Oregon Global Warming Commission

[DRAFT] 2018 Biennial Report to the Legislature

For the 2019 Legislative Session

Cover Photo Credit: Angus Duncan
Mt. Washington from Black Butte Ranch
near Sisters, Oregon
September 1, 2017

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Executive Summary

[Under development]

2018 Letter from the Chair

> "Owing to past neglect, in the face of the plainest warnings, we have now entered upon a period of danger…The era of procrastination, of half-measures, of soothing and baffling expedients, of delays, is coming to its close. In its place we are entering a period of consequences…We cannot avoid this period; we are in it now."
>
> **Winston Churchill, in the House of Commons, November 1936**

Government and leadership have come a long way from Churchillian rhetoric in those dark days leading into World War II, and not in any direction that should give us comfort. As grim as the world's prospects were in the 1930's, at least there were Churchills and Roosevelts summoning us to the great tasks of those times.

We've looked for that kind of leadership over the 30 years or so that climate change has loomed as an existential threat to our society and our children's future. Rarely have we found it. Identifying a climate threat so profound has been difficult in the absence of immediate physical evidence that the climate was changing, but not more so than inferring a threat from a rearming Nazi Germany. Most of the world, and most of the United States, then and now, chose to look elsewhere, to more immediate opportunities, smaller tasks and narrower challenges. Climate science, after all, spoke in data sets and modeled probabilities. Outcomes remained fuzzy around the edges. Our leaders would have to ask us to make often uncomfortable changes in budgets, policies and livelihoods, to forestall . . . probabilities.

The time of probabilities is now past. The first tangible effects of climate change are upon us. We see it in stronger hurricanes inundating coastal communities around the world. We see it in the smoke blanketing our state and region from forest fires that start earlier, persist longer and burn more extensively; smoke that is attacking the lungs of our children, of the elderly and the asthmatic. We see it in half-full reservoirs and mountaintops devoid of midwinter snow. (See Section 1 of this Report for links between earlier projections of climate effects and the realized ones of today.)

Progress and Slippage

In this Report the Global Warming Commission reviews Oregon's successes and remaining challenges in meeting its greenhouse gas emissions goals. This Letter reflects my profound concern, after ten years as Commission Chair, with whether we are rising to the challenges in meaningful and sufficient ways.

I wrote the first of these Report Letters as a forward to our 2009 Report to the Legislature. In that letter I described as "unvarnished good news" the wind projects and solar cell manufacturing, the "green buildings" and energy efficient land use choices that we thought would make Oregon a leader for dark but not hopeless times. The country had just elected a President committed to addressing climate issues. The Congress was debating national carbon cap legislation. Countries around the world were telegraphing their parallel commitments to a global climate strategy.

Indeed, much has been accomplished in the ten years since, especially in the realm of energy technologies that are replacing the nation's fleet of superannuated coal plants with cleaner (but, let us be clear, still not *clean*) gas supplies, and with wind and solar plants that are offering ever lower costs and higher efficiencies. This cleaner, carbon free electricity, we speculated then, could power an emerging fleet of electric cars, trucks, buses, possibly even aircraft.

Momentum is still evident globally. In 2018 two of the last three holdouts from the Paris Climate Accord, Nicaragua and Syria, signed on. Only the United States of America, once a global leader for responsible climate action, now remains outside the global accord, its politics dominated by feckless policies that are indifferent or outright hostile to the tested, peer-reviewed findings of science. This is leadership of a sort, but of a sort that will lead the country over the climate cliff.

So it falls to us as Oregonians and Washingtonians and Californians, as citizens of San Francisco and Portland and Chicago and New York, to demonstrate what real leadership is in coping with the slow-motion but inexorable emergency we face. It falls to us to rescue the country from itself, to bear our share of the burden and realize our share of the promise to the rest of the world.

Oregon's Emissions Inventories

The Inventory section of this 2018 Report carries both encouraging and challenging news. We can be legitimately encouraged by accomplishments and opportunities in the electric utility sector. The ten years past have seen:

- PGE's decision to end coal burning at Oregon's only in-state coal plant at Boardman;
- a negotiated agreement between environmental groups and our two large electric utilities, validated by the 2016 Legislature, to terminate coal-generated electricity imports by 2030, and sharply increase renewables in the mix; and
- PGE's corporate commitment to "deep decarbonization, and the determination of Northwest Gas to seriously exploring the potential of renewable gas and hydrogen.

The combined effects of these commitments, fully realized, should drive utility emissions to, and below, a proportional share of Oregon's greenhouse gas goals (see the section in the Inventory section of this Report on utility emissions).

The mounting challenge we face is with transportation emissions, which have been rising since 2013 after several years of flat-lining or incrementally dropping. Other states are showing the same backsliding effects as the effects of the 2008 Great

Recession retreat. More miles[1] are being driven in larger and less fuel-efficient cars, while the Trump Administration undermines the effectiveness of national vehicle fuel economy standards.

And the strategy of negotiated change that has been successful with two electric utilities is harder to succeed at with Oregon's three million vehicle owners/drivers. Alternative vehicles are slowly entering the market, notwithstanding that electric vehicle purchase costs are coming down, their operating costs are far lower than for gasoline and diesel vehicles, and their range between charging sessions is dramatically up[2].

To lock in real emissions reductions and shore up slippage, leadership from the Oregon Legislature and Governor on climate issues is crucial in 2019. A carbon cap will inform Oregon drivers of both the costs of failure and the rewards of success, while encouraging movement to more cost- and carbon-efficient travel. The cap is the largest missing building block (first called for in Governor Kulongoski's Advisory Group Report in 2003) in Oregon's carbon strategy. The Joint Committee On Carbon Reduction chaired by President of the Senate Courtney and Speaker of the House Kotek, and with an admirable membership from both legislative chambers, assures that this issue is getting serious legislative treatment at long last.

Consumption-Based Emissions

Oregon's consumption-based inventory tracks our state's greenhouse gas footprint as measured by the emissions we create with our consumption choices. Through it we can calculate – and choose to take responsibility for – the emissions associated with the overseas fabrication of a product, its transport to Oregon, its use and disposal here, even if some of the emissions may originate in Europe or Asia. These emissions numbers are rising also. This outcome is a function of increased consumption by Oregon households and businesses and is consistent with post-recession economic growth. As Oregon consumers purchase more goods and services, a share of these are imported from producers in other countries, often where carbon efficiencies are poorer than here. Increased consumption of imported goods means increased total and per capita *consumption-based emissions*.

In the near future Oregon will need to heed these findings by considering consumption-based emissions reduction goals and tools, since wherever those emissions occur, they are an outcome of our choices and will result in global climate change that affects Oregonians.

Oregon Forest Carbon Accounting

Oregon's forests are world-class at capturing and holding atmospheric carbon in their trunks, roots, and soils, on par with equally-dense tropical and Alaskan rain forests. The OGWC's Forest Carbon Accounting Project worked with the US Forest Service and

[1] . . . a 14% increase since 2012, or up more than 4.5 billion more vehicle miles traveled in Oregon in 2016 (37.5 billion) compared to 2012 (33.0 billion) (per USFHWA, ODOT, Oregon Office of Economic Analysis – [oregoneconomicanalysis.com]).

[2] >300 miles for the latest Kia e-Niro

Oregon State University scientists to reveal some striking findings: that some 11 billion tons of CO2e[3] are packed into Oregon forests today; and that we appear to be increasing that store at somewhere between 15 million tons and 60 million tons (CO2e) annually.[4] We were further advised that the opportunity exists to substantially increase this uptake and storage through modest changes in forest management and harvest practices. Reducing our (mostly) energy-related emissions plus increasing forest carbon capture and sequestration could move Oregon toward overall carbon neutrality by the 2030's, and to negative carbon thereafter; that is, go from being part of the problem to being a notable part of the global solution. In the process we could pioneer forest carbon measures for other forested jurisdictions. The 2019 Legislature can take a significant step in this direction by packaging forest carbon incentives into its carbon cap legislation.

Extreme Climate Events

Section 1 of this Report outlines in sometimes painful detail the climate change effects Oregon, and the wider world, have already begun to suffer. The Fourth National Climate Assessment (2017)[5] allocates a chapter to "Potential Surprises: Compound Extremes and Tipping Elements." Chapter 15 of the Assessment notes the significant ways in which "average" projections could be decidedly worse. It observes that "climate models are more likely to underestimate than to overestimate the amount of long-term future change." It notes that "compound extreme events (such as simultaneous heat and drought, wildfires associated with hot and dry conditions, or flooding associated with high precipitation on top of snow or waterlogged ground) can be greater than the sum of the parts." "Tipping points" are generally stable conditions that can be "tipped" into highly unstable ones by a small increment of climate change – a needle that breaks the camel's back – such as a small degree of Antarctic warming that could release a rapid disintegration and melting of glacial ice, raising sea levels more rapidly than humans are prepared to adapt to them. It warns us that as devastating as linear effects of climate change will be, the non-linear effects may be far more so because we are unprepared to cope with them.

In Oregon those effects might include a dramatic die-off of forests (such as has occurred already in Canadian and Alaskan boreal forests, and in the Russian taiga forests), or unlooked for sea level rise that swamps Oregon coastal communities, economies and highways.

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[3] Forest carbon only becomes carbon dioxide when the fiber burns (oxidizes). We can restate quantities of forest carbon as a "carbon dioxide equivalent" to allow one-to-one comparisons of carbon stored in trees with carbon dioxide emissions released when fossil fuels are burned using standard conversion factors.

[4] For reference, note that Oregon's total annual Sector Inventory emissions are about 60 million metric tonnes CO2e. A metric tonne is equal to 2200 pounds, or 1.1 short tons.

[5] US Global Change Research Program, Volume 1, Chapter 15. 2017

Oil Companies: A Final Note

We applaud the real progress Oregon has made in resetting our electric utilities toward a low carbon future, and regret our failure to do the same in transportation. Much of this slow slog is due to the well-financed[6] resistance from oil companies determined to extract the last dollar of profit out of a product that has no place in a decarbonized world. Upton Sinclair, quotable muckraker from this country's first Gilded Age, said it best:

> *It is difficult to get a man to understand something when his salary depends upon his not understanding it.*

But even Upton Sinclair could not have imagined the irony of this same oil industry, while pumping more US oil than ever before and laboring to protect its markets, at the same time asking for oceanfront "protection" from rising sea levels along the Texas Gulf coast. The State of Texas is seeking $12 Billion in federal funding to build "a 60-mile spine of concrete seawalls, earthern barriers, floating gates and steel levees" to protect one of the world's largest concentrations of petrochemical facilities, including most of Texas' 30 refineries, which represent 30% of the nation's refining capacity." The spine would reach from Louisiana to south of Houston.

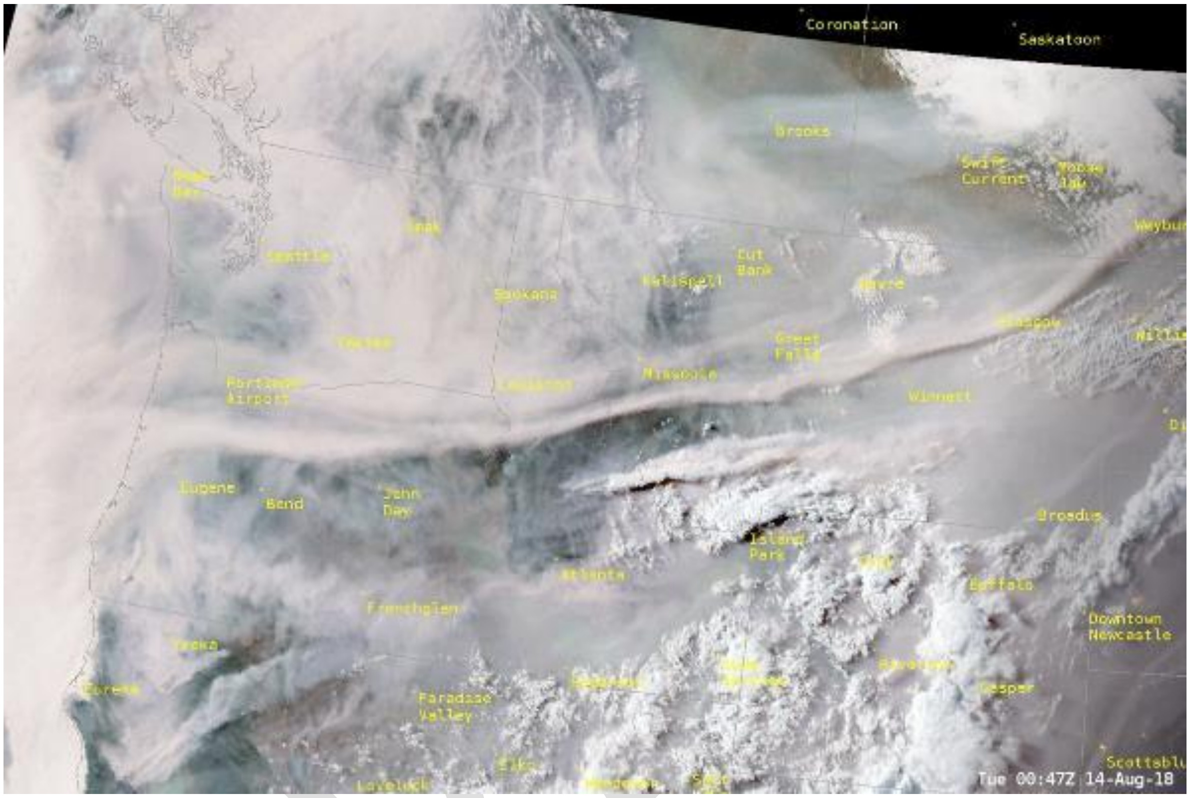
"Our overall economy . . . is so much at risk from a high storm surge," said Republican Bazoria County judge Matt Sebesta. Republican Senators John Cornyn and Ted Cruz both support this use of taxpayer funds to protect the oil industry from, in effect, itself. The first commitment of $3.9 billion was fast-tracked by the Administration after Hurricane Harvey hit the Texas coast a year ago, knocking out a quarter of the area's oil refining capability.[7]

Not Upton Sinclair, not Doonesbury, not even The Onion, could imagine theater absurd as this. I leave readers to draw their own conclusions.

Angus Duncan, Chair
Oregon Global Warming Commission
September 24, 2018

[6] Most recent financial filings in Washington's Measure 1631, on the ballot this fall, which would establish a carbon fee in that state, showed >75% of the $16 million received by the No on 1631 campaign are from oil companies.
[7] Associated Press report in The Oregonian/OregonLive 26 August, 2018.

Section 1: Climate Change Comes to Oregon 2018



Smoke Across the PNW. National Weather Service Photo 7:28 pm August 13, 2018

The Oregonian for Wednesday, August 15, 2018 led with the story of smoke that “choked” the Portland airshed from forest fires “filtering into Northeast Oregon from blazes in almost all directions . . . Washington, British Columbia, Eastern Oregon . . . (and) Northern California.” DEQ issued an air quality advisory warning people to stay indoors if possible, especially children, seniors, and those with respiratory conditions.

The Oregon Smoke Blog for August 21 read: “Currently all Oregon counties except Coos and Curry are under air quality advisories . . . . “[8]

Less than a year ago Portlanders awoke to a similarly brownish haze obscuring the sky, and the same public health advisory. DEQ said 2017 was “different” from earlier bad fire years in that “the entire state is . . . blanketed by smoke” coming from not only the Eagle Creek fire in the Columbia Gorge but a dozen fires from the Rogue River to Mt. Hood, along with fires in Canada and California. DEQ called the condition “rare.”

But it’s not, anymore.

[8] http://oraqi.deb.state.or.us/home/map

Larger forest and grassland fires are more frequent, a consequence of warmer, drier summers. The fire season begins earlier and ends later[9].

On August 15 of this year the National Interagency Fire Center reported fires burning in all 13 Western State west of the 100th Meridian; 108 "active large fires", four of which were contained. On August 22, the Forest Service reported "23 large fires burning nearly 440,000 acres" in Oregon (@ ForestServiceNW). The 80,000 acre "Substation Fire" near The Dalles, OR, in July burned one to two million bushels of wheat at a cost of ≥$5 million. Farmers in the fire's path "got wiped out, most of their crop if not all," said Tara Simpson of the Oregon Wheat Commission.[10]

At least Oregon communities have been spared the devastation suffered in California: deaths and whole neighborhoods destroyed in Redding this year, and in Santa Rosa last year. Of California's 15 largest fires (by acreage), 12 have occurred since 2000, three of them this year and last[11].

Oregon communities have not been spared other impacts, however. Last year's Eagle Creek fire closed Interstate 84 for three weeks, disrupting personal and commercial traffic, adding costs and delays to shipping. The Shakespearean Festival in Ashland had to cancel or relocate 26 performances from its outdoor theater in 2018, more than in its smoke-plagued 2017 season (each cancellation directly costs the Festival $50,000 in foregone revenues – an estimated $2 million total loss in 2018 -- and the Ashland community, thousands more in foregone lodging, food and drink revenues from missing playgoers).[12] In 2017 the Central Oregon town of Sisters canceled its September Folk Festival, a signal tourist draw and community money maker (estimated lost community earnings in excess of $1 million).

Here's how the Oregon Climate Change Research Institute (OCCRI), in its 2017 Oregon Climate Assessment, described prevailing conditions:

> "Over the last several decades, warmer and drier conditions during the summer months have contributed to an increase in fuel aridity and enabled more frequent large fires, an increase in the total area burned, and a longer fire season. . . .[13]"

And here is OCCRI's forward look at forest wildfire, from its 2010 Assessment:

> **"Wildfire is projected to increase in all Oregon forest types in the coming decades.** Warmer and drier summers leave forests more vulnerable to the stresses from fire danger west of the Cascades. Wildfire in forests east of the Cascades is mainly influenced by vegetation growth in the winters that provides fuel for future fires. An in- crease in fire activity is expected for all major forest types in the state under climate change. Large fires could become more common in western Oregon forests[14].

Even earlier, the University of Washington Climate Impacts Group wrote, in 1999:

> **". . . the net direct effect of the climatic changes is not likely to be favorable** to the productivity and stability of existing forests. Warmer summers, leading to increased evapotranspiration, are likely to overwhelm any benefits of increased CO fertilization. Predicted climatic changes are

[9] See OCCRI Third Climate Assessment, Chapter 5 Forest Ecosystems, January 2017

[10] Reported in The Oregonian/Oregon Live July 20

[11] Berke, Business Insider July 31, 2018 (https://www.businessinsider.com/ventura-county-la-fires-california-worsening-trend-2017-12).

[12] "Wildfire smoke costs famed Oregon Shakespeare Festival" Associated Press report 25 September, 2018

[13] FOOTNOTE

[14] FOOTNOTE

likely to have profound. . . immediate and easily observed impacts . . . most obvious in the case of fire where increased summer temperatures and moisture deficits will substantially increase the potential for the occurrence, intensity, and extent of wildfires.[15]"

Past Reports to the Legislature from the Global Warming Commission (OGWC) and OCCRI have been heavy on predicting what Oregonians can expect *in the future* if climate change is not brought under control. But those climate effects *predicted* for Oregon in 2010 and earlier have arrived on our doorstep in 2018: fire, flooding, drought, disease and health impacts, heat, sea level rise, erosion of Oregon's coastline, and damage to fragile forest, grassland, aquatic and alpine ecosystems and the plants and animals they contain.

The personal and economic consequences that once were distant predictions are becoming accomplished fact.

So this Report will be different. It reports, below, how those earlier predictions are coming true. It reports not the future but the present.

It's not a comforting sight.

Elsewhere in the country in 2018, summer fires raged across California. Yosemite Valley closed for three weeks due to smoke and fire risk. Residences in large sections of Santa Rosa (2017) and Redding (2018) burned with loss of life and property. Notwithstanding adequate soil moisture content from winter precipitation in both 2017 and 2018, California experienced intense fires.

"The factor that clearly made the difference in 2017, and again in 2018, is heat," said Professor Park Williams of Columbia University. *"Last summer was record-breaking, or near record-breaking, hot across much of the West, and I believe July 2018 will break records or come close to it again this year. Even if the deep soils are wet following winter and spring, a hot and dry atmosphere seems to be able to overwhelm that effect*." In fact July 2018 was the hottest month California has ever recorded[16].

And, with reference to increased extent of forest fires: "*We estimate that human-caused climate change contributed to an additional 4.2 million ha of forest fire area during 1984–2015, nearly doubling the forest fire area expected in its absence.*[17]"

Elsewhere on the planet in 2018, intense and rapidly moving fires in Greece this summer left 97 dead and communities devastated, with more than 1000 buildings destroyed or damaged[18]. Europe coped with its worst heat wave and drought in decades; countries as far north as Sweden were fighting forest

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[15] Mote, P.W., and 18 co-authors, 1999: *Impacts of climate variability and change: Pacific Northwest.* Page 67. Report of the JISAO/SMA Climate Impacts Group.

[16] "Why the Wildfires of 2018 Have Been So Ferocious: It's the heat, not the humidity." Robinson Meyer, The Atlantic August 10, 2018

[17] Abatzoglou and Williams, "Impact of anthropogenic climate change on wildfire across western US forests," Proceedings of the National Academy of Sciences, October 10, 2016

[18] Wikipedia article "2018 Attica Wildfires"

fires above the Arctic Circle[19]. Millions of hectares (one hectare = 2.47 acres) of Russian/Siberian taiga forest appear to have burned in 2018[20].

Although predictions of these and other climate impacts can be summoned up from three or four decades back, just reading the OCCRI 2010 and 2017 Assessments side by side should be sobering to Oregonians and their leaders alike.

A note of qualification for what follows: heat waves, drought, intense storms, forest fires and other inconveniences and disasters have been suffered throughout human history. Oregon has seen its share of these events, such as the very large west-side fires during a cyclical dry period[21] in the 1930's. The difference today is in the *amplification* of naturally-occurring weather events. The National Academy of Sciences stated (in 2016) that:

> "In many cases, it is now often possible to make and defend quantitative statements about the extent to which human-induced climate change (or another causal factor, such as a specific mode of natural variability) has influenced either the magnitude or the probability of occurrence of specific types of events or event classes.[22]"

Thus climate change does not start forest fires (either lightning or careless humans do this) but climate change lengthens the calendar window for weather conducive to such fires and supplies the fire with more tinder-dry fuel that can contribute to larger and more persistent fires.

A parallel might be a baseball player who might naturally hit 40 home runs a season; playing with performance-enhancing drugs, he might hit 60 instead. The drugs don't make him a better hitter but increase his chances, each time he bats, of sending one into the bleachers.

So what other climate change predictions are coming about, and with what consequences? The following references should be read as illustrative; for a complete accounting, look to OCCRI's most recent (2017) assessment report.[23] Note that both data-based and anecdotal evidence of current effects are 2018 snapshots; these effects will continue to intensify in future years even if emissions growth is reversed today and systematically reduced over the next two decades or so. The "*Then*" predictions are from the OCCRI 2010 Assessment unless noted otherwise.

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[19] London *Express* July 25, 2018

[20] Reported in the Siberian Times 13 July 2018.

[21] The recurring Pacific Decadal Oscillation is a naturally-occurring climate cycle of roughly 30 years duration alternating between drier and wetter weather periods. Another naturally occurring, shorter-term cycle affecting the Pacific Northwest is from El Nino (drier; warmer) to La Nina (wetter, cooler). Climate change is superimposed on these cycles, amplifying warmer effects and, in different geographies, amplifying or diminishing precipitation.

[22] National Academies of Sciences, Engineering, and Medicine, 2016: Attribution of Extreme Weather Events in the Context of Climate Change. Washington, DC: *National Academies Press.* doi: 10.17226/21852.

[23] The Third Oregon Climate Assessment, January 2017, at: http://www.occri.net/media/1042/ocar3_final_125_web.pdf)

Heat

Then . . . the 2010 Assessment predicted Oregon would see average temperature increases of "0.2-1º F" per decade;

Now . . . Oregon's average temperature has risen 1ºF in the last 30 years[24]. By August 22 of this year, Portland had set a new record for hottest days (30 days above 90ºF)[25]. Higher maximum night-time temperatures also were recorded over the last century.

". . . rising greenhouse gases have added almost 2ºF to the Northwest's average temperature over the past 100 years. It follows, then, that when Oregon experienced a year (2015) that was about 5°F warmer than the 20th century average, greenhouse gases contributed about 2°F of that.[26]"

Elsewhere . . . globally, 2018 is on track to be the fourth hottest year on record; with 2018, the hottest four years have been the last four; and 17 of the 18 warmest years have occurred since 2001[27]. Heat waves and record temperatures have been recorded across the globe, from the Arctic to the tropics. The World Meteorological Society reports that ". . . heat is drying out forests and making them more susceptible to burn. A recent study found Earth's boreal forests are now burning at a rate unseen in at least 10,000 years[28]."

Globally, each of the decades since 1950 has been warmer than any of the decades preceding. 2010-2019 is on a course to be 1.31º warmer than the 1951-1980 mean temperature[29].

NOAA reported in 2015 that "nighttime temperatures are slightly outpacing daytime temperatures in the rate of warming (and in 2017 hit)a nationally averaged minimum . . . 60.9 ºF in the contiguous US – 2.5ºF above average.[30]" The inability of cities and their inhabitants, especially, to cool off at night is a public health threat, and a greater one in many third world cities (and "third world neighborhoods" in a first world country like the US) where air conditioning is rare and humidity levels are high, limiting the ability of bodies to shed heat.

Warmer nighttime temperatures close off what firefighters call the "nighttime recovery window," and allow fires to burn hot through the night, make containment more difficult.[31]

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[24] . . . and two degrees F since 1895, per OCCRI and Associated Press, June 18, 2018
[25] Reported in Willamette Week, August 22, 2018
[26] Abatzoglou, J., D.E. Rupp, and P.W. Mote, 2014: Understanding seasonal climate variability and change in the Pacific Northwest of the United States. *J. Climate*, 27, 2125–2142 doi: 10.1175/JCLI-D-13-00218.1.
[27] Reported in New York Times August 9, 2018
[28] World Meteorological Society, reported in The Washington Post 30 July, 2018 (Angela Fritz)
[29] NASA combined land-surface air and sea-surface water temperature anomalies, 2018.
[30] National Oceanic and Atmospheric Administration, 2015-17, reported in InsideClimateNews 11 July 2018, updated 7 September with record summer 2018 temperatures.
[31] Reported in Salem Statesman Journal 10 August 2018.

(In 2018) The El Paso Chapin High School Huskies football team starts its practices at 6 am, when it's a cool 82º in August, instead of the more usual mid-afternoon schedule when it's expected to go above 100º[32].

Scientists analyzed the exceptionally deadly 2003 heat wave in Europe – the hottest summer on record since 1540 – to which 70,000 deaths were attributed. They found that in Paris – the hottest city – 70% of the deaths (506 out of 735) could be ascribed to climate change amplifying the heat[33].

Public Health

Apart from the direct effects of heat stress and other weather extremes on those without the means of protection – usually the poor – climate change can aggravate certain chronic disease conditions like asthma and heart disease and increase exposure to illnesses usually associated with warmer climates.

***Then** . . .* The 2010 Assessment warns of "Incidents of extreme weather (such as floods, droughts, severe storms, heat waves and fires) can directly affect human health . . . heat-related morbidity and mortality, especially among vulnerable populations . . . threat of vector-borne diseases and emerging infections. Respiratory insults, especially among persons with preexisting lung health problems would be exacerbated by exposure to smoke from wild land and forest fires . . . allergies, asthma and other respiratory conditions among susceptible populations.[34]"

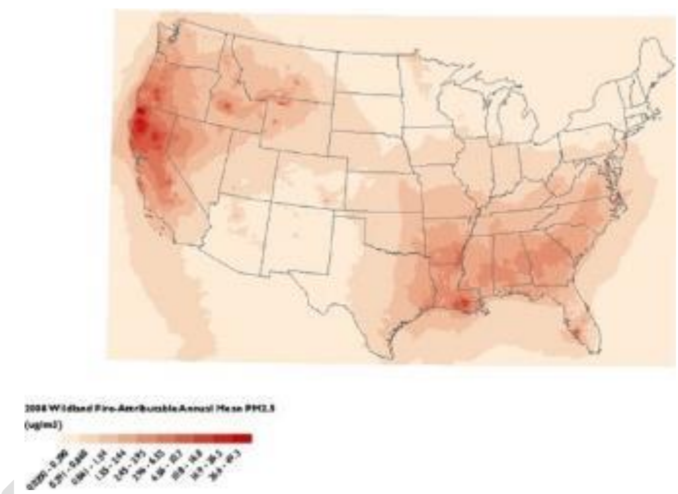
Now . . . "In Oregon, analysis of hospitalization and climate data showed that each 1ºF increase in daily maximum temperature was associated with a nearly 3-fold increase in the incidence of heat-related illness.[35]" The Oregon Health Authority recorded a 29% rise in emergency room visits for respiratory symptoms in the metro region during the 2017 Eagle Creek fire,[36] indicative of health risks of smoke from more extensive wildfire.

The Oregon Health Authority issues health "advisories" to warn Oregonians of health risks. These include recreational use advisories for cyanotoxins produced by harmful algae blooms (HABs) that can arise in freshwater bodies across the state. The recreational use advisories warn Oregonians against ingesting water affected by the toxins through swimming, water skiing, and other water-based recreational activities. Health risks can range from gastrointestinal illness and dizziness to seizures and liver failure; young children, dogs, and livestock are especially susceptible. Conditions that foster freshwater HABs are increasing – higher air temperatures, more sunlight, lower snowpack (and thus higher water temperatures), and more intense rain events causing higher runoff of organic matter to water bodies. While recreational use advisories have become a routine spring-through-fall occurrence, in May, 2018 Oregon experienced its first-ever drinking water advisory due to cyanotoxins in finished drinking water. Detroit Reservoir, the source of drinking water supplies for the City of Salem and other

[32] "As Temperatures Keep Trending Up," The Washington Post August 29, 2018
[33] "Attributing human mortality during extreme heat waves to anthropogenic climate change." Mitchell, Heaviside et al in IOPScience 8 July 2016. Overall, France recorded 14,802 heat-related deaths in 2003.
[34] 2010 OCCRI Assessment, p. 403
[35] Mote, Snover, "Climate Change in the Northwest." Island Press. Available at www.occri.net/reports.
[36] Statewide Fire Activation Surveillance Report (090517-090617), Oregon Health Authority

communities, experienced a persistent algae bloom that resulted not only in recreational use advisories at Detroit Lake, but also led to levels of cyanotoxin above safe drinking water levels for sensitive populations such as children, the elderly, and those with compromised immune systems in downstream communities. The State declared a "state of emergency" and the Oregon National Guard distributed drinking water in affected communities.[37]

Forest wildfire generates higher levels of particulate (PM2.5) in western states including Oregon; fires 2008-2012 result in higher premature deaths and respiratory ailments with long term US costs, principally in the west and southeast upwards of $450 billion[38]. As fires and smoke become more ubiquitous, disease and cost impacts will rise.



Annual mean levels of PM2.5 attributable to wildfire (2008); levels in excess of 10 μg/m³ (in red) considered unhealthy by WHO.

Elsewhere . . . Of 244 US cities analyzed for increased risk of mosquito-borne diseases (including Zika, West Nile, and Dengue fever), 94% saw significant increases in days warm enough to sustain disease-carrying mosquito species. While most of these are southern cities, they include middle and northern urban areas such as San Francisco (47 more days since 1970), Helena MT and Erie PN. Ironically, some southern cities (Phoenix AZ) may see a lower risk . . . because it becomes too hot for the mosquitos to survive[39].

Drought and Snowpack

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[37] Reported by Oregon Public Broadcasting (Erin Ross) 7 June 2018; and Oregon Environmental Council at https://oeconline.maps.arcgis.com/apps/MapJournal/index.html?appid=5aacb7b363684c90945d0c4e8e77964a#map

[38] The health impacts and economic value of wildland fire episodes in the US: 2008-2012. Neal, Fanna et al, Elsevier January 2018. Annual mean levels of PM2.5 considered safe by the World Health Organization rates as safe for human health annual mean PM2.5 levels that do not exceed 10 μg/m³ (micrograms per cubic meter)

[39] "Rise in Mosquito Disease Days", Climate Central August 8, 2018

Detroit Reservoir 2015
Reinert, Oregon State University

Hoodoo Ski Summit Feb 2015 Hoodoo webcam Dave
23 February 2015

Then . . . "By mid (21st) century, Cascade mountain snowpacks are projected to be less than half of what they were in the 20th Century . . . ."

Now . . . while total precipitation shows no great variance, as predicted it shows more moisture arriving as rain than as snow. The 3rd Assessment reports on 2015, in which this effect was exceptional:

"The 2015 snow drought as a glimpse into Oregon's future. Precipitation during the winter of that year (2015) was near normal, but winter temperatures that were 5–6°F above average caused the precipitation that did fall to fall as rain instead of snow, reducing mountain snowpack accumulation (Mote et al., 2016). This resulted in record low snowpack across the state, earning official drought declarations for 25 of Oregon's 36 counties[40]. . . . for each 1.8°F of warming, peak snow water equivalent in the Cascade Range can be expected to decline 22%–30%[41]. . . . Spring snowpack . . . decreased at nearly all stations in Oregon over the period 1955–2015 with an average decline of about 37% (Mote and Sharp, 2015)[42]."

[40] OCCRI Third Assessment, page 13. January 2017
[41] Cooper et al, 2016 in OCCRI Third Assessment 2017, page 14
[42] Mote and Sharp, 2015 in OCCRI Third Assessment 2017, page 19

Figure 2.4. US Drought Monitor for August 25, 2015. All of Oregon was in severe (orange) or extreme (red) drought. Map courtesy of NDMC-UNL.

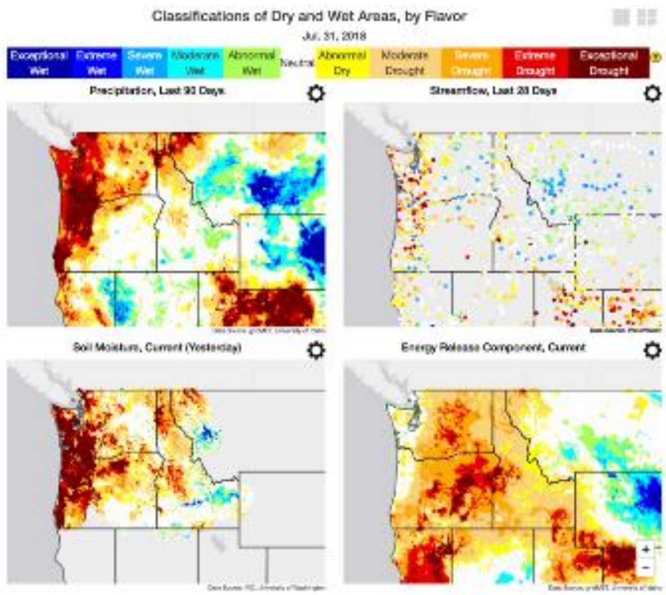

Image Credit: Northwest Climate Toolbox, OCCRI

OCCRI Director Dr. Phil Mote and colleagues confirmed earlier predictions in reporting ". . . a decline in average April 1 snow water equivalent since mid-century is roughly 15-30% . . . . Declining trends (in western winter snowpack) are observed across all months, states and climates, but are largest in spring, in the Pacific states, and in locations with mild winter climate.[43]"

That's Oregon.

OCCRI's website posting includes an August 2, 2018 article by Dr. John Abatzoglou titled "Drought Returns to the Pacific Northwest" in which the author identifies five "flavors" of drought including low precipitation but also low surface supply and low snowpack. He then maps these effects for 2018 to date, and observes that "the maps all show an awful lot of red, indicating extreme to exceptional drought across parts of western Oregon (with) impacts that cover the gamut from fire to farms to fish.[44]"

OCCRI Deputy Director Kathie Dello summarized the Institute's review of the 2017/18 drought summers as "low snowpack and a hot and dry summer caused water shortages for livestock, small water systems and stressed forests and other ecosystems. Multiple years of hot and dry summers (have) caused damage to Douglas Fir trees in western Oregon.[45]

Elsewhere*:* The Mote article also showed snowpack decreases in excess of 70 percent also occurred at locations in California, Montana, Washington, Idaho and Arizona46." The Arizona State Climate Office reports that the state "is currently in our 21st year of a long-term drought. While California has a long history of wet and dry periods, in 2015 the state "experienced its lowest snowpack in at least 500 years (and) the 2012-15 period was the driest in at least 1200

[43] Mote, Li et al, "Dramatic declines in snowpack in the western US." Climate and Atmospheric Sciences 2 March 2018
[44] Abatzoglou, "Drought Returns to the Pacific Northwest," OCCRI Climate Circulator 2 August 2018
[45] Personal communication/Email from Kathie Dello to Angus Duncan, 1 October 2018.
[46] Mote, Li et al, Dramatic declines in snowpack in the western US. Science Daily March 2, 2018

years.[47]" A related study ascribes "8-27% of the observed anomaly in 2012-2014" to global warming[48].

A 2016 NASA study found that drought conditions beginning in 1998 and afflicting countries in the Middle East ". . . is likely the worst drought of the past nine centuries . . ." and well outside the range of natural variability for modern times[49]."

Droughts in 2018 affected countries from western and northern Europe to South Africa to Australia. Another NASA study suggests, consistent with predictions of climate effects, that there is a "redistribution" of fresh water supplies from the middle latitudes (SW US/Mexico; north Africa and the Middle East; India) to the north and south. The data are not sufficient to discern a clear climate fingerprint, says Jay Famiglietti, one of the NASA researchers, but it sure . . . matches that pattern (and is) cause for concern.[50]"

Extreme Weather and Flooding; Sea Level Rise

Then . . . Stronger ocean storms and coastal flooding; "significant physical impacts along the coast and estuarine shorelands of Oregon . . . increased erosion and inundation . . . wetland loss . . . ≥ 1.0 meter sea level rise by 2100 . . . increasing storm intensities and the heights of the waves . . .

Now . . . In 2007, Vernonia in Oregon's coast range suffered severe flooding for the third time in 19 years as the Nehalem River responded to 6.5" to 7.5" of rain in 24 hours; other north coastal towns were hit as well. In November, 2015, flooding shut down US 101 in Tillamook, OR. Other incidents of heavier than expected rain events have been associated with storm activity in the past two decades. However it is not yet clear whether these eventful recent precipitation patterns have resulted in significant new levels of winter flooding in Oregon that can be "fingerprinted" as climate-change induced.

[47] Wikipedia, "Droughts in California"; and Griffin, Anchukaitis, "How unusual is the 2012-2015 Californai drought?" in Geophysical Research Letters, 3 December 2014

[48] Park; et al. (2015). "Contribution of anthropogenic warming to California drought during 2012–2014". *Geophysical Research Letters*

[49] Cook, Anchukaitis et al, "Spatiotemporal drought variability in the Mediterranean over the last 900 years", Journal of Geophysical Research 4 February 2016

[50] Results of 2002-2016 GRACE Mission, reported in the Washington Post 16 May 2018.

North Oregon coast showing 1997 high water line moving inland (red line) by 2008.[51] (Photos by Don Best)

Closer to the ocean, some 7400 north coast people live in the “inundation” zone[52] at risk from predicted 2100 sea level rise. . . . sea level rise has been accelerating . . . to (at least) 3.2 mm/year since 1993 (up from 1.2mm/year 1901-1990); “Tall waves, intense storms and El Nino combine with sea level rise to produce amplified coastal erosion . . . the cost of adaptation to sea level rise and storm surge may be on the order of $1.5 billion through 2100[53].”

Elsewhere . . . On average global sea levels are rising at more than 3 mm/year (and rose 17 centimeters during the 20th Century[54], or almost 7 inches, from two effects of climate change: melting ice sheets and thermal expansion of ocean waters. The effect puts at risk coastal populations around the world; threatens to submerge many low-lying island nations; increases risk of coastal flooding from stronger storm surges acting on higher sea levels (see Hurricanes Florence, Harvey, Irma, Sandy, Katrina etc.), and of contamination of fresh water supplies with salt water; and alters ecological habitats for many animal and plant species.

“100 year” flood zones are becoming 50-year or riskier zones. New York City, battered by flooding into lower Manhattan from Hurricane Sandy, is planning for the much worse flooding expected with a 2.5 foot global sea level rise by 2050. Some 40% of US population lives in coastal zones, while elsewhere around the world much poorer populations are at risk equivalent to New York City but without the means to construct barriers and other coping structures.

Hurricane Florence is pounding the Carolinas as this is being written with rainfall 50% greater than it would have been without climate change, according to new analytic tools for

[51] “Implications of Climate Change to the Oregon Coast”, Jonathan Allen, 2008. Oregon Department of Geology and Mineral Industries (DOGAMI)
[52] Defined as “within reach of the mean highest high tide projected for 2100.” Page 35, OCCRI 2017 Assessment
[53] OCCRI 2017 Assessment, pp 34- 35
[54] NASA, at https://climate.nasa.gov/resources/education/pbs_modules/lesson3Overview/

distinguishing the climate "footprint" in extreme weather events. Fueled by ocean temperatures 2º to 4º F above historic averages, the storm was larger (8% to 9%) and slower-moving (allowing more rain intensity) than it would have been without the climate change bump[55].

In August 2017 Hurricane Harvey flooded Houston with up to 51 inches of rain in some areas – 30 trillion gallons of water[56], causing some 106 deaths and $125 billion in damages. Harvey's precipitation accumulations appear to have been ± 38% higher than absent climate change effects[57].

In the United States, 2017 was notable for its destructive hurricane season, with Irma and Maria piling atop Harvey. Updated casualty figures attributed 2975 deaths in Puerto Rico to Maria, along with major impacts to infrastructure (e.g., nearly a year's delays in restoring electrical service island-wide; estimated damage costs of $90 billion). Earlier, New Orleans has yet to recover from 2005's Katrina (1833 deaths; $160 billion in damages).[58]

2018 saw extreme flooding events in Japan (200 dead)[59], India (350 dead; 800,000 displaced)[60], Southeast Asia (notable for the 12 teenage soccer players rescued from their flooded cave in Thailand) and elsewhere.

While the impacts of tropical storms and flooding are hardly unknown in human history, their extent, intensity (wind strength) and moisture content (rainfall) have measurably increased as climate change effects have become more pronounced[61]. Category 5-equivalent Typhoon Mangkut hit the Philippines with winds up to 125 mph and gusts over 200 mph[62], doubling down on the destruction from last year's Typhoon Haima and from 2013's deadly Haiyan (Yolanda -- sustained winds of 195 mph, more than 7000 people dead or missing and estimated damages of $14.5 Billion[63]). There is emerging consensus that such extreme storm events in the Pacific are becoming more intense and destructive, and these changes are fueled by warming ocean temperatures[64]

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[55] https://www.somas.stonybrook.edu/2018/09/13/estimating-the-potential-impact-of-climate-change-on-hurricane-florence/

[56] Mimi Schwartz, "What we didn't learn from Harvey", in New York Times 25 August 2018.

[57] Per Dr. Michael Wehner, LBNL: "Attributable Human-Induced Changes in the Likelihood and Magnitude of the Observed Extreme Precipitation during Hurricane Harvey."

[58] Reported in The Economist pp. 54-55. 22 September 2018.

[59] Reported by CNN 12 July, 2018

[60] "Flooding (in) the Indian State of Kerala," reported in Business Insider 19 August 2018

[61] Tropical cyclones and climate change, reported in Wikipedia

[62] Reported by BBC News 15 September, 2018

[63] Reported by Bloomberg November 11, 2013

[64] "…typhoons in the north-west Pacific had intensified by 12–15% on average since 1977. The proportion of the most violent storms - categories 4 and 5 - doubled and even tripled in some regions over that time and the intensification was most marked for those storms which hit land. . . . The intensity of a typhoon is measured by the maximum sustained wind speed, but the damage caused by its high winds, storm surges, intense rains and floods increases disproportionately, meaning a 15% rise in intensity leads to a 50% rise in destructive power." Nature Geoscience 5 September, 2016, quoted in The Guardian 5 September, 2016. And, "the strongest future storms will

Ocean Conditions

Then . . . In the OCCRI 2010 Assessment: "Substantial increases in water temperatures in the ocean are likely and will exceed natural variability. The ocean also absorbs carbon dioxide (CO2) from the atmosphere, which forms carbonic acid and is making waters corrosive to certain species. . . . The combination of these climate and nearshore ocean changes will exert stress on the communities of near-coastal and estuarine organisms."[65]

Now . . . " the West Coast has already reached (an acidification) threshold and negative impacts are already evident, such as dissolved shells in pteropod populations and impaired oyster hatchery operations. . . . 60% of the dissolved inorganic carbon in surface waters off Oregon's coast in 2013 is attributed to increasing greenhouse gas concentrations.[66]" Heat in OR offshore waters is contributing to marine harmful algal blooms (HABs) adverse to the $50 million annual Oregon Dungeness crab catch[67]; also impacts to salmon food species.[68]" "Ocean acidification . . . impairs the ability (of shellfish) to build shells[69]." Scientists project that the west coast "will face some of the earliest, most severe changes in ocean carbon chemistry (driven by climate change, including) intensification and expansion of low dissolved oxygen – or hypoxic – zones.[70]" Oregon's commercial and recreational fisheries together amount to around $200mm annually.[71]

Elsewhere . . . 1982-2016 saw a doubling of the number of marine heat waves (exceeding the 99th percentile) globally, affecting phytoplankton[72] that are the base of the ocean food chain. . . the "Blob," a large area of persistent warm Pacific Ocean water present 2013-2016, reflecting wider abnormal ocean temperatures that depressed phytoplankton production causing widespread declines in the ocean food web that, among other effects, let to death by starvation for thousands of California sea lion pups[73]."

Infrastructure

Then . . . "Projected climate changes in precipitation rates and temperatures are likely to threaten the integrity of the built environment, including buildings, roads, highways and

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exceed the strength of any in the past." Ramstorf, Emanuel et al, "Does Global Warming Make Tropical Cyclones Stronger?" at RealClimate website (www.realclimate.org/)

[65] Legislative Summary, and Executive Summary Chapter 6, 2010 Oregon Climate Assessment, OCCRI

[66] OCCRI, Third Oregon Climate Assessment Report January 2017, page

[67] McCabe et al., 2016. An unprecedented coastwide toxic algal bloom linked to anomalous ocean conditions. Geophys. Res. Lett., 43(19), 10,366–10,376.

[68] Cavole et al., 2016. Biological impacts of the 2013–2015 warm-water anomaly in the Northeast Pacific: Winners, losers, and the future. Oceanography, 29(2), 273–285, http://dx.doi.org/10.5670/oceanog.2016.32; and direct communication from Dr. Caren Braby, ODFW, October 2, 2018 re: value of Oregon Dungeness crab fishery.

[69] 2017 OCCRI Climate Assessment p. 36

[70] West Coast Ocean Acidification and Hypoxia Science Panel, "Major Findings, Recommendations and Actions," SCCWRP Technical Report 926, April 2016

[71] Economic Impact of Oregon's Commercial and Recreational Ocean Fisheries, Oregon Department of Fish and Wildlife web site (https://www.dfw.state.or.us/agency/economic_impact.asp).

[72] Thomas L. Frölicher, Erich M. Fischer & Nicolas Gruber, 2018. Marine heatwaves under global warming. Nature, 560, 360–364.

[73] Cavole et al., 2016. Biological impacts of the 2013–2015 warm-water anomaly in the Northeast Pacific: Winners, losers, and the future. Oceanography, 29(2), 273–285, http://dx.doi.org/10.5670/oceanog.2016.32.

railroads, water and sewage systems, and energy facilities throughout Oregon (CLI 2008, 2010)[74]".

Now… The Eagle Creek fire interrupts commercial traffic on I-84; flooding (Vernonia, 2007); unseasonable warming in November, 2006 that melted ice and released a rock slide that closed OR 35 for >30 days (OR 35 has history of such washouts, more than 20 since 1907; five have occurred since 1998)[75] . . . Less predictable river/reservoir flows make scheduling flood drawdowns and hydro generation more difficult[76]; while potential low summer stream flows put Oregon's irrigated agriculture sector at risk.

Some 2800 miles of roads in OR and WA are in the 100-year floodplain; some highways may face increased inundation with two feet of sea level rise[77]. From an ODOT 2012 analysis, "Oregon's coastal roadways already experience the effects of climate change. U.S. Highway 101 near the City of Seaside, Oregon experiences habitual flooding problems causing road closures and delays multiple times every year." Impacts to coastal roadways will come, according to ODOT, from "2-4 feet of sea level rise by 2100 . . . Increases in wave heights . . . (and) inundation and erosion (leading to slides) along entire coastline.[78]"

Summer 2018 heat in Portland forces MAX lines to slow down when temperatures exceed 95ºF, in turn slowing the overall commute.[79]

Elsewhere *. . .* The integrity of dikes and levees in The Netherlands is threatened in 2018's drought by scarcity of the fresh water flows necessary to offset sea water pressure[80]. Elsewhere, hurricanes Sandy (New York City subway flooding), Katrina (all New Orleans city services interrupted) and Maria (Puerto Rico electricity service failed and not fully restored for almost a year) illustrate the infrastructure impacts potential, always remembering that third world infrastructure is already often unsteady and fragile, prone to interruption from lesser forces than those threatened by climate change, and far slower to recovery (see Puerto Rico power system recovery).

The US Government Accountability Office reported in 2017 direct federal government costs for responding to "extreme weather and fire events" of $350 billion over the prior decade.[81] The Report referenced The 3rd National Climate Assessment that: "the impacts and costs of extreme events—such as floods, drought, and other events—will increase in significance as what are considered rare events become more common and intense because of climate change."

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[74] 2010 OCCRI Climate Assessment, p. 393.
[75] Wikipedia article "Oregon Route 35"
[76] "Climate Change Initiative Briefing" to NW Power Planning Council, July 13, 2011. BPA, BuRec, COE
[77] Mote, Snover, "Climate Change in the Northwest" 2013
[78] ODOT, Climate Change Adaptation Strategy Report April 2012, page 16
[79] Oregonian/Oregon Live, "Why do TriMet Max and WES trains have to slow down in the heat?", 4 August 2016
[80] London *Express* July 25, 2018
[81] USGAO Report 28 September, 2017, relying on US Office of Management and Budget FY 2017 Budget: "including $205 billion for domestic disaster response and relief; $90 billion for crop and flood insurance; $34 billion for wildland fire management; and $28 billion for maintenance and repairs to federal facilities and federally managed lands, infrastructure, and waterways."

Economy

Then *. . .* The 2010 Report warned that "climate change poses economic risks to the state.[82]"

Now *. . .* "Nearly $51 million in tourism revenue was lost in Oregon (in 2017) because of wildfires, according to a study conducted by Travel Oregon . . .[83]" By the end of August 2018 the Shakespearean Festival in Ashland estimated that it had already lost 10% of its budgeted revenues, or $2 million[84], to smoke-driven performance cancellations or performance moves[85]. Costs for health care, fire-fighting, commercial freight interruptions, reduced hydropower generation, drought effects on agriculture and coping with other economic impacts of advancing climate change are increasingly identifiable to Oregonians.

Since 1915, western US snowpack has declined by 21% or 36 km2, greater than the volume of water stored in the West's largest reservoir, Lake Mead (creating a challenge) to western water managers." Irrigation, hydropower generation, navigation, recreation and ecological sustainability are all put at risk. In recent years such as 2014-15, Oregon ski resorts have struggled to open (e.g., Mt. Ashland failed to open at all that year).

Oregon's forests provide Oregonians with "ecosystem services" the value of which can in many cases be quantified. Thus intact, sustainably functioning forest ecosystems provide the Pacific Northwest with $3.2mm/year in water purification, $5.5mm in erosion control (in the Willamette Valley alone), and $144 per household per year in cultural and aesthetic uses (e.g., hiking, camping, and viewing). Climate change in PNW forests could cost the region $650mm in recreation revenue losses by 2060.[86]

Some agricultural crops may benefit from the added carbon dioxide supporting growth, but other crops (and farm earnings) stand to suffer from heat, insect predation, weed growth, and reduced precipitation and irrigation water during summer months, excessive precipitation in winter months, reduced chilling temperatures for fruit set, and impaired nutrient value of food crops.

An analysis of the costs associated with public health effects of wildland smoke exposure estimated the "value" (cost) of long-term exposure, nationwide, at between $76 billion and $130 billion annually. Six states, including Oregon, were judged to be most affected[87].

The Pacific Northwest seafood industries including scallops, oysters, mussels and crabs, subject to ocean acidification and hypoxia (see above) will be affected, as will commercial and recreational fishing ($9.5 billion industry in the two states, with 84,000 jobs at stake). Ocean salmon, herring, mackerel and other commercial finfish, dependent on food chain base species

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[82] OCCRI 2010 Assessment, Legislative Summary

[83] Per Travel Oregon, reported by Oregon Public Broadcasting August 23, 2018

[84] OR Shakespeare Festival, reported in Willamette Week August 29, 2018, page 24

[85] "Wildfire Smoke Disrupts OSF", The New York Times August 24, 2018; and "Smoky", The Oregonian August 22, 2018.

[86] Dalton, Mote, Snover, "Climate Change in the Northwest" Executive Summary page 14; available at www.occri.net/reports.

[87] Fann, Alman et al, "The health impacts and economic value of wildland fire episodes in the US 2008-2012." In Science of the Total Environment, 18 August 2017.

such as pteropods whose shells are being damaged by ocean acidification, are likely to be adversely affected[88].

Elsewhere *. . .* Extreme weather ("cold winter and baking summer") projected to increase household food bills in the United Kingdom by 5% in 2018; harvest of European wheat and other grains down in 2018 by 5%[89]. A UN Report on global hunger identifies "climate shocks, such as droughts and floods, as 'among the key drivers' for the rise (in global hunger) in 2017," the third such year since 2015, after years of progress in reducing this affliction (the Report issued this year does not take account of 2018's weather extremes, but OXFAM GB warns that "a hotter world is proving to be a hungrier world.")[90].

Few third world countries are positioned to fund both decarbonization of their energy sectors *and* sufficient adaptation and preparation strategies for expected public health, food supply, infrastructure and other impacts.

There are ample additional examples of climate change effects locally and globally. From these we can infer three broad truths:

1. On a plain reading of the evidence, climate change is occurring in real time. Its effects are being felt, in Oregon and around the world, today and not in some distant and uncertain future. Discerning these effects no longer requires scientific instruments and models, only stepping outdoors to take in the heat and smoke.
2. Over the last three decades we have been repeatedly warned of higher deferred costs if we fail to intervene early, both to reduce emissions and to adapt to the effects of climate change. It's now later, and in many cases – not all – costs are performing as predicted. The happy exception is that the costs of certain critical renewable resources and clean vehicle technologies have come down (but these would have come down earlier, with greater savings, if we'd forced the technologies earlier). Notwithstanding these examples of how to successfully deal with this challenge, we still drag our feet.
3. If we ended greenhouse gas emissions tomorrow, climate change effects would persist and worsen for decades to come. Cutting climate change off from its greenhouse gas fuel is like stopping a ship's engines; it does not stop the inertial forward motion but only allows it to gradually slow. Our children, and theirs, will be living for decades with the worsening consequences of our failure to take timely action when we knew we should. Bad as that is, further delay only makes it worse.

[88] University of Washington researcher Janet Armstrong, quoted in the Seattle Times 30 April 2014.
[89] Center for Economics and Business Research, reported in The Guardian Weekly, August 27, 2018. Also of note: ". . . for every degree Celsius (about 1.8 °F) that temperatures increase, the world loses about 6% of its wheat crop. University of Florida professor of agriculture and biological engineering Senthold Asseng, determined these findings through computer modeling. Global food production needs to *grow* (italics added) by 60% by 2050 to keep up with population increases.[89]" (AgWeb – Farm Journal 2018]
[90] "Global hunger levels rising due to extreme weather, UN warns" in The Guardian, September 11, 2018

Oregon, and the nation, must also anticipate that climate change may not be linear. While average temperatures and other effects may take place predictably, their consequences may surprise and shock us with a kind of climatic "suddenness." The Fourth National Climate Assessment includes a "Chapter 15: Potential Surprises, Compound Extremes and Tipping Elements." It contemplates multiple events reinforcing each other and compounding their effects, such as: warm, wet winters followed by early and drier springs and summers; heavy rain-on-snow exacerbating flooding; or powerful ocean wind storms leveraging higher sea levels to create extreme tidal storm surges.

We've already seen some of these effects (e.g., Hurricanes Sandy, Harvey and Florence). Others (e.g., release of frozen methane from melting permafrost) could have more far-reaching consequences.

And the Report acknowledges that "climate models . . . are more likely to underestimate than to overestimate the amount of long-term future change."

Even if they're not right about this, but more so if they are . . . we've only begun to sense the change our children will be called upon to cope with.

Section 2: Update on Oregon's Greenhouse Gas Emissions Inventories

In May 2018, Oregon Department of Environmental Quality (DEQ) published a comprehensive report evaluating Oregon's greenhouse gas emissions (DEQ 2018a) using both "sector-based" and "consumption-based" accounting frameworks. This report builds on a history of statewide inventory work:

- Prior to 2011, Oregon's GHG inventory was limited to a single accounting framework (now called "sector-based") that included in-state emissions as well as emissions from generating electricity used in Oregon, regardless of where the generation occurred. Historically, this sector-based 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, allowing DEQ to begin estimating most sector-based emissions using a "bottom-up" method.
- In 2011, Oregon DEQ published its first estimate of Oregon's emissions using an alternative, supplemental accounting framework: Oregon's consumption-based emissions inventory for 2005.
- In 2013, the Oregon Departments of Environmental Quality, Energy, and Transportation produced an integrated report that combined three inventories using data up to 2010: (1) "in-boundary" (now called "sector-based") emissions, which are those that occur within Oregon's borders plus emissions associated with the generation of electricity used in Oregon; (2) consumption-based emissions, which are those global emissions associated with satisfying Oregon's consumption of goods and services, including energy; and (3) 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.
- In 2015, the Oregon Global Warming Commission (OGWC) Biennial Report to the Legislature included updates to these three inventories.
- In 2017, the OGWC Biennial Report to the Legislature included updates to the sector-based inventory.

A summary of results from the 2018 DEQ report is presented below. For more information and to download copies of the report, please see: https://www.oregon.gov/deq/aq/programs/Pages/GHG-Oregon-Emissions.aspx

Sector-Based Inventory

Oregon's sector-based emissions from 1990 through 2016 are shown in Figure 2-1 and Table 2-1 below. The graph illustrates trends in emissions in this period within the key sectors, including emissions from the generation of electricity used in Oregon, regardless of where that electricity was generated. Sector-based emissions were 63 million metric tons of carbon dioxide equivalent ($MTCO_2e$) in 2015 and 62 $MTCO_2e$ in 2016. Statewide emissions declined from 2007 through 2012 but have since increased. Transportation continues to be Oregon's largest in-state contributor to emissions and accounted for 39 percent of the statewide sector-based total in 2016. In fact, transportation emissions have risen during each of the past three years. The second largest sector of emissions originates from the generation of electricity used in Oregon, with the residential sector creating the greatest demand. Emission trends in the electricity sector reflect both the impact associated with electricity demand and the influence of the availability of hydroelectricity, Oregon's largest source of zero-emitting energy.

Figure 2-1. Statewide sector-based greenhouse gas emissions 1990-2016 (DEQ 2018a)

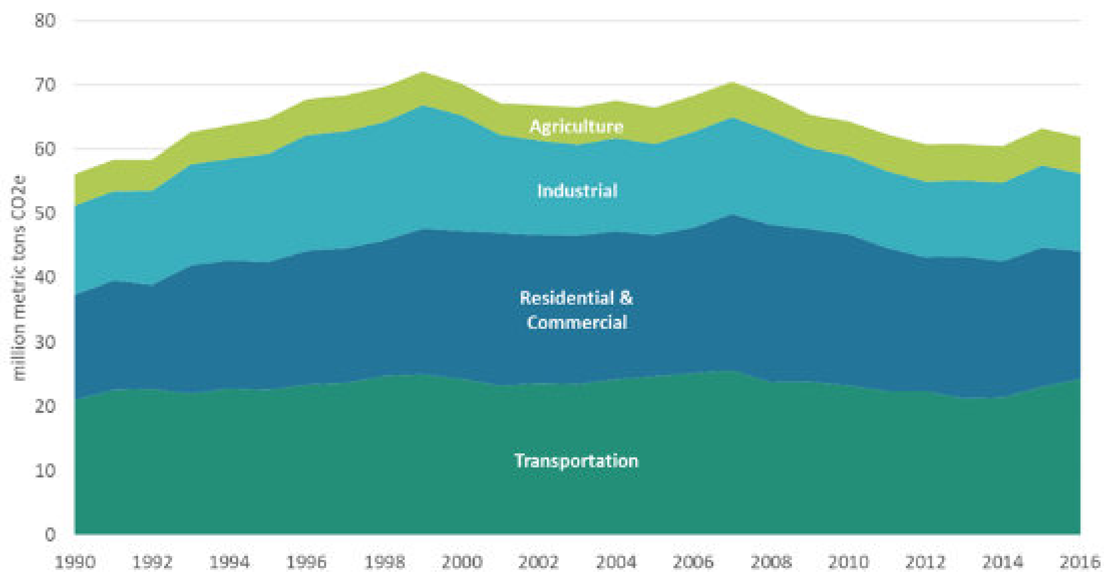


Table 2-1. Oregon Emissions by Sector: 1990-2017 (in Million MTCO2e by 5-year increments + 8 most recent years) (based on DEQ 2018b)

	1990	*1995*	*2000*	*2005*	*'10*	*'11*	*'12*	*'13*	*'14*	*'15*	*'16*	*'17*
Transportation	21	23	24	25	23	22	22	21	21	23	24	25 (prelim)
Residential & Commercial	16	20	23	22	24	22	21	22	21	22	20	21 (prelim)
Industrial	14	17	18	14	12	12	12	12	12	13	12	not yet available
Agriculture	5	5	5	6	5	6	6	6	6	6	*6*	not yet available
Total	56	65	70	66	64	62	61	61	60	63	62	not yet available

Figure 2-2 and Table 2-2 present a different view of statewide emissions, breaking out and aggregating electricity and natural gas emissions from all sectors separately from the residential, commercial, and industrial sectors When viewed this way transportation is still Oregon's largest sector of emissions, followed by statewide electricity use and natural gas combustion. Emissions in the remaining sectors primarily include petroleum combustion (e.g., fuel oil for heating), waste and wastewater, and industrial process manufacturing.

Over half of the recent increased level of emissions is due to gasoline and diesel use (DEQ 2018). Transportation emissions have grown as a share of Oregon's statewide GHG emissions total compared to emissions from electricity use. Specifically, transportation went from 35 percent of the statewide total in 2014 to 39 percent in 2016, while electricity use emissions decreased from 30 percent to 26 percent of the state's total emissions, and all other sectors stayed relatively constant over the same period. Section 3 of this OGWC report will provide a deeper dive into transportation and electricity sector emissions and future projections.

Figure 2-2. Sector-Based Emissions with electricity and natural gas aggregated for all sectors 1990-2016 (DEQ 2018)

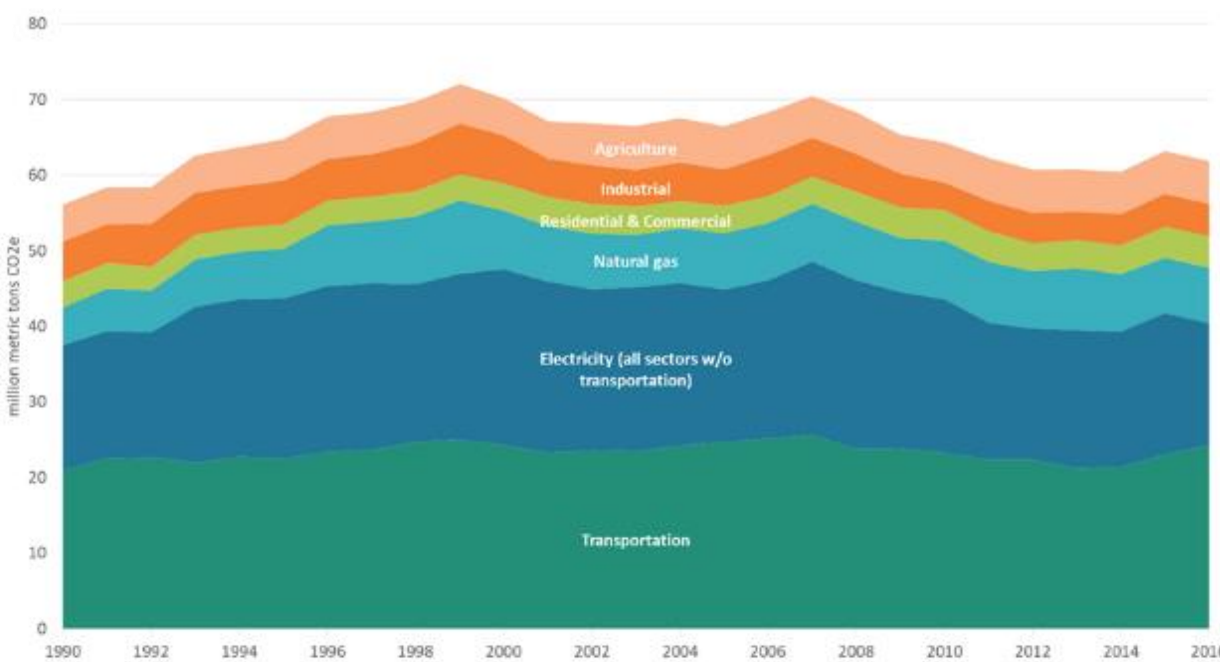


Table 2-2. Oregon Sector-Based Emissions with an Energy Lens: 1990-2017 (in Million MTCO2e by 5-year increments + 8 most recent years) (based on DEQ 2018b)

	1990	*1995*	*2000*	*2005*	*'10*	*'11*	*'12*	*'13*	*'14*	*'15*	*'16*	*2017*
Transportation	21	23	24	25	23	22	22	21	21	23	24	25 (prelim)
Electricity Use	17	21	23	20	20	18	17	18	18	19	16	17 (prelim)

Natural Gas Use	5	7	8	7	8	8	8	8	8	7	7	not yet available
Other Residential & Commercial[91]	3	3	4	4	4	4	4	4	4	4	4	not yet available
Other Industrial[92]	5	6	6	5	4	4	4	4	4	4	4	not yet available
Agriculture	5	5	5	6	5	5	6	6	6	6	6	not yet available
Total	56	65	70	66	64	62	61	61	60	63	62	not yet available

While Oregon's emission reduction goals apply to total annual emissions, as Oregon's population grows it is also helpful to understand emission trends from a population perspective. Oregon's population has increased 43 percent since 1990 while sector-based emissions per capita have decreased by 23 percent in the same time period. More detailed information on per capita emissions trends can be found in Appendix 2-A.

Figure 2.3 show the breakdown of Oregon's emissions by key greenhouse gas, including carbon dioxide, methane, nitrous oxide and high global warming potential (HGWP) gases. Carbon dioxide comprises approximately 80 percent of statewide sector-based emissions and primarily originates from the combustion of fuels including the generation of electricity. The second most abundant gas, methane, comprises approximately 10 percent of the statewide sector-based total. Methane emissions are primarily a result of agricultural activity but also originate from landfills and natural gas distribution.

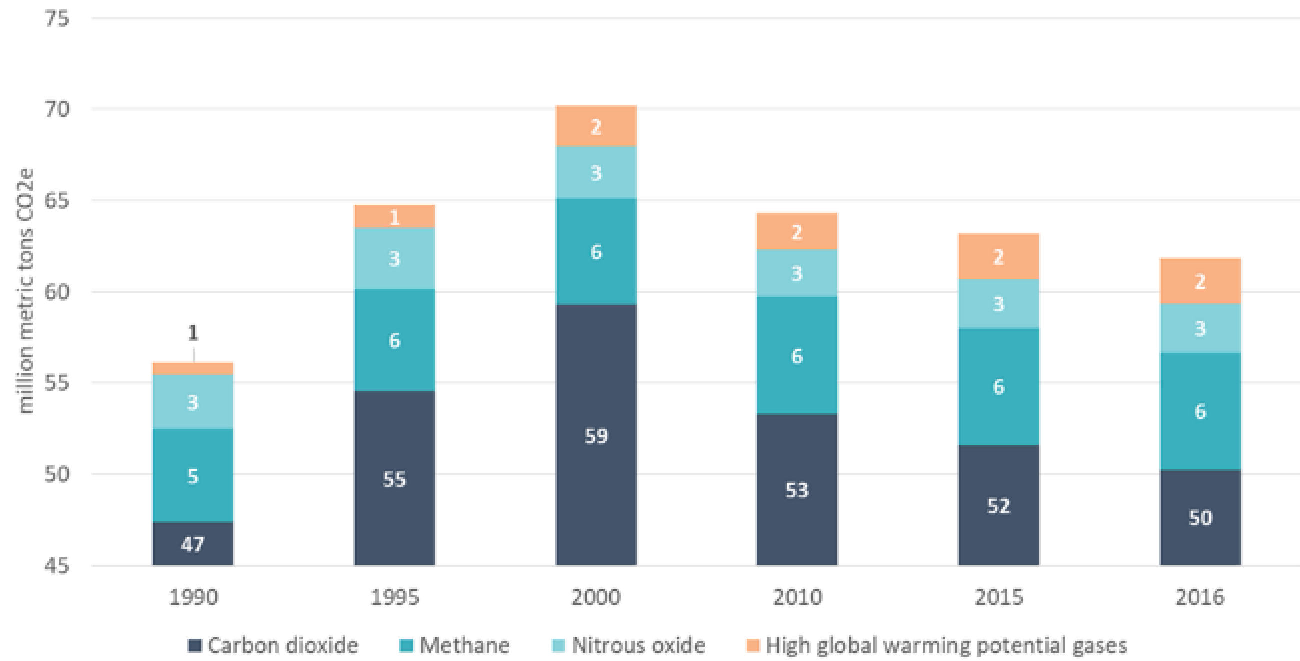
Over time the relative contributions from carbon dioxide, methane, and nitrous oxide have stayed relatively constant while the share of HGWP gases has grown from 1 percent of statewide emissions in 1990 to 4 percent of emissions in 2016. Although HGWP gases are emitted in small quantities their impact is significant due to their long atmospheric lifetimes and their ability to absorb energy, which is hundreds to thousands of times higher than carbon dioxide.[93]

Figure 2.3. Statewide greenhouse gas emissions by gas over time (DEQ 2018a)

[91] This row presents the remaining GHG emissions after emissions from electricity and natural gas use is separated out. These are primarily associated with petroleum combustion (e.g., fuel oil for heating) and GHG emissions from waste and wastewater originating in the residential and commercial sectors.

[92] This row presents the remaining GHG emissions after emissions from electricity and natural gas use is separated out. These are comprised primarily of emissions from petroleum combustion, industrial waste and wastewater, and industrial process manufacturing (e.g., production of cement, paper products, ammonia, urea, etc.).

[93] DEQ utilizes Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment (AR4) 100-year Global Warming Potentials to quantify greenhouse gas emissions in accordance with the most current accounting guidance from the United Nations Framework Convention on Climate Change (UNFCCC).



Consumption-Based Inventory

Oregon also estimates its contribution to global greenhouse gas emissions using a consumption-based inventory. The consumption-based inventory estimates the global emissions resulting from consumption of goods and services (including energy) by Oregon consumers. Consistent with standards for national economic accounting, "consumers" include households and governments, as well as certain types of business expenditures (capital investment and inventory formation). Consumption-based emissions are calculated across the life-cycle of items consumed. The consumption-based inventory supplements the sector-based inventory primarily by highlighting emissions resulting from the consumption of imported goods and services. Combined, the two inventories tell a more comprehensive story of how Oregon contributes to greenhouse gases, and by extension, opportunities to reduce emissions.

Oregon's consumption-based greenhouse gas emissions in 2015 were 88.7 million $MTCO_2e$, up from 79.6 million $MTCO_2e$ in 2005 and 80.2 million $MTCO_2e$ in 2010. Data from the consumption-based inventory also indicates that household demand is overwhelmingly the driver of consumption-based emissions, and that lower-income households on average consume less and generate fewer emissions (per household) while higher-income households on average generate more emissions.

Figure 2-4 illustrates how these and other emissions have changed between 2005 and 2015. The use of vehicles, production of food, and use of appliances (primarily for heating and cooling) contribute the most to these emissions, followed by emissions from provision of services, construction, and healthcare. Figure 2-5 below shows that one category – vehicles and parts – represents fully 20 percent of all of Oregon's consumption-based emissions, while the next highest category is food and beverages at 13 percent of the total. The figure also illustrates that the majority of emissions associated with vehicles and their parts are from vehicle use, while for food and beverages the majority of emissions are "pre-purchase" – e.g., associated with their production and sale. Nearly two-thirds of Oregon's consumption-based emissions are associated with just the five highest-emitting categories: vehicles, food and beverages, appliances, services, and construction.

Figure 2-4. Consumption-based emissions by major category, 2005 - 2015

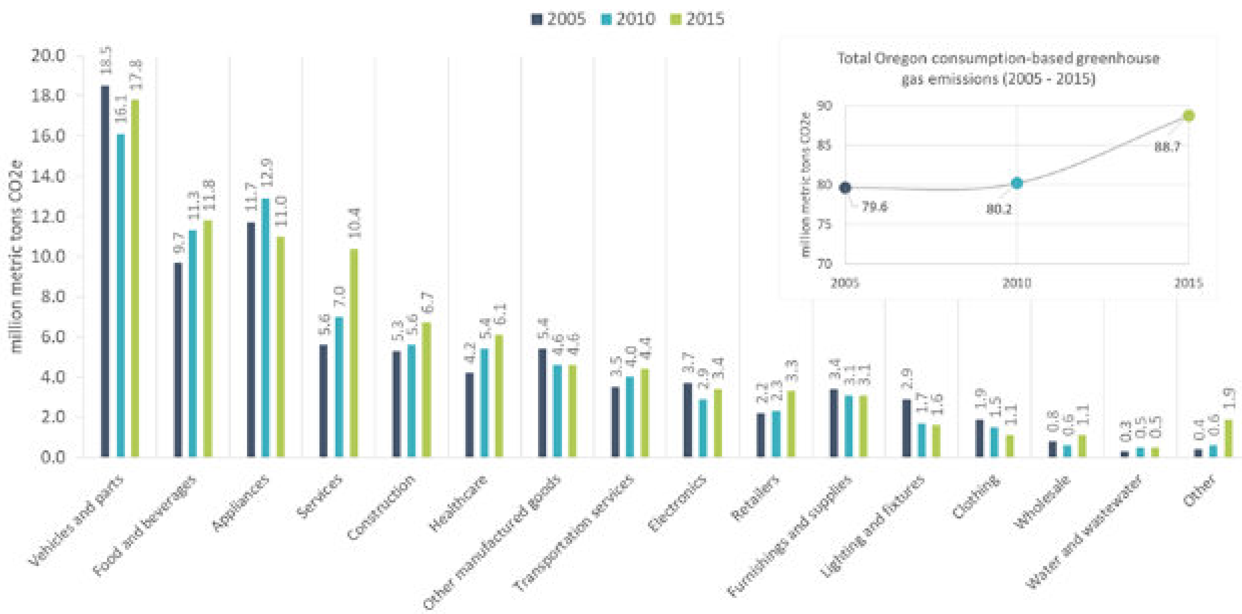
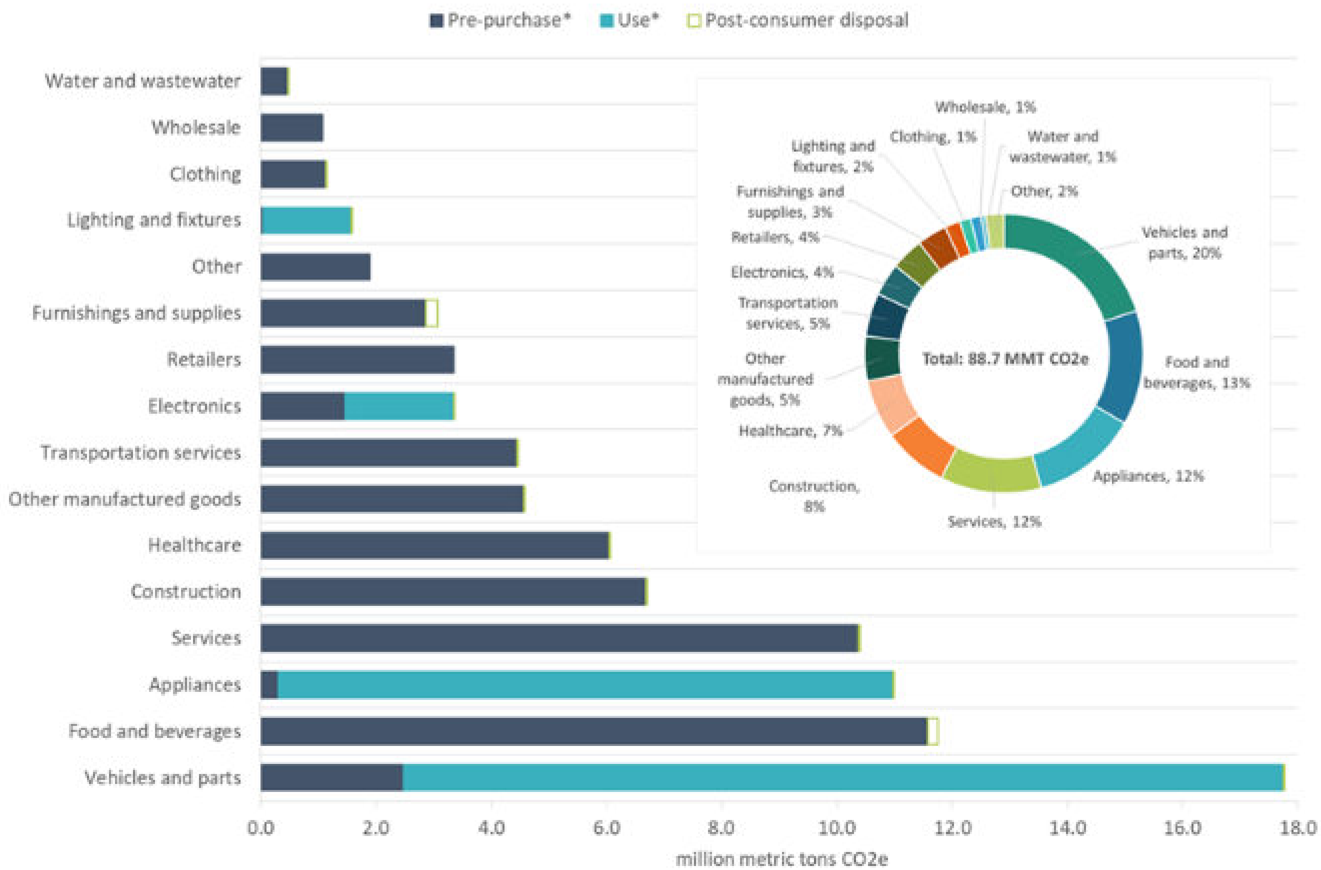


Figure 2-5. 2015 Oregon consumption-based greenhouse gas emissions, by category and life-cycle stage



* "Pre-purchase" are all emissions that occur prior to final purchase, including production, supply chain, transport, retail and wholesale. "Use" refers to emissions resulting from the use of vehicles, appliances, electronics and lighting. Other categories (e.g., food and clothing) have use phase emissions that are accounted for elsewhere. For example, emissions from cooking and laundering are both assigned to the category of "appliances", which include ranges and clothes dryers.

Comparison

Figure 2-6 illustrates the relationship between the two inventories. Sector-based emissions for 2015 were approximately 63 million $MTCO_2e$, while consumption-based emissions were approximately 89 million $MTCO_2e$. The inventories share about 38 million $MTCO_2e$ in common. These shared emissions are from household and government use of energy and waste disposal, as well as commercial and industrial emissions associated with producing goods and services in Oregon that are consumed in Oregon, such as Oregonians' purchases of local ice cream or healthcare. This overlap between the two inventories creates the potential for double-counting, which is why the inventory totals are never simply added together.

Approximately 25 million $MTCO_2e$ of emissions in the sector-based inventory are distinct, and are associated with the in-state production of exported goods and services. These include Oregon's signature exports: foods, transportation equipment, semiconductors and electrical devices, and machinery. It also includes services that are "exported" to the extent that they are purchased by non-Oregonians, such as hotel stays and restaurant visits by tourists.

Oregon's imported emissions – at 51 million $MTCO_2e$ – are double those of our exports. These imported emissions are unique to the consumption-based inventory, and include emissions associated with a wide variety of imported finished goods. It also includes additional out-of-state emissions that aren't otherwise included in the sector-based inventory such as out-of-state emissions associated with extracting and producing fossil fuels consumed by Oregonians and the out-of-state emissions embedded in the supply chains of many services and goods consumed by Oregonians, such as Chinese cement and steel.

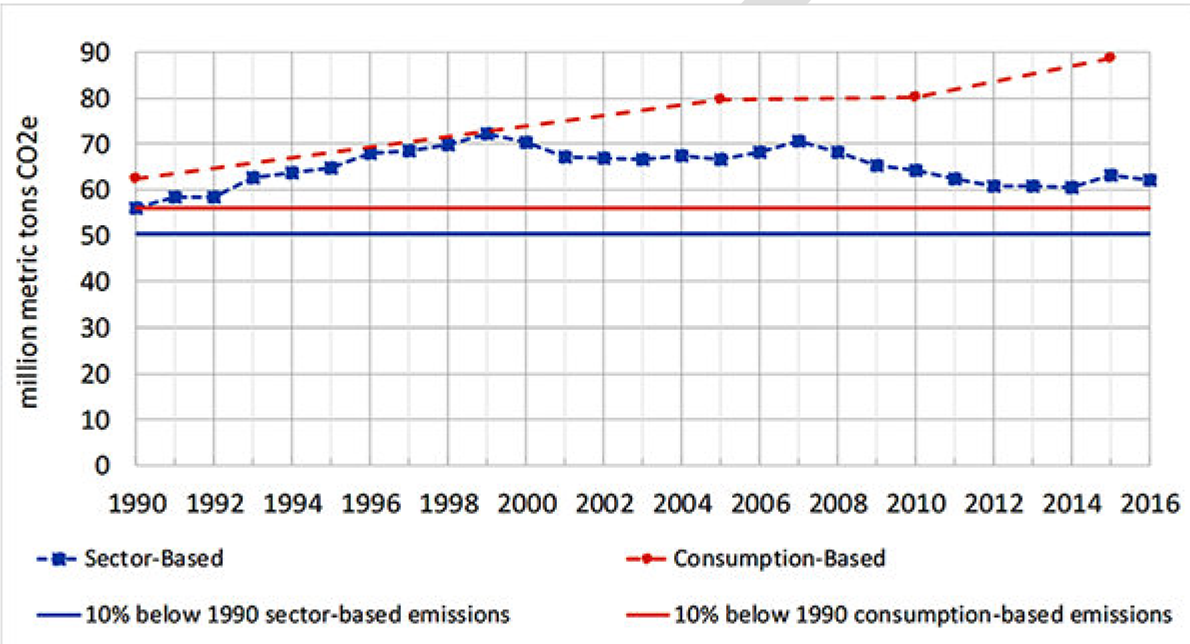
After eliminating any overlap, the sum of Oregon's 2015 emissions demonstrates a carbon footprint of 114 million metric tons of CO2e - more than either inventory alone. Indeed, Oregon contributes to climate change in many different ways, and when viewed together, these distinct inventories provide a broader understanding of both our emissions, and opportunities to reduce them.

Figure 2-6. Comparison of Oregon's 2015 sector- and consumption-based greenhouse gas emissions

Additional Key Findings

Results from Oregon's updated inventories indicate that Oregon's contribution to global concentrations of greenhouse gases is not subsiding. The combustion of fossil fuel, whether occurring within Oregon or as a result of our consumption, is the key driver of greenhouse gas emissions. Figure 2-7 shows that Oregon is not on track to reduce statewide emissions 10 percent below 1990 levels by 2020 in accordance with its goals. Rather, consumption-based emissions are rising, while sector-based emissions are not declining. The gap between the inventories has also grown over time. Consumption-based emissions were approximately 6 million MTCO2e higher than sector-based emissions in 1990. Fifteen years later, in 2005, that gap doubled (to 13 million MTCO2e) and ten years later doubled again (to 26 million MTCO2e in 2015). The OGWC will continue to rely on the research and analysis at DEQ and other state agencies to monitor and report on the course of current trends in Oregon's greenhouse gas emissions.

Figure 2-7. Trends from Oregon's Updated GHG Inventories (DEQ 2018c)



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DEQ 2018a. Oregon's Greenhouse Gas Emissions though 2015: An assessment of Oregon's sector-based and consumption-based greenhouse gas emissions. May 2018. Oregon Department of Environmental Quality, Portland, OR. https://www.oregon.gov/deq/aq/programs/Pages/GHG-Oregon-Emissions.aspx

DEQ 2018b. Data from Appendix A.

DEQ 2018c. Figure from website. https://www.oregon.gov/deq/aq/programs/Pages/GHG-Oregon-Emissions.aspx

Section 3: A Closer Look at Oregon Utility Emissions

Figure 1. Comparison of PacifiCorp Forecasted Emissions to OGWC Proposed Utility Trajectory

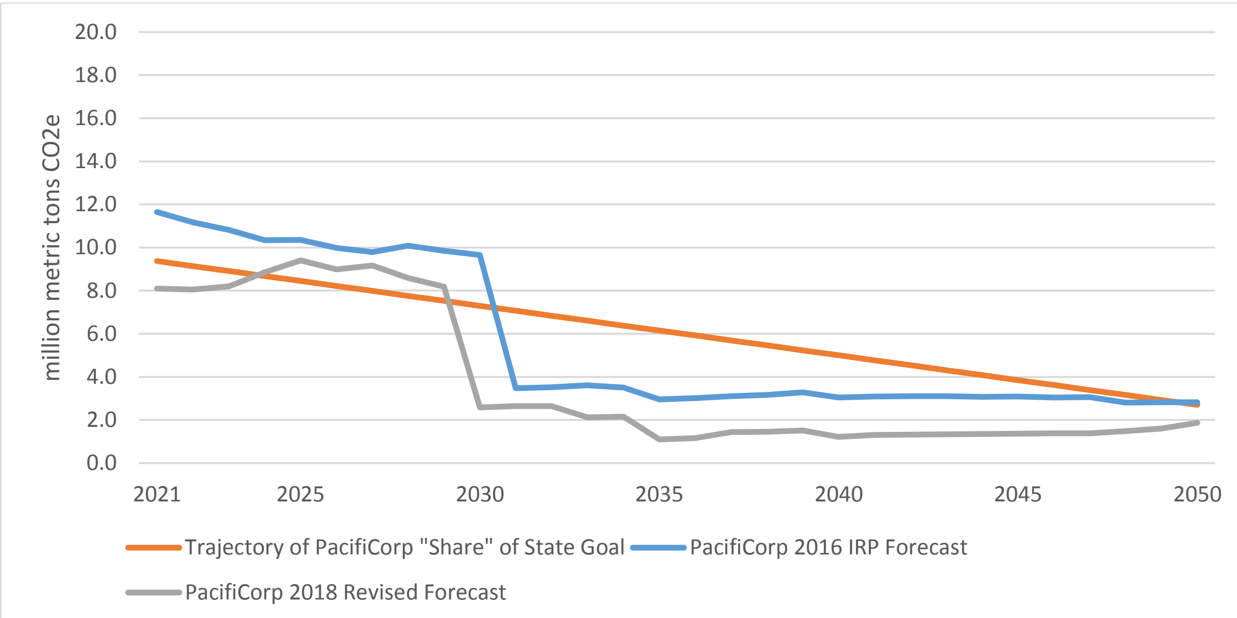


Figure 2. Comparison of Portland General Electric Forecasted Emissions to OGWC Proposed Utility Trajectory

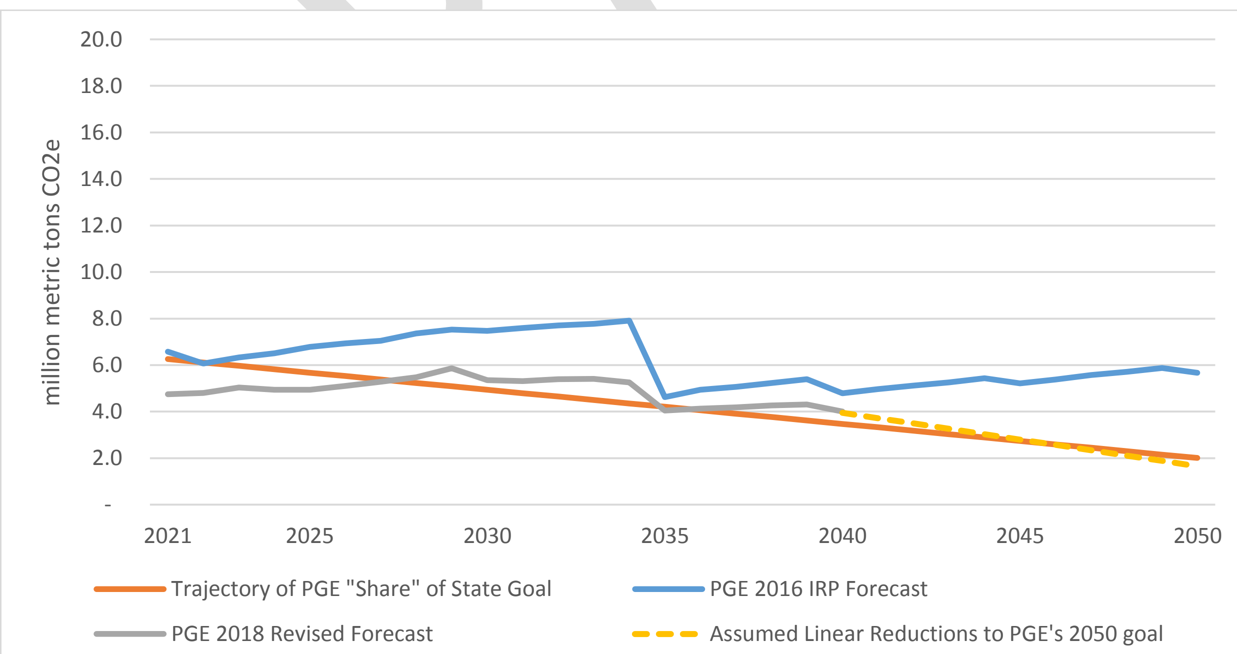
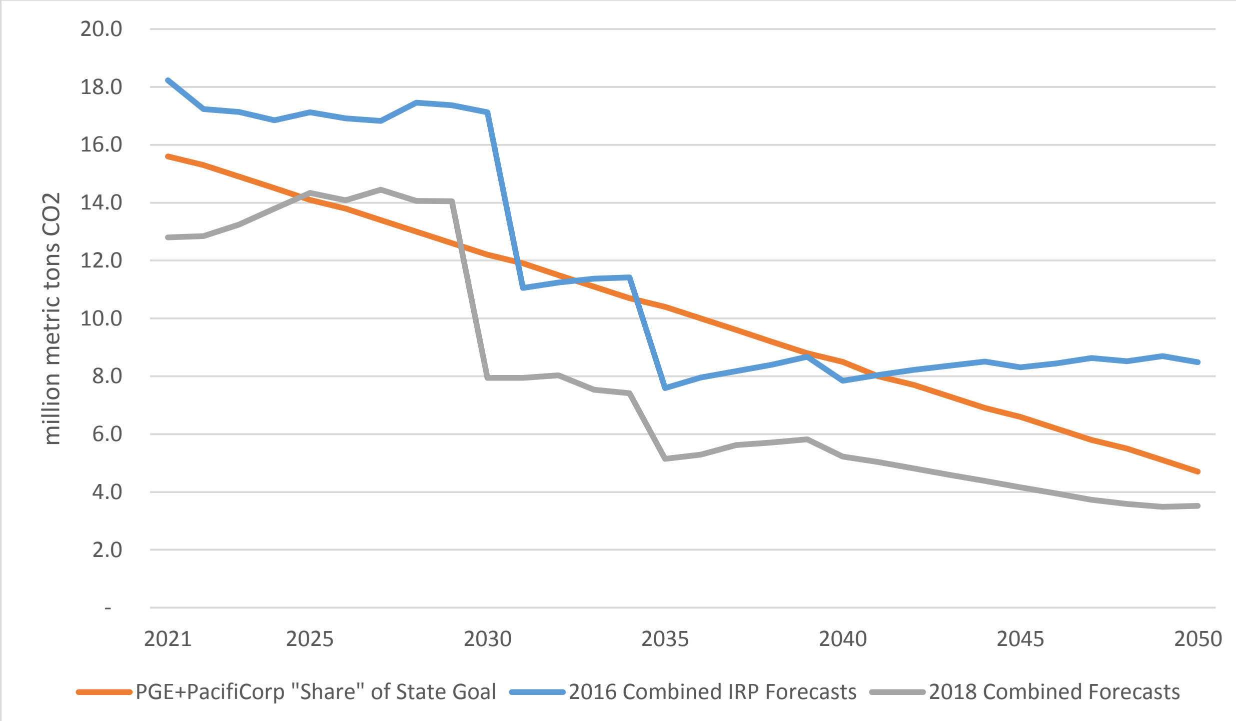


Figure 3. Comparison of Combined Portland General Electric and PacifiCorp Forecasted Emissions to OGWC Proposed Utility Trajectory



Electricity emissions in Oregon are largely a tale of the two largest investor-owned utilities, Portland General Electric (PGE) and PacifiCorp (called "PAC" in this report; it is also known as Pacific Power to customers in Oregon). The former serves customers only within the state of Oregon, while the latter has customers spread over six western states (we focus on the share of PAC's deliveries just to Oregon customers). PGE and PAC together serve about two-thirds of Oregon's utility customers. The other third is mostly served by Oregon's consumer owned utilities (COUs), who are primarily supplied by the Bonneville Power Administration (BPA), which provides an electricity mix that is almost entirely hydroelectricity with a near-zero carbon content. A small subset of COUs generate or purchase additional electricity beyond what they receive from BPA. Idaho Power Company serves approximately 18,000 people in far eastern Oregon (eastern Baker, Harney, and Malheur counties).

Both PGE and PAC have generating facilities within and outside Oregon's boundaries. PGE owns Oregon's only in-state coal facility (Boardman), numerous gas-fired facilities, and a share of the Colstrip coal plant in eastern Montana. PAC generates >60% of its power from coal facilities in several western states, but not in Oregon. For years in which the region's snowpack allows greater than average hydroelectric generation, both utilities will make purchases of lower-cost hydro and operate their thermal plants less, resulting in some unevenness of year-to-year carbon emissions and some difficulty in making comparisons.

Nevertheless, the story of PGE/PAC carbon emissions is largely one of how long the utilities' coal plants will continue to operate, and what will replace any terminated such plants. It is also a story of a consistent commitment over the last four decades, driven by public policy and implemented by the utilities and others, to invest first in energy efficiency before building new power plants. And it is becoming, as well, a story of renewable energy technologies that are not new but have gained new traction as their costs come down and carbon concerns grow.

While greenhouse gas emissions from natural gas deliveries and onsite combustion have remained relatively stable in Oregon within a range of about 7 to 9 million metric tonnes since 2000 (or about 11 to 14 percent of total state emissions), the record looks better on a per customer basis. NW Natural, formerly Northwest Natural Gas Company, which supplies about two-thirds of gas deliveries in the state – mostly to residential and commercial heating loads – has itself seen a steady level of emissions but a per customer decline in usage (weather adjusted) of 19 percent since 2000.

A Tale of Two Years

In the Year 2005, Oregon's largest electric utilities – Portland General Electric (PGE) and PacifiCorp (PAC) – emitted 22.72 million (mm) tonnes of CO2e, or 33% of the state's total.

By 2016 these emissions had dropped to 14.95 mm tonnes (24% of total Oregon CO2e), a reduction of almost 30%. A large share of this reduction is associated with a 22% reduction in overall electricity generated for delivery to customers or resale; actual deliveries to Oregon customers stayed about the same (about 30 mm MWh in both 2005 and 2016).

Because sales to industrial customers and for resale to other utilities are numbers that can bounce around, we can understand underlying trends best by focusing on residential customers and loads.

Both utilities have seen their numbers of residential customer accounts grow in this period by about 11%. But total kWh's delivered to these customers have remained level, which should mean that each customer is using less. And in fact data from the Oregon Public Utility Commission show a reduction in kWh/customer of 9% (PGE) and 8% (PAC). So customers are using electricity more efficiently, notwithstanding that households are increasing their use of appliances and amenities that plug into the wall sockets (hence, "plug loads"). Televisions, phones, computers, kitchen appliances, air conditioning and other increasing electric uses are being offset by increasingly efficient lighting, appliances and heating/cooling electrical equipment.

But carbon reductions aren't achieved by holding electrical loads steady. Either loads have to decrease, or carbon efficiencies in generating electricity have to gain traction. In addition, if there is to be a significant shift in vehicle fuels from gasoline and diesel to electricity, that the sources of generated electricity become more important still.

The Carbon Chapter

While electricity deliveries have remained flat in the face of population growth and the spread of plug loads, electric utility carbon emissions have actually declined. PGE's carbon emissions in 2005 were 10.35 mm metric tonnes; by 2016 they were down to 6.45 mm tonnes.

PAC's emissions, for the share of its overall generation allocated to its Oregon loads, dropped from 12.37 mm tonnes in 2005 to 8.50 mm tonnes in 2016.

The Oregon Department of Energy (ODOE) reports that from 2014 through 2016 the average kilowatt-hour of electricity from Portland General Electric resulted in 0.896 pounds of carbon-dioxide emissions (ODOE 2017). For PAC, the comparable figure was 1.552 pounds, reflecting the greater concentration of coal-fired generation in the PAC resource portfolio (ODOE 2017).

The reductions achieved early in the 2005-2016 period came from the utilities using their coal plants less heavily as reliance shifted to natural gas produced from new drilling and recovery techniques. The newest, most efficient gas power plants produce electricity at a carbon intensity roughly half that of coal, and at all-in costs (capital + operations) that are challenging the operating costs of existing coal plants.

In the last 8 to 10 years, the challenge to coal is coming increasingly from wind and solar renewable generation where production costs have fallen even more dramatically than with gas. The most efficient new wind projects are competitive with new gas. While there are very modest carbon emissions embedded in fabricating wind and solar equipment, they will operate for 20 years or more at emissions per kWh levels that are effectively zero.

As these low-carbon alternative resources have become increasingly available and cost-competitive, the economic logic for continuing to burn coal at often old and inefficient facilities – some from as far back as the 1950's and 1960's – becomes increasingly threadbare. When coal plants also come under pressure to meet other environmental emissions standards (e.g., mercury and other heavy metals, particulate matter), owners are faced with the choice to retrofit costly emissions control equipment or close the plants.

Thus PGE, in 2010, had to weigh a retrofit of its Boardman, OR, coal plant at a cost of half a billion dollars. Had it made this choice, it would then have had that added investment at risk for the two decades or more it would take to recover the cost from ratepayers. Regulators, stakeholders and PGE eventually landed on an alternative: invest $50mm in equipment that would meet Clean Air Act emissions requirements for ten years, then end coal combustion at the plant.

PGE's decision to pursue this alternative should result in the utility's overall carbon emissions dropping under 6mm tonnes in 2021, from over 10 mm tonnes only 15 years earlier. It will then face additional choices, starting with the disposition of its share of Montana's Colstrip coal plant, and finding the right low carbon path past that plant and onward to 2050.

PAC has its own hard choices ahead, with ≥60% of its generation coal-fired, mostly from aging power plants[94]. Oregon law requires it to end "coal-by-wire" deliveries of electricity to Oregon customers not later than 2030. Oregon and Washington regulators are directing the utility to review the cost and operating assumptions under which PAC is entitled to include those costs in bills to customers. PAC's 2017 IRP projects that most of its coal fleet will be operating through 2036, when half the coal burning capacity will have closed. But it is also proposing to five of the six states in which it operates an accelerated depreciation schedule that would bring them in line with Oregon, which has all the plants fully depreciated not later than 2030.

"This recommendation supports compliance with Oregon's Senate Bill 1547, and (anticipates) Washington energy policy developments and customer-driven demands," said Chad Teply, PAC Vice President.[95] Some of these adjustments shorten depreciation schedules by nearly 20 years. While they do not commit the utility to coal plant termination by these dates, they would insure that the company substantially recovers its capital investments if the plants are obliged to close earlier than now planned.

It is notable that the prevailing PAC IRP proposes substantial wind and solar resource additions, along with new transmission to support the wind. It includes, for the first time since IRP's were required, no

[94] Dave Johnston Unit 1, in Wyoming, was placed into service in 1959.
[95] Clearing Up 21 September 2018, page 10

new gas or coal through the 20 year planning horizon. But the schedule for terminating PAC's coal fleet remains uncertain.

Should Oregon's legislature in 2019 adopt an economy-wide carbon cap, additional backpressure will affect the continued operation of both utilities' out-of-state plants (the cap should also accelerate the transition of the state's vehicle fleet from gasoline and diesel to electric vehicles and other low carbon options).

Looking Forward

Investor-owned electric utilities, regulated by the Oregon Public Utilities Commission (PUC), are required to do Integrated Resource Plans (IRP) every two years. These plans weigh cost and operational choices – including existing and potential environmental regulation – to bring regulators a least-cost path forward that includes disposition of existing facilities and proposals for developing new ones. The plans include forecasts by each utility of a plausible carbon emissions trajectory. Making use of both historical emissions data and projections contained in each utility's 2017 update of its filed 2016 IRP, we can sketch out what would be a likely path for the state's utility emissions. This table assumes that PGE's "decarbonization" commitment continues after 2040 to drive the utility's emissions downward.

Year	PGE (million metric tonnes)	PAC (million metric tonnes)
2005[96]	10.02	13.49
2016	6.39	8.41
2021	4.75	8.10
2031	5.31	2.60
2040	3.95	1.20
2050*	1.65*	1.90*

*2050 emissions levels represent post-IRP (2016 update) emissions reduction goals, for each utility, of ± 85% below 2005 levels. Emissions projections beyond the 2016 IRP planning horizon are aspirational and dependent on technical and policy evolutions that are uncertain, but utility planning and resource strategies that align with State emissions goals should result in intermediate decision-making that will enable their achievement.[97]

The State's 2050 greenhouse gas reduction goal is "at least 75% below 1990 levels." In an earlier (2016) analysis the OGWC proposed a roughly parallel calculation for these two electric utilities of at least 80%

[96] Estimated baseline using a 5-year average (2003-2007)

[97] This forecast is primarily based on PGE's acknowledged 2016 IRP and 2016 IRP Update, which may differ from the emissions forecast resulting from PGE's next IRP. Consistent with PGE's 2016 IRP and 2016 IRP Update, this forecast:

- Incorporates PGE's December 2017 load forecast.
- Simulates dispatch and emissions from PGE's thermal resources in AURORA under the 2016 IRP Update Reference Case, which includes a federal carbon price that starts at $22/short ton CO2 beginning in 2022 and escalates to $90/short ton CO2 by 2040 (all in nominal dollars). To estimate the effects of carbon pricing in 2021 for this forecast, PGE assumed that thermal plant dispatch in 2021 is identical to forecasted thermal plant dispatch in 2022.

The forecast assumes that RPS resources are procured incrementally over time to ensure physical compliance with PGE's RPS obligations. With the exception of a proxy resource representing the successful outcome of PGE's ongoing Renewables RFP, it does not include RPS-eligible resources in excess of PGE's RPS obligations unless they are already online. This simplifying assumption is applied in part because PGE did not receive acknowledgement of a specific glide path of future RPS procurement in the 2016 IRP. Market purchases are assumed to have a GHG emissions rate of 0.428 MTCO2e-/MWh, consistent with the California Air Resources Board's unspecified import emissions rate.

below 2005 levels[98]. By this measure, utility emissions in 2050 would be below the combined utilities' proportionate share goal of 4.5 mm tonnes CO2e.

We can't say what these utilities *share* of Oregon's emissions will be in 2031 and 2040. That depends on whether the state gains control of and succeeds in driving down its transportation emissions, which have risen in the last four years. We can say that Oregon's electric utilities are on a path that, if sustained, will deliver their proportional share – as this Commission calculates such a share – of Oregon's 2050 greenhouse-owned se gas reduction goal.

How has this measure of utility emissions reduction success come about to date and what is required to sustain it?

Energy Efficiency

First and foremost, Oregon's utilities have participated in and supported the state's commitment to energy efficiency.

While Oregon's electricity use per capita is about average nationally, this is qualified in several ways.

First, Oregon's electricity costs are on average a third to a half what these costs (especially during peak demand hours) are in states like California and Hawaii, which rank one and two for lowest kWh per capita. Those higher electricity costs create a strong economic incentive for consumers to conserve, while in Oregon we rely more on individual commitment, state and local incentives, and program outreach and support to achieve efficiency savings. PGE and PAC customer efficiency efforts are supported by technical staff and financing tools from the Energy Trust of Oregon, a non-profit agency with the sole mission of providing these customers with access to efficiency and renewable energy technologies.

Second, over decades Oregon consumers have benefited from shared access to the region's low-cost hydroelectricity, encouraging disproportionate reliance on electricity for their lighting, heating/cooling and appliances, while other regions were more reliant on other fuels (gas; heating oil). Half the homes in Oregon still heat with electricity, often using old low-efficiency resistance units. [99]On overall energy use (all sources), Oregon ranks 39th in residential energy use (USEIA 2017).

Third, a cooler, wetter Oregon climate means more reliance on energy to keep homes and businesses warm in winter months, compared to California, Hawaii and other states with warmer winters. This distinction is weakening as these warmer areas of the country ramp up their reliance on summer air conditioning.

Finally, larger house sizes and appliance loads, even if met with efficient heating/cooling and appliances, have acted against lowering electricity usage.

These qualifying factors notwithstanding, Oregon consumers, with assists from utilities and the Energy Trust of Oregon, have driven their per household usage down over this period by almost 10%. The American Council for an Energy Efficient Economy (ACEEE) annually ranks states by their energy efficiency accomplishments. Oregon (and Washington) are regularly ranked within the top ten, along

[98] The OGWC suggested this alternative to reflect the complication created by the closure of PGE's Trojan nuclear plant in the early 1990's. Since nuclear energy is effectively a zero-carbon emissions technology, PGE's Trojan closure resulted in higher mid-90's emissions from the replacement gas-fired generation PGE opted to develop. Selecting a 2005 average (2003-2007) as the utility baseline steps around this anomalous action and outcome, while upping the end goal to 80% below 2005 levels keeps a degree of rigor in the goal.

[99] Oregon still meets 40% of its electricity demand from hydro, although most of this goes to consumer-owned utilities, while PGE and PAC rely more heavily still on gas- and coal-fired generation.

with states whose power costs (and therefore economic incentives) are twice or three times those in the Pacific Northwest.

That said, the State's energy and carbon goals both militate against resting on these laurels. Achieving the very aggressive carbon goals will require a redoubling of efforts to both identify technological efficiency advances and move them into the marketplace at cost-competitive levels.

Renewable Energy

Oregon is used to relying on renewable electricity. Until the 1960's most electric loads, of all utilities, were served from the region's extensive system of hydroelectric dams. Oregon was an early adopter (2007) among the states of a utility Renewable Portfolio Standard (RPS), which required electric utilities of a certain size (PGE, PAC and certain COUs) to be meeting 25% of their loads from *new* renewable generation by 2025. This new generation was additive to the existing renewable hydroelectric base.

In 2016 the state, with support from PGE and PAC, increased the standard to 50% new renewables by 2040.

Both utilities were on compliance paths for meeting the earlier standard, and both have expressed their expectations of meeting the new standards in a manner that manages for both customer cost affordability and system reliability.

In 2016 Oregon was receiving almost 7% of its electric energy from new renewables, up from ± 1% only ten years earlier. Both utilities were proposing significant new wind and solar facility investments in their 2016 Integrated Resource Plans.

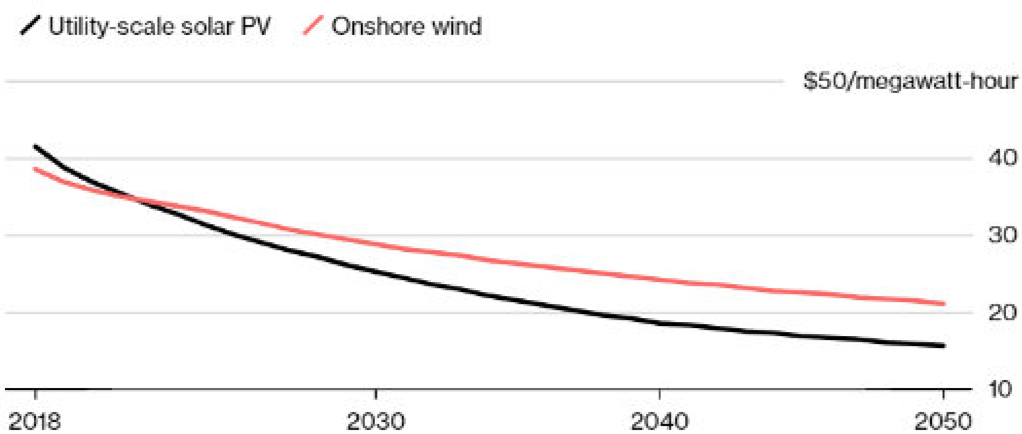
Going forward, neither utility is proposing any significant early new gas-fired generation. Both are proposing several hundred (PGE) to several thousand (PAC) megawatts of new wind and solar, anticipating the prospects of the two technologies continuing to achieve significant new cost reductions, efficiency gains and wider deployment. The series of figures below illustrate trends in falling costs of renewable electricity generation technologies and the projected shares these technologies will comprise in the global energy mix of the future.

Figure 4. Trends in Average Levelized Cost of Energy (LCOE[100]) for Selected Generation Technologies

Source: Lazard 2017. Reflects average of unsubsidized high and low LCOE ranges from past reports starting with LCOE version 3.0. Primarily reflects North American alternative energy landscape, but also broader/global cost declines.

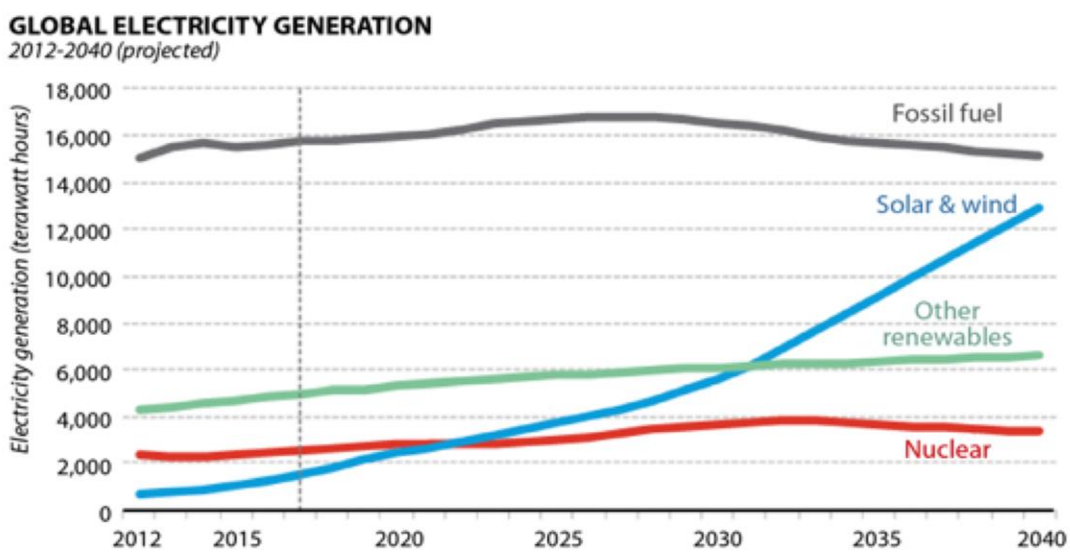
[100] LCOE calculations provide a convenient summary measure of the overall competiveness of different generating technologies. It represents the per-megawatt-hour cost (in discounted real dollars) of building and operating a generating plant over its assumed lifetime. Calculating LCOE relies principally on information about capital costs, fuel costs, fixed and variable operations and maintenance (O&M) costs, financing costs, and an assumed utilization rate for each plant type. The importance of these factors varies among the technologies—for instance, solar and wind generation that have no fuel costs and relatively small variable O&M costs, so their LCOE calculation changes in rough proportion to the estimated capital cost of generation capacity. For technologies with significant fuel cost, like coal, both fuel cost and overnight cost estimates significantly affect LCOE.

Figure 5. U.S.Forceast of Utility-Scale Solar and Wind Levelized Costs



Source: Bloomberg New Energy Finance 2018.[101]

Figure 6. Historical and Projected Global Electricity Generation by Technology



Source: Bloomberg New Energy Finance 2017. Their 2018 analysis[102] *projects that by 2050, the global electricity mix will be 63 percent renewables, 29 percent fossil fuels, and 7 percent nuclear.*

Utilities, regulators and technical staff express prudent concern about integrating variable generating wind and solar into a grid that sets and attains very high reliability and power quality standards. To date these criteria have been largely met by searching the grid for additional flexibility to achieve integration

[101] https://www.bloomberg.com/news/articles/2018-06-19/coal-is-being-squeezed-out-of-power-industry-by-cheap-renewables

[102] https://www.bloomberg.com/news/articles/2018-06-19/coal-is-being-squeezed-out-of-power-industry-by-cheap-renewables

while respecting reliability standards. Wider Energy Imbalance Markets (EIM's) have allowed the grids peaks and valleys to find and offset themselves. Going forward, some observers believe these flexibilities will continue to be discovered in sufficient depth and breadth. Others argue that additional short and intermediate-term electricity storage – batteries, pumped storage, underground compressed air, among other technologies – will be required. Much attention is going into these, especially short-term battery storage where a $100/kWh threshold is posited as the target for new battery technologies.

Natural Gas

Homes and commercial establishments in the urban areas of Oregon and the Pacific Northwest are reliant on natural gas utilities to meet a substantial share of winter peaking needs for space and water heating, while many industrial processes use significant quantities of gas as well. Three gas utilities operate in Oregon: Avista Corporation, Cascade Natural Gas, and NW Natural (formerly called Northwest Natural Gas Company). Direct use of gas (in home furnaces and water heaters, for example) is a more efficient way to derive useful energy than burning the same gas in a power plant, but the combustion remains a significant source of greenhouse gas emissions[103]. From 2005 to 2016, GHG emissions from all gas users in Oregon have stayed relatively level, ranging from a low of 7.1 million metric tons of carbon dioxide equivalent (MMT CO2e) in 2009 to a high of 8.2 MMT CO2e in 2013 and comprising from 11 to 14 percent of Oregon's total annual GHG emissions .

NW Natural is the largest supplier of gas in Oregon, primarily serving residential and commercial customers[104]. According to the utility, NW Natural's emissions (expressed as CO2 equivalent) were a little over 3.5 million tonnes in 2017, or a little less than 6% of the state's total. NW Natural's GHG emissions can vary year by year -- especially as winters are colder or warmer -- but have remained roughly flat since 2000, while its customer numbers have increased significantly. On a weather-adjusted basis, NW Natural reports that its emissions per customer have declined 19% since 2000.

The first line of defense in terms of GHG reductions for both electricity and natural gas is energy efficiency, and NW Natural has demonstrated its commitment to this strategy. It voluntarily enlisted the services of the Energy Trust of Oregon to work with its customers on gas efficiency, weatherization, and other strategies that contribute to lower GHG emissions.

NW Natural voluntarily agreed with its regulators to "decoupling" the amount of gas it supplies to customers from the returns the utility earns. This step removes the utility's profit incentive to encourage customers to use more gas, while still allowing it to earn a reasonable return for its product.

NW Natural has invested in modernizing its pipelines, replacing materials susceptible to leakage with coated steel and polyethylene; the action is expected to reduce gas losses in transit, improve safety, and keep "fugitive" methane, a powerful greenhouse gas, out of the atmosphere.

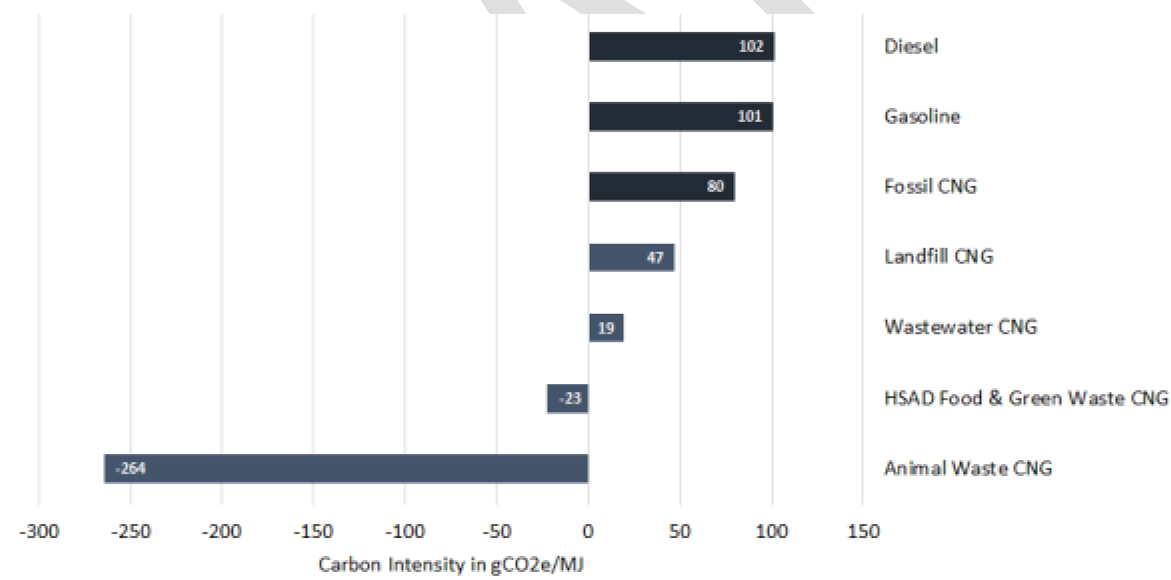
Compressed Natural Gas (CNG) has been advanced by NW Natural and other gas utilities as a lower carbon transportation fuel compared to gasoline and diesel. The Oregon Clean Fuels Program creates opportunities for alternative fuels such as electricity, natural gas, renewable natural gas, propane, and hydrogen to voluntarily opt-in and generate credits to trade in the program. Specifically, the program allows entities to register fossil- and bio-based CNG, as well as fossil- and bio-based liquefied natural gas (LNG). There has been some resulting interest by fleets (trucks; buses), though widespread uptake has

[103] 8.6 million metric tonnes in 2015, from inventory data tables published by the Oregon Global Warming Commission Biennial Report to the Legislature, 2017; or about 14% of total state emissions
[104] Larger industrial users often buy their gas directly, then contract with NW Natural to transport it.

been hampered by the economic and logistical challenges of developing an efficient, extensive system of compression/distribution networks.

NW Natural has set itself a target of reducing its overall GHG emissions – not just per customer – with a savings goal of 30% from 2015 levels by 2035. The primary strategies identified in their "low carbon pathway" include reducing the carbon intensity of their product, reducing and offsetting consumption, and replacing more carbon intensive transportation fuels (NW Natural 2018). Regarding the first and third strategies, NW Natural is pursuing some measure of fossil-based natural gas displacement with renewable natural gas (RNG) and potentially hydrogen (derived from water by electrolysis technologies). RNG is biogas[105] that has been processed to be interchangeable with conventional natural gas for the purpose of meeting pipeline quality standards or transportation fuel-grade requirements. Combustion of biogas and RNG still releases carbon dioxide to the atmosphere at the point of emission, but displaces the more potent greenhouse gas effects of methane. On a lifecycle basis of analysis, the California and Oregon Low Carbon Fuels programs consider certain forms of RNG to be net negative in terms of their GHG emissions impact (Figure 5).

Figure 7. Carbon Intensity of Approved RNG Pathways used in CA and OR Low Carbon Fuels Programs



California Air Resources Board Low Carbon Fuel Standard. 2018.

Source: ODOE 2018[106]

The Oregon Department of Energy recently published the results of a detailed inventory of all potential sources of biogas and RNG available in Oregon (ODOE 2018). This study, which was requested by the

[105] Biogas is a naturally-forming gas that is generated from the decomposition of organic wastes or other organic materials in anaerobic environments or processes, such as gasification, pyrolysis or other technologies which convert organic waste to gas in the absence of oxygen (ODOE 2018). Biogas a lower methane content and heating value than natural gas and contains many impurities. In some applications it can be used directly, but in others it is considered an intermediate product that must undergo additional processing before use as fuel.

[106] https://www.oregon.gov/energy/Data-and-Reports/Documents/2018-RNG-Inventory-Report.pdf

state legislature in SB 334 (2017), also identifies financial, technical, market, policy and regulatory barriers to developing and using biogas and RNG as an energy source that can help Oregon reduce GHG emissions and improve air quality. NW Natural served on the Advisory Committee for the inventory.

The inventory indicates that there is potential for a substantial amount of RNG to be produced in Oregon from a variety of biogas production pathways. The gross potential for RNG production when using anaerobic digestion technology is around 10 billion cubic feet of methane per year, which is about 4.6 percent of Oregon's total yearly use of natural gas. The gross potential for RNG production when using thermal gasification technology is nearly 40 billion cubic feet of methane per year, which is about 17.5 percent of Oregon's total yearly use of natural gas. The report estimated the following types of GHG benefits associated with these estimates of gross RNG potential:

- RNG production prevents methane from sources like landfills and animal waste from being directly emitted to the atmosphere. The combustion of captured gas results primarily in carbon dioxide, a GHG that is at least 25 times less potent in the atmosphere than methane. If the volume of RNG that could be potentially captured and utilized in Oregon displaced fossil fuel natural gas for stationary combustion (e.g., heating, cooking, electricity generation, or industrial process heat), approximately 2 million MTCO2e would be prevented from entering the atmosphere.
- RNG used as an alternative to diesel fuel could produce significant GHG reductions. When used as an alternative for an equivalent amount of diesel fuel, the state's total RNG production potential from anaerobic digestion reduced net GHG emissions by almost 2.3 million MTCO2e. This is a 33 percent reduction in diesel fuel's total GHG contributions to the transportation sector, or a nine percent reduction in the total emissions from the sector's total emissions of 24 million MTCO2e in 2016.

In order to realize these types of potential benefits, many barriers will need to be overcome, including financial, informational, markets, policy and regulatory (described in detail in the ODOE 2018 report). NW Natural has made positive progress in this area in partnership with the City of Portland, where they are beginning to produce RNG from the city's Columbia Boulevard Wastewater Treatment Plant for pipeline injection as well as a natural gas vehicle fueling station. However, more work is needed enable the development of RNG at scale in Oregon.

NW Natural has chosen an aspirational and challenging – and necessary – path to lower GHG emissions, and now needs to identify and implement more specific ways and means for achieving that outcome.

Conclusion

With the discipline of State law that will displace coal generation and require new renewables, Oregon electric utilities are on an emissions reduction trajectory that is in general alignment with Oregon's overall emissions reductions goals. Without those same statutory incentives, Northwest Gas has set itself a comparably challenging GHG reduction goal. Oregon's ability to meet its overall emissions goals depends on locking in these utility reductions.

There remains, for the electrics, the considerable overhang of aging coal plants to move to retirement in a prudent but accelerated manner. Both PAC and PGE resource plans would have these facilities operating well into the 2030's (and in PAC's case, beyond). While shifting plant outputs to customers outside our state is an alternative Oregon cannot directly control, it must work with Washington and other allies to bring about earlier retirement.

Coal retirement will leave substantial gas generation in place, most of it today configured for operating to meet base load customer requirements. To keep emissions going down, these plants will likely need to find a new vocation as integrating units that support increasing levels of variable (wind and solar) renewable generation. New gas plants are unlikely to be approved except in such an integrating role.

New wind and solar generation are clearly the mainstays of the new renewable electrical grid. They may be joined in a decarbonized utility world by other renewable generating technologies (ocean, geothermal, biomass, etc.), and by biogas and hydrogen replacing fossil-derived gas in gas utility pipelines. Wind and solar, while more reliably predictable than many utility observers first thought, nevertheless will require some measure of storage support as they penetrate the grid at higher and higher levels. They also will require rethinking and some refiguring of the transmission grid and operations to optimize their system value.

At the same time, the ability of Oregon's gas suppliers to find, or fabricate, low carbon versions of natural gas and package these with ongoing energy efficiency savings, will determine whether gas remains a significant contributor to Oregon's energy banks.

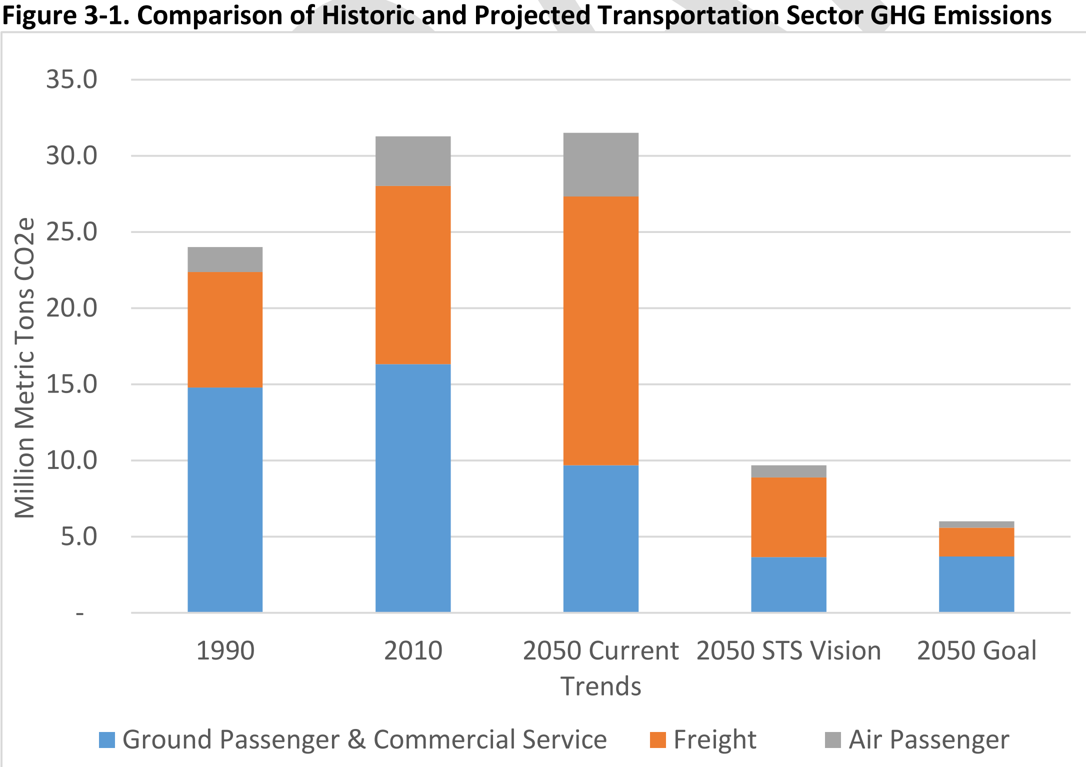
Utilities are in for interesting times.

Section 4: Projected GHG Emissions from the Transportation Sector

There are multiple data sources available that provide an understanding of where we think Oregon's transportation emissions are headed. These projections are based on our understanding of the factors affecting overall fossil fuel consumption, such as vehicle miles traveled (VMT), projected vehicle fuel efficiencies, and population growth, which are in turn affected by factors such as economic cycles, global oil market dynamics, human migration and settlement trends, and individual purchasing patterns. Data on these types of factors and modeling capabilities to integrate them are continually being updated and refined. So although emissions projection results are necessarily snapshots in time, they still provide useful points of reference for policy tracking and evaluation.

In 2013, Oregon Department of Transportation (ODOT) modeled what would happen to GHG emissions from the transportation sector if all of the actions called for in their Sustainable Transportation Strategy (STS) vision were fully implemented. Specific details of the STS vision and their implementation status are discussed in the following section. Figure 3-1 below shows their results in comparison to actual transportation emissions from 1990 and 2010, and presents the relative contribution of different transport modes to the emissions totals in each column. Under full STS implementation depicted in the "2050 STS Vision" column, by 2050 transportation emissions would be reduced by 60 percent (to 9.7 million metric tons (MMT) CO2e) compared to 1990 transportation sector emissions (24 MMT CO2e). The column "2050 Goal" shows that an additional reduction of 3.7 MMT would be needed by 2050 if the sector was asked to achieve an 75 percent total sector reduction (to 6 MMT CO2e) compared to the sector's 1990 level for combined air, ground and freight modes.

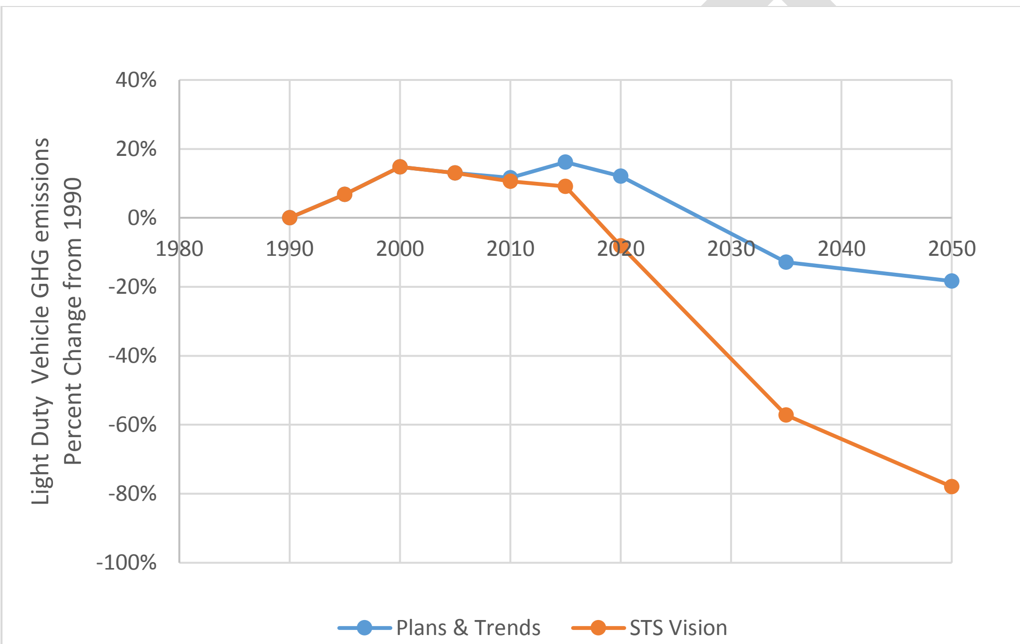
Figure 3-1. Comparison of Historic and Projected Transportation Sector GHG Emissions



Source: (ODOT STS 2013)

In 2018, ODOT published a Monitoring Report to document progress implementing the STS since 2013. They identified a number of areas of short-term positive progress offset by other areas of stalled progress or negative trends, particularly in GHG emissions from light-duty or passenger vehicles. Figure 3-2 shows a projection of GHG reductions from light duty vehicles attributable to current "plans and trends" (blue line), compared to an STS vision trajectory for light-duty vehicles that would result in around an 80 percent reduction below 1990 levels. The blue line shows that assuming a conservative level of implementation of the current suite of policies in combination with current market trends, passenger vehicle GHG emissions are expected to be reduced by about 15-20 percent below 1990 levels by 2050.

Figure 3-2: Projected light-duty GHG emissions of current plans and trends compared to the STS vision



Source: ODOT 2018

This projection is based on updated data about multiple drivers of fossil fuel consumption and GHG emissions in the transportation sector. Policy/plan drivers include Oregon's Clean Fuels Program, public transportation funding from the 2017 Keep Oregon Moving Act, and improved systems operations. With regard to other changing Oregon trends that affect GHG emissions projections from light-duty vehicles, the 2018 Monitoring Report (ODOT 2018, page 19) states:

> In 2012, when the majority of work on the STS was completed, fuel prices were at an all-time high. In the six years since, prices have dropped and according to national sources are forecasted to stay low. In addition Oregonians have held onto their vehicles longer than originally anticipated and have not transitioned to newer more fuel efficient or low/no emission vehicles. The result is more internal combustion engines in the fleet that get fewer miles per gallon than was anticipated in the STS. Additionally, Oregon's population continues strong growth and incomes have recovered from the recession. As a result, lower gas prices coupled with higher incomes and post-recession increases in driving means that vehicle miles traveled (VMT) have increased in Oregon… The chart

[above] shows an uptick in emissions following the recession and projected reductions in the long term. In the long term it is assumed that vehicles get more efficient, which helps to bring the curve down. While the overall trend line is moving in the right direction, it falls short of the levels called for in the STS vision.

Is the Current State Framework for Reducing Transportation GHG Emissions Enough?

The STS development process was the first statewide planning effort targeting a single goal (GHG emission reduction) and spanning the authority of multiple state agencies. The Oregon Transportation Commission (OTC) chose to “accept” – a weaker option -- rather than “adopt” the STS document outright when it was completed in 2013. In 2018, the STS was formally adopted by the OTC into the Oregon Transportation Plan, calling for a pursuit of strategies in the STS. Still, even an adopted STS is only advisory and has no force of law or programmatic consequences unless the Legislature chooses otherwise.

Six categories of strategies and 133 elements were identified and included in the STS. As summarized in the ODOT 2018 Monitoring Report, the categories for critical actions called for under the STS vision are:

1. **Vehicle and Engine Technology Advancements** – Strategies in this category increase the operating efficiency of multiple transportation modes through a transition to more fuel-efficient vehicles, improvements in engine technologies, and other technological advancements. Example elements include Zero Emission Vehicle (ZEV) programs, electric vehicle charging infrastructure, and fleet turnover to a greater share of electric or low carbon fuel vehicles. Many of the elements in this category require legislative action, are under the authority of the Department of Environmental Quality, or are reliant on market forces to drive change. Multiple state agencies are supporting efforts to increase EV adoption as a result of the Governor’s Executive Order 17-21 on zero emission vehicles.[107]
2. **Fuel Technology Advancements** – This category contains improvements in vehicle efficiency and reductions in the carbon intensity of fuels and electricity used to power vehicles. Strategies in this category increase the operating efficiency of transportation modes through transitions to fuels that produce fewer GHG emissions or have lower lifecycle carbon intensity. Example elements include Clean Fuels Standards, and transitioning to low carbon renewable fuels. Many of the elements in this category require federal programs, legislative action, are under the authority of the Department of Environmental Quality and Oregon Department of Energy, or are reliant on market forces to drive change.
3. **Systems and Operations Performance** – Strategies in this category address intelligent transportation systems, air traffic operational improvements and other innovative approaches to improving the flow of traffic, reducing delay on transportation systems, and providing travelers with information that helps them drive more fuel efficiently or avoid significant delays. Strategies in this category improve the efficiency of the transportation system and operations through technology, infrastructure investment, and operations management. Example elements include in-car displays that notify the driver of their fuel efficiency as they travel, providing real time information on crashes and delays, promoting vehicle-to-vehicle communications, and supporting autonomous vehicles. Many of these elements are under the authority of the private sector, ODOT, local jurisdictions, and Oregon Department of Aviation, or are reliant on market forces to drive change.

[107] https://www.oregon.gov/gov/Documents/executive_orders/eo_17-21.pdf

4. **Transportation Options** – This category contains strategies for providing infrastructure and options for public transportation, bicycle, and pedestrian travel, enhancing transportation demand management programs, shifting to more efficient modes of goods movement, and providing alternatives to certain air passenger trips. This category encourages a shift to transportation modes that produce fewer emissions and provide for the more efficient movement of people and goods. Example elements include providing park-and-ride facilities, promoting ride-matching services, adding biking and walking infrastructure, enhancing passenger rail services, and a significant growth in public transportation service. Many of these elements are under the authority of ODOT, local jurisdictions, transit agencies, and Oregon Department of Aviation, or are reliant on market forces to drive change.
5. **Efficient Land Use** – Strategies in this category focus on infill and mixed-use development in urban areas to reduce demand for vehicle travel, expand non-auto travel mode choices for Oregonians, and enhance the effectiveness of public transportation and other modal options. This category promotes more efficient movement throughout the transportation system by supporting compact growth and development. This type of development pattern reduces the distances that people and goods must travel, and provides more opportunities for people to use zero or low energy transportation modes. Example elements include supporting mixed-use development, limited expansion of urban growth boundaries, and development of urban consolidation centers for freight. Many of these elements are under the authority of Oregon Department of Land Conservation and Development and local jurisdictions, or are reliant on the market forces of housing costs, generational preferences, or job locations to drive change.
6. **Pricing Funding and Markets** – This category addresses the true costs of using the transportation system and pricing mechanisms for incentivizing less travel or travel on more energy efficient modes. A "user pays true cost" approach ensures that less efficient modes are responsible for the true cost of their impacts to the transportation system and environment. Strategies in this category support a transition to more sustainable funding sources to maintain and operate the transportation system, pay for environmental costs, and provide market incentives for developing and implementing efficient ways to reduce emissions. Example elements include transitioning to a user or mileage based fee, adding a carbon fee, promoting pay-as-you-drive insurance programs, and diversification of Oregon's economy. Many of the elements in this category require legislative action.

The 2018 Monitoring Report assessed progress in each of these areas. ODOT found positive short-term progress in a number of categories, summarized below in rows marked with a blue circle. Rows with a blue half circle are showing moderate progress, while white and red circles indicate areas where additional policy interventions may be needed to reverse current trends.

- on track with or exceeding the STS vision;
- moving in the direction of the STS vision;
- little to no progress towards the STS vision; or
- moving away from the STS vision / trending in a negative direction.

Vehicle Technology

Vehicle Mix	○
Fuel Efficiency (MPG)	◐
Battery Range	●
SUV/Light truck share	
Vehicle Age	
Fuel Technology	
Fuel Carbon Intensity	◐
Electric Carbon Intensity	●
Bus Fuels	
Systems and Operations	
Intelligent Transportation Systems	◐
Managed Road Growth	●
Parking Coverage	●
Parking Price	
Fuel Efficient Driving	
Transportation Options	
Transit Service	◐
Bike	◐
Carshare	●
Demand Management Programs	●
Land Use	
Urban Growth Boundary Expansion	●
Mixed Use Areas	●

Pricing

More Sustainable Funding Source	
Congestion Fee (Portland area)	
PAYD Insurance	
True Cost Pricing (Social and Physical Costs)	

For light-duty vehicles, although progress has been noted in several important areas, the projected 15 to 20 percent reduction is far short of what is needed to achieve the state's sustainable transportation and climate goals. Current efforts under the state's existing policy framework are occurring against a backdrop of relatively rapid and sometimes uncertain changes in the policy and economic/consumer landscape for successfully promoting alternatives to traditional fossil- fueled internal combustion engine (ICE) passenger cars and trucks.

In the passenger vehicle segment especially, ODOT's analysis indicates that effectiveness of efforts that support cleaner vehicles and fuels is most heavily reliant on consumer behavior. Fewer people than anticipated in the STS have transitioned to higher miles per gallon cars or alternative fuel/lower emission vehicles, including EVs. Some of this is related to market factors—such as lower gasoline prices, higher up-front costs for alternative fuel vehicles, and certain operating aspects of EVs on the market to date (like limited range, limited charging infrastructure, and slow charging times)—that will fluctuate or become less relevant over time as the market changes. Other consumer-related trends observed in Oregon that affect the state's efforts on cleaner vehicles and fuels include:

- Older vehicles on the road that get fewer miles per gallon: average vehicle age on Oregon roadways has increased to at least 12 years old (with some estimates up to 13.5 years old).
- The share of larger vehicles (light trucks and SUVs) in the passenger vehicle fleet that get fewer miles per gallon has not decreased as expected and continues to be a very popular market segment for automobile consumers in Oregon.
- Lower gasoline prices since 2012, when the majority of work on the STS was completed.
- Resurging economy since 2012, when the majority of work on the STS was completed.
- Oregon's population is increasing, and more people are in the state traveling.

On the policy side, the timing of when current polices start to influence overall emissions trends is also an important consideration. In areas such as land use/urban design, emissions reduction effects will not be seen immediately but will be important in the intermediate and long-term future. And while ODOT is studying and preparing initial steps (e.g., submitting an application to the Federal Highway Administration) towards congestion pricing in the Portland area, the reality is that it will be a number of years before tolling would potentially be implemented on Portland area.

ODOT's 2018 Monitoring Report concluded that assumptions around certain legislative actions will need to hold true in order to get back on track with the STS vision. These include extended Federal Corporate Average Fuel Economy (CAFE) standards and the Zero Emissions Vehicle program, as well as extension of Oregon's Clean Fuels Program and initiation of mechanism(s) for true-cost pricing. As will be discussed in the section below on federal deregulation trends, sustained implementation of current policies is not always guaranteed.

Regarding fuels, the federal Renewable Fuel Standard,[108] the Oregon Renewable Fuels Standard,[109] and the Oregon Clean Fuels Program[110] have increased the amount of cleaner alternative fuels used in Oregon's transportation mix from less than two percent in 2005 to 7.4 percent in 2017 on an energy equivalent basis (ODOE 2018). The Oregon Clean Fuels Program is responsible for the introduction of new low-carbon fuels into the state's transportation fuel mix, including renewable natural gas from wastewater treatment plants and landfills, and renewable diesel sourced from a by-product of ethanol production. Some of these fuels are, or can be, produced in Oregon. The program is currently on track to meet its goal of reducing the carbon intensity of transportation fuels, though continued progress depends on factors including production and adoption rates for EVs, biodiesel, and other alternative fuels.

Regarding true-cost pricing, those involved in the STS development process have recognized and emphasized the importance of sending a price signal of the impact of driving and thus incentivizing other, less carbon-intensive, modal options. ODOT (2018) found that few fees have been imposed that are called for in the STS, although many are being considered, like congestion (value pricing), and per-mile (OReGO) charges. An economy-wide cap on greenhouse gas emissions, expected to be considered by the Oregon Legislature in 2019, would reinforce these programmatic incentives to cleaner vehicles and fuels.

ODOT (2018) indicated that continued and increased investments or work in the areas listed below are also needed to address light-duty vehicle emissions. ODOT identified a separate set of strategies to address some of the unique aspects of freight and heavy-duty vehicle emissions. Both sets of strategies will be needed to get the state on an effective pathway to achieving the STS vision, and should be designed to be robust in the face of continuing changes in the policy and economic/consumer landscape.

- *Vehicles and fuels* – cleaner low-no emission vehicles and fuels. Cleaner vehicles and fuels are essential, representing 50 to 60 percent of the remaining gap of implementation actions for light-duty vehicles in the STS. Immediate attention is needed to get cleaner vehicles on the road to reduce the carbon footprint of those who continue to drive.
  - Today's vehicle mix includes older, larger and less fuel-efficient vehicles then when the STS was completed, and certainly than what the STS envisions by 2020 and beyond. This, combined with no reductions in overall vehicle miles traveled has led to increased emissions from transportation.
  - A vehicle fleet shift to electric vehicles (EV) must be combined with an electric utilities shift to a decarbonized electricity supply to these vehicles.
  - The EV industry must accelerate progress toward vehicles with less costly and more durable batteries, longer ranges between charges, and faster charging "fillups." State

[108] Congress passed the RFS program in 2005 and amended it in 2007 to increase the required amount of renewable fuels that must be included in the nation's fuel mix, as well as set requirements for the fuels' carbon content.
[109] The Oregon RFS passed in 2007 also sets standards for the amount of renewable, low-carbon fuels to be included in most transportation fuels sold in the state. The standard requires Oregon diesel fuel to contain 5 percent biodiesel and gasoline to contain 10 percent ethanol.
[110] The Oregon Clean Fuels Program was established by the state legislature in 2009, with the goal of reducing GHG emissions from Oregon's transportation fuels by 10 percent over a ten year period. The program sets the carbon intensity for individual fuels, creates annual baselines for regulated parties to meet, and establishes a market for clean fuels credits. The program has been fully operational since 2016.

and local governments must work with the private sector to ensure adequate charging infrastructure is available to meet the travel needs of Oregonians.

- *Public transportation* – buses, light rail, passenger rail, and similar services. These types of strategies make up about 13 to 15 percent of the gap in implementation actions for light-duty vehicles in the STS. While continued investments in transportation options, like biking and walking and public transportation are essential, mode shift is likely to be slow.
    - Although recent funding from the 2017 Keep Oregon Moving Act helps move in the direction of the STS, the levels envisioned in the STS call for exponentially more investment in transit service, along with converting bus fleets – public transit and school buses – to electricity as older buses are replaced.
    - Continued investments and actions are needed to maintain gains in biking and walking and control of land uses. Transportation options investments, such as park-and-ride, vanpools, and other efforts to manage demand are also essential.

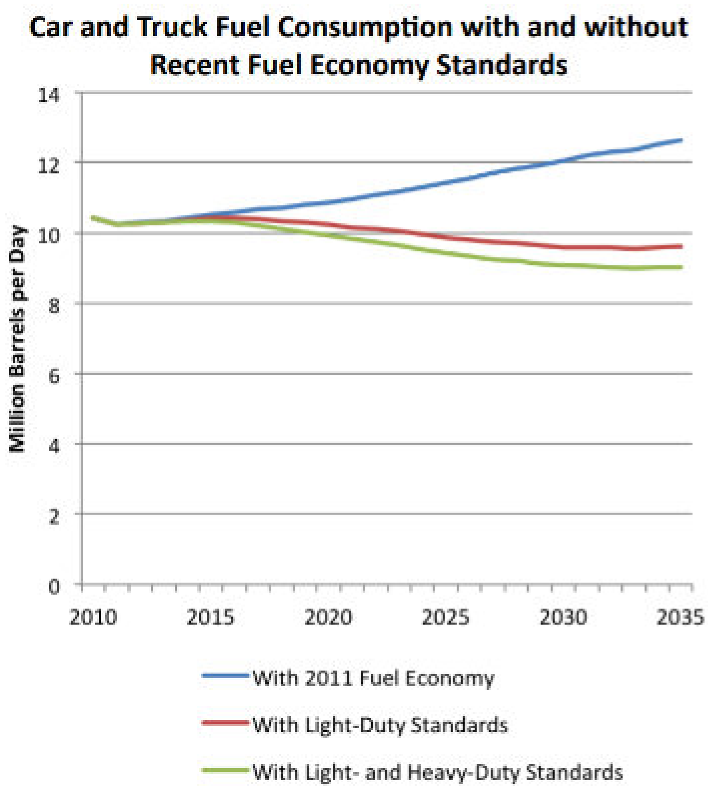
- *Systems and operations* – technologies that smooth traffic and help reduce idling. These types of strategies make up about 20 to 25 percent of the gap in implementation actions for light-duty vehicles in the STS.
    - These types of investments are important because they reduce idling for vehicles on the road. The stop-start movement of traffic jams burns fuel at a higher rate than does steady travel.
    - Without such strategies, emissions are likely to continue to increase. These strategies will be most impactful in the short-term until significant vehicle turn-over (to cleaner vehicles) occurs.

How Important are Federal Deregulation Trends for Meeting Oregon's Transportation Emissions Goals?

ODOT (2018) has stated that extended Federal Corporate Average Fuel Economy (CAFE) standards and ZEV II requirements are needed for the STS vision to be realized. The CAFE standards are the primary pathway for reducing fuel use. Established by Congress in 1975, CAFE standards set fuel efficiency goals that automobile manufacturers must achieve in the development of new vehicle models. Congress granted California a special waiver to allow the state to set its own, more stringent, standards to help better manage high levels of air pollution in its major cities. Oregon, along with 12 other states, signed on with California and agreed to follow their fuel efficiency standards. As the standards are updated, new targets are established for vehicle manufacturers to meet.

California adopted a new set of fuel efficiency goals through 2025, which the federal government subsequently adopted in 2009. The new set of standards covered both fuel efficiency and GHG emissions. On August 2, 2018, the Environmental Protection Agency (EPA) and National Highway Traffic Safety Administration (NHTSA) submitted a proposed rule to freeze the standards to 2020 levels, making them less stringent on fuel efficiency and carbon emissions for years 2021 through 2026. The proposed rule would also revoke California's waiver and establish a single nationwide standard with weaker fuel economy goals than the current standard.

Fuel efficiency standards create benefits that continue throughout the lifetime of a vehicle, including decreasing petroleum consumption, saving money, and reducing harmful emissions. For example, if fuel efficiency standards had remained the same since 2011, rather than vehicles becoming more efficient based on CAFE standards set for 2016 and 2020, the U.S. would see increasing petroleum consumption. The figure below shows projected fuel consumption through 2035 for the 2011 standards (blue line) and the current efficiency standards (red and green lines). The standards are projected to save more than three million barrels a day by 2035, which is a key contributor to reducing GHG emissions.



Source: ODOE Biennial Energy Report (2018)

The EPA/NHTSA proposal to freeze the vehicle fuel efficiency standards also includes revoking California's authority to set rules for their Zero Emission Vehicle (ZEV) Program. Nine states, including Oregon, participate in the California ZEV Program, which requires most vehicle manufacturers to deliver a certain number of zero emission vehicles, such as battery electric and fuel cell vehicles, plug-in hybrids, other hybrids, and gasoline vehicles with near-zero tail pipe emissions. This program is widely credited for the development of today's generation of electric cars on the market.

Conclusion

Oregon, and the nation, are off track in curbing vehicle greenhouse gas emissions and straying further away from the necessary pace every day. While EV sales are ramping up, new gasoline-fueled SUVs are entering the national fleet at far greater numbers. Even California, considered by many to be at the forefront of GHG reduction efforts, is seeing transportation emissions headed upward.

The Federal Government sets fuel economy standards and overall vehicle efficiency and emissions standards. Under the Trump Administration the gains and directions set by previous Administrations are now going in reverse. The states that have adopted California standards, including Oregon, are suing the Administration's challenge to California's privilege, under the terms of the Clean Air Act, to set our own climate-sensitive fuel economy standards.

Oregon and other states can enable progress on transportation emissions reduction with policies that incentivize low-carbon choices: EVs, bicycle and pedestrian travel, and urban design, to name a few. The states can reshape their electricity system to deliver clean, low carbon electricity to a growing EV fleet. But states also face a difficult next several years of offering sufficient market pull on vehicle manufacturers that the necessary progress toward a clean vehicle fleet is maintained.

Appendix A. Detailed Breakdown of Oregon Sector-Based Greenhouse Gas Emissions

1990-2015 inventory data with preliminary emissions estimates for 2016

[Will reproduce spreadsheet from https://www.oregon.gov/deq/FilterDocs/GHGInventory.pdf]