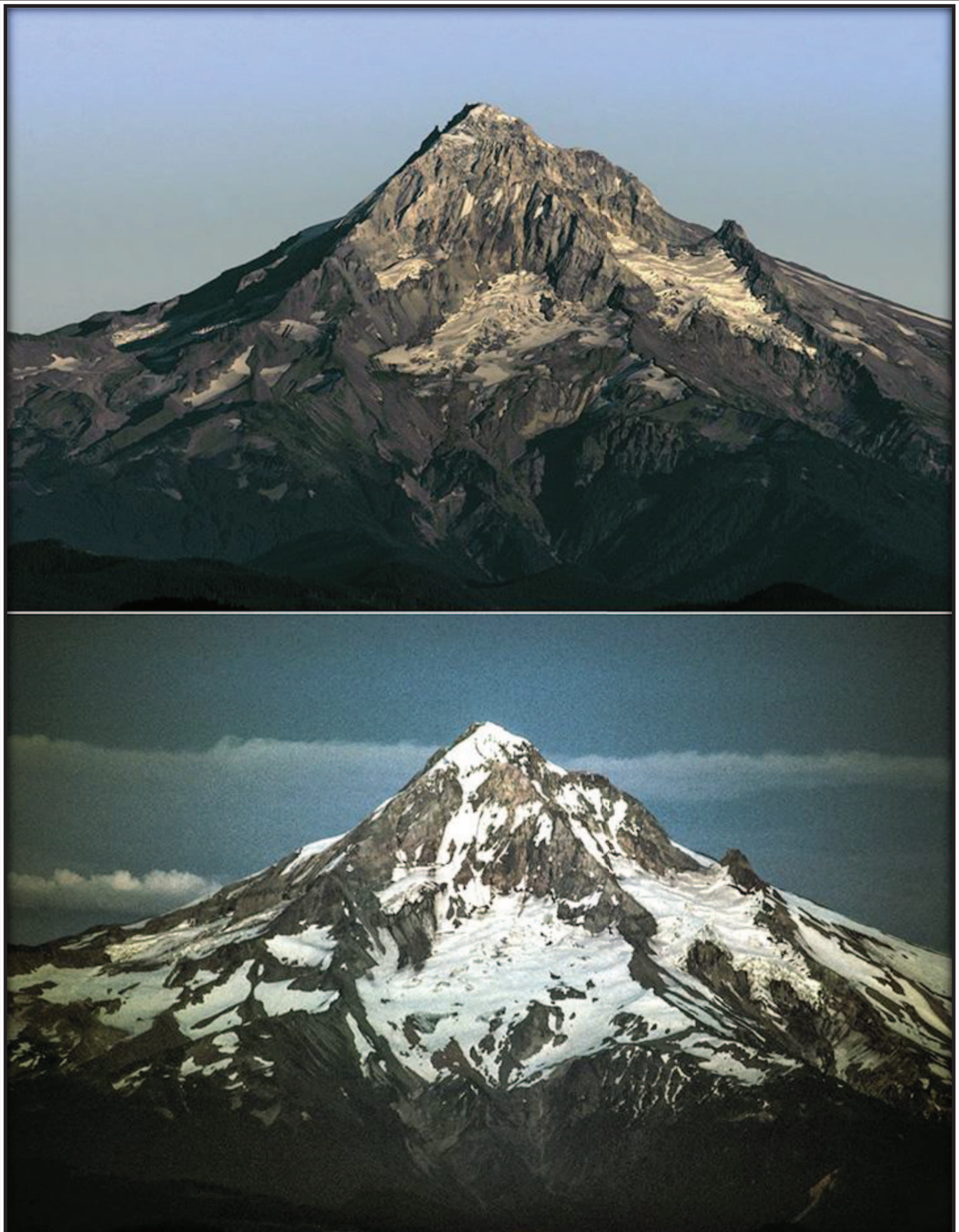

Mt. Hood Oregon Sept 11, 2013 and Aug 30 1984. Update on ice loss. © 2013 Gary Braasch•WorldViewOfGlobalWarming.org

Oregon Global Warming Commission

Biennial Report to the Legislature

2017

The before-and-after cover photographs of Mt. Hood are from Gary Braasch, an Oregon-based international environmental photo-journalist who died in 2016 while pursuing his passion of documenting the painful progress of climate change around the world. Braasch was known and appreciated worldwide for both his artistry and his social conscience. He had wide experience in reporting on and photographing natural history, science and environmental issues. He wrote two books on climate change; and his images and stories have been published by the United Nations, major news websites, magazines ranging from Scientific American to Vanity Fair, and as postage stamps and iPhone and iPad apps.

KeepOregonCool
Oregon Global Warming Commission

Oregon Global Warming Commission

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Vice–Chair

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Vacant	Oregon State Legislature

*Two voting member positions of the Commission are vacant at the time of this Report

OREGON GLOBAL WARMING COMMISSION

Biennial Report to the Legislature

February 2017

For more information on the Oregon Global Warming Commission please visit the Commission's website at www.KeepOregonCool.org.

KeepOregonCool
Oregon Global Warming Commission

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Oregon Global Warming Commission
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Commission email: Oregon.GWC@state.or.us

Table of Contents

Executive Summary

This Oregon Global Warming Commission (OGWC) 2017 Biennial Report to the Legislature contains five somewhat distinct sections covering a wide range of the topics that the OGWC is statutorily directed to track and evaluate. Some sections, like providing the most current available greenhouse gas inventory data and recently updated emission projection, are topics that the Commission has covered in detail in previous reports. Others, notably a discussion of forest carbon accounting in Oregon, represent new or updated work by the Commission that remains ongoing at the time that this report is being published. The key takeaways and recommendations from each of these sections are summarized below.

Oregon's Greenhouse Gas Emissions: In-Boundary Inventory Update

Key Takeaway: Rising transportation emissions are driving increases in statewide emissions.

As the updated greenhouse gas inventory data clearly indicate, Oregon's emissions had been declining or holding relatively steady through 2014 but recorded a non-trivial increase between 2014 and 2015. The majority of this increase (60%) was due to increased emissions from the transportation sector, specifically the use of gasoline and diesel. The reversal of the recent trend in emissions declines, both in the transportation sector and statewide, likely means that Oregon will not meet its 2020 emission reduction goal. More action is needed, particularly in the transportation sector, if the state is to meet our longer-term GHG reduction goals.

In the 2017 session, the Oregon Legislature has an opportunity in the context of discussing a transportation funding package to prioritize policies and programs that will make material differences in the GHG emissions from transportation, and, by extension, the state's ability to meet its legislatively adopted reduction goals.

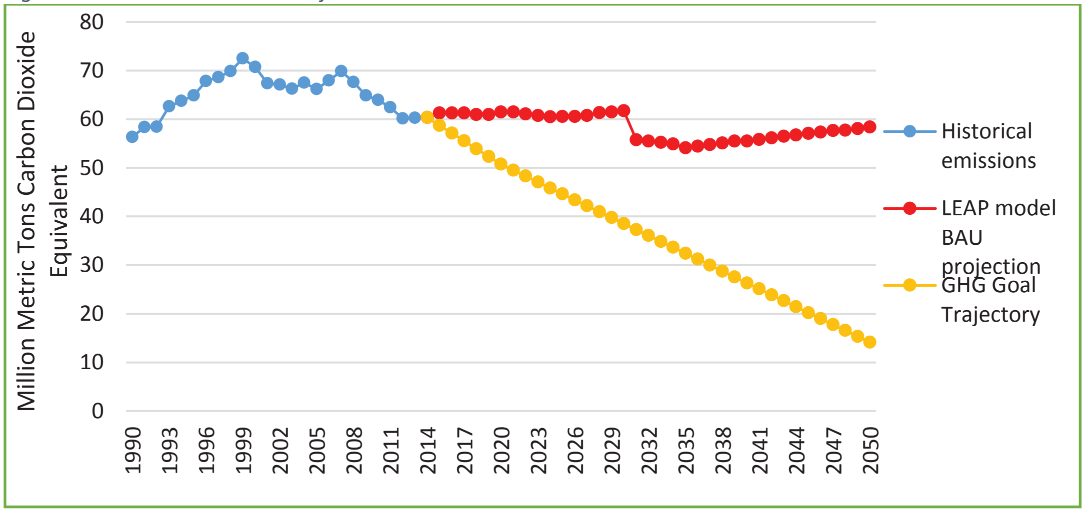
The Commission recommends that the 2017 Legislature, in addressing Oregon's overall transportation and transportation funding needs, use the occasion to devise and adopt measures that will bring transportation GHG emissions under control and aligned with Oregon's Greenhouse Gas Reduction Goals.

Oregon's Greenhouse Gas Emission Projection

Key Takeaway: Oregon's GHG goals are not likely to be met with existing and planned actions.

The new forecast clearly shows the expected impacts of legislation from 2016 which extended the renewable portfolio standard and implemented a coal import ban that comes into effect in 2030. We appear to be on track to miss our 2020 goal by just under 11 million MTCO2e. In 2035, we project we will miss the Commission's adopted interim goal by just under 22 million MTCO2e.

Figure 1: Statewide Emission Projection



Despite the anticipated reductions due to implementation of Oregon's RPS and other policies, the state's forecast is not expected to come within striking distance of either the statutorily mandated 2020 and 2050 emission reduction goals, or the 2035 interim goal that the Commission proposed in our last report.

Forest Carbon Accounting in Oregon

Key Takeaways and Recommendations for the Oregon Legislature: The Commission recommends that the Legislature defer enacting new forest management policies that would significantly affect carbon balances in Oregon's forests until the Commission's Forest Carbon Accounting Project is complete and can inform such policies.

Oregon's forests sequester very large quantities of carbon, presenting both risks (of release) and opportunities (for greater capture and containment). Tools for quantifying amounts and tracking flows and fluctuations – due to normal forest function, to climate change-induced effects, and to human intervention – are evolving but incomplete.

There are three observations that argue for paying new and urgent attention to tracking forest carbon fluctuations (flux):

1. Oregon forests contain on the order of 3 BILLION tons of carbon (roughly equal to 9.7 billion tons of CO2 equivalent), variously in standing timber and vegetation, standing and fallen dead trees, and soils.
2. In the two reference periods (2001-05, and 2011-15) identified by the OGWC Forest Carbon Task Force and involved experts, average CO2e emissions from wildfire averaged between 1.5 and 4 million tons (mmT) annually. We are unable to establish yet if this can be considered excessive, or normal, or somewhere in between. We find it difficult, in fact, to define and identify a normative period. Absent additional information and analysis, we hesitate to assert that this is a significant, or non-significant, addition to Oregon's ± 60 mmT overall emissions inventory, especially after it is netted against

carbon taken up by and sequestered in growing trees? We also need to better understand the flux effects of human interventions in the forests, whether for timber harvest, forest health (thinnings), forest biomass-to-energy or other purposes.

3. When we have reliable inventory and flux numbers, we will still need to anticipate how they may evolve as climate change increasingly affects Oregon's forests? What does this suggest about modifying forest practices going forward? What does it suggest about human interventions in forests, whether to harvest for lumber or biomass-to-energy feedstock, or to address forest health concerns resulting from historical and prevailing practices (fire suppression; clear-cutting)? If forest health considerations indicate removal of overgrowth and/or controlled fire as remediation, what are the implications for both forest carbon accounts and carbon reduction options in other sectors?

Fixing State Climate Policymaking

Key Takeaways and Recommendations for the Oregon Legislature: the State's climate policymaking machinery is not measuring up to the task of achieving GHG reduction goals and preparing the state for the effects of climate change.

This failure is especially noteworthy for tasks not being informed by rigorous cost/benefit analysis, guided by agency assignments and benchmarks, and tracked for performance.

The Commission recommends that the Legislature direct agencies to collaborate with the Commission to set assignments (from the Commission's Roadmap) and benchmarks, and to report annually to the Commission on progress or lack of progress, and reasons why.

The Commission further recommends that the Legislature provide the Commission with modest but sufficient resources – staff and budget – to enable it to discharge its responsibilities in a timely and efficient way, including its analysis, communications and tracking functions.

Climate Impacts, Adaptation and Preparation

Key Takeaways: Oregon is warming and the consequences are, and will be, notable. Adaptation is necessary, as mitigation alone will not prevent serious impacts. Oregon must do more to adapt to climate changes already underway.

Oregon at its peril remains unprepared for the health, flooding, drought, fire and ecosystem damages that climate change is likely to bring. As noted in the Third Assessment Report from the Oregon Climate Change Research Institute (OCCRI), some Oregon agencies have begun work to prepare for the future effects of climate change. Despite efforts at a few select agencies, there remains no statewide strategy for identifying adaptation and preparation needs or tracking progress toward meeting those needs. At the State level the only effort to look broadly across all agencies' responsibilities took place in 2010 and needs updating, particularly in light of the accumulated analysis and findings by OCCRI and other climate scientists.

Letter from the Chair

This Oregon Global Warming Commission 2017 Report to the Legislature differs from previous reports in important respects – including specific recommendations – that we hope the Legislature will carefully consider in its 2017 session deliberations.

Urgency of Action: Two recent developments argue for the Legislature to address climate issues in 2017 with new urgency. The first is the not-unexpected but still sobering news that 2016 has become the planet's warmest year since reliable records have been kept. In taking that dubious honor, 2016 edged out 2015, which in turn had eclipsed 2014. The steadily accumulating evidence should erase any lingering doubts that we are rapidly transforming the fundamental climatic conditions under which human civilization emerged and evolved into the world we inherited, and of which we are the stewards for succeeding generations. If it is not too late to protect our children from the most severe effects of climate change, it soon will be.

At the same time the political pendulum in the federal government has swung 180 degrees, from an Administration that committed to an historic 2016 global Paris Agreement and was actively driving down power plant and vehicle emissions, to one that has characterized climate change as a Chinese hoax. While this shift was largely unrelated to climate policy, it casts a dark cloud over prospects for progress at the federal level.

Both developments underscore the importance of elevating our commitments – and deliveries – at the state and community levels in regions of the country that are already the climate leaders. The west coast states, including Oregon, have special obligations and opportunities to re-commit to our goals and the fulfilling of those commitments. Oregon took a nationally significant step last year in committing to end coal generation serving Oregon electricity customers and in setting a new, higher standard for reliance on renewably generated electricity. We cannot rest on those achievements in 2017, but must build on them instead, most emphatically in our largest greenhouse gas-emitting sector, transportation.

Timeliness of Report Delivery: For the first time we are delivering this 2017 Commission Biennial Report to the Legislature *in advance* of a legislative session rather than four or five months into the session. In doing so we seek to inform the legislature in advance of consideration of the important energy and climate decisions are made, and not after they are set in stone or nearly so. Pending legislative decisions this year on transportation, forest management, and how state agencies discharge their climate responsibilities are critically important to the state making progress in a timely and meaningful way. The legislature must also address these issues in a timely way, not defer them to a later session or allow the immediate to again drive out the important. This Report, by providing timely data and recommendations, allows the legislature to in turn do its job.

Transportation Emissions: Reliable 2015 data on transportation GHG emissions – Oregon's largest emissions sector; see pp. 17-18 of this report -- will allow 2017's legislators to rationally weigh choices to substantially reduce those emissions alongside other transportation policies that provide economic stimulation and congestion relief (of course many clean transportation choices also contribute materially to these other important policy outcomes). The 2015 numbers suggest this debate is timely if not overdue, as the increasing transportation emissions describe a perilous reversal of the progress we've made over the last 15 years. This disturbing trend may be resulting from the compounded effects of (1) a 2013-2015 upturn in Vehicle Miles Traveled by Oregon drivers, and (2) a flattening out, since early 2015, of vehicle fuel efficiency (MPG) gains nationally.

As legislators gather for their 2017 session and likely transportation legislation including a gas tax increase, their choices should be guided by both economic and environmental outcomes including these disturbing transportation emissions trends, and by the findings of the 2013 Sustainable Transportation Strategy ODOT analysis that identifies increased transit service levels, and wider deployment of Electric Vehicles (EV's) reliant on a clean electrical grid as two critical strategies to contain those emissions.

Other GHG Sector Emissions Data: Addressing utilities and transportation leaves an important 25% of emissions needing attention as well. Our data for these areas are slower to assemble, although we'll be working on their timeliness also. For now we'll use two year old data in most cases, a lag that should not greatly impair legislative decision-making as technology and policy changes accumulate more slowly in sectors such as agriculture and materials management.

Forest Carbon Accounting: A signal exception to this generalization is, we believe, in forests and forest carbon accounting. The potential game-changer in forest carbon management is climate change itself, acting through insects, disease and wildfire, to change the carbon equation in Oregon's forests. Reliable, comprehensive data on greenhouse gas emissions and sequestration associated with forests was largely non-existent when the Commission proposed policies in its 2010 Roadmap to 2020.

There are three observations that argue for paying new and urgent attention to tracking forest carbon flux.

1. Oregon forests contain on the order of 3 BILLION tons of carbon[1], variously in standing timber and vegetation, standing and fallen dead trees, and soils.[2]
2. In the two reference periods (2001-05, and 2011-15) identified by the OGWC Forest Carbon Task Force and involved experts, average CO2e emissions from wildfire averaged between 3 and 4 million tons annually. It's unclear whether we should consider this excessive, or normal, or somewhere in between when compared to a "normative" period . . . if we can define and identify a normative period at all? What, if anything, does it add to Oregon's $\pm$ 60 mm Ton overall emissions inventory after it is netted against carbon taken up by and sequestered in growing trees?[3]
3. When we have the numbers, how should we expect them to evolve as climate change tightens its grip on Oregon and its forests? What does this suggest about modifying forest practices going forward? What does it suggest about human interventions in forests, whether to harvest for lumber or biomass-to-energy feedstock, or to address forest health concerns resulting from past and prevailing practices (fire suppression; clear-cutting)? If forest health considerations indicate removal of overgrowth and/or controlled fire as remediation, what are the implications for both forest carbon accounts and other carbon reduction options?

The OGWC recommends that the Legislature defer new policies or management actions until the accounting project now underway is complete. At that point legislators, agency staff and the Commission will have a clearer idea what combination of actions can best optimize for both forest health and carbon sequestration outcomes.

Adaptation and Preparation: We are pleased to highlight the work of the Oregon Health Authority in preparing Oregonians for the health risks anticipated as climate

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[1] When calculating a forestry carbon impact per ton it's important to distinguish between the element "carbon" and the molecule "carbon dioxide (CO2)." For purposes of analyzing forest carbon, the focus is on the flow of the carbon atom among the pools (or into a forest products pool); and then, if carbon-based plants and trees are combusted (oxidized) in or out of the forest, on the flow of the resulting carbon dioxide into the atmosphere. To convert from "carbon" to "carbon dioxide equivalent/CO2e" multiply the carbon/acre by 3.67, then divide by 1.102. Thus the total FIA all-pools Oregon forest carbon amount of 2,907.6 mm tons equals 9,683.2 mm tons CO2e.

[2] Per USFS Forest Inventory and Analysis (FIA) data (2016).

[3] For purposes of comparison, the Boardman coal-fired power plant, the largest single point source of in-state carbon emissions, emits an average of around 2mm tons of carbon dioxide annually.

change takes a firmer grip on our state. This report, and the actions recommended, stand in stark contrast to the general absence of systematic, comprehensive preparation by the State of Oregon as a whole. There are instances of other individual agencies studying climate trends and effects, and as well some local jurisdictions have attended to these, but at the State level the only effort to look broadly across all agencies' responsibilities took place in 2010 (see: Oregon Climate Change Adaptation Framework; http://www.oregon.gov/LCD/docs/climatechange/framework_summary.pdf). That admirable but limited effort sorely needs updating, particularly in light of the accumulated analysis and findings over the last six years by the Oregon Climate Change Research Institute.[4] The OGWC had hoped to revisit adaptation issues in 2016 but was unable to do so for the same reasons the agencies have deferred: limited resources and competing priorities. Nonetheless, Oregon at its peril remains unprepared for the health, flooding, drought, fire and ecosystem unraveling that climate change is likely to bring.

<u>Timeliness of Data</u>: The Commission, and staff at ODEQ and ODOE, have worked diligently to accelerate the assembly and verification of greenhouse gas emissions data for Oregon. The Legislature and the Governor, going forward from this Report, will have data on transportation- and utility-related GHG emissions that are no more than six to nine months old. This Report includes 2015 emissions numbers in these two areas, which comprise ± 75% of overall state emissions.

Having timely electric utility numbers would have better informed the Legislature on both urgency and outcomes when it considered SB 1547 (the Clean Electricity and Coal Transition Act) last February. Instead it had to make do with three-year old data – an age when electricity technologies and resource choices are rapidly and dramatically changing.

<u>Consistent Climate Policies, Implementation, Oversight and Accountability</u>: To take up adaptation and preparation, to provide the Legislature with a workable forest carbon accounting methodology, to provide Oregonians with useful and accurate information on the risks they should be preparing for and the preventative actions they can take, and to track and work with State agencies as they discharge their climate responsibilities, Oregon needs better machinery than it's got today.

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[4] The most recent comprehensive assessment was published in 2013. An updated assessment is due in early 2017.

The OGWC, early on, adopted Principles that said in summary: first, follow the science; second, figure out least cost remedies and frame our recommendations around these. But absent the minimal resources and access to professional analysis, neither the OGWC nor any other State entity has been able to make more than a cursory stab at ranking and prioritizing such remedies across the range of State programs and responsibilities.

From agency to agency, climate considerations surface and submerge in priority in no predictable pattern except as immediate demands drive out any consistent climate focus. The OGWC was established by the 2007 Legislature as the party responsible for making sense of this ball of yarn, but then was given neither budget nor authority, and only limited staff support, to discharge responsibilities that extend across most State agencies and actions. Climate change causes and effects involve jurisdictions outside the State as well: businesses, private citizens, ecosystems and interactions with Federal regulatory and resource management entities.

The OGWC (or any replacement entity) isn't responsible for all such interactions; isn't, couldn't be and shouldn't be. But the State's climate policies need an entity that can assure important questions aren't being deferred or falling through the cracks; that can work with State agencies and their stakeholders to create goals and benchmarks; and that can track progress or its absence, the reasons why, and what the Governor and Legislature should do to sustain the first and address the second.

The OGWC has worked with Members of this 2017 Legislature on crafting statutory language that could begin to address this unwholesome absence of accountability. We are prepared to meet with legislators at their request to explain, clarify, rewrite or otherwise assist in bringing Oregon's ability to deal with its climate responsibilities in ways commensurate with the opportunities and hazards they contain.

Sincerely,

Angus Duncan, Chair

Oregon Global Warming Commission

Oregon's Greenhouse Gas Emissions: In-Boundary Inventory Update

Key Takeaway: Rising Transportation Emissions

As the data summarized below clearly indicate, Oregon's greenhouse gas emissions had been declining or holding relatively steady through 2014 but recorded a non-trivial increase between 2014 and 2015. The majority of this increase (60%) was due to increased emissions from the transportation sector, specifically the use of gasoline and diesel.[5] The reversal of the recent trend in emissions declines, both in the transportation sector and statewide, likely means that Oregon will not meet its 2020 emission reduction goal (more on the GHG forecast below). More action is needed, particularly in the transportation sector, if the state is to meet our longer-term GHG reduction goals. In the 2017 session, the Oregon Legislature has an opportunity in the context of discussing a transportation funding package to prioritize policies and programs that will make material differences in the GHG emissions from transportation, and, by extension, the state's ability to meet its legislatively adopted reduction goals.

The Commission recommends that the 2017 Legislature, in addressing Oregon's overall transportation and transportation funding needs, use the occasion to devise and adopt measures that will bring transportation GHG emissions under control and aligned with Oregon's GHG reduction goals.

Overview

Oregonians contribute to greenhouse gas emissions in a variety of ways, spanning nearly all of the activities that we engage in. Having a solid understanding of these emissions, including those that occur both in-state and out-of-state and from both production and consumption, is the first step to analyzing what sorts of actions might be required for us to meet our long-term emission reduction goals.

Prior to 2010, Oregon's GHG inventory was constructed in a "top-down" fashion, using an inventory tool published by the U.S. Environmental Protection Agency (EPA). Beginning in 2010, Oregon's largest emitters of GHGs began reporting their emissions to the Oregon DEQ as part of the mandatory GHG reporting program. In 2013, the Oregon Departments of Environmental Quality, Energy, and Transportation produced a technical report[6] which utilized both the "top-down" method and the reported data, and provided a greenhouse gas inventory using multiple emission accounting methodologies.

The report analyzed data up to the year 2010 and described three inventories: in-boundary emissions, which are those that occur within Oregon's borders plus emissions associated with the use of electricity within Oregon; consumption-based emissions, which are those global

[5] Most of the balance of the increase was in residential/commercial emissions, where action taken by the 2016 legislative session to back out coal-by-wire electricity imports and increase the Renewable Portfolio Standard should result in long-term decreased sector emissions. There is no parallel driver to reduce transportation emissions.

[6] http://www.oregon.gov/deq/AQ/Documents/OregonGHGinventory07_17_13FINAL.pdf

emissions associated with satisfying Oregon's consumption of goods and services, including energy; and expanded transportation sector emissions, which evaluated the full life-cycle emissions from fuel use by ground and commercial vehicles, freight movement of in-bound goods, and air passenger travel. The 2015 Oregon Global Warming Commission (OGWC) Biennial Report to the Legislature contained the first update to these inventories.[7]

This 2017 OGWC Biennial Report to the Legislature provides an update to the in-boundary emissions inventory through 2015. Although EPA's inventory tool only currently contains data through 2013, Oregon DEQ is able to construct a "hybrid" inventory through 2015 using the most recently reported GHG data that it collects along with slightly older GHG data for other sectors available through the EPA's tool. The data that comprise the in-boundary inventory are contained in the Appendix to this Report.

In-Boundary Emissions Inventory

Inventory Overview

Oregon's in-boundary inventory estimates greenhouse gas emissions that occur within the State's jurisdictional boundary and those that are associated with the generation of electricity used by Oregonians within that boundary. This inventory includes emissions from the combustion of fuel used in Oregon, the processing and disposal of waste and other materials, the generation and transmission of electricity used in Oregon, agricultural and industrial operations, and a variety of other processes. Most of these emissions occur within the State, though a substantial share of the electricity used by Oregonians is generated out of state, and the emissions from this out of state generation are included in this inventory. Likewise, emissions from electricity generation occurring in Oregon that is used out of state are presented separately and not included in the statewide emission totals of this inventory.

Total Emissions

Following is a discussion of the 2015 inventory, how it compares with prior years, and how the estimates of prior year emissions have changed slightly since the last inventory.[8] Key economic sectors and their trends are presented, followed by an examination of those sectors in greater detail. Additional information and data on sources of emissions is available in the Appendix. In addition, the Appendix contains data on per capita emissions and the carbon intensity of Oregon's economy over time.

[7] http://www.keeporegoncool.org/sites/default/files/ogwc-standard-documents/OGWC_Rpt_Leg_2015_final.pdf

[8] We endeavor to work with state agencies to reduce the time to 1-2 years between when raw data is reported and when the updated state inventory is available.

Table 1: Oregon Emissions by Sector, 1990-2015 (Million MT CO2e)

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Transportation	21.0	22.6	24.4	24.7	23.2	22.3	22.3	21.3	21.4	23.2
Residential & Commercial	16.6	19.9	23.1	22.0	23.3	22.5	20.8	22.0	21.4	22.2
Industrial	13.9	16.9	18.0	13.7	12.3	12.2	11.5	11.9	12.4	12.8
Agriculture	4.9	5.5	5.3	5.7	5.2	5.5	5.5	5.2	5.2	5.2
Total	56.4	64.9	70.7	66.2	63.9	62.4	60.2	60.3	60.3	63.4

Table 1 summarizes greenhouse gas emissions by economic sectors since 1990. Transportation remains the largest contributor to the State's in-boundary emissions. Residential and commercial activity continues to be the second largest contributor. The industrial sector is the third largest contributor, with about half as much emissions as the transportation or the residential and commercial sectors. Finally, agricultural activity is a distant fourth. Overall, emissions declined approximately 15 percent between 2000 and 2014, but increased by 5% in just one year (between 2014 and 2015). A more detailed discussion of this increase is included below and in the sector-specific sections on the pages that follow.

Figure 2: Oregon Emissions by Sector, 1990-2015 (Million Metric Tons of Carbon Dioxide Equivalent)

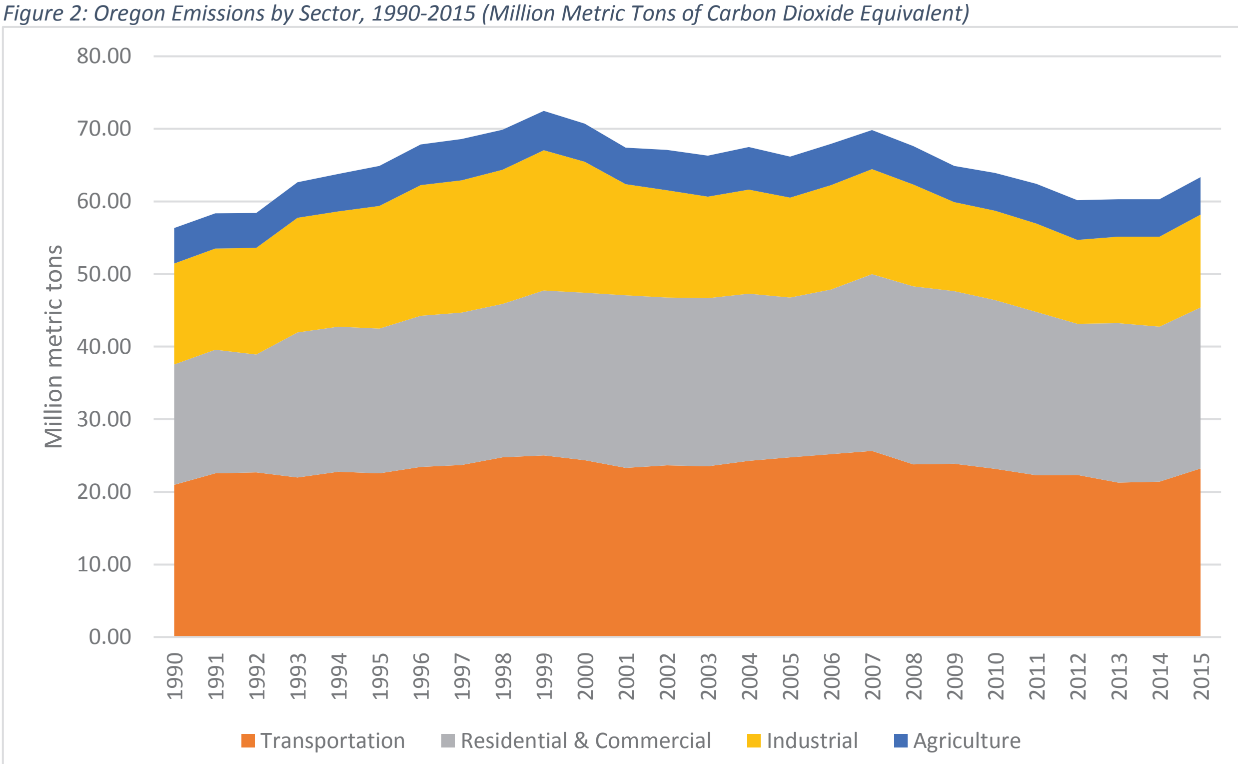


Figure 2 illustrates how the state's emissions have changed in each economic sector since 1990. Emissions from agriculture have been relatively constant, at slightly above 5 million $MTCO_2e$ each year. The transportation sector has failed to show needed emissions reductions, remaining mostly flat since 1990 at just above 20 million $MTCO_2e$, with slight declines in recent years largely erased by increased emissions in 2015. The residential and commercial sector grew through the 1990s, in part due to the retirement of GHG free Trojan Nuclear Plant, but has since declined to approximately 1993 emission levels, likely due to the drop in emissions associated with electricity use over that time. However, similar to the transportation sector, residential and commercial sector emissions increased in 2015 due primarily to increased emissions from electricity use. The industrial sector's emissions rose gradually through the 1990s to a peak in 1999 of 19.3 million $MTCO_2e$, and declined most years since then, and were 12.8 million $MTCO_2e$ in 2015.

Transportation Sector Emissions

Emissions attributed to transportation are primarily from fuel used by on-road vehicles, including passenger cars and trucks, as well as freight and commercial vehicles. This sector also includes aviation fuel and off-road transportation such as farm vehicles, locomotives, and boats.

Figure 3 illustrates how the state's emissions from transportation fuel have changed since 1990 by the relative contribution of each fuel type. Non-CO_2 gases include methane and nitrous oxide that are byproducts of fuel combustion and fluorinated gases with high global warming potential from air conditioning and other auxiliary systems on vehicles. The other fuels category includes propane, natural gas, lubricant emissions and electricity. Aviation fuels include kerosene jet fuel, aviation-grade gasoline, and naphtha jet fuel. Diesel & residuals include all distillate and residual fuels used for transportation.

Total emissions from transportation have fluctuated since 1990 rather than declining consistent with Oregon's goals. From 2007 to 2014, emissions from transportation were either relatively flat or declining. In 2015, there was a noticeable uptick in emissions from motor gasoline and diesel use which caused emissions from the sector to increase by 1.8 million $MTCO_2e$, an 8 percent increase between 2014 and 2015. It is possible that this is a reflection of the economy rebounding from the recession, and the corresponding increase in driving and purchases of goods. The increase is also likely driven in part by increasing vehicle miles traveled (VMT) which saw a dramatic spike in 2015 compared to 2014 (See Figure 4).[9]

[9] Note: This chart only shows vehicle miles traveled on Oregon highways and excludes VMT on other types of roads because the rest of the data for 2015 was not available at the time of writing.

Figure 3: Oregon Emissions from Transportation Fuel Use (Million Metric Tons of Carbon Dioxide Equivalent)

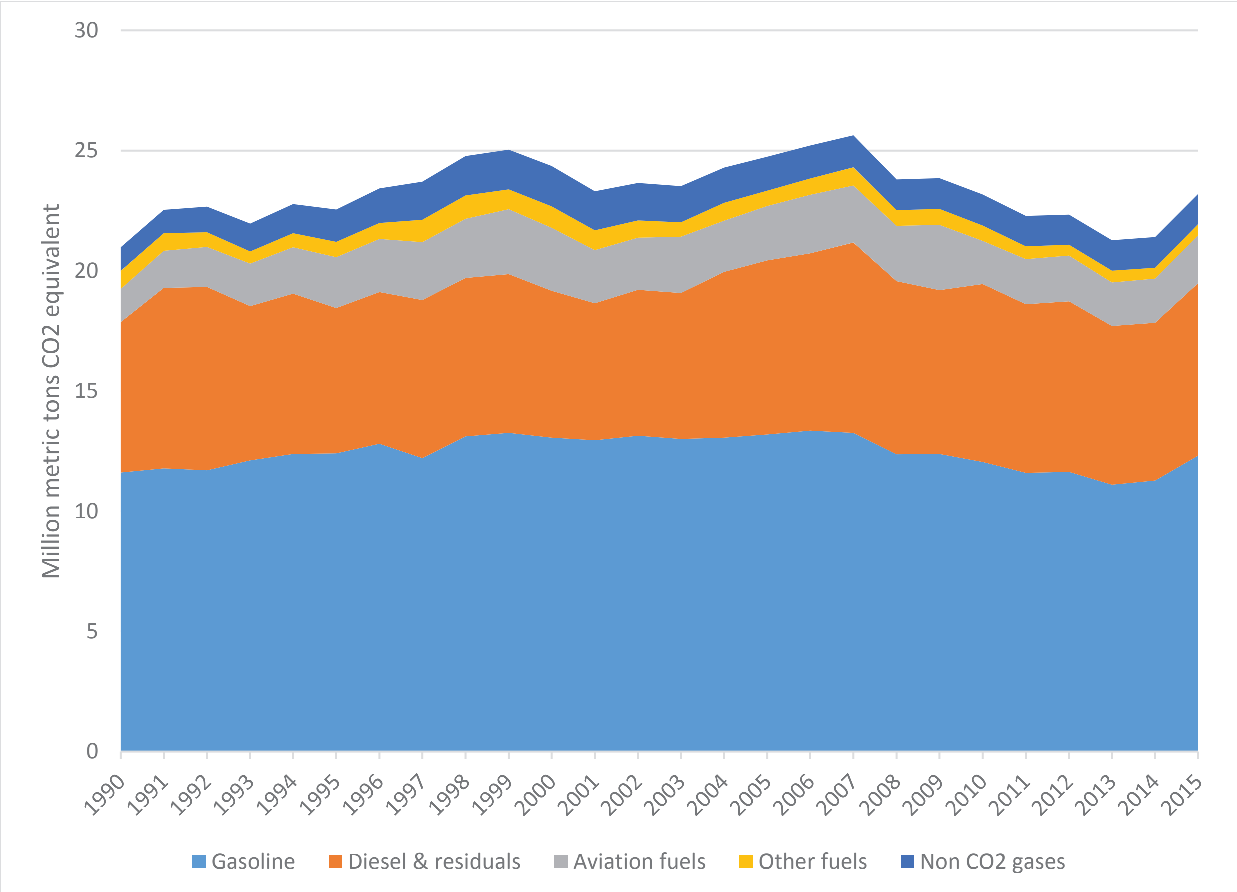
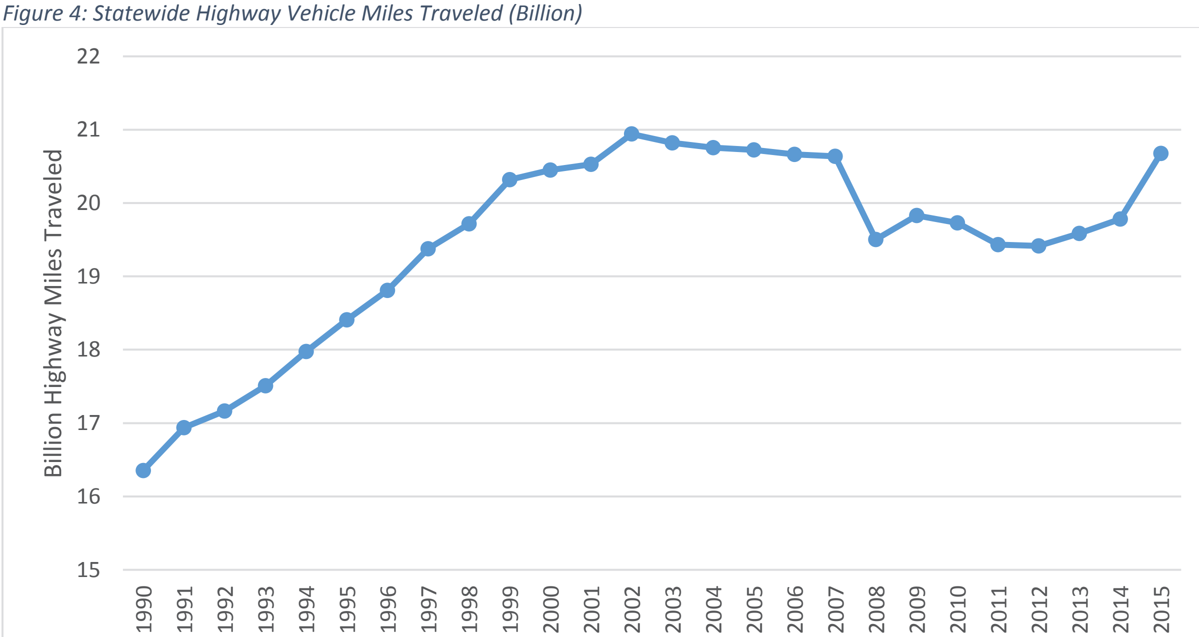


Figure 4: Statewide Highway Vehicle Miles Traveled (Billion)



Source: Oregon Department of Transportation, http://www.oregon.gov/ODOT/TD/TDATA/Pages/tsm/vmtpage.aspx

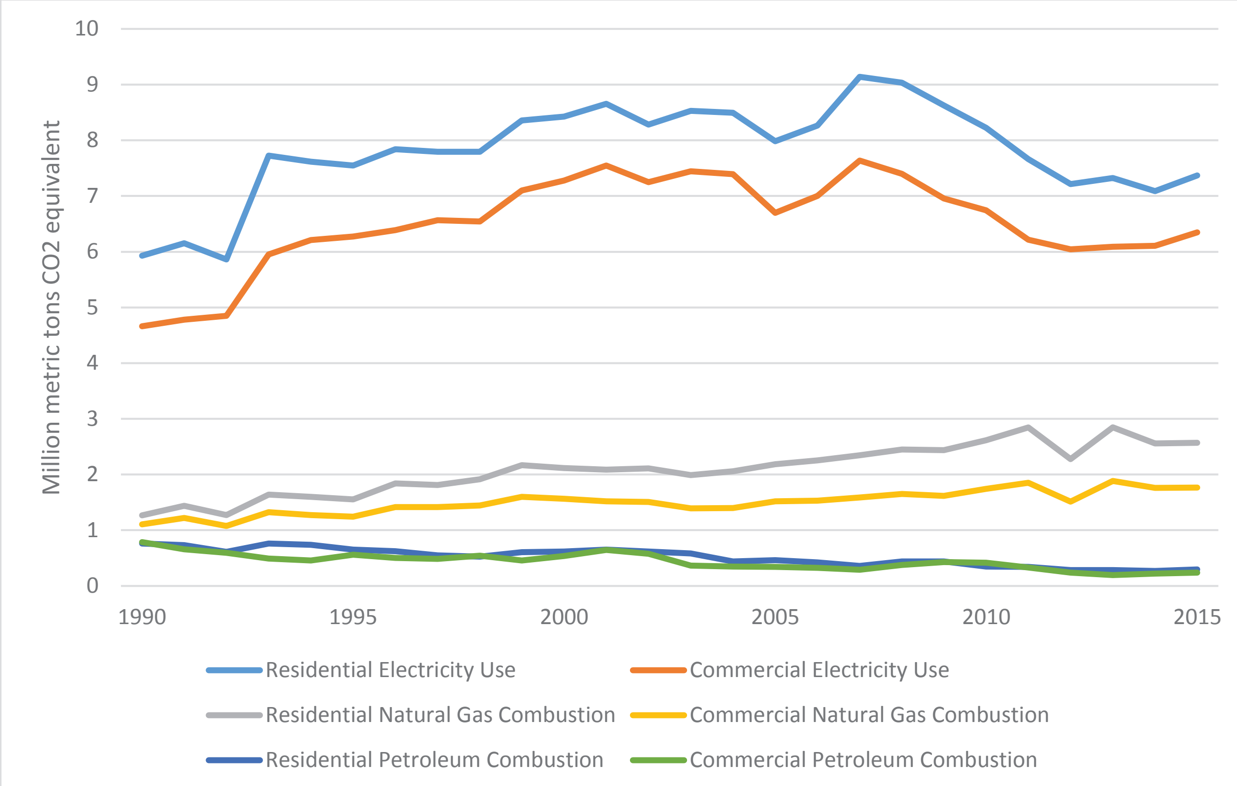
Residential and Commercial Emissions

Emissions from residential and commercial activities come primarily from generation of electricity and natural gas combustion to meet the energy demand from this sector. Other sources of emissions from this sector include small amounts of petroleum fuels burned primarily for heating, decomposition of waste in landfills, waste incineration, wastewater treatment, fugitive emissions associated with the distribution of natural gas, and from the fertilization of landscaped areas. Fluorinated gases from refrigerants, aerosols, and fire protection are also a small but increasing source of emissions from this sector.

Figure 5 illustrates how the state's emissions from electricity, natural gas, and petroleum use in residential and commercial activities have changed since 1990. Emissions from residential and commercial electricity use have followed a similar trend during this period, with residential use consistently between one and two million $MTCO_2e$ higher than commercial use each year. Annual variation in weather influences both electricity demand and the supply of renewable energy from wind and hydroelectric sources. Emissions associated with natural gas direct use in residential and commercial applications have increased steadily since 1990 with the exception of 2012.

The annual emissions intensity of Oregon's electricity is influenced by weather and hydrological conditions that affect hydroelectric generation. The less power that is available from dams, the more electricity Oregon utilities must acquire from other sources, much of which is generated with fossil fuels. So, changes in annual emissions from various uses within each sector may have as much or more to do with annual differences in the emissions intensity of Oregon's electricity as with changes in demand. Emissions associated with electricity use rose during the 1990s but have been on a downward trend in recent years, although the last few years have seen flat or increasing emissions from electricity.

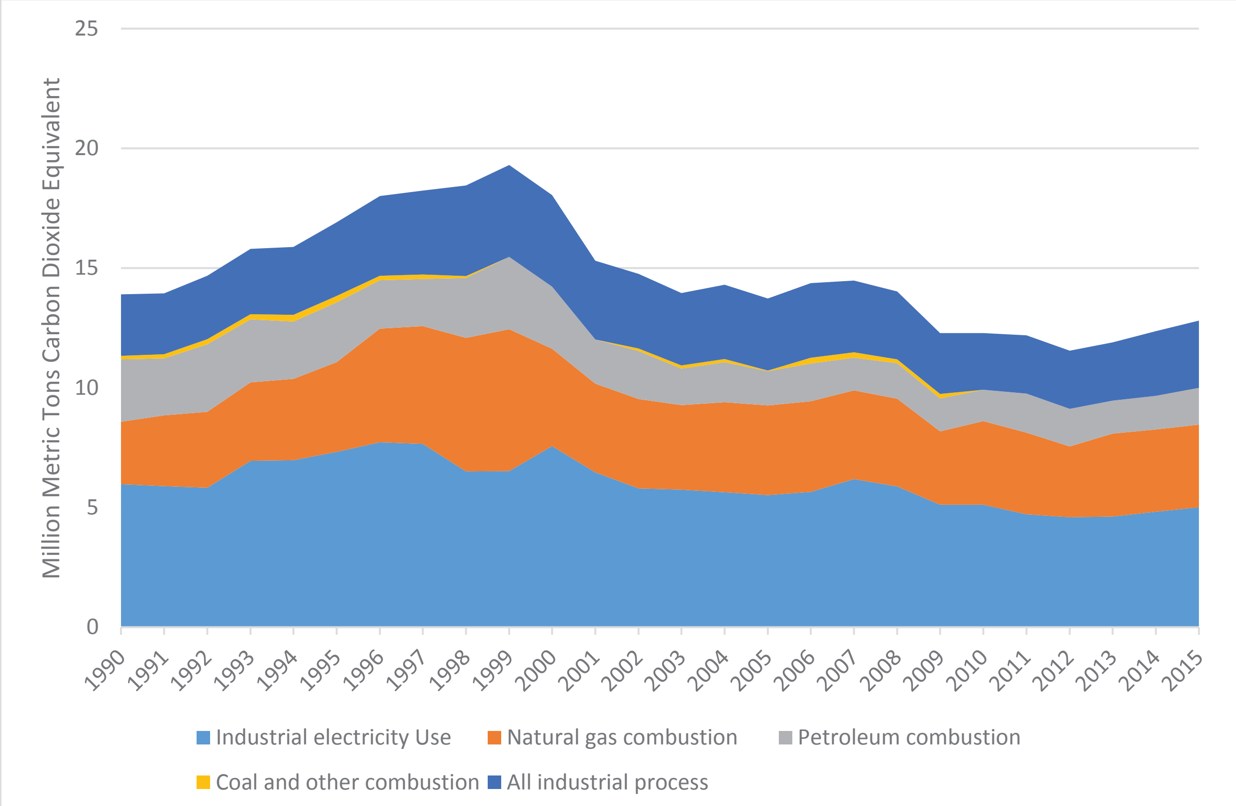
Figure 5: Oregon Residential and Commercial Emissions from Electricity, Natural Gas, and Petroleum Use (Million Metric Tons of Carbon Dioxide Equivalent)



Industrial Emissions

Similar to residential and commercial activities, emissions from the industrial sector come primarily from electricity generation and natural gas combustion. Emissions from petroleum combustion have declined since the late 1990s largely because many facilities transitioned from distillate fuels to natural gas and from structural changes in Oregon's industrial base. Emissions from coal combustion are nominal as there are very few industrial facilities in Oregon using coal onsite.

Figure 6: Oregon Emissions from Industrial Processes and Fuel Use (Million Metric Tons of Carbon Dioxide Equivalent)



Certain industries emit greenhouse gases from processes other than fuel combustion. In Oregon, these industrial processes are chiefly cement manufacturing, pulp and paper manufacturing, and semiconductor manufacturing. Emissions from these processes collectively account for approximately 2.8 million $MTCO_2e$ in 2015.

Agriculture Emissions

Agricultural activities have consistently accounted for approximately 5 million $MTCO_2e$ since the mid-1990s. In contrast to other sectors, most of these greenhouse gas emissions are from methane and nitrous oxide rather than carbon dioxide. Slightly more than 2 million $MTCO_2e$ is from methane that results from enteric fermentation (i.e. digestion of feed from livestock). About 2 million $MTCO_2e$ is from nitrous oxide, estimated from nitrogen-based fertilizers used for soil management. Methane and nitrous oxide from management of livestock manure have accounted for roughly 0.5 million $MTCO_2e$ since 2000. Other agricultural sources of emissions, including urea fertilization, liming of soils, and residue burning, produce less than 0.2 million $MTCO_2e$.

Oregon's Greenhouse Gas Emission Projection

Key Takeaway

Despite the anticipated reductions due to implementation of Oregon's RPS and other policies, the state's forecast is not expected to come within striking distance of either the statutorily mandated 2020 and 2050 emission reduction goals, or the 2035 interim goal that the Commission proposed in our last report.

Methodology

Using data available through the Mandatory Reporting program at Oregon DEQ and other tools available to Oregon, we are able to continually assess whether or not we are likely to meet our statutorily required emission reduction goals, and where the best opportunities lie for the most efficient reductions. This section examines what the data tell us about whether we are on track to meet our goals, which are to reduce emissions by 10% and 75% below 1990 levels by 2020 and 2050, respectively.

For this Report we have access to an analysis of Oregon's projected future greenhouse gas emissions that was conducted by a consultant for Oregon DEQ in response to a legislative request during the 2016 legislative session.[10] The analysis was conducted using the Long-range Energy Alternatives Planning (LEAP) model which was developed by the Stockholm Environment Institute for the purposes of conducting long-term energy and greenhouse gas forecasts and scenario analyses. State staff are hoping to make use of this tool for future Oregon GHG forecasts because it is superior to our previous methodology in several ways, notably its ability to disaggregate the forecast by sector and/or fuel type.[11] The forecast allows us to see the direction the state's emissions are headed in the absence of additional policy intervention.

Figure 9 shows the current "business as usual" (BAU) forecast using the new methodology discussed above in comparison to the Commission's previous estimate of BAU. Our new forecast for BAU includes one significant update from our last forecast:

In 2016, the Oregon Legislature increased and extended the Renewable Portfolio Standard (RPS) and banned the import of coal-fired power into Oregon after 2030.[12] The two largest investor-owned utilities (Portland General Electric and Pacificorp) are now required to acquire 50 percent of the power they use to serve Oregon customers from qualifying renewable sources by 2040.[13] In addition, these utilities may not allocate the costs or benefits of coal-fired

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[10] http://www.deq.state.or.us/aq/climate/GHGmarket.htm

[11] In preparing the data for this report, state staff compared the GHG forecasting methodology with the previous methodology (using EPA's SIT tool) and found the resulting state-wide forecasts to be similar with a couple of differences that can be explained. The similar nature of the overall forecasts allows us to be confident in switching to a new modeling tool for future forecasts, while being able to take advantage of the benefits of the new tool.

[12] The coal import ban may apply in 2035 to Portland General Electric's ownership share of Colstrip.

[13] The original RPS required the largest utilities to acquire 25 percent of their power from renewable sources by 2025 with no further increased requirements after 2025.

power to Oregon customers after 2030, effectively banning its import into Oregon. These two utilities provided an estimate of resource procurement strategies that would allow them to meet the new requirements for purposes of constructing a new statewide GHG forecast (See Figures 7 and 8). The individual utility forecasts are shown below. These forecasts were included in the modeling of the statewide GHG forecast conducted using the LEAP model, shown in Figure 9.

Figure 7: Pacificorp Oregon Emissions Projection

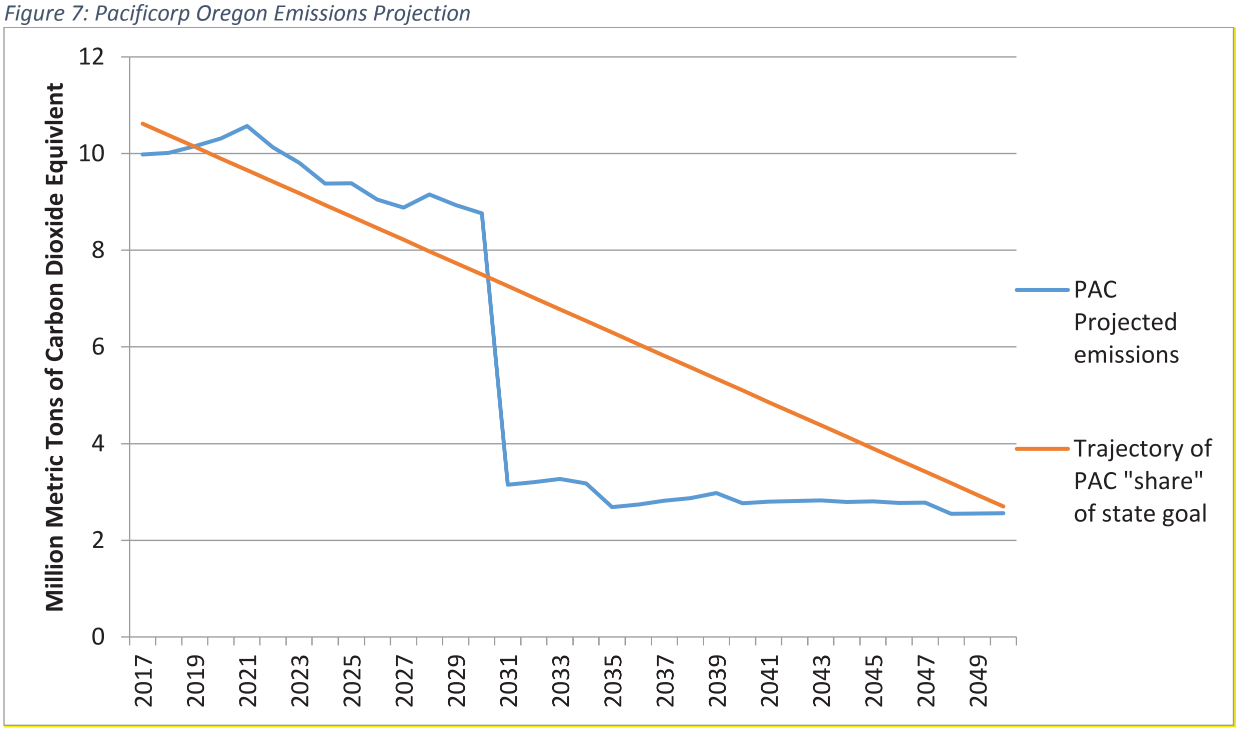
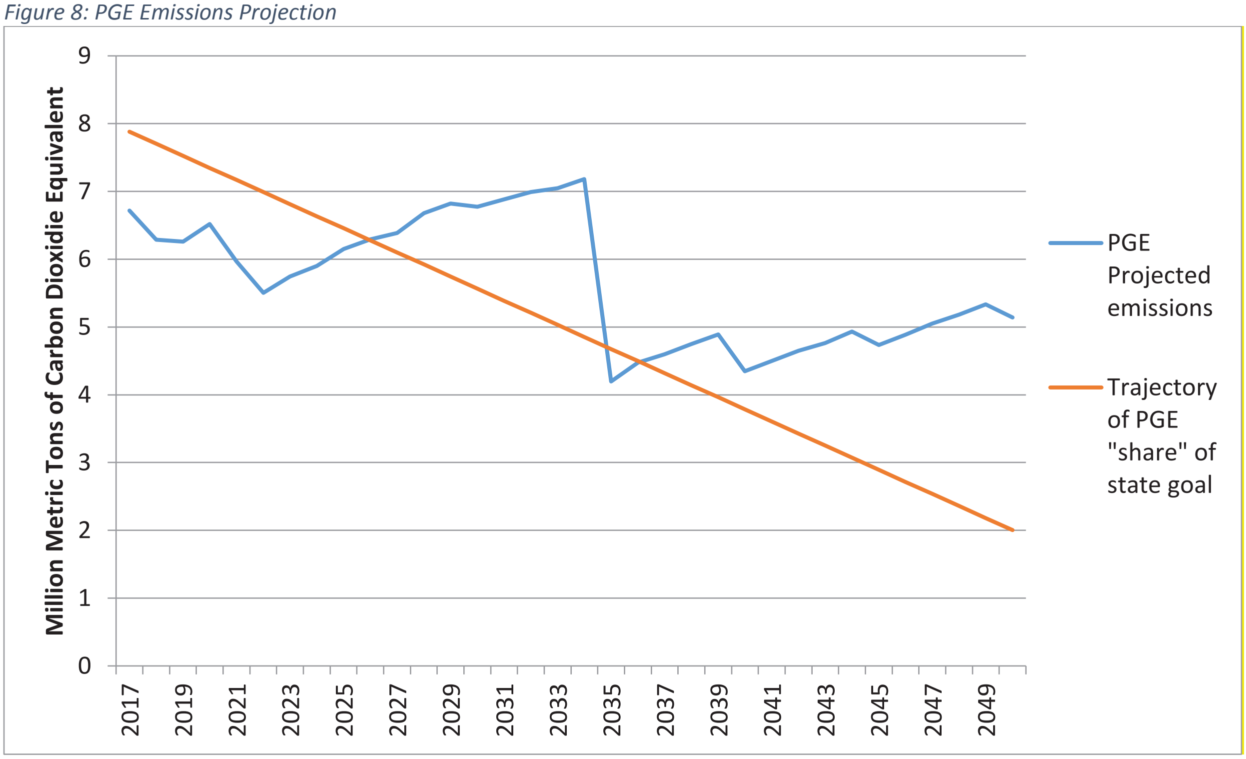
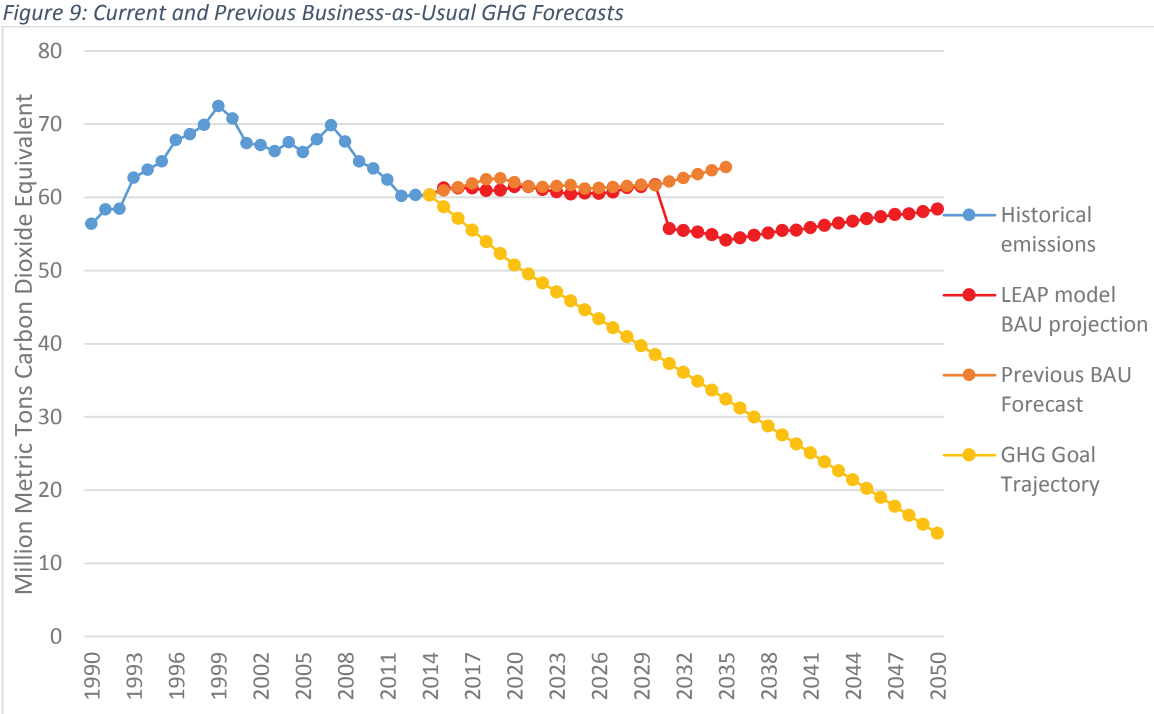


Figure 8: PGE Emissions Projection



It is clear from the utilities' projections that their strategies for meeting the new resource procurement requirements will produce mixed results with regard to meeting a proportional share of the state's GHG reduction goals.[14] These projections will change over time as the utilities develop strategies to meet their competing demands and requirements. The data behind these projections is incorporated into the statewide forecast below.

Figure 9: Current and Previous Business-as-Usual GHG Forecasts



Conclusions

The new forecast clearly shows the expected impacts of the 2016 legislation, particularly the coal import ban that comes into effect in 2030. In the years leading up to 2030, the previous forecast and our new projection look quite similar, which would be expected given that there are no new major planned policy changes during those years as compared to our last forecast.

Despite the anticipated reductions due to implementation of Oregon's RPS and other policies, the state's forecast is not expected to come within striking distance of either the statutorily mandated 2020 and 2050 emission reduction goals, or the 2035 interim goal that the Commission proposed in our last report. We appear to be on track to miss our 2020 goal by just under 11 million MTCO2e. In 2035, we project we will miss our interim goal by just under 22 million MTCO2e, which is an improvement from the gap for 2035 that we projected in our last report (32 million MTCO2e).

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[14] The GHG reduction goals adopted by the 2007 Legislature are for the state economy overall and are not specific to any single source (company or facility).

Forest Carbon Accounting in Oregon

Key Takeaways and Recommendations for the Oregon Legislature

Oregon's forests sequester very large quantities of carbon, presenting both risks (of release) and opportunities (for greater capture and containment). Tools for quantifying amounts and tracking flows and fluctuations – due to normal forest function, to climate change-induced effects, and to human intervention – are evolving but incomplete.

The Commission recommends that the Legislature defer enacting new forest management policies that would significantly affect carbon balances in Oregon's forests until the Commission's Forest Carbon Accounting Project is complete and can inform such policies.

Introduction

There are three observations that argue for paying new and urgent attention to tracking forest carbon fluctuations (flux).

1. Oregon forests contain on the order of 3 BILLION tons of carbon,[15] variously in standing timber and vegetation, standing and fallen dead trees, and soils.[16]
2. In the two reference periods (2001-05, and 2011-15) identified by the OGWC Forest Carbon Task Force and involved experts, average CO2e emissions from wildfire averaged between 1.5 and 4 million tons (mmT) annually. We are unable to establish yet if this can be considered excessive, or normal, or somewhere in between. We find it difficult, in fact, to define and identify a normative period. Absent additional information and analysis, we hesitate to assert that this is a significant, or non-significant, addition to Oregon's ± 60 mmT overall emissions inventory, especially after it is netted against carbon taken up by and sequestered in growing trees?[17] We also need to better understand the flux effects of human interventions in the forests, whether for timber harvest, forest health (thinnings), forest biomass-to-energy or other purposes.
3. When we have reliable inventory and flux numbers, we will still need to anticipate how they may evolve as climate change increasingly affects Oregon's forests? What does this suggest about modifying forest practices going forward? What does it suggest

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[15] "Carbon dioxide" (CO2) is a colorless, odorless gas that exists in the earth's atmosphere at a present ratio of ± 402 ppm and acts as a "greenhouse gas" that reflects radiated heat back to earth and adds to atmospheric warming and planetary climate disruption. "Carbon" is an element with an atomic weight of 12; add two oxygen atoms to create a molecule of CO2 with an atomic weight of 44. When calculating a "carbon cost" per ton it's important to distinguish between the two. For purposes of analyzing forest carbon, the focus is on the flow of the carbon atom among the pools (or into a forest products pool); and then, if carbon-based plants and trees are combusted (oxidized) in or out of the forest, on the flow of the resulting carbon dioxide into the atmosphere. To convert from "carbon" to "carbon dioxide equivalent/CO2e" multiply the carbon/acre by 3.67, then divide by 1.102. Thus the total FIA all-pools Oregon forest carbon amount of 2,907.6 mm tons equals 9,683.2 mm tons CO2e.
) in or out of the forest, on the flow of the resulting carbon dioxide into the atmosphere.

[16] Per USFS Forest Inventory and Analysis (FIA) data (2016).

[17] For purposes of comparison, the Boardman coal-fired power plant, the largest single point source of in-state carbon emissions, emits an average of around 2mm tons of carbon dioxide annually.

about human interventions in forests, whether to harvest for lumber or biomass-to-energy feedstock, or to address forest health concerns resulting from historical and prevailing practices (fire suppression; clear-cutting)? If forest health considerations indicate removal of overgrowth and/or controlled fire as remediation, what are the implications for both forest carbon accounts and carbon reduction options in other sectors?

Carbon flux in forests is both an Oregon and a national concern. US Senator Susan Collins (R-Maine) has offered language over the last several years that would define forest biomass-to-energy conversions as "carbon neutral," intentionally overlooking the critical time dimension to emissions impacts.[18] Oregon has considered legislation that would connect wildfire to black carbon emissions and potentially lead to new forest wildfire suppression policies, in the absence of being able to quantify either net GHG benefits or forest health tradeoffs.

The OGWC Roadmap to 2020

The Roadmap to 2020, adopted by the Commission in 2010, sets out broad objectives and specific tasks for managing the carbon contained in Oregon's forests.

The Roadmap sets forth an overall goal, between 2010 and 2150, of "no net loss of Oregon forested lands and a net gain in carbon storage in an amount to be determined."

The Roadmap sees "Eastside forests . . . managed primarily for ecosystem restoration, safety and climate adaptation with a minimum of incurred carbon (loss). West-side forests (are) managed . . . to increase carbon storage. . . . .private forestlands (are) managed primarily for production of timber and wood products . . ." with carbon stores remaining stable or increasing.

Specific tasks identified include:

- Establish a Carbon Inventory for Oregon Forests
- Pursue Reforestation/Afforestation
- Invest in Key Research Actions - impacts of climate change, adaptation tools, and benefits of durable products
- Advance Energy and Forest policies supporting biomass facilities

With this Report the Commission will have completed its first task, and commenced serious enquiry into its third task.

[18] That is, a forest harvested for biomass-to-energy combustion may regenerate and reclaim its carbon content over the succeeding 100 years or so. This may be true but not relevant, since the critical period for cutting carbon releases is in the next 10-30 years if we are to avoid the worst effects of global climate disruption later in this century.

Forest Wildfire

Historical Context: Managing for forest carbon releases is often associated with, and offered as supporting, new policies to limit forest wildfire. The historical role fire has played in forest ecosystem health and in forest products harvest is a complex one. For most of the 20th Century, federal and state forest management practices included fire suppression as a default strategy in dealing with forest wildfire (see: Smokey The Bear). This was in reaction to extensive fires during the 1850-1940 period that included the largest forest wildfires in recorded Oregon history.

Reconsidering the Utility of Forest Fire: In the last 20 years or so of the last century and continuing into this one, forest management professionals have come to acknowledge the natural and essential role fire has historically played in forest ecology (or "roles" to be more precise, since wildfire contributes differently in different forest ecosystems[19] but is generally seen now to be essential in most or all forests). Some informed observers posit a wildfire "deficit" persisting from the many years of fire suppression, as forest stands have grown crowded with smaller trees, altering ecosystem balances and increasing the risk of catastrophic wildfire that can "ladder" up the small trees to reach the crowns of large ones, then move from crown to crown. Such modern era "crown" fires are seen by many as doing greater forest ecosystem damage than might have been caused by earlier conflagrations extending over more acres but, by burning closer to the forest floor, proceeded at lower intensities and contributed to overall forest health. Whether to respond actively to address this deficit (by forest thinning and controlled burning) or more passively (letting wildfires themselves redress the imbalance more slowly) is an ongoing debate.

Forest Management Practices for Forest and Watershed Ecosystem Health:
Whether or not such a deficit is accepted as context for ongoing forest management, it is clear that there are large extents of Oregon forest congested with small trees that would likely have been cleared by normal fire regime. In some instances forests may be afflicted with abnormal disease and insect activity, killing trees or weakening their resistance to further infestations or to wildfire. High levels of infestation and/or overcrowding represent a departure from what many forestry professionals would deem a more normative condition of forest health, and one more historically resilient to fire when it occurs. Overstocked conditions, especially when accompanied by extended seasonal or interannual dry periods, may result in more, and more extensive, wildfires. While clearly a normative level of wildfire is a necessary and important feature of a living forest ecosystem, higher levels of infestation and fire can seriously stress both natural ecosystem function (e.g., regeneration) and essential habitat for indigenous species (e.g., resident and anadromous fish populations in mountain waters). Describing a

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[19] Fire is necessary in the regeneration of lodgepole forests, as the fallen cones rely on fire to activate seed dispersal and rooting. Fire opens the understory of Ponderosa forests, keeping new seedlings and saplings from crowding the forest and enabling fire to "ladder" its way into the mature treetops. Grassland fire has historically limited the intrusion of juniper into central Oregon grasslands, where it competes with and can overwhelm native grasses and sagebrush, by destroying seedlings that otherwise would grow into fire-resistant mature juniper.

desired future condition for all of Oregon's diverse forests that integrates a normative level of disease, insect infestation, fire and vegetative densities is a major challenge for forest management professionals. It is made more difficult still by the two factors described below.

Wild-Urban Interface: Over the same three to four decades past a new complication has entered the equation: the "wild-urban interface (WUI)." This is generally described as human settlement that in recent decades has extended further and further into native forests and grasslands, creating a conflict between a "normative"[20] forest fire regime that can allow for necessary rejuvenating wildfire, and protecting against fire risk to these homes and communities[21]. In recent years, forest management professionals have generally favored controlling and suppressing fires in WUI areas while allowing back-country wildfires to burn as they might have pre-settlement periods; and they have favored preventive control measures – thinning overgrown forests in WUI areas along with controlled burns during low fire hazard seasons – over a return to historical fire suppression practices.

Human settlement continues to intrude, however, as most states are without even the modest land use tools Oregon uses to prioritize and preserve farm and forest land.
Since 1990, some 8.5mm new homes, or 60% of the new homes built in the US, have been located in the WUI, resulting in around 46 million homes now occupying the defined areas.[22] Over the period in question the average number of structures burned has increased an order of magnitude (from 405 structures in the 1970's to 4500 in 2015). Managing and controlling WUI fires has put intense pressure on forest management budgets,[23] pressure that is crowding out other management responsibilities – including, most critically and ironically, forest health treatments that would reduce the probability and severity of WUI fires.

Climate Change and Forest Fire: If land development complications weren't headache enough for policymakers, climate change further complicates the challenges. It remains unclear whether total precipitation will increase or decrease in Pacific Northwest forests (and may increase in certain forests while decreasing in others). But it is apparent that critical precipitation patterns are changing already. Research shows that precipitation between May

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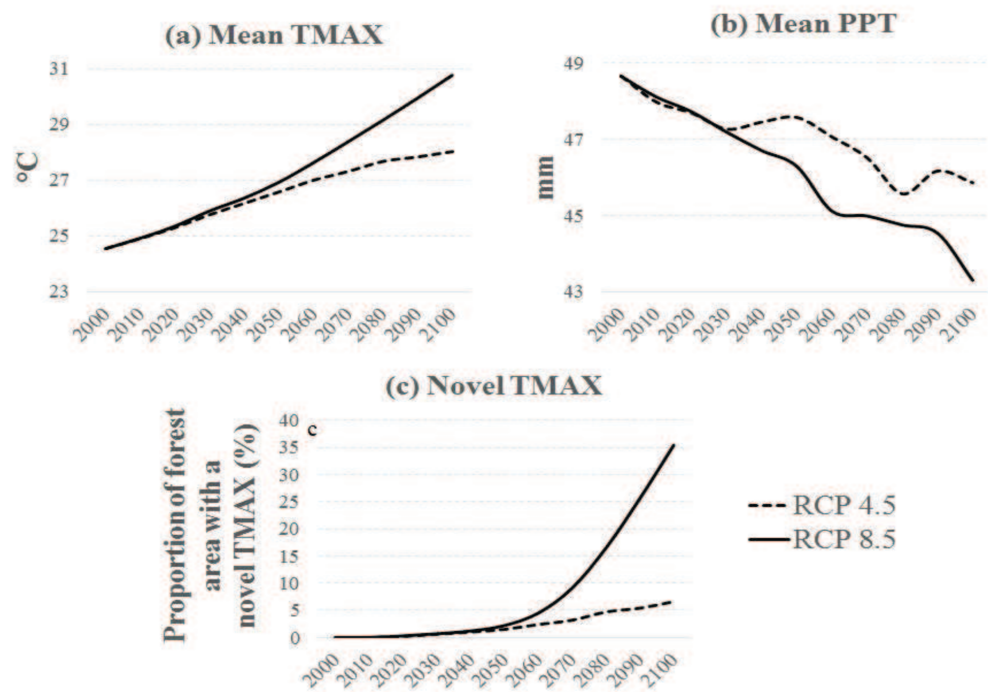
[20] A normative forest and grassland fire regime might be defined as one in which fire occurs at intervals, in extents and degrees of severity, as it did prior to Euro-American development, but including both natural causes (e.g., lightning) and active use of fire by Native American tribes to manage vegetation and animal habitat.
[21] A wildland–urban interface refers to the zone of transition between unoccupied land and human development. Communities that are within 0.5 miles (0.80 km) of the zone may also be included. These lands and communities adjacent to and surrounded by wildlands are considered at risk from forest and grassland wildfire.

[22] InternaPonal Code Council. The Blue Ribbon Panel Report on Wildland Urban Interface. April 4, 2008. hMps://inawf.memberclicks.net/assets/blueribbonreport-low.pdf . The 2008 data need updating, and likely would show these conditions have worsened.
[23] From ± $1B/year in the 1990s to ±$3B/year in the 2000's.

and September is expected to decrease through this century (Figure 1)(Davis et al, *In press).*[24] More moisture is falling as rain than as snow; mountain snowpacks are on average declining; snowpacks are melting earlier, potentially leading to increased spring flooding and to drier summers and early falls. More earlier precipitation may actually lead to larger understory fuel loading (annual grasses and brush). The summers and falls that are historical forest and range fire seasons are growing longer,[25] and drier. We should expect, then, both more and more extensive fires than before.[26]

Figure 10: (a) increasing July-August temperature TMAX (b), decreasing May-September precipitation, and (c) increasing areas with novel TMAX over time across the forests of Oregon and Washington under RCP 4.5



Some of the newest research shows that the amount of area exposed to climate conditions moderately and highly suitable for large wildfires is predicted to increase in forests of Oregon and Washington through this century (Davis et al. *In press*). It remains unclear, however, whether and to what extent a next generation of wildfires will depart from historical norms.

Whether this will also result in more or fewer carbon emissions than would be expected in a "normative" state is also unclear, in part because of the difficulty of describing, with supporting

[24] Davis R, Yang Z, Yost AC, Belongie C, Cohen W. *In press*. The normal fire environment—modeling environmental suitability for large forest wildfires using past, present, and future climate normal. Manuscript "accepted with revision" to Forest Ecology Management.

[25] ". . . over two months (longer) since the 1970's" per Tom Tidwell, USFS Chief, in Senate testimony June 2, 2013.

[26] There remains considerable uncertainty whether the resulting fires may also be more severe, i.e., hotter and more adverse to forest regeneration. Recent experience in California suggests this may be the case in drier southern and eastside forests, but evidence in the Pacific Northwest does not now appear to support the same conclusion.

evidence, just what a normative state might be. This analytic challenge is important to take up and clarify if only so we have a benchmark from which to measure the effects of our interventions.

That said, however, *any* substantial forest carbon emissions in the near term, from fire, harvest practices or other causes, and even if consistent with a normative condition or with redressing a long-standing fire deficit, may still prove too great to accept until other, manmade emissions from fossil fuel combustion and other sources can be capped and reduced.

On the other hand, the forest thinning and fuels reduction work that would reduce fire prevalence and extent will also, by definition, reduce the total quantity of sequestered carbon in the forests. While such practices may reduce fire risk whether we choose to practice them widely or target them narrowly (e.g., to Wild-Urban Interface areas), either way we will be removing carbon stores from forest. We may be obliged to make an explicit tradeoff between keeping total quantities of carbon sequestered in our forests, or accepting the removal of some quantity of carbon from those sequestered stores as the price of restoring some measure of forest health.

Harvest

About half of Oregon's 63mm acres of land is forested, and a little over a third has historically been considered harvestable. Historical timber harvest in Oregon, primarily for construction lumber and paper products has declined from an annual average of 8.7mm board feet in the 1950's to 3.8mm board feet in the 2000's. While the reasons for the decline and the justice of the reductions are argued, generally it reflects a growing understanding of the requirements of ecological balance in forests and forest watersheds and the need to redress the effects of overharvest in some areas. Notwithstanding these trends, Oregon remains the largest supplier of softwood (usually fir and pine) products among US states.

The role of forests in a world increasingly reshaped by climate change will likely need to change again. Forest ecosystems are greatly affected by climate change-driven conditions of higher average temperatures, more frequent drought and fire, and migration of species, both flora and fauna, from south to north and from lower to higher elevations. At the same time, forests play a remediating role in responding to climate change, acting as storage and sink of atmospheric carbon (by growing and retaining more carbon-based vegetation) and moderating climate change effects through watershed and species protection from these effects.

It is critical that we understand, describe and quantify forest function in these respects.

Where the Roadmap to 2020 found conditional agreement among stakeholders on allocating roles among public westside and eastside forests, and privately-held forests, thorough forest carbon accounting requires that we look at carbon flux in each of these forest categories; and that we further differentiate among different kinds of forest ecosystems (dry-side lodgepole, dry-side Ponderosa, as well as more diverse forest makeups such as are found in the Siskiyou's of Southern Oregon; wet-side coastal cedar forests, wet-side Douglas Fir-dominated Cascade forests; etc.). If carbon uptake and retention varies among these types, so will the carbon release effects of harvest. It is likely that different harvest techniques – clear-cuts vs. selective logging – may have different carbon release outcomes.

Calculating the carbon flux resulting from harvest further varies with the uses to which product is put. Carbon from trees that are harvested to feed paper mills or packaging will likely be cycled and released rapidly (e.g., from disposal through incineration or open dumps) or more slowly (if recycled or buried in landfills). When fiber is embedded in structures (framing; cabinetry) its carbon is sequestered for longer periods. In both cases the forest product may displace another product (plastic bags; steel framing) that has a higher (or lower) carbon footprint, requiring analysis to net the carbon effect.

If trees are harvested to feed biomass-to-energy facilities, a net carbon calculation is also required. The result may be positive (more carbon released) if, say, generation from a wind or solar facility is displaced; or negative (less net carbon released) if displacement is for a coal or gas facility. This net calculation also must consider whether the harvested fiber would otherwise have been burned intentionally (e.g., in a controlled burn or burned as stacked thinnings) or, on a probability basis, in an unintended forest fire (either caused naturally, e.g., from a lightning strike, or from human agency).

These are all complicated calculations, but they are not beyond our ability to frame and solve. Indeed, when the stakes are so very high, we are obliged to develop a methodology that can support chosen policies in an informed way. That's the objective the OGWC has in view.

Proposed Forest Carbon Accounting Methodology Development, Progress and Status

Early in 2016 the OGWC created a Forest Carbon Accounting Task Force to assist the Commission to gain a better understanding of forest carbon dynamics and accounting. The Task Force ultimately agreed on the foundational first step of establishing a forest carbon content baseline. The Task Force and staff understood that such a baseline could serve as a reference point for necessary quantitative analysis, while understanding that the designation was an arbitrary but functionally necessary point in time and forest condition.

Another way of expressing this is to acknowledge that we are unable to describe a normative condition for Oregon forests; a "desired future condition" as we say of watersheds. There simply aren't the data to support such a description, as they would need to arise from a period prior to Euro-American settlement when no one was collecting, or able to collect, the needed data. Additionally there are multi-year and multi-decadal climate cycles to which forests respond; which can be said to represent the normative state if all are natural and recurring? And there are now the superimposed effects of man-made climate change which have been accumulating for most of Oregon's recorded scientific history.

This first step of establishing a baseline became possible in 2016 with the availability of USFS Forest Inventory and Analysis (FIA)-collected carbon content data for Oregon forestlands. Using these data as a starting point, technical members of the Task Force advise us that it should be possible to proceed through the following steps:

1. Measure and/or model existing aboveground living matter carbon stores in Oregon forests. This will include living woody and non-woody plants, and include both their aboveground and root fiber. It captures carbon flux from growth and mortality, including transfers from this pool to other pools (see below) including to harvested fiber for all purposes.
2. Measure and/or model existing aboveground dead carbon stores. Dead carbon stores include woody and non-woody matter that has died from all causes but remains standing or down in the forest, and continues to store carbon. There are different causes for carbon to flow into and out of this pool, including decomposition, combustion and harvest, that will need to be accounted for.
3. Measure and/or model dead belowground carbon. This is likely a small pool of dead woody roots that can be sampled, modeled and calculated.
4. Measure and/or model soil carbon. This is a very large pool that must be included because a very large amount of carbon flows into and out of the pool. We are advised that measuring and modeling these flows will be difficult and require informed assumptions that can be modified as data and tools improve in the future.

With the publication herein of the USFS/FIA data on carbon pools in Oregon forests we can check off the basic inventory task (summary tables follow this section of the report). These data should then allow us to take the essential next steps: to measure and/or model the fluctuations within each pool and the flows among the pools. When this is accomplished we will have a dynamic description of forest carbon amounts *within* forest boundaries that will enable the critical next steps – critical because they begin to involve policy choices for forest ecosystem sustainability, carbon sequestration and acquisition, harvest (and choice of harvest practices) for commercial use, and the role of commercial forest products in reducing or increasing forest carbon releases into the atmosphere.

The next steps:

5. Describe through modeling the likely effects of climate change in Oregon on in-forest carbon quantities and flows. These effects may variously include near-term increased acquisition of carbon into the in-forest pools, the modification of flows among pools (e.g., from increased mortality), and increased releases of carbon into the atmosphere from insect-, disease- and fire-related mortality. Human intervention to redress effects of climate change – for example, from fuels reduction through controlled burn and/or thinning operations and disposal in situ -- will also need to be modeled here, based on a

reasonable range of assumptions. Effects of fire management practices, which will be sternly tested in a climate-change influenced future, could be quantified here or in a separate step, to be determined.

6. Describe and quantify effects on reference in-forest carbon pools from harvest and other interventions. Harvest may occur for multiple reasons and with different carbon consequences; e.g., for forest health (thinning and removal), for commercial products (structural lumber; paper products), and for forest biomass-to-energy conversion. In these cases further calculations will be required to establish the *net* carbon outcomes of different uses and means of disposal. For example, structural wood products may continue to sequester carbon for extended periods of time measured in decades (e.g., a structure's lifetime) while paper products will have a much shorter time before releasing a greenhouse gas (carbon; methane) into the atmosphere. Methods of end-of-lifetime disposition will affect both quantity and timing of such releases. In the case of some structural products and forest biomass-to-energy uses, a further calculation is required to determine if there is a substitution effect; i.e., did the forest product displace a product with greater or lesser life cycle GHG effect? Thus forest biomass-to-energy would most likely displace a fossil (coal or gas) fueled source of electricity on the grid, in which case the biomass GHG emissions would be netted against the avoided fossil fuel emissions.

Conclusion and Recommendations

The sheer size of the carbon reservoir in Oregon's forests and grasslands – three billion tons – and the comparison with annual Oregon CO2e emissions – about 60 million tons – is a first clue to why State policy needs a forest carbon accounting methodology. If those 3B tons were locked in and disconnected with the earth's atmosphere we could put this in a footnote and move on.

But there are active flows among the different carbon pools in the forest, which may add to or deplete forest carbon stores; and there are flows into and out of the forest from harvest, wildfire, clearing for development and/or thinning for ecosystem health. The latter result in lowering the total quantity of carbon stored in forests and grasslands, and may result in increases in atmospheric greenhouse gases released into the atmosphere when combusted (carbon dioxide) or decayed (methane). Both increased GHG sequestration and increased GHG release need to be understood to inform public policy on forest and grassland management for carbon outcomes.

Because all of these conditions are not now well documented and tracked, the OGWC has undertaken this project to advance our forest carbon accounting capabilities. The first product of this work is the FIA-scored quantification of total forest carbon stores, stores by pool, stores within different publicly- and privately-owned forests and stores that will vary by the different species that will be regionally dominant.

The OGWC, working with its Task Force (including USFS and academic forest scientists) has laid out an approach to complete the remaining tasks described above. When this work is completed, Oregon's policymakers will have a reliable, scientific basis for considering what changes, if any, to forest practices in Oregon are warranted.

Until then, the Commission recommends that the Legislature defer enacting new forest management policies that would significantly affect carbon balances in Oregon's forests until the Commission's Forest Carbon Accounting Project is complete and can inform such policies.

Figure 11: Eco-regions for USFS/FIA data tables

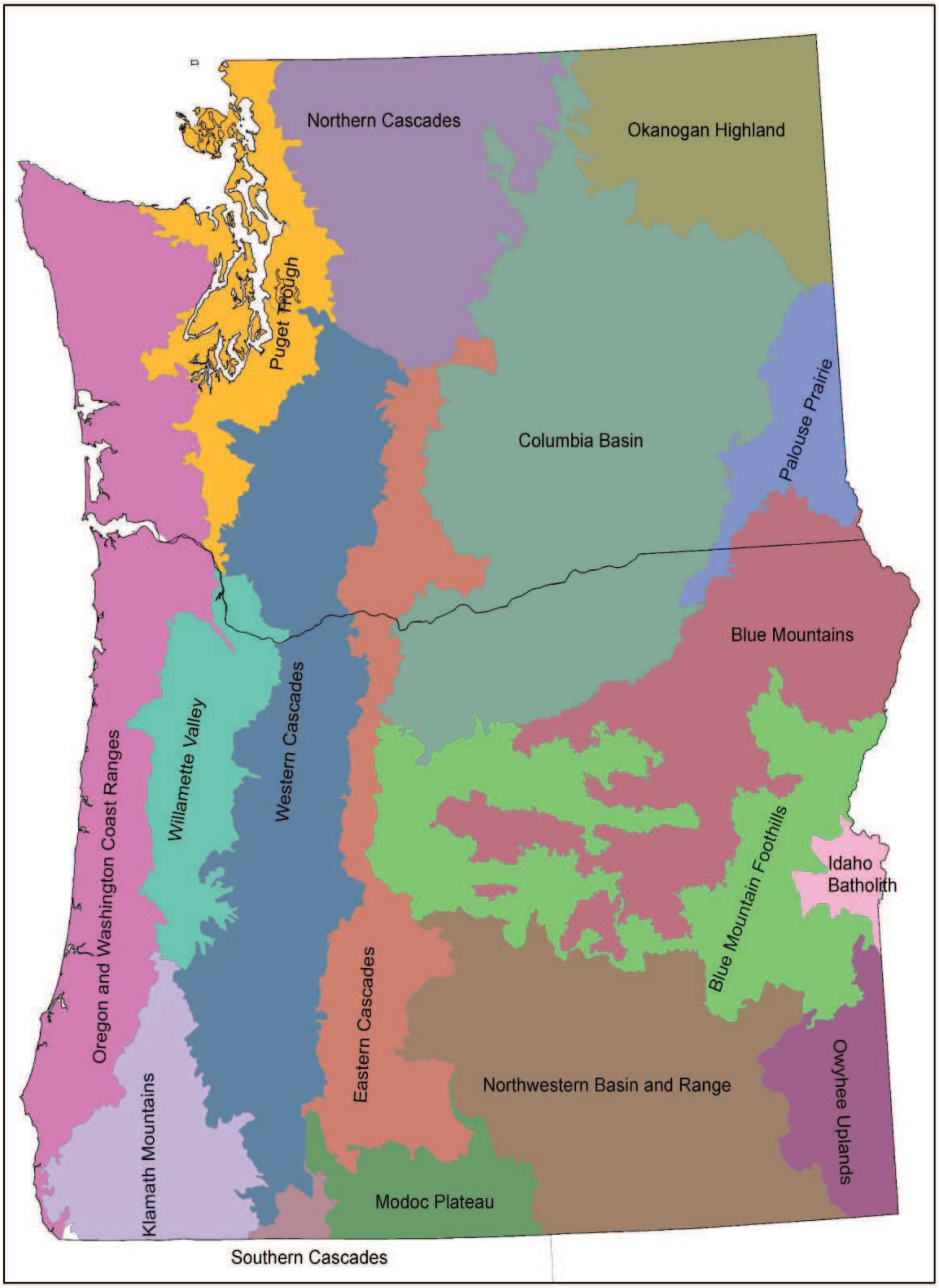


Table 2: Legend of terms for USFS/FIA data tables

Label	Translation	Label	Translation
BLM	*Bureau of Land Management*	**PNI**	*Private non-industrial*
NFSres	*National Forest Service Restricted*	**State**	*State-owned*
NFSunr	*National Forest Service unrestricted*	**Eco-total**	*Total for the eco-region*
Other	*Other land ownerships not captured by rest of categories*	**Tg CO2e**	*Teragrams carbon dioxide equivalent*
PI	*Private Industrial*	**Mg/ha**	*Megagrams per hectare (equivalent to metric tons per hectare*

Table 3: USFS/FIA data on carbon pools in Oregon forests (part 1)

Blue Mtns													
		Live Trees		Dead Trees		Down wood		Forest Floor (litter + duff)		soil (includes roots)		Forest Total	
Owner	Area (ac)	Tg CO2e	Mg/ha	Tg CO2e	Mg/ha	Tg CO2e	Mg/ha	Tg CO2e	Mg/ha	Tg CO2e	Mg/ha	Tg CO2e	Mg/ha
BLM	906,003	13.9	38.2	1.7	4.8	3.0	8.3	5.2	14.3	116.0	317.4	139.9	383.0
NFSres	862,078	72.6	208.9	22.9	65.9	19.4	55.8	13.1	37.6	104.6	300.9	232.6	669.1
NFSunr	3,967,071	253.5	158.5	38.9	24.3	76.8	48.0	77.2	48.2	475.7	297.4	922.1	576.4
Other	24,758	0.8	83.4	0.0	0.0	0.1	14.4	0.1	11.5	3.6	361.6	4.7	471.0
PI	779,574	28.3	90.0	1.9	6.1	10.6	33.6	9.1	28.8	87.2	277.5	137.1	436.1
PNI	1,481,124	40.0	67.0	1.9	3.2	9.2	15.5	17.7	29.6	192.4	322.2	261.3	437.5
State	42,032	2.4	138.9	0.3	20.2	0.2	11.1	0.5	31.9	5.5	323.9	8.9	526.0
Eco Total	8,062,640	411.5	126.6	67.7	20.8	119.4	36.7	122.9	37.8	985.1	303.0	1706.6	524.9
Coast Range													
		Live Trees		Dead Trees		Down wood		Forest Floor (litter + duff)		soil (includes roots)		Forest Total	
Owner	Area (ac)	Tg CO2e	Mg/ha	Tg CO2e	Mg/ha	Tg CO2e	Mg/ha	Tg CO2e	Mg/ha	Tg CO2e	Mg/ha	Tg CO2e	Mg/ha
BLM	794,448	185.2	578.0	12.2	38.2	27.7	86.4	16.9	52.6	142.1	443.4	384.0	1,198.6
NFSres	62,281	18.5	738.1	1.8	70.4	1.7	65.8	2.1	85.0	12.7	504.2	36.8	1,463.5
NFSunr	711,453	196.5	685.0	19.0	66.1	22.9	79.8	25.5	88.9	145.8	508.4	409.7	1,428.2
Other	62,114	7.9	316.7	0.5	21.8	1.2	47.0	2.9	114.4	15.3	609.3	27.8	1,109.4
PI	2,203,390	248.7	279.9	13.1	14.8	72.7	81.9	66.0	74.3	431.1	485.3	831.7	936.2
PNI	736,450	79.1	266.3	3.2	10.9	15.6	52.4	22.4	75.3	166.4	560.3	286.6	965.2
State	656,638	123.1	464.8	9.8	37.0	27.1	102.2	22.0	83.3	124.8	471.5	306.8	1,158.8
Eco Total	5,226,774	859.0	407.6	59.7	28.3	168.7	80.1	157.8	74.9	1038.2	492.6	2283.4	1,083.4

Table 4: USFS/FIA data on carbon pools in Oregon forests (part 2)

East Cascades													
		Live Trees		Dead Trees		Down wood		Forest Floor (litter + duff)		soil (includes roots)		Forest Total	
Owner	Area (ac)	Tg CO2e	Mg/ha	Tg CO2e	Mg/ha	Tg CO2e	Mg/ha	Tg CO2e	Mg/ha	Tg CO2e	Mg/ha	Tg CO2e	Mg/ha
BLM	44,270	0.9	48.6	0.0	2.1	0.5	27.4	0.6	36.1	4.5	253.0	6.6	367.2
NFSres	145,041	15.5	264.9	3.1	52.6	3.6	61.9	2.9	48.8	15.3	261.7	40.3	689.9
NFSunr	2,309,623	149.0	160.0	15.5	16.6	41.8	44.9	43.9	47.2	244.8	262.9	495.0	531.5
Other	33,591	1.1	84.3	0.0	2.1	0.5	35.0	1.3	98.7	6.1	453.3	9.1	673.4
PI	919,480	40.9	110.3	3.0	8.0	23.6	63.7	12.9	34.7	92.7	249.9	173.0	466.5
PNI	237,712	11.7	122.2	0.5	5.3	2.6	27.1	5.7	59.1	33.4	348.9	53.9	562.6
State	47,816	2.8	144.3	0.1	6.0	1.2	60.4	0.6	30.6	5.4	277.6	10.0	518.8
Eco Total	3,737,533	221.8	147.2	22.2	14.7	73.8	49.0	67.9	45.0	402.2	266.9	787.9	522.8
Klamath													
		Live Trees		Dead Trees		Down wood		Forest Floor (litter + duff)		soil (includes roots)		Forest Total	
Owner	Area (ac)	Tg CO2e	Mg/ha	Tg CO2e	Mg/ha	Tg CO2e	Mg/ha	Tg CO2e	Mg/ha	Tg CO2e	Mg/ha	Tg CO2e	Mg/ha
BLM	866,967	145.9	417.3	13.1	37.4	16.5	47.1	26.6	76.1	151.3	432.9	353.3	1,010.7
NFSres	234,890	32.6	343.9	6.2	65.4	2.9	30.7	2.4	25.9	44.7	472.1	88.8	937.8
NFSunr	847,087	137.6	402.9	24.5	71.7	15.7	46.0	17.2	50.4	159.7	467.6	354.7	1,038.6
Other	59,072	6.3	263.1	0.7	28.7	1.1	44.5	1.2	49.5	9.6	403.9	18.8	789.7
PI	756,591	58.5	191.7	3.1	10.3	16.1	52.7	17.2	56.5	118.8	389.3	213.7	700.5
PNI	637,818	56.0	217.7	4.2	16.3	7.7	29.9	15.1	58.9	113.7	442.0	196.7	764.8
State	36,421	6.2	421.8	0.3	19.3	0.9	59.2	0.5	31.3	5.6	380.2	13.4	912.0
Eco Total	3,438,846	443.0	319.5	52.0	37.5	60.8	43.8	80.3	57.9	603.4	435.2	1239.5	893.9

Table 5: USFS/FIA data on carbon pools in Oregon forests (part 3)

West Cacades													
		Live Trees		Dead Trees		Down wood		Forest Floor (litter + duff)		soil (includes roots)		Forest Total	
Owner	Area (ac)	Tg CO2e	Mg/ha	Tg CO2e	Mg/ha	Tg CO2e	Mg/ha	Tg CO2e	Mg/ha	Tg CO2e	Mg/ha	Tg CO2e	Mg/ha
BLM	443,141	94.5	529.1	9.1	50.9	13.7	76.5	9.0	50.6	82.6	462.5	209.0	1,169.5
NFSres	1,103,828	241.2	541.8	45.8	103.0	34.0	76.3	24.6	55.3	144.1	323.7	489.6	1,100.0
NFSunr	3,218,228	727.2	560.4	89.4	68.9	117.5	90.6	84.8	65.3	540.3	416.3	1559.2	1,201.5
NPS	166,922	27.9	415.2	3.7	54.5	3.9	58.3	2.1	31.9	16.2	240.9	53.9	800.8
Other	14,577	3.0	518.1	0.2	37.2	0.2	39.9	0.3	43.8	4.0	672.6	7.7	1,311.5
PI	1,294,278	133.1	255.1	8.2	15.8	43.2	82.7	26.7	51.2	228.9	438.5	440.1	843.3
PNI	385,612	45.2	290.6	1.8	11.3	12.6	81.1	9.3	59.9	76.1	489.7	145.0	932.6
State	60,873	8.4	342.2	0.8	30.7	4.4	179.1	1.3	54.7	11.5	469.2	26.4	1,075.9
Eco Total	6,687,459	1280.6	474.9	158.9	58.9	229.5	85.1	158.2	58.7	1103.7	409.3	2931.0	1,086.9
Other													
		Live Trees		Dead Trees		Down wood		Forest Floor (litter + duff)		soil (includes roots)		Forest Total	
Owner	Area (ac)	Tg CO2e	Mg/ha	Tg CO2e	Mg/ha	Tg CO2e	Mg/ha	Tg CO2e	Mg/ha	Tg CO2e	Mg/ha	Tg CO2e	Mg/ha
BLM	687,547	26.5	95.7	1.1	4.1	4.0	14.4	4.6	16.5	87.4	315.4	123.7	446.1
NFSunr	638,576	45.1	175.0	5.8	22.6	10.9	42.4	12.4	48.0	76.9	298.5	151.0	586.6
Other	25,993	1.4	129.8	0.0	2.9	0.2	15.0	0.5	43.9	4.8	458.4	6.8	650.0
PI	592,142	42.4	177.4	1.8	7.4	11.8	49.3	9.7	40.7	96.3	403.2	161.9	678.1
PNI	872,661	63.7	181.1	2.6	7.3	8.6	24.6	15.4	43.8	174.6	496.3	265.0	753.0
State	95,318	7.3	190.6	0.4	9.7	0.7	18.4	1.4	35.2	16.8	436.0	26.5	689.9
Eco Total	2,912,237	186.4	158.7	11.7	10.0	36.2	30.8	43.9	37.4	456.8	389.0	734.9	625.8

Table 6: USFS/FIA data on carbon pools in Oregon forests (part 4)

All													
		Live Trees		Dead Trees		Down wood		Forest Floor (litter + duff)		soil (includes roots)		Forest Total	
Owner	Area (ac)	Tg CO2e	Mg/ha	Tg CO2e	Mg/ha	Tg CO2e	Mg/ha	Tg CO2e	Mg/ha	Tg CO2e	Mg/ha	Tg CO2e	Mg/ha
BLM	3,742,376	466.9	309.4	37.3	24.7	65.3	43.3	63.0	41.7	584.0	387.0	1216.4	806.1
NFSres	2,408,117	380.4	391.7	79.8	82.1	61.5	63.4	45.1	46.5	321.3	330.9	888.1	914.6
NFSunr	11,692,038	1508.9	320.0	193.0	40.9	285.7	60.6	260.9	55.3	1643.3	348.6	3891.8	825.5
NPS	166,922	27.9	415.2	3.7	54.5	3.9	58.3	2.1	31.9	16.2	240.9	53.9	800.8
Other	220,105	20.6	231.9	1.5	17.0	3.2	36.6	6.2	70.0	43.4	488.9	74.9	844.4
PI	6,545,455	551.8	209.1	31.2	11.8	177.9	67.4	141.6	53.7	1054.9	399.7	1957.5	741.7
PNI	4,351,377	295.7	168.5	14.2	8.1	56.3	32.1	85.6	48.8	756.7	431.3	1208.5	688.8
State	939,097	150.1	396.5	11.7	30.8	34.4	90.8	26.3	69.5	169.5	447.7	392.1	1,035.4
State total	30,065,488	3402.3	280.6	372.3	30.7	688.4	56.8	630.9	52.0	4589.4	378.6	9683.2	798.7

Members of the OGWC Forest Carbon Accounting Advisory Task Force

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Fixing State Climate Policymaking

Key Takeaways and Recommendations for the Oregon Legislature

The State's climate policymaking machinery is not measuring up to the task of achieving GHG reduction goals and preparing the state for the effects of climate change. This failure is especially noteworthy for tasks not being informed by rigorous cost/benefit analysis, guided by agency assignments and benchmarks, and tracked for performance.

The Commission recommends that the Legislature direct agencies to collaborate with the Commission to set assignments (from the Commission's Roadmap) and benchmarks, and to report annually to the Commission on progress or lack of progress, and reasons why.

The Commission further recommends that the Legislature provide the Commission with modest but sufficient resources – staff and budget – to enable it to discharge its responsibilities in a timely and efficient way, including its analysis, communications and tracking functions.

Statement of the Problem

Oregon ought to be a national leader in advancing sound climate policy, and in many respects it is – in energy efficiency, renewables deployment, and urban transportation. These interim successes make the failures and blank spots more galling and less forgivable.

While individual agencies have taken up both emissions reduction and adaptation issues episodically, the State has no overall climate change adaptation/preparation strategy, action plan or investment criteria.

In 2016 Oregon made decided progress in addressing electric utility greenhouse gas (GHG) emissions,[27] but continued diligence is required to ensure our utilities are not replacing their reliance on one fossil fuel – coal – with overreliance on another – gas – to a degree that would ensure failure to meet Oregon's GHG goals. However, in the near- and mid-term, utilities face a need for resources that provide firm, on-peak energy. The challenge for utilities in pursuit of the state's low-carbon future is the current limited availability of non-emitting or low-carbon resources and technologies such as energy storage to meet this need in a least cost and least risk manner.

Oregon has limited State funding for the critical elements of transportation greenhouse gas reduction: electric vehicles incentives and transit/bike/pedestrian infrastructure, equipment and operations.[28]

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[27] SB 1547, passed in the short 2016 session, commits PGE and PAC to eliminating coal-generated electricity from Oregon's mix by not later than 2035 (and mostly by 2030), and increases the State Renewable Portfolio Standard for these utilities in steps to 50% by 2040.
[28] Per ORS 366.514, 1% of annual gas tax revenues are dedicated to bike and pedestrian infrastructure.

Oregon has insufficient understanding of the carbon contributions – credits and debits – of our forests[29] and agricultural lands and activities.

Oregon doesn't keep systematic track of, or seek to manage, consumption-associated emissions (e.g., waste management).

Oregon has no integrated state GHG policy on non-carbon/methane GHG's (e.g., CFC's, Ozone, N2O).

Oregon does not have a comprehensive current strategy for adapting to and preparing for the accumulating and already visible effects of climate change. Individual agencies and some communities have acted in this critical area, but their actions are isolated and often seriously dated.[30]

Oregon doesn't have a cost- and consequences-driven agenda of the most effective GHG abatement measures apart from an extremely modest[31] and dated analysis. When legislators ask if we're doing what's cost-effective first, we answer formulaically that energy efficiency is our priority (but even that's misleading since it's true primarily for electric and gas utilities, and not for other critical sectors such as transportation).

The Oregon Global Warming Commission was established by the 2007 Legislature and empaneled by Governor Kulongoski in 2008. The Legislature gave the Commission broad statutory responsibilities[32] but no authority and no operating budget. While the statute directed all State agencies to "support" the work of the Commission, that support is always subject to existing agency priorities for staff and budget. As a practical matter, the OGWC has had to rely on its own sparse resources, principally volunteer experts and funding raised from foundations.

These limitations notwithstanding, the Commission has provided significant value added to the State in numerous ways in its first eight years or so, often by acting as a stakeholder in

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[29] In 2016 the OGWC undertook to develop a basis for carbon accounting in Oregon's forests, and that work proceeds, but slowly, reflecting again the absence of resources to proceed with more dispatch.

[30] In 2010 Oregon State agencies undertook a planning exercise that resulted in a published Framework for Climate Adaptation. There has been no further cross-agency work since; neither has there been any lookback review of whether any of the recommendations were acted upon, and with what outcomes.

[31] Oregon spent $50K of federal recession grant money on a "McKinsey" curve analysis that left much to be desired when it was current, a condition it left behind years ago.

[32] "The Oregon Global Warming Commission shall recommend ways to coordinate state and local efforts to reduce greenhouse gas emissions in Oregon consistent with the greenhouse gas emissions reduction goals established by section 2 of this 2007 Act and shall recommend efforts to help Oregon prepare for the effects of global warming. In furtherance of the greenhouse gas emissions reduction goals established by section 2 of this 2007 Act, the Oregon Global Warming Commission may recommend statutory and administrative changes, policy measures and other recommendations to be carried out by state and local governments, businesses, nonprofit organizations or residents. In developing its recommendations, the commission shall consider economic, environmental, health and social costs, and the risks and benefits of alternative strategies, including least-cost options. The commission shall solicit and consider public comment relating to statutory, administrative or policy recommendations."

prompting and shaping State agency work. At the end of this section we have provided a short list of the more important contributions made by the Commission.

Remedy: Agency Accountability for Climate Action

This state of affairs has many causes which need not be belabored here. The remedy could be some combination of comprehensive enforceable emissions standards, and/or a cap-and-trade mechanism or carbon tax. In addition, but especially in the absence of any of these, there should be assignments to State agencies of principal responsibility for implementing aspects of the OGWC Roadmap, together with intermediate progress benchmarks and a reporting process that includes reasons for making or missing benchmarks. Reporting is not the same as directing; there need be no displacement of existing board and commission authority, still less of legislative oversight, which would be better informed with the fruit of the reporting.

This would, however, require a collecting-and-evaluation function that could be housed within a staffed OGWC that is authorized to negotiate benchmarks with agencies and require annual progress reporting. Initially working from the Commission's 2010 "Roadmap to 2020" (and revising as necessary), and with legislatively-adopted State emissions reduction goals[33] and adaptation/preparation needs, the Commission would:

1. consult with the State agencies in assigning primary responsibility for specific Roadmap[34] recommendations (and climate change adaptation/preparation recommendations, when completed); jointly with agencies, develop benchmarks where appropriate, and assign;
2. receive annual or biennial reports from the responsible agencies on progress on recommendations, or failure to make progress, and reasons for each;
3. evaluate these reports against goals and needs, and integrate commission findings into its Biennial Report to the Legislature in advance of each long session.

The Commission could request (but not require) similar reports from other parties (e.g., cities; Metropolitan Planning Organizations), following where recommendations lead.

The Commission would have no authority to direct State agencies, intervene between the agency and its governing board or commission, or compel any action. The authority would only be to assign responsibilities and receive annual progress reports. Since agency reasons for failure to make progress are often lack of resources or authority, this process is as likely to provide support for an agency as to be critical of its progress while informing the Legislature of needs for implementation resources and tools.

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[33] The 2007 Legislature adopted three emissions reduction goals: begin lowering emissions not later than 2010; be 10% below 1990 levels by 2020; and be at least 75% below 1990 levels by 2050. The OGWC subsequently recommended an interim goal: approximately 40% below 1990 levels by 2035.

[34] "Interim Roadmap to 2020" Recommendations adopted by the OGWC October 28, 2010 and submitted to the Legislature as the Commission's 2011 Biennial Report.

Remedy: An OGWC Operating Budget and Resources

The Commission's ability to evaluate the work of the agencies, and to consolidate the information into a form usable by the Legislature and Governor, is close to zero today. The Commission's ability to pursue a substantive agenda – for example, the Forestry Carbon Accounting project now underway – is challenging, requiring almost entire reliance on the availability of volunteered expertise and without funding to support even minimal professional analysis. In particular, the Commission's inability to apply systematic cost/benefit analysis to the range of emissions reduction strategies and adaptation planning choices available to the state is costly and crippling.

The Commission is (ably) supported by ODOE at a 1/3 FTE level *when* there is not a pre-empting demand for that person's time and expertise.[35] The Commission has no independent funding to contract for technical expertise, and no budget for communications[36] or citizen involvement. The 2017 Legislature could elect to provide a small budget for minimal staff support (an Executive Director and a staff support position) and for a level of technical analytic support sufficient to review agency reports and perform independent analysis (e.g., of the economic feasibility and cost-efficiency of alternative approaches to GHG abatement).

Summing Up

- Oregon's GHG emissions are not under control, and both GHG abatement and preparation for impending climate change need systematic, not random and opportunistic, attention.
- Not all, or even the largest part, of Oregon's GHG emissions are from utilities. The largest, and fastest growing such emissions are from transportation. Other sources (forests; agriculture) are unattended. A separate, cross-cutting function begs to be performed.
- The Legislature and Governor need systematic, carefully evaluated reporting from State agencies and the Commission on where progress is being made (and why), and where it is not (and needs attention from policymakers). They need to be provided this information in context, so they can distinguish between the immediate and the important, understand what their policy choices, and be informed of the associated costs and consequences as they consider different strategies.

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[35] For example, for much of 2016 OGWC's staff support was seconded to ODEQ to assist in producing a "carbon market mechanism" report required of ODEQ by the Legislature. The task was aligned with the work of the OGWC, but necessarily required deferral of elements of the OGWC's own chosen agenda.

[36] The OGWC web site was designed and constructed with private foundation funding solicited by the Commission. It has no funds to maintain even site security, and still less to use the site to actively engage Oregonians in State climate policymaking or planning, or provide access to means for Oregonians to reduce their carbon footprint or prepare for the effects of climate change.

- The Oregon Global Warming Commission needs at least the modest level of budget and staff support that would enable it to discharge the very broad range of responsibilities it has been assigned by the Oregon Legislature.

OGWC Deliverables and Contributions to State and Community Climate Efforts

1. Since 2008, provided the Legislature and Governor with four Biennial Reports, as required by law, that have tracked progress toward State GHG emissions reduction goals, have highlighted specific agency and community work in service to the goals, and have identified challenges and failures. The 2011 Report included the "Roadmap to 2020" strategy for meeting Oregon's 2020 GHG reduction goal, subsequently offered for review in community meetings around the state.
2. Participated with State agency heads and staff in development of Oregon Climate Change Adaptation Framework (2010), the State's only existing adaptation strategy document.
3. Participated and contributed as a stakeholder in ODOT processes leading to:
    - Development of GreenSTEP, an ODOT analytic model for identifying GHG-reduction transportation and land use choices;
    - Sustainable Transportation Strategy (STS_20XX);
    - Integration of GHG criteria within MOSAIC/Least Cost Transportation Planning tool development (20XX);
    - Developing GHG criteria for STIP (State Transportation Improvement Program) allocation of ODOT discretionary funding.
4. Participated and contributed as a stakeholder in ODEQ processes leading to:
    - Developing timely GHG emissions inventory data, especially for utilities and transportation, improving lag time from four years to six months.
    - Development of consumption-based GHG inventory, offering a different perspective on GHG's for which Oregonians are responsible.
    - Development of a "market mechanism" (e.g., carbon cap or tax) as an option for Oregon's management of GHG's.
5. Participated and contributed as a stakeholder in DLCD process leading to adoption of GHG targets for Oregon communities (Metropolitan Planning Organizations, or MPPO's); reviewing progress and revising goals in 2017.
6. Participated and contributed as a stakeholder in Oregon Health process leading to its Climate and Health Resilience Plan (2016).
7. Provided the 2016 Legislature with GHG reduction analysis of SB 1547, legislation to eliminate coal-generated electricity from serving Oregon loads and ramping up the State's Renewable Portfolio Standard to a 50% level by 2040.
8. Initiated a Forest Carbon Accounting project in 2016 to develop data and a basis for integrating carbon storage and release outcomes in forests with different State policies on forest health, harvest, forest biomass-to-energy choices, and other forest management practices.

9. The Commission and individual Members have also participated in and contributed to community-based climate and GHG reduction activities, including the Portland/Multnomah County Climate Action Plan, Metro's Climate Smart Strategy, and the City of Eugene Climate Action Plan.

Climate Impacts, Adaptation and Preparation

Among the OGWC's many charges are to track and evaluate the "economic, environmental, health, and social assessments of global warming impacts on Oregon and the Pacific Northwest"[37] and to "recommend efforts to help Oregon prepare for the effects of global warming."[38] Fortunately for the state (and augmenting the OGWC's limited efforts on this front), the 2007 Oregon Legislature created the Oregon Climate Change Research Institute (OCCRI), a network of over 150 researchers at Oregon universities and federal and state labs, with the purpose of facilitating research on climate change impacts in Oregon and supporting the OGWC in efforts to prepare for the effects of climate change.[39] OCCRI has just released their third Oregon Climate Assessment Report,[40] and we provide select excerpts from that report below.

OCCRI Third Assessment Key Takeaways

> **Oregon is warming and the consequences are, and will be, notable.**
> Three years have passed since the previous Oregon Climate Assessment Report (Dalton et al., 2013). These years have been the three warmest years globally (NOAA, 2016), and the last three decades have been the warmest three decades (IPCC, 2013). The Earth's climate undoubtedly is warming. The warming observed since the mid-20th century is largely due to an increase in greenhouse gas concentrations caused by human activities (IPCC, 2013).
>
> Oregon is warming, too. Consequences of this warming are already being felt by Oregonians. Snowpack is declining, summer streamflow is lowering, wildfire activity is increasing, sea level is rising, and coastal waters are acidifying. Such consequences and others are expected to continue into the decades to come. Indeed, the year 2015, in which global and Oregon temperatures were the warmest on record, foreshadows what typical conditions may look like by the middle of this century.
>
> **Adaptation is necessary, as mitigation alone will not prevent serious impacts.**
> In order to avoid negative impacts, now and in the future, we must both mitigate climate change and adapt to climate change. That is, we must try to reduce or even eliminate greenhouse gas emissions, and we must make preparations and adjustments that will be needed to meet new environmental conditions, doing so at all levels of government and society, from the highest international agreements down to our own personal actions (Bierbaum et al., 2014). International and local mitigation efforts are already underway, but these are not yet sufficient to limit global warming to 2°C (3.6°F) above preindustrial levels and to avoid the serious

[37] https://www.oregonlaws.org/ors/468A.250
[38] https://www.oregonlaws.org/ors/468A.235
[39] https://www.oregonlaws.org/ors/352.823
[40] http://www.occri.net/media/1042/ocar3_final_125_web.pdf

impacts of climate change. Accounting for the future emissions reduction pledges by countries participating in the 2015 Paris Agreement, the globe would still likely warm by 3°C (5.4°F) above pre-industrial levels by 2100 (Le Quéré et al., 2016).

Oregon must do more to adapt to climate changes already underway.
Climate change is happening here, now. The climate in our dear state is already changing and will continue to change. We know much about the expected effects of climate change that Oregon is likely to see. We must strive, in our governments and in our communities, to build resilience to climate change, and we must do so now. Although building resilience could be costly, it could be even more costly to suffer the losses and the damage that come from not being prepared for new conditions. A few state agencies, such as the Oregon Health Authority and the Oregon Department of Transportation, have already begun planning; and there are opportunities to build preparedness for climate change into existing planning efforts such as the Oregon Water Resources Strategy and the Natural Hazards Mitigation Plan. Furthermore, implementing climate adaptation actions can be compatible with other societal goals, such as sustainable development and disaster risk reduction (Bierbaum et al., 2014).

State Agency Efforts to Prepare for Climate Impacts

As noted in the OCCRI report, some Oregon agencies have begun work to prepare for the future effects of climate change. Despite efforts at a few select agencies, there remains no statewide strategy for identifying adaptation and preparation needs or tracking progress toward meeting those needs. At the State level the only effort to look broadly across all agencies' responsibilities took place in 2010[41] and needs updating, particularly in light of the accumulated analysis and findings by OCCRI and other climate scientists. Some agencies, such as the Department of Forestry[42] and Department of Land Conservation and Development (through its support for local initiatives)[43] have begun work to develop adaptation strategies and make recommendations to decision-makers, but these efforts have not been carried through into actual work plans. Three agencies that have developed plans or strategies for addressing climate impacts are highlighted below.

Oregon Health Authority

In 2014, the Oregon Health Authority completed the Climate and Health Profile Report, which outlines the different health risks that will increase as our climate changes and describes the populations who are most vulnerable to these risks.[44] The report highlights increased

[41] Oregon Climate Change Adaptation Framework; http://www.oregon.gov/LCD/docs/climatechange/framework_summary.pdf

[42] https://www.oregon.gov/ODF/Documents/ForestBenefits/BOFATTCH201503040702ClimateChangeRecommendations.pdf

[43] http://www.oregon.gov/LCD/CLIMATECHANGE/Pages/index.aspx

[44] https://public.health.oregon.gov/HealthyEnvironments/climatechange/Pages/profile-report.aspx

occurrences of chronic diseases such as asthma, respiratory illnesses from increased ground-level ozone and wildfire smoke, and increased hospitalizations during extreme heat events, among other risks. It also describes how some communities, such as low-income households, American Indians, older adults, children, and communities of color, will be more affected than others.

The Oregon Health Authority recently released a Climate and Health Resilience plan that highlights strategies and policy priorities for state, local, and tribal public health practitioners and partners within the public health system.[45] The Resilience Plan focuses on strategies that not only prioritize hazards and increase preparedness, but also build community resilience to multiple hazards and climate impacts.

Oregon Department of Transportation

In 2012, ODOT produced a Climate Change Adaptation Strategy Report that assessed the potential impacts of climate change on Oregon's transportation infrastructure and the associated economic impacts.[46] The strategy outlines the range of possible actions that ODOT could take within its existing programs and initiatives, begins a discussion of the costs of inaction and the costs of adaptation strategies themselves, and suggests some next steps for the agency. The strategy recommended a comprehensive vulnerability and risk assessment to more clearly demonstrate the areas of higher risk, the formation of an ODOT Climate Change adaptation work group, and the identification of further research needs and data gaps. ODOT has developed analytic tools and data to help it plan for increased climate resilience, especially with respect to accelerating coastal erosion and landslide risk[47]. Beyond this, there remains much work to be done in identifying risks, developing operational and physical remedies, and

[45] http://public.health.oregon.gov/HealthyEnvironments/climatechange/Pages/resilience-plan.aspx

[46] http://www.oregon.gov/ODOT/TD/CLIMATECHANGE/docs/odot_adaptation_strategy_final.pdf

[47] (1) ODOT formed an Adaptation Work Group in 2013 to help inform and guide the agency's adaptation planning efforts.; (2) ODOT completed work on a Vulnerability Assessment and Adaptation Options Study in 2015, focused on state highways on the North Coast. The study was funded through the Federal Highway Administration (FHWA) Climate Resilience Pilot Program. Findings and lessons learned from the pilot study have informed ODOT's current and planned adaptation efforts. (3) ODOT has a Sea Level Rise Mapping and Guidance project currently underway. Through this project ODOT will determine how and when to use sea level rise data to inform planning and design of transportation projects. The project will use new flood and sea level rise inundation models available through a geographic information system (GIS) tool being developed as part of the project. (4) ODOT is looking to expand the use of data monitoring and risk assessments at high-priority coastal landslide sites. A coastal landslide and bluff retreat monitoring project is currently underway. Results from this research will inform rates of coastal change and targeted risk assessments for vulnerable coastal highways. This is long-term research scheduled for completion in 2023. (5) In 2016 ODOT received a federal (FHWA) applied research grant to explore the use of green infrastructure (or nature-based) engineering techniques that can help increase resilience of highways that are vulnerable to coastal erosion and storm surge. The project will develop a range of protection options at high risk sites and with input from land use regulators and coastal geo-morphologists. (6) ODOT is also participating in a national research panel focused on the use of climate change models to inform hydraulics and hydrologic design for bridges and culverts. (7) An emerging priority is the need to assess wildfire risks and mitigation strategies used before and immediately after catastrophic wildfire events that impact state highways.

deploying them elsewhere in the state's transportation infrastructure (for example, assessing wildfire risks and mitigation strategies that affect state transportation facilities).

Oregon Parks and Recreation Department

OPRD produced a Climate Response Preparedness and Action Plan in 2010 to help the department understand the potential effects of climate change and create a plan to inform actions.[48] It noted actions that could be taken within the department, such as incorporating sustainable practices into all facets of OPRD's mission, looking for opportunities to pursue carbon sequestration projects, and acquiring and restoring properties with wetlands that provide important ecosystem services that may help buffer against the effects of climate change.

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[48] http://www.oregon.gov/LCD/CLIMATECHANGE/Pages/index.aspx

Appendix: Oregon "In-Boundary" Greenhouse Gas Emission Data, 1990-2015

Note: All emissions data are expressed in million metric tons of carbon dioxide equivalent (MMTCO2e)

Table 8: Total Oregon Gross GHG Emissions, Including Emissions Associated with the Use of Electricity

1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
56	**58**	**58**	**63**	**64**	**65**	**68**	**69**	**70**	**72**	**71**	**67**	**67**	**66**	**68**	**66**	**68**	**70**	**68**	**65**	**64**	**62**	**60**	**60**	**60**	**63**

Carbon Intensity Data: A Different Light on our Emissions

In addition to our overall emissions, we should consider how our emissions per capita and per dollar of state GDP have changed over time. Looking at this data can help us be sure that recent declines in our in-boundary emissions are not due to the effects of net migration out of the state or loss of economic activity. The table below indicates that per capita emissions and the carbon intensity of our economy have declined since 2000, while our state population and GDP have risen over the same time period. In 2015, per capita emissions increased for the first time since 2000, although it is too early to know whether this is a trend that will continue.

Table 7: Carbon intensity data

	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Total emissions (Million Metric Tons)[1]	56.4	64.9	70.7	66.2	67.9	69.8	67.6	64.9	63.9	62.4	60.2	60.3	60.3	63.4
Population (Millions)[3]	2.8	3.2	3.4	3.6	3.7	3.7	3.8	3.8	3.8	3.9	3.9	3.9	4.0	4.0
Statewide per capita emissions (metric tons per person)[1,3]	19.8	20.4	20.7	18.3	18.4	18.7	17.9	17.0	16.7	16.2	15.5	15.4	15.2	15.8
State GDP ($2009 million)[2]	64,881	81,919	130,992	153,771	167,952	173,109	182,813	181,022	190,371	198,298	192,598	189,645	192,119	201,484
Carbon intensity (Metric tons/ $2009 million GDP)[1,2]	869.3	792.2	539.7	430.5	404.3	403.5	369.9	358.5	335.8	314.8	312.4	318.0	313.9	314.5

Sources: 1. Oregon GHG Inventory; 2. U.S. Department of Commerce (http://bea.gov/iTable/index_regional.cfm); 3. Portland State University Population Research Center (https://www.pdx.edu/prc/home)

While the carbon intensity data are a useful comparison to our inventory data, it is important to note that solving the problem of climate change will require absolute reductions in GHGs, not only reductions in emissions per person or per unit of output. It is for this reason that GHG reduction goals and targets around the world – including ours – are expressed in absolute terms. Nonetheless, we endeavor to present these additional data points wherever possible.

Table 9: Oregon Greenhouse Gas Emissions, Proportions by Economic Sector

Proportion by Key Sector

	Transportation	Residential & Commercial	Industrial	Agriculture
1990	37%	29%	25%	9%
1991	39%	29%	24%	8%
1992	39%	28%	25%	8%
1993	35%	32%	25%	8%
1994	36%	31%	25%	8%
1995	35%	31%	26%	8%
1996	35%	31%	27%	8%
1997	35%	31%	27%	8%
1998	35%	30%	26%	8%
1999	35%	31%	27%	7%
2000	34%	33%	26%	7%
2001	35%	35%	23%	7%
2002	35%	34%	22%	8%
2003	35%	35%	21%	9%
2004	36%	34%	21%	9%
2005	37%	33%	21%	9%
2006	37%	33%	21%	8%
2007	37%	35%	21%	8%
2008	35%	36%	21%	8%
2009	37%	37%	19%	8%
2010	36%	36%	19%	8%
2011	36%	36%	20%	9%
2012	37%	35%	19%	9%
2013	35%	36%	20%	9%
2014	35%	35%	21%	9%
2015	37%	35%	20%	8%

Table 10: Emissions from the Transportation Sector, Carbon Dioxide Only

	Carbon Dioxide									
	Motor Gasoline	Distillate Fuel	Jet Fuel, Kerosene	Natural Gas	Residual Fuel	Lubricants	Aviation Gasoline	LPG	Light Rail Electricity Use	Jet Fuel, Naphtha
1990	11.61	4.53	1.25	0.49	1.73	0.22	0.04	0.04	0.00	0.08
1991	11.78	4.84	1.39	0.48	2.66	0.20	0.04	0.04	0.00	0.11
1992	11.70	4.93	1.52	0.38	2.69	0.20	0.05	0.03	0.00	0.10
1993	12.11	4.66	1.66	0.27	1.76	0.20	0.04	0.03	0.00	0.07
1994	12.37	4.87	1.87	0.32	1.81	0.21	0.05	0.05	0.00	0.00
1995	12.40	4.57	2.05	0.40	1.49	0.21	0.05	0.03	0.01	0.00
1996	12.80	4.90	2.14	0.44	1.41	0.20	0.07	0.02	0.00	0.00
1997	12.21	5.06	2.34	0.71	1.51	0.21	0.06	0.02	0.00	0.00
1998	13.11	4.88	2.40	0.75	1.70	0.22	0.05	0.00	0.01	0.00
1999	13.26	5.49	2.64	0.58	1.12	0.23	0.06	0.01	0.02	0.00
2000	13.06	5.52	2.57	0.65	0.59	0.22	0.05	0.01	0.02	0.00
2001	12.96	5.14	2.14	0.60	0.55	0.20	0.08	0.01	0.02	0.00
2002	13.13	5.50	2.12	0.50	0.56	0.20	0.05	0.01	0.02	0.00
2003	13.00	5.37	2.29	0.38	0.71	0.19	0.05	0.02	0.01	0.00
2004	13.06	6.10	2.09	0.52	0.80	0.19	0.04	0.02	0.01	0.00
2005	13.20	6.35	2.21	0.41	0.88	0.19	0.05	0.04	0.01	0.00
2006	13.35	6.69	2.36	0.46	0.69	0.18	0.07	0.03	0.01	0.00
2007	13.26	6.90	2.31	0.53	1.02	0.19	0.07	0.02	0.01	0.00
2008	12.36	6.52	2.24	0.41	0.69	0.18	0.06	0.05	0.01	0.00
2009	12.38	6.46	2.67	0.45	0.36	0.16	0.05	0.04	0.01	0.00
2010	12.05	6.68	1.74	0.42	0.72	0.18	0.05	0.04	0.01	0.00
2011	11.59	6.60	1.83	0.32	0.42	0.17	0.04	0.04	0.01	0.00
2012	11.63	6.72	1.86	0.25	0.38	0.15	0.04	0.04	0.01	0.00
2013	11.10	6.33	1.78	0.26	0.27	0.16	0.03	0.05	0.01	0.00
2014	11.27	6.52	1.80	0.24	0.05	0.16	0.03	0.05	0.01	0.00
2015	12.32	7.12	1.97	0.24	0.05	0.16	0.03	0.05	0.01	0.00

Table 11: Emissions from the Transportation Sector, Methane, Nitrous Oxide, and HGWP Gases (Million Metric Tons of Carbon Dioxide Equivalent)

	Methane				Nitrous Oxide			HGWP
	Passenger & Light Vehicles	Non-Road Vehicles & Equipment	Heavy-Duty Vehicles	Natural Gas Distribution (sector share)	Passenger & Light Vehicles	Non-Road Vehicles & Equipment	Heavy-Duty Vehicles	Refrigerants, A/C, Fire Protection Use
1990	0.10	0.01	0.01	0.05	0.76	0.03	0.02	0.00
1991	0.09	0.01	0.01	0.05	0.76	0.04	0.02	0.00
1992	0.09	0.01	0.01	0.04	0.85	0.04	0.02	0.01
1993	0.09	0.01	0.01	0.03	0.92	0.04	0.02	0.04
1994	0.09	0.01	0.01	0.03	0.92	0.04	0.02	0.09
1995	0.08	0.01	0.01	0.04	0.94	0.04	0.02	0.21
1996	0.08	0.01	0.01	0.04	0.93	0.04	0.03	0.29
1997	0.08	0.01	0.01	0.06	0.98	0.05	0.03	0.38
1998	0.08	0.01	0.01	0.05	0.98	0.05	0.03	0.43
1999	0.07	0.01	0.01	0.04	0.97	0.04	0.03	0.49
2000	0.07	0.01	0.00	0.05	0.93	0.04	0.03	0.54
2001	0.06	0.01	0.00	0.04	0.86	0.04	0.03	0.58
2002	0.05	0.01	0.00	0.04	0.77	0.04	0.03	0.62
2003	0.05	0.01	0.00	0.03	0.71	0.04	0.03	0.64
2004	0.05	0.01	0.00	0.04	0.65	0.04	0.03	0.66
2005	0.04	0.01	0.00	0.03	0.58	0.04	0.02	0.68
2006	0.04	0.01	0.00	0.03	0.52	0.04	0.01	0.72
2007	0.03	0.01	0.00	0.03	0.44	0.04	0.01	0.76
2008	0.03	0.01	0.00	0.03	0.37	0.04	0.01	0.80
2009	0.03	0.01	0.00	0.03	0.31	0.04	0.02	0.85
2010	0.03	0.01	0.00	0.03	0.27	0.04	0.01	0.90
2011	0.02	0.01	0.00	0.02	0.23	0.04	0.01	0.92
2012	0.02	0.01	0.00	0.02	0.20	0.04	0.01	0.95
2013	0.02	0.01	0.00	0.02	0.18	0.05	0.01	0.99
2014	0.02	0.01	0.00	0.02	0.18	0.05	0.01	0.99
2015	0.03	0.01	0.00	0.02	0.16	0.04	0.01	0.99

Table 12: Emissions from the Residential and Commercial Sectors, Carbon Dioxide Only

	Carbon Dioxide								
	Residential Electricity Use	Commercial Electricity Use	Residential Natural Gas Combustion	Commercial Natural Gas Combustion	Commercial Petroleum Combustion	Residential Petroleum Combustion	Waste Incineration	Residential Coal Combustion	Commercial Coal Combustion
1990	5.93	4.66	1.27	1.11	0.79	0.76	0.17	0.00	0.00
1991	6.15	4.78	1.44	1.22	0.66	0.73	0.17	0.00	0.00
1992	5.86	4.85	1.27	1.08	0.59	0.61	0.16	0.00	0.00
1993	7.73	5.95	1.64	1.33	0.49	0.76	0.17	0.00	0.00
1994	7.62	6.21	1.60	1.27	0.46	0.74	0.16	0.00	0.00
1995	7.55	6.27	1.55	1.24	0.56	0.65	0.16	0.00	0.00
1996	7.84	6.39	1.84	1.42	0.50	0.62	0.16	0.00	0.00
1997	7.80	6.57	1.81	1.42	0.49	0.55	0.16	0.00	0.00
1998	7.79	6.55	1.92	1.45	0.54	0.53	0.16	0.00	0.00
1999	8.36	7.10	2.17	1.60	0.45	0.60	0.15	0.00	0.00
2000	8.43	7.28	2.12	1.56	0.54	0.62	0.15	0.00	0.00
2001	8.65	7.55	2.09	1.52	0.65	0.65	0.15	0.00	0.00
2002	8.28	7.25	2.11	1.51	0.58	0.62	0.15	0.00	0.00
2003	8.53	7.44	1.99	1.39	0.37	0.58	0.14	0.00	0.00
2004	8.49	7.39	2.06	1.40	0.35	0.44	0.14	0.00	0.00
2005	7.99	6.70	2.19	1.52	0.34	0.46	0.14	0.00	0.00
2006	8.26	7.00	2.25	1.53	0.32	0.42	0.14	0.00	0.00
2007	9.14	7.64	2.35	1.59	0.29	0.36	0.14	0.00	0.00
2008	9.03	7.40	2.45	1.65	0.37	0.44	0.13	0.00	0.00
2009	8.62	6.96	2.44	1.62	0.43	0.44	0.13	0.00	0.00
2010	8.22	6.75	2.61	1.74	0.41	0.35	0.13	0.00	0.00
2011	7.66	6.21	2.85	1.85	0.33	0.34	0.12	0.00	0.00
2012	7.21	6.05	2.28	1.51	0.24	0.29	0.13	0.00	0.00
2013	7.32	6.09	2.85	1.89	0.20	0.29	0.13	0.00	0.00
2014	7.09	6.11	2.56	1.76	0.22	0.27	0.13	0.00	0.00
2015	7.37	6.35	2.57	1.77	0.24	0.29	0.13	0.00	0.00

Table 13: Emissions from the Residential and Commercial Sectors, Methane, Nitrous Oxide, and HGWP Gases (Million Metric Tons of Carbon Dioxide Equivalent)

	Methane						Nitrous Oxide					HGWP
	Municipal Solid Waste Landfills	Natural Gas Distribution (sector share)	Municipal Wastewater	Residential Combustion Byproducts	Commercial Combustion Byproducts	Waste Incineration	Fertilization of Landscaped Areas	Residential Combustion Byproducts	Waste Incineration	Commercial Combustion Byproducts	Municipal Wastewater	Refrigerants, Aerosols, Fire Protection Use
1990	1.15	0.26	0.23	0.06	0.02	0.00	0.05	0.01	0.01	0.00	0.07	0.00
1991	1.16	0.27	0.23	0.06	0.02	0.00	0.05	0.01	0.01	0.00	0.08	0.00
1992	1.10	0.25	0.24	0.07	0.02	0.00	0.06	0.01	0.01	0.00	0.08	0.01
1993	1.08	0.29	0.24	0.08	0.02	0.00	0.05	0.01	0.01	0.00	0.08	0.03
1994	1.06	0.27	0.25	0.08	0.01	0.00	0.06	0.01	0.01	0.00	0.08	0.07
1995	1.02	0.27	0.25	0.08	0.01	0.00	0.06	0.01	0.01	0.00	0.08	0.15
1996	1.07	0.26	0.26	0.08	0.01	0.00	0.06	0.01	0.01	0.00	0.09	0.21
1997	1.14	0.26	0.26	0.07	0.02	0.00	0.07	0.01	0.01	0.00	0.09	0.26
1998	1.17	0.22	0.26	0.06	0.01	0.00	0.07	0.01	0.01	0.00	0.09	0.30
1999	1.18	0.24	0.27	0.06	0.01	0.00	0.05	0.01	0.01	0.00	0.09	0.34
2000	1.21	0.26	0.27	0.07	0.02	0.00	0.04	0.01	0.01	0.00	0.09	0.38
2001	1.27	0.25	0.28	0.11	0.02	0.00	0.06	0.02	0.01	0.01	0.09	0.41
2002	1.30	0.29	0.28	0.11	0.02	0.00	0.08	0.02	0.01	0.01	0.10	0.43
2003	1.37	0.26	0.28	0.11	0.02	0.00	0.09	0.02	0.01	0.00	0.10	0.45
2004	1.41	0.24	0.29	0.12	0.02	0.00	0.09	0.02	0.01	0.00	0.10	0.46
2005	1.40	0.26	0.29	0.08	0.02	0.00	0.08	0.01	0.01	0.00	0.10	0.48
2006	1.36	0.28	0.29	0.07	0.02	0.00	0.08	0.01	0.01	0.00	0.10	0.50
2007	1.46	0.26	0.30	0.08	0.02	0.00	0.08	0.01	0.01	0.00	0.10	0.53
2008	1.59	0.26	0.30	0.08	0.02	0.00	0.07	0.01	0.01	0.00	0.10	0.56
2009	1.62	0.28	0.31	0.12	0.02	0.00	0.06	0.02	0.01	0.00	0.11	0.59
2010	1.51	0.27	0.31	0.11	0.02	0.00	0.08	0.02	0.01	0.00	0.11	0.63
2011	1.45	0.37	0.31	0.11	0.02	0.00	0.08	0.02	0.01	0.00	0.11	0.64
2012	1.50	0.29	0.31	0.10	0.02	0.00	0.08	0.02	0.00	0.00	0.11	0.67
2013	1.55	0.30	0.31	0.14	0.02	0.00	0.05	0.02	0.00	0.00	0.11	0.69
2014	1.57	0.30	0.31	0.14	0.02	0.00	0.05	0.02	0.00	0.00	0.11	0.69
2015	1.76	0.34	0.35	0.14	0.02	0.00	0.05	0.02	0.00	0.00	0.10	0.69

Table 14: Emissions from the Industrial Sector, Carbon Dioxide Only

	Carbon Dioxide											
	Industrial Electricity Use	Natural Gas Combustion	Petroleum Combustion	Cement Manufacture	Coal Combustion	Ammonia Production	Urea Consumption	Waste Incineration	Iron & Steel Production	Soda Ash Production & Consumption	Limestone and Dolomite Use	Lime Manufacture
1990	5.98	2.60	2.62	0.22	0.14	0.07	0.01	0.07	0.70	0.03	0.01	0.09
1991	5.90	2.95	2.37	0.14	0.18	0.07	0.01	0.07	0.70	0.03	0.01	0.11
1992	5.83	3.16	2.82	0.17	0.22	0.07	0.01	0.07	0.70	0.03	0.01	0.12
1993	6.95	3.28	2.63	0.19	0.21	0.06	0.01	0.07	0.70	0.03	0.01	0.14
1994	6.97	3.40	2.40	0.21	0.27	0.07	0.01	0.07	0.70	0.03	0.01	0.15
1995	7.33	3.74	2.50	0.21	0.27	0.07	0.01	0.11	0.70	0.03	0.01	0.16
1996	7.72	4.75	2.03	0.36	0.19	0.07	0.01	0.05	0.70	0.03	0.01	0.17
1997	7.66	4.92	1.97	0.38	0.19	0.07	0.01	0.03	0.81	0.03	0.01	0.16
1998	6.51	5.58	2.50	0.40	0.07	0.07	0.01	0.03	0.75	0.03	0.01	0.17
1999	6.53	5.91	3.03	0.46	0.00	0.07	0.01	0.01	0.64	0.03	0.01	0.16
2000	7.57	4.06	2.59	0.44	0.00	0.07	0.01	0.02	0.75	0.03	0.01	0.14
2001	6.47	3.71	1.84	0.43	0.00	0.05	0.01	0.01	0.57	0.03	0.01	0.10
2002	5.80	3.73	2.01	0.43	0.10	0.06	0.02	0.01	0.44	0.03	0.01	0.07
2003	5.75	3.52	1.52	0.37	0.14	0.05	0.02	0.01	0.43	0.03	0.00	0.08
2004	5.64	3.75	1.67	0.42	0.13	0.06	0.02	0.01	0.43	0.03	0.01	0.10
2005	5.52	3.75	1.43	0.44	0.02	0.06	0.02	0.02	0.34	0.03	0.01	0.09
2006	5.66	3.78	1.57	0.45	0.25	0.06	0.02	0.01	0.36	0.03	0.01	0.08
2007	6.19	3.70	1.37	0.45	0.22	0.06	0.02	0.01	0.37	0.03	0.01	0.07
2008	5.87	3.67	1.48	0.32	0.16	0.06	0.01	0.03	0.37	0.03	0.01	0.06
2009	5.12	3.06	1.38	0.31	0.18	0.06	0.01	0.05	0.23	0.03	0.01	0.05
2010	5.11	3.49	1.31	0.46	0.00	0.11	0.02	0.04	0.03	0.03	0.01	0.05
2011	4.72	3.40	1.63	0.46	0.00	0.13	0.02	0.02	0.03	0.03	0.01	0.05
2012	4.59	2.96	1.57	0.45	0.00	0.11	0.02	0.01	0.03	0.03	0.01	0.05
2013	4.62	3.46	1.38	0.49	0.00	0.13	0.02	0.01	0.04	0.03	0.01	0.06
2014	4.82	3.44	1.41	0.69	0.00	0.13	0.02	0.01	0.03	0.03	0.01	0.06
2015	5.01	3.45	1.54	0.71	0.00	0.10	0.02	0.01	0.04	0.03	0.01	0.06

Table 15: Emissions from the Industrial Sector, Methane, Nitrous Oxide, and HGWP Gases (Million Metric Tons of Carbon Dioxide Equivalent)

	Methane						Nitrous Oxide			HGWP		
	Pulp & Paper Wastewater	Natural Gas Distribution & Production	Industrial Landfills	Combustion Byproducts	Food Processing Wastewater	Waste Incineration	Combustion Byproducts	Waste Incineration	Nitric Acid Production	Semiconductor Manufacturing	Refrigerant, Foam, Solvent, Aerosol Use	Aluminum Production
1990	0.34	0.08	0.03	0.01	0.00	0.05	0.00	0.00	0.36	0.00	0.31	0.34
1991	0.37	0.09	0.03	0.01	0.00	0.05	0.00	0.00	0.36	0.00	0.32	0.37
1992	0.42	0.09	0.02	0.01	0.00	0.04	0.00	0.00	0.36	0.00	0.31	0.42
1993	0.42	0.09	0.02	0.01	0.00	0.04	0.00	0.00	0.45	0.01	0.28	0.42
1994	0.46	0.09	0.02	0.01	0.00	0.04	0.00	0.00	0.50	0.03	0.25	0.46
1995	0.47	0.10	0.02	0.01	0.00	0.04	0.00	0.00	0.63	0.06	0.26	0.47
1996	0.50	0.10	0.03	0.01	0.00	0.04	0.00	0.00	0.69	0.09	0.27	0.50
1997	0.50	0.11	0.03	0.01	0.00	0.05	0.00	0.00	0.73	0.11	0.27	0.50
1998	0.56	0.11	0.03	0.01	0.00	0.04	0.00	0.00	0.97	0.13	0.28	0.56
1999	0.56	0.12	0.02	0.01	0.00	0.04	0.01	0.00	1.07	0.15	0.28	0.56
2000	0.56	0.13	0.02	0.01	0.00	0.04	0.00	0.00	0.97	0.16	0.27	0.56
2001	0.58	0.13	0.02	0.01	0.00	0.04	0.01	0.00	0.74	0.17	0.19	0.58
2002	0.55	0.14	0.02	0.01	0.00	0.03	0.01	0.00	0.83	0.18	0.08	0.55
2003	0.59	0.14	0.02	0.01	0.00	0.03	0.01	0.00	0.79	0.19	0.08	0.59
2004	0.61	0.14	0.02	0.01	0.00	0.03	0.01	0.00	0.75	0.20	0.09	0.61
2005	0.60	0.15	0.02	0.01	0.00	0.03	0.01	0.00	0.70	0.20	0.09	0.60
2006	0.59	0.16	0.02	0.01	0.00	0.04	0.01	0.00	0.77	0.22	0.09	0.59
2007	0.61	0.18	0.02	0.01	0.00	0.04	0.01	0.00	0.70	0.23	0.00	0.61
2008	0.63	0.19	0.02	0.01	0.00	0.03	0.01	0.00	0.64	0.24	0.00	0.63
2009	0.62	0.21	0.02	0.01	0.00	0.03	0.01	0.00	0.46	0.25	0.00	0.62
2010	0.64	0.23	0.02	0.01	0.00	0.03	0.01	0.00	0.36	0.15	0.00	0.64
2011	0.54	0.24	0.02	0.01	0.00	0.03	0.01	0.00	0.55	0.10	0.00	0.54
2012	0.62	0.24	0.02	0.01	0.00	0.04	0.01	0.00	0.46	0.13	0.00	0.62
2013	0.62	0.25	0.03	0.01	0.00	0.04	0.01	0.00	0.45	0.11	0.00	0.62
2014	0.62	0.26	0.03	0.01	0.00	0.04	0.01	0.00	0.51	0.11	0.00	0.62
2015	0.70	0.26	0.03	0.01	0.00	0.04	0.01	0.00	0.54	0.11	0.00	0.70

Table 16: Emissions from the Agriculture Sector (Million Metric Tons of Carbon Dioxide Equivalent)

	Carbon Dioxide		Methane			Nitrous Oxide		
	Urea Fertilization	Liming of Agricultural Soils	Enteric Fermentation	Manure Management	Agricultural Residue Burning	Agricultural Soil Management	Manure Management	Agricultural Residue Burning
1990	0.06	0.03	2.58	0.30	0.00	1.82	0.10	0.00
1991	0.06	0.02	2.60	0.30	0.00	1.73	0.10	0.00
1992	0.06	0.03	2.61	0.31	0.00	1.69	0.10	0.00
1993	0.07	0.03	2.60	0.30	0.00	1.83	0.09	0.00
1994	0.07	0.03	2.78	0.32	0.00	1.84	0.11	0.00
1995	0.07	0.03	2.94	0.32	0.00	2.00	0.12	0.00
1996	0.07	0.04	3.01	0.31	0.00	2.03	0.11	0.00
1997	0.08	0.04	3.00	0.32	0.00	2.16	0.11	0.00
1998	0.08	0.04	2.92	0.32	0.00	2.06	0.12	0.00
1999	0.07	0.04	2.93	0.34	0.00	1.91	0.13	0.00
2000	0.05	0.04	2.82	0.36	0.00	1.87	0.14	0.00
2001	0.08	0.04	2.66	0.37	0.00	1.72	0.14	0.00
2002	0.13	0.03	2.77	0.43	0.00	2.06	0.15	0.00
2003	0.14	0.03	2.76	0.42	0.00	2.13	0.15	0.00
2004	0.12	0.04	2.95	0.47	0.00	2.14	0.16	0.00
2005	0.12	0.04	2.97	0.47	0.00	1.92	0.14	0.00
2006	0.12	0.04	2.94	0.45	0.00	2.00	0.14	0.00
2007	0.13	0.04	2.63	0.45	0.00	2.01	0.14	0.00
2008	0.11	0.04	2.75	0.45	0.00	1.80	0.14	0.00
2009	0.10	0.03	2.58	0.44	0.00	1.70	0.13	0.00
2010	0.12	0.03	2.56	0.45	0.00	1.93	0.13	0.00
2011	0.13	0.04	2.68	0.47	0.01	2.01	0.13	0.00
2012	0.13	0.04	2.67	0.47	0.00	2.02	0.13	0.00
2013	0.14	0.05	2.44	0.47	0.00	1.94	0.13	0.00
2014	0.14	0.05	2.44	0.47	0.00	1.94	0.13	0.00
2015	0.14	0.05	2.44	0.47	0.00	1.94	0.13	0.00

Table 17: In-State Electric Power Generation Emissions and Derivation of Production-Based Emissions Inventory

	Carbon Dioxide			Methane	Nitrous Oxide	HGWP		Add In-State Electric Power Generation Sub-Total to Statewide Emissions Total	Production-Based Emissions Calculation Adjustment	
	OR Power Plant Natural Gas Combustion	OR Power Plant Coal Combustion	OR Power Plant Petroleum Combustion	OR Power Plant Combustion Byproducts	OR Power Plant Combustion Byproducts	Transmission and Distribution Systems	***In-State Electric Power Generation Sub-total***		Remove Total Electricity Use Emissions	***Gross Emissions, Production Basis***
1990	0.40	1.37	0.02	0.00	0.01	0.42	2.23		-16.57	42.02
1991	0.62	2.98	0.01	0.00	0.02	0.40	4.04		-16.83	45.57
1992	0.79	3.71	0.01	0.00	0.02	0.39	4.93		-16.55	46.80
1993	0.93	3.36	0.02	0.00	0.02	0.38	4.72		-20.63	46.76
1994	1.43	4.01	0.00	0.00	0.02	0.36	5.84		-20.81	48.81
1995	1.05	1.67	0.01	0.00	0.01	0.32	3.07		-21.16	46.80
1996	1.42	1.77	0.00	0.00	0.01	0.31	3.52		-21.96	49.42
1997	1.30	1.39	0.01	0.00	0.01	0.28	2.99		-22.02	49.58
1998	2.86	3.31	0.03	0.01	0.02	0.22	6.44		-20.85	55.49
1999	2.68	3.54	0.01	0.00	0.02	0.22	6.47		-22.00	56.96
2000	3.75	3.55	0.04	0.01	0.02	0.22	7.59		-23.29	55.04
2001	4.47	3.98	0.08	0.01	0.03	0.19	8.75		-22.69	53.47
2002	3.01	3.36	0.01	0.00	0.02	0.17	6.58		-21.35	52.35
2003	4.03	3.98	0.04	0.01	0.03	0.16	8.24		-21.73	52.80
2004	4.80	3.21	0.02	0.00	0.02	0.15	8.20		-21.53	54.18
2005	4.76	3.25	0.04	0.01	0.03	0.14	8.22		-20.21	54.18
2006	4.08	2.22	0.00	0.01	0.02	0.13	6.46		-20.93	53.47
2007	5.56	3.95	0.00	0.01	0.03	0.11	9.66		-22.97	56.54
2008	6.31	3.64	0.01	0.01	0.02	0.11	10.10		-22.31	55.41
2009	5.89	2.86	0.00	0.01	0.02	0.10	8.88		-20.71	53.06
2010	5.95	4.04	0.00	0.02	0.03	0.09	10.13		-20.09	53.97
2011	3.25	3.32	0.00	0.01	0.02	0.09	6.70		-18.61	50.52
2012	4.46	2.65	0.00	0.01	0.02	0.08	7.22		-17.86	49.52
2013	5.47	3.65	0.00	0.01	0.02	0.07	9.23		-18.04	51.49
2014	4.86	3.10	0.01	0.01	0.02	0.07	8.07		-18.02	50.46
2015	5.91	2.30	0.01	0.01	0.02	0.07	8.31		-18.74	52.95