Technical report on opportunities to reduce greenhouse gas emissions caused by Oregon´s consumption

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Prepared for the Oregon Department of Environmental Quality

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1. Introduction

This report provides a detailed summary of analysis conducted by the Stockholm Environment Institute (SEI) to assess opportunities and approaches in Oregon for reducing consumption-based greenhouse gas emissions. Under contract to the Oregon Department of Environmental Quality, SEI was asked to produce the following work products:

1. **Consumption-based emissions forecast and abatement wedge analysis**. The goal of this analysis was to quantitatively estimate the potential for reducing Oregon's consumption-based greenhouse gas emissions between now and 2050. The analysis builds off Oregon's 2021 consumption-based emissions inventory, providing a simplified forecast for how these emissions may grow over time due to population and income growth. It then shows how existing and planned policies in Oregon, along with potential additional measures targeting consumption (identified in work product #2), could reduce these emissions over time, and represents these graphically as emissions abatement "wedges." Section 2 of this report summarizes the results, and provides a detailed explanation of the methodology applied.
2. **Identification and evaluation of options for reducing consumption-based emissions**. For this analysis, SEI conducted a comprehensive review of options for reducing consumption-based greenhouse gas emissions, and identified a subset of options that could be applied in Oregon. Major options were identified at the level of "outcomes" that could be achieved, such as reducing food waste, reducing embodied carbon in new construction, or shifting consumption to less emissions-intensive meat and dairy products. These outcomes were then modeled quantitatively as "additional measures" in the abatement wedge analysis (work product #1). For this work product, SEI identified *potential policy approaches* for achieving each of the outcomes, and conducted qualitative evaluations of these policy approaches against a common set of criteria (e.g., likelihood of emissions impact, cost-effectiveness, and economic, environmental, and societal impacts). In addition, SEI identified several options that were deemed worthy of consideration, but for which time and resources did not allow for as detailed of an assessment. These options received higher-level summaries and evaluations. The options identified, evaluation approach, and results are presented in Section 3 of this report.
3. **Illustrative marginal abatement cost analysis.** For this work product, SEI conducted a simplified assessment of marginal abatement costs associated with a subset of measures for reducing consumption-base emissions. For each measure, the assessment estimated both greenhouse gas abatement potential and implementation costs (savings). The result was a simplified marginal abatement cost curve, illustrating both potential emission reductions and the cost per metric ton of CO_2-equivalent reduced, for the handful of

measures assessed. The analysis illustrates that measures to address consumption-based emissions may be cost-effective, including when compared to more traditional measures targeting sector-based emissions in Oregon. For this analysis, the assessed measures parallel, but in some cases are specified differently from, the measures modeled in work product #1. The methodology used and results are summarized in Section 4 of this report.

4. **Discussion papers.** SEI developed two discussion papers on topics related to addressing consumption-based greenhouse gas emissions in Oregon. The first addresses target-setting, outlining why it could be helpful to supplement the state's greenhouse gas reduction goals with targets for reducing consumption-based emissions, and identifying options for doing so. The second explores considerations and approaches for achieving deep reductions in consumption-based emissions, in line with targets based on equitable and climate-safe global emission budgets. These papers are included in Section 5 of this report.

Each of these work products was developed to support further understanding and exploration of opportunities for reducing consumption-based emissions, applying methods and approaches that were feasible given the time and budget allowed. In each case, there is potential to develop the analyses in much more depth, including with respect to the evaluation of potential policy approaches. Where relevant, potential limitations and caveats associated with the methods applied are identified in the following sections.

2. Consumption-Based Emissions Forecast and Abatement Wedge Analysis

For this analysis, SEI developed an Excel-based model (the "Oregon Consumption-Based Greenhouse Gas Emission Abatement Scenario Tool") to allow exploration of a variety of measures that could, over time, lower the total carbon footprint of Oregon's consumption of energy, materials, goods, and services. The tool estimates potential emission reductions against a simplified *reference scenario*, which projects how consumption-based emissions would grow over time assuming Oregon's population and state income levels continue to grow, but consumption patterns and emissions intensities[1] remain constant. The tool builds off Oregon's latest (2021) consumption-based emissions inventory (CBEI), and allows the separate assessment of measures affecting household consumption, government consumption, and business capital investment.

The effects of different measures are graphically depicted as "abatement wedges," indicating the expected magnitude of emissions reductions achieved by each measure between 2021 and 2050, assuming emissions would otherwise increase in line with the reference scenario. The tool also graphically depicts a cross-section of abatement achieved by different measures in individual years (using a waterfall chart), which displays expected indirect "rebound" emissions (i.e., emission *increases* that occur when reduced consumption in one area leads to increased spending in others).

By default, the tool displays abatement wedges associated with major *existing and planned policies*. These include Oregon state policies, and some federal policies, that are "on the books," as well as Oregon's planned Climate Protection Program (CPP).[2] All of these policies could reduce Oregon's consumption-based emissions by either directly changing consumption (e.g., reducing energy-use intensity in homes, or increasing purchases of electric vehicles), or by reducing the emissions intensity of consumption (e.g., reducing power sector greenhouse gas emissions). Settings and assumptions related to existing policies can be configured on a single worksheet ("Existing Policy Settings").

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[1] In this context, "emissions intensity" refers to the greenhouse gas emissions that arise per dollar of expenditure on different categories of consumption (e.g., goods, services, and materials), expressed as $tCO_2e/\$$.

[2] As noted in section 2.5, the original CPP was declared invalid and DEQ is currently working to replace it. Adoption of a new CPP is not assured, and the new CPP may be designed differently from the original CPP, but for the purposes of this analysis SEI estimated its effects as previously conceived.

The tool also allows configuration of *additional measures* that could reduce consumption-based emissions by reducing or shifting consumption relative to the reference scenario. These measures are organized into four major sectors within Oregon's CBEI: the built environment, food, goods, and transportation. (Some measures may be cross-cutting and affect consumption in multiple sectors.)

The effects of different measures are configured as discrete outcomes to be achieved by a certain date. For example, the tool can indicate the expected change in emissions if, by 2050, Oregon residents were to (on average) reduce air travel 20% below reference levels, reduce food waste by 40%, reduce private vehicle travel by 20%, or reduce major goods purchases by 30%. For each measure, the basic inputs are:

- The year in which a consumption change is initiated
- The year in which the change is completed – that is, the year in which the full specified shift or reduction in consumption is achieved
- The full percentage change in consumption to be achieved

For some measures, additional parameters are also required (a full list is provided below, in section 2.6).

In most cases, reductions achieved in interim years (between initiation and completion) are modeled linearly. For example, if a change is specified that would begin in 2025 and achieve a 10% reduction by 2035, the reduction in 2030 will be 5% below the reference level. For some measures, however, more detailed reduction schedules are defined (e.g., to reflect prescribed regulatory targets, or to align with projected dates by which embodied carbon limits could be achieved).

It is important to note that in the reference scenario, overall consumption is projected to grow between 2021 and 2050, due to a combination of population growth and per capita income growth. Therefore, abatement measures may result in *reduced growth*, not absolute emission reductions relative to 2021. This highlights an important challenge: how to reduce Oregon's consumption-based carbon footprint in line with global goals, given current population and economic growth trends. (This topic is further discussed in an accompanying discussion paper; see section 5.2.)

2.1. Results

The following charts, derived from the abatement scenario tool, indicate the results of the analysis, using the parameters and assumptions described below in sections 2.5 (for existing and planned policies) and 2.6 (additional measures). For a fuller overview of the additional measures that were modeled, and more detailed numerical summaries of the results, please see section 3. (Table 2-3 in section 2.6 provides cross-references to relevant subsections in section 3 for each measure.)

Several caveats should be kept in mind when interpreting these results. Section 2.4 provides an overview of the limitations of the modeling approach used and how the results should be interpreted. Also, the abatement wedges displayed in the following charts account for rebound effects (i.e., increases in emissions that may occur due to reallocated spending) – see section 2.3.

Figure 2-1 and Figure 2-2 show how Oregon's consumption-based emissions (total and per capita, respectively) might be reduced solely due to existing and planned policies. While these policies (in Oregon and at the US federal level) primarily target sector-based emissions, they may reduce the carbon intensity of goods and services consumed in Oregon (by reducing production-phase emissions), and will also reduce household and government use-phase emissions (e.g., energy consumed in residential and government buildings and during household and government automobile use). [3] Oregon's Clean Energy Targets law (HB 2021), for example, will reduce the carbon intensity of electricity used to produce goods and services in Oregon, as well as electricity used in Oregon homes. Under the Advanced Clean Cars rule, 100% of new vehicle sales in Oregon must be electric by 2035; this will reduce some embodied emissions associated with goods and services (i.e., emissions arising from in-state use of cars in the production, transportation, and sale of goods and services consumed in Oregon), and will directly (and substantially) reduce vehicle use emissions.

The model captures the expected effects of the following existing and planned policies (see section 2.5 for descriptions of these policies and the modeling assumptions used):

- Oregon existing and planned policies
    - Climate Friendly and Equitable Communities (CFEC)
    - Advanced Clean Cars II

[3] For a full explanation of the structure of Oregon's consumption-based emissions inventory and the distinction between "production"- and "use"-phase emissions (among other distinctions) associated with consumption, please see Oregon Department of Environmental Quality (2024). *Oregon's Consumption-Based Greenhouse Gas Emissions 1990 – 2021: Technical Report in Support of DEQ's Report to the Legislature on Opportunities to Reduce Consumption-Based Greenhouse Gas Emissions*.

    - Advanced Clean Trucks
    - Oregon Clean Fuels Program (Clean Fuels)
    - Oregon Building Codes (Building Codes)
    - Renewable natural gas portfolio requirement (SB98)
    - Clean Energy Targets (HB 2021)
    - PLANNED: Climate Protection Program (CPP)
- US federal existing policies
    - Corporate average fuel economy standards (CAFE)
    - American Innovation and Manufacturing Act (AIM) elements related to refrigerants

Table 2-1 summarizes the emission reductions achieved by each of these policies, cumulatively between 2021 and 2050, and annually in 2050, relative to the "no action" reference scenario.

Table 2-1. Estimated emission reductions from existing and planned policies only

	Cumulative emissions reductions[1] between 2021 and 2050		**Annual emission reduction[1] in 2050**	
	Metric tCO_2e	**% reduction from reference**	**Metric tCO_2e**	**% reduction from reference**
CFEC	13,914,000	0.4%	850,000	0.6%
Advanced Clean Cars II	225,686,000	6.6%	14,941,000	11.4%
Advanced Clean Trucks	27,764,000	0.8%	1,842,000	1.4%
CAFE	28,094,000	0.8%	1,013,000	0.8%
Clean Fuels	15,532,000	0.5%	276,000	0.2%
Building Codes	52,148,000	1.5%	3,400,000	2.6%
SB98	20,609,000	0.6%	1,458,000	1.1%
HB2021	258,567,000	7.6%	12,607,000	9.6%
AIM	28,987,000	0.9%	1,520,000	1.2%
CPP (planned)	42,979,000	1.3%	3,109,000	2.4%
TOTAL	**714,279,000**	**21.0%**	**41,016,000**	**31.3%**

[1] Emission reductions are net of rebound effects, and represent reductions below reference case emissions (full Oregon CBEI), derived from a simplified projection of current trends.

Figure 2-1. Projected consumption-based emission reductions from existing and planned policies – total emissions

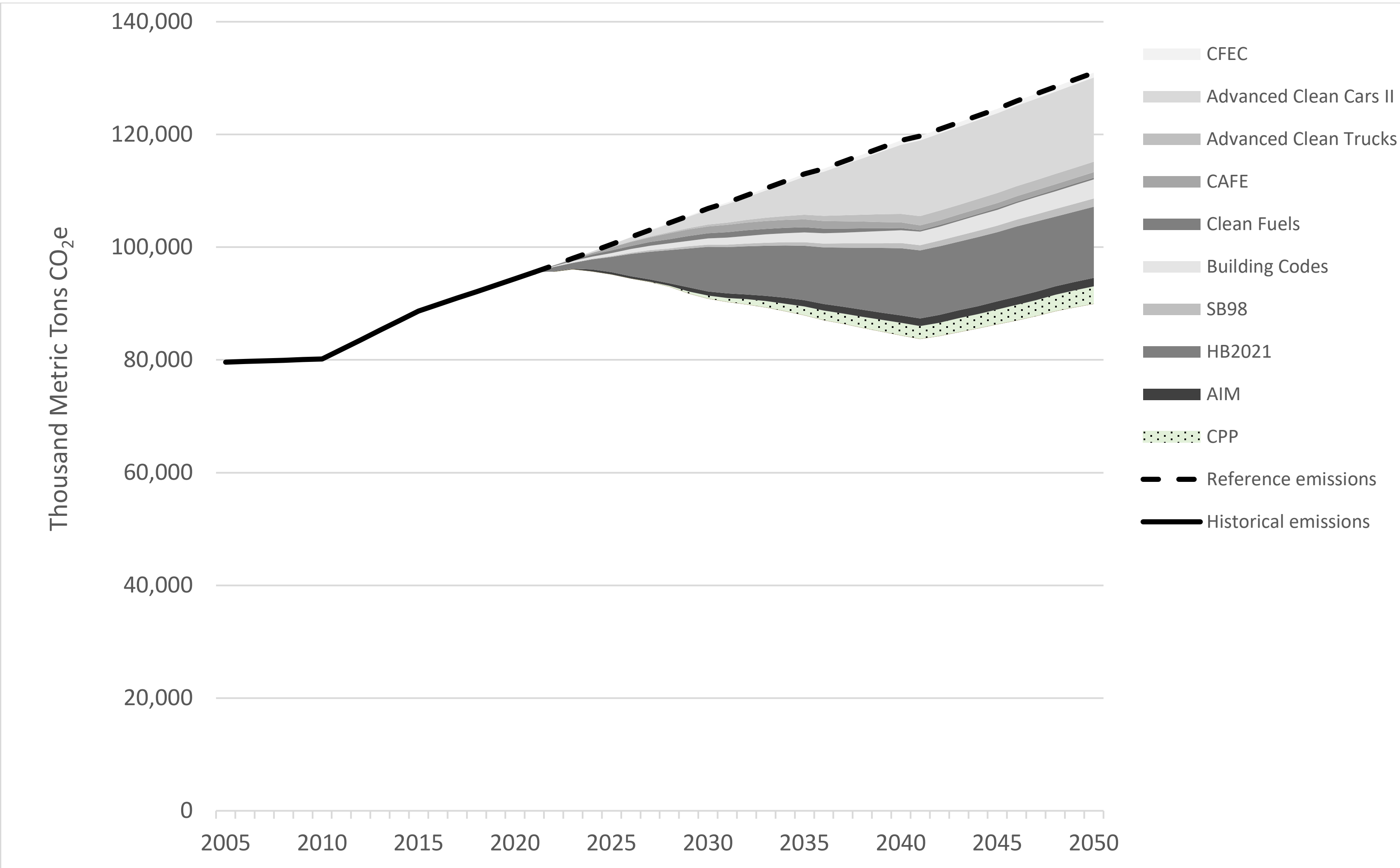


Figure 2-2. Projected consumption-based emission reductions from existing and planned policies – per capita

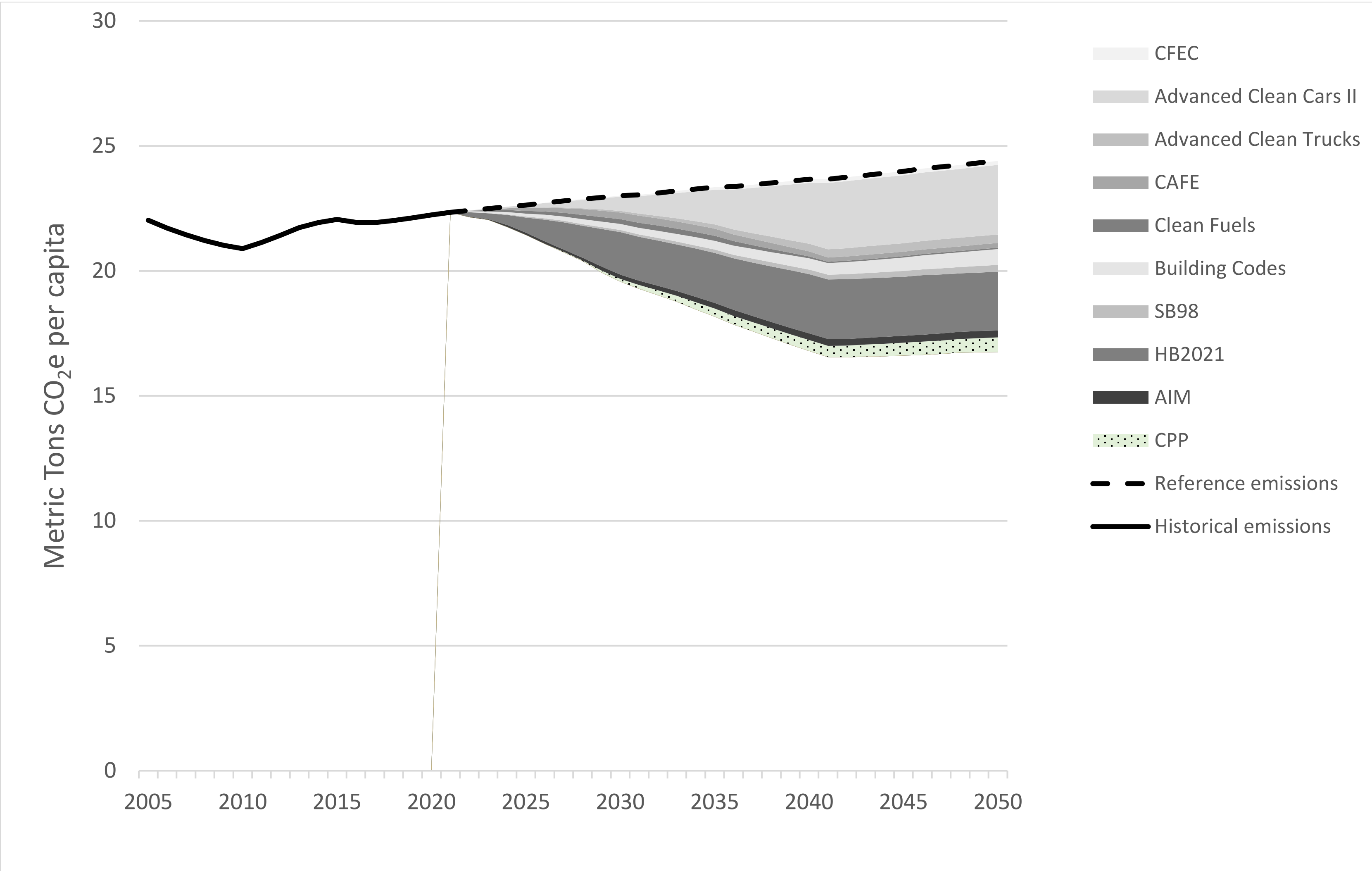


Figure 2-3 and Figure 2-4 show how Oregon's consumption-based emissions (total and per capita, respectively) might be reduced from a combination existing and planned policies plus a suite of 13 additional measures directly targeting consumption. Within the tool, these are mostly specified as *outcomes that could be achieved* (e.g., reductions in consumption, or shifts in consumption to lower-emitting alternatives), not specific policies or approaches that might *produce* these outcomes.[4] Potential policy approaches related to these outcomes are identified and evaluated in a separate analysis (section 3). Descriptions and modeling assumptions for each of these additional measures are provided in section 2.6.

Figure 2-4 also indicates *existing* per capita emissions in a range of other countries and a range of *targeted* per capita emissions that align with current state emission targets for 2050 (the top of the range, at 2.9 tCO_2e per capita) and a climate-safe global emission budget in 2050 (as low as 0.5 tCO_2e per capita – for further explanation, see the discussion paper in section 5.1 of this report). Even with all existing policies and additional measures combined, the model suggests Oregon's per capita consumption-based emissions would remain well above this target – presenting an "emissions gap" in 2050.

The emissions gap arises in part because the model does not account for emissions abatement efforts that may occur in the rest of the world, either from additional policy action or economic drivers. This deliberately omits some reduction in Oregon's carbon footprint that could occur even without further action in Oregon. Under the Paris Agreement, for example, every country in the world has pledged to take action to reduce emissions, and to do so more ambitiously over time. Oregon can realistically expect that its carbon footprint will grow less quickly than the "no action" reference scenario assumed in our analysis. Even so, there may still be a gap between Oregon's consumption-based emissions and a "climate safe" level by 2050. Approaches for closing this gap are discussed in the paper in section 5.2.

Table 2-2 summarizes the emission reductions achieved by a combination of existing and planned policies plus additional measures, cumulatively between 2021 and 2050, and annually in 2050, relative to the "no action" reference scenario. Note that when additional consumption-based measures are implemented, the total reductions attributed to existing policies are reduced. This is because several of the additional measures *reduce demand* for energy, goods, and services, meaning that there are fewer emissions for existing policies to act upon – in other words, implementing measures to reduce consumption can make it easier to achieve the emission reduction goals of existing and planned policies. See section 2.2.1 for further

[4] The one exception is "expanded smart growth programs," which is modeled as a range of potential outcomes related to urban form (such as reduced travel demand, vehicle ownership, and urban infrastructure needs).

discussion of how scenario tool accounts for interactions between different policies and measures, and attributes emission reductions to each of them.

Table 2-2. Estimated emission reductions from existing and planned policies plus additional measures

	Cumulative emissions reductions[1] between 2021 and 2050		Annual emission reduction[1] in 2050	
Existing & planned policies	**Metric tCO_2e**	**% reduction from reference**	**Metric tCO_2e**	**% reduction from reference**
CFEC	14,044,000	0.4%	862,000	0.7%
Advanced Clean Cars II	196,637,000	5.8%	12,020,000	9.2%
Advanced Clean Trucks	27,796,000	0.8%	1,859,000	1.4%
CAFE	26,984,000	0.8%	942,000	0.7%
Clean Fuels	15,126,000	0.4%	260,000	0.2%
Building Codes	35,709,000	1.1%	2,046,000	1.6%
SB98	20,720,000	0.6%	1,479,000	1.1%
HB2021	258,476,000	7.6%	12,572,000	9.6%
AIM	28,140,000	0.8%	1,455,000	1.1%
CPP (planned)	44,136,000	1.3%	3,200,000	2.4%
Subtotal	**667,766,000**	**19.6%**	**36,696,000**	**28.0%**
Additional measures				
Lighter weight cars	13,212,000	0.4%	1,238,000	0.9%
Reduced air travel	3,084,000	0.1%	259,000	0.2%
Enhanced building utilization	4,919,000	0.1%	110,000	0.1%
Smaller new home construction	12,868,000	0.4%	981,000	0.7%
Reduced construction emissions	68,879,000	2.0%	5,316,000	4.1%
Reduced food waste	25,126,000	0.7%	1,259,000	1.0%
Reduced meat consumption	21,530,000	0.6%	1,799,000	1.4%
Reduced dairy consumption	7,154,000	0.2%	550,000	0.4%
Lower-carbon meat and dairy	10,473,000	0.3%	740,000	0.6%
Reduced clothing consumption	6,786,000	0.2%	368,000	0.3%
Reduced electronics consumption	12,157,000	0.4%	696,000	0.5%
Reduced goods consumption	7,490,000	0.2%	455,000	0.3%
Expanded smart growth	22,560,000	0.7%	2,102,000	1.6%
Subtotal	**216,238,000**	**6.4%**	**15,874,000**	**12.1%**
GRAND TOTAL	**883,928,000**	**26.0%**	**52,570,000**	**40.1%**

[1] Emission reductions are net of rebound effects, and represent reductions below reference case emissions (total Oregon CBEI), derived from a simplified projection of current trends.

Figure 2-3. Projected consumption-based emission reductions from all policies and additional measures – total emissions

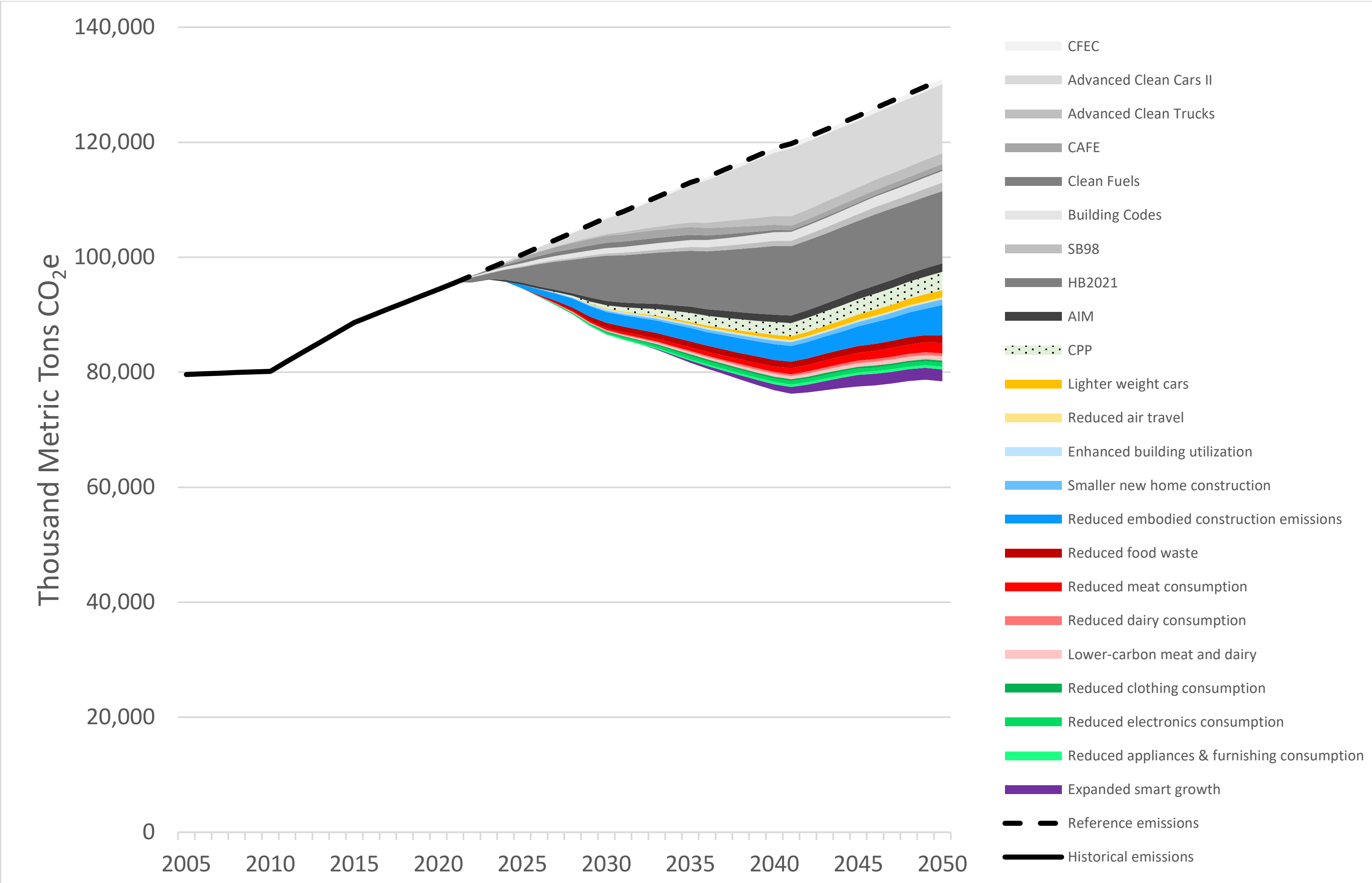
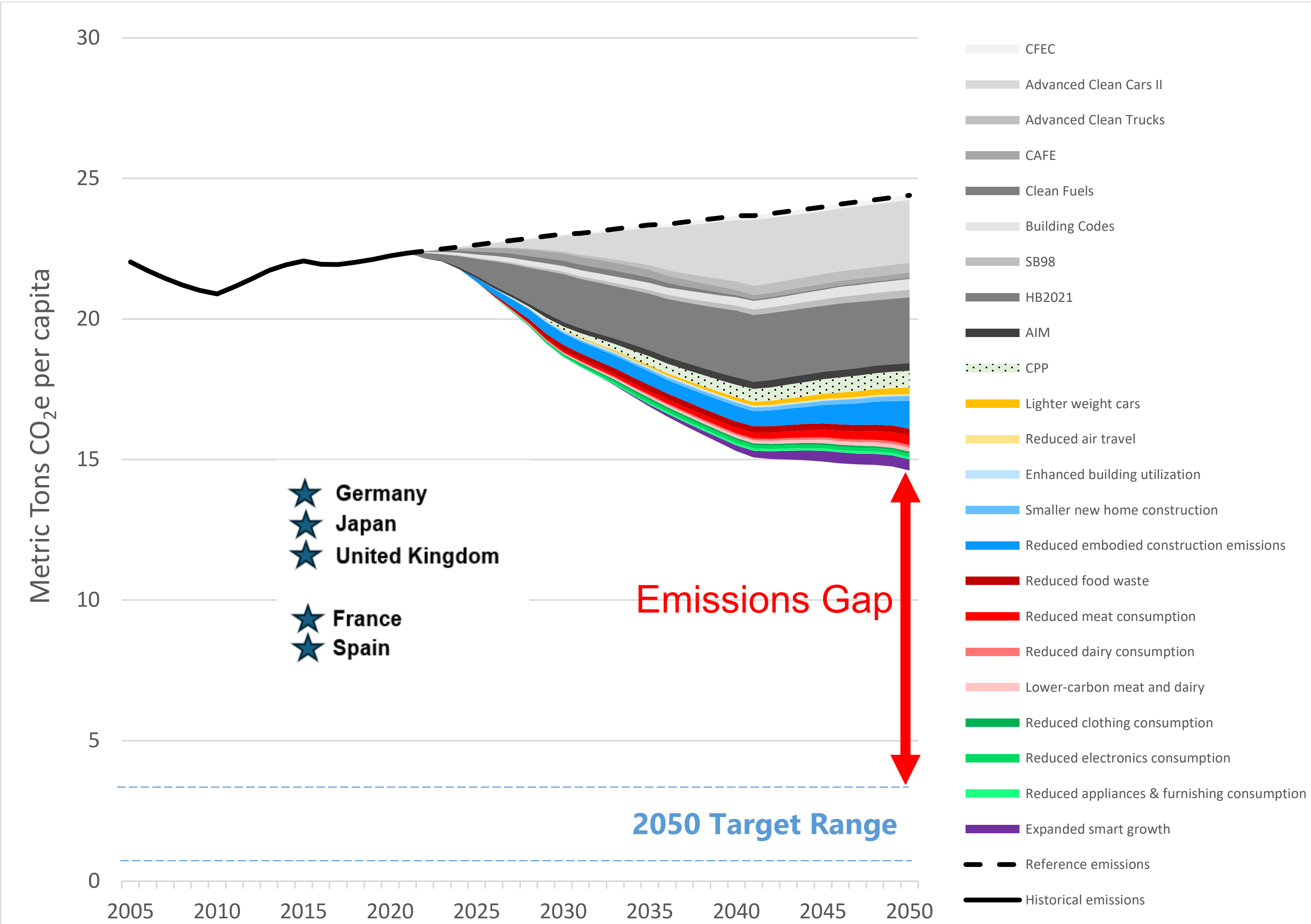


Figure 2-4. Projected consumption-based emission reductions from all policies and additional measures – per capita



The following figures display results broken down by consumption sector, including:

- The built environment (Figure 2-5)
- Food (Figure 2-6)
- Other goods (appliances, clothing, electronics, furnishings, etc.) (Figure 2-7)
- Transportation (Figure 2-8)
- Other sectors (services, healthcare, other manufactured goods, etc.) (Figure 2-9)

These charts provide additional detail, but also differ in that the abatement wedges are sequenced (from top to bottom) in the order in which they are calculated. Thus, for some sectors, some additional measures (i.e., those that directly reduce or avoid consumption) are sequenced before existing policies – leading to fewer reductions attributed to existing policies. Again, further explanation of this sequencing can be found in section 2.2.1.

Also, it is worth noting that these charts indicate the effects of *all* policies and additional measures in reducing consumption-based emissions, even if those effects are indirect. For example, in Figure 2-7 abatement wedges for federal CAFE standards and Oregon building codes are displayed in relation to "other goods" consumption. This is because some of the consumption-based emissions associated with goods arise from automobile transportation and building energy use that occur upstream of final consumption, e.g., when the goods are manufactured and transported to market. Because of this, fuel economy standards and building codes (and other policies) will play a role in reducing Oregon's consumption-based emissions across the board, even though they may not directly target certain sectors like "other goods."

Finally, note that emissions in "other sectors" are only affected by existing and planned policies – no additional consumption-focused measures were identified targeting these sectors. Thus, as Figure 2-9 indicates, consumption-based emissions in "other sectors" are affected only by existing and planned policies that reduce upstream emissions associated with their production, transportation, and sale.

Figure 2-5. Projected consumption-based emission reductions in the built environment sector

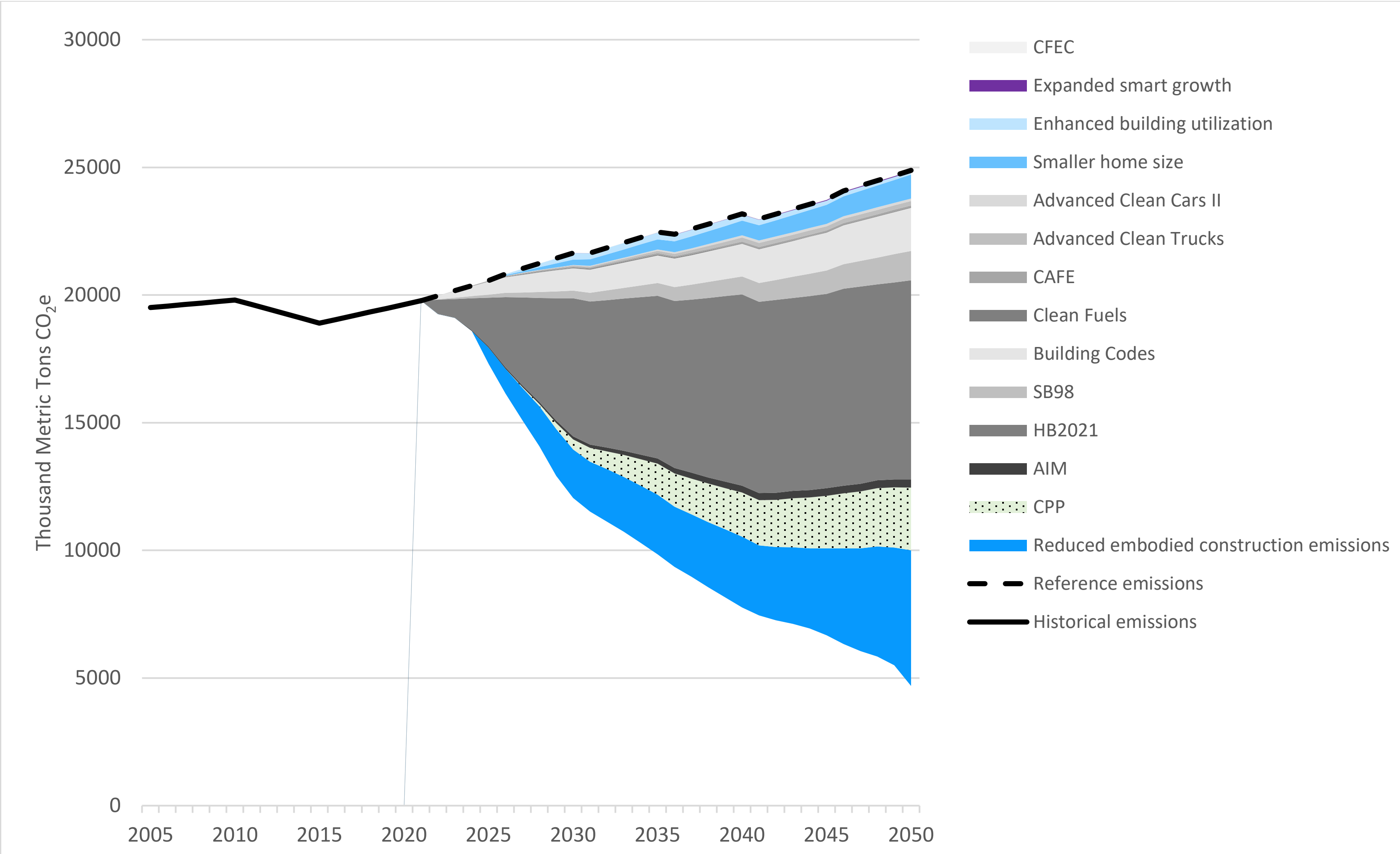


Figure 2-6. Projected consumption-based emission reductions in the food sector

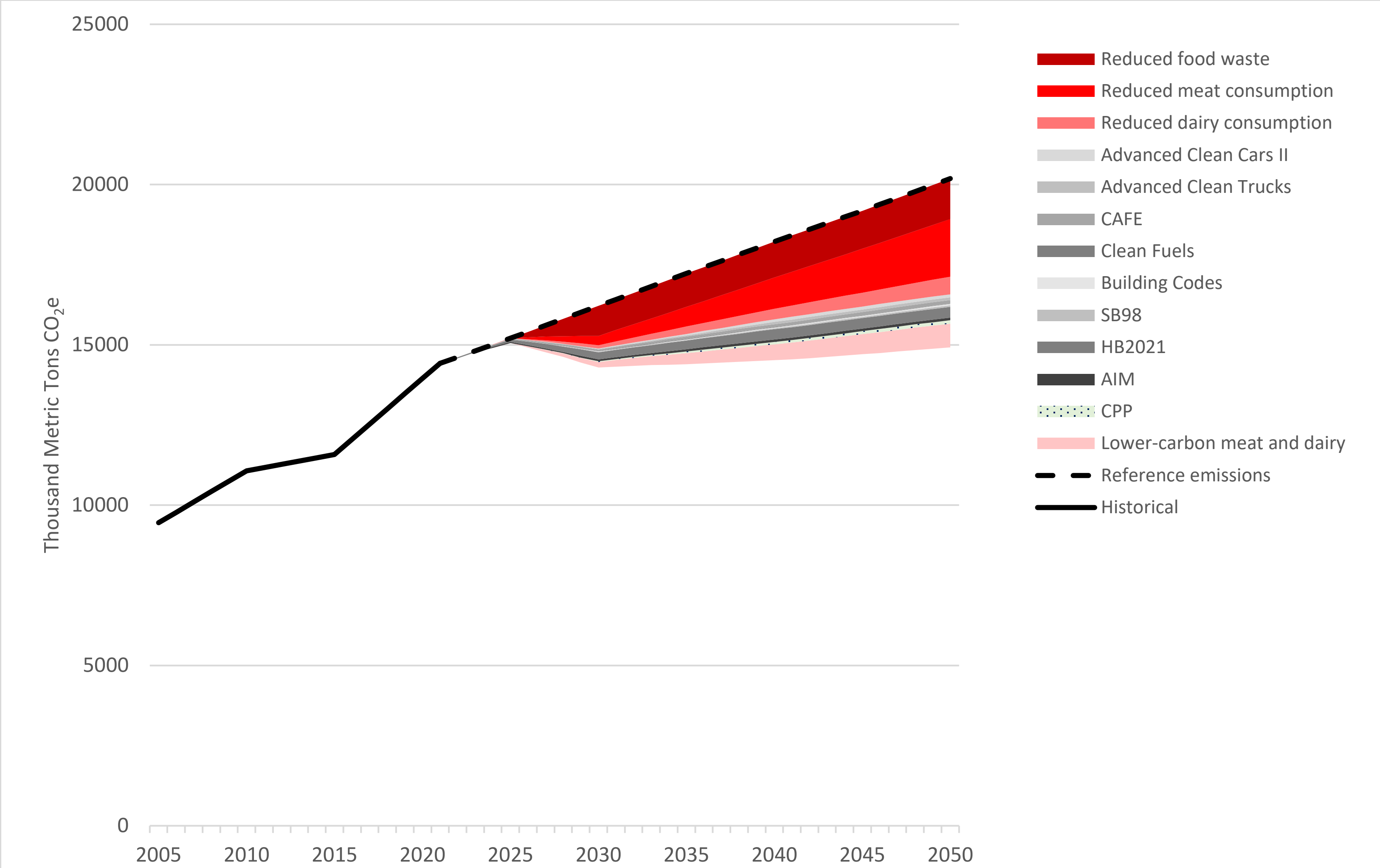


Figure 2-7. Projected consumption-based emission reductions in the goods sector

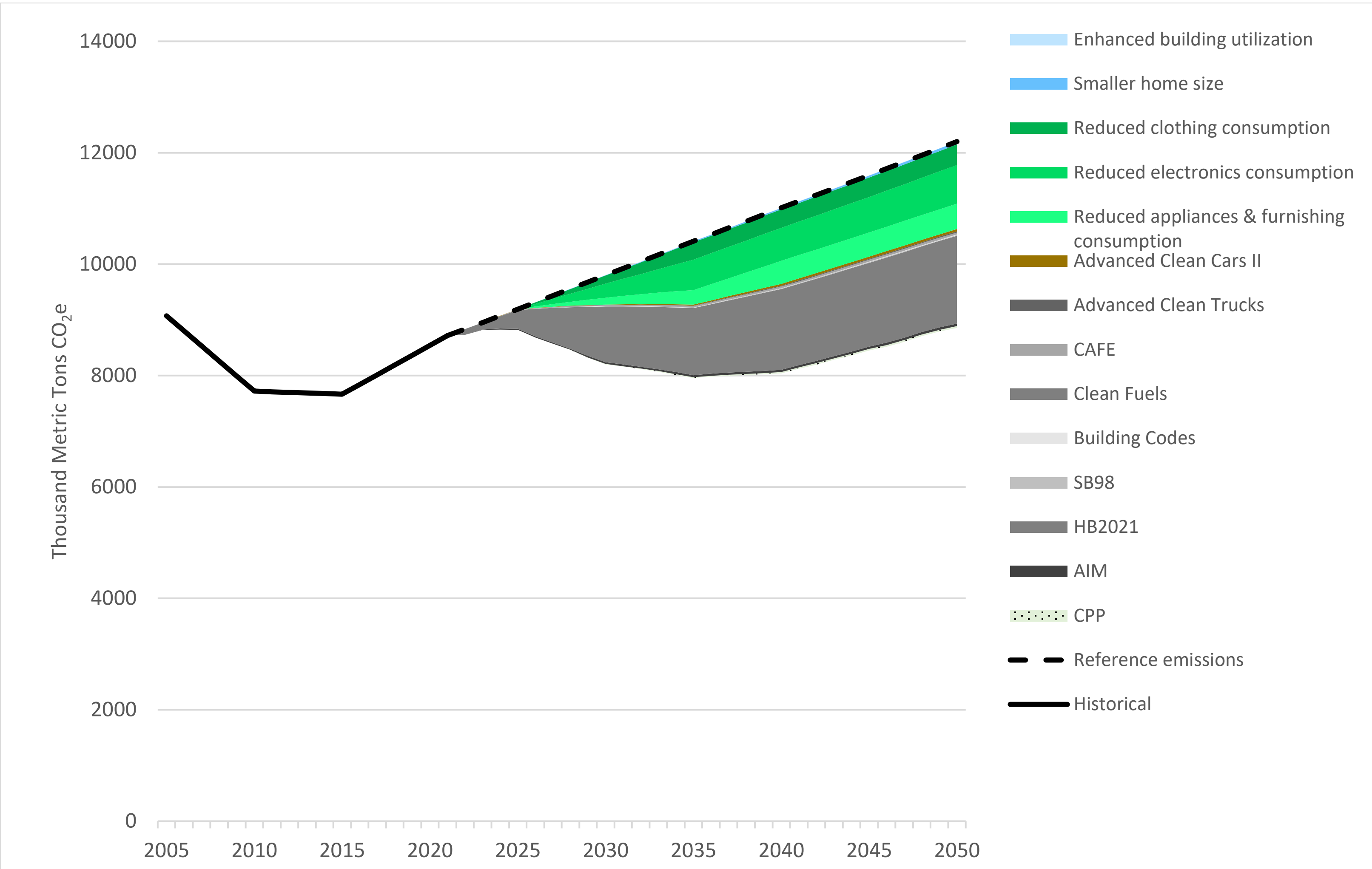


Figure 2-8. Projected consumption-based emission reductions in the transportation sector

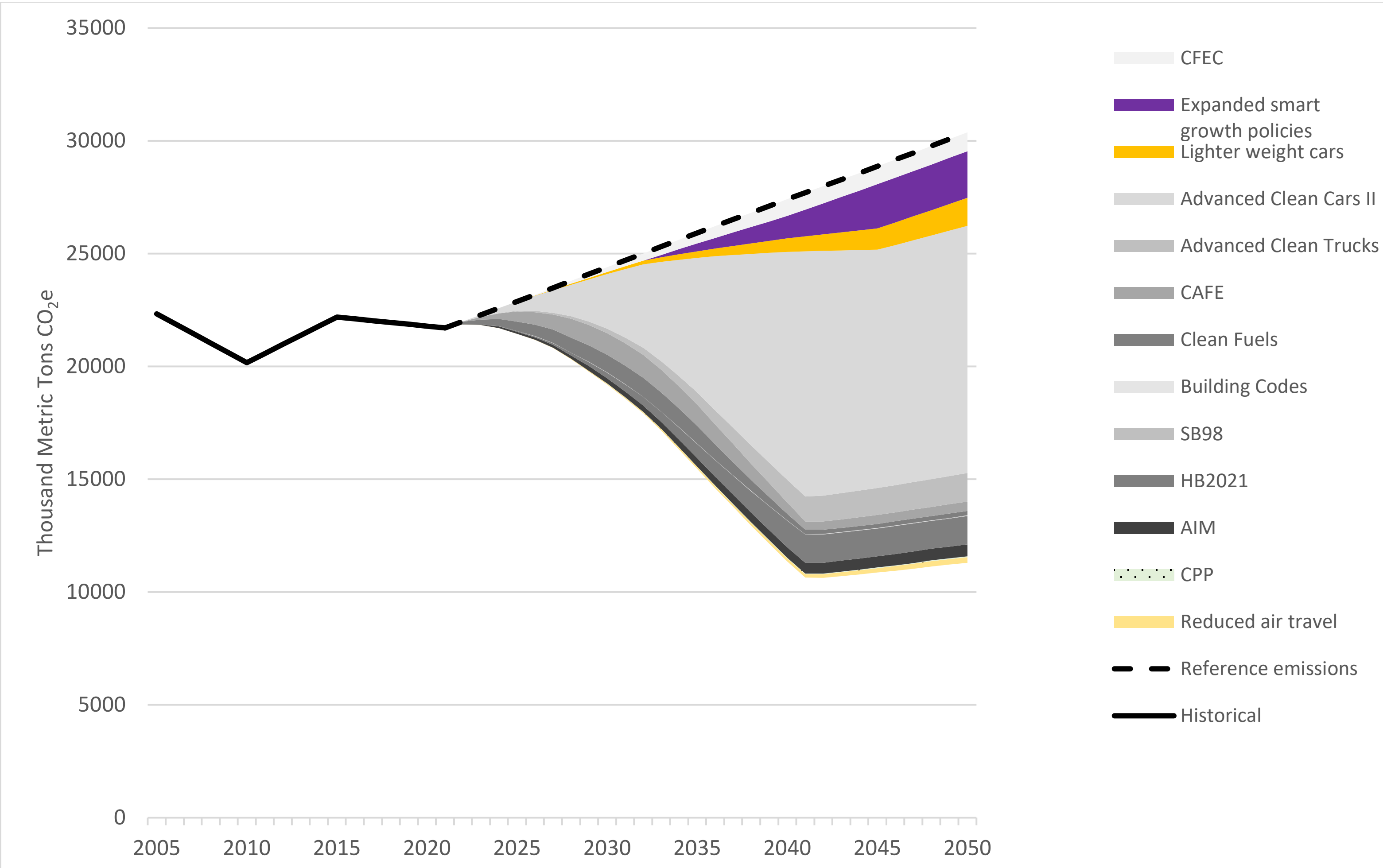
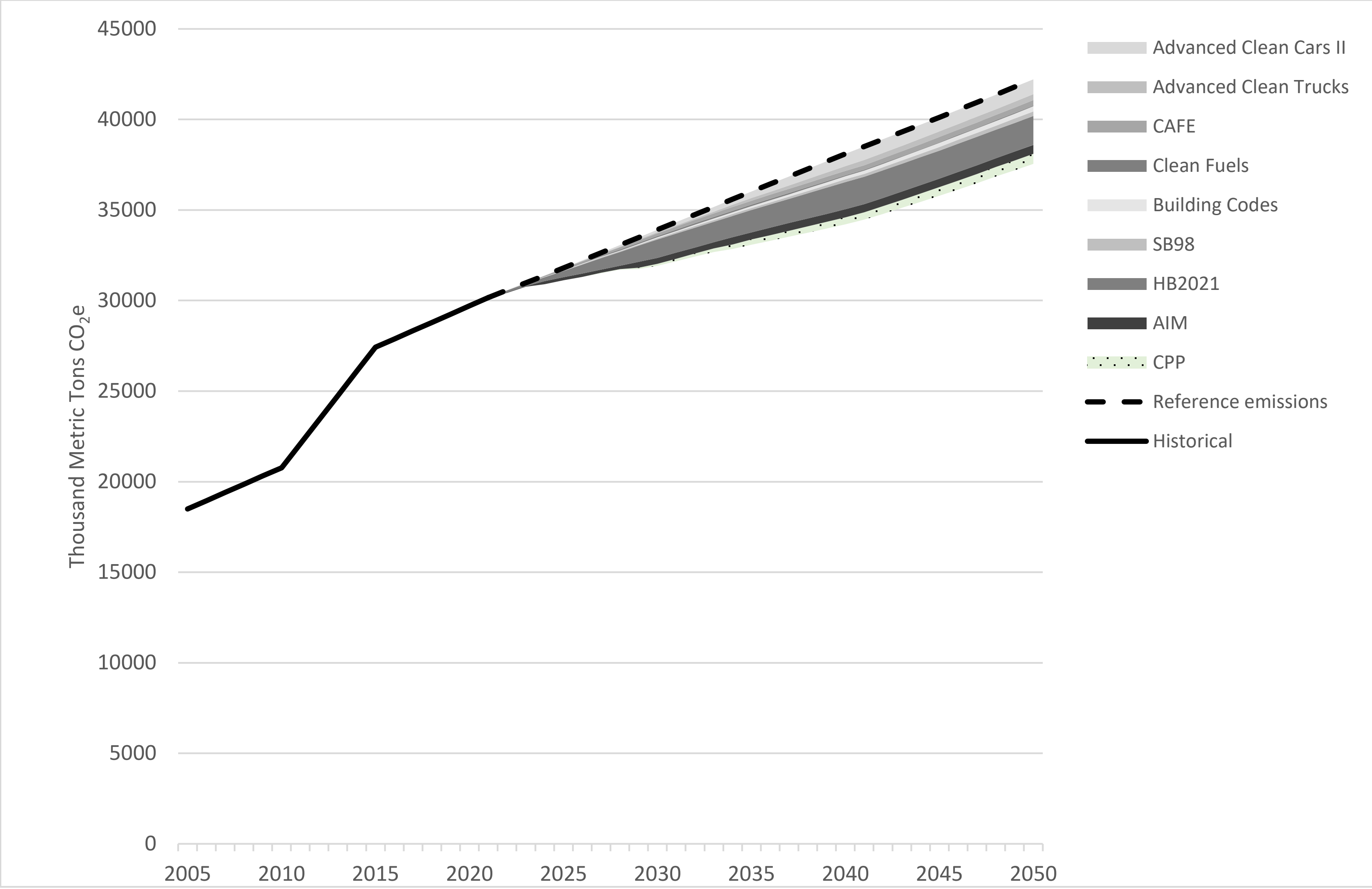


Figure 2-9. Projected consumption-based emission reductions in other sectors



2.2. Abatement wedge tool overview

This section and the following subsections provide an overview of the Oregon Consumption-Based Greenhouse Gas Emission Abatement Scenario Tool and how it is structured (written as a "user's guide"), along with details of the methodology and assumptions used in the tool to estimate abatement potentials associated with different policies and measures.

The main interface for the tool consists of three separate Excel worksheets ("Household Results," "Government Results," and "Capital Results") which allow configuration of abatement measures for the three segments of Oregon's CBEI: households, government, and business capital investment. Each of these worksheets is organized in the same way, with aggregate abatement wedge and waterfall charts displayed at the top, and individual sector charts – along with configuration parameters – displayed further below. Changes in the configuration of abatement measures within each sector will "feed up" to the aggregate abatement charts at the top of each worksheet. Each worksheet is organized into the following sections:

- Aggregate Results (top of worksheet)
- Built Environment
- Food
- Other Goods
- Transportation
- Remaining Emissions (Services, Healthcare, Other Manufactured Goods, Etc.)

Abatement wedges associated with existing policies are displayed in each section: in aggregate (across all sectors) at the top, and separately within each sector. Abatement wedges for additional measures can be configured under the sections corresponding to the relevant sector. Measures that affect consumption in more than one sector (e.g., enhanced building utilization and smaller home construction, which affect both construction emissions and goods consumption) have separate configuration parameters within each sector. Finally, measures that affect consumption in the same manner across multiple segments of Oregon consumption (household, government, and business capital) have configurable settings on a separate worksheet ("Cross-Cutting Measures"). There are two such measures: reducing embodied carbon in construction materials (affecting all construction), and low carbon meat and dairy consumption (affecting household and government consumption).

Finally, no *additional* measures are configured targeting the "remaining emissions" sectors. However, these sectors may still be affected by existing or planned policies that reduce upstream (pre-purchase) emissions in these sectors (e.g., Oregon's HB 2021 law, which will reduce emissions from electricity used in the provision of services and healthcare).

In addition to the Household, Government, and Capital results worksheets, there is an "Aggregate Results" worksheet that presents combined results across Oregon's entire CBEI. This worksheet does not have any configuration options, but displays aggregated outputs derived from the other main worksheets.

2.2.1. Sequencing of wedges

Because various policies and measures can interact with each other, the sequencing of abatement wedges will affect their apparent size. For example, the emission reductions from switching to electric vehicles (EVs) will appear smaller if they are calculated *before* adding in effects of policies to decarbonize electricity, and much larger if they are calculated after. In the same vein, measures that reduce demand for automobile use could appear to have *zero* effect on emissions if they are modeled *after* assuming a full shift to EVs and 100% decarbonization of electricity. This would fail to convey, however, the contribution of such measures to full decarbonization (i.e., reducing total energy demand, making transport decarbonization both physically and economically more feasible). To highlight the contribution of measures that reduce and shift consumption, the tool calculates abatement wedges in the following general sequence:

1. Measures that reduce/avoid consumption
2. Measures that shift consumption (e.g., to lower-carbon alternatives within a category)
3. Measures that reduce the energy and/or carbon intensity of consumption

The order in which abatement wedges are *displayed*, however, depends on the chart:

- For the wedge charts specific to each sector (e.g., built environment, food, goods, and transport), wedges are displayed in the order they are calculated. In some cases, this means that wedges associated with existing and planned policies (e.g., HB2021, which requires deep reductions in electricity emissions) are calculated *after* wedges associated with new measures (e.g., expanded "smart growth" policies, which could reduce vehicle-miles traveled).
- For the aggregated wedge charts (at the top of each worksheet), wedges for existing and planned policies are displayed first, followed by wedges for additional measures. This sequencing conveys the relative size of the contribution of additional measures beyond existing policies. However, it does not change the order in which wedges are calculated.

At the top of each main worksheet, there is a "toggle" for switching all additional measures "on" or "off." Turning these off means that all charts in the worksheet will display only wedges associated with existing and planned policies. The size of some "existing and planned policy" wedges may change as a result. For example, fewer reductions in vehicle-miles traveled due to "smart growth" measures may mean *more* apparent reductions from federal CAFE standards and Oregon's "Clean Cars" rule. This is because, without additional policies targeting consumption, more aggressive efforts will be needed to implement these existing policies to achieve their targeted outcomes (e.g., more cars on the road will require more manufacturing of electric vehicles to achieve the goals of the "Clean Cars" rule). Thus, an important effect of reducing and shifting *consumption* is to make it easier – and more likely – for policies targeting *production* emissions to succeed.

That said, measures targeting consumption-based emissions will also yield reductions *above and beyond* what can be expected under existing and planned policies. Comparing the full wedge charts with the "only existing and planned policy" charts allows an assessment of the *incremental* contribution of additional measures beyond what would happen if existing policies were successfully implemented by themselves.

2.2.2. Other worksheets

For each main segment of Oregon's CBEI (households, government, and business capital investment) a separate set of parallel worksheets is used to calculate reference scenario emissions and abatement potentials. These worksheets include the following:

Base emissions

This worksheet organizes historical and current CBEI data, and includes starting inputs needed for estimating the effects of existing policies on upstream (three-phase) and use-phase emissions. Use-phase emission totals are recalculated for each energy/fuel type used in appliances, electronics, and vehicles. This allows the effects of policies that target specific energy sources and refrigerants to be calculated (e.g., electricity, transportation fuels, natural gas, and refrigerants in both buildings and vehicles).[5]

For three-phase (pre-purchase) emissions, a matrix is provided indicating the percentage of emissions in each consumption category that arises from certain sources targeted by existing policies. These include, for example, *upstream* emissions arising from electricity, natural gas, and other fuel use in Oregon buildings; upstream emissions arising from fuels used in Oregon and US automobiles and trucks; and upstream emissions from refrigerants used in buildings and

[5] Note that use-phase emissions from vehicle lubricants are excluded, since these are a (very) small component of total use-phase emissions, and are not likely to be significantly affected by policies or measures targeting vehicle use-phase emissions, such as VMT reduction measures or CAFE standards. Likewise, for households, direct aviation use-phase emissions are excluded, since these are a tiny segment of total vehicle use-phases emissions and are not targeted by any policies.

vehicles. These percentages are needed to estimate the effects of existing policies on upstream emissions. For example, Oregon's building codes will reduce energy-use intensity in buildings used in the production of goods and services consumed in Oregon.

Intensities

This worksheet calculates greenhouse gas emission intensities (denominated as kgCO2e per dollar of expenditure) for each category of consumption in Oregon's CBEI. These intensities are used to estimate rebound effects from reducing consumption – see discussion of rebound effects further below. Emission intensities decline over time as policies and measures are applied that reduce upstream (three-phase) emissions. The trajectory of the decline is also calculated in this worksheet.

Reference

This worksheet forecasts reference scenario emissions for all consumption categories. Reference scenario emissions are calculated by assuming (1) fixed emissions intensities; and (2) fixed relative expenditures across consumption categories (i.e., the same percentage of expenditure is allocated to each category, even if total expenditures rise). Future emissions then rise in proportion to:

1. Population growth. Expected statewide population growth data were obtained from the Portland State Population Research Center website. See the "Pop data" worksheet in the tool.
2. Income growth. Per capita expenditures (and emissions) are projected to increase in line with future income growth. Future income growth is estimated using a simple linear projection from historical data (see the "Income data" worksheet). Income growth is forecast on a real (inflation-adjusted) as opposed to nominal basis.

The one exception to this approach is for projecting construction emissions. Unlike other categories of consumption, which can be expected to grow in proportion to *total* population and income, new construction demand is primarily driven by a combination of (1) the population increase in each year; (2) the rate of demolition of old buildings in each year; and (3) income growth. Future construction emissions are therefore estimated using the following steps:

- Building stock turnover is estimated at 0.5% per year[6]

[6] This is based on the average turnover rate assumed for advanced economies in a global study of building energy efficiency potential: http://www.gbpn.org/sites/default/files/08.CEU%20Technical%20Report%20copy_0.pdf.

- The projected population increase in each year – relative to the year-on-year increase from 2020 to 2021 – is used to calibrate expected construction emissions in each year.
    - For example, the population increase from 2020 to 2021 was close to 1%, so base year (2021) construction emissions are attributed to: (1) a 0.5% turnover in existing housing stock; and (2) a 1% increase in population.[7] If, in 2025, the projected population increase is 1.3%, then construction emissions for 2025 would be (0.5+1.3) / (0.5+1) = 120% of the base year value.
- Income growth is still expected to contribute to future construction demand (e.g., as households, all else equal, demand larger housing) – so the base value for construction demand (as calculated above) is increased in proportion to projected income growth.

Calculations specific to projecting construction emissions are contained on a separate spreadsheet tab: "New Construction."

Finally, the same forecast is used for household, government, and business capital consumption. That is, government and business capital expenditures are also assumed to grow in proportion to statewide population and income growth (or, for construction emissions, in line with building turnover, the annual population increase relative to 2020-2021, and income growth).

Sector Worksheets (Built Environment, Food, Goods, Transport, Other)

These worksheets contain all abatement wedge calculations, organized by consumption sector. Abatement wedges for both existing (and proposed) policies and additional consumption-based measures are calculated in the same worksheet, and sequenced according to the order in which they are calculated. Color coding is used to indicate which wedges are associated with existing and planned policies (green) and which are additional measures targeting consumption (blue).

The categories of consumption – and associated reference scenario emissions – included in each sector are listed at the top of each worksheet. These data are pulled in from the relevant "Reference" worksheets.

The settings and assumptions for all **existing and planned policies** are contained on the "Existing & Planned Policies" worksheet. This worksheet serves as a universal control panel, determining how the effects of existing and planned policies are modeled across all sectors and CBEI segments. (Note: Settings for enhanced building utilization and smaller home size wedges

[7] For this step, the number inhabitants per unit of new housing stock is assumed to be the same as the number per unit of existing housing stock.

are also contained on the "Existing & Planned Policies" worksheet, since these *could* be a component of existing programs like the Climate Friendly and Equitable Communities program. By default, however, these two wedges are treated as additional measures [not part of the CFEC or expanded smart growth policies] and are configured separately on the "Household Results" worksheet. Sections of the worksheet devoted to these measures are indicated by blue banners.)

The settings for additional measures are configured on the main "Results" worksheets (as described above). However, detailed assumptions – including references – behind the default settings are contained in each sector worksheet. In some cases, additional parameters (not selectable in the "Results" worksheets) may be configured on the sector worksheets as well. Configurable values are indicated by gray-colored "input" boxes – however, note that many of these are linked to the "Results" worksheet input boxes (so should not be permanently overwritten).

Summary data and "draft" charts are provided at the bottom of each sector worksheet. These data are pulled into the "Results" worksheets, so are provided only for reference.

2.3. Rebound emissions

So-called "rebound" emissions can occur when money saved by reducing consumption in one area is spent in other areas (which then generate their own emissions). The rebound is considered direct if savings are spent on a similar product within the same general consumption category. Reduced meat consumption, for example, typically translates to more spending on other types of food (although, to the extent other foods cost less per calorie than meat, some spending may be shifted to other types of consumption as well). Likewise, reducing private automobile use often translates to greater use of transit options. Indirect rebound occurs when money saved by reduced consumption is allocated more generally across several categories, i.e., there is not necessarily a discrete alternative. As the meat example suggests, rebounds can be both direct and indirect. Another example would be a household that replaces an inefficient furnace with a more efficient one and thereby saves hundreds of dollars annually in fuel costs. The household may respond by turning up their thermostat (which would be a direct rebound), using their savings to buy concert tickets (an indirect rebound), or some combination of the two.

Within the tool, where direct rebound is likely to occur, the type and magnitude of this rebound is configurable in conjunction with the specific abatement action. For example, for measures associated with reducing meat and dairy consumption, users can configure how spending is reallocated to other food categories. (A separate parameter specifies how much money consumers will save by undertaking these diets shifts; this is currently set to 33%, based on published research.[8])

For indirect rebound effects, monetary savings are assumed to be reallocated to a mix of all other consumption, in proportion to base year spending patterns. Rebound emissions are determined using the weighted average emissions intensity of all consumption (excluding disposal phase emissions, which are minor). **Emissions intensity, however, is recalculated for each year of the forecast period, taking into account the effects of existing/planned policies and additional measures that reduce the carbon intensity of consumption.** The reduction in intensity is calculated for different categories of consumption in each of the relevant sector worksheets.

This approach provides a simplified estimate of rebound emissions. One qualification is that the calculations do not reflect any reallocation of spending across categories resulting from consumption changes (which could change total weighted average emission intensity). Instead, any savings are assumed to be spent on all categories of consumption in proportion to base-year spending patterns.

Note that a reduction in consumption may not always be associated with an emissions rebound. Buying fewer, more durable goods, for example, may reduce consumption without any overall cost savings (since more durable goods may be more expensive). Thus, for goods consumption changes in particular, the expected cost savings associated with reduced consumption is a key input (based on assumptions about how reduced consumption is achieved).[9] Where relevant, the percent cost savings per unit of reduced consumption can be set in each of the "Results" worksheets.

2.4. Notes and caveats

A few caveats should be noted when using the tool and understanding its outputs.

[8] Springmann, M., Clark, M. A., Rayner, M., Scarborough, P. and Webb, P. (2021). The global and regional costs of healthy and sustainable dietary patterns: a modelling study. *The Lancet Planetary Health*, 5(11). e797–807. DOI:10.1016/S2542-5196(21)00251-5.

[9] It should also be noted that cost *increases* associated with some lower-carbon alternatives could have an "inverse rebound" effect – shifting spending *away* from other forms of consumption. These potential effects are not modeled.

2.4.1. Calculations are against reference scenario emissions, not base year

In using the tool, it is important to bear in mind that the effects of consumption changes are calculated against reference scenario values. Thus, if a user specifies a 30% reduction in air travel or goods consumption, for example, this will be calculated as a 30% reduction below reference levels – NOT a 30% reduction relative to base year levels (e.g., 2021) or the "initiation year" for the implemented change.

2.4.2. The tool provides simplified estimates of emission reductions

The tool's outputs illustrate potentially achievable consumption-based emission reductions, assuming relative changes in consumption. The outputs are not modeled forecasts. In particular, the tool does not model economic interactions, including shifts in production, supply chains, and emissions intensities, that might occur in response to major shifts in household, government, or business consumption. Using the tool is *not* equivalent to re-calculating Oregon's CBEI, for example, with different assumptions about prices, production methods, and consumption patterns. Nor are the results equivalent to applying a full consequential greenhouse gas accounting analysis. The tool should therefore be considered as a kind of "sketch tool" for exploring abatement potentials.

2.4.3. Assumptions are used to disaggregate emissions for some subcategories

The tool includes abatement options for some types of consumption that are represented in subcategories of Oregon's CBEI. In particular:

- Emissions associated with food consumption are a component of the emissions footprint of "restaurants." To apply measures such as "reducing meat consumption," the tool derives the proportion of emissions within "restaurants" that arises from food consumption using relative emission intensities. Specifically, the proportion is determined by assuming food consumed at restaurants has the same emissions intensity (kgCO2e/$ spent) as food consumed at home, and all other restaurant spending has the same emissions intensity as "other services" (a separate CBEI category). Thus, "reduced meat consumption" is applied to food purchases by households both in the supermarket and when eating out, but only affects a subset of restaurant emissions.
- Household air travel emissions are a component of "transportation services" emissions. From Oregon's CBEI model, we know that around 31% of 2021 household transportation service emissions arose from air travel. Of this, however,

the percentage attributable to passenger (non-freight) travel must be estimated. By default, the model assumes 75% of air travel is for passenger flights.[10]

2.4.4. Treatment of wholesale, retail, and disposal phase emissions

Because of the way Oregon's CBEI is constructed, it is not possible to attribute wholesale-, retail- and disposal-phase emissions to individual consumption categories. This means that the full abatement potential associated with some policies and measures is not captured in the wedge analysis. For example, measures that reduce consumption of goods will reduce not just embodied (production-phase) emissions, but also associated wholesale, retail, and disposal emissions. In the tool, however, **abatement wedges for reduced consumption will reflect only the reduction in production-phase emissions**. The "missing" abatement is typically not large for disposal-phase emissions (which are a small component of the total CBEI), but could be significant for wholesale and retail emissions arising from some consumption categories (e.g., goods or vehicles).

By the same token, some rebound emissions may go unaccounted for, since savings from reduced consumption could include some – unaccounted – savings in wholesale and retail expenditures. However, these savings may "wash out" if spending is shifted to other consumption with similar wholesale and retail footprints.

Note that existing policies affecting "upstream" energy consumption and emissions intensities (e.g., building codes, fuel economy standards, and electricity decarbonization policies) will also reduce wholesale and retail emissions. It is only measures involving a direct reduction in consumption whose effects are not reflected in the wholesale, retail, and disposal phases.

2.4.5. Incomplete accounting for existing policies and other climate action that may occur outside Oregon

The tool estimates the effects that some significant existing policies could have on Oregon's consumption-based greenhouse gas emissions. These include major state policies targeting building energy, transportation, electricity and fossil fuels, as well as federal fuel economy standards (CAFE) and high-GWP refrigerant phaseout requirements (under the U.S. AIM Act). However, the tool does not attempt to capture the effects of <u>all</u> policies and programs in

[10] Based on data in Cf. Bergero, C., Gosnell, G., Gielen, D., Kang, S., Bazilian, M. and Davis, S. J. (2023). Pathways to net-zero emissions from aviation. Nature Sustainability, 6(4). 404–14. DOI:10.1038/s41893-022-01046-9.

Oregon (e.g., energy efficiency programs could have impacts above and beyond the effects of Oregon's building codes), nor does it capture the potential effects of policies in other states, U.S. federal programs like the Inflation Reduction Act, or climate policies in other countries. Collectively, policies undertaken in the United States and around the world could lower consumption-based emissions in Oregon beyond what is illustrated in the tool (before any additional measures are undertaken). Furthermore, if the United States and other nations make good on their commitments under the Paris Agreement (which will require widespread adoption of *new* policies), Oregon's consumption-based emissions could decline rapidly over the next 25 years. A primary purpose of the tool is to illustrate how major existing policies, within the state and federally, could contribute to lowering Oregon's broader carbon footprint, while also illustrating how changes in consumption could contribute to further lowering this footprint, and aid wider efforts to decarbonize economies in the United States and globally.

2.5. Overview of existing and planned policies

The abatement scenario tool estimates the effects of major existing policies (state and federal) on Oregon's consumption-based emissions. An overview of these policies and how they are modeled is provided below. (This information is also provided in the "Existing Policy List" tab in the tool; configuration options for these policies can be changed on the "Existing Policy Settings" worksheet.)

Policy	Description	Modeling Assumptions
Climate Friendly Equitable Communities	The Climate-Friendly and Equitable Communities (CFEC) program aims to reduce climate pollution, provide more transportation and housing choices, and promote more equitable land use planning outcomes. The program strengthens Oregon's transportation and housing planning in regions with populations over 50,000 people (Albany, Bend, Corvallis, Eugene/Springfield, Grants Pass, Medford/Ashland, Portland Metro, and Salem/Keizer).	The CFEC could contribute to:[11] • Reduced travel demand, including fewer miles driven by cars • Reductions in per capita vehicle ownership • Reductions in required building & infrastructure construction The extent of each of these potential effects can be configured in the tool. As a default, the CFEC is assumed to result in: • A 5.5% reduction statewide in vehicle-miles traveled by households in private automobiles • A 3.5% reduction in statewide household vehicle ownership • A 10% reduction in material needed for new public infrastructure in CFEC communities (estimated at 59% of statewide population)

[11] "Smart growth"-style policies like the CFEC may also contribute to denser development, enhanced building utilization, and smaller average home sizes – all of which may lower consumption-based emissions. Enhanced building utilization and small home size are modeled as separate abatement measures, however, and not included under the CFEC or the additional measure of "expanded smart growth" (see next section, below).

		SEI developed these estimates after consultation with DLCD and ODOT staff, its own analysis, and consideration of independent studies of the effects of "smart growth" policies.[12]
Advanced Clean Cars II	This is an Oregon state policy that establishes light-duty electric vehicle sales targets. Specifically, by 2035, all new passenger cars, SUVs, and light-duty pickup trucks must either be battery electric or plug-in hybrid electric vehicles (EVs).	The tool estimates total EV penetration for light-duty vehicles by approximating stock turnover in Oregon's existing vehicle fleet (assuming an average 15-year useful lifespan). As a default, 25% of EV sales are assumed to be plug-in hybrids (PHEVs), and 25% of PHEV miles are assumed to be gasoline powered. The tool also accounts for increased production phase emissions associated with EV purchases, taking into account expected trends in embodied emissions over time.[13] For households and government, use-phase reductions greatly exceed the increase in embodied emissions. For capital investments, the Advanced Clean Cars policy results in a "negative" wedge of increased emissions, since use-phase emissions are not included.
Advanced Clean Trucks	Requires manufacturers of medium- and heavy- duty vehicles to sell a certain percentage of zero emission vehicles beginning with the 2025 vehicle model year (https://www.oregon.gov/deq/rulemaking/pages/ctr2021.aspx). Specifically, by 2035 new sales will be: Light Duty Truck: 75% ZEV -	The tool assumes 50% of new medium- and heavy-duty vehicle sales will be EVs starting in 2035 (maintained at that level thereafter). Total EV penetration is estimated by approximating stock turnover (also assuming a 15-year average lifespan). This policy ONLY affects upstream (three-phase) emissions, across all consumption categories. (The percentage of upstream emissions that arise from trucking in Oregon was calculated from the 2021 CBEI for each consumption category). The increase in embodied emissions for truck EVs is **not** accounted for, since this is difficult to quantify within the CBEI

[12] Reduced infrastructure requirements were estimated from Litman, T. (2024). *Understanding Smart Growth Savings: Evaluating Economic Savings and Benefits of Compact Development*. Victoria Transport Policy Institute, Victoria, British Columbia. https://vtpi.org/sg_save.pdf.

[13] Based on a UK study by Ricardo Energy & Environment (Ricardo Energy & Environment (2021). Lifecycle Analysis of UK Road Vehicles. United Kingdom Department of Transport. https://www.gov.uk/government/publications/lifecycle-analysis-of-uk-road-vehicles)

	Medium Duty Truck: 55% ZEV - Heavy Duty Truck: 40% ZEV	(and is unlikely to make a significant difference, given that this policy only affects upstream emissions).
Federal CAFE standards	Federal Corporate Average Fuel Economy (CAFE) standards require steadily increasing improvement in the fuel economy of automobiles and trucks.	CAFE standards set fleetwide average fuel economy benchmarks for vehicle manufacturers. In future years, meeting these benchmarks will require increasing sales of EVs. Since switching to EVs (within Oregon) is already captured in the tool under the Advanced Clean Cars and Trucks policies, the effect of CAFE is modeled *exclusively with respect to conventional vehicle fuel economy improvements*. The net effect of CAFE on conventional vehicle fuel economy is estimated using reference forecast data from the Energy Information Administration's Annual Energy Outlook report for 2023 (see "AEO fuel economy" worksheet in the tool). Since, over time, EVs will dominate Oregon's vehicle fleet, the size of the CAFE wedge declines over time. (However, it does not "disappear," because it assumed to continue to affect vehicles in the rest of the United States, where a separate transition to EVs is not modeled. Those vehicles contribute to Oregon's consumption-based emissions by virtue of their role in transporting intermediate and finished goods and in the provision of services.)
Oregon Clean Fuels Program	The Oregon Clean Fuels Program requires a reduction in transportation fuel carbon intensity. The program sets the following goals: 10% reduction by 2025 20% reduction by 2030 37% reduction by 2035 (https://www.oregon.gov/deq/ghgp/cfp/Pages/CFP-Overview.aspx)	While this program will achieve substantial overall reductions in greenhouse gas emissions from Oregon vehicles, compliance can be achieved through vehicle electrification, so the actual reduction in emission intensity of combusted *liquid fuels* is likely to be less

		than targeted reductions. The tool assumes a 10% reduction in liquid fuel carbon intensity by 2035.[14]
Oregon Building Codes (ORSC and OEESC)	The Oregon Energy Efficiency Specialty Code (OEESC) and Oregon Residential Specialty Code (ORSC) require a 60% reduction in energy use intensity (EUI) for new & renovated commercial and residential buildings (respectively) by 2030, compared to 2006. [An array of other policies and programs in Oregon – including appliance standards and Oregon's Energy Trust programs – are also likely to improve building energy efficiency over time. However, the effects of these programs above and beyond code requirements are difficult to estimate, and are not (currently) modeled. Building codes are expected to be the main driver of energy savings.]	The OEESC and ORSC are assumed to drive reductions in whole-building energy use intensity (EUI), affecting both appliance and lighting energy use. The expected reduction in EUI to be achieved by 2030 - relative to *2021* levels - is estimated at 39%, based on figures from the Oregon Building Codes Division.[15] To estimate total (statewide) energy and emissions reductions, the tool assumes the following: • The rate of new building construction & renovation is determined by demolition rates, population growth, and income growth (as described above in section 2.2.2). • No difference is assumed in the square footage of new construction, relative to prior years (this could be affected by other measures, like reducing average home size, but would be modeled as a separate effect) Effects are modeled for both upstream emissions (e.g., where Oregon buildings contribute to embodied emissions in products and services) and use-phase emissions, where relevant.

[14] This estimate was derived from data presented in Figure 8 of Rosenfeld, J. (2021). *2021 Illustrative Compliance Scenarios: Final Report*. ICF. https://www.oregon.gov/deq/ghgp/Documents/cfpIlluCompScenD.pdf.

[15] https://www.oregon.gov/bcd/boards/Documents/cieb-20221018-IVA-presentation.pdf

SB98 – renewable natural gas (RNG) portfolio requirement	SB98 requires large Oregon utilities to ensure that 30% of the natural gas they deliver is "renewable" (RNG) by 2050. Specifically, up to 5% must be RNG in each calendar year from 2020-2024, increasing every 5 years up to 30% for the years 2045-2050. In practice, only NW Natural qualifies as a "large utility."	The tool models SB98 by assuming RNG has zero emissions, and therefore the emissions intensity of natural gas delivered to residential, commercial, and industrial customers is reduced according to SB98's prescribed schedule. The effect on statewide emissions is prorated, given that NW Natural serves just under 80% of total gas customers in the state.[16]
HB 2021 – Clean energy targets	HB 2021 requires investor-owned utilities (IOUs) to reduce greenhouse gas emissions associated with the electricity they sell to Oregon consumers to: 80% below baseline (2019) emissions levels by 2030 90% below baseline emissions levels by 2035 100% below baseline emissions levels by 2040	The tool models a reduction in the carbon intensity of electricity, following the listed schedule for IOUs. IOUs generate around 80% of Oregon's electricity-related emissions. For the remaining 20% of emissions, emission intensity is estimated using forecasts from the U.S. EIA of the future CO_2 emissions intensity of the Northwest Power Pool.[17]

[16] https://www.nwceatlas.org/visualization/oregon-and-washington-natural-gas-utilities

[17] https://www.eia.gov/outlooks/aeo/data/browser/#/?id=62-AEO2023&region=5-23&cases=ref2023&start=2021&end=2050&f=A&linechart=ref2023-d020623a.5-62-AEO2023.5-23&map=&sourcekey=0

Federal AIM Act	The federal American Innovation and Manufacturing (AIM) act requires a phase down of U.S. production and consumption of hydrofluorocarbons (HFCs) by 85% over the next 15 years (starting 2021).	The tool models AIM as follows: • The phasedown of HFC consumption follows the schedule prescribed in the AIM Act.[18] • Substitute refrigerants are assumed to have a 70% lower global warming potential compared to replaced HFCs.[19] • Reductions in upstream (three-phase) refrigerant emissions directly follow the phasedown schedule.[20] • Reductions in *use-phase* refrigerant emissions are gradually achieved over time as existing equipment (using legacy HFCs) is eventually replaced, assuming a 12-year average lifetime (reflecting a mix of vehicle and building HVAC end uses).
PLANNED POLICY: Oregon Climate Protection Program (CPP)	The original CPP was declared invalid and DEQ is currently working to replace it. Adoption of a new CPP is not assured, and the new CPP may be designed differently from the original CPP, but for the purposes of this analysis we have estimated its effects as previously conceived.	The tool models the effects of the CPP by assuming a straight-line progression to a 90% reduction in Oregon natural gas emissions by 2050, relative to a 2017-2019 baseline. The effect is only modeled if, in any given year, it exceeds what would be required under SB98. In later years, it is assumed a 90% reduction could only be achieved through an absolute reduction in natural gas consumption (e.g., via electrification of end uses). The tool

[18] See https://uscode.house.gov/view.xhtml?req=granuleid:USC-prelim-title42-section7675(a)&num=0&edition=prelim

[19] Based on estimate provided here: https://www.clearesult.com/insights/rundown-of-refrigerant-restrictions. Actual reductions could be greater over time, as low- and zero-emitting substitutes (and equipment that can use them) become more widely available.

[20] This is because upstream, embodied refrigerant emissions are attributed to the consumption-based inventory at the time they are purchased as inputs, even though the emissions may not occur immediately.

		As previously promulgated, the CPP would have established a cap-and-trade system for natural gas and transportation fuel suppliers, and impose "best available emission reduction" (BAER) requirements for large stationary emitters of greenhouse gases (>25,000 MtCO2e/year). The cap would have required a 90% reduction in emissions from natural gas and transportation fuels by 2050.	assumes that renewable natural gas potential would be capped at the targets set by SB98, so any additional reductions would be met (effectively) through electrification. Electricity emissions are calculated assuming achievement of targets under HB2021, as described above. No change is assumed in emissions from fuel suppliers, since a transition to EVs is already assumed under advanced clean car & truck rules, and VMT reduction is assumed under CFEC. (Specifically, for the purposes of this analysis, we assumed the CPP could help ensure achievement of these other policies, but would not accelerate fuel switching or VMT reduction beyond them. This assumption would ultimately need to be verified through more detailed modeling.) The BAER requirements are not modeled, since these were not fully specified, and their effect is therefore difficult to predict.

2.6. Overview of additional measures

To assess the potential for further reducing consumption-based emissions, the tool is configured with 13 additional measures directly targeting consumption. Within the tool, these are mostly specified as *outcomes that could be achieved* (e.g., reductions in consumption, or shifts in consumption to lower-emitting alternatives), not specific policies or approaches that might produce these outcomes.[21] Potential policy approaches related to the outcomes are identified and evaluated in a separate analysis (see section 3). Table 2-3 lists the additional measures/outcomes included in the tool and identifies the section of the analysis where policy approaches are evaluated. Further details on each of the 13 additional measures/outcomes and how they are modeled are provided below.

As noted in section 2.2.1, these additional measures may in some cases facilitate the achievement of existing policies (e.g., by reducing building and transportation energy demand) but will also reduce consumption-based emissions beyond what could be achieved by existing and planned policies.

Table 2-3. Additional measures targeting consumption-based emissions

Additional measures/outcomes	**Evaluation of potential policy approaches for achieving outcomes**
1. Expanded smart growth polices	Expanded smart growth (Section 3.4)
2. Enhanced building utilization	Enhanced building utilization (Section 3.5)
3. Smaller new home construction	Smaller new home construction (Section 3.6)
4. Reduced embodied emissions in new construction	Reduced embodied emissions in new construction (Section 3.7)
5. Reduced non-farm food waste	Reduced food waste – household level (Section 3.8) Reduced food waste - manufacturing, retail, and food service level (Section 3.9)

[21] The one exception is "expanded smart growth programs," which is modeled as a range of potential outcomes related to urban form (such as reduced travel demand, vehicle ownership, and urban infrastructure needs).

6. Reduced meat consumption 7. Reduced dairy consumption	Reduced meat and dairy consumption (Section 3.10)
8. Lower-emission meat and dairy consumption	Shift to lower-emission meat and dairy products (Section 3.11)
9. Reduced clothing consumption	Reduced clothing consumption (Section 3.12)
10. Reduced electronics consumption	Reduced electronics consumption (Section 3.13)
11. Reduced appliances and furnishings consumption	Reduced appliance and furnishings consumption (Section 3.14)
12. Lighter weight cars	Lighter weight cars (Section 3.15)
13. Reduced air travel	Reduced air travel (Section 3.16)

2.6.1. Cross-Cutting Measures

Additional measure	Description	Modeling assumptions
1. Expanded smart growth policies	This is an assumed expansion of smart growth programs (similar to the CFEC), e.g., deepening measures to make communities more accessible, reduce vehicle-miles traveled, boost public and active transit options, and promote greater density and multi-family housing. These programs could be implemented more widely, e.g., covering all urban areas in the state.	Expanded smart growth programs are modeled in the same way as the existing CFEC policy, but with deeper reductions in car ownership, vehicle-miles traveled in cars, and new urban infrastructure demand – and covering more urban area (67% of the state population, in contrast to 59% covered by CFEC).[22] By default, the tool models expanded smart growth policies as producing: • A 19% reduction statewide in vehicle-miles traveled by households in private automobiles • A 14% reduction in statewide household vehicle ownership • A 20% reduction in material needed for new public infrastructure in targeted communities (estimated at 67% of statewide population) As with CFEC assumptions, SEI developed these estimates after consultation with DLCD and ODOT staff, its own analysis, and consideration of independent studies of the effects of "smart growth" policies .[23]

[22] Expanded smart growth policies could also include policies that drive greater utilization of existing buildings and smaller home construction. In the tool, these are both modeled independently as separate, additional measures (they are represented as separate abatement wedges).

[23] Reduced infrastructure requirements were estimated from Litman, T. (2024). *Understanding Smart Growth Savings: Evaluating Economic Savings and Benefits of Compact Development*. Victoria Transport Policy Institute, Victoria, British Columbia. https://vtpi.org/sg_save.pdf.

2.6.2. Built Environment

Additional measure	Description	Modeling assumptions
2. Enhanced building utilization	Some new building construction could be avoided by intensifying existing building use. This measure applies to new home construction, new government building construction, and new capital building construction. For new *housing* units in existing buildings, the tool assumes smaller average dwelling sizes as well, leading to reduced energy and goods consumption (relative to the reference scenario).	As a default, the tool applies the following assumptions: • Enhanced utilization occurs in urban areas (potentially affecting approximately 67% of all new building construction) • Feasible uptake is limited. Within targeted areas, the rate of *avoided* new construction peaks at around 10% of all new construction between 2030 and 2037, and declines thereafter (as potential space available for enhanced utilization is assumed to decline). • Combining enhanced utilization with reductions in the average size of new dwelling units results in a 38% reduction in home energy consumption and a 19% reduction in household consumption of major goods (specifically, "other" appliances and furnishings).[24] These reductions result in costs savings, which lead to rebound emissions. (Note: The tool does not model the dynamics of local real estate markets, or include location-specific estimates of available building space that could be adaptively reused or utilized more intensively. Results may be considered

[24] These estimates parallel estimates for the effect of building smaller new homes (assessed as a separate measure).

		indicative of the magnitude of emission reduction potential over time, but they do not reflect a bottom-up analysis of utilization potential.)
3. Smaller new home construction	For new home construction in urban areas that is *not* avoided through utilization of existing buildings, the tool separately models the effect of building smaller, so that fewer construction materials are needed. Smaller dwelling units will also have lower energy consumption on average, and lead to less consumption of household goods. Note: This measure applies to household (private) home construction, not government construction (e.g., affordable housing projects), which is assumed to already be efficiently sized.	As a default, the tool estimates that reducing the average size of new home size will lead to a 20% reduction in embodied carbon, relative to the reference case, by 2030 (starting in 2025).[25] This reduction is applied to all new home construction in urban areas (estimated at 67% of <u>all</u> new home construction), after taking into account any construction that was avoided due to enhanced building utilization. In addition, the tool assumes that reducing the average size of new dwelling units (once targets are fully achieved by 2030) results in a 38% reduction in home energy consumption and a 19% reduction in household consumption of major goods (specifically, "other" appliances and furnishings).[26] These reductions result in costs savings, which lead to rebound emissions.
4. Reduced embodied emissions in	Construction- and renovation-related greenhouse gas emissions (arising primarily from production of materials) are a significant component of the "carbon	The tool models this measure as a "whole project" embodied carbon reduction, affecting both new building and infrastructure construction, and applying to household, government, and business capital

[25] This was derived from the results of a 2010 study for DEQ by Quantis, assuming a switch from "medium" sized new homes (~2,300 square feet) to a mix of smaller homes (~1,150 square feet) and multi-family dwellings (also ~1,150 square feet per unit). Cf. Oregon Department of Environmental Quality (2010). *A Life Cycle Approach to Prioritizing Methods of Preventing Waste from the Residential Construction Sector in the State of Oregon: Phase II Report*. Quantis, Earth Advantage, and Oregon Home Builders Association for the Oregon DEQ, Portland. https://www.oregon.gov/deq/FilterDocs/ADU-ResBldgLCA-Report.pdf.

[26] These estimates were derived from the same 2010 Quantis study (footnote 25).

new construction	footprint" of buildings and infrastructure. These emissions could be substantially reduced by reducing materials where appropriate (e.g., using structure as a finish material), substituting lower carbon materials for high carbon materials, and utilizing lower carbon options for a select material. This abatement wedge is modeled *subsequent* to all other wedges, for both existing and additional measures. The wedge therefore reflects reductions in embodied carbon above and beyond any reductions in supply chain emissions due to existing policies.	construction. Reductions occur according to the following schedule, declining linearly in interim years where relevant:[27] • 2025: 10% reduction • 2026: 15% reduction • 2027: 20% reduction • 2028: 25% reduction • 2029: 30% reduction • 2034: 40% reduction • 2039: 50% reduction • 2044: 60% reduction • 2049: 80% reduction • 2050: 90% reduction No cost savings are assumed, so these reductions do not result in rebound emissions.

[27] This schedule was derived in consultation DEQ staff, and based on technical potential studies, including: Esau, R., Jungclaus, M., Olgyay, V. and Rempher, A. (2021). *Reducing Embodied Carbon in Buildings: Low Cost, High Value Opportunities*. Rocky Mountain Institute; and SSG (2022). *Oregon Resilient Efficient Buildings - Policy Modeling Report*. State of Oregon. https://olis.oregonlegislature.gov/liz/2021I1/Downloads/CommitteeMeetingDocument/258717.

2.6.3. Food

Additional measure	Description	Modeling assumptions
5. Reduced non-farm food waste	Food is a major source of Oregon's consumption-based greenhouse gas emissions, and in the United States approximately 38% of food that is produced goes unsold or uneaten.[28] Reducing non-farm food waste has the potential to achieve significant reductions in consumption-based emissions.	Based on data from ReFED, the tool assumes that 31% of all produced food is effectively wasted in manufacturing, the food service and restaurant industries, and by households (around 18% occurs at the household level, and 13% is other non-farm food waste). The tool further assumes that by 2030 (and thereafter):[29] • 30% of household-level food waste could be avoided • 40% of food waste occurring in manufacturing, food services, and restaurants (associated with household consumption) could be avoided • 40% of food waste associated with government consumption could be avoided[30] Reduced food waste is assumed to generate cost savings, which also result in some rebound emissions.
6. Reduced meat consumption	Meat production (and red meat in particular) is highly greenhouse gas intensive. Studies have consistently found that reducing meat and dairy consumption would be one of the most effective ways to reduce agricultural greenhouse gas emissions, and to reduce consumption-based emissions in general.	The tool models the effect on emissions of switching from meat consumption (both "poultry and eggs" as well as "other meat" and "other animal product" consumption) to other types of food. Several assumptions are applied: • Meat, poultry, and egg consumption accounts for about

		7% of restaurant consumption-based emissions[31] • Meat consumption could be reduced by 50%, and poultry and eggs by 30%, by 2050, with this shift starting in 2025 • Meat (and egg) consumption would be shifted to a mix of other food categories (one third fruit & vegetables, one third grains and cereals, and one third seafood) • Reducing meat consumption would result in food cost savings of 33%,[32] which will lead to some rebound spending and emissions These same assumptions are applied to both household and government meat consumption.

[28] https://refed.org/food-waste/the-problem/#overview

[29] These estimates were derived from ReFED's "insights engine" (https://refed.org/) and consultation with DEQ staff.

[30] Food waste associated with government food consumption is assumed to be 13% (equivalent to industry-wide non-farm, non-household food waste).

[31] This was derived from Oregon's CBEI, assuming that the food component of restaurant emissions has the same emissions intensity (kg CO_2e/$) as household food consumption, and the proportion of meat, poultry, and eggs (relative to other foods) consumed in restaurants is equal to the proportion consumed at home.

[32] Estimated based on Springmann, M., Clark, M. A., Rayner, M., Scarborough, P. and Webb, P. (2021). The global and regional costs of healthy and sustainable dietary patterns: a modelling study. *The Lancet Planetary Health*, 5(11). e797–807. DOI:10.1016/S2542-5196(21)00251-5.

7. Reduced dairy consumption	Like meat, dairy production is also highly greenhouse gas intensive. Reducing dairy consumption is therefore another way to significantly reduce emissions from food consumption.	The tool models the effect on emissions of switching from dairy product consumption to other types of food. Several assumptions are applied: • Dairy consumption accounts for about 3% of restaurant consumption-based emissions[33] • Dairy consumption could be reduced by 30% by 2050, with this shift starting in 2025 • Dairy consumption would be shifted to a mix of other food categories (20% beverages, 40% fruit & vegetables, and 40% grains and cereals) • Like meat, reducing dairy consumption would result in food cost savings of 33%, which will lead to some rebound spending and emissions These same assumptions are applied to both household and government dairy consumption.
8. Lower-emission meat and	While directly reducing meat and dairy consumption could be highly effective at reducing emissions, eliminating consumption of these foods could be difficult. Additional reductions could be achieved by	As a default, the tool assumes the following: • Enteric methane emissions associated with meat and dairy

[33] This was derived from Oregon's CBEI, assuming that the food component of restaurant emissions has the same emissions intensity (kg CO_2e/$) as household food consumption, and the proportion of dairy (relative to other foods) consumed in restaurants is equal to the proportion consumed at home.

dairy consumption	shifting to lower-emission alternatives *within* these food categories, such as consuming sustainably produced beef and dairy products with a lower greenhouse gas footprint compared to conventional production methods.	production could be reduced by 25% by 2050, starting in 2025[34] • Manure management methane and N_2O emissions from meat and dairy production could be reduced by 50% by 2050, starting in 2025[35] The same assumptions are applied to household and government meat and dairy consumption. The tool assumes there are no cost savings associated with lower-emission alternatives, so no rebound emissions occur.

2.6.4. Goods

Additional measure	Description	Modeling assumptions
9. Reduced clothing consumption	Clothing accounts for around 1% of total household consumption-based emissions (all phases), and stands out as a single category of "goods" consumption. This measure models the effect of reducing clothing consumption, e.g., by avoiding low-quality "fast fashion" options.	By default, the tool assumes the following: • Clothing consumption could be reduced by 30% by 2035, starting in 2025[36] • This would be achieved primarily by shifting to higher quality, more

[34] Based on Smith, P., Martino, D., Cai, Z., Gwary, D., Janzen, H., et al. (2008). Greenhouse gas mitigation in agriculture. Philosophical Transactions of the Royal Society B: Biological Sciences, 363(1492). 789–813. DOI:10.1098/rstb.2007.2184.

[35] Based on https://enst.umd.edu/sites/enst.umd.edu/files/files/documents/Extension/Anaerobic-Digest_GHG-Impact_UW.pdf

[36] Based on a lower end of the range assumed in C40 Cities, Arup, and University of Leeds (2019). *The Future of Urban Consumption in a 1.5°C World*. C40 Cities. https://www.arup.com/perspectives/publications/research/section/the-future-of-urban-consumption-in-a-1-5c-world.

		durable clothing, resulting in limited cost savings per unit of 10% (i.e., only 10% of the reduction would be achieved through simply procuring fewer clothing items). This leads to only a limited rebound effect. These assumptions are applied to both household and government consumption.
10. Reduced electronics consumption	There may be limited potential for reducing electronics *usage* (which could result in lower use-phase emissions). However, through design improvements and extended producer responsibility measures, electronic products could be designed to be purchased less frequently, leading to a reduction in consumption-based emissions.	By default, the tool assumes the following: • Electronics consumption could be reduced by 33% by 2035, starting in 2025[37] • On a per unit basis, reduced consumption of electronics would lead to a 50% cost savings (assuming products with greater longevity would have a relatively low cost premium, and/or some consumers might choose to keep current products for longer). This leads to some rebound emissions. These assumptions are applied to both household and government consumption.
11. Reduced appliances and	As with electronics, this measure assumes there is limited potential for reducing appliance usage, but	By default, the tool assumes the following: • Appliances and furnishings consumption could be reduced by

[37] Based on C40 Cities, Arup, and University of Leeds (2019). *The Future of Urban Consumption in a 1.5°C World*. C40 Cities. https://www.arup.com/perspectives/publications/research/section/the-future-of-urban-consumption-in-a-1-5c-world.

furnishings consumption	that appliances could be purchased less frequently (e.g., due to higher quality / greater durability).	25% by 2040, starting in 2025[38] (equivalent to extending usable lifetime by one third) • On a per unit basis, reduced consumption of major appliances and furnishings would lead to a 10% cost savings. This leads to limited rebound emissions. These assumptions are applied to both household and government consumption.

2.6.5. Transport

Additional measure	Description	Modeling assumptions
12. Lighter weight cars	Although climate policymakers tend to focus on use-phase greenhouse gas emissions from vehicles, emissions from vehicle *production* are non-trivial, contributing to more emissions than those from lighting and computers combined, and surpassing emissions from meat and dairy consumption individually. Households have increasingly preferred larger trucks and SUVs in the last few decades, leading to an increase in both use- and production-	By default, the tool assumes the following: • For households, new car purchases would shift from 45% sedans (the 2021 value) to 75% sedans by 2045, starting in 2025 (reducing the percentage of SUVs and light trucks to 25%)

[38] Based on a less aggressive version of assumptions applied in Erickson, P., Chandler, C. and Lazarus, M. (2012). *Reducing Greenhouse Gas Emissions Associated with Consumption: A Methodology for Scenario Analysis*. Working Paper 2012-05. Stockholm Environment Institute (U.S.), Seattle, WA. https://www.sei.org/publications/reducing-greenhouse-gas-emissions-associated-with-consumption-a-methodology-for-scenario-analysis/.

	related emissions. Reversing this trend could significantly improve fuel economy and reduce embodied vehicle emissions.	• Sedans weigh about 33% less than their SUV/light truck counterparts,[39] translating to a proportional 33% reduction in embodied emissions. • Sedans cost 28% less than their SUV/light truck counterparts,[40] leading to cost savings and rebound emissions. • Sedans use 29% less fuel than their SUV/light truck counterparts,[41] leading to a proportional reduction in use-phase vehicle emissions associated with new cars.[42] Savings in fuel/energy costs will also produce rebound emissions.
13. Reduced air travel	Compared to other forms of consumption, air travel is highly emissions intensive. This measure models the effect of reducing household air travel (passenger flights).	By default, the tool assumes: • Household air travel accounts for 23% of "transportation service"

[39] Based on data from Table 1 in Woody, M., Vaishnav, P., Keoleian, G. A., Kleine, R. D., Kim, H. C., Anderson, J. E. and Wallington, T. J. (2022). The role of pickup truck electrification in the decarbonization of light-duty vehicles. Environmental Research Letters, 17(3). 034031. DOI:10.1088/1748-9326/ac5142.

[40] Based on a comparison of 2021 costs of midsize sedans and midsize SUV / pickup trucks, from data here: https://www.moneygeek.com/insurance/auto/average-price-of-a-new-car/

[41] Based on data from the Energy Information Administration's Annual Energy Outlook report for 2023.

[42] The tool assumes a 15-year lifetime for household vehicles.

		emissions in Oregon's 2021 CBEI (calculated from CBEI detail data)[43] • Household air travel could be reduced by 20% by 2050, starting in 2025[44] • Reducing air travel would result in cost savings, leading to rebound emissions (but still yielding net reductions).

[43] All air travel (passenger and freight) accounts for 31% of "transportation service" emissions. We estimate about 75% of this amount is associated with passenger travel, based on Bergero, C., Gosnell, G., Gielen, D., Kang, S., Bazilian, M. and Davis, S. J. (2023). Pathways to net-zero emissions from aviation. Nature Sustainability, 6(4). 404–14. DOI:10.1038/s41893-022-01046-9.

[44] For reference, the IEA's "net zero" scenario assumes air travel emissions could be reduced by 50% by 2050 due to behavioral change & reduced demand (including keeping long-haul flights at 2019 levels, and switching to high-speed rail).

3. Identification and Evaluation of Abatement Options

SEI conducted a comprehensive review of options for reducing consumption-based greenhouse gas emissions, and identified a subset of options that could be applied in Oregon. Major options were identified at the level of "outcomes" that could be achieved, such as reducing food waste, reducing embodied carbon in new construction, or shifting consumption to less emissions-intensive meat and dairy products. The process SEI undertook to screen and identify options is described in section 3.1.

Once targeted outcomes were identified, SEI identified *potential policy approaches* for achieving each of the outcomes. A typology of policy tools was developed to categorize common approaches across different sectors of consumption (section 3.2).

SEI then conducted qualitative evaluations of the identified policy approaches against a common set of criteria (e.g., likelihood of emissions impact, cost-effectiveness, and economic, environmental, and societal impacts). The framework for conducting these evaluations is described in section 3.3. Evaluations of policy approaches related to the 13 major outcomes identified are presented in sections 3.4 to 3.16.

Note: as indicated in Table 2-3, the outcomes evaluated do not precisely match the outcomes modeled in the abatement wedge analysis under work product #1. Specifically, reduced meat and dairy consumption were modeled as separate abatement wedges, but policy approaches for achieving these outcomes were evaluated together as a single package (section 3.10). Conversely, reducing non-farm food waste was modeled as a single abatement wedge, but evaluations were conducted for two distinct elements of this outcome: reducing household-level food waste and reducing (non-farm) supply chain food waste (sections 3.8 and 3.9). The correspondence between evaluated outcomes and modeled abatement wedges in indicated in Table 2-3.

SEI also identified several options that were deemed worthy of consideration, but for which time and resources did not allow for a full assessment. These options received higher-level summaries and evaluations, as presented in section 3.17.

3.1. Review of options for reducing consumption-based emissions

This section summarizes SEI's approach to identifying possible targeted outcomes – along with actions and measures to achieve these outcomes – for reducing consumption-based greenhouse gas emissions in Oregon. As indicated above, SEI defined *outcomes* as major changes in household or government consumption that would reduce emissions, such as reducing food waste, reducing embodied carbon in new construction, or shifting consumption to less emissions-intensive meat and dairy products. *Actions* were defined as specific changes in consumer behavior that could contribute to achieving these outcomes, such as purchasing more imperfect or soon-to-expire produce, or choosing a healthier, less meat-heavy diet. Finally, *potential policy approaches* were identified that could induce or encourage identified actions.

The exercise described below produced a list of 38 possible outcomes (i.e.,); a longer list of specific actions that could contribute to achieving those outcomes; and preliminary lists of government policies and programs that could induce, incentivize, or require emission-reducing actions.

3.1.1. Identification of initial list of outcomes, actions, and policy options

To compile an initial list of options, SEI consulted multiple sources, including academic and grey literature, that provide lists of specific actions, measures, and/or consumer behaviors that could reduce consumption-based emissions (as opposed to broad policy approaches - see references section, below). One challenge in compiling such a list is that different studies define options at different levels of detail and aggregation. The initial list reflected the diversity found in the literature, covering both broad actions as well as (in some cases) very specific kinds of consumer behavior change or policy interventions.

Another challenge is that the literature does not always distinguish between broad *outcomes* to be achieved, consumer *actions* that could realize or contribute to those outcomes, and different types of *policies, measures, or programs* that could drive or induce those actions. The initial list SEI compiled organized options into a taxonomy along these lines.

SEI also mapped its initial list onto categories of consumption found in Oregon's consumption-based emissions inventory (CBEI). Some major categories of consumption are not covered by any of the outcomes or actions SEI identified. These include services, healthcare, and "other" emissions. Partly, this reflects their lack of coverage in the literature SEI consulted, which mostly targets material and energy consumption. However, it also reflects the nature of these consumption categories. First, they tend to have low emissions *intensity* (embodied emissions per dollar spent). In short, these are categories for which *increased* consumption could help to lower total consumption-based emissions, to the extent consumption is shifted *away* from goods and energy with higher embodied emissions. Second, services and healthcare offer fewer options for discretionary shifts or reductions in spending. The West Coast Climate Forum identifies several strategies for *governments* to procure lower-carbon professional services.[45] For governments, however, these services may include energy- and emissions-intensive activities like transportation and construction, which are reflected in other CBEI categories. Options for addressing household services and healthcare emissions, from a consumer perspective, are likely to be more limited.

A subset of the "other" category includes direct use of petroleum and mineral products, for which emissions intensity is relatively high. However, these subcategories are a very small component of Oregon's total CBEI (for both households and government). Specific options for reducing "other" emissions are therefore not further considered.

Finally, few of the options identified would target transportation service, wholesale, or retail emissions *as distinct consumption categories*. A handful of identified actions would address transportation service emissions by, for example, shifting consumption to locally sourced food, goods, or materials (or reducing consumption of aviation services). Where relevant, these options were grouped under major categories of primary consumption (e.g., food, goods, or transportation), not in the transportation service or wholesale/retail categories.

3.1.2. Recommendations for further evaluation

The initial list of options was intended to provide a comprehensive overview of possible outcomes, actions, and policies that Oregon could pursue to reduce consumption-based emissions across multiple "sectors," or major categories of consumption. Options were identified across the following categories:

- **Buildings and infrastructure** (including emissions from construction and building energy use)
- **Food** (including at restaurants and institutions)
- **Clothing**
- **Goods** (including durable goods, electronics, appliances, media, and materials)
- **Transport** (including embodied and energy-use emissions, from all modes including aviation)
- **Waste**

[45] http://westcoastclimateforum.com/cfpt/professionalservices

- **Multiple sectors** (for options that could reduce overall consumption, or across multiple categories)

SEI recommended that only a subset be considered for further evaluation. This "short list" included the following:

- All options (outcomes, actions, and policies) for reducing embodied emissions in buildings and infrastructure.
- Options for adopting healthier diets, reducing meat and dairy consumption, and reducing household and supply chain food waste.
- Options for reducing clothing consumption.
- Options for reducing purchases of new goods (including appliances) and for purchasing goods with lower lifecycle emissions. (Some options may be worth considering only for certain categories of goods and materials, such as major durable goods.)
- Options for reducing car ownership, buying lighter vehicles, and reducing airplane flights.

For all options, SEI took note of policy and program approaches that could be used to achieve them. Specific identification of policy approaches and their evaluation, however, were conducted separately. The initial screening focused on targeted outcomes to be achieved.

3.1.3. Criteria for prioritizing options

The following criteria were applied to prioritize options for further evaluation:

- **Focus on reducing embodied (three-phase) emissions**. Many studies of options for reducing consumption-based emissions include actions that would reduce use-phase emissions, e.g., from energy consumption in buildings, appliances, and vehicles. This makes sense, given that direct energy consumption is a major component of most CBEIs (including Oregon's, where use-phase emissions are nearly 30% of total CBE). Furthermore, there are many ways to reduce these emissions involving consumer behavioral change (e.g., turning off lights, or turning down thermostats) that may not be the focus of "conventional" energy sector policies, and which could be included (for example) in broader efforts to shift consumption norms. However, for this project the assumption was that these emissions will be sufficiently addressed through conventional energy sector policies in Oregon. SEI therefore recommended focusing on options for which the primary goal is reducing embodied emissions. Some of these options may also promote lower energy consumption (e.g., reducing home size or vehicle ownership), but they would not typically be the subject of conventional policies for reducing state greenhouse gas emissions.
- **Expected abatement potential**. A holistic approach might leave nothing off the table in terms of consumption changes, even minor ones, that could reduce emissions; many

small changes could in principle yield large results. For the purpose of prioritizing actions and making policy recommendations, however, the preference was for options that could significantly reduce emissions. For this initial screen, therefore, some options were recommended for less consideration because of their relatively small abatement potential. A related consideration is the emissions intensity of targeted consumption. Some options were deprioritized if they primarily target goods (e.g., media and office supplies) with relatively low emissions intensities, and therefore might not significantly reduce emissions (especially once potential rebound effects are considered).

- **Ability for Oregon government and residents to influence emissions**. Some options that could significantly reduce consumption-based emissions involve changes in production methods or supply chains. In principle, final consumers (households or government buyers) could promote these changes through their purchasing decisions, if they had the ability to discriminate between similar products with lower or higher lifecycle emissions. For some types of goods and services, however, this may be easier than for others. For example, some studies suggest there is significant potential for reducing supply chain waste in clothing and textiles production. However, because production-phase emissions for clothing occur almost entirely in foreign countries, there may be limited capacity for Oregon to require direct supply chain interventions that might reduce emissions.

3.1.4. Recommendation details

The following sections provide more detail on which CBE abatement options were initially recommended for further evaluation, and which ones were initially identified for less consideration.

3.1.4.1. Buildings and infrastructure

Home construction is a significant (>6%) source of embodied emissions for Oregon households, and non-residential construction is a very significant source of embodied emissions (>36%) for Oregon government consumption. There is significant potential for reducing these emissions, and this is already a priority program area for the Oregon DEQ. SEI recommended prioritizing all identified approaches (targeted outcomes) for reducing embodied emissions, along with associated actions.

SEI also identified a range of consumption-oriented options for reducing the emissions from energy use in buildings. These were deprioritized because they are already the subject of state energy policies.

Options included for further evaluation

Targeted outcome
Enhanced building utilization
Smaller (new) homes
Improved materials efficiency
Switch to low-carbon cement/concrete

Options identified for more limited evaluation

Targeted outcome
Switch to lower carbon alternative materials for building construction (e.g. timber instead of concrete)
Shift to lower-GWP refrigerants
Reduce refrigerant leakage

Deprioritized options

Targeted outcome
Reuse building components
Energy efficient building design and technologies
Switch to non-fossil fuel technologies
Adopt energy-reducing behaviors

3.1.4.2. Food

In 2021, food and beverage consumption contributed more to embodied greenhouse gas emissions than any other category in Oregon's household CBEI (about 29% of household three-phase emissions). It is also a significant category for government consumption (contributing to about 17% of three-phase emissions in 2021). Significant reduction opportunities exist, including through shifting diets away from (highly emissions-intensive) meat and dairy products and reducing food waste. While changing food consumption habits can be a challenge for public policy, it is worth exploring options for doing so, and for reducing both household and supply chain food waste. Food packaging efficiency and recycling options were deprioritized due to their limited potential for reducing greenhouse gas emissions (although these measures could contribute to other environmental benefits).

Options included for further evaluation

Targeted outcome
Lower dairy consumption
Lower meat consumption
Reduce consumer food waste
Reduce supply chain (including retail) food waste

Options identified for more limited evaluation

Targeted outcome
Substitute food with sustainable and lower carbon alternatives (within same category)
Divert food waste from landfills

Deprioritized options

Targeted outcome
Consume more nutritious foods
Households eat more at home
Food packaging: Improve materials efficiency
Food packaging: recycle packaging

3.1.4.3. Other Goods

Consumption of various types of goods is a significant source of embodied emissions for both households and governments. In terms of prioritization, a key focus should be on durable manufactured goods with higher emissions intensities. These include appliances, "other" electronics, furnishings and supplies (other than media and office supplies), and other manufactured goods. In addition, clothing consumption stands out as a notable source of embodied emissions, comprising 2.5% of all production-phase emissions associated with household consumption in 2021.

Options included for further evaluation

Targeted outcome
Optimize lifetimes of electronic equipment
Reduce the purchase of new major appliances and furnishings
Reduce the purchase of new clothing

Options identified for more limited evaluation

Targeted outcome
Shift to goods with lower-carbon supply chains
Use goods with recycled material

Deprioritized options

Targeted outcome
Reduce consumption of materials (consumables)
Reduce supply chain waste (e.g., pre-consumer textile waste)
Switch to alternative clothing materials

3.1.4.4. Transport

In 2021, vehicle use-phase emissions amounted to 23.5% of Oregon's entire consumption-based emissions inventory. SEI recommended deprioritizing outcomes and actions related to use-phase emissions, however, because they are already targeted by Oregon state and local policies. *Embodied* emissions in household and government vehicles are still significant, however, and could be reduced through multiple measures (some of which overlap or correlate with measures that might reduce vehicle usage, like reducing car ownership for households).

In addition, aviation is a significant component of household "transportation service" emissions. Given the prominence of aviation in many discussions about consumption-based emissions, SEI recommended further evaluation of options to reduce air travel.

Options included for further evaluation

Targeted outcome
Increase material efficiency of vehicles
Reduce car ownership
Reduce number of flights

Deprioritized options

Targeted outcome
Fuel switching and fuel efficiency
Reduce vehicle miles traveled
Increase adoption of sustainable aviation fuel
Increase car lifespans

3.1.4.5. Waste

Many actions that reduce consumption will also reduce waste. In the literature it reviewed, SEI identified one distinct possible outcome related to reducing waste emissions: diverting waste from landfills (e.g., through increased recycling, or organic waste diversion programs). SEI recommended conducting a lighter evaluation of this option because it is already the target of Oregon state and local policies (although those policies could be expanded).

3.1.4.6. Multi-sector approaches

SEI identified two "multi-sector" options that could warrant further consideration.

The first was the pursuit (or enhancement of) "smart growth" policies in Oregon (similar to the Climate Friendly and Equitable Communities program). One challenge is that "smart growth" is an umbrella term for what could be a wide range of different interventions with varying effects. Urban form is a key element, but so are (or could be) transit services, provision of local services and amenities, etc. As such, one concern was that it could be difficult to define and evaluate this option in the same manner as others – however, see further discussion and evaluation in section 3.4.

The second option was a "four-day work week" policy. Like smart growth, however, a concern was that it could be difficult to evaluate this option in the same manner as other options. It was ultimately dropped from evaluation, though it could be considered further as way to address systemic barriers to more sustainable consumption – see discussion paper in section 5.2.

3.1.5. References consulted

SEI consulted multiple sources to identify options for reducing consumption-based emissions. A selected list sources in academic and gray literature is provided below.

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3.2. Typology of consumption-based emissions policies

A wide range of policy tools and approaches could be deployed to achieve reductions in consumption-based greenhouse gas emissions. The specific mix of policies will vary by the type of *outcome* that is targeted, i.e., targeted shifts or changes in consumption of materials, food, goods, and services.

To evaluate the feasibility, costs, and potential impacts of achieving different outcomes, SEI identified a set of policies that would likely be needed to achieve them. SEI grouped these policies into several broad categories based on their general approach (e.g., educating or informing consumer behavior, incentivizing change, or steering consumption to lower-emitting alternatives through regulation or public investment). The following typology describes these categories and provides illustrative examples. Specific policy measures under each category are identified in conjunction with each targeted outcome.

Not all policy approaches are relevant to all kinds of outcomes. Reliably achieving most outcomes, however, will require combining multiple policies of the sorts identified here.

3.2.1. Types of policies targeting household (and business) consumption

3.2.1.1. Outreach and education

Outreach and education measures seek to educate the public (consumers and businesses) about the environmental footprint of consumption and encourage environmentally friendly behaviors, in general or with respect to specific kinds of products or services. Measures can include education campaigns (including advertising, outreach events, and informational programs); efforts to collect and disseminate information on specific product impacts, such as embodied greenhouse gas emissions (but without requiring product labels); and training programs aimed at promoting low-carbon procurement practices, or waste reduction, efficiency, or other decarbonization measures in manufacturing or business operations. Outreach and education measures can be effective at raising awareness and shifting some consumer behavior, but they are generally most effective when combined with other policy approaches.

Some examples:

- Campaigns to encourage local tourism (rather than flying).
- Campaigns to increase awareness of food waste impacts and inform consumers on strategies for reducing waste.
- Collecting and disseminating information on the embodied emissions (and other environmental impacts) of construction materials.

3.2.1.2. Information disclosure

Information disclosure policies require or incentivize accurate communication by producers of the environmental impacts associated with their products and services. Although they are a form of consumer education, the key difference is that they obligate *producers* to provide information relevant to changing consumer behavior. Through product labelling, relevant information can potentially reach a wider consumer audience. In addition, information disclosure often encourages *producers* to pre-emptively reduce the impact of their products.[46]

Illustrative examples:

- Standards, incentives, mandates to disclose environmental impacts to consumers, e.g., through environmental product declarations – or EPDs – for construction materials or appliances.
- Marketing standards that regulate what producers can, or must, communicate about the environmental footprint of their products.

3.2.1.3. Product regulations & standards

Product regulations and standards go a step further and *require* that products and services meet environmental performance benchmarks. These types of policies can take several forms, but in general ensure that consumers are only able to purchase products and services that meet minimum requirements for sustainability or embodied emissions.

Illustrative examples:

- Embodied carbon standards (for products, construction materials, etc.), including embodied carbon limits in building codes.
- Extended warranty requirements (which encourage greater durability, thereby reducing the need for repeat purchases).
- Product stewardship requirements, including the formation of producer responsibility organizations (PROs)[47].

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[46] See, for example, this study from the Oregon Department of Environmental Quality: https://www.oregon.gov/deq/FilterDocs/QuantisPEFResearchReport.pdf. Notable examples of disclosure requirements that have induced producers to mitigate their impacts include the federal Toxic Release Inventory program (e.g., https://www2.census.gov/ces/wp/2013/CES-WP-13-07.pdf) and state hydraulic fracturing disclosure requirements (e.g., https://epic.uchicago.edu/news/transparency-in-hydraulic-fracturing-operations-leads-to-reduced-pollution).

[47] Oregon has already pioneered such PRO programs; see for example (https://www.oregon.gov/deq/rulemaking/Documents/rec2023m13faq.pdf). Although this example is

- Product bans or sales restrictions, based on environmental impacts.

3.2.1.4. Financial incentives

Financial incentive policies seek to change consumption by making environmentally friendly (lower emitting) consumption choices more financially attractive, or making environmentally impactful options less attractive. They can take many forms, including various forms of subsidies, along with taxes, fees, and charges. Taxes and fees impose additional costs on consumers, but the revenues they generate can be used to alleviate costs for lower-income households and to invest in other measures that help to lower greenhouse gas emissions.

Illustrative examples:

- Tax rebates or permitting waivers for low-carbon, energy efficient building designs.
- Carbon "performance grants" for new construction that subsidize use of low-carbon materials.
- Food waste charges or penalties (e.g., at restaurants or grocery stores).
- Removal of subsidies for emissions-intensive products (e.g., meat and dairy products).
- Subsidies for low-emitting alternatives (e.g., lighter weight, electric vehicles).
- Taxes on products or services with high embodied emissions.

3.2.1.5. Zoning and land use policies

Zoning and land use policies are a sub-class of regulatory policies focused on the built environment. A wide range of zoning and land use policies could be deployed to reduce both the material intensity of urban development and embodied carbon in urban buildings and infrastructure. Zoning and land use also heavily influence transportation demand, which affects consumption of both energy and vehicles.

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limited to packaging, food service-ware, and printing and writing paper, and the PRO's obligations focus primarily on recycling, the concept could be applied to other types of products (in addition to other extended producer responsibility laws in Oregon addressing paint, electronics, mattresses and waste pharmaceuticals) and/or could require the PRO to implement programming more directly related to reductions of greenhouse gas emissions. Indeed, this example already incorporates two precedent-setting sets of requirements largely unrelated to recycling: dedicated funding to reduce environmental impacts of covered products through means other than waste recovery (see https://www.oregon.gov/deq/recycling/pages/impact-reduction-and-reuse.aspx) and standards, incentives and mandates for the disclosure, evaluation, and reduction of life cycle environmental impacts (see https://www.oregon.gov/deq/recycling/Pages/Life-Cycle-Impact-Evaluation.aspx and https://ormswd2.synergydcs.com/HPRMWebDrawer/Record/6660667/File/document).

Illustrative examples:

- Zoning for more compact, accessible, mixed-use development.
- Zoning for more multi-unit dwellings.
- Setting embodied carbon targets in zoning requirements.
- Reforming parking requirements for new buildings.
- (Re)zoning to promote infill development.
- Removing minimum size restrictions to allow for smaller homes / housing units.
- Setting local home size limits.

3.2.1.6. Other regulatory requirements

Other kinds of regulation may have a role to play in reducing consumption-based emissions, including policies that require businesses and organization to implement emission-reducing programs or other measures.

Illustrative examples:

- Requirements on food service providers to implement food waste prevention and recovery programs.
- Requirements for employers to implement commute trip reduction programs.

3.2.1.7. Public investment

Governments can influence consumption choices both through the provision of public infrastructure and financial support for programs that enable reduced consumption and/or purchase of low-carbon alternatives.

Illustrative examples:

- Infrastructure investments that enable lower-carbon activities and consumption (e.g., transit infrastructure, walking and cycling infrastructure, IT infrastructure to enable telecommuting, etc.).
- Provision of amenities like accessible parks and greenspaces, or facilities for sharing tools and other goods, etc.
- Provision of transit services.
- Financial support for programs that reduce waste or promote product sharing, reuse, or repair.

3.2.2. Types of policies targeting government consumption

Government is itself a significant consumer of material, goods, and services in Oregon. Government agencies can implement policies that reduce waste and avoid unnecessary consumption, and require or encourage the use of low-carbon products and construction materials. Government policies may also play an important signaling and education role that could influence wider consumption behaviors (such as shifting to lower-carbon food alternatives).

3.2.2.1. Public procurement standards & requirements

Public procurement standards and requirements, such as Oregon's Buy Clean program (HB 4139, 2022) which requires ODOT to collect EPDs for concrete, asphalt and steel, can have a significant impact on consumption-based emissions for government construction projects and other areas of government consumption. Options here include parallels to information disclosure and product standard policies targeted at household consumption.

Illustrative examples:

- Requiring EPDs for construction materials used in government construction projects (both buildings and infrastructure).
- Setting embodied carbon limits for construction projects standards, or for other types of major government purchases.
- Establishing other types of procurement standards (e.g., related to product design, longevity, warranties, etc.).
- Procuring (and offering) fewer meat and dairy options in government food service.

3.2.2.2. Internal policies and programs

A multitude of options are possible here. Some illustrative examples include:

- Government waste reduction programs (for food and/or products and materials).
- Guidelines encouraging use of lower-emitting travel modes for government employees.
- Public employee commute reduction programs.

3.3. Evaluation framework

Oregon has a wide range of options for reducing consumption-based greenhouse gas emissions. To characterize these options, SEI identified a set of 13 specific *outcomes* that could be targeted by state and local government policies (see section 2 and sections 3.4 through 3.16). Outcomes are changes in consumption within different sectors or categories (e.g., the built environment, food, goods, or transportation) that could lead to greenhouse gas emission reductions. In general, targeted outcomes involve:

1. Reducing consumption of carbon-intensive materials, foods, goods, or services; and/or
2. Consuming lower-carbon alternatives for materials, food, goods, or services.

Not all targeted outcomes may be equally achievable, nor will they yield equivalent levels of greenhouse gas reductions. Furthermore, different outcomes will have different costs and benefits for consumers and businesses, and will differ in terms of their economic, environmental, and societal impacts. Prioritizing among the identified outcomes is important as Oregon considers how to reduce its consumption-based emissions.

For most outcomes, a range of different *policy tools and approaches* could be deployed to achieve them. Some approaches may be more effective and/or feasible than others, and policy tools may differ with respect to likely impact, ease of implementation, cost-effectiveness, and co-benefits or impacts. Separately evaluating every possible combination of policies would require extensive time and resources. To make evaluation and prioritization more tractable, for each outcome SEI assumed implementation of *a potential set of policies with at least some track record of application in Oregon or other jurisdictions*. For example, many policies promoting "smart growth" urban development have been adopted in some form around the world (including in Oregon), and SEI assumed these could be feasibly pursued and scaled. By contrast, few if any jurisdictions have imposed outright bans on high-impact consumer goods, so in most cases such policies were excluded from evaluation.

Bearing this approach in mind, SEI evaluated each outcome according to a common set of criteria:

1. **Likelihood and durability of impact**. Given the potential set of policies for achieving the outcome, how likely is it that significant greenhouse gas emission reductions could be achieved and sustained over time?
2. **Ease of implementation and enforceability**. How easy would it be to implement and enforce the potential set of policies needed to realize the outcome?
3. **Cost-effectiveness**. Would implementing the potential set of policies be a cost-effective way to reduce greenhouse gas emissions, considering the costs or savings that these policies might generate for consumers and businesses?
4. **Economic, environmental, and social impacts**. What impacts would implementing the potential set of policies have on equity, jobs, health in Oregon, and on the environment both within and outside Oregon?

For each criterion, SEI provided short narrative evaluations along with a score from 1 to 3. The scoring system and meaning of each score is further described below.

As much as possible, SEI's evaluations were informed by published data and literature pertaining to each outcome, and to the potential set of policies identified. Where relevant, SEI has provided citations to consulted sources. The evaluations also benefited from review and input from subject matter experts at the Oregon Department of Environmental Quality. Ultimately, however, the evaluations reflect SEI's professional judgment, based on available information and the expertise of SEI staff. They should be viewed as indicative of the potential challenges and opportunities associated with pursuing potential policies.

3.3.1. Likelihood and durability of impact

Whether potential emission reductions are achieved, especially over the longer term, can depend on a variety of factors, including whether a potential action "locks in" consumption change through capital investments (e.g., by constructing smaller, more energy efficient homes) or induces changes in consumer preferences (which may be malleable over time).

Score	Interpretation
1	Emission reductions depend on ongoing and maintained shifts in consumption choices, with policies providing few direct financial or structural incentives (e.g., they rely mostly on education campaigns or information disclosure). Durability depends mostly on the "staying power" of shifts in consumer choice.
2	Emission reductions depend on ongoing shifts in consumption choices, but this is achieved by maintaining financial or structural incentives (e.g., subsidizing transit service and increasing its provision to make it a more attractive option). Effects are likely to be durable so long as policies are maintained.
3	Emission reductions are "locked in" by technology choices, structural conditions (e.g., smaller house size), or new infrastructure that drive changes in consumption, and whose effects will persist even if policies are no longer maintained. (Removing policies, however, may forgo future opportunities to lock in additional reductions.)

3.3.2. Ease of implementation and enforceability

Some policies may be easier to adopt and implement than others. Variables here include technical feasibility, political receptivity, and possible consumer or business resistance.

3.3.2.1. Implementation

Score	Interpretation
1	Difficult to implement. The potential policies are largely untested in Oregon and would require significant new investment and development of new skills or capacities, and/or would adversely affect well-established consumer or business practices.
2	Average. Effort would be required for implementation, but the policies are well understood and/or extensions of existing policy frameworks and approaches.
3	Easy implementation. Policies rely on familiar approaches and would be welcomed by consumers, businesses, and governmental agencies.

3.3.2.2. Enforceability

Score	Interpretation
1	Compliance with policies is difficult to achieve, monitor and/or verify.
2	Compliance is relatively easy to monitor and verify (e.g., through audits or spot checks)
3	Enforcement is not necessary, or compliance is highly likely without significant oversight or monitoring.

3.3.3. Cost-effectiveness

Policies may differ in terms of the costs they impose on (or savings they generate for) consumers or businesses. This criterion looks only at direct costs (or savings) *that accrue to the actors targeted* by the potential set of policies. Externalities and social costs or benefits are therefore not included, nor does the criterion consider costs to government for policy design, development, administration, and enforcement. Equity considerations (such as whether costs disproportionately benefit or burden certain groups of people) are evaluated separately, below.

Score	Interpretation
1	Policies will require significant direct costs to implement, and/or impose significant costs on businesses and consumers.
2	Policies are cost-efficient and neither raise or lower costs for businesses and consumers.
3	Policies are not excessively costly to implement and will likely result in cost savings to businesses and consumers.

3.3.4. Economic, environmental, and societal impacts

Policies that reduce consumption-based emissions may have multiple co-benefits, as well as potential negative impacts. These are assessed along four dimensions: equity, job impacts, health impacts, and environmental impacts.

3.3.4.1. Equity considerations

Score	Interpretation
1	Policies are likely to be regressive (i.e., disproportionately burdening lower income households and/or frontline communities OR disproportionately benefitting higher incomes households). Careful policy design will be needed to address regressivity.
2	Policies could be regressive to some degree, but regressive impacts could be easily addressed.
3	No concerns about regressivity, or policies are likely to be progressive in their effects (e.g., benefitting mostly lower-income households, or higher income households would bear more cost burden).

3.3.4.2. Job impacts

Score	Interpretation
1	Policy implementation could lead to net job losses in Oregon, or significant retraining and transitioning of workforces may be required to shift to other sectors.
2	Policy implementation is unlikely to affect employment in Oregon, or any job losses are likely to be balanced by growth in similar job opportunities. Some accommodation may be required to retrain or transition existing workforces.
3	Policy implementation could lead to new employment and job growth in Oregon (without any significant job losses).

3.3.4.3. Health impacts

Score	Interpretation
1	Policy implementation could adversely affect human health in Oregon, e.g., through greater exposure to pollution or toxicants, or encouraging unhealthy behaviors (including food consumption).
2	Policy implementation is unlikely to adversely affect human health in Oregon.
3	Policy implementation could lead to health benefits for Oregonians.

3.3.4.4. Environmental impacts

Score	Interpretation
1	Policy implementation could lead to increased pollution or environmental degradation, in Oregon and/or elsewhere.
2	Policy implementation is unlikely to have significant environmental impacts, positive or negative, other than reducing greenhouse gas emissions.
3	Policy implementation is likely to contribute to positive environmental outcomes (reduced pollution or preservation of natural resources), in Oregon and/or elsewhere.

3.4. Expanded smart growth

"Smart growth" is an umbrella term for more compact, accessible, multi-use, and less auto-dependent development in urban areas, including both infill and greenfield development (Litman 2024; OECD 2012).[48] Specific outcomes associated with smart growth – in terms of urban form, housing size and density, accessibility, and mix of transportation modes – may differ from community to community. Likewise, there is no single policy approach or tool for promoting smart growth (Litman 2023). That said, smart growth is associated with a range of outcomes that would reduce consumption-based greenhouse gas emissions, including fewer vehicle-miles traveled in cars; reduced car ownership; fewer materials required for construction of housing and urban infrastructure; and reduced goods consumption (which correlates with smaller average home sizes). Two *related* outcomes – and specific policies for achieving them – have been evaluated separately for this project: enhanced building utilization and smaller new home sizes. This review provides a holistic evaluation of smart growth policies, evaluating their potential effects and outcomes on consumption at an aggregate level.

Note that Oregon is already actively promoting smart growth-style policies in the state's eight major metropolitan regions (>50,000 population) under the Climate Friendly and Equitable Communities program.[49] Additional smart growth policies and programs could enhance the CFEC's benefits and potentially contribute to additional reductions in Oregon's consumption-based greenhouse gas emissions.

3.4.1. Potential policy approaches

There is no single policy tool or approach for promoting smart growth; rather, successful strategies involve an array of zoning policies, regulations, incentives, and public investment that encourage development of more compact, accessible neighborhoods and communities. Most of these policy approaches are within the jurisdiction of local (or metro area) governments, although state agencies – including, but not limited to, the Department of Land Conservation and Development – will have important supporting and enabling roles to play (Litman 2023; Broekhoff et al. 2018). A broad (but not exhaustive) list of policy approaches covering multiple facets of smart growth development could include:

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[48] The term "smart growth" is used to distinguish this form of development from both urban sprawl and negative forms of urban densification that fail to address accessibility and provision of public amenities.

[49] https://www.oregon.gov/lcd/cl/pages/cfec.aspx

Zoning and land use policies[50]	• Zone for more multi-unit dwellings • Increase allowable densities, height, and mix, especially near existing water, energy, and transport infrastructure • Remove or reduce minimum size restrictions to allow for smaller homes / housing units • Lower or remove minimum parking requirements or move to market-based approaches to parking capacity[51] • Emphasize accessibility (not just mobility) in designing transportation systems, including accommodation for transit and non-motorized travel
Financial incentives	• Lower taxes and or development fees for smaller, more space-efficient housing • Offer density bonuses for new development • Charge higher fees for utility and public services in more dispersed locations • Adopt split-rate property taxes (charging a higher rate for land, lower for buildings/improvements) • Raise property taxes for vacant or under-occupied properties • Implement congestion pricing in central urban areas • Provide tax credits to businesses implementing projects that reduce work-related travel or commuting[52]
Public investment	• Choose accessible locations and designs for government offices, schools, and public housing • Provide enhanced transit services • Invest in non-motorized transportation infrastructure • Support or implement commute-trip reduction and car-sharing programs
Regulation	• Require employers to implement commute-trip reduction policies[53]

[50] Oregon has for many years required cities to implement "urban growth boundaries" (UGBs) that have reduced sprawl and protected forest and farmland (https://www.oregon.gov/lcd/up/pages/ugbs-and-urbanrural-reserves.aspx). The policies listed here could complement this approach, fostering greater density and accessibility within UGBs.

[51] Note that Oregon has already adopted a parking reform law (OAR 660-012-0400 through 0450); see summary here: https://www.oregon.gov/lcd/CL/Documents/ParkingReformOverview.pdf.

[52] Oregon has provided such tax credits in the past, under the Business Energy Tax Credit program, as described in Litman (2023), p. 77.

[53] Oregon's Employee Commute Options program already requires this for larger employers in the Portland area: https://www.oregon.gov/deq/aq/programs/pages/eco.aspx

Litman (2023) provides a more detailed and comprehensive list of policy tools and approaches for promoting smart growth (including examples from Oregon).

3.4.2. Greenhouse gas reduction potential

Study assumptions: Depending on the specific set of policies deployed, smart growth could reduce consumption-based emissions in multiple ways. Major sources of emission reductions (roughly in order of highest to lowest potential magnitude) include:

- **Reducing private automobile travel (distance and number of trips)**. The CFEC is expected to result in a 5.5% per capita reduction in vehicle-miles traveled statewide,[54] which could achieve net reductions in household transport emissions of 4.9% per year once fully implemented (before accounting for other emission reduction measures, such as shifting to electric vehicles and decarbonizing electricity).[55] Under an expanded smart growth program (similar to CFEC, but expanded in scope and with a full suite of supporting policies), statewide VMT per capita could be reduced by up to 19%, yielding emission reductions of nearly 17%.[56]
- **Reducing the need for car ownership**. On average, Oregonians own about 2.5 cars per household. Smart growth could alleviate the need for owning as many cars, reducing the number of vehicle purchases and thus embodied emissions associated with vehicle manufacturing. Thus, in addition to reducing travel demand, we estimate CFEC could result in a 3.5% reduction in vehicle embodied emissions per year by 2050, with expanded smart growth policies increasing this amount to 14%.[57]
- **Reducing construction materials needed for public infrastructure**. More compact communities can mean that fewer materials (like steel and concrete) are needed for road construction and other public infrastructure. Under the CFEC, reduced demand for

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[54] SEI estimate based on consultation with DLCD and ODOT staff, SEI's own analysis, and consideration of independent studies of the effects of "smart growth" policies.

[55] Some emissions are shifted to public transit, yielding less than a full 5.5% reduction in emissions.

[56] SEI estimate based on consultation with DLCD and ODOT staff, SEI's own analysis, and consideration of independent studies of the effects of "smart growth" policies..

[57] These estimates were derived from analysis by Martin Brown at the Oregon Department of Environmental Quality, using data from the CoolClimate Network (https://coolclimate.org/).

infrastructure construction could avoid embodied emissions of up to 6% per year by 2050; and an expanded smart growth program could avoid up to 13% of these emissions.[58]

- ***Reducing home energy demand***. More compact, accessible communities typically have a greater prevalence of smaller houses and multi-family dwellings, which can translate to reduced energy usage per household. For this project, we estimated these potential reductions in energy-related emissions separately, in relation to measures targeting enhanced building usage and smaller home sizes (which are both separately evaluated).
- **Reducing goods consumption**. Smaller average dwelling sizes can also translate to lower goods consumption, as households accumulate less "stuff." For this project, we estimated these potential reductions in embodied emissions separately, in relation measures targeting enhanced building usage and smaller home sizes (both separately evaluated).

Rebound potential: Some emissions rebound can be expected from smart growth policies. Although smart growth may have mixed effects on housing affordability (Ewing et al. 2016), it can be expected to result in cost savings (and therefore rebound emissions) related to household transportation costs, energy, and goods consumption. Modeling for this project suggests rebound emissions would be moderate (on the order of 13% of direct reductions between 2025 and 2050), since average emission intensities (emissions per dollar of savings) for energy consumption (both transportation and housing), vehicle purchases, and major durable goods are all greater than the average for other goods and services purchased by Oregon households.

Emissions reduction potential: *Looking only at effects on vehicle miles traveled, reduced car ownership, and reduced public infrastructure needs*, we estimate that expanded smart growth policies could – when combined with other measures[59] – contribute to the following greenhouse gas emission reductions *above and beyond* those that might be achieved by the CFEC program:

	Metric tons CO_2e	% reduction from reference case
Annual emission reduction[1] in 2050	2,102,000	1.6%
Cumulative emissions reductions[1] between 2021 and 2050[2]	22,560,000	0.7%

[58] These estimates are derived from Litman (2024), Table ES-4, assuming smart growth policies would affect around 59% (CFEC) and 67% (expanded policies) of public infrastructure requirements.

[59] Emission reduction estimates account for interactions between different assessed measures, and so do not reflect potential reductions if each outcome were achieved in isolation. See section 2.2 for a description of the methodology used and the sequencing of abatement measures.

[1] Emission reductions are net of rebound effects, and represent reductions below reference case emissions, derived from a simplified projection of current trends.
[2] Expanded smart growth policies are modeled to begin implementation in 2030, reaching full effect by 2045.

3.4.3. Evaluation

The following is a high-level evaluation of potential smart growth impacts, assuming a broad suite of policy approaches aligned with the measures identified above.

3.4.3.1. Likelihood and durability of impact

Evaluation	Score
Smart growth is highly likely to result in greenhouse gas emission reductions associated with vehicle use and ownership (Busch et al. 2015; Replogle and Fulton 2014; Cambridge Systematics 2009; Seto et al. 2014), and in embodied emissions from construction materials (Deuskar et al. 2021). It is also highly correlated with lower building energy use (Güneralp et al. 2017; Osorio et al. 2017; Jones and Kammen 2014). Evidence for lower goods consumption is more limited, but can be inferred from studies correlating consumption based emissions with urban location and home size (Jones and Kammen 2014; Jones and Kammen 2015). Emission reductions are likely to be highly durable, since they arise in large part from changes in urban form.	3

3.4.3.2. Ease of implementation and enforceability

Criteria	Evaluation	Score
Implementation	Implementing a full suite of smart growth policies, comprehensively and consistently, and at comparable levels of ambition across Oregon's major metropolitan regions could be a difficult implementation challenge (score of 1). However, the individual types of policies needed are well understood, have been implemented successfully in different combinations in multiple jurisdictions in the US and around the world – and many are already being implemented in Oregon. Pursued in a phased approach over time, implementation is feasible (score of 2).	1-2
Enforceability	Enforceability will vary significantly depending on the types of policy instruments being used. Some measures require no enforcement; others require regular auditing and oversight. However, few pose challenges in terms of monitoring and achieving compliance.	2

3.4.3.3. Cost-effectiveness

Evaluation	Score
Smart growth policies can entail some implementation costs, and require adjustments in housing and infrastructure development. However, there is abundant evidence that smart growth policies are cost-effective at a societal level, as they can (among other things) lower household transportation and energy costs, and lower the cost of public infrastructure (Litman 2024; Busch et al. 2015).	3

3.4.3.4. Economic, environmental, and societal impacts

Criteria	Evaluation	Score
Equity	Smart growth may be associated with multiple outcomes that contribute to greater equity, including provision of more affordable, efficient housing, lower transportation costs for many households, and increased economic opportunities (including for non-drivers) (Litman 2024) (score of 3). At the same, some policies that promote smart growth objectives – such as congestion pricing and increased taxes or utility fees for more dispersed development – could have regressive impacts that require amelioration (score of 1). On balance, carefully designed policies could be expected to yield equity benefits.	2-3
Jobs	While little evidence exists on the job *creation* effects of smart growth, studies suggest that more compact urban design – especially if associated with mixed-use development that increases the concentration of jobs (number of jobs per acre of land) – is associated with great opportunity and upward mobility (Ewing et al. 2016).	2
Health	Multiple studies suggest that smart growth, by encouraging more active transport (walking and cycling), can contribute to improved public fitness and health, and also reduce traffic fatalities (Litman 2024).	3
Environment	By reducing energy consumption for transportation and in buildings, reducing the need for construction materials, and alleviating land use pressures, smart growth policies can contribute to multiple environmental co-benefits, including reduced air pollution, reduced impacts associated with resource extraction and material manufacturing, and preservation of open space, agriculture, and forestry resources.	3

3.4.4. Addressing government consumption

As already noted above, smart growth policies could contribute to a reduction in materials and resources needed for public infrastructure. In addition, government agencies could set internal policies to ensure smart growth-compatible development of public housing and government buildings.

3.4.5. Addressing business capital investment

Smart growth policies can contribute to more compact, efficient development and location of commercial buildings as well as residential. With appropriate policies and incentives, reductions in material needed for non-residential building construction (a component of business/capital consumption) may be another benefit of smart growth policies.

3.4.6. References

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3.5. Enhanced building utilization

Oregon currently has a significant vacant building stock, with a 23.2 percent vacancy rate for office buildings in Portland,[60] and a 47 percent vacancy rate in upper stories of downtown retail buildings in smaller communities across the state (Community Planning Workshop 2022). Converting these spaces and utilizing them for residential housing (or other uses when housing is not feasible) could reduce the need for new construction. Similarly, modification of existing (non-vacant) building stock to more intensive uses or shared uses could also reduce future construction demand. This could include modification of existing housing stock, e.g., by converting single-family homes to duplexes, or creating internal accessory dwelling units (ADUs) through conversion of existing spaces such as attics, basements, and garages. Intensifying existing building use could avoid embodied emissions from new construction and – if space efficiency is emphasized – contribute to lower household, business, and government energy use and goods consumption. Enhanced building utilization could be pursued in conjunction with policies to promote smaller *new* home construction to significantly reduce the carbon footprint of Oregon households.

3.5.1. Potential policy approaches

Repurposing vacant office space for housing often requires investment in remediation (e.g., removing lead and asbestos), additional systems, and seismic upgrades to meet standards for occupant health and life safety. For main street upper story conversions, the primary cost barriers are elevators/ADA compliance, fire/life safety and seismic upgrades (Community Planning Workshop, 2022). Intensifying use of non-vacant office or residential buildings may entail permitting and renovation costs. Policies to support all of these approaches could focus on subsidizing the costs of remediation and other upgrades.

Enhanced building utilization would ideally be pursued as part of broader "smart growth" strategies – such as Oregon's Climate Friendly and Equitably Communities (CFEC) program – that promote greater density, provide more housing choices and more transportation choices, promote equitable land use outcomes, and preserve environmental resources. Key policy levers *specific* to enhancing building utilization would include:

Zoning and land use policies	• Rezone for more multi-unit dwellings, including rooming houses, in both existing residential zones and formerly commercial-only areas (Durning 2013) • Increase allowable densities, height, and mix near existing water, energy, and transport infrastructure (CNCA et al. 2021)

[60] https://mktgdocs.cbre.com/2299/c940fe2b-c163-49d3-bd73-b2ac38052fa2-2455804233.pdf

	• Remove or reduce minimum size restrictions to allow for smaller homes or housing units • Allow construction of internal ADUs • Boost home occupancy limits (Durning 2013) • Allow for multi-tenant leases (e.g., where tenants use buildings on alternate workdays or split the same workspace) • Establish a state-wide deconstruction ordinance (which could incentivize adaptive reuse over demolition and rebuilding)
Financial incentives	• Provide tax breaks or other incentives to pay down remediation and other upgrade costs for converting existing buildings to residential and other uses • Lower taxes and or development fees for converting or reconfiguring existing buildings to create smaller, more space-efficient housing units • Incentivize hybrid and remote work policies that allow for better utilization of existing building stock through multi-tenant leases • Provide a matching fund for preservation of existing buildings • Raise property taxes for vacant or under-occupied properties

3.5.2. Greenhouse gas reduction potential

Study assumptions: In the analysis conducted for this project, we assumed that enhanced building utilization could be pursued in urban areas, and therefore potentially affect around 67% of all new building construction. We assumed feasible uptake would be limited, however, with the rate of avoided new construction peaking at around 10% of all new construction in urban areas between 2030 and 2037, and declining thereafter (as potential space available for enhanced utilization is assumed to decline). Finally, we assumed enhanced utilization would yield smaller average dwelling sizes, resulting in a 38% reduction in home energy consumption and 19% reduction in major household goods consumption, compared to new construction in the reference case.[61] (Additional emissions reductions – e.g., associated with reduced vehicle use from reusing existing buildings near transit – could also be achieved if enhanced utilization were pursued in conjunction with broader smart growth policies. These potential effects are assessed separately, under the evaluation of expanded smart growth.)

Rebound potential: Greenhouse gas emission reductions may be partially offset by rebound. Reuse of existing buildings is typically more costly than new construction (Wilkerson et al. 2024).

[61] These figures were derived from the results of a 2010 study for DEQ by Quantis (Oregon Department of Environmental Quality 2010), assuming a switch from "medium" sized new homes (~2,300 square feet) to a mix of smaller homes (~1,150 square feet) and multi-family dwelling s(also ~1,150 square feet per unit).

However, savings on energy and goods consumption (assuming smaller dwelling size relative to reference scenario housing) could be significant and lead to increased spending on other forms of consumption. Because the bulk of emission reductions arise from avoided construction, however, this effect would be small, amounting to less than 1.5% of cumulative emission reductions.

Emissions reduction potential: Altogether, we estimate enhanced building utilization could – when combined with other measures[62] – contribute to the following greenhouse gas emission reductions:

	Metric tons CO_2e	% reduction from reference case
Annual emission reduction[1] in 2050	110,000	0.08%
Cumulative emissions reductions[1] between 2021 and 2050[2]	4,919,000	0.14%

[1] Emission reductions are net of rebound effects, and represent reductions below reference case emissions, derived from a simplified projection of current trends.
[2] Enhanced building utilization policies are modeled to begin implementation in 2025, and effects peak around 2030-2037; because of this annual emission reductions are greater in earlier years than in 2050.

3.5.3. Evaluation

For evaluation purposes, we assume a mix of zoning policies and financial incentives (including tax increases) to achieve enhanced building utilization.

3.5.3.1. Likelihood and durability of impact

Evaluation	Score
Policy approaches that combine zoning requirements with financial incentives are highly likely to be effective (CNCA et al. 2021). The total magnitude of achievable emission reductions is somewhat uncertain, given multiple possible effects (e.g., reduced embodied emissions, along with reduced energy and goods consumption). However, the effects will be highly durable given that intensifying existing building use will "lock in" these reductions – they are not dependent, for example, on maintaining ongoing discretionary consumption behaviors.	3

[62] Emission reduction estimates account for interactions between different assessed measures, and so do not reflect potential reductions if each outcome were achieved in isolation. See section 2.2 for a description of the methodology used and the sequencing of abatement measures.

3.5.3.2. Ease of implementation and enforceability

Criteria	Evaluation	Score
Implementation	These policies could require effort and determination to implement. Statewide, implementation would require coordinated efforts across multiple local jurisdictions (as under the CFEC program), with possibly varying levels of implementation. Developers and building owners could benefit from (and therefore welcome) incentive policies; some communities may resist greater multi-unit housing (and other types of building-use intensification), especially if not accompanied by policies to improve neighborhood accessibility and alleviate traffic burdens (Litman 2023).	2
Enforceability	Highly enforceable at local levels. Statewide coordination (ensuring similarly ambitious policies across jurisdictions) could be more challenging.	2

3.5.3.3. Cost-effectiveness

Evaluation	Score
Enhanced building utilization focused on smaller housing units, or more efficient use of existing building stock for other uses, could reduce per-unit and per-square foot costs and yield both direct cost savings to households, businesses, and government as well as market-wide cost savings from greater housing supply (Andersen 2019; Mast 2019). However, given conversion, remediation, and other improvement costs, it is not clear that enhanced utilization will always yield cost savings.	2

3.5.3.4. Economic, environmental, and societal impacts

Criteria	Evaluation	Score
Equity	Policies designed to promote enhanced building utilization for residential purposes are likely to be progressive, e.g., by increasing housing affordability for lower income households (Mast 2019). Adversely affected households (e.g., those affected by vacancy taxes) are more likely to be wealthier. In addition, reductions in pollution associated with less material production can benefit frontline communities (in Oregon and elsewhere) and avoid contributing to forced labor around the world (Lewis et al. 2021; Oregon Department of Environmental Quality 2023).	3
Jobs	These policies are expected to have little to no effect on employment in Oregon; jobs in new construction may be shifted to jobs in	2

	building conversion and remediation. Lower material and goods consumption could lead to job losses in some sectors, mostly outside of Oregon.	
Health	Although no direct health impacts from these policies are expected for Oregonians, living in smaller dwellings (to the extent this results from more intense building use) can correlate with greater well-being and happiness for some households (Hague 2019; Kristian 2017). Associated reductions in pollution (see below) could also yield indirect health benefits, within and outside Oregon.	2
Environment	In addition to reducing greenhouse gas emissions, avoiding new home construction could correlate with a range of other environmental benefits, including reduced impacts from production and use of construction materials (Oregon Department of Environmental Quality 2023; CNCA et al. 2021), and a range of reduced environmental impacts from reduced consumption of household goods and materials. More efficient use of building space could also result in energy savings, which may translate to reduced air pollution. Finally, enhanced building utilization pursued in conjunction with other "smart growth" policies could yield a range of environmental benefits associated with higher urban densities (see separate evaluation of smart growth outcomes).	3

3.5.4. Addressing government consumption

Government agencies in Oregon could contribute to efforts to enhance building utilization by (1) maximizing efficient use of space in existing government buildings (including reconfiguration to allow more intensive use); (2) requiring use of available space in existing buildings before building new buildings/facilities for government use; and (3) facilitating conversion of unused or (under-used) government buildings for residential (or commercial) use. The greenhouse gas reduction potential associated with these efforts is smaller than for enhanced utilization for residential or commercial purposes, but government efforts could have a significant signaling effect.

3.5.5. Addressing business capital investment

Because of high commercial vacancy rates and a shortage of housing supply, the greatest near-term opportunity for enhancing building utilization is likely to be adaptive reuse for residential purposes. However, there may still be potential for enhancing commercial building space as well. Many of the same policy tools identified above could be used to encourage enhanced utilization of existing buildings for office or retail space. The potential opportunity here, and associated greenhouse gas emission reductions, are less certain given current high vacancy rates, but effects could be similarly durable.

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3.6. Smaller new home construction

Larger home size is a major driver of energy consumption and is associated with a range of lifecycle environmental impacts, including but not limited to greenhouse gas emissions (Oregon Department of Environmental Quality 2010). Building larger dwellings, for example, leads to higher demand for construction materials, and more space can lead to greater overall consumption as families accumulate more belongings (Dubois et al. 2019). Until recently, the average size of new housing in the United States was steadily increasing, even as average household size has leveled off (Moura et al. 2015). This trend has started to reverse in Oregon (Andersen 2019), but further reducing the average size of newly constructed dwellings could significantly reduce embodied carbon emissions, and lock in energy- and other consumption-based emissions reductions over many years.

3.6.1. Potential policy approaches

While Oregon has promoted development of smaller dwellings for many years,[63] these efforts could be enhanced. New efforts could be pursued in combination with efforts to intensify the use of existing buildings (including existing residences) and as part of "smart growth" strategies – such as Oregon's Climate Friendly and Equitable Communities (CFEC) program – that provide more housing choices and more transportation options, promote equitable land use outcomes, and preserve environmental resources. Key policy levers specific to reducing new house size would include:

Zoning and land use policies	• Zone for more multi-unit dwellings (as is already required under HB 2001 (2019), but this could be expanded to additional jurisdictions) • Increase allowable densities, height, and mix • Remove or reduce minimum size restrictions to allow for smaller homes / housing units • Set local home size limits • Lower minimum parking requirements or move to market-based approaches to parking capacity[64]

[63] https://www.oregon.gov/deq/mm/production/Pages/Small-Housing.aspx

[64] While this does not directly affect house size as such, it can reduce the total amount of material required for new housing development and allow for greater density. Note that Oregon has already adopted a parking reform law (OAR 660-012).

Financial incentives	• Lower taxes and or development fees for smaller, more space-efficient housing • Density bonuses for smaller housing • Progressive property tax rates based on housing size

3.6.2. Greenhouse gas reduction potential

Study assumptions: In the analysis conducted for this project, we estimated that reducing the average size of new home size could achieve up to a 20% reduction in embodied carbon in new home construction by 2030, relative to the reference case. This reduction is applied to new reference case home construction in urban areas (estimated at 67% of all new home construction), *after* accounting for any construction that was avoided due to enhanced building utilization (which is evaluated as a separate outcome). In addition, we estimated that reducing the average size of new dwelling units (once targets are fully achieved by 2030) results in a 38% reduction in home energy consumption and a 19% reduction in household consumption of major goods (specifically, "other" appliances and furnishings).[65]

Rebound potential: Smaller dwellings may be less costly than typical new construction. Although the price differential for households may depend on market conditions, for this analysis we assumed savings will be proportional to embodied carbon reductions. In addition, savings on energy and goods consumption (relative to reference scenario housing) could be significant and lead to increased spending on other forms of consumption. In the case of households that are severely cost burdened, lower housing costs may allow them to meet additional basic needs (food, health care, utilities), which would significantly improve the quality of their lives. Overall, however, significant rebound emissions are expected, equal to around 33% of cumulative avoided emissions.

Emissions reduction potential: Altogether, we estimate smaller new home construction could – when combined with other measures[66] – contribute to the following greenhouse gas emission reductions:

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[65] These figures – include the estimated reduction in embodied carbon emissions – were derived from the results of a 2010 study for DEQ by Quantis (Oregon Department of Environmental Quality 2010), assuming a switch from "medium" sized new homes (~2,300 square feet) to a mix of smaller homes (~1,150 square feet) and multi-family dwelling s(also ~1,150 square feet per unit).

[66] Emission reduction estimates account for interactions between different assessed measures, and so do not reflect potential reductions if each outcome were achieved in isolation. See section 2.2 for a description of the methodology used and the sequencing of abatement measures.

	Metric tons CO_2e	% reduction from reference case
Annual emission reduction[1] in 2050	981,000	0.75%
Cumulative emissions reductions[1] between 2021 and 2050[2]	12,868,000	0.38%

[1] Emission reductions are net of rebound effects, and represent reductions below reference case emissions, derived from a simplified projection of current trends.
[2] Smaller new home size policies are modeled to begin in 2025, reaching full effect by 2030.

3.6.3. Evaluation

For evaluation purposes, we assume a mix of both zoning policies and financial incentives to achieve home size reductions.

3.6.3.1. Likelihood and durability of impact

Evaluation	Score
Policy approaches that combine zoning requirements with financial incentives are highly likely to be effective (CNCA et al. 2021). The total magnitude of achievable emission reductions is somewhat uncertain, given multiple possible effects (e.g., reduced embodied emissions, reduced energy use, and possibly reduced consumption of goods). However, the effects will be highly durable given that smaller home sizes will “lock in” these reductions – they are not dependent, for example, on maintaining ongoing discretionary consumption behaviors.	3

3.6.3.2. Ease of implementation and enforceability

Criteria	Evaluation	Score
Implementation	Could require effort and determination to implement. Statewide, implementation would require coordinated efforts across multiple jurisdictions (as under the CFEC program), with possibly varying levels of implementation. Developers could benefit from (and therefore welcome) incentive policies; some communities may resist greater multi-unit housing or restrictions on home size. Progressive property tax rates could face political resistance as well.	2
Enforceability	Highly enforceable at local levels. Statewide coordination (ensuring similarly ambitious policies across jurisdictions) could be more challenging.	2

3.6.3.3. Cost-effectiveness

Evaluation	Score
More development of smaller, multi-family dwellings and space-efficient housing could reduce per-unit housing costs and yield both direct cost savings to households as well as market-wide cost savings from greater housing supply (Andersen 2019; Mast 2019).	3

3.6.3.4. Economic, environmental, and societal impacts

Criteria	Evaluation	Score
Equity	Policies designed to promote smaller new homes are likely to be progressive, e.g., by increasing affordability for lower income households. Adversely affected households (e.g., due to home size restrictions) are more likely to be wealthier. In addition, reductions in pollution associated with less material production can benefit frontline communities (in Oregon and elsewhere) and avoid contributing to forced labor around the world (Lewis et al. 2021; Oregon Department of Environmental Quality 2023).	3
Jobs	Policies are expected to have little to no effect on employment in Oregon. Lower material and goods consumption could lead to job losses in some sectors, mostly outside of Oregon.	2
Health	In terms of direct effects, living in smaller homes can correlate with greater well-being and happiness for some households (Hague 2019; Kristian 2017). However, smaller homes may also correlate with indirect pollution reduction (and associated health benefits) within and outside Oregon due to material and energy savings. Furthermore, as noted above, for cost-burdened households these savings could translate to increased spending on basic needs, including health care, resulting in improved health outcomes.	2-3
Environment	In addition to reducing greenhouse gas emissions, smaller home size correlates with a range of other environmental benefits, including reduced air pollution (from energy savings), reduced impacts from the production and use of construction materials (Oregon Department of Environmental Quality 2023), and a range of reduced environmental impacts from reduced consumption of household goods and materials.	3

3.6.4. Addressing government consumption

State and local government in Oregon are investing hundreds of millions of dollars in public and affordable housing developments.[67] Government agencies could set internal policies to ensure "right size" development for public housing and other government-related housing needs.

3.6.5. Addressing business capital investment

Not applicable (residential construction is not a component of business capital emissions in Oregon's CBEI; while the underlying economic model treats all housing development as a form of business capital and investment, the CBEI model transfers emissions associated with housing development from the "business capital/investment" consumer-type to households).

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[67] See, for example, https://t.e2ma.net/message/ycapa1e/mfsr23wc and https://www.oregonmetro.gov/public-projects/affordable-housing-bond-program.

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3.7. Reduced embodied emissions in new construction

Buildings and infrastructure are a major source of Oregon's consumption-based greenhouse gas emissions, accounting for more than 25% of total emissions in 2021. The bulk of these emissions arise from energy use, but typically, at least 25% of a building's lifecycle emissions come from "embodied carbon," i.e., the greenhouse gas emissions associated with materials and construction (Esau et al. 2021; Lewis et al. 2021). Public infrastructure (e.g., roads, streets, bridges, etc.) is also a major source of embodied emissions – about 10% of all government consumption-based emissions in 2021 arose from infrastructure construction. Embodied carbon could be reduced in multiple ways, including through waste reduction and reduced, or more efficient, use of construction materials (e.g., where appropriate, using structure as a finish material) (Oregon Department of Environmental Quality 2010). However, some of the biggest potential comes from using specific products/materials with lower embodied carbon, with selections informed by Environmental Product Declarations. This can involve switching to lower carbon alternative materials, or utilizing low-carbon versions of the same material (Esau et al. 2021; Bureau of Planning and Sustainability 2024).

3.7.1. Potential policy approaches

A range of policy approaches are being deployed in jurisdictions around the world aimed at reducing embodied carbon in construction (Kalsman et al. 2024; CNCA et al. 2021; World Green Building Council 2019). These range from information disclosure policies (e.g., requiring environmental product declarations, or EPDs, for construction materials), to financial incentives, building codes, and zoning requirements. Oregon is already promoting use of lower-carbon materials, such as low-carbon concretes, through product disclosures and voluntary assistance programs.[68] New policies focused on cost-effective opportunities to reduce embodied carbon could yield substantial emission reductions. A phased approach could begin with materials that have high emissions or emissions intensity (such as concrete and steel), with the goal of expanding to include additional material types. Key policy levers for reducing embodied carbon in <u>building</u> construction (residential, commercial, and institutional) include:

Outreach and education	• Disseminate information on construction material impacts and provide advice to design and construction industry professionals, developers, lenders, and procurement professionals, as well as general public consumers. • Provide training to design and construction industry professionals.

[68] https://www.oregon.gov/deq/mm/production/Pages/Built-Environment.aspx

Information disclosure	• Require manufacturers of materials used in construction in Oregon to provide product-specific EPDs • Require whole-building lifecycle analysis of greenhouse gas emissions (including embodied carbon) during design stage of new buildings
Product regulations & standards	• Incorporate as compliance options both whole-building embodied carbon and GWP limits for product categories in Oregon's building code • Adopt product stewardship requirements that address building materials, e.g., requiring owner/developer responsibility for whole building impacts and burdens. • Adopt low-carbon concrete requirements[69] • Establish structural design requirements that encourage or require more efficient use of materials
Financial incentives	• Provide financial incentives (e.g., tax rebates, permitting waivers, system development charge waivers, or density bonuses) for new buildings that meet or exceed embodied carbon benchmarks, and meet high environmental, health, and equity requirements.[70] • Charge land use fees based on lifecycle greenhouse gas emissions • Provide "carbon performance" grants for new projects, ensuring use of low-carbon materials • Provide financial incentives for in-state manufacturers of low-carbon construction materials (including bio-based materials) • Provide financial incentives and technical assistance to manufacturers of construction materials to develop Environmental Product Declarations for their goods.
Zoning and land use policies	• Set embodied carbon targets as part of zoning requirements, or adopt carbon-optimal building typologies (cf. CNCA et al. 2021) • Conduct carbon-scored land sale competitions

In addition to residential and commercial buildings, government-funded buildings and public infrastructure are a significant contributor to Oregon's consumption-based emissions, accounting for around 30% of total embodied emissions from construction. Oregon has already adopted a Buy Clean law requiring life cycle emission assessments for certain construction

[69] For example, modeled on Marin County's low-carbon concrete requirements (https://www.marincounty.org/depts/cd/divisions/sustainability/low-carbon-concrete-2022)

[70] For example, this approach could be incorporated under Oregon's existing Sustainable Buildings for All framework: https://www.oregon.gov/deq/mm/production/Pages/SB4A.aspx

materials (including asphalt, concrete, and steel) used for public infrastructure projects. This law could be further extended to apply to more types of projects and to require meeting embodied emission limits.

Public procurement standards & requirements	• Extend Oregon's Buy Clean law to state-funded buildings • Amend the Buy Clean law to *require* meeting global warming potential (GWP) limits in building and infrastructure construction projects • Require whole-building lifecycle analysis for state-funded building projects • Require whole-pavement lifecycle analysis for infrastructure projects • Establish whole-building lifecycle emission limits (embodied and operational) for state-funded building projects • Establish whole-pavement lifecycle emission limits for infrastructure projects

3.7.2. Greenhouse gas reduction potential

Study assumptions: There is substantial potential for reducing embodied carbon in new Oregon construction projects, both for buildings and public infrastructure. Analysis conducted for the Oregon Joint Task Force on Resilient Efficient Buildings indicated that theoretical reductions in embodied carbon of up to 100% could be achieved by 2050 (SSG 2022). Realistically, however, this would likely involve "netting" some remaining emissions with carbon dioxide removals. Analysis conducted for this project assumes decarbonization of construction by up to 90% could be achieved by 2050, with targeted reductions phased in over time. Reductions of embodied emissions in infrastructure projects (e.g., roadway construction) may also be possible in line with these targets (Ashtiani et al. 2024).

Rebound potential: Decarbonization of construction materials is unlikely to lead to rebound emissions. Significant reductions in embodied carbon in building materials are typically achievable for only a small increase in cost (Esau et al. 2021). However, there are unlikely to be significant cost *savings* for households, government, or businesses.

Emissions reduction potential: Altogether, we estimate reducing embodied carbon in new construction (buildings and infrastructure) could – when combined with other measures[71] – contribute to the following greenhouse gas emission reductions:

	Metric tons CO_2e	**% reduction from reference case**
Annual emission reduction[1] in 2050	5,316,000	4%
Cumulative emissions reductions[1] between 2021 and 2050[2]	68,879,000	2%

[1] Emission reductions are net of rebound effects, and represent reductions below reference case emissions, derived from a simplified projection of current trends.
[2] Policies to reduce embodied carbon are modeled to take effect in 2025, achieving a 10% reduction against the reference case and ramping up to 90% by 2050; the schedule of graduated reductions assumed in the model is provided in section 2.6.

3.7.3. Evaluation

Achieving deep reductions in embodied carbon will likely require a full range of policy interventions, starting with information disclosure (including product-specific EPDs) but ultimately including financial incentives, zoning requirements, and – most importantly – incorporation of embodied carbon limits in Oregon's building code and in public procurement requirements. A phased approach could help to mitigate costs and implementation challenges (Simonen et al. 2019; Esau et al. 2021).

3.7.3.1. Likelihood and durability of impact

Evaluation	**Score**
Reductions in embodied carbon occur as a "one time event" at the time buildings and infrastructure are designed and constructed, or (in the case of maintenance or renovation) at the time materials are used. Maintaining and driving emission reductions over time will require ongoing policy support and regulation. However, policy support can help develop markets for low-carbon construction materials that may eventually be self-sustaining.	2

[71] Emission reduction estimates account for interactions between different assessed measures, and so do not reflect potential reductions if each outcome were achieved in isolation. See section 2.2 for a description of the methodology used and the sequencing of abatement measures.

3.7.3.2. Ease of implementation and enforceability

Criteria	Evaluation	Score
Implementation	Graduated policies for driving deep reductions in embodied carbon will require effort and determination to implement. Information disclosure approaches are already underway in Oregon and could be easily extended. Established embodied carbon limits in zoning, building codes, and state procurement policy could be challenging, and disruptive to current industry practices. However, a phased approach – building off experience gained from information disclosure, and including financial incentives – has been successful so far and could ease implementation of more ambitious measures.	1-2
Enforceability	Policies related to reducing embodied carbon are highly enforceable (CNCA et al. 2021).	3

3.7.3.3. Cost-effectiveness

Evaluation	Score
Case studies in the Pacific Northwest suggest that substantial reductions in embodied carbon in building construction – up to 46% - could be achieved for a cost premium of less than one percent (Esau et al. 2021). Deeper reductions are likely to be more costly, although expert analysis suggests premiums could still be in the range of only 2-3% (SSG 2022). Costs may come down over time as markets for alternative materials develop, and low-carbon building and construction practices become more widespread. (Note that total construction costs may increase only slightly, the *cost per ton* of CO_2 reduced may nevertheless be relatively high, e.g., in the range of $50-100 – see separate assessment of marginal abatement costs in section 4.)	2

3.7.3.4. Economic, environmental, and societal impacts

Criteria	Evaluation	Score
Equity	Requirements for low-carbon construction could slightly increase costs for households, government, and businesses. Increasing costs for housing construction could adversely affect lower-income households. As noted above, however, cost increases are likely to be small, and could be alleviated through financial incentives that, for example, help pay down the costs of using lower-carbon materials. In addition, reductions in pollution associated with less material production can benefit frontline communities (in Oregon and elsewhere) and avoid contributing to forced labor around the world (Lewis et al. 2021; Oregon Department of Environmental Quality 2023).	2
Jobs	Since cost premiums for low-carbon construction may be relatively low, policies are not likely to cause significant job loss. However, a transition to lower-carbon materials and practices could require some retraining of workforces in Oregon manufacturing and construction sectors. Investing in such training and education may be an important complement to policies directly regulating embodied carbon (Dell 2020). To the extent that Oregon manufacturers are better positioned than out-of-state competition to provide lower-carbon materials, a preference for lower-carbon materials (both in Oregon and elsewhere) could increase local manufacturing job opportunities.	2
Health	No significant health impacts from these policies are expected for Oregonians, positive or negative. Some health benefits may accrue to the extent that lower-carbon building materials are also those with lower toxicant risk (Oregon Department of Environmental Quality 2023), or are produced using methods with fewer pollutant emissions. Programs that bundle required product disclosure for carbon, toxics and working conditions, such as the State of Washington's "Buy Clean & Buy Fair"[72] program, hold the potential for improving the environment, health and jobs.	2
Environment	Some environmental benefits from low-carbon construction could result from more efficient design that consumes fewer resources. Also, if lower-carbon materials are produced in ways that also result in fewer emissions of other pollutants, additional environmental benefits may result. Otherwise, the environmental co-benefits of using lower-carbon materials are unclear.	2

[72] See https://ofm.wa.gov/buy-clean-and-buy-fair

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3.8. Reduced food waste – household level

Globally, food production accounts for around a quarter of human-caused greenhouse gas emissions (Ritchie and Roser 2024) and in Oregon, food consumption (including at restaurants) accounts for over 15% of consumption-based emissions (Oregon Department of Environmental Quality 2024)). A significant percentage of food's carbon footprint, however, is associated with food that is produced but never consumed. In the United States, fully 30-40 percent of total food supply is "surplus" (beyond what is sold and eaten) – and the vast majority of this surplus is wasted, rather than recycled or donated (ReFED 2024; Buzby et al. 2014). Reducing this amount of food waste could substantially reduce greenhouse gas emissions. The United Nations has targeted food waste reduction as a global sustainable development goal,[73] and accordingly both the federal government (USDA and U.S. EPA) and State of Oregon have set a goal of reducing food waste by 50% by 2030.[74]

In Oregon, about 60% of all non-farm food waste occurs at the household level, i.e., after food is purchased and brought home for consumption (ReFED 2024).[75] Reducing household food waste could therefore significantly reduce consumption-based greenhouse gas emissions.

3.8.1. Potential policy approaches

One challenge with household food waste is that it is difficult to directly regulate. However, a range of policy approaches, some of which Oregon is already pursuing, could be effective at reducing waste. While changing consumer behavior through outreach and education is important, some of the most effective mechanisms involve changes in how food is manufactured, marketed, and sold, making it easier for consumers to avoid wasting food (e.g., by ensuring freshness and providing appropriate packaging and portion sizes). (Some of these options overlap with strategies for reducing supply chain and food service waste, which are evaluated separately). Under a comprehensive approach, key policy levers could include:

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[73] https://champions123.org/target-123

[74] To achieve this goal, a national strategy for reducing food loss and waste was announced on June 12, 2024: https://www.usda.gov/media/press-releases/2024/06/12/biden-harris-administration-announces-national-strategy-reduce-food

[75] https://insights-engine.refed.org/food-waste-monitor?break_by=sector&indicator=tons-surplus&state=OR&view=detail&year=2021

Outreach and education	• Continue and expand Oregon's existing consumer education campaigns[76] to increase awareness of food waste impacts and inform consumers on strategies for reducing waste at home[77] • Implement outreach campaigns specifically to improve consumer understanding of food expiration dates, so that less food is discarded at home
Information disclosure	• Require standardized food date labeling at grocery stores
Financial incentives	• Provide incentives to food retailers and manufacturers to change food marketing practices, including eliminating buy one/get one approaches, or changing packaging of food to accommodate smaller household sizes. • Implement food waste "weigh and charge" programs, e.g., requiring separation of food waste and charging for its disposal[78] • Subsidize purchase of refrigeration equipment for low-income households (who may otherwise have difficulty avoiding food waste due to lack of adequate refrigeration)[79] • Provide tax incentives for locating grocery stores in "food desert" communities (urban and rural) (Eden Green 2023)[80] • Subsidize research and deployment of new packaging technologies that enhance shelf life and reduce spoilage[81]
Public investment	• Implement programs to assist producers and manufacturers in improving logistics (decreasing food transit times, improving

[76] For example, see Oregon's existing "Bad Apple" campaign: https://www.oregon.gov/deq/mm/food/pages/bad-apple.aspx

[77] https://insights-engine.refed.org/solution-database/consumer-education-campaigns

[78] This type of program has been successfully implemented in Korea (Broom 2019).

[79] This measure was identified from Appendix B of Oregon's 2024 Priority Climate Action Plan (Oregon Department of Environmental Quality 2024). Anecdotal evidence suggests that poor refrigeration in low-income housing may lead to excess food spoilage (Laura Kutner Tokarski personal communication to DEQ), and studies suggest that optimizing household refrigeration can extend the shelf life of fresh food products (Holsteijn and Kemna 2018).

[80] One consequence of living in food desert (defined as areas where residents live at least a mile from fresh food retailers) is that households may tend to "over-buy" food when they visit a grocery store, leading to more spoilage.

[81] Oregon State University, for example, has helped to research packaging that enhances the shelf life of produces, such as pears (https://insights-engine.refed.org/solution-database/active-intelligent-packaging)

	temperature monitoring, increasing food delivery frequency, etc.) to enhance freshness of food purchased by households • Increase funding for public transit (targeting food desert areas) • Sponsor gardens and urban farming initiatives in food desert areas

(Note: Government food waste reduction strategies are assessed separately as part of measures to reduce supply chain and food service waste.)

3.8.2. Greenhouse gas reduction potential

Study assumptions: If households were to eliminate all food waste (thus reducing the amount of food they purchase and consume), they could eliminate over 18% of consumption-based emissions associated with food.[82] However, not all food waste is avoidable; Oregon DEQ estimates that close to 30% of food waste is inedible (McDermott et al. 2019). Furthermore, it may be unrealistic to expect households to eliminate all edible food waste. In a study of measures for reducing consumption-based greenhouse gas emissions, C40 Cities identified a "progressive" target of reducing household food waste by 50% (in line with the UN Sustainable Development Goals and U.S. targets). For this analysis, we assume a more realistic target of reducing household waste by 30% by 2030 and thereafter (contributing towards the United Nations' goal of a 50% reduction in household and retail food waste by 2030).

Rebound potential: Reducing household food waste also means reducing the amount of food that households need to buy. This could result in rebound emissions if households spend the savings on other forms of consumption. However, food consumption has a higher emissions intensity per dollar than most other consumption categories – in the case of meat and dairy products, much higher – so rebound effects are moderate. We estimate rebound emissions to be around 25% of cumulative emission reductions achieved between 2025 and 2050.

[82] According to ReFED data for the entire United States, in 2022 about 42.8 million tons of food were wasted at the household level, out of 235 million tons of food produced (https://refed.org/food-waste/the-problem/#overview).

Emissions reduction potential: Altogether, we estimate that reducing household food waste could – when combined with other measures[83] – contribute to the following greenhouse gas emission reductions:

	Metric tons CO_2e	% reduction from reference case
Annual emission reduction[1] in 2050	640,000	0.5%
Cumulative emissions reductions[1] between 2021 and 2050[2]	12,762,000	0.4%

[1] Emission reductions are net of rebound effects, and represent reductions below reference case emissions, derived from a simplified projection of current trends.
[2] Policies are modeled to begin in 2025, reaching full effect by 2030.

3.8.3. Evaluation

The nonprofit ReFED identifies consumer education programs as having the greatest potential impact on food waste of any single approach or measure; they are also highly cost-effective.[84] However, approaches targeting the manufacturing, packaging, logistics, and marketing of foods may have a more durable impact, and together could promote even greater reductions in household food waste.

3.8.3.1. Likelihood and durability of impact

Evaluation	Score
Education campaigns often have an uncertain – and difficult to evaluate – effect on household behavior and avoided emissions. Furthermore, over time changes in behavior in response to these campaigns may not be durable, as some households revert to old practices (Dietz et al. 2009; Timmer et al. 2009). This is not to suggest that these policy approaches – including education and outreach – should not be pursued. However, it may be difficult to guarantee achievement of "hard" targets for avoiding household food waste (score of 1). Other policy measures, including improved labeling requirements, financial incentives, and public investment, could have a more durable impact – especially if they are maintained over time and drive long-term shifts in marketing practices,	1-2

[83] Emission reduction estimates account for interactions between different assessed measures, and so do not reflect potential reductions if each outcome were achieved in isolation. See section 2.2 for a description of the methodology used and the sequencing of abatement measures.

[84] https://insights-engine.refed.org/solution-database?dataView=total&indicator=us-dollars-profit&stakeholder=consumers

packaging, and logistics. However, their effects on reducing waste may still be somewhat uncertain (score of 2).	

3.8.3.2. Ease of implementation and enforceability

Criteria	**Evaluation**	**Score**
Implementation	Consumer education campaigns related to reducing food waste are easy to implement (score of 3). Other policy measures may face some implementation challenges, especially where new and improved packaging and logistics practices are concerned (score of 2). A food waste "weigh and charge" policy – while it has had success in Korea – could require significant effort to adopt in Oregon communities (score of 1).	1-3
Enforceability	Not applicable for consumer education programs, public investment, and financial subsidy measures (score of 3). Requiring standardized food labelling and "weigh and charge" programs could pose moderate or difficult enforcement challenges (score of 1-2).	1-3

3.8.3.3. Cost-effectiveness

Evaluation	**Score**
ReFED identifies consumer education campaigns – despite their uncertainty of impact – as being highly cost-effective, because they significantly reduce costs for individual consumers who respond to them (score of 3). Other identified policy measures are also likely to financially benefit consumers and, according to estimates from ReFED, would likely yield net savings across all stakeholders (score of 3).[85]	3

[85] See: https://insights-engine.refed.org/solution-database?dataView=total&indicator=us-dollars-profit. Note, however, that entities incurring costs (e.g., manufacturers and retailers) may not be the same entities realizing the most savings (e.g., households).

"Weigh and charge" programs could impose both direct and indirect costs (score of 1).[86]	

3.8.3.4. Economic, environmental, and societal impacts

Criteria	Evaluation	Score
Equity	Consumer education campaigns pose few equity risks (in terms of imposing disproportionate burdens), although careful design may be needed to ensure they reach and benefit all communities (score of 3). The public investment and financial subsidy measures identified above are likely to have positive (progressive) effects on equity (score of 3). Food waste "weigh and charge" programs may need to be carefully designed to avoid regressive impacts on lower income households (score of 1).[87]	3
Jobs	Most of the policy approaches identified here would have moderately positive impacts on employment. Tax incentives for locating grocery stores in food deserts, and public investment in transit could have some positive effect on jobs, as would most measures to improve food packaging, marketing, and logistics (score of 3).[88] ReFED estimates that consumer education campaigns could negatively affect grocery and food service business income (by reducing demand),[89] but economy-wide they would produce a modest employment *benefit* (e.g., because less waste frees up spending and leads to greater economic productivity) (score of 2).[90]	2-3
Health	Few direct health impacts from these policies are expected for Oregonians, positive or negative, although the provision of refrigerators (or replacement of inefficient/poorly functioning	2

[86] Not included in overall score because this is only a single potential measure.

[87] Ibid (footnote 86).

[88] See https://insights-engine.refed.org/solution-database?dataView=total&indicator=jobs-created

[89] This effect, however, may be modest. A 2014 econometric study from the United Kingdom, for example, suggested that consumers who reduced food waste spent about half of their savings in retail stores, e.g., on higher-value food items or nonfood goods (Hanson and Mitchell 2017).

[90] See https://insights-engine.refed.org/solution-database/consumer-education-campaigns

	refrigerators) to households currently lacking them would both reduce wasting of food and deliver health benefits.	
Environment	Food production can have multiple adverse environmental impacts beyond contributing to greenhouse gas emissions, including water stress and pollution, and depending on circumstances, can put pressure on land use, biodiversity, and other natural resources (Ritchie et al. 2022). Reducing food waste can contribute to alleviating these other impacts, both within and outside Oregon.	3

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3.9. Reduce food waste - manufacturing, retail, and food service level

As noted above, food production accounts for around a quarter of human-caused greenhouse gas emissions around the world (Ritchie and Roser 2024) and in Oregon, food consumption (including at restaurants) accounts for over 15% of consumption-based emissions (Oregon Department of Environmental Quality 2024)). Reducing food waste could substantially reduce greenhouse gas emissions.

In Oregon, around 40% of all non-farm food waste occurs at manufacturing facilities, grocery stores, restaurants, and other food service providers (ReFED 2024).[91] While these establishments waste less food than households, there may be more opportunities for reducing this waste – and associated greenhouse gas emissions – than at the household level. Most manufacturing waste comes from byproducts and production-line inefficiencies.[92] Retail waste primarily arises from a food perishing (or reaching potentially confusing "sell by" dates) before being sold. In restaurants, about half of food waste is from food that is never served, and the other half from food that is served but goes uneaten (e.g., because of large portion sizes).[93]

Note that all the actors addressed here – manufacturers, food retailers, and food service providers – can implement measures that will also reduce *household* food waste. This assessment, however, focuses on food waste in supply chains and food service. Measures and policy approaches for reducing household food waste are assessed separately.

3.9.1. Potential policy approaches

A range of policy approaches could be deployed to reduce waste in the food "supply chain" and at restaurants and other food service providers, many of which already have successful track records. Under the Pacific Coast Food Waste Commitment (PCFWC)[94], for example, a program of voluntary engagement with food retailers (representing more than 50% of regional market share) has reduced unsold food by 28% since 2019. The PCFWC has considered expanding its

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[91] https://insights-engine.refed.org/food-waste-monitor?break_by=sector&indicator=tons-surplus&state=OR&view=detail&year=2021

[92] https://refed.org/stakeholders/manufacturers/

[93] Oregon DEQ personal communication (May 14, 2024).

[94] The PCFWC is a program of the Pacific Coast Collaborative (https://pacificcoastcollaborative.org/), of which Oregon is a founding and participating member.

engagement to include manufacturers and food service providers. An expanded and even more ambitious program could rely on the following key policy approaches:

Outreach and education	• Implement outreach campaigns to consumers to improve understanding of food expiration dates, encourage consumption of "unattractive" produce, etc., so that less food goes unpurchased • Implement education campaigns for food retailers, restaurants, and food service providers around food donation options, including options that generate higher societal benefits, including greenhouse gas reductions[95] • Require restaurants and grocers to provide food waste prevention messaging to their customers • Continue and expand programs to train grocers, restaurants, and food service providers on food waste reduction techniques (e.g., better menu planning and buffet service approaches)
Information disclosure	• Require standardized, clearer, and evidence-based food date labeling at grocery stores
Financial incentives	• Provide subsidies to commercial food service providers to support reducing plate and portion sizes • Provide incentives for deployment of dynamic food pricing and "markdown alert" systems at grocery stores • Provide incentives for deployment of AI inventory control in retail • Impose financial penalties for food waste generation at food retailers, food service providers, and restaurants • Provide grants to businesses enabling them to store, transfer, and "upcycle" byproducts from food manufacturing [96] • Provide grants to food manufacturers for implementing production line efficiency improvements
Regulation	• Mandate food waste prevention plans at commercial food service establishments as a part of granting a business license • Revoke restrictions on sale or donation of food after "sell by" dates
Public investment	• Implement programs to assist producers and manufacturers in improving logistics (e.g., decreasing food transit times,

[95] Not all "food donation" programs are equally beneficial in terms of delivering nutritious, healthy food to people that will actually use it. In addition, not all food rescue programs are necessarily optimized from a climate perspective; see https://www.oregon.gov/deq/mm/food/pages/food-rescue.aspx.

[96] See, for example: https://insights-engine.refed.org/solution-database/manufacturing-byproduct-utilization-upcycling

	improving temperature monitoring, increasing food delivery frequency, etc.) to reduce supply chain food spoilage • Support "solution provider" programs that enable enhanced collection, transfer, and distribution of "distressed" food and food manufacturing byproducts • Provide, or fund, improved food donation logistics and support programs – including in "food desert" areas

Government food service operations can also take steps to reduce food waste. (In 2021, government food consumption accounted for about 8.5% of total Oregon consumption-based greenhouse gas emissions from food.) Options for government food service providers parallel those for the food service and grocery industries.

Waste reduction	• Implement portion-reduction experiments or policies in schools and other government-operated food services • Implement food waste reduction programs, including adoption of food waste prevention plans, in government food service operations (e.g., installation of milk dispensers instead of cartons)

3.9.2. Greenhouse gas reduction potential

Study assumptions: Avoiding all food-product manufacturing, supply chain, and restaurant/food service waste could eliminate around 13% of consumption-based emissions associated with food.[97] Fully eliminating this waste may not be feasible; for this analysis we assume Oregon retail food providers – including government food service operations – could reduce waste by 40% by 2030 and thereafter (contributing towards the United Nations' goal of a 50% reduction in household and retail food waste by 2030).

Rebound potential: Reducing food waste also means reducing the amount of food that retail providers need to buy. It is not clear how much of these savings would be passed on to consumers. However, the savings could directly or indirectly be reallocated to other forms of spending. Food consumption has a higher emissions intensity per dollar than most other consumption categories – in the case of meat and dairy products, much higher – so rebound

[97] According to ReFED data for the entire United States, in 2022 about 31.1 million tons of food were wasted at the household level, out of 235 million tons of food produced (https://refed.org/food-waste/the-problem/#overview).

effects are moderate. We estimate rebound emissions to be around 25% of cumulative emission reductions achieved between 2025 and 2050.

Emissions reduction potential: Altogether, we estimate that reducing manufacturing, retail, and food service food waste could – when combined with other measures[98] – contribute to the following greenhouse gas emission reductions:

	Metric tons CO_2e	% reduction from reference case
Annual emission reduction[1] in 2050	620,000	0.5%
Cumulative emissions reductions[1] between 2021 and 2050[2]	12,364,000	0.4%

[1] Emission reductions are net of rebound effects, and represent reductions below reference case emissions, derived from a simplified projection of current trends.
[2] Policies are modeled to begin in 2025, reaching full effect by 2030.

3.9.3. Evaluation

As with household food waste, the nonprofit ReFED identifies consumer education programs as the single most effective – and cost-beneficial – tool for reducing retail food waste.[99] However, measures like reducing portion sizes (which we classify here as a food service-oriented option), have similar potential. The following assessment assumes a full array of programs, financial incentives, and regulation that will likely be required to achieve major reductions in retail food waste.

3.9.3.1. Likelihood and durability of impact

Evaluation	Score
By themselves, outreach, education, and information disclosure approaches may have uncertain and less durable impacts (score of 1; although engagement programs like the PCFWC have been quite successful so far with participating retailers). However, together with an array of other incentives and requirements for retailers, significant impacts are much more likely. Effects are likely to be durable as long as these policies are maintained, and some changes – like reductions in	2

[98] Emission reduction estimates account for interactions between different assessed measures, and so do not reflect potential reductions if each outcome were achieved in isolation. See section 2.2 for a description of the methodology used and the sequencing of abatement measures.

[99] https://insights-engine.refed.org/solution-database?dataView=total&indicator=total-mtco2e-avoided&stakeholder=retailers

portion size – could over time become part of new business and consumer norms (overall score of 2).	

3.9.3.2. Ease of implementation and enforceability

Criteria	Evaluation	Score
Implementation	Most of the policy approaches considered here would not be difficult for government agencies or affected retailers to implement. Some measures, like revoking sell-by dates and providing subsidies, may be welcomed by retailers (score of 3). Others, such as implementing dynamic pricing systems, may require investments in new systems and equipment.	2
Enforceability	Some measures (including subsidies and public investment) would not require enforcement (score of 3). Others, such as requiring standardized food labels or imposing food waste penalties would require enforcement, similar to other regulations affecting the food service and grocery industries (overall score of 2).	2

3.9.3.3. Cost-effectiveness

Evaluation	Score
For most of the policy approaches identified here, ReFED estimates net financial benefits to businesses and consumers, primarily due to food cost savings.[100] Those bearing costs may not always be the same entities realizing savings. However, costs to manufacturers and retailers of deploying new systems (labelling, dynamic pricing, markup alerts, etc.) will often be exceeded by food cost savings. In addition, households may benefit from lower prices, including where dynamic pricing is implemented.	3

3.9.3.4. Economic, environmental, and societal impacts

Criteria	Evaluation	Score
Equity	The policy approaches considered here would not adversely impact lower income households (nor disproportionately benefit higher-income households). Public investment to support enhanced food donation and distribution programs could have net benefits for communities that are food insecure.	3

[100] https://insights-engine.refed.org/solution-database?dataView=total&indicator=us-dollars-profit

Jobs	Most of the policy approaches identified here are not expected to have significant impacts on employment. Several measures would impose costs on manufacturers, retails, and food service providers, but according to ReFED, food cost savings will in most cases compensate for increased costs and these measures would have net job benefits.[101]	2
Health	No significant health impacts from these policies are expected for Oregonians. Measures to reduce portion sizes in restaurants and food service institutions could yield some modest health benefits (especially if combined with a shift to healthier, more sustainable foods).	2
Environment	Food production can have multiple adverse environmental impacts beyond contributing to greenhouse gas emissions, including water stress and pollution, and depending on circumstances, can put pressure on land use, biodiversity, and other natural resources (Ritchie et al. 2022). Reducing food waste can contribute to alleviating these other impacts, both within and outside Oregon.	3

3.9.4. References

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[101] https://insights-engine.refed.org/solution-database?dataView=total&indicator=jobs-created

3.10. Reduced meat and dairy consumption

In 2021, food consumption (including consumption at restaurants) accounted for over 15% of Oregon's consumption-based greenhouse gas emissions. Of this amount, 38% comes from consumption of meat (including beef, pork, and poultry) and dairy products. Meat and dairy are highly emissions-intensive because they consume significant agricultural resources (e.g., crops grown for animal feed, which contribute to N_2O emissions) and produce large volumes of methane (Ritchie 2024). Methane from enteric fermentation in livestock (especially dairy cattle) produces over one quarter of U.S. methane emissions, and manure management contributes another 9% (U.S. EPA 2022). Studies have consistently found that reducing meat and dairy consumption would be one of the most effective ways to reduce agricultural greenhouse gas emissions (U. S. Global Change Research Program 2023; Ranganathan et al. 2016; Foley et al. 2011) – and to reduce consumption-based emissions in general (Ivanova et al. 2020; C40 Cities et al. 2019b).

3.10.1. Potential policy approaches

A key challenge with shifting diets away from meat and dairy is overcoming social and behavioral norms. A range of policy approaches are possible, ranging from information and education campaigns to "harder" interventions like product bans or taxation. In practice, few jurisdictions have pursued policies in this area beyond efforts to persuade consumers to shift their consumption. Experience with taxation of unhealthy foods, however, suggests similar approaches could be effective for meat and dairy, especially if applied in ways that mitigate unfair distributional consequences (Ranganathan et al. 2016). A broad set of policies targeting household (home and restaurant) consumption could include the following:

Outreach and education	• Implement public awareness campaigns on the climate and health impacts of meat and dairy consumption
Information disclosure	• Require carbon footprint and/or health impact labeling for meat and dairy products (e.g., at grocery stores and/or restaurants)[102] • Ban or restrict advertising for meat and dairy products
Product regulations & standards	• Restrict sales of meat and/or dairy in restaurants, or require that they be offered alongside comparable plant-based alternatives
Financial incentives	• Tax meat and dairy products (possibly limited to more carbon-intensive options) • Subsidize plant-based meat and dairy alternatives

[102] See https://www.eatright.org/food/planning/food-security-and-sustainability/sustainability-labels-on-restaurant-menus, for example, as well as Rybak et al. (2023).

	• Favor or subsidize healthy alternatives to meat and dairy options in food assistance programs • Remove government subsidies for meat and dairy production

Government food service operations can also take steps to reduce meat and dairy consumption, including by directly limiting meat and dairy options (the effects of which may be more consistent and certain than, for example, consumer education campaigns). Based on data from Oregon's 2021 consumption-based greenhouse gas inventory, government food services account for about 8.4% of total emissions from Oregon food consumption. However, government programs (e.g., in schools) could have important signaling effects in terms of shifting societal norms.

Public procurement standards & requirements	• Limit meat and dairy options in schools and other government-run food service operations[103] • Experiment with menu, labeling and food placement options that discourage meat and dairy consumption or encourage consumption of alternatives[104] • Serve allergen-friendly, plant-based alternatives to meat and dairy in public institutions

3.10.2. Greenhouse gas reduction potential

Study assumptions: If all Oregonians were to adopt a "vegan" diet – i.e., eliminating all meat and dairy consumption and shifting to other foods – consumption-based greenhouse gas emissions would be significantly reduced. While technically possible, this may not be a socially and politically plausible target and – if such a transition were not carefully managed – could pose equity, health, and nutritional risks (Verkuijl et al. 2023). However, substantially *limiting* meat and dairy consumption could both reduce emissions and lead to healthier diets. For this analysis, we assume meat and dairy consumption could be reduced in line with both human and planetary goals – around a 50% reduction for meat (beef and pork) and a 30% reduction for poultry, eggs, and dairy by 2050 (EAT Lancet Commission 2019; C40 Cities et al. 2019a).

[103] For example, New York City has a food purchasing initiative that is substantially reducing emissions from food consumption in hospitals and schools, by serving plant-based meals (https://resilientcitiesnetwork.org/new-york-city-reducing-food-based-emissions/).

[104] Note that these approaches may not be as simple as providing "vegan" or "vegetarian" food labels, which can backfire in some cases (Berke and Larson 2023).

Rebound potential: Reducing meat and dairy consumption would mean shifting consumption to other foods. Per calorie, however, shifting to a less meat- and dairy-heavy diet typically results in cost savings (Springmann et al. 2021). These savings could lead to indirect rebound effects, as money saved on food is spent on other types of consumption. Food consumption has a higher emissions intensity per dollar than most other consumption categories – in the case of meat and dairy products, much higher – so rebound effects are modest. We estimate rebound emissions to be around 5% of cumulative emission reductions achieved between 2025 and 2050.

Emissions reduction potential: Altogether, we estimate that reducing meat and dairy consumption could – when combined with other measures[105] – contribute to the following greenhouse gas emission reductions:

	Metric tons CO_2e	% reduction from reference case
Annual emission reduction[1] in 2050	2,350,000	1.8%
Cumulative emissions reductions[1] between 2021 and 2050[2]	28,684,000	0.8%

[1] Emission reductions are net of rebound effects, and represent reductions below reference case emissions, derived from a simplified projection of current trends.
[2] Policies are modeled to begin in 2025, reaching full effect by 2050.

3.10.3. Evaluation

Although a range of policy approaches could be deployed to drive a shift in Oregonians' diets, the assessment here focuses on the less coercive options identified, including education campaigns, information disclosure, and subsidies (or subsidy reform). The implications of meat and dairy taxation approaches are discussed under each criterion, but are not reflected in the summary scores. Sales restrictions in restaurants are not considered, as these policies are likely to be difficult to implement, could have limited impact, and may have adverse economic consequences.

3.10.3.1. Likelihood and durability of impact

Evaluation	Score
Education and information disclosure campaigns often have an uncertain – and difficult to evaluate – effect on household behavior and avoided emissions.	1-2

[105] Emission reduction estimates account for interactions between different assessed measures, and so do not reflect potential reductions if each outcome were achieved in isolation. See section 2.2 for a description of the methodology used and the sequencing of abatement measures.

Furthermore, over time changes in behavior in response to these campaigns may not be durable, as some households revert to old dietary preferences (Dietz et al. 2009; Timmer et al. 2009) (score of 1). Financial incentives may have more reliable effects on consumer behavior, as long as they are maintained. Aggressive taxation policies could have the most near-term impact (score of 2). However, an array of ongoing education, information disclosure, and incentive policies – possibly combined with limited taxation – may have the most durable impact on consumer behavior over the long run (score of 2). For government measures to reduce meat and dairy offerings in public institutions, there is a strong likelihood of impact that could be maintained as long as policies are maintained (score of 2).	

3.10.3.2. Ease of implementation and enforceability

Criteria	**Evaluation**	**Score**
Implementation	Most of the policy approaches considered here (including consumer education and measures implemented in government food service) would not be difficult to implement (score of 3). Developing carbon intensity labels for meat and dairy products could require new investment and/or capacity development among producers and/or retailers, including where these are used to support implementation of product standards and financial incentives (score of 2).	2-3
Enforceability	Education campaigns and government food service programs require no enforcement. Labeling, marketing restrictions, and taxation policies would require oversight and enforcement, but compliance would not be difficult to achieve.	2-3

3.10.3.3. Cost-effectiveness

Evaluation	**Score**
Viewed strictly in terms of monetary cost, a shift to less meat and dairy consumption is likely to be highly cost-effective, leading to cost savings for most households, restaurants, and food service institutions (Springmann et al. 2021). Some measures – such as requiring carbon-intensity or health labels, or removing producer subsidies – could result in some cost to businesses. The other main (non-taxation) policy approaches considered here – e.g., education campaigns – would not impose significant cost burdens.	3

3.10.3.4. Economic, environmental, and societal impacts

Criteria	Evaluation	Score
Equity	Consumer education and information disclosure policies pose few equity risks, although careful design may be needed to ensure they reach and benefit all communities. Financial subsidy measures could be neutral or positive in their distributional effects; however, it would be important to design policies in ways that avoid steering only (or primarily) food insecure or low-income families towards lower meat and dairy consumption. Taxation policies are likely to be regressive and would require careful policy design to redress negative distributional impacts (Springmann et al. 2017) (score of 1). At a systemic level, reduced meat production could have unintended adverse consequences for under-resourced and food-insecure communities; these may need be carefully managed over time (Verkuijl et al. 2023). In addition, large changes in meat and dairy consumption could impact Oregon's rural economies, which could require producer and workforce transition assistance (including financial and other assistance to reduce the greenhouse gas intensity of livestock production – see separate evaluation related to these measures in section 3.11).	2
Jobs	Substantially reducing meat and dairy consumption across the state could lead to significant shifts in Oregon's agriculture sector, and the need to ensure a smooth economic transition from livestock production to greater crop production or other activities (which may require, for example, some relocation of workforces) (Verkuijl et al. 2023). The expected net effect on jobs would need further research.	2
Health	Multiple studies suggest that, as long as protein and nutritional needs are met, diets lower in meat and dairy consumption can also be healthier (Bui et al. 2024; EAT Lancet Commission 2019; Godfray et al. 2018; Willett 2001). Meeting nutritional needs is essential (Giromini and Givens 2022), and where this is ensured, a shift in diet could lead to health benefits for many Oregonians.	3
Environment	In addition to being more greenhouse gas intensive than crop production, meat and dairy production have outsize environmental impacts in other areas, especially in terms of water use and land use pressure (Ritchie et al. 2022; Ritchie and Roser 2024). Reducing meat and dairy consumption can contribute to alleviating these other impacts, both within and outside Oregon.	3

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3.11. Shift to lower-emission meat and dairy products

The largest potential for reducing greenhouse gas emissions from food consumption comes from shifting meat and dairy consumption to less emission-intensive (e.g., plant-based) alternatives. This option is evaluated in section 3.10. Additional reductions, however, could in principle be achieved by shifting to lower-emission alternatives *within* certain food categories, such as consuming sustainably produced beef and dairy products with a lower greenhouse gas footprint compared to conventional production methods. This could be achieved, for example, by incentivizing or requiring food producers (within and outside of Oregon) to disclose information about the lifecycle greenhouse gas emissions associated with their products. Such policies would require the development of reliable emissions-intensity data for different producers. Developing these data could be difficult for food commodities with complex, and difficult-to-trace, supply chains (Poore and Nemecek 2018). The data challenges may be more tractable for meat (especially pork and beef) and dairy products. Furthermore, there are discrete and quantifiable measures meat and dairy producers could take to reduce methane emissions (e.g., improving manure management, using feed supplements, and/or adapting grazing methods), which form the largest part of their greenhouse gas footprint. Some producers in Oregon are already adopting these measures. This evaluation is therefore focused on these food categories.

3.11.1. Policy approaches

As with other categories of consumption (e.g., goods and appliances, clothing, electronics, building materials, etc.) an effective approach to encouraging consumption of lower-emission meat and dairy products would likely involve a combination of multiple policy tools. Initial policies could be focused on information disclosure to consumers. (Note, however, that one of the effects of incentivizing or requiring information disclosure may be to encourage producers to lower their emissions, regardless of – or in addition to – any changes in consumer behavior.) Possible policy approaches could include:

Outreach and education	• Implement public awareness campaigns on the climate and health impacts of meat and dairy consumption, and to inform them about lower-emission products • Implement outreach programs to livestock producers related to opportunities associated with lower-emitting production methods (Anderson et al. 2022)
Information disclosure	• Incentivize or require carbon footprint, or low-emission production-method, labeling for meat and dairy products

Product regulations & standards	• Require meat and dairy products sold in Oregon to meet greenhouse gas intensity benchmarks (or that they be produced using methods with lower emissions)
Financial incentives	• Subsidize low-emission meat and dairy product offerings • Provide funding to support Oregon producers in transitioning to lower-emitting production methods • Tax meat and dairy products produced using higher-emitting methods

Government institutions could also take steps to increase consumption of lower-emitting meat and dairy products, by making these available in food service operations. Government programs (e.g., in schools) could have important signaling effects in terms of shifting societal norms.

Public procurement standards & requirements	• Source meat and dairy products used in schools and other government-run food service operations from lower-emitting producers

3.11.2. Greenhouse gas reduction potential

Study assumptions: For beef and dairy production, improved feeding methods are possible that reduce enteric fermentation methane emissions, and methane generated from manure management at large-scale livestock operations can be captured and destroyed (producing energy in the process, which can displace use of fossil fuels). Alternative farming methods, such as adaptive grazing, could also reduce methane emissions (both enteric and manure-related) (Williams 2021; Chadwick et al. 2011). The potential emission reductions achievable from information disclosure or product standard-type policies are somewhat speculative. However, a 2008 study suggested that, in North America, reductions of up to 20-25% are possible in enteric methane emissions from dairy and beef production, using improved feeding practices and dietary additives (Smith et al. 2008). For manure management, studies suggest that anaerobic digestion methods can reduce methane emissions up to 50% or more (Aguirre-Villegas et al. 2014).

Rebound potential: Rebound emissions should be limited or non-existent, given that lower-emission livestock production methods (based on current practice) tend to be as or more expensive than conventional methods.

Emissions reduction potential: If methane emissions associated with meat and dairy products consumed in Oregon were reduced in line with the estimates provided above, this could – when combined with other measures[106] – contribute to the following greenhouse gas emission reductions:

	Metric tons CO_2e	% reduction from reference case
Annual emission reduction[1] in 2050	740,000	0.6%
Cumulative emissions reductions[1] between 2021 and 2050[2]	10,473,000	0.3%

[1] Emission reductions are net of rebound effects, and represent reductions below reference case emissions, derived from a simplified projection of current trends.
[2] Policies are modeled to begin in 2025, reaching full effect by 2050.

3.11.3. Evaluation

Although a range of policy approaches could be deployed to encourage consumption of lower-emission meat and dairy products in Oregon (as identified above), the assessment here focuses on outreach, information disclosure, and subsidies or financial support.

3.11.3.1. Likelihood and durability of impact

Evaluation	Score
Impact and durability could be low for outreach and information disclosure policies; however, an important effect of information disclosure requirements could be to induce producers to reduce emissions, even in the absence of a direct consumer response (score of 1-2). Larger and more durable impacts could be expected if policies are combined with labeling requirements or financial incentives, particularly if the financial incentives result in infrastructure changes (e.g., installation of anerobic digesters and other improved methods for manure management) (score of 2-3).	2

[106] Emission reduction estimates account for interactions between different assessed measures, and so do not reflect potential reductions if each outcome were achieved in isolation. See section 2.2 for a description of the methodology used and the sequencing of abatement measures.

3.11.3.2. Ease of implementation and enforceability

Criteria	Evaluation	Score
Implementation	The most difficult implementation challenge is likely to be obtaining robust practice or emission-intensity data for different producers, which could require developing new standards for meat and dairy "environmental product disclosures" (score of 1). (At the same time, there are relevant models to draw from here, including existing organic and fair-trade labelling programs.)	1
Enforceability	A key component of a successful policy approach would be information disclosure by producers related either to greenhouse gas intensity, or to the methods used in production. Ensuring this information is accurate could pose enforcement challenges related to auditing and verification (score of 1 to 2).	1-2

3.11.3.3. Cost-effectiveness

Evaluation	Score
A significant barrier to adopting methods for reducing enteric methane is the perceived cost by dairy and beef producers (Anderson et al. 2022). Manure management solutions can also be costly (although they are increasingly incentivized by climate policies, such as clean fuels standards, in states like California, Oregon, and Washington). For consumers, current low-emission dairy product offerings are more expensive than conventional alternatives. However, the overall cost per metric ton of CO_2-equivalent reduced is not likely to be excessive for some types of mitigation efforts, as evidenced by the participation of many livestock operations in existing carbon pricing programs (e.g., carbon crediting programs and clean fuel standard programs, which pay for emission reductions achieved).	1

3.11.3.4. Economic, environmental, and societal impacts

Criteria	Evaluation	Score
Equity	Further research may be needed to assess equity and employment implications. To the extent policies increase the price of meat and dairy products, impacts may be mildly regressive. Under a simple information disclosure approach, however, consumers would retain access to conventional (possibly lower priced) product options.	2
Jobs	Under a policy approach based on outreach, information disclosure and financial subsidies, job impacts are expected to be minimal. Although producers might bear higher costs to adopt greenhouse gas-reducing production methods, a flexible approach means they	2

	would only do so where the perceived benefits outweigh costs. An Oregon policy that supports in-state producers to adopt lower-emitting production methods could also boost industry competitiveness, as many producers anticipate the need to control emissions in the future (Anderson et al. 2022).	
Health	The primary methods for reducing livestock methane emissions (e.g., feed additives for enteric methane, and anaerobic digestion for manure management) would not be expected to have significant public health impacts, either positive or negative.	2
Environment	As with health impacts, the primary mitigation methods considered here would not lead to significantly different environmental outcomes beyond methane emission reductions (score of 2). However, alternative practices involving regenerative agriculture (e.g., adaptive grazing, which can reduce both enteric and manure methane emissions) could yield substantial environmental benefits (score of 3) (Williams 2021).	2-3

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3.12. Reduced clothing consumption

In 2021, the embodied emissions in clothing, textiles and shoes accounted for 1.0% of Oregon's total consumption-based GHG emissions (Oregon Department of Environmental Quality 2024).[107] Beyond greenhouse gas emissions, clothing and textiles are a significant contributor to water stress, industrial water pollution, chemical and microplastic pollution, and textile waste (Niinimäki et al. 2020). Additionally, many garments and clothing fibers are manufactured using child labor and forced labor, violating international standards (U.S. Bureau of International Labor Affairs 2022).

Consumers can adopt various strategies to reduce the purchase of new garments, including maximizing the use of existing clothing, repairing and repurposing clothes and textiles, opting for secondhand options such as thrift shopping or clothing swaps, prioritizing quality and durability over quantity when making purchases, and planning wardrobe essentials to minimize overall consumption. Sustainable laundry practices, such as washing full loads only, washing in cold water, turning clothes inside out, washing clothes less often and air-drying clothes, can increase longevity of clothes and reduce use phase emissions associated with washing and drying.

3.12.1. Potential policy approaches

Various policies could be implemented to reduce the purchase of new clothing:

Outreach and education	• Creating awareness around the environmental impacts of clothing and textiles, in particular fast fashion • Promoting strategies, such as DEQ's Make Every Thread Count[108] outreach toolkit, to reduce purchase of new clothing such as through wardrobe planning, repair and reuse, buying secondhand, buying high quality and durable clothes, etc.) • Encourage workplaces to adopt the use of workplace uniforms • Encourage sustainable laundry practices
Information disclosure	• Eco-labels and supply chain information disclosure

[107] Emissions associated with the use of clothing, such as those from washing and drying, are categorized separately under appliance-related emissions. If we combine the emissions associated with purchasing clothing and textiles and using and washing clothing and textiles, emissions double to around 2.1% of total consumption emissions in Oregon.

[108] https://www.oregon.gov/deq/mm/wpcampaigns/Pages/textiles.aspx

Financial incentives (or disincentives)	• Continue to provide Materials Management grants,[109] including reuse/repair grants, to support businesses
Product regulations & standards	• Introduce Oregon version of Fashion Act. For example, New York's proposed *Fashion Sustainability and Social Accountability Act*[110] would require large apparel and footwear producers to track and reduce their environmental impact across the supply chain • Introduce Extended Producer Responsibilities (EPR) for large producers of clothing and textiles to implement and fund end markets for clothing recycling programs. California is proposing a similar policy in their *Responsible Textile Recovery Act of 2024*[111] • Ban the destruction of unsold and returned textiles and footwear by retailers and producers located in Oregon (European Environment Agency 2024)

3.12.2. Greenhouse gas reduction potential

Study assumptions: A C40 Cities study found that if typical consumers aimed to purchase only 8 new clothing items per year, emissions in the clothing and textiles sector could decrease by 47% between 2017 and 2050 (C40 Cities et al. 2019). In a similar analysis, the Hot or Cool Institute determined that the purchase of new garments should be limited to an average of 5 items per person per year to align clothing consumption levels with the 1.5-degree Paris target (Coscieme et al. 2022). Given this background and the policy measures proposed above, this study assumes that Oregon consumers could reduce clothing purchases (and associated embodied emissions)[112] by 30% by 2035, by shifting to higher quality, more durable clothes (e.g., avoiding low-quality "fast fashion" options).

Rebound potential: Similar to other forms of consumption, the cost savings from reduced clothing purchases, or the purchase of lower-cost second-hand clothing, may potentially lead to an increase in emissions-intensive spending in other sectors. For this analysis, we assume a reduction in clothing and textile purchases would be achieved primarily through a shift to higher

[109] https://www.oregon.gov/deq/mm/Pages/Product-Lifespan-Extension.aspx

[110] https://www.nysenate.gov/legislation/bills/2023/S4746

[111] https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=202320240SB707

[112] Our analysis did not account for reductions in use-phase emissions associated with washing and drying.

quality items, leading to limited cost savings (overall savings are estimated at around 10%). Based on this assumption, we estimate rebound emissions to be around 6% of cumulative emission reductions achieved between 2025 and 2050.

Emissions reduction potential: Given the above assumptions, we estimate that reducing clothing consumption could – when combined with other measures[113] – contribute to the following greenhouse gas emission reductions:

	Metric tons CO_2e	**% reduction from reference case**
Annual emission reduction[1] in 2050	368,000	0.3%
Cumulative emissions reductions[1] between 2021 and 2050[2]	6,786,000	0.2%

[1] Emission reductions are net of rebound effects, and represent reductions below reference case emissions, derived from a simplified projection of current trends.
[2] Policies are modeled to begin in 2025, reaching full effect by 2035.

3.12.3. Evaluation

The following section provides an evaluation of the policies identified above aimed at minimizing the purchase of new clothing.

3.12.3.1. Likelihood and durability of impact

Evaluation	**Score**
Education campaigns often have an uncertain – and difficult to evaluate – effect on household behavior and avoided emissions. Furthermore, over time changes in behavior in response to these campaigns may not be durable (Dietz et al. 2009; Timmer et al. 2009). However, clothing is often viewed as a status symbol, and there is a strong desire to conform to current behaviors and fashion trends. Recent studies have shown that consumer sentiment toward sustainability in fashion and the effects of social media platforms, such as TikTok, are shaping consumer behavior and influencing their buying habits (Cernansky 2024; McKinsey 2020). However, while this is impacting some consumer segments, these sentiments are not necessarily translating into a reduction in the number of clothes purchased on a broad scale (Kleinhückelkotten and Neitzke 2019) (score of 1).	1-2

[113] Emission reduction estimates account for interactions between different assessed measures, and so do not reflect potential reductions if each outcome were achieved in isolation. See section 2.2 for a description of the methodology used and the sequencing of abatement measures.

Evaluation	Score
On the other hand, the effects of Fashion Act-style legislation and EPR could have a more lasting impact as these measures would be legally mandated. They would also provide dedicated funding for clothing reuse and recycling and establish infrastructure and frameworks that can be maintained over a longer period (Ellen MacArthur Foundation 2024) (score of 2).	

3.12.3.2. Ease of implementation and enforceability

Criteria	Evaluation	Score
Implementation	Consumer education campaigns and information disclosures related to reducing clothing purchases are easy to implement. Requiring companies to monitor and report environmental impacts across the clothing and textile supply chain will require some initial effort to implement, but in general, voluntary sustainability reporting is a practice that many companies are already implementing to some extent.	2
Enforceability	Not applicable for consumer education programs and information disclosures (score of 3). Enforcing the reporting of environmental impacts is relatively straightforward if reporting requirements are well-designed; audits or spot checks would be necessary to verify compliance (score of 2).	2-3

3.12.3.3. Cost-effectiveness

Evaluation	Score
Consumer education campaigns, information disclosure requirements, and the implementation of standards are relatively low cost. Providing small grants to small reuse/repair businesses will also be low cost. This will have minimal impacts on households and could lead to cost savings (score of 3). However, Fashion Act-style legislation and EPR policies will require producers to invest time and budget to track and reduce supply chain emissions and implement clothing recycling programs (score of 1).	1-3

3.12.3.4. Economic, environmental, and societal impacts

Criteria	Evaluation	Score
Equity	The policies outlined in this measure will have minimal impact on equity. Generally, secondhand items are consumed by lower-income households to begin with. While secondhand items are also lower price, they can be perceived as not fashionable, low quality	3

	and of insufficient variety (Kleinhückelkotten and Neitzke 2019). More sustainable fashion that uses more durable, higher-quality fabrics and has a lower environmental impact can be more expensive. Therefore, lower cost, fast fashion brands are found to make fashion accessible to lower-income households. For these reasons, lower-income households are less likely to shift consumption patterns (Gwozdz et al. 2017). Generally, higher-income households tend to purchase more clothing (Gwozdz et al. 2017), so consumer education campaigns and information disclosures should be targeted towards these households.	
Jobs	This measure has the potential to result in job losses in conventional and fast fashion clothing and textile retail stores in Oregon. However, at the same time, it could give rise to slow-fashion producers and second-hand sellers originating from Oregon, as well as clothing repair shops. For example, an analysis of social enterprises in the European Union found that 20 to 35 jobs could be created for every 1,000 metric tons of used textiles that are collected and sorted for reuse and recycling (rreuse 2021).	3
Health	The health benefits from reducing the amount of clothing purchased is generally indirect, through reduced environmental impacts such in air, water, and soil quality and climate benefits. There are direct health benefits associated with the purchase of durable clothing made of natural fibers such as wool, hemp, flax, rather than plastic-based clothing. For example, in a landmark study, it was found that micro-plastics, which are commonly shed from plastic-based clothing, is a risk factor in cardiovascular diseases (Marfella et al. 2024). Also, synthetic fabrics, and at times natural fabrics, are often treated with toxic chemicals like chromium, PFAS, TBBPA, and BPA for dyeing or to create flame, water, stain, or pest resistance (Muñoz and Lein 2024).	3
Environment	Policy implementation is likely to contribute to positive environmental outcomes (reduced pollution or preservation of natural resources), in Oregon and/or elsewhere (score of 3). However, a potential increase in demand for certain natural fabrics, such as traditional cotton, could have adverse impacts due to the high levels of water extraction and land use requirements associated with these fabrics (Beton et al. 2014) (score of 1).	1-3

3.12.4. References

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3.13. Reduced electronics consumption

In Oregon, electronics consumption accounts for over 4% of consumption-based emissions, with approximately 68% of these emissions related to the production of electronics, and the remainder largely associated with the energy consumed during their use (Oregon Department of Environmental Quality 2024). However, empirical evidence shows that product lifespans are decreasing, particularly among electronics and accessories such as LCD monitors, TVs, PCs, laptops, and mobile phones, largely due to planned obsolescence (Bakker et al. 2014; Wieser 2016). This not only has implications for emissions but also for electronic waste. Optimizing the lifetimes of electronic equipment is one way to reduce production-related emissions, but it also offers many benefits including decreasing electronic waste, conserving raw (and often, rare) materials, providing cost savings, and contributing to energy efficiency during the production and disposal stage. There are several ways to extend the lifetimes of electronics, such as repairing or upgrading them, buying refurbished items, sharing/renting/leasing equipment instead of buying new, and acquiring new TVs, personal computers (PCs), and smartphones only when replacement is necessary. Additionally, individuals can choose to have fewer or simpler electronic goods and prioritize leisure activities such as spending more time outdoors, reading or volunteering, rather than watching TV, for example.

3.13.1. Potential policy approaches

Potential policy approaches identified for optimizing the lifetimes of electronics include:

Outreach and education	• Implement consumer education campaigns on the environmental and cost impacts of planned obsolescence and inform consumers on strategies to maximize the use of electronics, including sharing or repairing electronics
Information disclosure	• Establish a repairability index for products (which shows how repairable products are based on the availability of spare parts, technical documents, and the ease with which a product can be disassembled)
Financial incentives	• Establish repair funds (e.g., with producers paying a portion of repair costs) or repair vouchers for consumers • Subsidize sharing and repair services • Provide financial incentives to build careers in repairing difficult-to-repair products • Provide financial and other types of support to businesses specializing in repair, reuse, and product lifespan extension of electronics • To reduce use of electronic goods, subsidize non-digital activities, or make them free of cost and more readily accessible

	(e.g., locate them close to neighborhoods to minimize transport emissions), especially for children and youth (Katapally et al. 2018). Examples include promotion of community support and volunteering, encouraging reading, local classes, activities or spaces for pottery, painting, handicraft, carpentry, singing, music, etc. where needed equipment and tools are shared, promotion of benefits of outdoor activities and green spaces, making recreational equipment available for rent, improving accessibility of trails, providing outdoor spaces, etc.
Product regulations & standards	• Evaluate recently adopted right-to-repair policy and consider future improvements or modifications as warranted • Prohibit planned obsolescence • Prohibit disposal of functional products • Binding requirements for products (energy efficiency, lifespan, repairability, compatibility, etc.) • Require extended warranties on high-cost durable goods • Establish transparent and universal standards for refurbishment (Hazelwood and Pecht 2021)
Public investment	• Invest in low-emissions intensive leisure activities

Drawing upon the Oregon DEQ's *Strategic Plan for Reuse, Repair, and Extending the Lifespan of Products in Oregon* (2016), there are also actions the government can take with respect to its procurement of electronic devices:

Public procurement standards & requirements	• Support reuse, repair and durability considerations in public procurement of electronics, including purchases of goods that are remanufactured or reused and are designed with durability, repairability or reusability attributes.

3.13.2. Greenhouse gas reduction potential

Study assumptions: As part of a C40 Cities study on measures to reduce consumption-based greenhouse gas emissions, a "progressive" target was identified to extend the lifetimes of laptops and similar devices to 7 years (C40 Cities et al. 2019). This study calculated that if households and government met this target, it could reduce electronics consumption emissions by 33%. We assume a similar reduction could be met in Oregon by 2035, starting with reductions in 2025.

Rebound potential: Increasing the lifetime of electronics equipment also means reducing how frequently they are purchased. This could result in rebound emissions if there is no change in the cost of electronics, and households spend any cost savings on other forms of consumption. Given that electronics consumption has a somewhat low emissions intensity per dollar, relative rebound effect could be large. For this analysis, we assume that, on a per unit basis, reduced consumption of electronics would lead to a 50% cost savings (e.g., products with greater longevity would have a relatively low cost premium, and/or some consumers might choose to keep current products for longer). Under this assumption, we estimate rebound emissions to be around 50% of cumulative emission reductions achieved between 2025 and 2050.

Emissions reduction potential: Given the above assumptions, we estimate that optimizing the lifetime of electronics could – when combined with other measures[114] – contribute to the following greenhouse gas emission reductions:

	Metric tons CO_2e	**% reduction from reference case**
Annual emission reduction[1] in 2050	696,000	0.5%
Cumulative emissions reductions[1] between 2021 and 2050[2]	12,157,000	0.4%

[1] Emission reductions are net of rebound effects, and represent reductions below reference case emissions, derived from a simplified projection of current trends.
[2] Policies are modeled to begin in 2025, reaching full effect by 2035.

3.13.3. Evaluation

The following assessment considers a combination of policy measures, similar to those implemented in France, that promote a circular economy and anti-waste, including right-to-repair laws, extended warranties, repairability indices and more (see a summary in Ellen MacArthur Foundation (2022)).

3.13.3.1. Likelihood and durability of impact

Evaluation	**Score**
From a consumer perspective, education campaigns often have an uncertain – and difficult to evaluate – effect on household behavior and avoided emissions. Furthermore, over time changes in behavior in response to these campaigns may not be durable, as some households revert to old practices (Dietz et al. 2009; Timmer et al. 2009). Prior to the adoption by manufacturers of "planned obsolescence" practices, goods, including electronics, were produced in a way that made them more easily repairable. As a result, the likelihood of success for right-to-repair policies and their durability of impact is highly dependent upon product	1-2

[114] Emission reduction estimates account for interactions between different assessed measures, and so do not reflect potential reductions if each outcome were achieved in isolation. See section 2.2 for a description of the methodology used and the sequencing of abatement measures.

durability and whether manufacturers incorporate repairability and reusability into their designs (Thomas 2003). Product regulations to reduce planned obsolescence and build in repairability will improve durability (score of 2). The cost of repair, consumer trust in reuse products and the complexity in scaling up repair and reuse businesses can limit the potential success of this measure (Dagnaud 2020). Financial incentives, such as vouchers, and availability of electronics repair shops are also important to encourage consumers to actively attempt to extend the lifetimes of their products.	

3.13.3.2. Ease of implementation and enforceability

Criteria	**Evaluation**	**Score**
Implementation	Consumer education campaigns related to optimizing the lifetimes of electronics are easy to implement (score of 3). Other policy measures may face some implementation challenges (score 2). Prohibiting disposal of functional electronics will be challenging to implement, as will banning planned obsolescence (score of 1).	2-3
Enforceability	Not applicable for consumer education programs and financial subsidy measures and public procurement guidelines/policies. There will be some level of effort to ensure products have proper informational disclosures. Enforcement of bans on disposal of functional electronics and ban on planned obsolescence could be difficult (score of 1).	2-3

3.13.3.3. Cost-effectiveness

Evaluation	**Score**
Consumer education campaigns – despite their uncertainty of impact – can be highly cost-effective compared to regulations, because they have the potential to significantly reduce costs for individual consumers who respond to them. However, if consumers do not respond, the cost effectiveness goes down (score of 2). Lack of response could be due to the reasons mentioned above, including the cost of repair compared to the purchase of a new product or lack of consumer trust in reusing products (Dagnaud 2020). Other identified policy measures are likely to financially benefit consumers (score of 3). For example, one study found that repairs could reduce household spending on electronics and appliances by 22 percent, which would save an average American family approximately $330 per year (U.S. PIRG 2021). For low-income households, repairs may be costly, but financial incentives like vouchers, can make them more cost-effective.	2-3

3.13.3.4. Economic, environmental, and societal impacts

Criteria	Evaluation	Score
Equity	Consumer education campaigns and information disclosures pose few equity risks, although careful design may be needed to ensure they reach and benefit all communities. As mentioned above, for low-income households, repairs may be costly, but financial incentives like vouchers, can make it more cost-effective. As such, the financial subsidy measures identified above are likely to have positive (progressive) effects on equity.	3
Jobs	There is the potential for job losses in electronics manufacturing and electronic retail stores by reducing demand for these products, but there is the potential for job growth in repair shops.	2
Health	There are many indirect health impacts from the reduction of e-waste and emissions of both greenhouse gases and toxics during production of electronic devices and components. Potential for modest reductions in direct health impacts from these policies.	2
Environment	Electronics production and waste can have multiple adverse environmental impacts beyond contributing to greenhouse gas emissions, including water and soil pollution from mining and waste disposal as well as manufacturing. Optimizing the lifetimes of electronics, and reducing the purchase of new electronics, can contribute to alleviating these other impacts, both within and outside Oregon.	3

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3.14. Reduced appliance and furnishings consumption

In 2021, major appliances, including heating and cooling equipment, ranges and microwaves, refrigerators and freezers, washers and dryers, as well as furnishings and supplies (including lawn equipment, tools and office equipment), accounted for around 16% of consumption-related emissions in Oregon (Oregon Department of Environmental Quality 2024). Major appliances alone accounted for 12%. For appliances, most of the emissions (94%) are use-related, e.g., arising from energy consumed for space heating and cooling. In contrast, nearly 94% of the emissions from furnishings and supplies are production-related, with the remaining 6% associated with disposal. For major appliances, such as refrigerators, empirical evidence shows that product lifespans are decreasing, largely due to "planned obsolescence" practices by manufacturers (Bakker et al. 2014; Wieser 2016).

Reducing the purchase of new major appliances, furnishings and supplies can be achieved through various approaches, such as through buying used goods, maintaining and repairing goods, using services rather than owning appliances (such as laundry or food services), or sharing goods (such as tools or lawn mowers) with others. Taking proper care of goods and appliances, and considering reuse or redesign of furniture components, can also help extend their lifespan.

3.14.1. Potential policy approaches

Key policy approaches identified for reducing the purchase of new major appliances, electronics and furnishings include:

Consumer education	• Public outreach and education on reusing furniture and appliances, such as to reduce the stigma on buying used goods • Implement consumer education campaigns on the environmental and cost impacts of planned obsolescence and inform consumers on strategies to maximize the use of appliances, furnishings, and supplies including sharing or repairing goods • Consider leasing or pay-per-use of appliances, rather than ownership (Bocken et al. 2018; Bressanelli et al. 2020b)
Information disclosure	• Repairability index for products (shows how repairable a product is based on the availability of spare parts, technical documents, and the ease with which a product can be disassembled)
Financial incentives	• Establish repair funds (e.g., with producers paying a portion of repair costs) or repair vouchers for consumers • Subsidize, sharing and repair services

	• Provide financial incentives to build careers in repairing difficult-to-repair products, including the use of 3D printing to repair goods or build spare parts (Bressanelli et al. 2020a) • Provide financial and other types of support to businesses specializing in repair, reuse, and product lifespan extension of electronics in both low- and high-income neighborhoods • Provide financial and other types of support for service-oriented businesses across both low- and high-income neighborhoods
Product regulations & standards	• Evaluate recently adopted right-to-repair policy and consider future improvements or modifications as warranted • Prohibit planned obsolescence • Prohibit disposal of functional products • Binding requirements for products (energy efficiency, lifespan, repairability, compatibility, etc.) • Require extended warranties on high-cost durable goods • Create standards for reused items and materials, so that they are less "boutique" items and more like "commodities." (e.g., support the creation of databases and grades of reusable items) • Require appliance manufacturers to form or join a producer responsibility organization (PRO) that is tasked with providing an appliance repair hotline or service for low-income households. The PRO would contract with existing repair companies and offer discounted services. • Provide funding to community-based organizations for the purpose of replacing inefficient appliances in the homes of low-income Oregonians. Producer responsibility organizations (PROs) could contribute to this fund. • Require appliance manufacturers to join a PRO that develops and implements a plan to achieve progressively increasing goals for the repair and remanufacture of items such as office equipment, furniture, etc.
Public investment	• Lending libraries for tools, lawn and office equipment

Drawing upon the Oregon DEQ's *Strategic Plan for Reuse, Repair, and Extending the Lifespan of Products in Oregon* (2016), there are also actions the government can take with respect to its procurement of major durable goods:

Public procurement standards & requirements	• Support reuse, repair and durability considerations in public procurement of appliances and furnishings, including purchases of goods that are remanufactured or reused and are designed with durability, repairability or reusability attributes.

Internal policies and programs	• Share or reuse major appliances and furnishings between public institutions

3.14.2. Greenhouse gas reduction potential

Study assumptions: For this analysis, we estimated that households and government could reduce the purchase of appliances and furnishings by 25% by 2040, based on a less aggressive version of the scenario assumptions applied in Erickson et al. (2012). This is equivalent to extending these products' usable lifetime by one third.

Rebound potential: Reducing the purchase of these goods could result in rebound emissions if households spend the cost savings on other forms of consumption. Appliances and furnishings tend to have higher-than-average emissions intensities, meaning that any rebound spending is likely to generate fewer emissions than the emissions avoided. For this analysis, we assume a reduction in appliance and furnishings purchases would be achieved primarily through a shift to higher quality items, leading to limited cost savings (overall savings are estimated at around 10%). Based on this assumption, we estimate rebound emissions to be around 5% of cumulative emission reductions achieved between 2025 and 2050.

Emissions reduction potential: Given the above assumptions, we estimate that reducing appliance and furnishings consumption could – when combined with other measures[115] – contribute to the following greenhouse gas emission reductions:

	Metric tons CO_2e	**% reduction from reference case**
Annual emission reduction[1] in 2050	455,000	0.4%
Cumulative emissions reductions[1] between 2021 and 2050[2]	7,490,000	0.2%

[1] Emission reductions are net of rebound effects, and represent reductions below reference case emissions, derived from a simplified projection of current trends.
[2] Policies are modeled to begin in 2025, reaching full effect by 2040.

3.14.3. Evaluation

The following assessment considers a combination of policy measures, as described above.

[115] Emission reduction estimates account for interactions between different assessed measures, and so do not reflect potential reductions if each outcome were achieved in isolation. See section 2.2 for a description of the methodology used and the sequencing of abatement measures.

3.14.3.1. Likelihood and durability of impact

Evaluation	Score
Education campaigns often have an uncertain – and difficult to evaluate – effect on household behavior and avoided emissions. Furthermore, over time changes in behavior in response to these campaigns may not be durable, as some households revert to old practices (Dietz et al. 2009; Timmer et al. 2009) (score of 1). Durability of impact, however, is also highly dependent upon product durability, and whether manufacturers build in repairability and reusability into their products. For furnishings, ensuring durability is more feasible than appliances in the instances that they do not contain any mechanical parts (this does not apply to supplies such as lawn mowers and snow blowers). Product regulations to reduce planned obsolescence and build in repairability will improve durability. The cost of repair, lack of consumer trust in reuse products and the complexity in scaling up repair and reuse businesses can limit the potential success of these measures (Dagnaud 2020) (score of 2). Financial incentives, such as vouchers, and availability of repair shops and services are also important to encourage consumers to actively attempt to extend the lifetimes of their products (score of 2). Given the individualized nature of households and the desire for convenience, sharing of major appliances or using services, may require a significant cultural shift with the former likely exhibiting resistance from higher-income households, and the latter not being economically feasible for lower-income households (score of 2).	1-2

3.14.3.2. Ease of implementation and enforceability

Criteria	Evaluation	Score
Implementation	Consumer education campaigns, information disclosures, financial incentives and the public investments listed above are relatively easy to implement (score 3). Other policy measures may face some implementation challenges (score of 2). Prohibiting disposal of functional goods will be challenging to implement, as will banning planned obsolescence (score of 1).	2-3
Enforceability	Not applicable for consumer education programs, financial subsidy measures, and public procurement guidelines/policies. There will be some level of effort to ensure products have proper informational disclosures and to implement public investments such as lending libraries. Enforcement of bans on disposal of	2-3

	functional goods and ban on planned obsolescence could be difficult (score of 1).	

3.14.3.3. Cost-effectiveness

Evaluation	**Score**
Consumer education campaigns – despite their uncertainty of impact – can be highly cost-effective compared to regulations, because they have the potential to significantly reduce costs for individual consumers who respond to them (score of 2). However, if consumers do not respond, the cost effectiveness goes down. This could be due to the reasons mentioned above, including the cost of repair compared to the purchase of a new product or lack of consumer trust in reuse products (Dagnaud 2020). Other identified policy measures are also likely to financially benefit consumers and will have minimal cost implications for their implementation (score of 3).	2-3

3.14.3.4. Economic, environmental, and societal impacts

Criteria	**Evaluation**	**Score**
Equity	Consumer education campaigns and information disclosures pose few equity risks, although careful design may be needed to ensure they reach and benefit all communities. For low-income households, repairs may be costly, but financial incentives like vouchers, can make this more cost-effective for them. Similarly, the use of services can be cost-prohibitive or inconvenient unless they are close to a household and are less costly than the purchase and maintenance of an appliance. Used goods typically sell at a significant discount, but they may also not last as long, and ensuring they work and that delivery costs are feasible, particularly for large appliances and furnishings, is important. The financial subsidy measures identified above are likely to have positive (progressive) effects on equity, although more can be done to ensure this is economically feasible for lower-income households.	3
Jobs	There is the potential for job losses in appliance and furniture manufacturing and associated retail stores by reducing demand for these products, but there is the potential for job growth in repair shops and related servicing industries.	2
Health	No direct health impacts from these policies are expected for Oregonians, positive or negative.	2
Environment	There are environmental impacts related to the materials needed to manufacture major appliances, furnishings and supplies, including forest and wood products as well as metals and mined resources.	3

	The production process also requires the use of water and can result in air pollution. Reducing the purchase of new goods, can contribute to alleviating these other environmental impacts, both within and outside Oregon.	

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3.15. Lighter weight cars

Vehicles and parts account for the largest share of consumption-related emissions in Oregon at around 17% of total emissions in 2021, of which 82% is from vehicle use (i.e., fuel combustion) and 18% is from manufacturing and parts (Oregon Department of Environmental Quality 2024). The emissions from vehicle *production* are non-trivial, contributing to more emissions than those from lighting and computers combined, and surpassing emissions from meat and dairy consumption individually. While emissions per mile have decreased over time due to advances in fuel economy and the expansion of hybrid and electric vehicles, the growth of light trucks and SUVs has the potential to undo that progress. SUVs, vans and light trucks are increasingly popular, comprising nearly 60% of registered passenger vehicles in the state (Oregon Department of Energy 2023). This poses a challenge as these larger vehicles are heavier, less fuel-efficient and cause more traffic fatalities[116] than smaller vehicles such as sedans. Electric vehicles have lower life cycle emissions than their conventional counterparts (Woody et al. 2022), but are also heavier, putting a premium on weight considerations.

Choosing lighter-weight cars would reduce greenhouse gas emissions from vehicle production, transportation, and use. It would also reduce wear and tear on roadways and parking infrastructure (thereby reducing associated costs and environmental impacts from maintenance and replacement). This assessment looks at the potential for choosing smaller, lighter-weight vehicles (e.g., sedans) over larger, heavier options.[117]

3.15.1. Potential policy approaches

To encourage the purchase of lighter vehicles, a range of policies could be deployed:

Outreach and education	• Promote benefits of smaller and lighter vehicles from an economic, environmental and safety perspective

[116] https://www.consumerreports.org/cars/car-safety/the-hidden-danger-of-big-pickup-trucks-a9662450602/

[117] Alternatively, consumers could choose vehicles made with lighter-weight materials and designs (referred to in the auto industry as "lightweighting"). For example, substituting traditional steel and cast iron components with lightweight materials such as high-strength steel, magnesium alloys, aluminum alloys, carbon fiber, and polymer composites can reduce a vehicle's body and chassis weight by up to 50% (www.energy.gov/eere/vehicles/lightweight-materials-cars-and-trucks) However, the level of emissions reduction possible depends on the material used (e.g., Lewis et al. 2014). The analysis here is therefore focused on arresting the consumer trend towards larger vehicle types.

Information disclosure	• Require or incentivize disclosure of vehicle life cycle emissions, weight and materials used • Encourage marketers to disclose environmental impacts, and avoid greenwashing and deceptive environmental claims in advertisements of large vehicles (see FTC's Green Guides for non-binding standards on the use of environmental marketing claims; California, for example, incorporated the Green Guide into law)
Financial incentives (or disincentives)	• Tax credits on the purchase of lighter weight or smaller cars • Scale vehicle registration fees to vehicle weight or car length • Set lower insurance rates for sedans and higher rates for SUVs • Congestion pricing by vehicle class (e.g., London) • Increase parking fees for SUVs and trucks (e.g., Paris)
Product regulations & standards	• Encourage the US EPA to set vehicle emissions standards based on a full life cycle perspective[118]
Zoning and land use policies	• Restrict or ban larger vehicles, such as SUVs, in designated urban areas

The government can implement procurement standards to purchase lighter vehicles:

Public procurement standards & requirements	• Procure lighter and smaller vehicles for government fleet

3.15.2. Greenhouse gas reduction potential

Study assumptions: This study assumes that the proportion of sedans will increase to 75% by 2045, compared to 45% in 2021. In this case, the share of smaller, lighter cars will increase by approximately 1.5% per year starting in 2025, reversing the current trend where the share of registered passenger cars is decreasing by 1% annually.

Note that as Oregon shifts to greater adoption of electric vehicles (EVs), the average vehicle weight will increase because EVs – all else equal – are at least 10 to 15 percent heavier than their conventional (internal combustion engine) counterparts (Jung et al. 2018; Woody et al. 2022). However, choosing lighter-weight EVs (e.g., electric sedans over electric SUVs) will yield proportional energy and emissions savings. We assume policies in this area would promote adoption of lighter-weight versions of the same vehicle technology and powertrain (e.g., conventional, hybrid, or EV) rather than simply less weight overall (which could favor

[118] For example, EPA's Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles is currently based on use phase emissions.

conventional vehicles over EVs). That said, in our analysis we modeled the effects of choosing lighter-weight vehicles *before* calculating the effects of switching to EVs (e.g., achieved through Oregon's Advanced Clean Cars II rule), so attributed emission reductions reflect a reduction in *conventional fuel emissions* relative to the reference case.

Rebound potential: The use of smaller and lighter cars can lead to fuel cost savings. This could trigger a rebound effect, where the lower cost per mile of driving can encourage more driving, more spending or the purchase of larger vehicles (e.g., Dimitropoulos et al. 2018; Greene, Sims, et al. 2020; Greene, Greenwald, et al. 2020). We estimate rebound emissions to be around 12% of cumulative emission reductions achieved between 2025 and 2050.

Emissions reduction potential: Given the above assumptions, we estimate that purchasing lighter weight vehicles could – when combined with other measures[119] – contribute to the following greenhouse gas emission reductions:

	Metric tons CO_2e	**% reduction from reference case**
Annual emission reduction[1] in 2050	1,238,000	0.9%
Cumulative emissions reductions[1] between 2021 and 2050[2]	13,212,000	0.4%

[1] Emission reductions are net of rebound effects, and represent reductions below reference case emissions, derived from a simplified projection of current trends.
[2] Policies are modeled to begin in 2025, reaching full effect by 2045.

3.15.3. Evaluation

This evaluation of shifting to smaller and lighter weight vehicles covers a range of policy measures, including financial incentives and disincentives, standards, regulations and consumer information initiatives.

3.15.3.1. Likelihood and durability of impact

Evaluation	**Score**
The recent shift in consumer preference towards larger vehicles demonstrates a clear trend away from smaller and lighter cars. One study found that consumers favored SUVs over smaller cars because they perceived SUVs to offer higher levels of safety, more space, better handling, increased enjoyment when driving, and a	2

[119] Emission reduction estimates account for interactions between different assessed measures, and so do not reflect potential reductions if each outcome were achieved in isolation. See section 2.2 for a description of the methodology used and the sequencing of abatement measures.

greater status symbol (Axsen and Long 2022). The same study found that only one third of SUV owners were willing to downsize if a strong financial incentive was presented. For example, the introduction of congestion charges has been shown to decrease the share of SUVs on the road (Winston and Yan 2021). Because of the established cultural attitudes and preferences that favor larger vehicles, any shift towards smaller cars is expected to be gradual and restricted, but still possible. Given the strong evidence of rebound the durability of this measure appears to be strongly dependent on the policies that are in place.	

3.15.3.2. Ease of implementation and enforceability

Criteria	**Evaluation**	**Score**
Implementation	Consumer education campaigns, information disclosure, taxes, registration and insurance fees, standards for suppliers, and public procurement standards are moderately easy to implement (score of 3). The implementation of congestion pricing, or a restriction or ban of certain cars in specific zones will require investment in infrastructure (like automatic number-plate recognition systems into certain zones) and monitoring systems, but the process of doing so is well understood as it has been done in many cities, particularly in Europe (score of 2). Further analysis will be needed to assess the legality of states implementing their own vehicle weight standards. California (and states that follow its lead, like Oregon), has been able to establish its own emissions standards by obtaining a waiver from the U.S. Environmental Protection Agency[120], therefore setting a precedent for states to implement their own vehicle standards (score of 1).	1-3
Enforceability	Not applicable for consumer education programs and information disclosures. Financial instruments, in particular, the use of congestion and parking fees, will involve some degree of monitoring and enforcement. Enforceability of government procurement policies will be required and can be monitored.	2

[120] www.epa.gov/regulations-emissions-vehicles-and-engines/california-greenhouse-gas-waiver-request

3.15.3.3. Cost-effectiveness

Evaluation	Score
Consumer education campaigns, information disclosure requirements, and the implementation of standards are relatively low cost. Subsidies for lighter-weight vehicles would reduce costs for consumers and businesses. Financial disincentives for heavier vehicles – including congestion pricing programs - would impose costs that could negatively impact consumers. This includes high-income households as they tend to purchase larger vehicles (Hossain et al. 2023), as well as small businesses such as contractors or others that use light trucks for their service.	2-3

3.15.3.4. Economic, environmental, and societal impacts

Criteria	Evaluation	Score
Equity	Lower income households are less likely to be driving larger, and typically more expensive vehicles like SUVs and light trucks (Hossain et al. 2023), unless they are pre-owned vehicles. Any financial penalties, such as congestion or parking fees, will further limit the ability of lower income individuals to purchase these vehicles. This can be an issue for lower-income households that have large families that require the use of larger vehicles or those that use their vehicle to run a small business. There are also concerns for rural residents or seniors traveling to cities for medical treatments. Therefore, some type of exceptions may be needed in these cases. Consumer education campaigns, information disclosures and standards will pose few impacts upon equity.	2
Jobs	The majority of the proposed policies are unlikely to affect employment in Oregon, either positively or negatively. However, potential effects on jobs remain uncertain in relation to congestion pricing and restrictions on large vehicles in urban areas. For example, in New York City, the use of congestion pricing was recently paused due to concerns from out-of-town workers as well as commercial establishments such as restaurants, theaters, and concert halls from a potential decrease in suburban customers.[121] However, congestion pricing can raise revenue to fund projects, such as public transit infrastructure, which has the potential to create jobs.	2
Health	Implementation of these policies is likely to result in the reduction of traffic fatalities from the use of SUVs, light trucks, vans and other	3

[121] https://www.governor.ny.gov/news/what-they-are-saying-governor-hochul-announces-pause-congestion-pricing-address-rising-cost

	large passenger vehicles. Air pollution benefits are also accrued, particularly for households located near major roadways (Green et al. 2020).	
Environment	Revenue generated from vehicle taxation or fees could be used towards climate action (such as public transit alternatives and improved roadway design) or addressing environmental impacts from other transport initiatives. Policy implementation is likely to contribute to positive environmental outcomes (reduced pollution or preservation of natural resources), in Oregon and elsewhere.	3

3.15.4. References

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3.16. Reduced air travel

Within Oregon's consumption-based emissions inventory, air travel emissions (including freight and passenger travel) are about 31% of total "transportation service" emissions, or about 2% of total consumption-based emissions in 2021 (Oregon Department of Environmental Quality 2024). Based on a global study of aviation emissions, we estimate that around 75% of these emissions are associated with passenger travel (Bergero et al. 2023). While this may seem like a small component of consumption, air travel is highly emissions-intensive,[122] and global scenarios for avoiding dangerous climate change suggest there is a need to mitigate air travel demand (IEA 2023).

A number of strategies are noted in Oregon's Statewide Transportation Strategy (Oregon Department of Transportation 2012) to reduce demand for air travel or shift demand to less carbon intensive modes. These can include encouraging remote attendance of meetings to reduce demand for business travel, using alternative modes of travel such as high-speed rail or buses, or choosing more local travel destinations for leisure travel.[123]

3.16.1. Potential policy approaches

To reduce passenger air travel demand, a range of policy approaches could be deployed. Potential policy approaches include:

Outreach and education	• Encourage residents to engage in local tourism • Encourage less frequent but longer stays for visiting friends and family; discourage frequent air travel and short stays (Dobruszkes et al. 2022) • Encourage videoconferencing and virtual meetings to decrease business air travel demand
Information disclosure	• Require travel booking services to include data on air travel emissions compared to other transportation modes (Ryley et al. 2023)

[122] Within Oregon's 2021 CBEI, air transportation has an average emission intensity of 1.04 kg CO_2e per dollar (Oregon Department of Environmental Quality 2024).

[123] There are also a number of measures to reduce aircraft emission rates such as through improved aircraft technologies or use of sustainable fuels, however those are not evaluated here. For example, bill HB 3257 aimed to establish an Electric Aircraft Task Force to identify issues related to facilitating electric aircraft use in Oregon and piloting electric aircraft readiness in six airports, but this bill did not pass (Oregon Department of Energy 2023)

Financial incentives	• Charge flight levies, i.e., taxes or fees imposed on airline tickets or air travel to reduce the environmental impact of flights. Target frequent fliers and/or private jet users (Zheng and Rutherford 2022) • Raise airport transportation and parking charges • Adjust airport passenger facility charges to price short-haul travel higher (such as flights with both an origin and destination in the Eugene to Vancouver, BC corridor)[124] • Implement carbon emissions-based pricing of flights (i.e., carbon fees) • Set new aviation fuel tax rates, such as to pay for both climate-related and non-climate related externalities such as energy security, air pollution, or noise impacts.
Public investment	• Invest in local leisure and cultural activities as a way to encourage more local vacations • Invest in infrastructure for lower-carbon forms of long-distance travel (e.g. improve connections between local public transport and long-distance train stations, improve rail service in Vancouver– Seattle–Portland–Eugene corridor, invest in high-speed rail) • Invest or encourage private sector investment in the widespread deployment of high-speed internet to support virtual meetings

In addition to household and business travel, the government can implement a travel policy to reduce air travel emissions by government employees.

Internal policies and programs	• Prohibit short flights (such as flights with both an origin and destination in the Eugene to Vancouver, BC corridor). For example, short-haul flights could be prohibited for flights less than 300-500 miles or less than 8 hours travel time (Stay Grounded 2020). • Implement or improve communications technologies to encourage videoconferencing and virtual meetings • If in-person events are necessary, make them hybrid

[124] Short-haul flights are approximately 27% more emissions-intensive compared to long-haul flights per passenger-mile traveled (see Table 10 in U.S. EPA 2024), however majority of air travel emissions are from long-haul flights. Taking an Amtrak train is less emissions-intensive compared to a short-haul flight and when traveling short distances by rail, such as between Portland and Seatle, the travel time is roughly the same, considering the waiting time in the airport. The difference in travel time between air and rail is much longer for long-distance travel, such between Portland and New York City, where rail would take 75-80 hours compared to a 6-hour flight.

	• Encourage lower-carbon forms of long-distance travel • If flights are necessary, discourage first or business class bookings and indirect flights (note that this is already in Oregon state government policy)

3.16.2. Greenhouse gas reduction potential

Study assumptions: This analysis assumes that household (non-business) passenger air travel could be reduced by 20% by 2050, if policies are introduced starting in 2025.

Rebound potential: Reducing flights could free up money for households that they may then spend on other forms of consumption. Since aviation is emissions-intensive (even on a per-dollar basis), however, any rebound is likely to be relatively small. We estimate rebound emissions to be around 10% of cumulative emission reductions achieved between 2025 and 2050.

Emissions reduction potential: Given the above assumptions, we estimate that reducing household passenger air travel could – when combined with other measures[125] – contribute to the following greenhouse gas emission reductions:

	Metric tons CO_2e	% reduction from reference case
Annual emission reduction[1] in 2050	259,000	0.2%
Cumulative emissions reductions[1] between 2021 and 2050[2]	3,084,000	0.1%

[1] Emission reductions are net of rebound effects, and represent reductions below reference case emissions, derived from a simplified projection of current trends.
[2] Policies are modeled to begin in 2025, reaching full effect by 2050.

3.16.3. Evaluation

Successfully reducing household and business-related air travel requires a range of policy interventions. Here we focus on the interventions that directly target air travel, such as consumer outreach initiatives, financial penalties, investment in local tourism and public employee

[125] Emission reduction estimates account for interactions between different assessed measures, and so do not reflect potential reductions if each outcome were achieved in isolation. See section 2.2 for a description of the methodology used and the sequencing of abatement measures.

guidelines, as described above. Investment in alternative modes of transport and communications infrastructure are indirect ways to reduce air travel and are also covered here.

3.16.3.1. Likelihood and durability of impact

Evaluation	Score
In the short term, measures could have limited impact. Air travel is considered inelastic to changes in price (Gössling and Dolnicar 2023), and recent initiatives like the "flight shame" campaign across Europe had limited impact on behaviors (Gössling et al. 2020). Despite factors such as inflation, high flight ticket prices and overall cost-of-living pressures, the demand for air passenger travel has returned to pre-COVID19 levels and is expected to increase in the coming years (IATA 2023; Ipsos 2022). While the COVID19 pandemic led to a rise in virtual meetings, business travel has largely returned to pre-pandemic levels.[126] Similarly, the pandemic encouraged local tourism[127], but air travel demand has rebounded and is on track to grow. Over the longer term, improved rail systems or the implementation of high-speed rail could serve as viable alternatives to short-haul flights and possibly some medium-haul flights within the US if travel time and costs are comparable or lower. However, infrastructure development will take time and benefits will only be realized in the long-term.	1 for short-term 2 for long-term

3.16.3.2. Ease of implementation and enforceability

Criteria	Evaluation	Score
Implementation	Implementation would be relatively easy for consumer education campaigns promoting local tourism and the use of alternative transport modes; the implementation of taxes and other charges (particularly airport fees); and the establishment of travel policies for government employees (score of 3). Infrastructure investment, especially for high-speed rail, will require significant effort and coordination, although the process of doing so is well understood (score of 2).	2-3
Enforceability	Not applicable for consumer education programs, public investment, and financial penalties (score of 3). Enforceability of	2-3

[126] https://www.tlnt.com/articles/face-value-business-travel-surges-as-virtual-meeting-fatigue-sets-in

[127] https://www.oecd.org/coronavirus/policy-responses/rebuilding-tourism-for-the-future-covid-19-policy-responses-and-recovery-bced9859/

	government employee policies and guidelines will be required and can be monitored (score of 2).	

3.16.3.3. Cost-effectiveness

Evaluation	**Score**
Consumer education campaigns are relatively low cost. There are numerous types of financial penalties proposed which will have implementation costs associated with them and will also negatively impact businesses and consumers. Investments in rail and related infrastructure measures are costly but will provide an overall benefit and cost savings to all, especially compared to growing air travel costs.	2-3

3.16.3.4. Economic, environmental, and societal impacts

Criteria	**Evaluation**	**Score**
Equity	Air travel is predominantly used by higher-income households, largely due to its unaffordability for lower-income households. Implementing financial penalties, such as taxes on airfare, will further limit the ability of lower income individuals to use air travel. This can be an issue when there is a need to visit or take care of family or friends, or attend special events, especially for lower-income individuals who may also be immigrants, refugees, or have family members living afar or abroad. Targeting financial penalties towards frequent fliers or private jet users rather than those that use lower-emitting, less frequent air travel methods can reduce this inequity. Furthermore, a portion of revenues can be used towards an air travel fund to compensate lower-income households traveling for certain designated reasons, such as to assist family with medical needs. Equity can be improved by investing in rail infrastructure or expanding broadband internet coverage, though it is important to ensure that both are affordable and accessible to lower-income and rural households. Consumer education campaigns have few impacts upon equity.	2
Jobs	Employment in the aviation industry experienced a sharp decline during the COVID-19 pandemic but has since rebounded and is currently performing better than it was before the pandemic (Bureau of Transportation Statistics 2024). Campaigns for local tourism and alternative modes of transport that result in a reduction of air travel will have implications on employment in the aviation industry. At the same time, investment in local tourism and cultural activities, as well as infrastructure will create jobs and boost the local economy.	2

Health	The implementation of these policies and resulting reduction of air travel may bring health benefits to households located near airports that currently experience air and noise pollution caused by aircrafts and airport activities (Stay Grounded 2024).	3
Environment	Revenue generated from the taxation or fees imposed on air travel could be used towards climate action or addressing environmental impacts either from airports or other transport activities. The development of new infrastructure may have some environmental impacts, such as land-use concerns related to the location of high-speed rail. However, with the implementation of proper environmental management plans, these impacts could be minimized. The effects of more local tourism could be managed by avoiding development in environmentally sensitive and protected areas.	3

3.16.4. References

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3.17. Other considered options

SEI and DEQ identified numerous options for reducing consumption-based emissions, but did not have sufficient resources to perform an equally robust evaluation of all of them. In this section, we provide an overview of some additional options that were deemed worthy of consideration, but which did not receive as much evaluation. These include the following:

- Reuse of building materials/components in new construction
- Reduced use of high-GWP refrigerants
- Recovering more food waste from landfills
- Shifting to goods with lower-carbon supply chains
- Increased use of goods made with recycled materials

3.17.1. Reuse of building materials/components in new construction

Multiple sources suggest that increased reuse (and recycling) of building materials in new construction projects could reduce greenhouse gas emissions by displacing production of virgin materials (C40 Cities et al. 2019; CNCA et al. 2021; ETC 2019a; ETC 2019b; Pales et al. 2019). Both the Oregon DEQ and local governments (e.g., Portland) have encouraged reuse of building materials through a variety of longstanding policies and programs. These programs could be expanded, e.g., as a complement to policies aimed at reducing embodied emissions in new construction (Bureau of Planning and Sustainability 2024). Key new policy approaches could include: new or expanded local ordinances requiring deconstruction and reuse of buildings instead of demolition; (increased) financial incentives for reuse of construction materials; and financial incentives for designing and building in ways that facilitate disassembly and reuse (e.g., through appropriate use of pre-fabricated and modular construction).

In Oregon, however, reuse may have, at best, only modest potential to reduce greenhouse gas emissions. There are several reasons for this. The primary climate benefit of reuse involves displacing production of new materials. While some salvaged building materials do displace new materials, in other cases salvaged materials, due to their lower prices, simply allow more construction or remodeling activity to occur. Also, as the housing stock changes over time, and as fewer old houses with higher-quality materials are available to be taken down, the quantity of salvageable material is decreasing. There are also limitations to how salvaged material can be used, although the state has recently made it easier to reuse salvaged lumber.[128] To facilitate

[128] Salvaged lumber needs to meet specified quality criteria (Oregon Residential Specialty Code (2021), section R104.9.1: https://www.oregon.gov/bcd/codes-stand/Documents/2021orsc-ch1.pdf).

reuse of materials, buildings need to be designed for disassembly and deconstruction. This can be done by choosing certain materials (e.g., mass timber and/or cross-laminated timber), certain fasteners (e.g. screws instead of nails and adhesives), as well as using reversible, modular and prefabricated building components. However, while modular construction produces less waste and can be easily disassembled (if appropriately implemented) (Oregon Department of Environmental Quality 2010), it can also be more material-intensive (since pre-fabricated components are sized for general application, not tailored to specific site needs) and may therefore have an uncertain impact on greenhouse gas emissions (CNCA et al. 2021, p.55). Globally, the emission reduction potential of concrete recycling in particular is limited (ETC 2019a).

3.17.1.1. Evaluation

Criteria	**Evaluation**	**Score**
Likelihood and durability of impact	Uncertain impact, given tradeoffs between promoting reuse/recycling and the need for (typically) more material intensive modular building designs. Sustained impact would require creation of markets for reused materials (C40 Cities et al. 2019; ETC 2019a). Net greenhouse gas (and other) benefits would be greatest for niche applications (CNCA et al. 2021).	2
Ease of implementation and enforceability	Policies could be relatively easily implemented and enforced. However, sustained impact over time may require significant shifts in building design and construction methods.	1-2
Cost-effectiveness	Although we have not identified studies of the cost per ton of reducing emissions through reuse of building materials, the uncertain reduction potential and significant costs of reclaiming and reusing materials suggest limited cost-effectiveness.	1
Economic, environmental, and societal impacts	Equity and job impacts could be negative to the extent reuse practices increase construction costs; these effects may be partially offset through the creation of new markets for modular building designs. To the extent that salvage creates jobs and increases the supply of lower-cost building materials, there are equity benefits to reuse. Increased recycling could reduce other environmental impacts; again, the net effect on a sustained basis may need to be weighed against	2

	the greater material requirements of modular construction.	

3.17.2. Reduced use of high-GWP refrigerants

Refrigerants used in building heating, ventilation, and air conditioning systems have a high global warming impact. In 2021, refrigerants accounted for about 3% of Oregon's *use-phase* emissions. Refrigerants are also a notable component of embodied emissions in consumed goods, services, and materials, contributing to about 2% of total *production-phase* emissions. Under the Kigali Amendment to the Montreal Protocol, countries have agreed to globally phase out high-GWP refrigerants, reducing their production and consumption by 80-85% by 2047. The United States is a signatory, and the federal 2020 American Innovation and Manufacturing (AIM) Act requires that U.S. manufacturers and consumers exceed Kigali targets by phasing down production and consumption of HFCs by 85% by 2036.[129]

The AIM Act directs the U.S. Environmental Protection Agency (EPA) to implement a quota-based system of transferrable production and consumption allowances for HFCs, which producers and importers must hold in quantities equal to the amount of HFCs they produce or import.[130] EPA has adopted regulations for implementing this approach and achieving the goals of the AIM act.[131] The EPA is also proposing new rules that would, in accordance with the AIM Act, "maximiz[e] reclamation and minimize[e] releases of HFCs from equipment" with the goal of creating market demand for reclaimed refrigerant and supporting the phasedown of HFCs.[132]

Although the U.S. EPA is charged with implementing regulations that will achieve the required phasedown at a national level, state governments can also play a role in facilitating reduced consumption of HFCs and aiding achievement of the phasedown. California's Refrigerant Recovery, Reclaim, and Reuse Program, for example, requires manufacturers to use reclaimed HFC-410A in new air conditioning equipment and in servicing of existing equipment. States could go further, however, in boosting recovery and reclamation of HFCs through "extended

[129] https://www.epa.gov/system/files/documents/2023-10/subsection-h-proposed-rule-fact-sheet-2023_1.pdf

[130] 42 U.S.C. § 7675, subsection (h).

[131] Cf. Allocation Framework Rule, 86 FR 55116 (October 5, 2021) and Phasedown of Hydrofluorocarbons: Allowance Allocation Methodology for 2024 and Later Years, 88 FR 46836 (July 20, 2023).

[132] https://www.epa.gov/system/files/documents/2023-10/subsection-h-proposed-rule-fact-sheet-2023_1.pdf

producer responsibility" (EPR) programs, like what is now being proposed in Washington State.[133] Oregon is already implementing EPR programs in other areas; an EPR program for refrigerants could create financial incentives for HFC recovery, help bring down the cost of reclamation, and aid the phasedown in use and production of HFCs (Theodoridi et al. 2022).

Because, at a national level, the phasedown in HFC production and consumption is being implemented through an allowance quota system, it is not clear that reducing leak rates and enhancing recovery and reclamation of HFCs will yield additional emission reductions. Instead, these efforts could simply reduce the need for new consumption and production and make it easier (less costly) to stay within quota requirements.[134] However, this facilitative effect – especially if replicated across multiple states and jurisdictions - could also pave the way for an accelerated phasedown schedule (which is allowed under the AIM Act), yielding positive (and potentially substantial) greenhouse gas benefits (Chao et al. 2024; Theodoridi et al. 2022).

Because the *additional* effect of an Oregon EPR policy for HFCs is unclear, we have not evaluated this as separate consumption-based emissions abatement outcome. However, it is an area where Oregon could play a valuable role in addressing an important component of both consumption- and sector-based greenhouse gas emissions.

3.17.2.1. Evaluation

Criteria	**Evaluation**	**Score**
Likelihood and durability of impact	Strong likelihood of impact, and high durability given that measures would effectively lock in emission reductions through leak repair and installation of equipment designed for use with low-GWP refrigerants.	3
Ease of implementation and enforceability	Based on the success of similar programs in other jurisdictions (e.g., Australia and Canada), an EPR program for HFC recovery and reclamation is likely to be highly implementable and enforceable.	3
Cost-effectiveness	While an EPR program would impose additional costs on Oregon HFC producers and importers, enhanced recovery and reclamation is likely to be an important – and ultimately cost-effective –	2

[133] HB 2401 would create an EPR program for refrigerant recovery, modeled on a successful program in Australia (see https://app.leg.wa.gov/billsummary?BillNumber=2401&Year=2023&Initiative=false)

[134] This is something that both California regulators and the U.S. EPA have acknowledged in their regulatory analyses, for example (Chao et al. 2024).

	component of efforts to achieve the phasedown of HFCs.	
Economic, environmental, and societal impacts	There is a possibility of some regressive cost impacts due to implementation costs, but these are likely to be minimal. The primary environmental benefit would be greenhouse gas reductions.	2

3.17.3. Recovering more food waste from landfills

Municipal and industrial landfills in Oregon produce around 25% of Oregon's *sector*-based methane emissions (Oregon DEQ 2018). Landfill methane is produced when organic matter decomposes anaerobically. Recovering organics (including food waste) and keeping them out of landfills has substantial potential to reduce these emissions. It can also yield organic soil amendments that enhance carbon sequestration and avoid emissions on farmland. Local food waste recovery programs are limited and vary in scope, with the bulk of recovered tonnages originating in more populated areas like the Portland Metro region. State-level programming to encourage food waste recovery is currently limited. These programs could be expanded and enhanced to increase their effect. Policy approaches could include statewide or municipal mandates to require household and business separation of food waste, and expanded composting programs.

Although these programs are important for reducing Oregon's greenhouse gas emission footprint, enhanced food waste recovery would have only a small (apparent) impact on Oregon's total consumption-based emissions. In 2021, for example, total "disposal phase" emissions (from all wastes) were only about 0.6% of all consumption-based emissions. Carbon fluxes (including enhanced carbon storage) on agricultural lands are not included in either Oregon's sector- or consumption-based greenhouse gas emissions inventories, meaning that a key benefit of recovery programs is not reflected in state emission totals. For these reasons, this project did not separately assess food waste recovery as an abatement option for consumption-based emissions. However, recovery could nevertheless be part of a comprehensive effort to reduce Oregon's total emissions footprint and promote sustainable Oregon agriculture.

3.17.3.1. Evaluation

Criteria	Evaluation	Score
Likelihood and durability of impact	Successful recovery programs require changing how consumers dispose of food waste. The likelihood and durability of impact could be enhanced through robust composting programs that make food waste separation easier for	1-2

	households and businesses, and/or provide financial incentives for separation and recovery.	
Ease of implementation and enforceability	Enforcing recovery of food waste, especially at a household level, could be difficult (score of 1). Policies to encourage recovery, however, such as providing free composting services or financial incentives could boost "compliance" and would require no enforcement.	1-2
Cost-effectiveness	Recovery programs may increase waste disposal service costs for consumers and businesses. Centralized composting, for example, will typically involve a net cost per ton of CO_2-equivalent reduced.[135] However, the cost is still likely to be competitive with many other greenhouse gas abatement options.	1-2
Economic, environmental, and societal impacts	Enhanced food waste recovery and composting would contribute to positive equity, health, and other environmental impacts in the agriculture sector. Recovery and *donation* of food could also have positive equity, health, and environmental benefits. ReFED estimates that major recovery measures (including composting and anaerobic digestion) would have positive effects on job creation.[136]	2

3.17.4. Shifting to goods with lower-carbon supply chains

A primary goal of consumption-based emissions policy is to both *reduce* consumption of carbon-intensive goods and materials and shift it to lower-emitting alternatives (including things like services, which tend to be less carbon intensive). Although the greatest potential for reducing the embodied emissions in things like major durable goods and appliances is to reduce consumption outright (e.g., through making fewer purchases of higher-quality, more durable options), there may also be significant potential for choosing goods with lower-carbon production methods and supply chains (Vita et al. 2021). Key policy approaches here would include consumer education campaigns (providing information about lower-carbon alternatives or brands); information disclosure policies (e.g., requiring or incentivizing environmental product disclosures – or EPDs – for certain types of goods); product standards (e.g., limiting available

135 https://insights-engine.refed.org/solution-database/centralized-composting

136 https://insights-engine.refed.org/solution-database?dataView=total&indicator=jobs-created

options to lower-carbon alternatives); and financial incentives (e.g., subsidies for goods produced using lower-emitting production methods, and/or taxes on high-emitting practices, like express delivery options).

As with switching to lower-emitting food of the same type (discussed elsewhere), enabling consumers to choose lower-emitting goods could require significant effort to develop standards and data for life-cycle emission estimates and generating reliable EPD information. For major home goods and appliances, such efforts may be feasible, but further research would be needed to characterize overall greenhouse gas reduction potential. Policies and options would likely need to be developed on a product-by-product basis, which could pose an implementation challenge.

3.17.4.1. Evaluation

Criteria	**Evaluation**	**Score**
Likelihood and durability of impact	The extent and likelihood of potential emission reductions needs further research. Durability could be low for information disclosure-style policies, but higher (score of 2) for product standards or financial incentives.	1-2
Ease of implementation and enforceability	The most difficult implementation challenge is likely to be obtaining robust emission-intensity data for different producers, which could require developing new standards for environmental product disclosures. There are, however, relevant models to draw on from current EPD programs.	1-2
Cost-effectiveness	Needs further research. In many cases, goods produced using (significantly) lower-emission production methods may be more costly for consumers.	-
Economic, environmental, and societal impacts	Lower-emitting production methods for goods and appliances will often correlate with other reduced environmental impacts. Fewer emissions overall (e.g., from greater reliance on renewable energy), for example, may yield reduced air pollution and enhanced public health (within and outside Oregon). However, greater costs for lower-emitting goods could lead to regressive impacts on lower-income households, unless policies involve subsidies or other measures to reduce the cost burden. Job impacts within Oregon would need to be assessed on a case-by-case basis.	2

3.17.5. Increased use of goods made with recycled materials

Choosing goods with greater recycled content can in principle reduce lifecycle greenhouse gas emissions, by avoiding the need for new virgin material. Globally, across all commodities, enhanced recycling has substantial potential for reducing emissions.[137] The potential for reductions within specific Oregon product categories, however, would require further research.

Key policy approaches here would include information disclosure (e.g., labeling with respect to recycling content); product standards (e.g., requiring recycled content); and financial incentives. Under the Recycling Modernization Act, the Oregon DEQ recently co-funded a study (with the Department of Administrative Services) to evaluate the effectiveness of current state "buy recycled" policies and programs; this could inform the design of future policy approaches.

3.17.5.1. Evaluation

Criteria	Evaluation	Score
Likelihood and durability of impact	Greenhouse gas reductions are likely as long as policies supporting purchases of products with higher recycled content remain in place.	2
Ease of implementation and enforceability	Enhanced policies would likely need to be modeled on laws in other states (e.g., Washington, California, Maryland, and others) mandating use of recycled content. Careful design is required to avoid creating loopholes and unintended consequences.	2
Cost-effectiveness	Further research needed. For many products, higher recycled context may correlate with higher costs.	-
Economic, environmental, and societal impacts	Recycling is associated with a range of environmental benefits associated with avoiding resource extraction and production of virgin materials. Net health and job impacts in Oregon may be small. Equity impacts are likewise likely to be minimal, except where policies increase costs for certain types of goods with recycled content.	2-3

137 https://drawdown.org/solutions/recycling

3.17.6. References

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Vita, G., Rao, N. D., Usubiaga-Liaño, A., Min, J. and Wood, R. (2021). Durable Goods Drive Two-Thirds of Global Households' Final Energy Footprints. *Environmental Science & Technology*, 55(5). 3175–87. DOI:10.1021/acs.est.0c03890.

4. Marginal Abatement Cost Analysis

A "marginal abatement cost curve" (MACC) is a commonly used tool for informing climate change mitigation policymaking. MACCs graphically illustrate the potential magnitude of abatement, and associated costs, of a portfolio of possible interventions that could reduce GHG emissions. Specifically, MACCs graphically illustrate (1) the magnitude of emission reductions that could be achieved by each intervention; and (2) the cost, per ton of CO_2-equivalent, of achieving those reductions. Using a MACC, policymakers can estimate the level of abatement that might be achieved under carbon pricing policies, or prioritize interventions based on their expected impact and cost-effectiveness.

For this work product, SEI conducted a marginal abatement cost assessment for a small number of measures in order to: (1) test the application of MACC analysis to consumption-based GHG abatement; and (2) demonstrate the potential benefits (and relative cost-effectiveness) of efforts to reduce consumption-based emissions.

The following six measures were assessed:

1. Reducing the average size of new residential housing units
2. Reducing embodied carbon in state-funded construction projects (buildings & infrastructure)
3. Reducing embodied carbon in new residential and commercial building construction
4. Reducing food waste in retail establishments (grocers, restaurants, and non-government food service)
5. Reducing food waste in government food service
6. Reducing household meat consumption

In all cases, potential emission reductions were assessed relative to the "reference case" scenario used in the abatement wedge analysis for this project (see section 2), covering the period between 2021 and 2050. The reference scenario projects future growth in consumption-based emissions based on population and income growth, while holding constant current (2021) consumption patterns and the emissions intensity of consumption (i.e., kg CO2e emitted per dollar of spending). **The estimated effects of the measures considered here, however, are calculated *independently* of the wedge analysis and do *not* reflect the effects of existing policies or interactions with other measures beyond the ones listed here.**

A summary of the results is provided in section 4.1. Details on how each of these measures were assessed (abatement potential and cost estimates) are provided below (section 4.2).

4.1. Results

The graphics presented below illustrate the results of SEI's MACC analysis for the six measures that were assessed. As indicated in section 4.2, potential costs, savings, and abatement potential were assessed at a high level, using data from Oregon's consumption-based emission inventory combined, where relevant, with independent cost estimates (for summaries of the assessed measures and detailed assumptions used, see section 4.2.4). Abatement potentials were calculated with respect to a "no action" reference scenario that, among other things, does not account for "business as usual" changes in greenhouse gas emissions intensity that could occur over time due to policies, economic trends, or technology development. Costs and benefits include only those directly incurred by consumers and actors involved in implementing the measures, and do not include indirect social and environmental co-benefits (which could be important to consider when assessing overall cost-effectiveness). Moreover, the assessed measures are a small subset of measures that could be undertaken to reduce consumption-based emissions, and so do not represent a complete and comprehensive "cost curve" for abatement.

For all these reasons, the results should be seen as strictly preliminary. *However, the preliminary results suggest that a range of measures targeting consumption-based emissions could be cost-effective* – in some cases generating significant cost savings per ton of CO_2 reduced (mainly because reducing consumption avoids costs for consumers and businesses, and many measures can be undertaken without major upfront or operational costs). The range of costs presented for the measures assessed here compare favorably, for example, with costs of more "traditional" interventions targeting sector-based energy production and consumption (e.g., as assessed in Oregon's 2023 [Climate Action Roadmap to 2030] – see section 4.2 of this report for additional details).

In addition, most of the measures also appear cost-effective when compared to U.S. federal government estimates of the "social cost of carbon" (SCC). The SCC is an estimate of the cost imposed, in terms of damage caused by climate change, from the emission of a ton of CO_2. Reducing greenhouse gas emissions will avoid such costs, meaning that if it costs *less* to reduce emissions, doing so will result in a net economic benefit to society. SCC estimates are subject to uncertainty, and are particularly sensitive to discount rates (see discussion in section 4.2.3.5, below). The federal government therefore calculates SCC values using a range of discount rates and other assumptions.

The following charts (Figure 4-1 through Figure 4-4) indicate how estimated abatement costs for the six assessed measures compare to the SCC at different discount rates. Figure 4-1 displays estimated abatement costs using a 5% social discount rate, the high end of the range. At a higher discount rate, costs and benefits that accrue in the future are given less weight than they would be if a lower discount rate were used. For measures that result in a stream of net savings over time – such as smaller new home construction and food-related measures – this means fewer savings per ton of CO_2e reduced. For measures that incur net costs over time, this means a lower cost per ton. This can be seen by comparing Figure 4-1 with Figure 4-2 (showing results for a 3% discount rate) and Figure 4-3 (showing results for a 2.5% discount rate).

Likewise, estimates of the SCC are *higher* when lower discount rates are used (because climate damage costs that occur in the future are given a greater weight in present-day dollars). In each of the figures below, the SCC associated with the relevant discount rate is indicated by a dashed line. These preliminary results suggest that, at a 2.5% discount rate, all the measures SEI evaluated would be cost-effective compared to the corresponding SCC (i.e., society would be better off if all the measures were implemented). At higher discount rates, some of the measures (those targeting embodied emissions in construction) might not be cost-effective.

However, Figure 4-4 shows expected abatement costs using a 3% discount rate, compared to the U.S. EPA's calculation of the SCC assuming a high (95th percentile) climate damage estimate (in this case, the estimated abatement costs are identical to those in Figure 4-2; only the SCC estimate is changed). In this scenario, all measures are cost-effective even at a 3% discount rate. This result suggests some of the uncertainties that must be confronted when assessing whether to pursue certain mitigation measures.

Finally, note that the SCC estimates presented below were determined by the Interagency Working Group on the Social Cost of Greenhouse Gases, adjusted to 2020 dollars,[138] as presented in ODOE (2020).[139] All values reflect the estimated value for the SCC in 2025 (costs increase over time regardless of discount rate, because the accumulation of greenhouse gases leads to increasing economic damage). The U.S. EPA has recently updated its estimates of the SCC (U.S. EPA 2023), and these estimates are significantly *higher* than prior estimates. These updated values have not yet been widely adopted in federal policymaking. However, with a higher SCC, more mitigation measures will appear cost-effective at the same discount rate(s).

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[138] In this analysis, abatement cost estimates were calculated in 2021 dollars, which leads to a slight mismatch. Within the range of uncertainty of SCC and abatement cost estimates, however, the values are still roughly comparable.

[139] See https://www.oregon.gov/energy/energy-oregon/Documents/2020-Social-Cost-of-Carbon-Primer.pdf

Figure 4-1. Abatement costs and 2025 social cost of carbon calculated using a 5% social discount rate

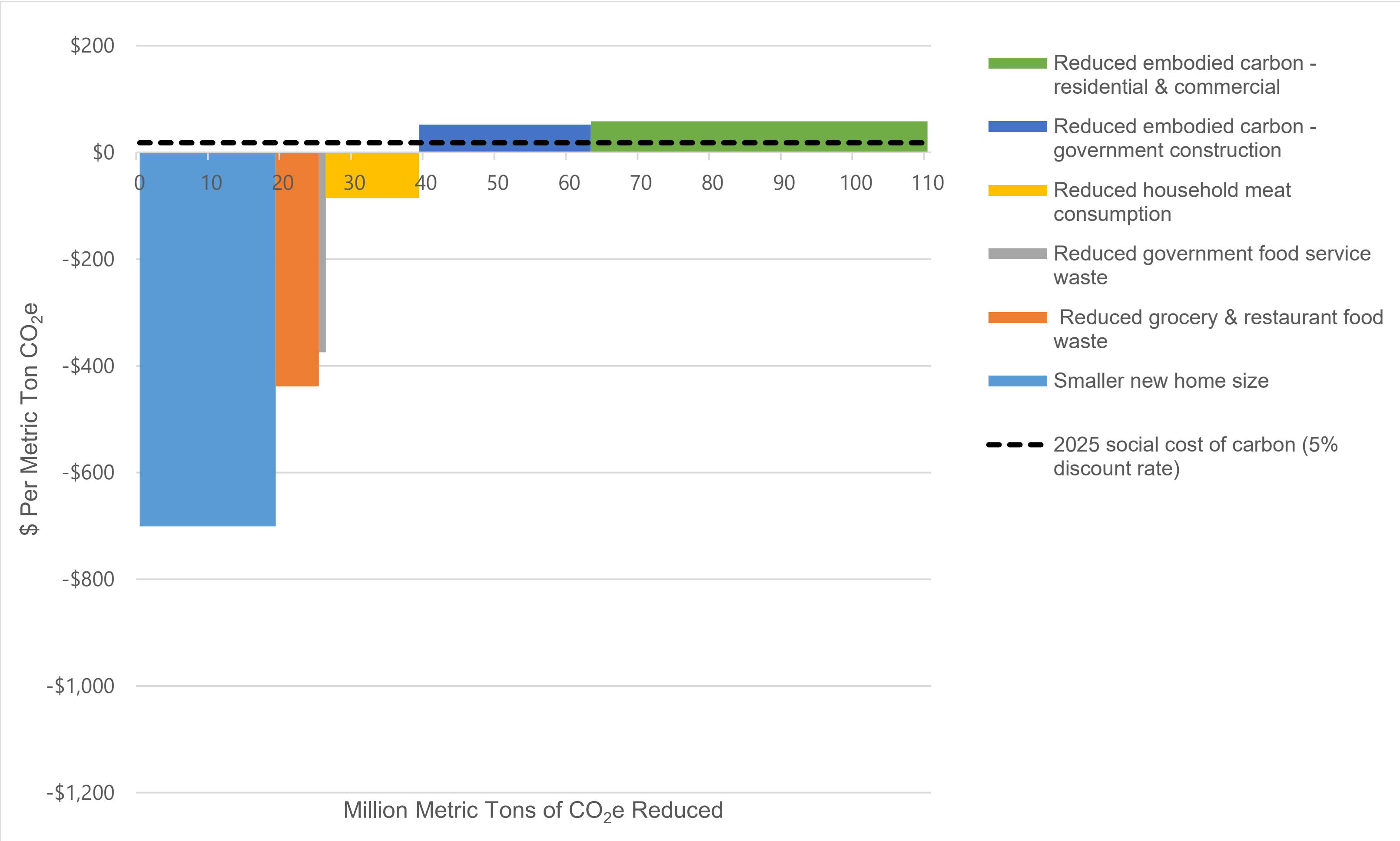


Figure 4-2. Abatement costs and 2025 social cost of carbon calculated using a 3% social discount rate

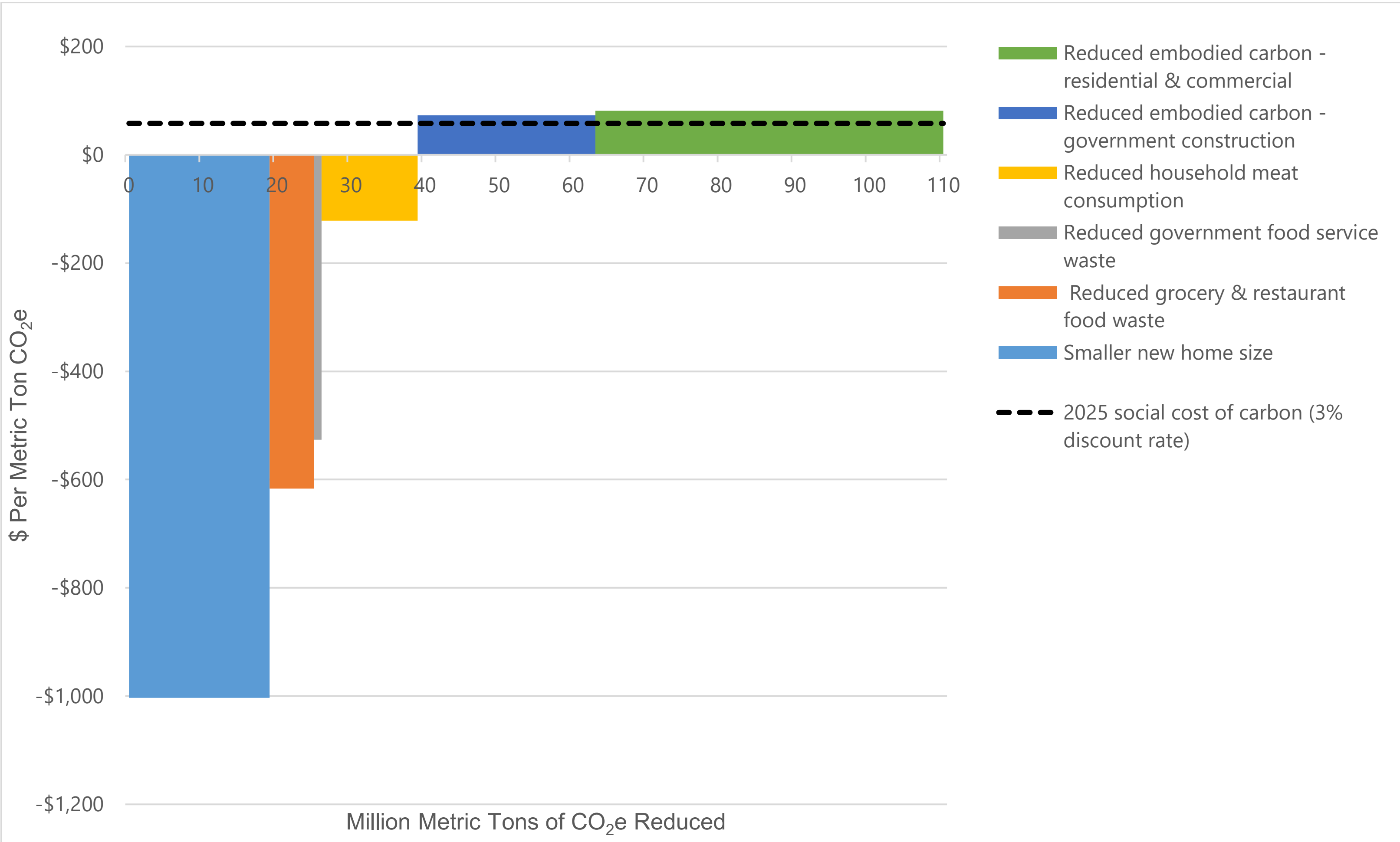
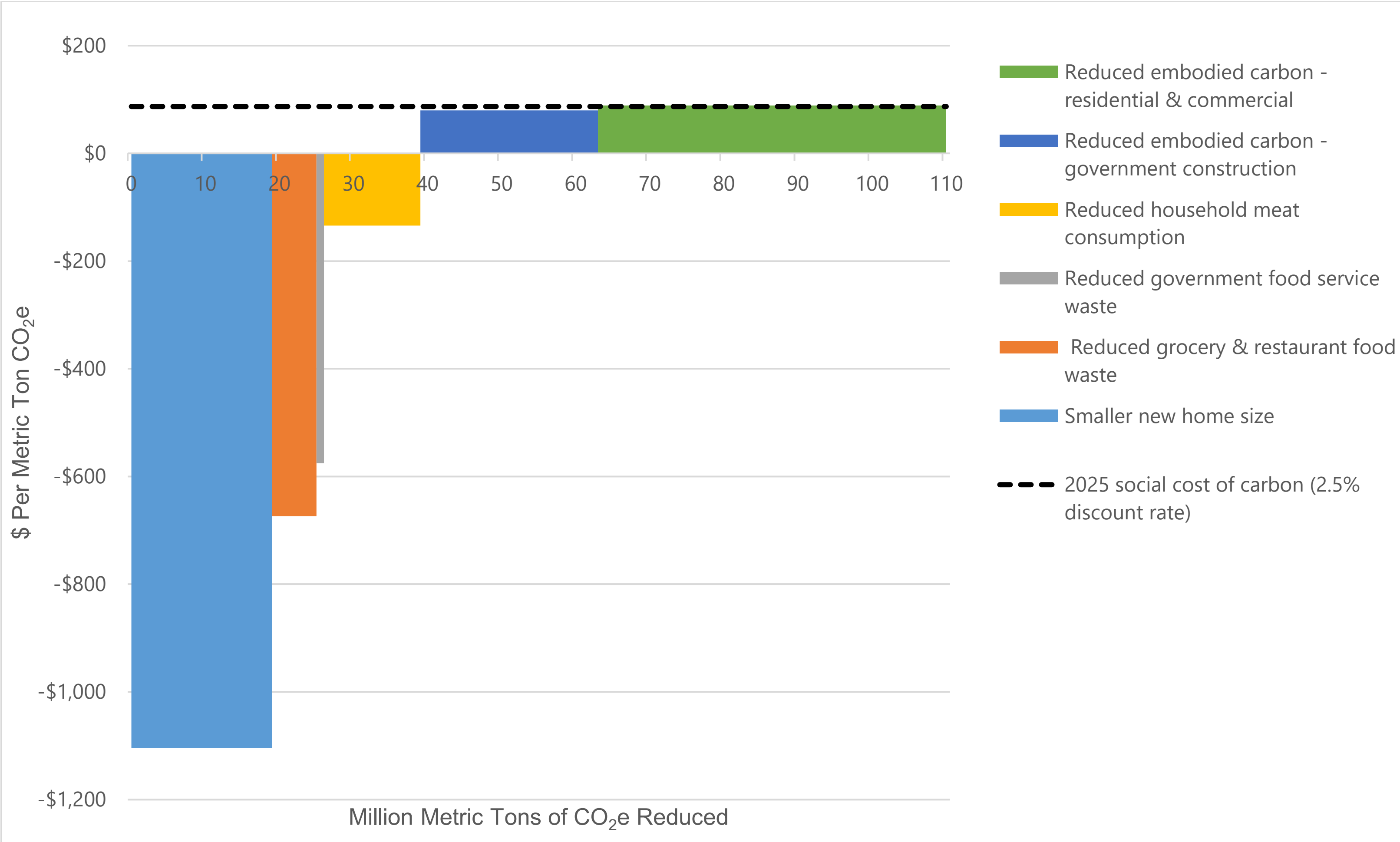


Figure 4-3. Abatement costs and 2025 social cost of carbon calculated using a 2.5% social discount rate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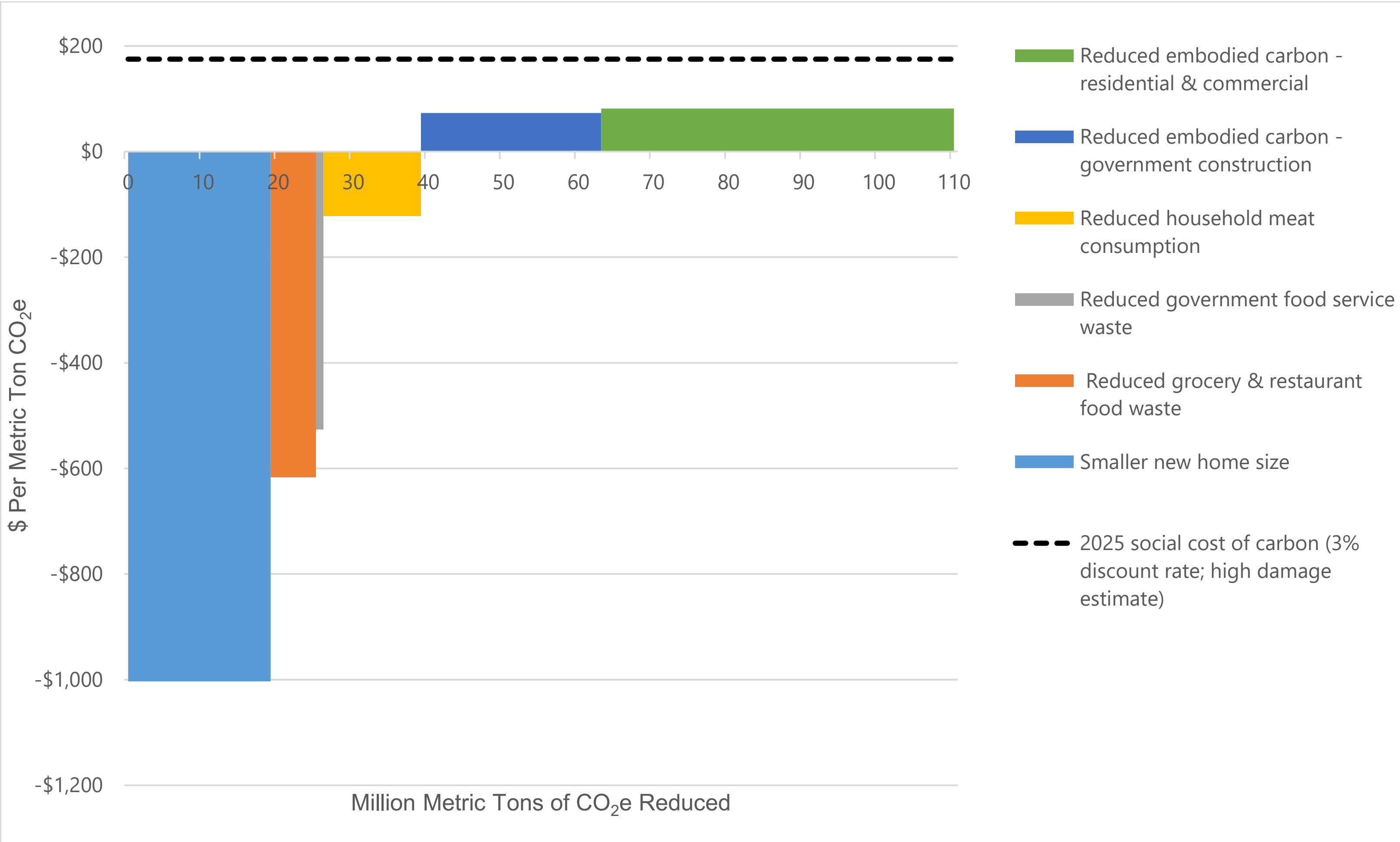
70
80
90
100
110
Million Metric Tons of CO_2e Reduced
Reduced embodied carbon - residential & commercial
Reduced embodied carbon - government construction
Reduced household meat consumption
Reduced government food service waste
Reduced grocery & restaurant food waste
Smaller new home size
2025 social cost of carbon (2.5% discount rate)

Figure 4-4. Abatement costs and 2025 social cost of carbon calculated using a 3% social discount rate – high (95th percentile) damage estimate



4.2. Methodology

A “marginal abatement cost curve” (MACC) is a commonly used tool for informing climate change mitigation policymaking.[140] To SEI’s knowledge, no one (in any jurisdiction) has developed a MACC explicitly focused on measures for reducing consumption-based greenhouse gas (GHG) emissions. The general approach adopted here is the same as that applied for assessing measures to reduce sector-based emissions. However, as with any MACC analysis, certain common parameters need to be specified.

This section provides a brief overview of how MACCs are constructed, discusses some caveats about MACC analysis and the interpretation of its results, and describes how the sample MACC analysis related to Oregon’s consumption-based emissions was developed.

4.2.1. Overview

MACCs graphically illustrate the potential magnitude of abatement, and associated costs, for a portfolio of possible interventions that could reduce GHG emissions. MACCs graphically illustrate (1) the magnitude of emission reductions that could be achieved by each intervention; and (2) the cost, per ton of CO_2-equivalent, of achieving those reductions. Using a MACC, policymakers can estimate the level of abatement that might be achieved under carbon pricing policies, or prioritize interventions based on their expected impact and cost-effectiveness.

The basic formula of MACC is to divide the *present value* of all costs (and benefits) associated with implementing a measure over a specified time period (PV_{costs}) by the total GHG emission reductions that will result from the measure over the same time period (tons CO_2e) (see Figure 4-5).

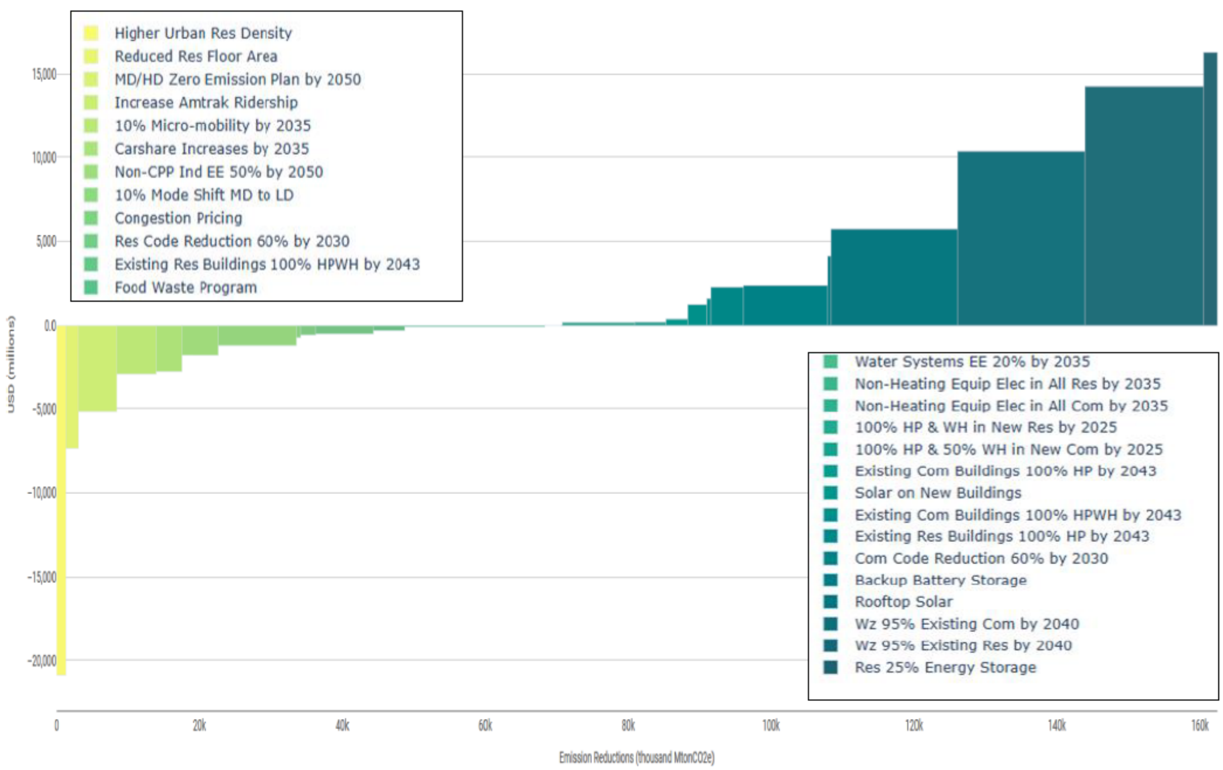
Figure 4-5. Formula for calculating marginal abatement cost (MAC)

$$MAC = \frac{PV_{costs}}{tons\ CO_2 e}$$

[140] Some of the earliest applications of MACCs involved analyses of energy conservation measures (cf. Meier, A., Rosenfeld, A. H. and Wright, J. (1982). Supply curves of conserved energy for California’s residential sector. *Energy*, 7(4). 347–58. DOI:10.1016/0360-5442(82)90094-9). They have since been widely used in climate change policy as a means for prioritizing abatement actions and informing the development of carbon pricing programs.

As an example, the Transformational Integrated Greenhouse Gas Emission Reduction (TIGHGER) project developed MACCs to inform the Oregon's 2023 Climate Action Roadmap to 2030.[141] The MACCs illustrate how a range of actions could contribute to reducing GHG emissions in Oregon's sector-based emissions inventory, along with their expected cost per ton in present value dollars (e.g., Figure 4-6).

Figure 4-6. Marginal abatement cost curve from Oregon's TIGHGER analysis



Each column in Figure 4-6 is associated with a defined "action" or intervention. The width of each column indicates magnitude of GHG reductions that could be achieved. The height of each column indicates the associated abatement cost.[142] Columns are ordered from lowest to highest cost; the ordering thus allows policymakers to infer what the "marginal" cost of abatement would be for achieving a given level of aggregate emission reductions. Certain measures, visualized in Figure 4-6 with the columns below the zero line, have a negative cost. In essence, this means that these are "no regrets" measures – implementing them will both reduce GHG

[141] https://www.keeporegoncool.org/tighger

[142] Note: In Figure 4-6, which is reproduced from ODOE (2023), the vertical axis is labeled in units of aggregate cost (USD $ millions); typically, however, MACCs indicate cost per ton of abatement on the vertical axis ($/tCO2e) (see, for example, Kesicki and Strachan (2011)).

emissions and result in cost savings to Oregon households and businesses (e.g., from not having to purchase as much energy).

In the TIGHGER analysis (as is typical for MACC analyses), measures are defined as "actions" that could be collectively undertaken by households and businesses to reduce emissions. They are not defined as specific policies, laws, or regulations that might *induce* those actions. The assessed costs therefore reflect the direct costs (or savings) incurred by households and businesses to undertake the actions, and not (for example) the cost to government of enacting and implementing associated policies. In the same vein, the TIGHGER MACCs do not incorporate the cost of infrastructure needed to enable certain actions, such as electrical grid upgrades or installation of electric vehicle charging stations.[143]

4.2.2. Caveats for conducting a MACC analysis

While MACCs can be a useful and informative tool for policymaking, they should be interpreted carefully, recognizing some of their potential limitations. These include:

- **Failure to account for systemic change and interactions over time**. Marginal abatement costs can change over time as technologies develop, economies evolve, and production systems shift. Some MACC analyses account for this by using energy system or integrated assessment models that capture future change (Harmsen et al. 2019; Yue et al. 2020). Other, simpler approaches may fail to account for interactions among measures over time (Kesicki and Ekins 2012). In general, individual MACCs are a poor guide to identifying economically optimal *pathways* to deep GHG reductions (Kesicki and Strachan 2011).
- **Dependencies among abatement measures**. The apparent abatement potential and cost per ton for different measures can depend on the sequence in which they are assessed. Energy efficiency measures, for example, may appear to have limited potential for reducing emissions (and high cost per ton reduced) if they are assessed *after* a measure that decarbonizes electricity production. Accurately portraying a cumulative "supply curve" for GHG abatement requires accounting for such interactions. One consequence, however, is that policymakers should be cautious about pursuing some measures and not others based on their position in a MACC. (The alternative would be to assess each measure on a standalone basis, which could produce a "menu" of options without interdependencies, but would fail to produce a coherent cost curve.)
- **Failure to account for non-financial benefits and costs**. Measures that reduce GHG emissions may have other effects that benefit or harm human health, the environment, or other dimensions of human well-being. Furthermore, some measures may appear to have low, or negative, cost because important non-financial barriers are not fully accounted for. However, these co-benefits and costs can only be incorporated in abatement cost assessments if they are monetized, and they are often excluded from analysis.

[143] See footnote 13 on p. 6 of ODOE (2023).

4.2.3. *Key methodological questions and proposed approaches*

Under this project, SEI developed a MACC analysis for a selection of potential consumption-based GHG reduction measures in the State of Oregon. To do this, the following analytical approach and specification of parameters were followed.

4.2.3.1. Basic approach

There are two broad approaches to developing MACCs. The first is to undertake individual assessments of abatement measures, evaluating reduction potentials and costs in a "bottom up" fashion and consolidating these into an ordered cost curve. The second is to develop MACCs using linear programming or other system models that attempt to capture system dynamics over time (Kesicki and Ekins 2012; Harmsen et al. 2019). The latter approach typically produces smoothly continuous cost curves, which may or may not indicate the individual measures associated with different points on the curve.

For this project, we applied the first method. It produces a MACC with discretely identified abatement measures, similar to the TIGHGER MACCs and other "McKinsey-style"[144] abatement cost curves.

4.2.3.2. Basis for estimating cost

The costs of abatement measures can be estimated as the simple (lifecycle) cost of implementing a measure, or on a net basis (accounting for both costs and revenues or savings). The first approach is appropriate in contexts where different abatement measures produce similar benefits or savings. Most MACCs, however, are based on the *net present value* of costs and benefits associated with different measures. Given the diversity of measures that could be included in a consumption-based emissions MACC – with differing cost and savings profiles – the latter approach is most appropriate, and was used in this analysis.

4.2.3.3. Reference case definition and period of analysis

Abatement costs for any given measure are calculated in five basic steps:

1. Determine the baseline, or reference case, emissions for the measure over a certain period.
2. Estimate how much the measure will reduce emissions relative to the baseline over the same period.
3. Estimate the stream of *incremental* costs and benefits of implementing the measure, relative to the baseline.

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[144] In 2007, the McKinsey company developed one of the first widely published MACCs for climate change mitigation measures. See here: https://www.mckinsey.com/capabilities/sustainability/our-insights/a-cost-curve-for-greenhouse-gas-reduction

4. Calculate the net present value (NPV) of the incremental costs and benefits (discounting future costs and benefits).
5. Divide the NPV by total GHG reductions to calculate the cost per ton reduced.

In developing a MACC, it is important to use the same reference case to estimate both emission reductions and NPV costs for each measure, and to apply the same reference case assumptions to all assessed measures. To develop a "sample" MACC, we adopted the same reference case and period of analysis as was used in the abatement wedge analysis for this project (see section 2). Specifically, we assessed emission reductions and NPV from 2021 to 2050, assuming that in the reference case:

- GHG emissions from sources affected by each measure grow from current (2021) values in line with population and income growth
- The reference case emission *intensity* of consumption (kg of CO2e emitted per dollar of spending) remains unchanged over the period of analysis
- Relative spending levels across different categories of consumption do not change (i.e., spending increases in line with income growth, but is spent on goods, services, materials, and energy in the same proportions as in the 2021 base year consumption-based emissions inventory)

4.2.3.4. Accounting boundaries

An important methodological decision is what to include in both emission reduction estimates and the calculation of costs and benefits for specific abatement measures.

GHG accounting boundaries

As in the abatement wedge analysis (presented in section 2), GHG emission reductions for the MACC analysis were calculated as reductions in Oregon's *consumption-based emissions inventory* (CBEI), compared to reference case emissions. The specific assumptions used to calculate reductions associated with each intervention are described further below (section 4.2.4). It is important to note, however, that Oregon's CBEI omits GHG emissions that arise from consumption in Oregon *by non-Oregon residents* (e.g., tourists and other visitors). At least two of the measures evaluated here – related to food waste reduction, and reduced meat and dairy consumption – could (depending on how they are implemented) affect consumption by out-of-state residents. Any emission reductions arising from changes in consumption by out-of-state residents are *not* captured in the analysis (i.e., they are excluded from the GHG accounting boundary). Thus, for at least some measures, the total magnitude of expected emission reductions may be larger than indicated in this analysis. (The estimated *cost per ton* of achieving these additional reductions should be roughly the same.) Other MACC analyses (including the

TIGHGER MACCs) may also exclude certain effects on emissions.[145] Capturing the *full* effects of abatement measures would require a different analytical approach, e.g., applying consequential accounting methods that consider a broader accounting boundary.

Abatement measures may have both direct and indirect effects on GHG emissions. For consumption-based emissions, these may include both direct and indirect rebound effects. For MACC development (as for the abatement wedge analysis), we assessed only direct effects, including direct rebound. For example, to assess the net GHG reductions achieved by reducing meat consumption, we estimated the reduction in emissions associated with consuming less meat and netted this against the *increase* in emissions associated with shifting food consumption to other sources of protein (i.e., the direct rebound). However, to the extent that this shift results in overall cost savings (because other protein sources are cheaper than meat), we did *not* include any emissions increase associated with increased spending on other types of consumption (i.e., the indirect rebound). This is consistent with other types of MACC analyses, which generally do not include *indirect* rebound effects associated with energy savings, for example. (Note, however, that the abatement wedge results calculated under work product #1, described in section 2, *do* account for these rebound effects.)

Finally, in estimating abatement potential for different measures, we accounted for potential interdependencies. Specifically, among the measures assessed for the MACC, reducing food waste reduces the potential mitigation associated with consuming less meat and dairy (since avoiding meat consumption no longer avoids as much waste). This reflects the same sequencing used in the abatement wedge analysis under work product #1 (section 2).

Cost and benefit accounting boundaries

For costs and benefits, we included only those costs and benefits that accrue to the actors targeted by a measure – i.e., households, businesses, or government actors who would directly implement the action(s) associated with the measure. This means *excluding* any costs associated with adopting and implementing *policies or regulations* designed to achieve a measure, or induce targeted outcomes. This is because (consistent with other MACC analyses, including the MACC developed under the TIGHGER project) our analysis was "policy agnostic," and did not try to assume a specific set of policy tools or approaches. (For measures undertaken by government actors to reduce government consumption, implementation costs are still fully included and accounted for.)

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[145] For example, the TIGHGER project's estimates of emission reductions associated with food waste reduction exclude reductions occurring outside the state of Oregon, e.g., at out-of-state farms that produce food for consumption in Oregon.

In general, costs include:

- Capital expenditures, i.e., upfront expenditures incurred by actors to implement a measure, such as increased costs for building materials, or investing in digital systems in grocery stores to allow for dynamic pricing as a way to reduce food waste.
- Operation and maintenance expenditures, i.e., ongoing costs associated with implementing a measure, such as running programs to reduce food waste in state institutions.

Benefits include:

- Cost savings, e.g., money saved by reducing consumption or shifting consumption to low-carbon alternatives. This may include upfront or ongoing savings. For measures that reduce emissions by reducing spending and/or avoiding consumption (i.e., measures 1, 4, 5, and 6, as discussed below), associated cost savings were calculated using emissions intensity data from Oregon's consumption-based emissions inventory. For example, if food has an emissions intensity of 0.5 kg CO2e per dollar, then an emission reduction of 10 tons from avoiding food waste would translate to $20 of cost savings.
- Revenues (if any) accruing to the actors involved in implementing a measure. For most consumption-based measures, revenues are not relevant (the measures will not result in increased production of revenue-generating goods or services).

Co-effects

Many consumption-based GHG abatement measures will yield co-effects (positive or negative) related to other environmental impacts, public health, and other public benefits. These effects can, in principle, be included in the NPV calculations to estimate abatement costs. However, to include these effects, they need to be quantified and "monetized" (i.e., they would need to be assigned a dollar value). Estimating the monetary value of co-effects can be difficult and subject to uncertainty (which is why they are often not included in MACC analyses). For this analysis, we did not attempt to include them. This means that actual costs to society (cost-effectiveness) may be lower (better) than shown in Figures 4-1 to 4-4.

Residual values

Depending on the types of measure involved, some implementation costs and benefits may accrue beyond the end of the analysis period (i.e., after 2050). MACC analyses typically account for this by assigning a "residual value" to be incorporated in the calculation of NPV. In some cases, this may be represented as a simple percentage (e.g., 5% of total lifecycle costs); in others, it may be based on more specific calculations of investment lifetimes and deployment schedules. For this analysis, residual values were only applied in the case of smaller residential home size construction (assuming residential buildings have a 40-year investment lifetime, consistent with assumptions used in the TIGHGER MACC analysis).

4.2.3.5. Discount rate

An important decision in any MACC analysis is the discount rate used to calculate the net present value of costs and benefits. The discount rate reflects a judgment about the "time value of money." That is, all other things being equal (and ignoring inflation), a dollar of value generated today is worth more to society than a dollar generated in the future. Likewise, costs incurred in the future are valued less than if they were incurred today. The choice of discount rate depends on many considerations, including "who" is conducting the analysis. For private firms, for example, discount rates typically reflect their opportunity cost of investment (i.e., their cost of borrowing and/or the return they could get by investing in alternatives to the measure being considered).

In public policymaking contexts, however, there is a general consensus among economists that that a "social" discount rate should be used (Drupp et al. 2018). The 2006 "Stern Review" on the economic effects of climate change, for example, applied a discount rate of 1.4% when assessing the future costs and benefits of avoiding climate change (Stern 2006). The U.S. federal government has developed estimates of the "social cost of carbon" (SCC) using social discount rates ranging from 1.5% to 5% (ODOE 2020; U.S. EPA 2023). For this analysis, SEI applied discount rates ranging from 2.5% to 5% to illustrate how abatement cost estimates compare to SCC estimates developed in 2016 at those same discount rates, as reported in ODOE (ODOE 2020). (The U.S. EPA has since developed updates SCC estimates that are significantly higher than these earlier values (U.S. EPA 2023); however, since these estimates have not been universally adopted,[146] SEI chose for illustration purposes to use the earlier values.)

4.2.4. Description of assessed measures and modeling assumptions

1. Reducing the average size of new residential housing units ("smaller new home size")
Larger home size is a major driver of energy consumption and is associated with a range of lifecycle environmental impacts, including greenhouse gas emissions. While Oregon has promoted development of smaller dwellings for many years, these efforts could be enhanced. This measure models the effect of reducing the average square footage of new home construction by 50%, based on a prior DEQ analysis evaluating the lifecycle greenhouse gas benefits and cost savings associated with building smaller homes (Oregon Department of Environmental Quality 2010).

[146] Federal agencies are advised to "use their professional judgment to determine which estimates of the SC-GHG reflect the best available evidence, are most appropriate for particular analytical contexts, and best facilitate sound decision-making" (https://www.whitehouse.gov/wp-content/uploads/2023/12/IWG-Memo-12.22.23.pdf).

Emission reduction estimates

- This measure assumes 67% of all new home construction would be affected.
- New home construction is assumed to be a product of: (1) the expected increase in state population in each year (relative to 2021 value); and (2) turnover in existing housing stock.
- Smaller new residential buildings are "phased in" between 2025 and 2030, with new housing units in 2030 and later reduced by 50% in size (on average) compared to the reference case.
- Building 50% smaller will result in: [147]
    - A 20% reduction in embodied greenhouse gas emissions associated with construction.
    - A 37.5% reduction in annual home energy consumption, relative to reference case energy consumption in the year of construction.

Estimated costs/savings

- Savings from reduced construction costs are estimated based on the emissions intensity of construction (so, a 50% smaller residence will result in 20% construction cost savings – based on an assumed mix of smaller separate homes plus multi-family units)
- Energy cost savings are similarly calculated based on emissions intensity (so, a 50% smaller residence means a 37.5% reduction in energy costs, relative to energy costs in the year of construction).
- Energy cost savings are calculated annually, differentiated for each new building cohort.
- A 40-year investment lifetime is assumed for new residential buildings.[148] Energy savings within this lifetime but beyond 2050 are calculated as a "residual value" in 2051 dollars (which are subsequently discounted to 2021 dollars).
- While construction *emissions* are around 1/3 of lifetime emissions (over 40 years), construction accounts for nearly 90% of total lifetime costs. Thus, lifetime cost savings per building are around 25% (reflecting primarily the savings in construction costs).

[147] Derived from Oregon DEQ (2010) analysis, based on shift from "medium" home to a mix of "extra small" homes and multi-family dwelling units.

[148] This aligns, for example, with assumptions about residential building investment lifetime used in the TIGHGER MACC analysis.

2. Reduced grocery, restaurant, and food service waste

Food consumption accounts for nearly 15% of consumption-based emissions. A significant percentage of food's carbon footprint, however, is associated with food that is produced but never consumed. This measure models the effects of a suite of interventions that food retailers (grocers, restaurants, and food service institutions) could take reduce food waste that occurs within their own operations and/or "downstream" in households.. Both emission reduction potential and cost estimates are based on data provided in ReFED's Food Waste Solutions Database.[149]

Emission reduction estimates

- This measure affects the approximately 26% of produced food that is wasted (goes uneaten) at the level of "consumer-facing businesses" (as defined by ReFED) and households. The 26% estimate is derived from ReFED data.[150]
- Emission reduction estimates were calculated assuming a set of specific interventions are undertaken affecting retail-level food waste. In the ReFED solutions database, these are:
    - Decreased Transit Time
    - First Expired First Out
    - Intelligent Routing
    - Reduced Warehouse Handling
    - Temperature Monitoring (Pallet Transport)
    - Assisted Distressed Sales
    - Decreased Minimum Order Quantity
    - Dynamic Pricing
    - Enhanced Demand Planning
    - Increased Delivery Frequency
    - Markdown Alert Applications
    - Minimized On Hand Inventory
    - Temperature Monitoring (Foodservice)
    - Waste Tracking (Foodservice)
- ReFED's food waste tonnage reduction estimates for each of these interventions were compared to total food waste generated at retail and consumer levels (which ReFED estimates at 60.8 million tons) to determine a *percentage* reduction estimate. Together, the interventions reduce retail and consumer food waste by approximately 8%.
- The MACC model assumes this level of food waste reduction could be achieved by 2030 and maintained thereafter, with reductions phased in starting in 2025.
- Emission reductions are calculated assuming that an 8% reduction in affected food waste would avoid the same proportion of emissions (i.e., *total* food consumption emissions would be reduced by 26% x 8% = 2.2%).

Estimated costs/savings

- A reduction in food waste is assumed to result in a proportional reduction in food expenditures (since the otherwise wasted food no longer needs to be purchased).

- Associated food cost savings were calculated by dividing estimated emission *reductions* by food *emissions intensity* (kg CO2e/$ of expenditure) from Oregon's 2021 consumption-based emissions inventory.
- ReFED estimates both the costs and financial benefits of implementing waste reduction interventions (calculated across all stakeholders involved in implementation; parties who benefit financially from reduced food waste may not be same as those incurring implementation costs). The cost and benefit data are reported on an annual basis.
- To estimate implementation *costs* for the MACC model, the ratio of implementation costs to implementation benefits estimated by ReFED was applied to the estimate of food cost savings derived from Oregon's CBEI. (That is, costs are assumed to be *proportional* to the costs estimated by ReFED.)[151]
- No residual values were calculated; annual emission reduction benefits (and cost savings) are assumed to arise from regular annual expenditures on the measures considered.

3. Reducing food waste in government food service

Food consumption accounts for nearly 12% of government consumption-based emissions. This measure models the effects of a suite of interventions that could reduce food waste that occurs in government food service operations (e.g., schools and prisons). Both emission reduction potential and cost estimates are based on data provided in ReFED's Food Waste Solutions Database.[152]

Emission reduction estimates

- For this measure, the model assumes government food service waste is proportional to the amount of food waste that occurs at "consumer facing businesses," as estimated by ReFED – i.e., 8% of government-procured food goes uneaten.[153]

149 https://refed.org/

150 https://refed.org/food-waste/the-problem/#overview (60.8 tons wasted at retail (i.e., "consumer-facing businesses") and consumer levels vs. 235 million tons produced)

151 This provides a rough approximation, since ReFED costs and benefits are annualized over 10 years, using a 4% discount rate. However, when the ReFED discount rate is adjusted within the range of discount rates used in this MACC analysis (1.5% to 5%), the ratio of benefits to costs is nearly identical.

152 https://refed.org/

153 https://refed.org/food-waste/the-problem/#overview (18 tons wasted at retail (i.e., "consumer-facing businesses") and consumer levels vs. 235 million tons produced)

- Emission reduction estimates were calculated assuming a set of specific interventions are undertaken affecting food waste in government institutions. In the ReFED solutions database, these are:
    - Decreased Minimum Order Quantity
    - Minimized On Hand Inventory
    - Temperature Monitoring (Foodservice)
    - Waste Tracking (Foodservice)
    - Buffet Signage
    - K-12 Lunch Improvements
    - Portion Sizes
    - Small Plates
    - Trayless
- ReFED's food waste tonnage reduction estimates for each of these interventions were compared to total food waste generated at the consumer-facing business level (which ReFED estimates at 18 million tons) to determine a *percentage* reduction estimate. Together, the interventions reduce retail and consumer food waste by approximately 21%.
- The MACC model assumes this level of food waste reduction could be achieved in Oregon government food service by 2030 and maintained thereafter, with reductions phased in starting in 2025.
- Emission reductions are calculated assuming that a 21% reduction in affected food waste would avoid the same proportion of emissions (i.e., *total* food consumption emissions would be reduced by 21% x 8% = 1.6%).

Estimated costs/savings

- A reduction in food waste is assumed to result in a proportional reduction in food expenditures (since the otherwise wasted food no longer needs to be purchased).
- Associated food cost savings were calculated by dividing estimated emission *reductions* by food *emissions intensity* (kg CO_2e/$ of expenditure) from Oregon's 2021 consumption-based emissions inventory.
- ReFED estimates both the costs and financial benefits of implementing waste reduction interventions (calculated across all stakeholders involved in implementation; parties who benefit financially from reduced food waste may not be same as those incurring implementation costs). The cost and benefit data are reported on an annual basis.
- To estimate implementation *costs* for the MACC model, the ratio of implementation costs to implementation benefits estimated by ReFED was applied to the estimate of food cost savings derived from Oregon's CBEI. (That is, costs are assumed to be *proportional* to the costs estimated by ReFED.)[154]

[154] As above, this provides a rough approximation, since ReFED costs and benefits are annualized over 10 years, using a 4% discount rate. However, when the ReFED discount rate is adjusted within the range of discount rates used in this MACC analysis (1.5% to 5%), the ratio of benefits to costs is nearly identical.

- No residual values were calculated; annual emission reduction benefits (and cost savings) are assumed to arise from regular annual expenditures on the measures considered.

4. Reducing household meat consumption

Meat consumption is highly emissions-intensive, and studies have consistently found that reducing meat consumption is one of the most effective ways to reduce consumption-based greenhouse gas emissions. This measure models the effects of reducing household meat consumption (by 25%) and shifting diets to other protein sources.

Emission reduction estimates

- This measure assumes meat consumption would be reduced, on average, across all Oregon households
- By 2035, meat consumption is assumed to be reduced by 25%, and maintained thereafter. Meat consumption gradually declines between 2025 and 2035.
- Gross emission reductions are calculated relative to reference case emission from meat consumption – a 25% reduction in meat consumption translate to a 25% reduction in consumption-based (production phase) emissions
- Consumption is assumed to be shifted to other food categories. The model assumes consumption is shifted evenly to the "fruits and vegetables," "grain, baked goods, cereal, nuts," and "seafood" inventory categories.
- Shifting from meat to other foods is estimated to reduce food *expenditures* by 33%; that is, for every dollar not spent on meat, $0.67 are spent on other foods.[155] Thus, to estimate the *increase* in emissions associated with other food consumption, two thirds of avoided meat consumption expenditures are assumed to be shifted to other categories. Emissions are then calculated by multiplying these expenditures by the emissions intensities (kg CO2e/$) for the other categories.
- Net emission reductions are calculated as the difference between gross reductions in meat emissions and gross increases in emissions from other food categories.
- For consumption at restaurants, the proportion of restaurant emissions from meat consumption is estimated using calculations in the abatement wedge model.

Estimated costs/savings

- Net cost savings are calculated by converting emissions reductions (for meat) or increases (from other food categories) into dollar values using CBEI emissions intensity factors. Cost savings are equivalent to a 33% reduction in reference case expenditures on meat consumption.

[155] This is based on findings in Springmann et al. (2021).

5. Reducing embodied carbon in state-funded construction projects ("government construction")

Buildings and infrastructure are a major source of Oregon's consumption-based greenhouse gas emissions. The bulk of these emissions arise from energy use, but typically, at least 25% of a building's lifecycle emissions come from "embodied carbon," i.e., the greenhouse gas emissions associated with materials and construction. Public infrastructure (e.g., roads, streets, bridges, etc.) is also a major source of embodied emissions. This measure models the effect of reducing embodied carbon by 50% (by 2040) in government construction projects (buildings and infrastructure), through waste reduction, more efficient use of construction materials, and use of low-carbon materials (e.g., enabled through EPD policies).

Emission reduction estimates

- This measure affects all new government construction.
- Reductions in embodied carbon are achieved on a phased schedule starting in 2025, reaching a 30% reduction by 2030 and a 50% reduction by 2040 and thereafter.

Estimated costs/savings

- Case studies in the Pacific Northwest suggest that substantial reductions in embodied carbon in building construction – up to 46% - could be achieved for a cost premium of less than one percent associated with alternative materials (Esau et al. 2021). This measure assumes similar savings could be achieved for government infrastructure.
- For this measure, an additional 0.5% increase is assumed, associated with additional design costs needed to evaluate embodied material and construction emissions. A cost increase of 1.5% is therefore assumed to achieve a 30% reduction in embodied carbon.
- To achieve a 50% reduction, a cost increase of 2% is assumed, reflecting the possible need for new technologies and processes.
- The level of cost increase correlates directly to the achievement of embodied emission reduction targets over time (e.g., in years prior to 2030 where less than a 30% reduction is achieved, the cost increase is reduced proportionally).
- Reference case costs of construction are derived from Oregon's 2021 CBEI expenditure data.

6. Reducing embodied carbon in new residential and commercial building construction

Residential and commercial (business capital) construction is also a major source of Oregon's consumption-based greenhouse gas emissions. This measure models the effect of reducing embodied carbon in new residential and commercial buildings and infrastructure by 50% (by 2040), through waste reduction, more efficient use of construction materials, and use of low-carbon materials (e.g., enabled through EPD policies) – following the same trajectory as embodied carbon reductions in government construction.

Emission reduction estimates

- This measure affects all new household building construction and business capital building and infrastructure construction.
- Reductions in embodied carbon are achieved on a phased schedule starting in 2025, reaching a 30% reduction by 2030 and a 50% reduction by 2040 and thereafter.
- Reductions are calculated *after* accounting for the reduced demand for construction material due to smaller home sizes (measure #1).

Estimated costs/savings

- Case studies in the Pacific Northwest suggest that substantial reductions in embodied carbon in building construction – up to 46% - could be achieved for a cost premium of less than one percent associated with alternative materials (Esau et al. 2021). This measure assumes similar savings could be achieved for infrastructure.
- For this measure, an additional 0.5% increase is assumed, associated with additional design costs needed to evaluate embodied material and construction emissions. A cost increase of 1.5% is therefore assumed to achieve a 30% reduction in embodied carbon.
- To achieve a 50% reduction, a cost increase of 2% is assumed, reflecting the possible need for new technologies and processes.
- The level of cost increase correlates directly to the achievement of embodied emission reduction targets over time (e.g., in years prior to 2030 where less than a 30% reduction is achieved, the cost increase is reduced proportionally).
- Reference case costs of construction are derived from Oregon's 2021 CBEI expenditure data.

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5. Discussion Papers

SEI was asked by the Oregon Department of Environmental Quality to develop two discussion papers on topics related to addressing consumption-based greenhouse gas emissions in Oregon. The first addresses target-setting, outlining why it could be helpful to supplement the state's greenhouse gas reduction goals with targets for reducing consumption-based emissions, and identifying approaches for doing so. The second explores considerations and approaches for achieving deep reductions in consumption-based emissions, in line with targets based on equitable and climate-safe global emission budgets. These papers are included in this report below.

5.1. Setting consumption-based emission reduction goals

Governments around the world have responded to the climate crisis by setting targets to reduce greenhouse gas emissions. Most governments, including Oregon, have goals to reduce sector-based emissions – those that arise from different economic sectors within their jurisdictional territory.[156] Increasingly, however, governments at city, county, state, and national and regional levels in the US and Europe are considering setting goals for consumption-based emissions – those that arise from the goods and services *consumed* within their territories.

Among jurisdictions considering consumption-based emissions, Oregon is a pioneer. In 2011, it became the first US state to produce a consumption-based emissions inventory. This inventory provides a broad perspective on the state's contribution to global climate change, and it presents a full accounting of the greenhouse gas emissions associated with the entire life cycle of energy, materials, and goods and services consumed in Oregon. The inventory includes emissions generated throughout the production, delivery, use, and disposal processes involved, regardless of where these emissions occur. By revealing how consumption drives emissions, the inventory also suggests ways to reduce them. For example, consuming fewer emissions-intensive goods and switching to lower-emitting products and services could help reduce emissions globally. Moreover, as analysis in this report suggests (see Section 4), making such changes could be a cost-effective way for Oregon to help mitigate global climate change.

[156] Examples of sector-based emissions include those arising from transportation, electricity generation, and industrial and agriculture activities occurring within a government's jurisdictional boundaries. Different jurisdictions handle emissions from electricity generation differently. Some assign emissions based on the location of the power plant. Others assign emissions based on the location of the electricity users, no matter where the power itself was generated. Oregon follows this second, location-based method.

Indeed, by embracing both consumption-based and sector-based goals, Oregon can consider a wider range of opportunities for reducing greenhouse gas emissions. Actions taken in Oregon to reduce emissions can have an impact on reducing emissions worldwide. And by focusing on its own consumption, Oregon can help enable a more just and equitable transition toward a decarbonized global economy. Thus, by setting and using both types of goals, Oregon can deepen and accelerate its contributions to global mitigation efforts.

Oregon has made progress in reducing its sector-based emissions, but its consumption-based emissions continue to rise (Oregon Department of Environmental Quality 2024). There are multiple reasons for this. A key one is that the state (like most other jurisdictions) has focused more on reducing its sector-based emissions. As this report makes clear, Oregon has many options for reducing consumption-based emissions. At the same time, for policymakers to pursue these options, such goals must be on their radar. Setting explicit targets for reducing consumption-based emissions would be an important first step in this direction.

With these issues as a backdrop, this paper explores rationales for setting consumption-based emissions targets, considers targets that other jurisdictions have set or are evaluating, and examines approaches that Oregon could use to set consumption-based goals. Options include aligning with Oregon's sector-based goals, consumption levels needed to maintain human well-being, global emissions limits, or the state's "fair share" of emissions.

5.1.1. What are the current goals for reducing Oregon's emissions?

Table 1 provides a summary of Oregon's proposed and adopted goals to reduce greenhouse gas emissions. Though nothing indicates whether these are sector-based or consumption-based goals, they have been widely interpreted as applying only to sector-based emissions. For example, when reporting progress to the Oregon Legislature, the Oregon Climate Action Commission (OCAC) (formerly the Oregon Global Warming Commission) used the sector-based inventory in its 2023 report.

Table 4: Summary of proposed and adopted goals to reduce greenhouse gas emissions

Year	Description	Goal	Status
2007	The Oregon Legislature adopted statutory goals to reduce the levels of the state's greenhouse gas emissions.	- By 2010: a peaking of emissions - By 2020: reduction of emissions to levels at least 10% below 1990 levels - By 2050: reduction of emissions to levels at least 75% below 1990 levels	**In law**
2015	The Oregon Climate Action Commission (OCAC) (formerly the Oregon Global Warming Commission) proposed an interim goal.	- By 2035: reduction of emissions to levels at least 44% below 1990 levels	**Not adopted**
2020	Oregon's emissions-reduction goals were updated via Executive Order No. 20-04.	- By 2035: reduction of emissions to levels at least 45% below 1990 levels - By 2050: reduction of emissions to levels at least 80% below 1990 levels.	**Adopted, but not by the legislature**
2023	As part of the Climate Action Roadmap to 2030, the OCAC recommended another update to the state's goals.	- By 2030: reduction of emissions to levels at least 45% below 1990 levels - By 2040: reduction of emissions to levels at least 70% below 1990 levels - By 2050: reduction of emissions to levels at least 95% below 1990 levels. - By 2050: achievement of net-zero emissions[1]	**Not yet adopted**

[1] Achieving "net-zero" emissions means balancing out any emissions that remain in 2050 (that is, compensating for the 5% of 1990-level emissions that are expected to remain when the 2050 target to reduce emissions has been achieved) with actions that remove an equal amount of greenhouse gases (mainly CO_2) from the atmosphere (Oregon Global Warming Commission 2023).

5.1.2. What are some reasons for adopting a goal to reduce consumption-based emissions?

Oregon residents have a longstanding interest in local and global sustainability. For example, the state's 2050 Vision and Framework for Action (adopted in 2012) addresses materials management by underscoring the importance of living within global resource constraints and keeping within the limits of Oregon's "*sustainable share of the world's natural resources.*" Lowering consumption-based emissions would be one way to follow this vision. Setting a goal for reducing consumption-based emissions – to complement, rather than replace, the state's existing goals – could be important for several reasons. These include:

- ***Explicitly acknowledging Oregon's full carbon footprint and its shared responsibility for reducing it.*** A goal to reduce consumption-based emissions would explicitly recognize Oregon's shared responsibility for emissions arising from the goods it consumes and services it uses, even if those emissions occur elsewhere. In doing so, Oregon could spur efforts to help manage and reduce those emissions.

- ***Equitably contributing to the global mission to reduce greenhouse gases.*** Other jurisdictions with consumption-based emissions goals (see case studies in this section) emphasize equity and fairness to justify this mission. The adverse effects of climate change disproportionately impact impoverished and marginalized communities in the US and around the world. Many goods consumed in Oregon are produced and manufactured in these same communities, where the negative social and ecological impacts of extracting resources and manufacturing goods in turn increase the vulnerability of these places to the impacts of climate change. By addressing consumption-based emissions, Oregon can help alleviate these inequities.

- ***Considering the broader impacts of Oregon's climate actions.*** One risk with a strictly sector-based approach is that it may inspire efforts that reduce greenhouse gas emissions in Oregon, but inadvertently *increase* emissions elsewhere. For example, while the US and Europe have made strides in reducing their sector-based emissions over the past 20 years, evidence suggests that at least some of this was achieved by shifting production of emissions-intensive goods and services to lower-income countries (Fuhr 2021). Looking at sector- and consumption-based emissions together can help Oregon avoid simply displacing emissions to other places. This approach can also help ensure that (relatively) low-emitting local industries remain competitive with those in jurisdictions with less stringent emission regulations.

- ***Facilitating sector-based decarbonization targets.*** By reducing consumption, Oregon can contribute to efforts to meet sector-based decarbonization targets. For example, shifts in demand toward lower-carbon options for goods and services can spur changes in production processes (both in and out of state). Reducing the demand for energy- and carbon-intensive products and services can make decarbonization easier and less costly. For example, reducing demand for cars will make it easier and less costly to meet Oregon's goals for reducing emissions from transportation and – as electric vehicles become more prevalent - the power sector.

- ***Motivating actions to reduce consumption-based emissions.*** A key reason for setting a consumption-based goal is to motivate action. What gets measured gets managed. Progress that Oregon has made to reduce its sector-based emissions offers a case in point. Incorporating consumption-based goals with established sector-based goals can lead the state to adopt more ambitious policies that tackle both sustainable consumption and production.

As is the case in other complex areas of public policy (such as education, finance, and housing), it is important to set goals and measure outcomes across multiple dimensions of climate policy.

Supplementing sector-based targets with goals for consumption (and climate adaptation) would help ensure that Oregon's efforts are more coherent, comprehensive, equitable, and effective.

5.1.3. Case studies: governments using consumption-based inventories to reduce emissions

Consumption-based inventories are being used to guide efforts to reduce emissions by local governments, such as San Francisco, London, Paris, and Portland (Oregon). Sweden and the European Union are also exploring binding consumption-based targets. More details on each case, including their reasons and approaches for adopting a consumption-based goal, are described here.

San Francisco, California: In 2021, the City and County of San Francisco adopted targets to reduce total consumption-based emissions from households, government, and private investments by 2030 to levels at least 40% below 1990 levels (at or below 30 metric tons of carbon dioxide equivalent (tCO_2e) per household) and by 2050 to levels at least 80% below 1990 levels (at or below 10 tCO_2e per household). According to San Francisco's Climate Action Plan, the consumption-based goal was primarily motivated by the principle of equity. Underscoring the global nature of climate change, the plan notes that "*purchases made in San Francisco have global ramifications, including the production and release of harmful chemicals and pollutants that impacts communities…generating harmful climate pollution and exacerbating environmental injustice.*" The plan further notes that "*[i]n keeping with its commitment to equity, San Francisco is determined to reduce the impacts of these outsourced emissions [by]…avoiding inequities associated with outsourcing high-emissions activities to other communities, locally, regionally, and internationally.*"

London: The London Councils, a collaborative government body representing London's 32 borough councils and the City of London, adopted a provisional target to reduce household consumption-based emissions to two-thirds below 2001 levels by the year 2030. According to the One Living World Action Plan by the London Councils, the target to reduce consumption-based emissions was informed by a report of the C40 Cities, a global network of nearly 100 mayors of the world's leading cities. The report, The Future of Urban Consumption in a 1.5°C World, recommended aiming to reduce emissions by 2030 to levels two-thirds below 2017 levels; this is a level that the report deemed to be a fair contribution for cities in developed countries (C40 Cities et al. 2019). The target set by the London Councils was also informed by a report from the Institute for Global Environmental Strategies (IGES), a Japanese research institute. The report, 1.5-Degree Lifestyles: Targets and options for reducing lifestyle carbon footprints, found that staying within an emissions budget aligned with keeping global warming below 1.5°C will require that by 2030 the carbon footprints of households do not exceed 2.5 tCO_2e per capita (Institute for Global Environmental Strategies et al. 2019). This limit is roughly half of London's 2020 per capita household consumption emissions of 5.09 tCO_2e. By comparison, Oregon's 2021 per capita household consumption emissions were 16.3 tCO_2e – and government and business capital/investment consumption added another 6.0 metric tons per capita.

Paris: In 2018, Paris established targets in its Climate Action Plan to decrease territorial and consumption-based emissions (the Paris carbon footprint) to 40% below 2004 levels by 2030 and 80% below 2004 levels by 2050. To reach its target for reducing the carbon footprint the city has outlined efforts to address emissions linked to the food and construction sectors and to transportation outside of Paris, including air transport. A key reason that the City of Paris is tackling consumption-based emissions is because they consider it a "*fair, ambitious and transparent approach to emissions accounting*." The target was established based on the emissions inventories for the years 2004, 2009, and 2014, as well as simulations that considered emissions trajectories for Paris and accounted for policies that aim to reduce emissions at the national level in France and at the EU level.

Portland, Oregon: The 2015 Climate Action Plan by the City of Portland and Multnomah County pledges to reduce emissions by 50% by 2030 and achieve net-zero emissions by 2050, addressing both sector- and consumption-based emissions. In 2021, Portland also produced a Sustainable Consumption and Production Report (SC&PR) It includes a two-year work plan, strategies to promote reduced consumption, and a more detailed set of Recommendations to Reduce Embodied Carbon in the Built Environment. Driven by considerations of climate, equity, and justice, the report seeks to shift away from "*traditional models of economic growth to measurements of equitable consumption and community well-being, all while acknowledging and dismantling historic injustice and oppression.*" It notes that achieving sustainable levels of local consumption and production is crucial not only for addressing the climate crisis but also for mitigating various other environmental and social impacts, such as product toxicity, air and water pollution, biodiversity loss, and unsafe working conditions in developing countries. It also seeks to align with Oregon's 2050 Vision for Materials Management.

Sweden: In 2022, Sweden became the first country to announce an intention to set a consumption-based target alongside a sector-based target – both aimed at achieving net-zero emissions by 2045. A research report, led by Chalmers University of Technology (Larsson et al. 2022) and commissioned by the Swedish parliament's Cross-Party Committee on Environmental Objectives, provided insight into Sweden's present and projected consumption-based emissions under multiple consumption scenarios, and reviewed two different approaches to setting a consumption-based target in Sweden based on principles of equity. One approach is to set the target to an average emissions per capita level aligned with the Paris Agreement, and the other is to further consider Sweden's historical responsibility and its capacity for a sustainable transition, following the principles of the United Nations Framework Convention on Climate Change (UNFCCC).

European Union (EU): The European Parliament voted in 2021 to create science-based, binding targets for 2030 for both for material use and the EU's consumption footprint. The EU's primary motive is a desire to shift from the current economic model to a circular economy by 2050. This approach goes beyond addressing emissions. The European Commission also outlined a Circular Economy Action Plan for "a cleaner and more competitive Europe." The plan seeks to prevent waste generation and to reduce energy and resource use. While targets have yet to be established, new indicators have been adopted on material footprints, resource productivity, consumption footprints, and greenhouse gas emissions from production activities and material dependencies. These indicators are part of EU's Circular Economy Monitoring Framework.

5.1.4. How should Oregon set its goal to reduce consumption-based emissions?

Goal setting is as much a political matter as a scientific one (Larsson et al. 2022). That is, determining goals is ultimately a matter of values.

Nevertheless, scientists and researchers have recommended multiple methods for setting consumption-based goals. For example, Morfeldt et al. (2023) suggest that consumption-based targets should:

- Adhere to existing international frameworks and agreements,
- Possess a well-designed policy approach, and
- Offer additional benefits by addressing limitations in sector-based approaches.

This section provides illustrative examples of four ways Oregon could establish a consumption-based target using methods and principles proposed in scientific literature. The state may want to consider setting a total, combined target, along the lines of the examples given in the previous section. This could be based on Oregon's consumption-based emissions inventory, which estimates emissions across all sources of consumption (including household consumption, government expenditures, and private investments). The potential targets outlined in the approaches offered here reflect these assumptions. They indicate total consumption emissions per capita across all sources of consumption.

5.1.4.1. Apply Oregon's existing emissions target to consumption-based emissions

A simple approach to set a consumption-based target would be to align with sector-based targets. This approach is perhaps the most straightforward. It has been adopted by cities, including Paris and Portland. Oregon could set its consumption-based target to align with the state's statutory goal for 2050 – that is, to reduce emissions by 2050 to levels that are 75% lower than 1990 levels. This would be equivalent to reducing per capita emissions from 21.9 tCO_2e in 1990[157] to 2.9 tCO_2e in 2050.[158]

5.1.4.2. Target minimum standards for well-being

Another approach could involve targeting consumption levels that align with minimum standards for well-being. A well-known, bottom-up method for estimating the minimum material needs for human well-being is the decent living standard (Rao and Baer 2012). Such a standard aligns with the idea of sufficiency, or living within environmental limits (Millward-Hopkins et al. 2020). Such an approach outlines minimum standards for housing, nutrition, healthcare, transportation, water, leisure, communication, and education. Using this approach, Kikstra et al. (2021) have estimated that individuals in North America need around 38 GJ of energy per capita per year. However, converting energy requirements into per capita emissions is difficult because the figures depend on the type of energy used. Additionally, while the decent living standard addresses essential needs, it represents only one aspect of what many people consider to be aspects of human well-being overall (Lamb and Steinberger 2017; Li and Chen 2021). One's happiness, life satisfaction, freedom and capabilities are more subjective aspects of human well-being. In comparison to the well-being markers used to assess a decent living standard, these attributes are hard to quantify in terms of energy needs and emissions (Li and Chen 2021).

5.1.4.3. Set per capita targets based on scenario analysis and global carbon budgets

A forward-looking allocation can be derived by scenario analysis of different consumption-emission pathways, or by projecting the future global carbon budget and dividing it by the population. This approach allows for a more equitable distribution of carbon footprints among individuals or groups. For example, a scenario analysis for Sweden conducted by Morfeldt et al. (2023) suggests that combining advanced mitigation technologies with behavioral changes could reduce Sweden's consumption-based emissions from 9.8 tCO_2e per capita in 2019 to between 2.7

[157] According to Oregon's 2021 consumption-based emissions inventory report, total consumption-based emissions in 1990 were estimated at 62.4 million tCO_2e. To calculate the per capita consumption emissions in 1990, the authors of this report divided this number by 2,847,000, the population of Oregon in 1990, according to estimates (for July 1st, 1990) from the Portland State University Population Research Center.

[158] The authors calculated the 2050 figure based on the projected 2050 population of 5,367,752, as estimated by the Portland State University Population Research Center.

tCO_2e and 4.8 tCO_2e by 2045, depending on global decarbonization pathways.[159] A similar calculation would be needed for Oregon to determine per capita values under various emissions scenarios. Alternatively, a simpler approach would be to consider a global emissions budget aligned with limiting warming to 1.5^{0}C. Under such an approach, global emissions in 2050 would range from 5 $GtCO_2e$ to 13 $GtCO_2e$ in 2050 (UN Environment Programme 2023). The wide range in emissions is a result of the varying assumptions used across different models and emission scenarios. Evenly dividing this among a projected 2050 global population of 9.6 billion (United Nations 2024) would result in per capita emissions of between 0.5 $GtCO_2e$ to 1.3 tCO_2e.

5.1.4.4. Set aspirational targets based on a global "fair share"

Targets also could be set using historical legacy and equity-based approaches that recognize past emissions and resource consumption patterns, and address disparities in responsibilities and capabilities to reduce carbon footprints. Wealthier countries have historically contributed much more to global greenhouse gas emissions on a per capita basis than poorer countries (Global Carbon Atlas 2023; Our World in Data 2024). Much of this disparity is driven by the unequal exchange of resources from lower-income to higher-income countries (Hickel et al. 2022). This is a major driver of global inequality.

Taking these historical inequities into account, the Climate Equity Reference Project (CERP) provides a framework for fair effort sharing. This approach is based on addressing key climate equity principles, including a country's responsibility for creating the climate crisis; its capabilities for addressing it; and its right to sustainable development. A recent Oxfam study found that per capita emissions in many high-income countries would need to be *negative* to align with these principles, meaning – in essence – that high-income nations would need to reduce their consumption while also assisting lower income nations to reduce their emissions (Oxfam 2023).[160]

5.1.4.5. Summary of approaches

Figure 5-1 illustrates what each of the approaches described above might imply for setting consumption-based emissions targets.[161] A range of targets is possible and defensible. Oregon's current consumption-based emissions are well above any of these potential targets, but choosing

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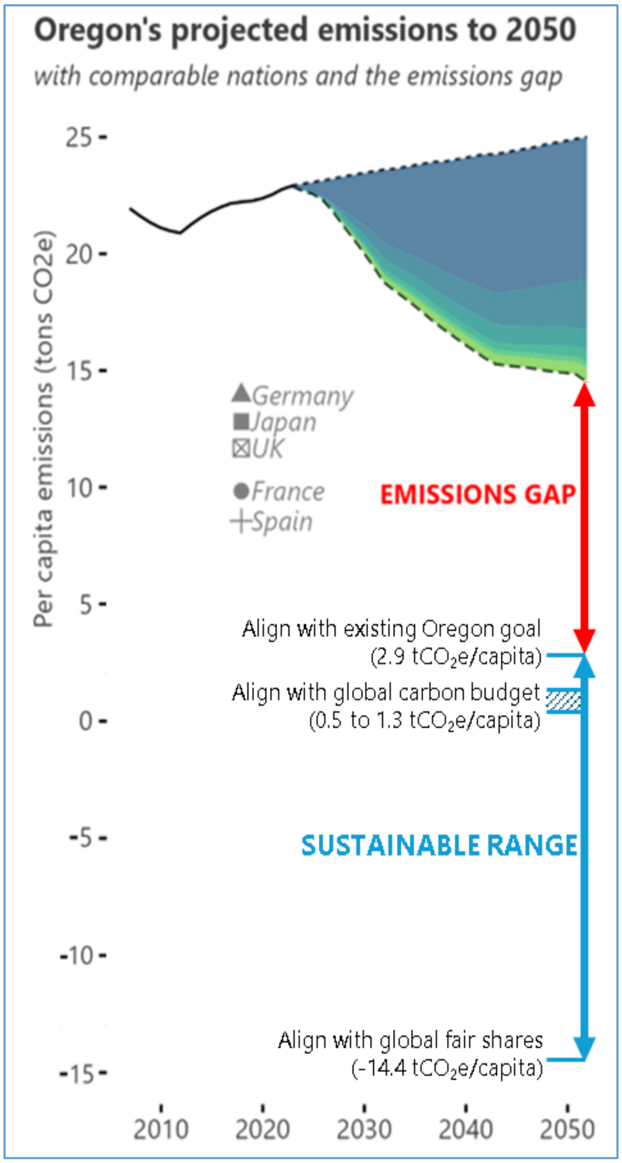
[159] The upper value reflects the existing trends and policies worldwide as of mid-2019, while the lower value signifies a global climate transition aligned with the goals of the Paris Agreement.

[160] The Oxfam study found that the US would need to reach an emissions target of *negative* 14.37 tCO_2e per capita.

[161] Note that these targets reflect emission reductions only. The scenarios proposed by the IPCC indicate that emission removals will be needed to achieve the net-zero goal by the middle of the century.

a target could help lead to strategies for closing the gap (see second discussion paper, in section 5.2, below).

Figure 5-1. Comparison of potential per capita consumption-based emissions targets to Oregon's projected emissions to 2050



Note: Values for other nations represent an estimate of their per-capita consumption-based emissions for 2016.

5.1.5. Conclusion

Setting consumption-based emission targets, in addition to sector-based targets, can contribute to a more comprehensive and equitable strategy for Oregon to reduce greenhouse gas emissions.

A consumption-based goal would align with the state's existing sustainability efforts, such those outlined in the 2050 Vision. It would also dovetail with Oregon's aim for its residents, businesses, and governments to act in ways that acknowledge and address global resource constraints.

Though Oregon does not control all its consumption-based emissions directly, it can take advantage of many policy interventions that can help reduce such emissions indirectly. Oregon can look to examples from other governments that are integrating consumption-based goals into their efforts to reduce emissions. The state can also explore the many options identified in sections 3 and 5.2 of this report.

More broadly, setting targets in line with global goals would provide a clearer picture of both Oregon's total contribution to climate change and its potential role in the global transition to a sustainable climate. Embracing a holistic approach to address both consumption- and sector-based emissions would ensure that Oregon's efforts are coherent, comprehensive, equitable, and, ultimately, effective in addressing the challenges of climate change.

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5.2. Closing the emissions gap: addressing consumption at a systemic level

Oregon can take multiple steps to reduce its consumption-based emissions. Policies aimed at reducing and shifting what households, institutions, and businesses consume—by reducing food waste, for example, or shifting toward smaller and less carbon-intensive home construction—could significantly lower Oregon's carbon footprint. Our analysis suggests that by 2050, these additional measures when combined with existing state and federal policies could reduce Oregon's consumption-based emissions *below* today's levels, even as Oregon's population and economy continue to grow. At the same time, these efforts would still fall short of achieving *per capita* emissions aligned with global carbon budgets or with a "fair share" of global emissions (see discussion paper 1, section 5.1).

Part of the reason for this is that Oregon's economy is highly connected to national and global economies. While Oregon's in-state emissions are stabilizing, emissions associated with consumption have grown over 20% in 16 years (Oregon Department of Environmental Quality 2024). As long as Oregon residents, institutions, and businesses consume goods and services produced elsewhere, achieving deep reductions in consumption-based emissions will require *other* jurisdictions—where the goods and services are produced—to reduce emissions from production. Our analysis did not try to account for what other states and countries around the world might do to reduce these emissions.

But our analysis indicates another reason for the projected "emissions gap" in 2050: per capita emissions in Oregon are today much higher than in other parts of the world, including in other advanced economies like Germany, Japan, and the United Kingdom. Without deeper structural changes to Oregon's economy, measures undertaken to shift consumption can only go so far—perhaps lowering per capita emissions *by 2050* (as our analysis suggests) to levels slightly higher than what we observe in these other countries *today*.

Structural factors influence consumption in multiple ways. Decisions by governments and businesses to invest in specific products, services, infrastructure, and technologies—such as roads over public transit—limit the consumption choices available to individuals. Socioeconomic factors such as income and education, as well as cultural factors and societal norms, all influence consumption behavior. Failure to consider negative externalities in the pricing of goods and services masks the true social and environmental costs of consumption behaviors, including those borne by poor and marginalized communities.

Structural barriers to achieving deep greenhouse gas reductions are not unique to Oregon. Around the world, there are ongoing debates about whether climate change can be solved using technological solutions alone or whether more systemic shifts are needed in what humans produce and consume. A growing body of research points to the need to shift local and global economic systems to prioritize human well-being (i.e., what we need) over traditional growth-oriented models (i.e., what we produce) in addressing the systemic causes behind unsustainable consumption. In the words of one study, "achieving sustainability rests almost entirely on getting the economy right" (UNEP 2011, p.2).

There are many things Oregon can do to facilitate both local and global transformations in economic activity and close its consumption-based emissions gap. Below, we dig deeper into the systemic issues behind unsustainable consumption in Oregon, examine alternative economic structures that center well-being and the environment, and propose steps that Oregon can take to bridge its emissions gap.

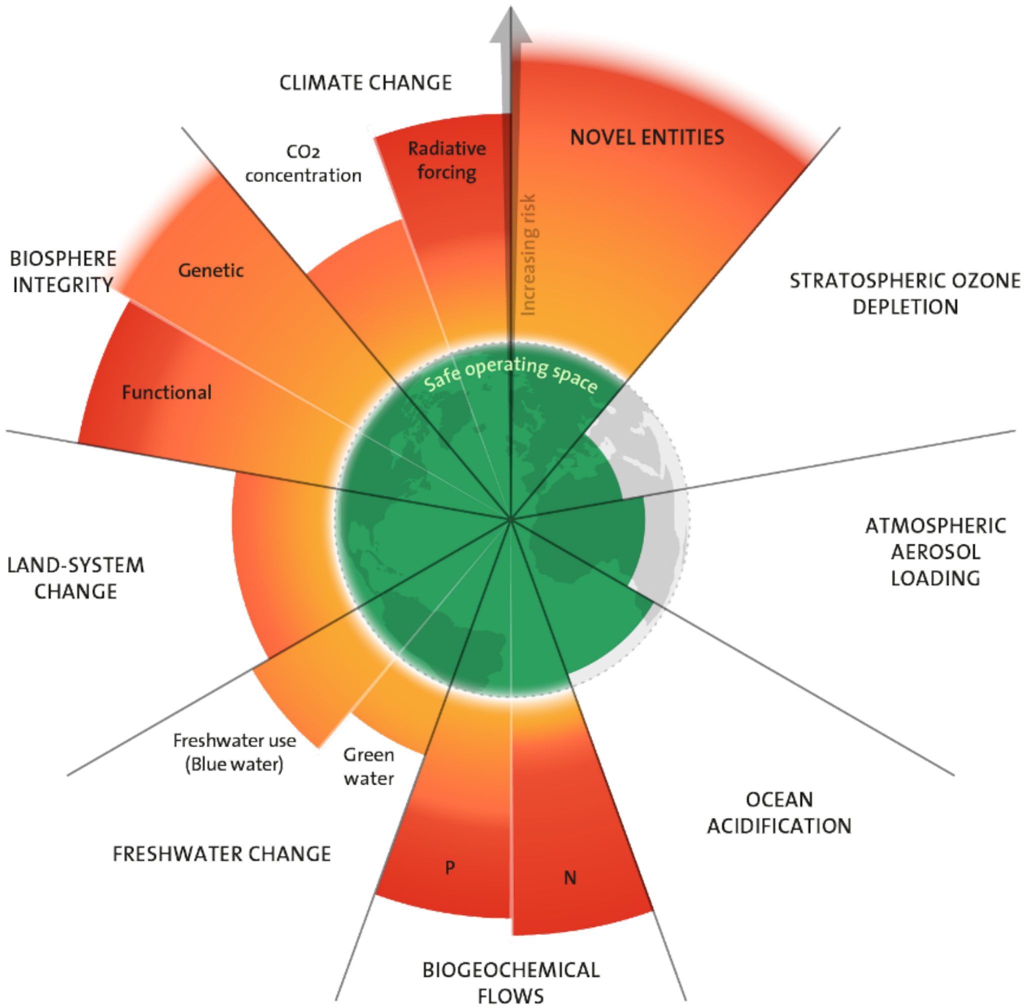
5.2.1. Why care about consumption?

One question that sometimes arises in debates about mitigating climate change is whether consumption must be addressed at all. If we (along with the rest of the world) manage to decarbonize our economies and meet people's needs without the use of fossil fuels, then consumption-based emissions would also be addressed. However, there are two reasons this approach is likely to be short-sighted and why policymakers should focus on consumption as well as production.

5.2.1.1. Avoiding "carbon tunnel vision"

Typical strategies that promote renewable energy and energy-efficient technologies aim to *shift* or *substitute* material and energy consumption to more sustainable sources, rather than *avoid* or *reduce* overall energy and material usage. For instance, promoting electric vehicles shifts consumption from gasoline to electricity but doesn't fundamentally address the total energy demand for transportation. As a result, even if goods are produced more sustainably, the overall demand for goods continues to drive resource extraction, energy consumption, and waste generation. Even if carbon emissions are avoided, this ongoing demand may not be sustainable. There are numerous planetary boundaries in addition to climate change, such as the loss of biosphere integrity and freshwater scarcity, that if exceeded, could have catastrophic effects upon our planet, (Rockström et al. 2009; Steffen et al. 2015; Richardson et al. 2023)—see Figure 5-2. To avoid "carbon tunnel vision," i.e., narrowly focusing on reducing carbon emissions, we must consider material and energy extraction and their implications for other environmental and social concerns.

Figure 5-2. Illustration of planetary boundaries (Azote for Stockholm Resilience Centre, based on analysis in Richardson et al. 2023)



5.2.1.2. Recognizing the technological limits to decarbonization

While it might be comforting to think that we can solve climate change through technological solutions alone, reality appears more complicated. In scenarios that scientists have explored to keep global warming "well below 2⁰C" (the goal of the Paris Agreement), the majority involve shifts in both production *and* consumption. A landmark 2021 analysis by the International Energy Agency (IEA), for example, developed a scenario for limiting global warming to 1.5⁰C that—while focusing on transforming energy systems—still requires significant consumer "behavioural change" (in the IEA's terminology), such as flying and driving less (IEA 2021). Other scenarios aligned with safe greenhouse gas emissions limits emphasize reductions in energy demand (e.g., Grubler et al. 2018). In short, there is a growing recognition that avoiding dangerous climate change will require transforming both supply and *demand* (Creutzig et al. 2018). Based on what we know today, technological solutions simply cannot be deployed at the pace and scale required to stay within a safe global carbon budget.

5.2.2. Reducing emissions requires addressing the structural barriers to sustainable consumption

A common assumption is that the way to address consumption-based emissions is to persuade individual consumers to change their behavior. Through interventions like eco-labeling and other incentives, consumers are targeted as the main agents of change. Consumer demand and choice, will, therefore, exert pressure on producers of goods and services to make the changes required for significant emissions reductions.

A growing body of evidence, however, suggests that these kinds of approaches—while effective in some contexts—can ultimately distract individuals and policymakers from more effective approaches. Reliance on behavioral mechanisms, which place primary responsibility on consumers themselves, has had limited effectiveness (Akenji 2014; Welch and Southerton 2019; Tukker et al. 2010; Jackson 2005). This is largely because focusing on "green consumerism" avoids grappling with the structural and systemic factors that constrain consumer choice.

Consumption is shaped not only by individual actions but also larger economic and social systems (van Vliet et al. 2005). Socioeconomic factors, including income and education, as well as cultural factors and societal norms all influence consumption behavior. Capital investments by businesses and governments determine the types and quantities of goods, services, materials, and infrastructure available in an economy, and thereby constrain consumption choices available to individuals. Moreover, the true social and environmental costs of consumption are often not reflected in the prices consumers pay. Failure to "internalize" these externalities perpetuates unsustainable consumption patterns and contributes to the high levels of consumption-based emissions seen today (Box 1).

Because of these constraints, Akenji (2014) argues that strategies focusing on individual behavior amount to a form of consumer "scapegoatism," which can be both inequitable and ineffective for achieving the degree of change required. To be effective, policies targeting consumer behavior must be combined with those that address the structural determinants of consumption. This means pursuing efforts to shape what is consumed (see, for example, the "information disclosure" and "product regulation and standard" type policies discussed in section 3.2) but also what gets produced, the supply chains used to deliver products and services to consumers, and the environments (e.g., urban forms and availability of public amenities) in which consumption takes place. Transformative change that leads to significant decarbonization will need to involve coordinated and targeted policies that focus on producers, intermediaries, and final consumers. As Grubb et al. (2020) put it, "behavioural changes will need to be implemented in concert with pervasive structural changes to make the right choice the easy choice" (p. 11).

Box 1. Social and environmental "externalities"

A widely recognized problem in environmental economics is that the true cost of producing goods and services is often not fully reflected in their prices. This is because various social costs—such as health and environmental costs associated with pollution—are not borne by the producers. If a manufacturer can make a product without paying for the pollution caused by its production methods (referred to by economists as an "externality"), it can sell the product for less than its true cost to society. In economic terms, this leads to inefficient overproduction and overconsumption. A recent study, for example, found that if the social cost of emitting greenhouse gases were fully borne by large corporations, it would erase about 44% of total profits across all industries—the materials manufacturing, energy, and transportation industries all had average damages that exceeded their profits. (Greenstone et al. 2023). A key structural requirement for a sustainable economy is to "internalize" these externalities (e.g., through carbon taxes), so that economic activity and sustainability are aligned.

5.2.3. Overcoming structural barriers: The need for new economic paradigms

A key challenge is that our economic structures (in Oregon and around the world) arise from fundamental—and too often unquestioned—assumptions about how economies are supposed to work. Modern economies predominantly follow a "neoclassical" paradigm, emphasizing continuous economic growth as measured by gross domestic product (GDP). GDP growth is fueled by a persistent demand for goods and by the ongoing investments made by both the public and private sectors in their production. While this paradigm has contributed to improvements in material well-being over time, many economists argue that its focus on providing private (non-shared) goods and economic growth have led to aggregate *over*production and *over*consumption, contributing to a range of environmental problems (Daly 1995; Princen 1999; Schoenmaker and Stegeman 2023).

An important qualification is that GDP itself does not account for other important elements of well-being, such as income distribution, environmental sustainability, and overall quality of life. Instead, GDP serves as a broad indicator of economic activity and is used as a proxy for measuring average societal welfare. GDP growth can give the impression that society is generally improving, when in fact average welfare may be skewed by wealth inequality and other environmental and social externalities. As a result, there is growing research into using indicators in addition to or instead of GDP to measure societal welfare—for example by the Beyond GDP Initiative in the European Union and a similar initiative in the U.S. led by the U.S. Bureau of Economic Analysis.

Alternative indicators are a core element of various alternative paradigms for how economies could be structured.

5.2.3.1. Looking at more than just GDP: Green growth

One prominent school of thought suggests we should continue to embrace economic growth because of its promise to deliver material well-being while steering this growth in more sustainable directions. **Green growth** emphasizes the need to "decouple" economic growth from environmental degradation and advocates for pursuing growth in a fair and inclusive manner (World Bank 2012). For this reason, green growth advocates adopt a broader set of indicators of economic performance beyond GDP (OECD 2011).

Green growth places responsibility on governments to establish favorable conditions for a sustainable economy and as such, green growth is often presented as a "business opportunity" aligned with GDP growth more generally (Hickel and Kallis 2020). Key measures to support green growth include enhancing regulatory frameworks and governance mechanisms; creating environmental awareness; advancing green technologies; developing a green workforce; providing financial incentives for green products; and imposing financial disincentives for environmentally harmful ones, such as through carbon taxes (Hoffmann 2015). Most of these policies focus on shifting consumption rather than reducing it.

In climate policy circles, green growth is a widely embraced paradigm. Many observers associate the Paris Agreement with green growth (Rijsberman et al. 2019), for example, as it envisions the climate transition mainly as a technological challenge that focuses on what countries need to do to reduce production-related greenhouse gas emissions.

Despite extensive efforts to promote a green economy since the 2008 global recession, however, governments have yet to implement policies to achieve an absolute decoupling of economic growth from environmental harms (Haberl et al. 2020; Vogel and Hickel 2023). In the U.S., investment in fossil fuel production is still high and at a similar level of investment as renewable energy (IEA 2024). A look at Oregon's consumption-based emissions underscores these challenges. Between 2005 and 2021, reductions in the emissions *intensity* of Oregon's economic activity—due to fuel switching, cleaner energy mixes, and some consumption shifts—were overshadowed by an increase in total consumption, leading to an increase in consumption-based emissions of 20% (Oregon Department of Environmental Quality 2024, fig.'3-13'). Production-related emissions reductions in Oregon and the rest of the world were not enough to decouple emissions from economic growth.

Because of this, some observers have raised questions about the potential of growth-oriented policies to achieve the world's climate objectives. Central to many of these critiques is a phenomenon known as Jevons Paradox, which arises when improvements in resource efficiency or conservation measures lead to an unintended *increase* in resource consumption rather than the intended decrease (also known as a "rebound effect"—see discussion in section 2.3). One reason this occurs is that efficiency gains can lower the cost of using a resource, leading consumers to increase their spending on it, or shift money to other forms of consumption, offsetting the initial gains from the efficiency improvements (Alcott 2005; Giampietro and Mayumi 2018). Such rebound effects, in addition to population growth, can hinder efforts to absolutely decouple growth from environmental impacts (climate-related and otherwise) (Brockway et al. 2021).

A related concept to green growth is the **circular economy**, under which the aim is to eliminate waste, keep products and materials in circulation at their highest value for as long as possible, and regenerate nature instead of simply extracting resources (Kirchherr et al. 2023). While a circular approach could enhance efforts to decouple growth from environmental impacts, there are concerns about its feasibility, specifically where optimal resource efficiency is constrained by technical and physical limitations (Paoli and Cullen 2020). The efficiency gains of a circular economy may also contribute to Jevons Paradox. Moreover, while academic literature on the circular economy tends to be comprehensive, implementation often falls short—focusing, for example, on keeping materials in "circular loops" at the expense of more holistic solutions (Mistry 2019).

Finally another concern is that, while green growth advocates explicitly call for economic growth that is fair and equitable, pursuing green growth may not always align well with poverty alleviation; therefore, the extent to which it is equitable depends greatly on how it is pursued (Dercon 2012). Again, the track record of countries pursuing green growth strategies is mixed in this regard.

5.2.3.2. Broader alternatives: Centering "well-being" and sustainability in economic policy

Moving beyond green growth, several alternative economic movements seek to prioritize well-being and sustainability over economic growth. The idea of a **well-being economy**, for example, challenges the traditional growth-centric model by advocating for other indicators of progress, such as happiness and life satisfaction, in addition to economic measures (Box 2). It seeks to redefine success in terms of the overall improvement in quality of life for all people, rather than the accumulation of wealth and material goods. In practice, proponents of the well-being economy argue for policies that support sustainable consumption and production, invest in social infrastructure (like public healthcare and education) and social enterprises, and prioritize environmental protection and restoration. Growth is not the primary focus, and some advocates argue that economic growth should not be pursued at all (Hayden 2024). Countries and other jurisdictions exploring this approach often pilot new metrics to assess well-being beyond GDP, aiming to capture broader societal outcomes and inform policymaking that better reflects the needs and values of their populations. The concept of well-being is also embedded in Oregon's *2050 Vision for Materials Management* (Oregon Department of Environmental Quality 2012), which aspires to a future where all Oregonians produce and use materials responsibly—conserving resources, protecting the environment, and living well.

Box 2. Definitions of human well-being

As the green growth model recognizes, metrics beyond GDP can provide insight into how well an economy is doing in a more holistic way—by focusing on well-being. There is no single agreed-upon definition of human well-being, and academic literature provides many perspectives on what it should encompass, such as minimum income requirements and establishing poverty lines (Jolliffe et al. 2022; Ravallion et al. 2009; World Bank 1990), meeting basic needs (Doyal and Gough 1991; Max-Neef et al. 1991; Rawls 1999; Reinert 2011), respecting human dignity and individual capabilities (Nussbaum 2000; Sen 1987), and ensuring decent living standards (Lettenmeier et al. 2014; Rao and Baer 2012; Rao and Min 2018).

Beyond the *minimum* essentials for human well-being, some literature explores *maximum* requirements, including ideas of "sufficiency" that consider what is adequate or satisfactory for a good quality of life (Hayden 2019; Jungell-Michelsson and Heikkurinen 2022). Sufficiency implies striking a balance between consumption and sustainability.

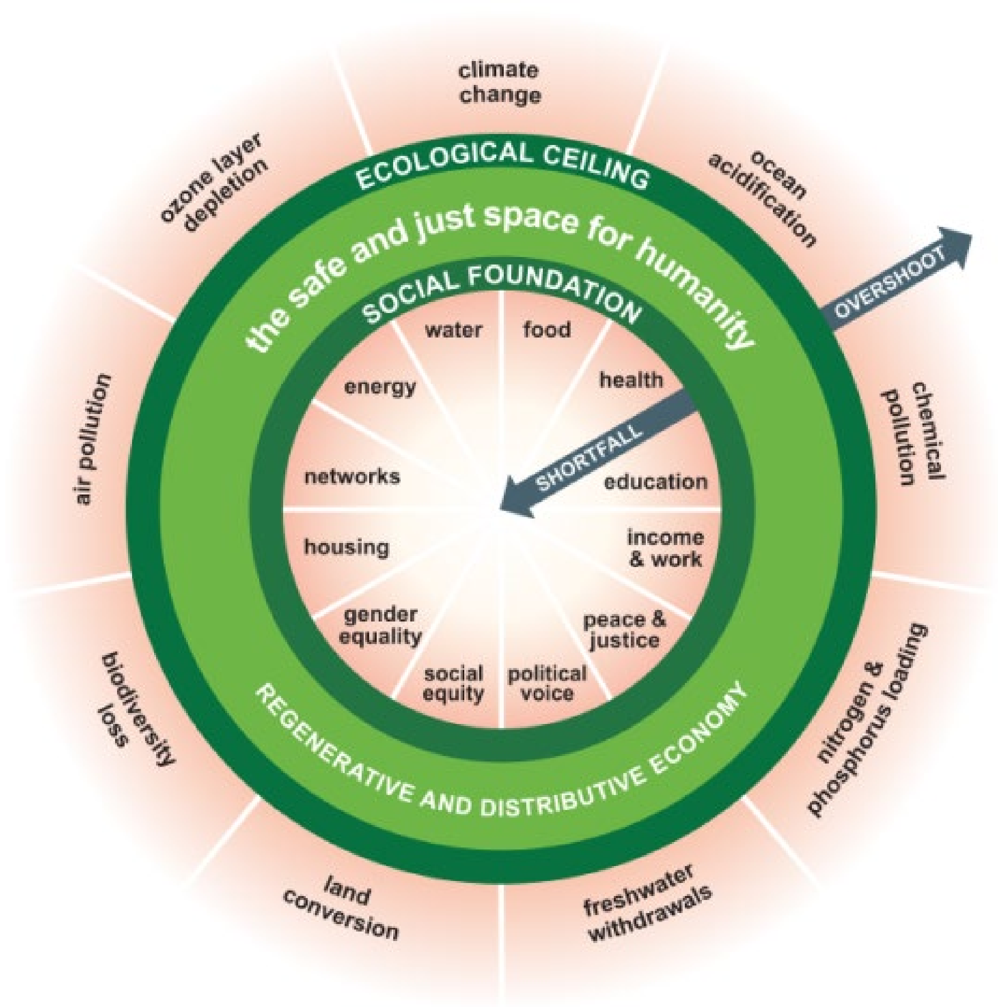
Two other prominent frameworks that challenge conventional economic paradigms are "degrowth" and "doughnut economics." **Degrowth is a growing alternative economic movement that** advocates for a deliberate reduction in economic activity and consumption, particularly in high-income countries. **It questions** the assumption that continuous economic growth is necessary for human well-being**,** arguing that growth is often prioritized above social and environmental needs. Degrowth scrutinizes the prevailing development model, which encourages the Global South to export large quantities of energy and materials to the Global North (Hickel et al. 2022). Central to degrowth is the principle of sufficiency, which emphasizes meeting basic needs while reducing overconsumption. Degrowth promotes lower overall consumption through sharing, reciprocity, and redistribution within a smaller "right-sized" market (Parrique 2019). Relatedly, it promotes localization of economies to enhance community resilience and reduce environmental impacts by minimizing dependence on global supply chains. Degrowth is considered a transition pathway toward a "steady state economy" (e.g., Daly 1991; Kerschner 2010), where resource use is stabilized.

From a climate policy perspective, one criticism of degrowth is that it does not explicitly address greenhouse gas emissions. Instead, degrowth tackles climate change and environmental issues indirectly by working toward a fairer distribution of wealth and resources through a **process of "**disaccumulation," "decommodification," and "decolonization," particularly by the Global North

(Hickel 2021). Beneficial climate outcomes are a consequence of this transition but not its primary objective.

By contrast, **doughnut economics**, developed by economist Kate Raworth, reimagines the economy as one that meets both human and ecological needs (Raworth 2017). In this theory, the economy is depicted schematically by a doughnut-shaped diagram, where the inner ring represents essential social needs such as food, water, healthcare, and education, and the outer ring denotes ecological limits encompassing climate change, biodiversity loss, and pollution (Rockström et al. 2009; Steffen et al. 2015a)—see Figure 5-3. The goal of doughnut economics is to stay within the two rings (inside the "doughnut"), which is a "safe and just space for humanity'" (Raworth 2017, p.38). Doughnut economics is agnostic to growth, although it critiques GDP as a narrow measure of progress and advocates for new metrics.

Figure 5-3: The doughnut of social and planetary boundaries (Raworth 2017)



Raworth (2017) identified five factors for a safe and just space for humanity: population stabilization, redistribution of resources, greater connection and deeper relationships with other humans (such as through arts, culture, and care work) instead of focusing on material possessions, technological innovation, and good governance across all scales. Doughnut economics also promotes a shift away from for-profit businesses toward nonprofits and distributed ownership structures by adopting a system that is "distributive by design." Similar to green growth, doughnut economics prioritizes resource efficiency and circularity, striving for a 98% resource efficiency rate—a target that some scholars believe is not technically feasible (Spash 2020). However, Raworth (2017) proposes that combining circularity and "dematerialism" (i.e., reducing or minimizing material possessions and consumption) could serve to maintain resource use within planetary boundaries.

5.2.4. Ensuring just and equitable transitions

Transformative change is necessary if the world is to meet global climate targets. However, for transitions in production and consumption to be successful, they must also be just and equitable. One criticism of consumption-focused climate policy is that it can overlook inequality and how the effects of policies are mediated by income (Seyfang and Paavola 2008). Socio-economic inequality is deeply embedded in consumption patterns, and some individuals are better placed to make changes than others. Globally, for example, consumption by the world's richest 10% contributes to 50% of global GHG emissions (Oxfam 2015). Multiple studies have emphasized this unequal distribution (Chancel 2022; Kartha et al. 2020), and both academics and policymakers have begun to foreground equity considerations when pursuing consumption-based climate policies (Gough 2017; Dawkins et al. 2023).

Wealth inequality is not just a global phenomenon. A recent study in Sweden, for example, found wide variation in consumption-based emissions from different socio-economic groups (Dawkins et al. 2023), and Oregon's consumption-based greenhouse gas inventory suggests similar disparities (Oregon Department of Environmental Quality 2024, fig.'3-5'). The risks and vulnerabilities that individuals and groups face in making a carbon transition vary considerably, and it is thus essential to design policies that protect poorer groups from adverse impacts and that support them in making changes (Green 2018). Efforts to decarbonize the built environment, for example, should be pursued in conjunction with measures to safeguard housing affordability; transportation policies should account for the different needs of urban and rural populations; and individuals in industries negatively affected by the sustainability transition (such as the fossil fuel industry) should be retrained or adequately compensated. While these measures could be viewed as a matter of basic fairness, it is also essential for success—perceptions of fairness play a key role in how policies are received and supported (Bergquist et al. 2021; Bergquist et al. 2020).

5.2.5. *What Oregon can do: Policies to promote sustainable consumption, well-being, and equity*

Oregon has multiple policy options for directly targeting consumption-based emissions, including public awareness campaigns, taxes and subsidies, regulations and standards, public investments in infrastructure, government procurement policies, and more. While these types of policies can drive important shifts in consumption, fully closing the "emissions gap" and achieving sustainable levels of emissions may require new economic paradigms. Oregon cannot go it alone; reorienting the economy toward well-being and sustainable consumption will require coordinated efforts at multiple scales and across geographies. However, there are steps that Oregon can take to start moving in this direction. Drawing upon ideas from the alternative economic frameworks discussed in the previous section, the following options could be explored.

5.2.5.1. Promoting structural change

To promote structural economic change that enables more sustainable consumption, Oregon could:

- **Align economic development with climate and sustainability plans.** Considering the strong link between the economic system and sustainable consumption, it is important for any economic development plans formulated within Oregon to be harmonized and aligned with one another. For example, Oregon's Equitable Economic Recovery Plan from 2022 does not mention climate or environment.
- **Redesign economic measurement.** Oregon could explore alternative indicators to GDP to measure well-being, such as the Genuine Progress Indicator (GPI) or the European Union's proposed GDP+3 metrics, which incorporate social and environmental factors. Tracking well-being-related indicators can help to prioritize well-being over (or in addition to) economic growth.
- **Invest in public services, cultural activities, and the care economy.** Oregon can prioritize investment in public services, such as education, healthcare, and public infrastructure, along with arts and cultural activities to enhance quality of life without relying on increased consumption and production. This aligns closely with the doughnut economics recommendation for dematerialism as well as degrowth's aspiration for greater conviviality.
- **Balance work and leisure time.** Multiple studies have documented the ecological benefits of achieving a greater balance between work and leisure time (Larsson et al. 2022; Knight et al. 2013). While policies to promote 32-hour work weeks, for example, would need careful design, they could be part of a larger shift toward a well-being centered economy.

- **Adopt cross-cutting policies to reduce production and consumption emissions.** Achieving deep reductions in emissions will require shifts in both production and consumption. Some of the most effective policies are those that alter both. The clearest candidate would be carbon pricing (e.g., fee-and-dividend or cap-and-invest policies) that provide financial incentives both to produce less carbon intensively and to consume lower-carbon goods and services. By internalizing some of the historically externalized social damages caused by climate change, carbon pricing can also lead to changes in supply and demand that would improve overall social outcomes. Combined with product disclosure requirements, such approaches could also be applied to embodied emissions, helping drive transformative change within and outside the state.
- **Address structural drivers of consumption.** To achieve sustained changes in consumption, the economy will need to change structurally so that "the right choice" (from a climate perspective) is also the "easy choice." Areas of focus could include:
    - **Urban form and the built environment.** Smart growth policies that encourage mixed-use, accessible neighborhoods, enhance the utilization of existing buildings, reclaim public spaces, and promote more compact urban forms could reduce embodied emissions in housing and infrastructure, make it easier for households to reduce their reliance on cars, and encourage broader shifts in consumption.
    - **Product standards.** Producer responsibility regulations can drive adoption of low-carbon products and services regardless of where they are produced (see policy options identified in section 3.2), thereby driving larger changes in product designs, supply chains, and production systems.
- **Support sustainable businesses and community organizations.** Several alternative economic frameworks propose the creation of community-based and sustainability-focused enterprises. Oregon can provide incentives and support for businesses, particularly nonprofits, B-Corps, and community organizations that prioritize sustainability and community well-being over maximizing profits and growth.
- **Promote and guide low-carbon, high-quality manufacturing and service industries in Oregon.** For Oregonians to choose lower-emitting, more sustainable consumption options, those options need to be available. Oregon could support and incentivize businesses that produce low-carbon food, goods, materials, and services, making these options available both in and out of state—and positioning the state as a leader in the shift to a low-carbon economy more generally.

Individually, any of the options mentioned above will have a limited impact on creating structural changes to the economy. However, when combined, they can shift Oregon to a place where greater structural changes become possible.

5.2.5.2. Ensuring equity

While these approaches could all contribute to shifts in sustainable production and consumption, they need to be pursued in ways that ensure a just transition and protect poor and marginalized households from adverse impacts. To do this, the following principles could inform policy development:

- **Reduce inequality, address poverty, and limit excessive wealth.** Both degrowth and doughnut economics advocate for the improved redistribution of wealth and resources to reduce inequality. Given the highly unequal distribution of emissions between low- and high-income households in Oregon (Oregon Department of Environmental Quality 2024), a differentiated response is needed when addressing consumption-based emissions. This could include ensuring lower-income households can meet decent living standards, while higher-income households reduce consumption. Targeting excessive wealth—for example, through progressive taxation (in line with degrowth's "steady state paradigm")—also has the potential to reduce inequality.
- **Ensure inclusive, consultative policy processes.** To design effective and fair policies, it is crucial to involve those most affected by their implementation and the changes they promote. Relevant groups should be identified, and special attention should be paid to those most likely to suffer losses from carbon transitions. Then a process for consulting and engaging with these constituencies should be designed to ensure policies are both effective and minimize losses. Promoting and facilitating coalitions of actors and groups with shared interests in the impacts of decarbonization can serve to ensure the political feasibility of policies that address consumption-based transitions (Green 2018).
- **Pursue both short-term support measures for disproportionately affected populations, along with long-term transition assistance.** To support those most vulnerable to consumption transitions, a variety of short-term policy options are available, such as cash transfers or tax reductions. Policymakers should also consider the scope of transitional assistance that may be required in support of those who stand to lose from structural change. Financial compensation is one form of assistance but other interventions such as re-training or re-employment programs can target specific groups who face job losses (Green 2018).
- **Tailor policies based on differences in impact.** Dawkins et al. (2023) focus their analysis of equity risks and impacts on the transport and food sectors, as they argue these sectors have the largest carbon footprints for consumption and the most significant equity implications. To keep equity as a central focus, they suggest that policy analysis begin with assessing the carbon footprints of different societal groups. For some sectors, such as food, the differences between lifestyle groups were not significant, so a policy approach did not need to be tailored to socio-economic differences in the same way that other sectoral interventions might. The same is not true for transportation, where poorer households living in less densely populated rural areas may find it challenging or impossible to access public transportation or afford alternatives to gas-powered vehicles.

5.2.6. Conclusion

When it comes to mitigating climate change and achieving a sustainable economy in Oregon, what and how much we consume is as important as how goods and services are produced. Focusing on consumption is necessary to avoid carbon tunnel vision, stay within planetary boundaries and avoid the risky and unproven assumption that technology alone can meet decarbonization goals. Achieving sustainable levels of consumption, however, requires addressing economic structures that emphasize growth over other metrics of well-being and sustainability and that make it difficult for consumers to adopt sustainable lifestyles. To close the gap between Oregon's current consumption-based emissions and a per capita footprint aligned with global carbon budgets by 2050, transformative steps will be required. As described in this paper, economic models that look beyond GDP growth, such as the well-being economy, degrowth and doughnut economics, offer a vision for what sustainable and equitable economies could look like. Realizing such a vision will require coordinated efforts within Oregon and beyond. In the meantime, Oregon can take steps today to help advance the development of a low-carbon economy that prioritizes well-being and equity.

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