# Paying for Oregon's Future:

## Costs Climate Change Will Impose on Oregon's Households

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Natural Resource Economics

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# Foreword

The Intergovernmental Panel on Climate Change (IPCC) and other scientific bodies have documented the effects of human-caused emissions of carbon dioxide and other greenhouse gases (GHGs). These effects include changes in climate—increasing average temperature, more extreme weather events, rising sea level, and ocean acidification—as well as resultant changes in ecosystems, species, human systems, and other aspects of life on Earth. They also have forecasted future emissions and their impacts under different scenarios that reflect different assumptions about the extent to which humans rein-in the behaviors underlying the emissions.

This report describes the potential economic costs that Oregon's households, businesses, communities, and governments will incur in the near future—perhaps in the year ahead, perhaps not until mid-century—if they and their counterparts around the world continue to behave in a business-as-usual manner, so that the emissions of carbon dioxide and other greenhouse gases would continue to grow at rates similar to those seen in recent years.

Ernie Niemi prepared this report for Natural Resource Economics, a consultancy in Eugene, Oregon USA, which remains solely responsible for its contents. The report draws extensively from his earlier efforts to describe the costs climate change will impose on households and communities. In particular, it draws on the work of a team of economists, which he directed, that, in 2009, developed the first detailed estimates of potential climate-related costs for Oregon, Washington, and New Mexico. It also draws on his assessment, which he prepared in 2015 on behalf of Lebanon's Ministry of Environment and the United Nations Development Programme, that describes the costs climate change potentially will impose on Lebanon.

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# Acronyms

| | |
|---|---|
| GHG | Greenhouse Gas |
| GDP | Gross Domestic Product |
| IPCC | Intergovernmental Panel on Climate Change |
| IWG | Interagency Working Group on the Social Cost of Carbon Dioxide |
| RCP | Representative Concentration Pathway |

# I. Introduction and Summary

This report describes the potential costs that changes in climate will impose on Oregon's households sometime in the near future. It first takes a bottom-up approach that sums values for seven categories of costs that will materialize in the near future:

1. Increases in food prices
2. Loss of income from climate-related slowdown in economic activity
3. Non-federal costs from climate-related increases in wildfires
4. Increases in exposure to smoke from climate-related wildfires
5. Increases in human deaths from climate-related increases in summer temperatures
6. Decreases in salmon populations
7. Reductions in federal services available to Oregon's households

The report also uses a top-down approach by estimating Oregon's share of the climate-related costs that will result from global emissions in 2020 and 2040.

These are the report's core findings:

A. If recent trends in GHG emissions continue unabated, the seven categories of climate-related costs will grow until, sometime in the near future, they impose additional costs, relative to today, totaling about $15,000 per household per year. Some costs, like those from exposure to climate-related wildfire smoke, could materialize immediately, but others, such as increases in food prices will take longer to materialize.

B. The costs from future GHG emissions will grow rapidly if recent trends in GHG emissions continue unabated. Global emissions in 2020 will impose costs of $6 billion on Oregonians, but 2040's emissions will impose costs of $21 billion, 3.5 times as large.

C. Quick action to curtail future emissions to levels necessary to hold mean global warming to no more than 2°C could reduce the cost from 2040's emissions by 60 percent.

The cost estimates in this report stem from arithmetic extrapolations of the results from research and analyses generally intended for purposes other than calculating the economic costs climate change will impose on Oregonians. Hence, they should be interpreted as indicative of the order of magnitude of costs that will occur sometime in the near future, if GHG emissions are not meaningfully curtailed.

# II. Bottom-Up Approach: Seven Categories of Costs Climate Change Will Impose on Oregon in the Near Future

This section describes seven categories of costs climate change will impose on Oregonians in the near future. The evidence presented in this section demonstrates:

A. Sufficient information exists to describe seven categories of costs that climate change will impose on Oregon's households sometime in the near future:
    1. Increases in food prices
    2. Loss of income from climate-related slowdown in economic activity
    3. Non-federal costs from climate-related increases in wildfires
    4. Increases in exposure to smoke from climate-related wildfires
    5. Increases in human deaths from climate-related increases in summer temperatures
    6. Decreases in salmon populations
    7. Reductions in federal services available to Oregon's households

B. Climate change has already begun to impose these costs on Oregon's households, but currently available information is not sufficient to quantify them.

C. If recent trends in GHG emissions continue, these seven categories of climate-related costs will grow until, sometime in the near future, they impose additional costs, relative to today, totaling about $15,000 per household per year.

D. Insufficient information exists to estimate many other categories of climate-related costs. Consequently, the actual total costs climate change imposes on Oregon's households in the near future likely will be even higher.

## A. Costs to Oregon's households from climate-related increases in food prices

Anticipated changes in global climate are expected to reduce world food supplies and increase food prices. Reductions in production would occur in response to increases in ambient temperatures, changes in annual and seasonal precipitation, and increases in extreme weather events, and other climate-related effects. Higher temperatures would generally reduce growth rates for livestock, and for all crops experiencing more than 3°C of local warming, although some crops might show variation in effects from lower temperature increases.[1] The resulting increases in world food prices would materialize in Oregon, increasing costs for Oregon's households.

Researchers recently concluded that, if recent trends in GHG emissions continue, food prices will likely rise by 15 – 20 percent in the near future, but the higher prices would induce consumers to reduce their purchases by 3 percent.[2] The Bureau of labor statistics has estimated that Americans currently spend about $7,200 per year per household on food.[3] These numbers reveal the potential additional amount Oregon's household will pay for food in the near future. Table 1 shows the results.

**Table 1. Potential annual cost per Oregon household from climate-related increases in food costs**

| | Potential additional cost in the near future[a] |
|---|---|
| Climate-related increases in food prices | $1,000 – $1,400 |

[a] Additional costs relative to today, expressed as equivalent dollar estimates in today's economy. Numbers rounded.

[1] Porter, J.R., L. Xie, A.J. Challinor, K. Cochrane, S.M. Howden, M.M. Iqbal, D.B. Lobell, and M.I. Travasso. 2014. "Food Security and Food Production Systems." In: *IPCC–Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*.

[2] Wiebe, Keith, Hermann Lotze-Campen, Ronald Sand, Andrzej Tabeau, Dominique van der Mensbrugghe, Anne Biewald, Benjamin Bodirsky, Shahnila Islam, Aikaterini Kavallari, Daniel Mason-D'Croz, Christoph Müller, Alexander Popp, Richard Robertson, Sherman Robinson, Hans van Meijl, and Dirk Willenbockel. 2015 . "Climate change impacts on agriculture in 2050 under a range of plausible socioeconomic and emissions scenarios." *Environmental Research Letters;* and Nelson, Gerald C., Hugo Valin, Ronald D. Sands, Petr Havlík, Helal Ahammad, Delphine Deryng, Joshua Elliott, Shinichiro Fujimori, Tomoko Hasegawa, Edwina Heyhoe, Page Kyle, Martin Von Lampe, Hermann Lotze-Campen, Daniel Mason d'Croz, Hans van Meijl, Dominique van der Mensbrugghe, Christoph Müller, Alexander Popp, Richard Robertson, Sherman Robinson, Erwin Schmid, Christoph Schmitz, Andrzej Tabeau, and Dirk Willenbocke, 2014. "Climate change effects on agriculture: Economic responses to biophysical shocks." *Proceedings of the National Academy of Sciences*.

[3] Bureau of Labor Statistics. 2017. "Consumer Expenditures—2016."

## B. Costs to Oregon's households from climate-related loss of income

Climate-related storms, diseases, heat waves, etc. can slow economic growth, reducing both the output of goods and services, known as gross domestic product (GDP), and household income derived from GDP. This slowing can occur directly in the U.S., as these events occur here. It also can occur indirectly, as climate-related slower economic growth in other countries has side-effects on the U.S. economy.[4]

Section II.G, below, employs the results of an analysis by the Office of Management and Budget (OMB) to show that found climate-related slowing of GDP growth in the near future will reduce federal revenues by about $500 – $900 per household per year. The slowdown in GDP also will result in lower household incomes than would occur absent the climate change. In recent years, federal receipts have been about 17 percent of national GDP.[5] If this percentage remains unchanged, the potential additional climate-related reduction GDP per household, relative to reductions that have already occurred, will roughly equal $500 – $900 divided by 17 percent. In Oregon, personal income is about 80 percent of the state's GDP.[6] These numbers suggest that the potential additional loss per household in 2040, relative to today, roughly equals 80 percent of the additional reduction in GDP per household. Table 2 shows the results.

**Table 2. Potential loss of annual income per Oregon household from climate-related slowdowns in GDP growth**

| | Potential additional cost in the near future[a] |
|---|---|
| Lost income from climate-related slowing of GDP | $2,400 – $4,200 |

[a] Additional costs relative to today, expressed as equivalent dollar estimates in today's economy. Numbers rounded.

[4] Recent research, for example, found that river-flooding in China has a greater negative effect on the U.S. economy than river-flooding in the U.S. Willner, Sven Norman, Christian Otto, and Anders Levermann. 2018. "Global Economic Response to Rover Floods."

[5] Reduction in federal revenue: Office of Management and Budget. 2016. *Climate Change: The Fiscal Risks Facing the Federal Government*. Federal receipts as percent of GDP: Federal Reserve Bank of St. Louis. 2018.

[6] Economic data for personal income as percent of GDP (Oregon): Federal Reserve Bank of St. Louis. 2018.

## C. Non-federal costs to Oregon's households from climate-related wildfires

In 2017, the (federal, state, and local) costs of suppressing wildfires in Oregon totaled $454 million.[7] Recent research suggests, though, that fire-suppression activities constitute only about 9 percent of the total costs of wildfires.[8] The full complement of costs includes:

| | |
|---|---|
| Total costs | 100% |
| ○ Suppression costs, federal | 8% |
| ○ Suppression costs, state/local | 1% |
| ○ Home and property loss | 21% |
| ○ Immediate road & landscape stabilization | 3% |
| ○ Aid relief & evacuation | 2% |
| ○ Degraded ecosystem services | 34% |
| ○ Energy & infrastructure | 4% |
| ○ Long-term landscape rehabilitation | 16% |
| ○ Tax, business, natural resource loss | 2% |
| ○ Human casualties | 1% |
| ○ Other | 0.1% |

In a summary of relevant scientific research, the Oregon Climate Change Research Institute anticipates that future climate change will increase both the number of fires and the acreage burned by wildfires in Oregon.[9] For Oregon west of the crest of the Cascades, models indicate the average number of years between fires at a given location will decrease by almost one-half in this century and the acreage burned will increase by about 40 percent. OMB, citing the Forest Service, anticipates acreage burned will double over the next few years. More recent events and research suggest increases in fires may occur even more rapidly.

These numbers form the basis for illustrating the additional costs in the near future, relative to costs already incurred, of climate-related wildfires in Oregon. Assume that federal/state/local fire-suppression costs of $454 million are 9 percent of the total costs, so that the total costs per year currently are about $5 billion. Subtracting the federal portion of these costs, described below, leaves about $4.6 billion of other costs. If costs correlate with acres burned, then these costs will increase 40–100 percent in the near future, or $1.8–$4.6 billion. Dividing by Oregon's 1.55 million households reveals the additional cost of future climate-related wildfires, relative to today.

Table 3 shows the results. These costs do not include the costs from exposure to wildfire smoke, which are described in the next section.

**Table 3. Potential annual cost (other than federal suppression costs) per Oregon household from climate-related increases in wildfires**

| | Potential additional cost in the near future[a] |
|---|---|
| Suppression and other costs from climate-related wildfires | $1,200 – $3,000 |

[a] Additional costs relative to today, expressed as equivalent dollar estimates in today's economy. Numbers rounded.

[7] Urness, Zach. 2018. "Oregon wildfire costs up to $454 million in 2017." *Seattle Times.*
[8] Headwaters Economics. 2018. *Full Community Costs of Wildfire.*
[9] Oregon Climate Change Research Institute. 2017. *The Third Oregon Climate Assessment Report.* January.

## D. Costs to Oregon's households from exposure to climate-related wildfire smoke

The wildfire-related costs discussed in the preceding section do not include costs associated with smoke from climate-related wildfires. Most of Oregon's communities have recently experienced intrusions of smoke from wildfires near and far. We're likely to see a lot more in the future. Oregon's leading climate scientists report that climate change is making summers longer, hotter, and drier, creating ideal conditions for more fires to burn more acres and produce more smoke.

Smoky days are not just inconvenient, they're expensive. Low levels can negatively affect the health of some. At high levels, everybody can have difficulty breathing. Some people require hospitalization, some people die. In addition, the smoke disrupts the economy and diminishes non-health aspects of our quality of life.

Economists have estimated that the costs from exposure to dense wildfire smoke can total about $370 per adult per day.[10] The cost for a household with two adults is $740 per day. Smoke intrusions can last several days, and, to illustrate their economic importance, this report assumes that climate-related wildfires will, sometime in the near future, expose Oregonians on seven days per year to levels of smoke considered unhealthy for sensitive groups. These numbers provide the basis for estimating the cost Oregon's households will incur, sometime in the near future, when they are exposed to a 7-day smoke intrusion from climate-related wildfires. Table 4 shows the results.

**Table 4. Potential annual cost per Oregon household from exposure to smoke from climate-related increases in wildfires**

| | Potential additional cost in the near future[a] |
|---|---|
| Health and other costs from 7-day exposure to smoke from climate-related wildfires | $5,200 |

[a] Additional costs relative to today, expressed as equivalent dollar estimates in today's economy. Numbers rounded.

[10] Jones, Benjamin A. 2017. "Willingness To pay Estimates for Wildfire Smoke Health Impacts in the US Using the Life Satisfaction Approach."

## E. Costs to Oregon's households associated with premature human deaths resulting from climate-related increases in summer temperatures

Climate-related increases in summer temperatures can make most people uncomfortable and many people sick. Some will die. This section describes the potential costs per household associated with the increases, relative to 1990, in premature deaths attributable to summer heat.

With "moderate" increases in GHG emissions, scientists estimate that climate-related summer heat will cause 8–13 persons in Lane County to die prematurely per year by 2030, relative to 1990, and these numbers will grow to 12–22 per year by 2050.[11] These numbers, together with estimates for the counties containing Portland, Medford, and Klamath Falls (62 percent of the state's total population)[12] suggest that, for the state as a whole, climate-related heat will kill an additional 119–163 Oregonians per year by 2030, relative to 1990, and an additional 166–250 Oregonians per year by 2050.

This report focuses on describing the potential costs to Oregon's households assuming that GHG emissions will rise not at the "moderate" pace that underlies these estimates of potential increases in heat-related deaths but, rather, rise more rapidly as recent trends in GHG emissions continue.[13] Consequently, to illustrate the potential risk to Oregon's households, this report uses the upper numbers for these two ranges, 163–250 additional deaths per year, sometime in the near future.[14]

It would be inappropriate to attempt to estimate the economic cost associated with the individual persons who will die prematurely because of climate-related heat. Economists have, however, estimated the costs associated with an increase, across society as a whole, in the risk of death. A "large and robust" literature on the economic value of an increased risk of death, across society as a whole, indicates this cost is about $10 million per potential death.[15] This cost, multiplied times the risk that climate-related heat will cause 163-250 premature deaths, yields the total costs to Oregon's households. Dividing by the number of Oregon households, 1.55 million yields the cost per household per year. Table 5 shows the results.

**Table 5. Potential annual cost per Oregon household associated with increased risk of premature death from climate-related increases in summer temperatures**

| | Potential additional cost in the near future[a] |
|---|---|
| Premature deaths of an additional 163–250 Oregonians from climate-related heat | $1,000 – $1,600 |

[a] Additional costs relative to today, expressed as equivalent dollar estimates in today's economy. Numbers rounded.

[11] Oregon Climate Change Research Institute. 2017. Refer to Schwartz et al., 2015.
[12] Population Research Center, Portland State University. 2018. Population Estimates for Oregon and Counties: 2017
[13] In general, continuation of recent trends in emissions corresponds to the IPCC's highest scenario, or Representative Concentration Pathway, RCP8.5.
[14] Recent events and research warrant using the upper numbers for the two ranges. Earlier this year the IPCC warned that temperature is on track to exceed the temperature target predicted for 2040. A recent research summary concludes that scientists probably have underestimated the risks of warming. A new analysis attributes this year's heatwave in northern Europe to climate change. Similar studies have attributed last year's heatwaves in Europe and Australia to climate change. Michael Mann has called these attribution studies "inherently conservative" indicating it is reasonable to anticipate that the actual effect of climate change on heatwaves will be higher than previously anticipated.
[15] Oregon Health Authority. 2014. "Climate Smart Strategy: Heath Impact Assessment."

## F. Costs to Oregon's households from climate-related reductions in salmon populations

By diminishing the amount and quality of suitable habitat, climate change is reducing Oregon's salmon populations. Longer, warmer summers raise the temperature of water in Oregon's streams and, for many, reduce the flow in summer. These changes degrade and reduce the high-quality, low-temperature habitat that salmon require.

Recent research from EPA confirms the threat climate change poses for Oregon's salmon populations. Figure 1 illustrates the findings, with one map showing that, absent climate change, nearly all of the state has the capability to produce water required by salmon and other cold-water species, and another that shows changes in climate will eliminate this capability over most of the state by the end of the century.

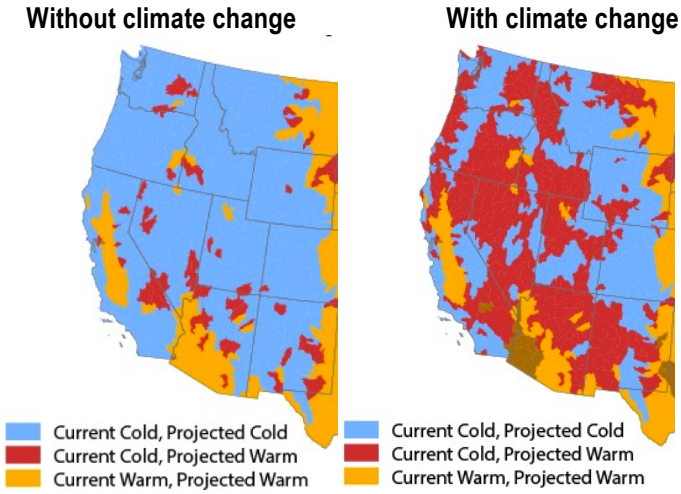


**Figure 1. Climate change will eliminate habitat required by salmon and other cold-water fish by the end of this century**

Declining salmon populations harm Oregonians in many different ways. These include, but are not limited to: harm to tribes and other groups for whom salmon have cultural value, reductions in commercial and recreational fishing, and injury to those who want to ensure that this generation passes healthy salmon populations to future generations. The 2009 analysis of climate-related costs to Oregonians estimated that the value of the harm to all Oregonians from climate-related declines in salmon populations in the near future is about $0.7 – $1.0 billion per year. This range, divided by the number of Oregon households, 1.55 million, yields the potential costs per household. Table 6 shows the results.

**Table 6. Potential annual cost per Oregon household from climate-related reductions in salmon populations**

| | Potential additional cost in the near future[a] |
|---|---|
| Reductions in salmon populations from climate-related degradation of habitat | $500 – $700 |

[a] Additional costs relative to today, expressed as equivalent dollar estimates in today's economy. Numbers rounded.

## G. Costs to Oregon's households from climate-related reductions in the availability of federal services

Climate change is already imposing costs on communities, families, and individuals throughout the U.S. Some of these costs are borne by the federal government, which, as a consequence, has less to spend on providing non-climate services to citizens. A search of the relevant literature did not locate a reliable estimate of the magnitude of these costs today or in recent years. But, the Office of Management and Budget (OMB) has illustrated two types of potential reductions in federal services that will occur sometime in the near future.

One involves reductions in federal revenues resulting from climate-related reductions in economic activity. Federal revenues decline when climate-related events, such as extreme storms, heat waves, and rising sea levels, reduce the value of the nation's production of goods and services, or gross domestic product (GDP). A slowdown in the growth of GDP reduces GDP-related revenues, such as income taxes, and results in a corresponding decline in the federal government's ability to provide Oregon's households with health care for veterans, recreational opportunities at national parks, and other services with discretionary budgets. OMB has not estimated the lost revenues occurring currently, but, using a range of plausible assumptions, it has illustrated the potential increase in lost revenues for the middle of this century. If changes in climate should depress GDP more severely than anticipated, the reductions in federal revenues and services would materialize sooner.

Oregon's households also will be harmed when federal agencies responding to future climate-related events, such as increases in wildfires, heat, and storms, divert funding from services unrelated to climate and reduce the supply of those services available to Oregonians. OMB has not estimated these climate-related expenses, but it has illustrated the additional expenses, relative to today, likely to materialize sometime in the next 2-to-4 decades. Its analysis focuses on funding consumed by just three categories of climate-related activities: suppression of climate-related increases in wildfire, healthcare for individuals adversely affected by climate-related degradation of air quality, and relief for climate-related coastal disasters.

Table 7 summarizes the OMB's findings. The top row shows the potential increase in cost per household in 2040, relative to today, from the climate-related slowdown in GDP growth. The bottom row shows the potential increase in cost per household in 2040, relative to today, from federal expenditures on climate-related increases in wildfires, air-quality-related healthcare, and coastal disasters.

**Table 7. Additional annual costs per Oregon household from climate-related reductions in federal non-climate services**

| | Potential additional cost in the near future[a] |
|---|---|
| Reductions in revenues from climate impacts on GDP | $500–$900 |
| Increased federal climate costs: wildfire suppression, healthcare for individuals harmed by degradation of air quality, coastal disasters | $100 |
| **Total reductions in availability of federal, non-climate services** | **$600 – 1,000** |

Reduction in federal revenue and increase in climate-related expenditures: Office of Management and Budget. 2016. *Climate Change: The Fiscal Risks Facing the Federal Government*. Number of households: Bureau of the Census. 2018. QuickFacts: Oregon and United States.

[a] Additional costs relative to today, expressed as equivalent dollar estimates in today's economy. Numbers rounded.

## G. Summary

Currently available information supports the description of seven categories of costs that climate change will impose on Oregon's households in the near future. Table 8 summarizes the potential additional amounts, relative to today. The numbers indicate that, sometime in the near future, these seven climate-related costs will total $12,000 – $17,000 per household per year. Or, for simplicity, the amount is about $15,000 per household per year.

**Table 8. Summary of potential, additional annual cost per Oregon household, relative to today, from climate change**

| | Potential additional cost in the near future[a] |
|---|---|
| Climate-related increases in food prices | $1,000 – $1,400 |
| Lost income from climate-related slowing of GDP | $2,400 – $4,200 |
| Suppression and other costs from climate-related wildfires | $1,200 – $3,000 |
| Health and other costs from 7-day exposure to smoke from climate-related wildfires | $5,200 |
| Premature deaths of an additional 163–250 Oregonians from climate-related heat | $1,000 – $1,600 |
| Reductions in salmon populations from climate-related degradation of habitat | $500 – $700 |
| Reductions in availability of federal, non-climate services | $600 – $1,000 |
| **Total** | **$12,000 – $17,000** |

[a] Additional costs relative to today, expressed as equivalent dollar estimates in today's economy. Numbers rounded.

Given the complexity and uncertainty of the relationships between the determinants of climate change and their economic impacts, it is impossible at this time to know exactly when these costs will materialize. Available evidence does, however, clearly indicate that the costs almost certainly will become real burdens for Oregon's households sometime before the middle of this century. Some, such as those associated with climate-related wildfires or heat waves, could materialize almost immediately. Others, such as reductions in salmon populations and increases in food prices, likely will emerge over time. Recent events and research, however, suggest that changes in climate are occurring more rapidly than anticipated earlier, increasing the likelihood that all seven of these costs will materialize before mid-century.

Insufficient information exists to estimate many other categories of climate-related costs. Consequently, the actual total costs climate change imposes on Oregon's households in the near future likely will be even higher. Table 9 lists some, but not all, of the cost categories omitted from this report.

**Table 9. Some of the categories of climate-related costs omitted from this report**

| |
|---|
| Direct, in-state impacts of more frequent and intense extreme storms, droughts, etc. |
| Increases in psycho-social trauma for individuals, families and communities |
| Changes in the productivity of Oregon's marine ecosystems |
| Changes in the productivity of Oregon's terrestrial ecosystems |
| Direct, in-state impacts of sea-level rise |
| Increased cooling costs for commercial and industrial businesses |
| Increased air conditioning and refrigeration |
| Degradation of infrastructure from higher temperatures |
| Increased variability in weather conditions |
| Heat stress and irrigation-water shortages for agricultural production |
| Increases in agricultural pests and diseases |
| Increased incidence of water- and food-borne diseases |
| Increased stress on threatened and endangered species |
| Accelerated spread of some undesirable invasive species |
| Increases in fish and wildlife diseases |
| Increased migration |
| Expanded range of tropical and sub-tropical diseases |
| Reduced opportunities for outdoor recreation |
| Reduced boating and other recreation opportunities due to decreased streamflows |
| Increases in violence and suicides stimulated by unusually high temperatures |

# III. Top-Down Approach: Costs to Oregon's Households from Global GHG Emissions in 2020 and 2040

This section describes an alternative way to calculate Oregon's share of the global economic harm resulting from global GHG emissions in 2020 and 2040. The preceding section estimated seven different categories of costs climate change will impose on Oregon's households in the near future and summed them. This section calculates the total, global costs from GHG emissions in 2020 and in 2040 and estimates Oregon's share of that total. The evidence presented below indicates:

A. Each metric ton of $CO_2$ emitted into the atmosphere will exacerbate climate change and impose economic costs on human society over several decades.

B. An Interagency Working Group of federal agencies has estimated the costs per metric ton of $CO_2$, called the social cost of carbon (SCC), but only for a subset of cost categories.

C. This partial SCC indicates that, if recent trends in GHG emissions continue unabated, the subset of social costs imposed on Oregonians from global GHG emissions in 2020 will equal $6 billion.

D. The harm from emissions in subsequent years will accelerate. For 2040's emissions, the subset of social costs to Oregonians will be at least $21 billion, or 3.5 times the costs for 2020's emissions.

E. Prompt, effective action to reduce global emissions can reduce the social costs, perhaps by 60 percent for 2040's emissions.

## A. The costs from 2040's GHG emissions will be at least 3.5-times the costs from 2020's Emissions

Each unit of carbon dioxide ($CO_2$) and other greenhouse gasses (GHGS) emitted into the atmosphere exacerbates climate change, a general term that embraces global warming, ocean acidification, extreme weather events, sea level rise, and changes in ecosystems and human systems. The social cost of carbon (SCC) measures the net global harm resulting from a small increase in atmospheric carbon dioxide or other GHGs. The SCC is usually expressed, for a given year, as the net global economic damage expected to result from a one metric-ton increase in atmospheric $CO_2$, or the equivalent for other GHGs ($tCO_2$-e). The "cost of carbon" part of the SCC is shorthand that reflects the importance of $CO_2$ relative to other GHGs. The "social cost" part recognizes that the costs from GHG emissions affect all of human society.

Economists widely use estimates of the SCC from the Obama administration's Interagency Working Group of U.S. agencies (IWG).[16] This effort focused on an important, but limited, subset of costs: the direct economic damage that would materialize as each year's emissions contribute, in subsequent years, to rising sea levels, extreme weather events, and other events that would damage infrastructure, destroy crops, impose heat stress on workers, etc. It lacked adequate information to address other important costs that could outweigh those included in the analysis. These include costs associated with ocean warming and acidification, the slowing of global economic growth due to storms and other disasters, the loss of biodiversity and impairment of ecosystems functions, psycho-social trauma to individuals and communities from climate-related disasters, potential increases in political instability and violence, and increases in human migration. In addition, the IWG did not look at the potentially catastrophic costs that could materialize if changes in climate changes reach so-called tipping points, where the response of geophysical, environmental, or human systems to GHG emissions becomes radically more extreme. Such a tipping point might materialize, for example, if ocean temperatures increase to levels that trigger abrupt mortality among the organisms that form coral reefs, or if changes in rainfall and temperature patterns trigger abrupt mortality among trees in the tropical or boreal forests.

The IWG found, for its subset of costs, that the SCC for 2020's GHG emissions, equals $71 (updated to 2016 dollars). That is, the emission of one metric ton of $CO_2$ in 2020 will cause damages in subsequent years that sum to $71 (Table 10).[17] The IWG expected the SCC will increase by about one-third over the next 20 years, to $95 for emissions in 2040. The increase in cost per ton occurs because, as atmospheric GHGs increase over time, they will have strongly nonlinear impacts on climate, oceans, ecosystems, and socioeconomic systems.

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[16] U.S. Environmental Protection Administration. 2015. EPA Fact Sheet: Social Cost of Carbon. http://www.epa.gov/climatechange/Downloads/EPAactivities/social-cost-carbon.pdf.

[17] In its calculations, the IWG looked at the potential emission of one $tCO_2$-e in a given year and then traced the potential net costs that would accrue in each subsequent year. It then converted this stream of annual net costs to an equivalent, single number, called the present value, using a process called discounting. The discounting process recognizes that most members of society generally assign a smaller value to the prospect of a harm in the future relative to an alternative in which the same harm would occur immediately. To complete the discounting process, the IWG used different percentages to measure the rate of discount. For its core analysis, it first used 3 percent, then used discount rates of 2.5 and 5 percent to examine the extent to which variation in the rate affects the calculations. Many economists, however, believe it is inappropriate to use a 5 percent discount rate, which greatly diminishes the importance of costs in future years. Indeed, roughly one-half of the economists responding to a survey said it would have been appropriate for the IWG to have used a discount rate smaller than 2.5% for its core analysis. In accord with this preference, this report assumes the estimates using a 2.5 percent discount rate best represent potential costs.

Calculating the total increase in the social costs from annual GHG emissions involves multiplying the cost per ton times the number of tons emitted. Table 10 shows that, if recent trends continue, GHG emissions in 2040 will grow from 25 to 66 billion tons $CO_2$-e.[18] costs generated by 2040's GHG emissions will be 3.5 times the costs generated by 2020's emissions.

**Table 10. The global social costs from anticipated GHG emissions in 2020 and 2040 if recent trends in emissions continue, focusing on the subset of costs identified by the Interagency Working Group**

| Year of Emissions | Partial SCC (per ton $CO_2$-e[a]) | Tons $CO_2$-e Emitted (billion) | Total Global Cost (trillion) |
|---|---|---|---|
| 2020 | $71 | 25 | $1.8 |
| 2040 | $95 | 66 | $6.3 |
| 2040 vs. 2020 | 134% | 260% | 350% |

Numbers rounded.

[a] Interagency Working Group on the Social Cost of Carbon Dioxide (U.S. Environmental Protection Administration 2015)

[b] Emissions of $CO_2$, $CH_4$, and $N_2O$ come from IPCC (2013a). Emissions of $CH_4$ and $N_2O$ converted to their $CO_2$ equivalent based on global warming potentials reported by Myhre et al. (2013).

[c] Global population estimate: World Bank. 2018 Population Estimates and Projections. https://datacatalog.worldbank.org/dataset/population-estimates-and-projections.

As noted above, the costs shown in Table 10 represent only a partial accounting of all the costs generated by GHG emissions. The actual costs—per ton emitted and the global total—likely will be much larger, especially for 2040, as future GHG emissions generate nonlinear changes in warming, climate, etc. The numbers are useful, nonetheless, because, by focusing on an unchanging subset of costs, they clearly illustrate that these nonlinearities will yield dramatic increases in costs. They also provide a foundation for an initial investigation of the potential costs GHG emissions and climate change impose on Oregonians.

[18] Continuation of recent trends in GHG emissions is represented by the IPCC's scenario, Representative Concentration Pathway 8.5 (RCP8.5). Emissions of $CO_2$, $CH_4$, and $N_2O$ come from IPCC (2013a). Emissions of $CH_4$ and $N_2O$ converted to their $CO_2$ equivalent based on global warming potentials reported by Myhre et al. (2013).

## B. Oregonians' share of this subset of global costs could be about $4,000 per household from 2020's GHG emissions, and $10,000 from 2040's emissions

It is impossible to know exactly how much of the global costs shown in Table 10 will materialize in Oregon. One plausible estimate, though, comes from assuming that Oregon's share will correspond to its share of the global economy, as indicated by its current share of the value of goods and services.[19] In 2017, the value of goods and services produced in Oregon, called its gross domestic product (GDP) was $236 billion, or about 0.32 percent of gross world product.[20] If this percentage holds constant, then it indicates that GHG emissions in 2020 and 2040 will impose costs on Oregon of $6 billion and $21 billion, respectfully. Table 11 shows these results. These costs translate into costs of about $4,000 per household for 2020's emissions and $10,000 for 2040's emissions.[21]

**Table 11. Oregon's share of the global social costs from anticipated GHG emissions in 2020 and 2040 if recent trends in emissions continue, focusing on the subset of costs identified by the Interagency Working Group**

| | 2020 | 2040 |
|---|---|---|
| Total Statewide | $6 bil. | $21 bil. |

Numbers rounded.

It is important to bear in mind that the numbers in Table 11 represent only the subset of costs considered by the Interagency Working Group on Social Cost of Carbon. This subset includes direct economic damage that would materialize as each year's emissions contribute, in subsequent years, to extreme weather events and other changes in climate that would destroy crops, impose heat stress on workers, etc. The Interagency Working Group did not consider all direct costs. It excluded costs likely to occur as increases in atmospheric GHGs result in warming and acidification of the oceans; threshold changes in ecosystems; extinctions of species; psycho-social trauma for individuals, families and communities from climate-related stress and disasters; tipping points in important natural processes, and many others.

[19] This assumption corresponds to the one used by OMB to calculate potential reductions in the national GDP and, hence, federal revenues from anticipated climate-related slowing of economic activity throughout the world.
[20] Oregon GDP: Bureau of Economic Analysis. 2018. "BEARFACTS: Oregon." Gross World Product: OECD. 2018. "GDP Long-Term Forecast."
[21] The cost per household does not increase as much as the total cost because the number of households also will increase. This report assumes Oregon will have 1.7 million households in 2020 and 2.0 million in 2040. These numbers come from projections of future population by the Oregon Office of Economic Analysis and the report assumes that the current household size, 2.5 persons, will remain unchanged.

## C. Oregonians could save $6,000 per household from 2040's emissions if global GHG emissions quickly slow to the IPCC's lowest emissions scenario

The estimates of potential costs described above generally correspond to the IPCC's scenario, called a Representative Concentration Pathway (RCP), that anticipates recent trends in GHG emissions will continue essentially unabated. This scenario, known as RCP8.5 sees global mean temperatures by the end of the century that are 3.5–4.5°C higher than historical levels, plus a substantial risk of even higher levels. Other RCPs describe the future with lower levels of GHG emissions. RCP2.6, the IPCC's lowest-emissions scenario, assumes that global annual GHG emissions reach their maximum before 2020 and decline substantially thereafter. Compliance with RCP2.6 is necessary to limit the increase of global mean temperature to 2°C, the core target of the 2015 Paris Agreement.

Shifting from RCP8.5 to RCP2.6 would reduce the costs climate change imposes on Oregon's household in the near future. Modeling the costs savings is beyond the scope of this exercise. An exercise similar to this one completed for Lebanon (the Middle East country, not the city in Oregon) found, however, that a shift to the lower scenario would reduce that country's climate-related costs from 2040's emissions by about 60 percent. The impacts on Oregon from this shift would be different. Nonetheless, this percentage provides a starting point for illustrating the potential cost saving for Oregon's households from a meaningful reduction in global GHG emissions. Table 12 shows the results.

**Table 12. Potential reduction in Oregon's share of the global social costs from anticipated GHG emissions in 2040 if emissions drop from RCP8.5 to RCP2.6, focusing on the subset of costs identified by the Interagency Working Group**

| | 2040 |
|---|---|
| Total Statewide | $13 bil. |
| Per Household | $6,000 |

As with Table 11, it is important to bear in mind that the numbers in Table 11 represent only the subset of costs considered by the Interagency Working Group on Social Cost of Carbon. This subset includes only direct economic damage that would materialize as each year's emissions contribute, in subsequent years, to extreme weather events and other changes in climate that would destroy crops, impose heat stress on workers, etc. Consideration of other costs, such as warming and acidification of the oceans and psycho-social trauma for individuals, families and communities from climate-related stress and disasters, likely would show much greater savings from a meaningful reduction in global GHG emissions.

## D. Summary

This sections looks at future climate-related costs borne by Oregonians from the top down by first calculating the global costs from worldwide emissions in 2020 and 2040 and then estimating the share that would fall on Oregon. The analysis focuses on a subset of costs identified by the Interagency Working Group. This subset of costs will total $1.8 trillion from emissions in 2020. If recent trends in GHG emissions—roughly represented by the IPCC's RCP8.5 scenario—continue, these costs will grow rapidly: to $6.3 trillion from 2040's emissions, or 3.5 times those from 2020's emissions. Oregon's share of these global costs will be about $6 billion from 2020's emissions and $21 billion from 2040's emissions.

If the world quickly curtails GHG emissions, shifting from the RCP8.5 scenario to the IPCC's lowest-emissions scenario, RCP2.6, the cost from 2040's emissions would decline by about 60 percent.