEQ), supplemented by data for Oregon available from federal sources. Assumptions were identified to supplement any gaps in the observed data. The data and assumptions were applied in modeling by means of the processes described below.

Zone System

The model is spatially explicit: population, employment, residential, and non-residential floorspace are allocated and tracked spatially for each of Oregon's 36 counties (see Figure 3). These elements drive stationary energy demand.

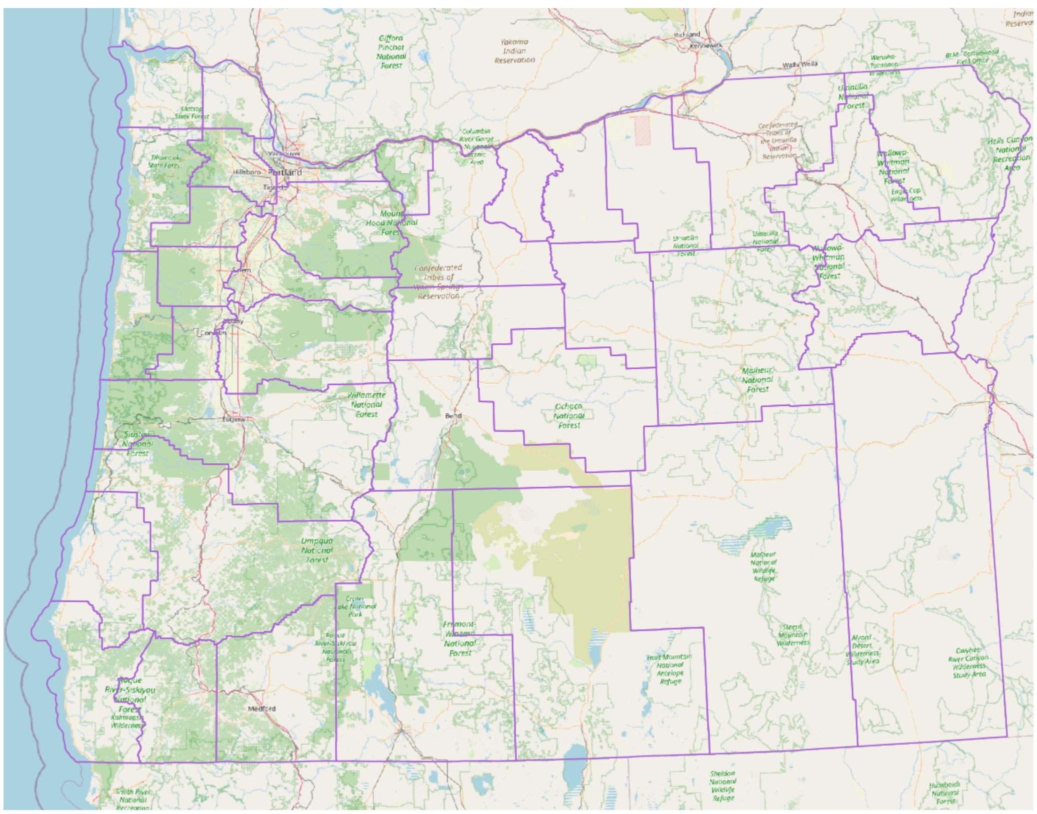

Figure 3. Zone system (Oregon counties) used in modeling.

Population and Employment

How the Sub-model Works

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

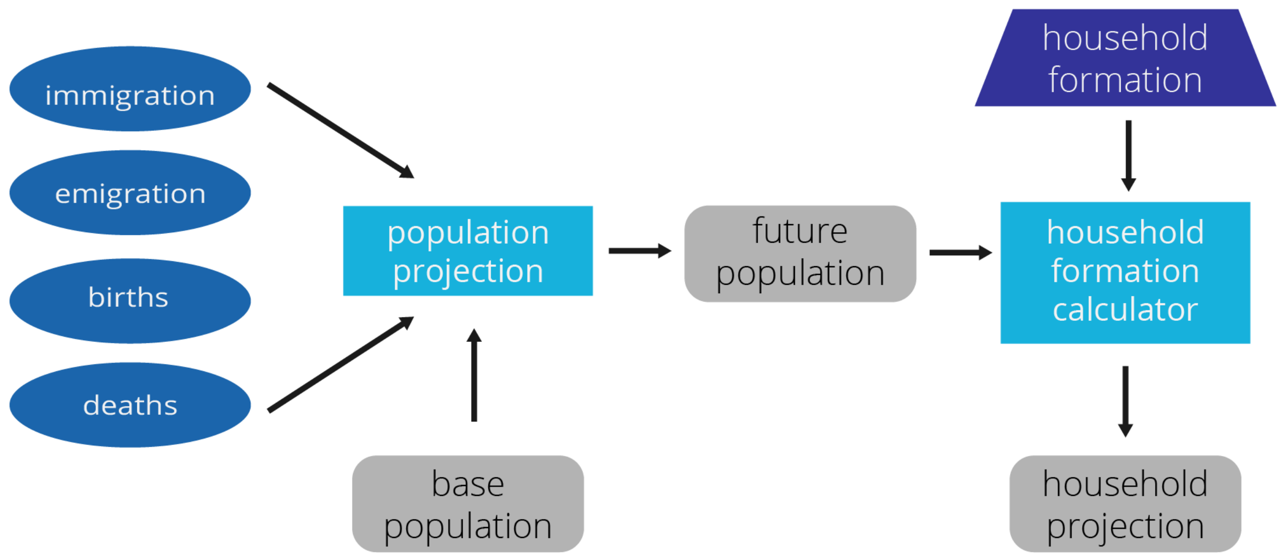

Figure 4. Population and employment submodel design flow. Blue ovals represent flows, light blue rectangles represent model calculations, gray rectangles represent stocks, and violet quadrangles represent model parameters.

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

An additional layer of model logic (not shown explicitly in Figure 4) captures energy-related financial flows and employment impacts. Calculated financial flows include the capital, operating, and maintenance costs of energy-consuming and energy-producing stocks, including fuel costs. We also model employment related to the construction of new buildings, retrofit activities and energy infrastructure; assess the financial impact on businesses and households of implementing the strategies, and apply various local economic multipliers (depending on the geographic and economic variability of the calculation and anticipated output) to investments.

How We Calibrate the Sub-model

We distributed the 2019 population to residential buildings in space, using initial assumptions about persons-per-unit (PPU) by dwelling type, and adjusting them so that the total population in the model (which is driven by the number of residential units by type multiplied by PPU by type) matches the total population from census/regional data.

Employment in 2019 is spatially allocated to non-residential buildings, using two categories of assumptions: population-related services and employment are allocated to corresponding building floorspace (e.g. teachers to school floorspace); and floorspace-driven employment are applied using intensities (e.g. retail employees per square foot). As with population, the model adjusts these initial ratios so that the derived total employment matches total employment from the census and regional data.

Buildings

How the Sub-model Works

Buildings are spatially located and classified using a detailed set of 12 building archetypes (see Appendix 2) capturing footprint, height, and type (single-family, duplex, semi-attached, row-housing, apartment high-rise, apartment low-rise, etc.) and year of construction. The archetypes are used to generate a "box" model that helps to estimate the floor area and energy use, and then is used to simulate the impact of energy efficiency measures.

Using assumptions on thermal envelope performance and heating and cooling degree days, the model calculates space-conditioning energy demand independent of space heating or cooling technologies. First, the model multiplies the residential building floorspace area by an estimated thermal conductance (heat flow per unit of surface area per degree day) and the number of degree days (heating and cooling) to derive the energy transferred out of the building during winter months and into the building during summer months. The energy transferred through the building envelope, the solar gain through the building windows, and the heat gains from equipment inside the building is netted from the space-conditioning load required to be provided by the heating and air-conditioning systems.

The space conditioning demand is satisfied by stocks of energy service technologies, including heating systems, air conditioners, and water heaters. These stocks are modeled with a stock-turnover approach, capturing equipment age, retirements, and additions—exposing opportunities for efficiency gains and fuel-switching, but also constraining the rate of technology adoption.

Residential building archetypes are also characterized by the number of dwelling units they contain, allowing the model to not only capture the energy effects of shared walls, but also the urban form and transportation implications of population density.

Non-residential buildings, commercial and otherwise (see Appendix 2) are located in space and mapped to a set of 40+ archetypes. The floorspace of these archetypes varies by location. Non-residential floorspace generates demand for energy and water, and provides an anchor point for locating employment of various types.

The model calculates the space-conditioning load for non-residential buildings as it does for residential buildings, with two distinctions: the thermal conductance parameter for non-residential buildings is based on floor area instead of surface area, and incorporates data from REPLICA, a proprietary provider of modelled and observed building and transportation data. Using assumptions for thermal envelope performance for each building type, the model calculates total energy demand for all buildings, independent of any space heating or cooling technology and fuel.

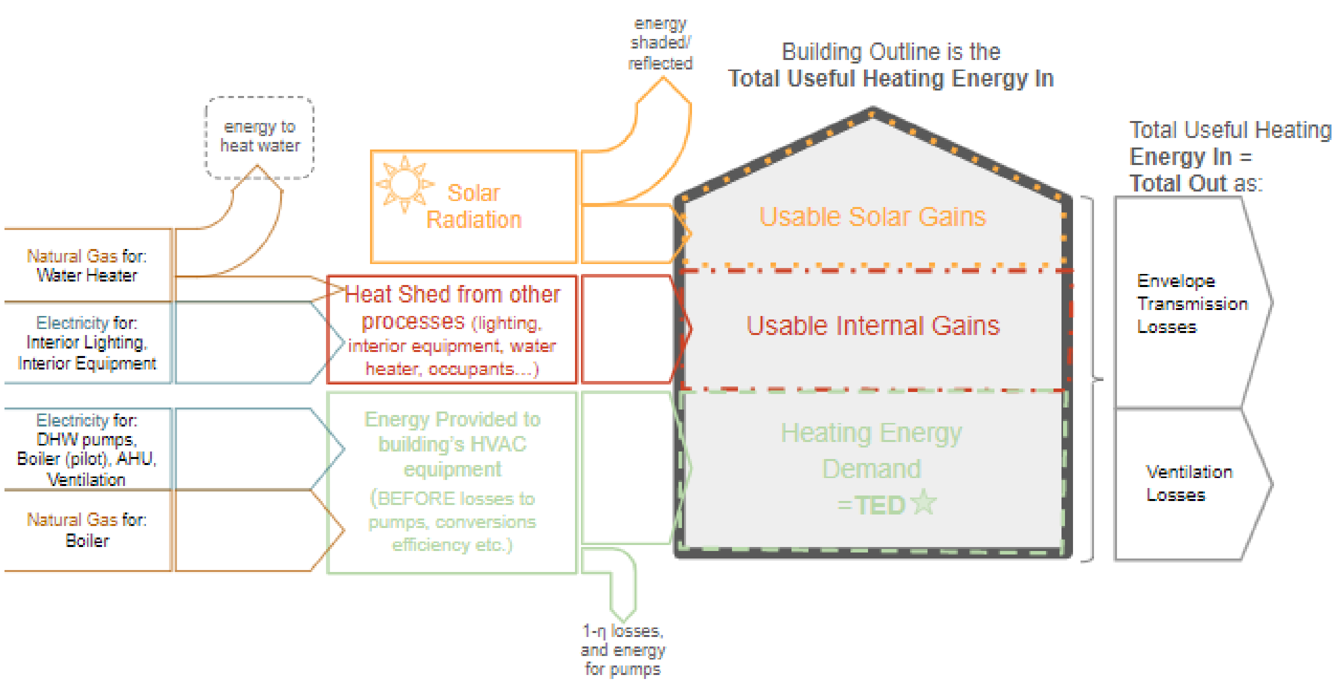

Figure 5: A diagram showing the considerations in the model for energy and emissions related to buildings.

How We Calibrate the Sub-model: Residential Buildings

For each Oregon county, building data (including building type, number of stories, number of units, and year built) was sourced from the 2020 U.S. Census for residential buildings, and from REPLICA for commercial and industrial buildings. Total floorspace area for each building type was calculated referencing building archetypes that are typical in Oregon.

The initial thermal conductance estimate is a regional average by dwelling type from a North American energy systems simulator, calibrated for the Pacific Northwest. This initial estimate is adjusted through the calibration process until energy use of residential buildings tracks on residential energy use as reported by the State Energy Data System (SEDS). As a reference, we also use values for output energy intensities and equipment efficiencies based on the 2015 Residential Energy Consumption Survey (RECS).

How We Calibrate the Sub-model: Non-residential Buildings

Starting values for output energy intensities and equipment efficiencies for non-residential end uses are taken from the 2018 Commercial Buildings Energy Consumption Survey (CBECS) complemented by the EPA's Portfolio Manager Technical Reference that provides Energy Use Intensity by Property Type for some additional building types. All parameter estimates are further adjusted during the calibration process. The calibration target for non-residential building energy use is the observed commercial and industrial fuel consumption in the base year.

Financial Analysis

Energy related financial flows and employment impacts are captured through an additional layer of model logic. Calculated financial flows include the capital, operating, and maintenance cost of both energy consuming and energy producing stocks, including fuel costs. Employment related to the construction of new buildings, retrofit activities, and energy infrastructure is also modeled.

Costs and savings modeling considers upfront capital expenditures, operating and maintenance costs (including fuel and electricity). Table 3 summarizes expenditure types that are evaluated.

Table 3. Categories of expenditures evaluated.

Category	Description
Residential buildings	Cost of dwelling construction and retrofitting; operating and maintenance costs (non-fuel).
Residential equipment	Cost of appliances, and lighting, heating, and cooling equipment.

Residential fuel	Energy costs for dwellings and residential transportation.
Commercial buildings	Cost of building construction and retrofitting; operating and maintenance costs (non-fuel).
Commercial equipment	Cost of lighting, heating and cooling equipment.
Non-residential fuel	Energy costs for commercial buildings, industry, and transport.

A financial cost catalog that summarizes all the financial assumptions used in the model is available as a separate document.

Financial Reporting Principles

The financial analysis is guided by the following reporting principles:

1. Sign convention: Costs are negative, revenue and savings are positive.
2. The financial viability of investments is measured by their net present value (NPV).
3. All cash flows are assumed to occur on the last day of the year and for purposes of estimating their present value in Year 1 are discounted back to time zero (the beginning of Year 1). This means that the initial capital outlay in Year 1 is discounted by a full year for purposes of present value calculations.
4. We use a discount rate of 3% in evaluating the present value of future government costs and revenues.
5. Each category of stocks has a different investment horizon, depending on the kind of stock (for example, a house has a different lifespan than a car).
6. Any price increases included in our analysis for fuel, electricity, carbon, or capital costs are real price increases, net of inflation.
7. Where a case can be made that a measure will continue to deliver savings after its economic life (e.g. after 25 years in the case of the longest lived measures), we capitalize the revenue forecast for the post-horizon years and add that amount to the final year of the investment horizon cash flow.
8. In presenting results of the financial analysis, results are rounded to the nearest thousand dollars, unless additional precision is meaningful.
9. Only actual cash flows are included in the financial analysis.

Data and Assumptions

Scenario Development

Scenarios are used to evaluate potential futures for communities. A scenario is defined as an internally consistent view of what the future might turn out to be—not a forecast, but one possible future outcome. Scenarios represent plausible options as identified by interested persons. For example, in the building sector, scenarios are generated by identifying future population projections, estimating how many additional households are required, and then applying those additional households according to the existing land-use plans and alternative scenarios. The model then evaluates the impact of new development on transportation behavior, building types, agricultural and forest land, and other variables.

Roadmap Reference Scenario

The Roadmap Reference scenario estimates energy use and emissions volumes from the base year (2019) to the target year (2050). Because it assumes the absence of policy measures that would differ substantially from those currently in place, it can be considered a projection of what would happen if nothing changes, except for the anticipated population and economic growth.

Methodology

1. Calibrate model and develop a 2019 base year data for the state using observed data and filling in gaps with assumptions where necessary.
2. Input existing projected quantitative data to 2050 where available, such as:
   - Population, employment, and housing projections by county
   - Build out (buildings) projections by county
   - Economic growth projections
3. Where quantitative projections are not carried through to 2050, extrapolate what the projected trend would be to 2050.
4. Where specific quantitative projections are not available, develop projections by:
   - Analyzing current, on-the-ground action (reviewing action plans, engagement with staff, etc.), and where possible, quantifying the action.
   - Analyzing existing policy that has potential impact and, where possible, quantifying the potential impact.

Programs and Regulations Adopted Scenario

The Programs and Regulations Adopted scenario estimates energy use and emissions volumes from the base year (2019) to the target year (2050), incorporating assumptions about the likely effects of planned policies and programs.

Methodology

- Create Roadmap Reference (see steps above)
- Create Programs and Regulations Adopted
  - Add additional assumptions to the Roadmap Reference to capture known policies and plans that are or will be implemented in the coming years:
    - Implementation of HB2021 (a bill that requires retail electricity providers to reduce GHG emissions associated with electricity sold to Oregon consumers to 80% below baseline emission levels by 2030, 90% below baseline emissions levels by 2035, and 100% below baseline emissions levels by 2040)
    - Implementation of the Climate Protection Program (CPP)[1]
    - CAFE Updated
    - Community Renewable Energy Program
    - Energy efficiency standards for appliances
    - Heat Pump Rebate Program
    - Implement Healthy Homes Repair Fund
    - Manufactured home replacement
    - Solar + Storage Rebate Program
  - In all cases: Where quantitative projections are not carried through to 2050, historical trends are extrapolated to 2050.
- Where specific quantitative projections are not available, assumptions are identified by:
  - Analyzing current, on-the-ground action (reviewing action plans, engagement with staff, etc.), and where possible, quantifying the action.

[1]Since the CPP does not currently require gasoline/diesel and natural gas suppliers to develop approved plans for how they will comply with the CPP, we cannot accurately anticipate and describe a plan for the gasoline/diesel and natural gas suppliers' reduction path. An overall CPP emissions reduction, showing the impact of the CPP target, will be shown as part of the Business as Planned. Detailed potential CPP pathways will be modeled as part of the low carbon scenarios to explore different ways gasoline/diesel and natural gas suppliers could comply with the CPP.

- Analyzing existing policy that has potential impact and, where possible, quantifying the potential impact.

Resilient Building Task Force Scenarios

Changes to energy flow and emissions profiles are illustrated by modeling potential changes in the context (e.g. population, development patterns), and by projecting energy services demand intensities, waste production, diversion rates, industrial processes, and composition of the energy system infrastructure.

Policies, Actions, and Strategies

Alternative behaviors of actors (e.g. households, various levels of government, industry, etc.) can be reflected by adjusting input variables. Varying the inputs creates "what if" type scenarios, enabling a flexible mix-and-match approach which connects behavioral assumptions to the physical model. A wide variety of policies, actions and strategies can be explored in this way, and the scenarios are highly flexible. The resolution of the model enables the user to apply scenarios to specific counties, technologies, building or vehicle types or eras, and configurations of the built environment.

Scenario Development

All policy scenarios have been identified by members of the Resilient Efficient Buildings taskforce. Table 4 describes the policy scenarios.

Table 4. Policy scenario descriptions.

1	**Building performance standards**	*1a*	*1b*	*1c*	*1d*
		Direct emissions need to reach 5% below 2035 levels in the BAP by 2035		Direct emissions need to reach 40% below 2035 levels in the BAP by 2035	
		Existing residential, commercial and multi-family buildings			
		All building sizes	Buildings ≥ 35,000 ft2	All building sizes	Buildings ≥ 35,000 ft2
2	**Promote, incentivize and or subsidize energy efficiency and heating/cooling**	*2a*	*2b*	*2c*	*2d*
		50% of buildings are retrofitted by 2050, thermal energy requirements reduced by 15%		100% of buildings are retrofitted by 2035, thermal energy requirements reduced by 50%	
		All building types			
		Buildings ≥ 50,000 ft2	Buildings ≥ 30,000 ft2	Buildings ≥ 50,000 ft2	Buildings ≥ 30,000 ft2
3	**Decarbonize institutional/public buildings**	*3a*	*3b*		
		New buildings after 2035 are carbon neutral	New buildings after 2023 are carbon neutral		
		50% of buildings are retrofitted by 2045; thermal energy requirements reduced by 15%; plug load reduced by 15%	100% of buildings are retrofitted by 2035: thermal energy requirements reduced by 50%; Plug load reduced by 50%		
4	**Promote, incentivize, and/or subsidize heat pumps**	*4a*	*4b*		
		80% of covered buildings have a heat pump installed by 2040	100% of buildings that are covered have a heat pump installed by 2035		
		New and existing residential and commercial buildings			
5	**Assess and disclose material-related emissions**	*5a*	*5b*	*5c*	
		Reduce embodied carbon from construction by 20% by 2030, compared to 2015	Reduce embodied carbon from construction by 60% by 2030, compared to 2015	Reduce embodied carbon from construction by 100% by 2050, compared to 2015	
		Residential and commercial buildings			

6	**Enact energy-efficient building codes- Existing**	*6a*	*6b*	*6c*	*6d*
		50% of existing buildings are retrofitted by 2050, thermal energy requirements reduced by 15%, plug load reduced by 15%		100% of existing buildings are retrofitted by 2035, thermal energy requirements reduced by 50%, plug load reduced by 50%	
		Existing residential and commercial buildings			
		Buildings ≥ 50,000 ft2	Buildings ≥ 30,000 ft2	Buildings ≥ 50,000 ft2	Buildings ≥ 30,000 ft2
	Enact energy-efficient building codes- New	A 40% reduction in new building energy consumption from the 2006 Oregon codes		A 80% reduction in new building energy consumption from the 2006 Oregon codes	
		New residential and commercial buildings			
		Buildings ≥ 50,000 ft2	All buildings	Buildings ≥ 50,000 ft2	All buildings

Appendix 1: Detailed Emissions Scope Table

Table 1-1. Detailed emissions scope.

GHG Emissions Sources & GHG Types				
Residential Buildings	**CO_2**	**CH_4**	**N_2O**	**HGWP**
Emissions from fuel combustion and grid-supplied energy consumed by residential buildings	Residential electricity use, natural gas consumption, petroleum consumption, coal consumption			
Commercial Buildings	**CO_2**	**CH_4**	**N2O**	**HGWP**
Emissions from fuel combustion and grid-supplied energy consumed by commercial buildings	Commercial electricity use, natural gas combustion, petroleum combustion, and coal combustion			
Refrigerants, etc.	**CO_2**	**CH_4**	**N_2O**	**HGWP**
HGWP emissions from all sectors				Air-conditioning, and fire protection use; residential and commercial refrigerants, aerosols, and fire protection use

Appendix 2: Building Types

Table 2-1. Building types in the model.

Residential Building Types	Non-residential Building Types
Single detached	School, college, university
Row house	Hospital
Apt 1 to 3 stories	Retail
Apt 4 to 6 stories	Commercial
Apt 7 stories and up	Institutional, state buildings

Appendix 3: Emissions Factors

Table 3-1. Emissions factors used in the model.

Category	Value	Comment
Natural gas	CO_2: 53.02 kg/MMBtu CH_4: 0.005 kg/MMBtu N_2O: 0.0001kg/MMBtu	The U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions by ICLEI—Local Governments for Sustainability USA (2012)
Electricity	2018 CO_2e: 1,098 lbs CO_2e per MWh	Electricity imported into the state is determined by MROW average emissions factor per US EPA eGRID (www.epa.gov/egrid/data-explorer)
Fuel oil	CO_2: 73.9 kg per MMBtu CH_4: 0.003 kg per MMBtu N_2O: 0.0006 kg per MMBtu	Environmental Protection Agency. "Emission factors for greenhouse gas inventories." *Stationary Combustion Emission Factors," US Environmental Protection Agency, available:* *https://www.epa.gov/sites/production/files/2015-07/documents/emission-factors_2014.pdf* (2014) Table 1 Stationary Combustion Emission Factor, Fuel Oil No. 2
Wood	CO_2: 93.80 kg per MMBtu CH_4: 0.0072 kg per MMBtu N_2O: 0.0036 kg per MMBtu	Environmental Protection Agency. "Emission factors for greenhouse gas inventories." *Stationary Combustion Emission Factors," US Environmental Protection Agency, available:* *https://www.epa.gov/sites/production/files/2015-07/documents/emission-factors_2014.pdf* (2014) Table 1 Stationary Combustion Emission Factor, Biomass fuels: Wood and Wood Residuals
Propane	CO_2: 62.87 kg per MMBtu CH_4 : 0.003 kg per MMBtu N_2O: 0.0006 kg per MMBtu	Environmental Protection Agency. "Emission factors for greenhouse gas inventories." *Stationary Combustion Emission Factors," US Environmental Protection Agency, available:*

Category	Value	Comment
	CO_2: 5.7 kg per gallon	https://www.epa.gov/sites/production/files/2015-07/documents/emission-factors_2014.pdf (2014) Table 1 Stationary Combustion Emission Factor, Petroleum Products: Propane Table 2 Mobile Combustion CO_2 Emission Factors: Propane

GHGs	Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are included. GWP CO_2 = 1 CH_4 = 34 N_2O = 298	Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF6), and nitrogen trifluoride (NF3) are not included in detail except as previously reported in Oregon's GHG inventory. Future projections of HGWP gasses are made outside the model.
Embodied Carbon	2015 CBEI construction (buildings)	https://www.oregon.gov/deq/FilterDocs/OregonGHGreport.pdf Future projections of embodied carbon are made outside the model based on assumptions from the State of Oregon Department of Environmental Quality.

Appendix 4: Data Sources & Uses

Table 4-1. Input assumptions and calibration targets.

Data	Source	Use
Population by age, sex	US Census - 2019 American Community Survey (ACS)	Calibration target
Residential buildings by county, type, and year built	US Census - 2019 American Community Survey (ACS)	Input assumption
Employment by county and sector	US Census - 2019 American Community Survey (ACS) DP03	Calibration target
Non-residential buildings by type	Replica land use data EIA	Input assumption
Non-residential floor space by county and type	Replica land use data	Input assumption
Non-residential floor space by type and year built	Northwest Energy Efficiency Alliance CBSA 4 (Commercial Building Stock Assessment)	
Natural Gas, Electricity and Other fuel use	State Energy Data System (SEDS)	Calibration target
End use equipment fuel shares	Northwest Energy Efficiency Alliance CBSA 4 (Commercial Building Stock Assessment) Northwest Energy Efficiency Alliance RBSA II (Residential Building Stock Assessment)	Input assumption
Electricity production capacity, generation, and fuel use	Department of Environmental Quality	Input assumption
Emissions Inventory	Department of Environmental Quality 2018 emissions inventory	Calibration target
Heating and cooling degree days by county	U.S. Climate Resilience Toolkit Climate Explore (Version 3.1)	Input assumption

Table 4-2. Business-As-Usual assumptions.

Data	Source
Population growth	Portland State University - Population Forecasts by County
Employment	State of Oregon Employment Department
Transportation Fuel Standards	CAFE Fuel standards: Vehicle fuel consumption rates reflect the implementation of the U.S. Corporate Average Fuel Economy (CAFE) Fuel Standard for Light-Duty Vehicles, and Phase 1 and Phase 2 of EPA HDV Fuel Standards for Medium- and Heavy-Duty Vehicles.
Heating & cooling degree days (HDD and CDD)	Climate Explorer (nemac.org)
Energy use	Baseline building equipment types/stocks held from 2019-20250, using data from the Residential Energy Consumption Survey (RECS) for baseline building equipment types and State Energy Data System (SEDS) for building equipment efficiencies
Building growth	Residential buildings are added alongside population growth; building types added based on the building mix of counties where population growth is happening. Non-residential building growth is based on projected growth in employment; building types added (where job growth is happening), based on the current building mix of each county.