Planning Oregon Emissions

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Executive Summary

Oregon lacks a plan for reducing greenhouse gas (GHG) and toxic fossil-fuel emissions. In the absence of a comprehensive plan, policy creation has been piecemeal and uncoordinated, resulting in policy gaps, inefficient planning, inefficient spending, and insufficient guidance for public or private investments. Planning has been further complicated by various recent trends:

- The lack of state or global progress on GHG emissions implies a more aggressive target for 2050 than the target adopted by the legislature in 2007.
- More countries are accepting that the healthcare costs of toxic emissions from fossil fuels are even higher than the climate costs, and countries are therefore accelerating local decarbonizations because the benefits are primarily local.
- The cost trajectories of clean-energy technologies indicate continued cost reductions and rapid adoption rates.
- New financing options and business models are disrupting utilities and will increasingly disrupt the fossil fuel industry.
- Oregon spends around $400 million of public money per annum on energy, yet none of that spending is tracked for planned or actual GHG reductions.

This survey paper considers the layers of emissions planning necessary for Oregon. It does not prescribe solutions; instead, it explores candidate targets, solutions, and policies for the purpose of assessing an integrated, albeit cursory, plan. This survey should be viewed as an architect's first sketches with a dull pencil—none of it considers enough options with enough depth, none of it is sufficiently vetted by experts, and none of it analyzes climate change, technology, or economic scenarios. The intent of this fuzzy picture is to illuminate known solutions, small or large gaps in the known solutions, and interactions not visible through piecemeal analyses. Comprehensive planning cycles are necessary to provide clarity and periodic updates.

Options for long-range goals: The survey begins by assuming a long-term target of zero GHG emissions by 2050 instead of 75% below 1990 levels. Zero emissions by 2050 follows recent IPCC recommendations and the intent of the Paris climate agreement. The physical implications of zero by 2050 include clear targets by sector and a short list of probable long-term solutions.

Economic options: The cost trajectories of salient renewable power generation and storage options are briefly surveyed, noting that their experience curves imply predictable cost reductions in LED lighting, wind and solar generation, battery storage, and electrified transportation. Just like consumers waiting to buy solar panels or electric cars until prices drop, the state must consider when and how to best accelerate infrastructure investments. Other relevant economic forces include the continuing, gradual macroeconomic decline in energy

costs of all types; the failures of pricing current GHG emissions, vs. pricing future GHG emissions; fundamental volatilities in emissions trading markets; the massive savings from shrinking Oregon's $10 billion annual spending on fuels; opportunities for job creation; opportunities to better leverage public spending on clean energy; the need to deploy low-carbon solutions for disadvantaged communities; etc.

Policy options: Policies will be necessary to force 100% clean electricity generation. New vehicles must be required to have zero emissions by about 2030. Conventional natural gas must be phased out, and probably replaced by carbon-neutral renewable natural gas (RNG) from agricultural and forest wastes, landfills, water-treatment plants, and other RNG generation such as power-to-gas (P2G), enabling seasonal energy storage and distribution through the existing natural gas infrastructure to power heavy trucking and shipping. Various energy efficiency (EE) improvements in buildings, transportation, and industrial processes are currently very economical and more will be necessary; however, EE is a means to lower energy consumption and lower costs, not necessarily lower emissions; thus, the charter of the Energy Trust of Oregon may be improved by including GHG and toxic emissions. The maturity of various technology gaps implies more R&D and pilot deployment for aviation biofuels; seasonal energy storage; better processes for agricultural and forest emissions, cement production, and other industrial processes; and atmospheric CO_2 capture and sequestration.

Gaps in emissions governance are significant, including the need to convert Oregon's greenhouse gas goals into mandates; to establish an energy czar, advisory body, or designated agency to lead long-term, comprehensive planning; to develop policies and create scenario models to project how the policies will function; to prevent unnecessary investments while promoting desired ones; to create an ongoing and transparent data collection, analysis, and public information process; to routinely evaluate progress and adjust policies as necessary; etc.

Elements of a sufficient planning process include, at a minimum:

- Addressing the constraints and interactions within and between the layers of the climate change problem: the science of GHG and toxic emissions and their physical and economic effects; the new technologies necessary to rebuild emitting infrastructure, their maturity levels and cost trajectories; the economic options and impacts of various new infrastructure scenarios; and the policies and governance necessary to efficiently steer new infrastructure investments.
- Metrics and quantified targets by sector and by agency, such as baseline and target emissions and costs to permanently cut emissions. It can't be improved if it's not measured.
- Analyzing policies for theoretical and empirical evidence of efficacy, potential adverse policy interactions, and ability to reach the overall long-term goals.
- Policy analyses that anticipate the full range of potential climate change scenarios, cost evolutions in clean technologies, and economic issues.

The scope, scale, and complexity of comprehensive emissions planning are challenging and worthy of careful forethought.

I. Introduction

We lack a plan

The increasing threats of extremely costly climate change and the ongoing healthcare costs of toxic pollution from fossil fuels represent unacceptable risks and costs to Oregon. Meanwhile the emerging opportunities for upgraded clean-energy infrastructure promise energy independence that is less expensive (even without social costs) and creates more local employment. Oregon urgently lacks a comprehensive plan to stop its greenhouse gas (GHG) emissions and toxic emissions from fossil fuels.

Exploring the changing landscape

This paper explores gaps in Oregon's emissions planning. It does not intend to prescribe solutions. Planning is more important than the plan, and any plan is better than no plan. This exploration is offered to survey the status of recent planning and to illuminate significant gaps and potential paths forward. The desired outcome is experts and agency staff creating a comprehensive emissions plan for Oregon (with stakeholder input) and then periodically iterating a comprehensive planning process.

Recent planning work

In 2012 Baldwin, et al surveyed Oregon's energy options and their suitability for emissions reductions. This work noted the cost-performance trends of renewables and their economic, health, job-creation, and energy-security advantages.

In 2012 ODOE commissioned the Center for Climate Strategies to quantify the effects and costs of 212 GHG mitigation measures. The resulting impacts of this wide study are not clear. It apparently did not consider the cost/performance trajectories of key technologies.

In 2014 Stanford Prof. Mark Jacobson and the Solutions Project proposed practical strategies for full decarbonization by state by 2050, including an in-depth study and recommendations for Washington state.

In 2014 OESTRA (now Power Oregon) commissioned a study by the Northwest Economic Research Center (NERC) that identified about $400 million of annual state expenditures on energy in Oregon and recommends more oversight of that spending.

In September 2015 the Oregon Global Warming Commission (OGWC, all volunteers) presented their Biennial Report to the Legislature. It estimated the impacts of several GHG measures, which together would decrease emissions by 34% vs. business-as-usual in 2035. OGWC notes that these combined measures do not meet the state's 2035 GHG goals; in November 2015 the Green Energy Institute attributed this anticipated shortfall to inadequate policy design and governance.

In October 2015 the Northwest Power and Conservation Council published their 7th draft plan for regional electricity supply through 2035. The plan reduces GHG emissions by 38% by retiring some coal plants, developing more energy efficiency, and adding some gas plants. In early 2016 the Oregon legislature passed SB 1547, which requires utilities to remove coal plants from their retail power costs by 2035 but allows utilities to continue buying and selling coal power through short-term transactions; and increases the renewable (non-hydro) portfolio standard to 50% by 2040.

New trends since 2012

It is instructive to note rapid, fundamental changes in the landscape since the Baldwin study:

- The lack of global emissions reductions has increased the urgency of even steeper reductions in the near future.
- Data confirming that the local and current healthcare costs of emissions from fossil-fuel combustion significantly exceed the social (external) costs of GHG emissions.
- Cost trajectories of clean-energy technologies have become established and will enable rapid disruptions, with electric vehicles (EVs) emerging as a major transportation disrupter. New technologies such as autonomous vehicles are likely to add to the advantages of EVs and ramp exponentially.
- Energy of all types is now abundant, partly due to increasing efficiencies and wind and solar capacities.
- For the first time, the 2015 Paris climate change agreement creates international emission-reduction commitments and expectations.
- Financing is now available for residential clean-energy with low or no costs up front and sharing the savings; and electric utilities are struggling to redefine their business models.
- The Oregon Talent Council was established in 2015, and energy is identified as one of the five key industry segments by the Oregon Talent Plan.

What hasn't changed since 2012

- The fossil fuel industry continues to block meaningful GHG legislation at the federal level and in many states.
- Oregon energy policies continue to be incremented with no central vetting or coordination. State energy spending continues to be fragmented and not measured for efficacy against useful targets.
- Energy–related talent constraints and opportunities for strategic investments have not been sufficiently identified.

Overview

This paper starts with the most recent climate science data and assumes that Oregon's 2050 emissions goal will be reset. The benefits and implications of a more ambitious goal are explored top-down, including economic effects and policy options by sector. Lastly, governance implications and conclusions are outlined.

II. Global emissions

'Last chance' to limit global warming to safe levels
The latest annual UN "emissions gap" report compares the goals of the Paris climate agreement to the pledges of its signatories. In it, the United Nations Environment Program (UNEP) warned that unless reductions in carbon pollution from the energy sector are reduced swiftly and steeply, it will be nearly impossible to keep warming below 2 degrees, let alone to the 1.5 degree aspiration. Figure 1 shows how a maximum allowable GHG inventory implies faster and steeper reductions as emissions continue.

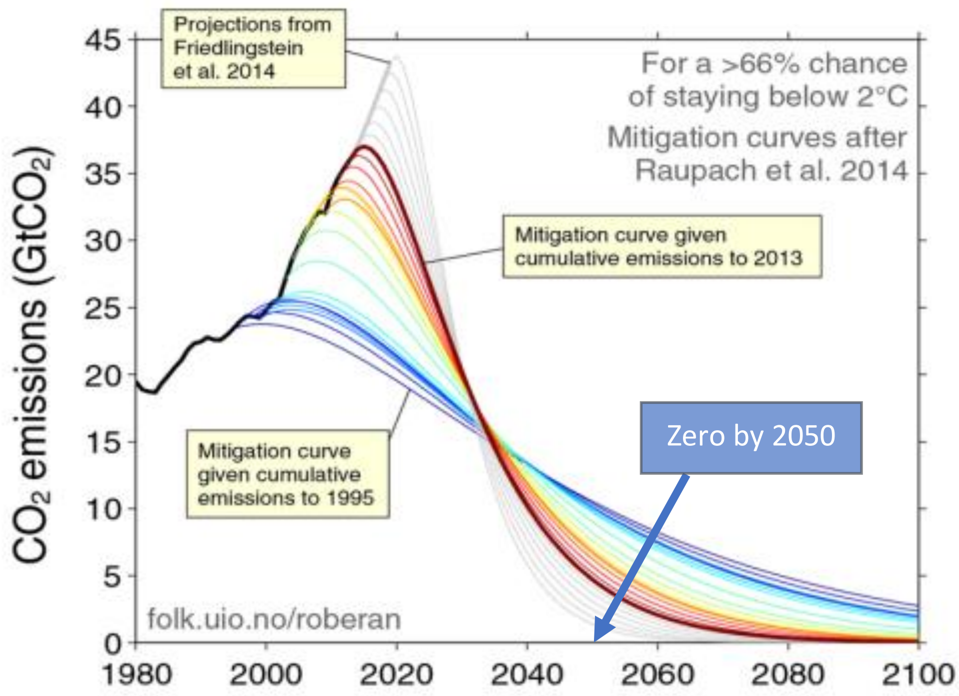

Figure 1. Delaying mitigation actions implies increasingly dramatic emissions reductions. (The allowable emissions--the area under each mitigation curve--is the same in each scenario.)

Climate change effects in Oregon
The Northwest Region Report in the 2014 National Climate Assessment and updates in the Third Oregon Climate Assessment Report find that the major climate change effects in Oregon will be much smaller snowpack, especially affecting summer streamflows; sea level rise, threatening coastal infrastructure; ocean acidification, which is already damaging fisheries; and much larger wildfires and insect infestations in our forests.

Toxic emissions costs are much higher than climate change costs
Obviously Oregon's GHG emissions alone cannot significantly directly affect atmospheric concentrations of pollutants, and opponents have used this 'free-rider' argument to advocate inaction. But the reality is that benefits of emissions reductions overwhelmingly accrue to local communities, due to the social costs of toxic fossil-fuel emissions.

For example, the Clean Air Task Force estimates the fine particle health impacts of diesel emissions alone in Oregon at about 176 premature deaths and $1.5 billion of healthcare costs annually. That compares with around $300 million of climate change costs from Oregon's 6 MMTCO2e of diesel emission at a social cost of $50/MTCO2e. Are thousands of avoidable deaths in the near term more politically compelling than a future with irreversible climate change?

Many countries, cities, businesses and investors are targeting zero emissions by 2050
Instead of waiting for China or India to cut their emissions, jurisdictions and investors are urgently installing clean infrastructure because it's cheaper and healthier. Dozens of countries and cities already have 100% renewable electricity. 198 cities and regions have committed to getting to zero by 2050 and/or 100% renewable energy. NGOs advocating 100% renewables by 2050 in the US include The Solutions Project, NextGen Climate, and the Sierra Club.

In December 2015 a US House Resolution proposed a goal of full transition to all clean, renewable energy and near-zero greenhouse gas emissions by 2050. Senator Jeff Merkley was crafting legislation that would require 100% of American energy to come from renewable sources by 2050. But the new Congress is unlikely to pursue anything like these, highlighting the need for Oregon to take action independent of Congress.

III. Oregon emissions and options

75% GHG reduction by 2050 aims to lose the race to cheaper and healthier infrastructure.
Figure 2 puts Oregon's 2050 emission goal in perspective with global emission requirements. While the 75% goal has been seen as ambitious, it is certainly not leading and not likely to attract the best and brightest talent or companies. A goal of zero emissions is also a much clearer mission for each sector than a partial reduction goal which invites hope that other sectors have an easier task and can thus do more than 75% reductions.

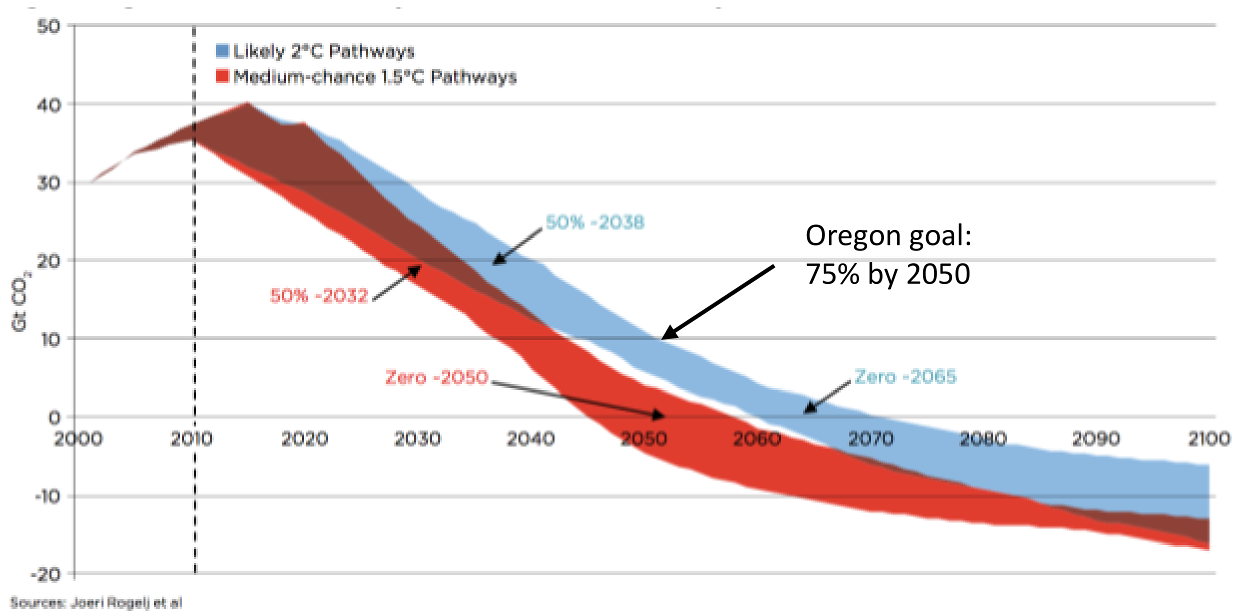

Figure 2. Range of global emission pathways in scenarios consistent with a likely chance of 2 ℃ or medium chance of 1.5 ℃. All of these scenarios assume aggressive adoption of methods to collect CO_2 from the atmosphere and sequester it; thus the negative emissions in the second half of the century. source

Oregon is on track to significantly miss its 2020 emissions goal.
In spite of significant improvements since its peak in 1999, Oregon's total emissions under current policies are expected to remain about flat through 2035, just above 60 MMTCO2e (figure 3). It is likely too late to affect 2020 emissions, thus missing the state's 2020 target of 51 MMTCO2e by more than 20%. Figure 4 shows the combined effects of several potential programmatic policies as well as a carbon pricing policy.

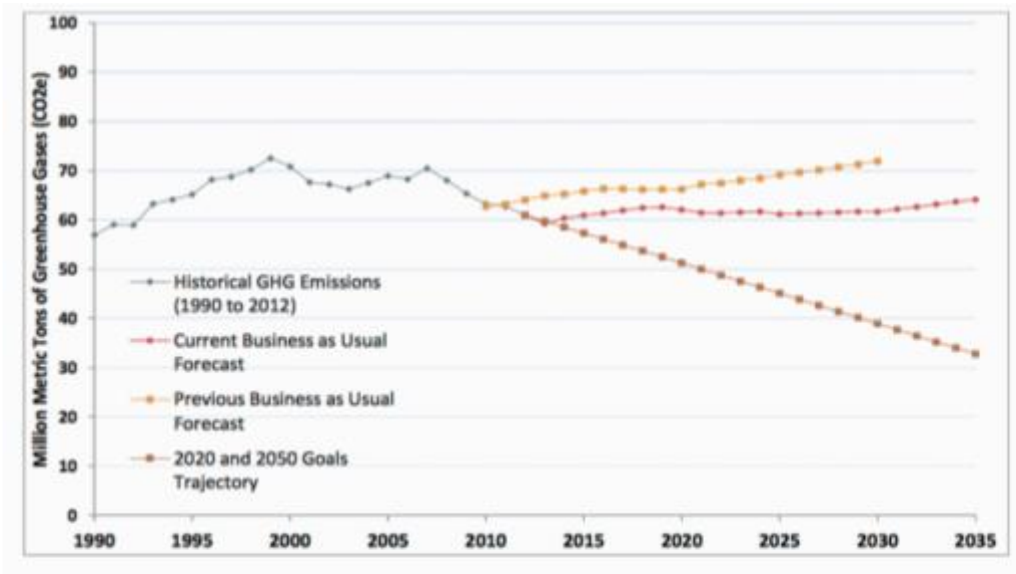

Figure 3. Existing and forecasted GHG emissions in Oregon, from [OGWC 2015](#).

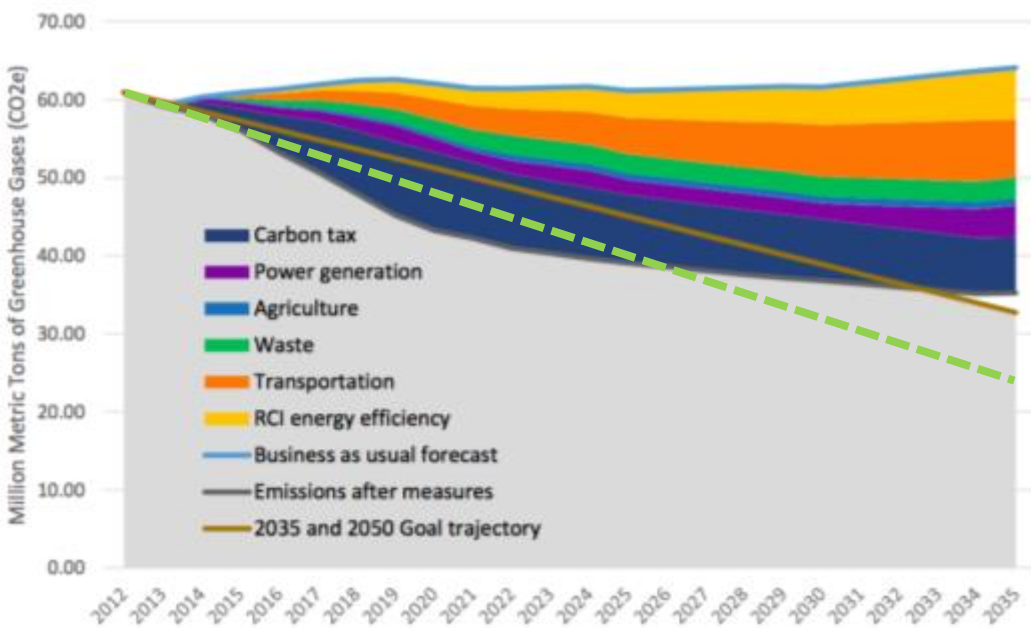

Figure 4. Estimated reduction contributions of various potential policies, from [OGWC 2015](#). The dotted green line depicts a trajectory to zero emissions by 2050.

Existing programs address GHG emissions, but not enough.
SB 1547 will push Oregon electricity to roughly 80% clean by 2040, and Oregon's Clean Fuels program is targeted to reduce GHG emissions 10% by 2026. The federal CAFÉ standards will also reduce emissions (assuming that policy survives the next administration), although quantification of the contribution to Oregon may be difficult. A baseline of contributions by

existing and proposed programs would facilitate near- and long-term planning, similar to the Berkeley Labs' analysis for California.

Oregon would benefit from some long-term emission goals and a comprehensive plan. Oregon's energy and emissions legislation is characterized by piecemeal programs and amendments without guiding goals and often lacking careful design. Long-term goals and milestones with corresponding agency charters and objectives are needed to efficiently and effectively attack Oregon's emissions. Comprehensive planning to address all the state's GHG and toxic emissions would help to avoid legislative gaps, overlaps, and adverse policy interactions.

Whether the 100% goal is 2050 or later, a 100% goal drives various physical, economic, and policy implications. A 100% goal is simpler than a 75% goal for accounting, by obviating inter-sector goal negotiations.

Physical implications of zero emissions

- In practice, conservation measures can cut emissions by only ~10-30%. Most consumers can adjust their thermostats, wear sweaters, drive less, drive the speed limit, carpool, take transit, etc., but these will only cut a minority of their personal emissions unless they unhook their utilities, ride a bicycle everywhere, and stop shopping. The vast majority of households and businesses will need upgraded infrastructure that is more efficient and uses clean energy.
- Oregon can't reach zero emissions or a 75% reduction by only avoiding new generation through efficiencies, as proposed in Oregon's 2012 ten-year energy action plan and the 7th NWPCC plan. All emitters must be shut down by 2050 or whatever date.
- Zero-emission energy generation implies *only* renewable sources such as wind (onshore or offshore), solar, hydro, wave, geothermal, or nuclear (GHG emissions from nuclear are debatable); or carbon-neutral biofuels such as renewable natural gas (RNG) or other biofuels. The current cost trajectories of these technologies probably favor a mix of mostly hydro, wind, and solar for Oregon electricity generation, plus RNG and other biofuels for heavy trucking, shipping, aviation, and seasonal energy storage.
- Zero-emission buildings implies electric heat pumps and heat-pump water heaters or RNG for gas heat. These heat pump options are already widely available and commonly used.
- The efficiency of a solution doesn't directly affect its GHG emissions—for example, a leaky building that is 100% powered by renewable electricity may be expensive to operate, but it doesn't add emissions. Conversely, a building can also be more energy-efficient than necessary for least-cost operation. The ETO charter is energy efficiency, but should the PUC amend the charter to additionally include, or instead be, GHG emissions?
- Zero-emission transportation implies electrification or carbon-neutral fuels. Electrification looks likely for all except the heaviest vehicles, shipping, and aviation.
- The microeconomic application of zero-emission constraints to a household over ten years or more in Oregon currently implies tightening up the house envelope, installing a heat pump and heat-pump water heater, electrifying vehicles, cutting air travel, and buying clean electricity or installing grid-tied solar. The resulting energy costs can be reduced to the

monthly connection charge, which is very attractive to consumers across the political spectrum (except cutting air travel).

- Firming up the intermittent generation of electricity from renewables will require grid balancing and regulation over the short-term (seconds to minutes); medium-term (minutes to hours); and long-term (more than hours). These grid services will increasingly be supplied by a mix of demand response (controlling loads such as hot-water heaters, electric vehicles, and large industrial loads from the grid); more transmission lines in the region; and batteries, power-to-gas (P2G) or other storage technologies.
- The last allowable year for adding any additional fossil fuel infrastructure without becoming a stranded asset is simply 2050 minus its useful lifetime. The last date for new gasoline or diesel passenger cars (typical 15-year lifetime) is thus 2035. Germany is proposing to ban sales of new gas/diesel cars after 2030 in the EU. Existing gas power plants will most likely become stranded unless we can generate enough RNG for them, and peaker plants are likely to become stranded soon after 2020 anyway.
- Zero emissions implies practical and economic technologies for carbon-neutral fuels, low-emission agricultural practices, seasonal energy storage, and low-carbon cement and other materials. These technologies are in the development or piloting phases, and represent more clean-energy opportunities for Oregon businesses. Forest sequestration and emissions are not well understood, and need more research efforts. Ensuring progress on these developments could be part of the charter of an energy/climate commission.
- Collection and sequestration of many billions of tons of CO_2 from the atmosphere is a critical technology need for achieving negative emissions after 2050. There are research efforts in this area which need much more funding, and the federal government or states should be providing R&D grants in this area. The current outlook for federal funding looks grim, so this technology may be developed by other countries and purchased, instead of manufactured, by the US.
- A February 2017 article in *Science* proposes actions similar to these on a global scale, including halving GHG emissions every decade and meeting that with increasing CO2 removal reaching 5 GTCO2/yr. (Figure 5)

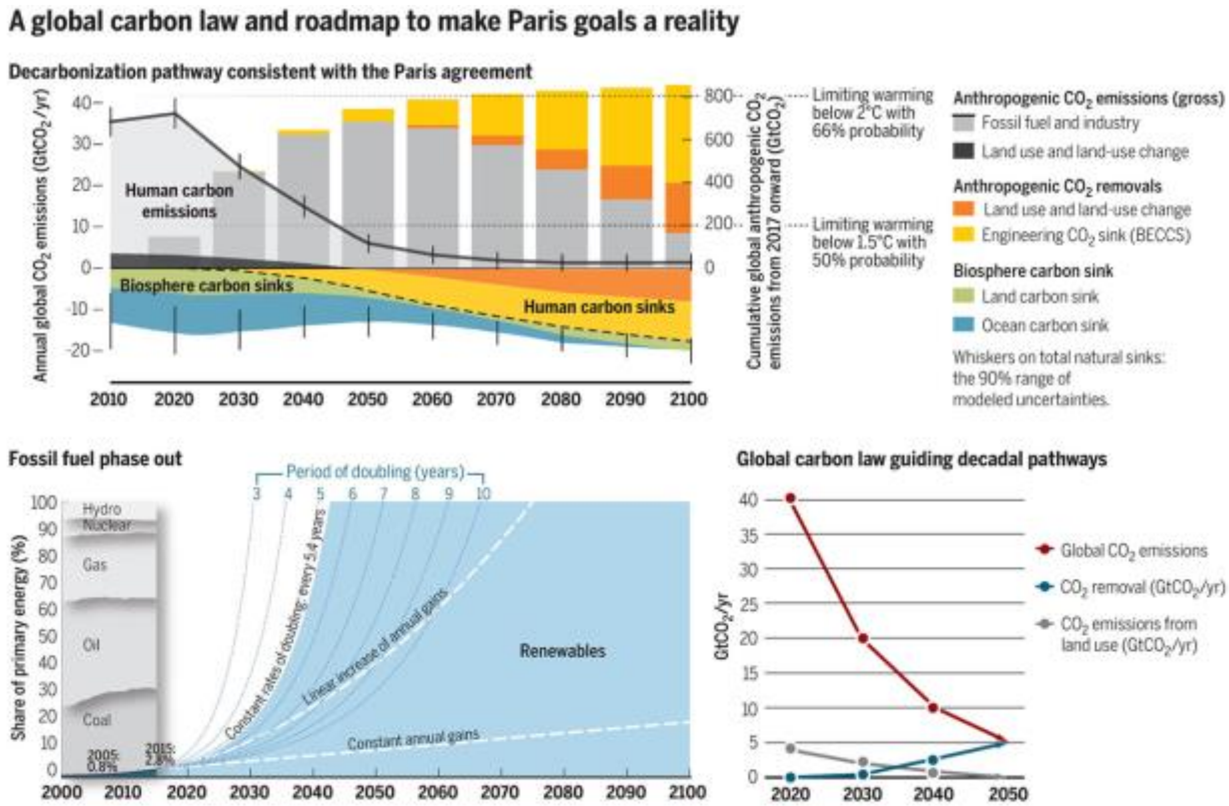

Figure 5. A detailed roadmap for meeting the Paris climate goals is eye-opening.

The governance challenge is steering the deployment of energy infrastructure that is sustainable, affordable, resilient, and well-integrated with other infrastructure. These parameters could be a general scope of authority for the energy/climate governing body.

IV. Economic effects and options

How much will this transition cost?
The list of physical requirements is relatively straightforward, and begs the obvious question, "How much will the transition cost?" The answer is not simple, but the transition is certainly affordable.

Firstly, the majority of our dirty infrastructure will be replaced over the next 30 years anyway. The average small vehicle lifetime is about 15 years, and even less for heavier vehicles. Energy-using appliances and heating/cooling units rarely last more than 25 years in homes. Commercial and industrial infrastructure must be upgraded often to remain competitive, although some large industrial infrastructure is expected to last for 50 years or more. The critical necessity is to steer emitting infrastructure choices at the point of initial investment, because the vehicle/furnace/factory/etc. will be burning fuel throughout its useful life. When a zero-emission car costs no more than a gas or diesel car, the cost of that transition is arguably zero and the lifetime cost of that transition is arguably negative.

Secondly, the costs of major clean-energy technologies will continue to decrease.
Like flat-screen TVs and digital cameras, the cost of wind and solar power generation, energy storage technologies such as various battery types, electric vehicles, LED lighting, and other clean-energy technologies have been dropping and will continue to drop (figure 6). Electric vehicles are expected to achieve a purchase price lower than ICE cars by about 2025.

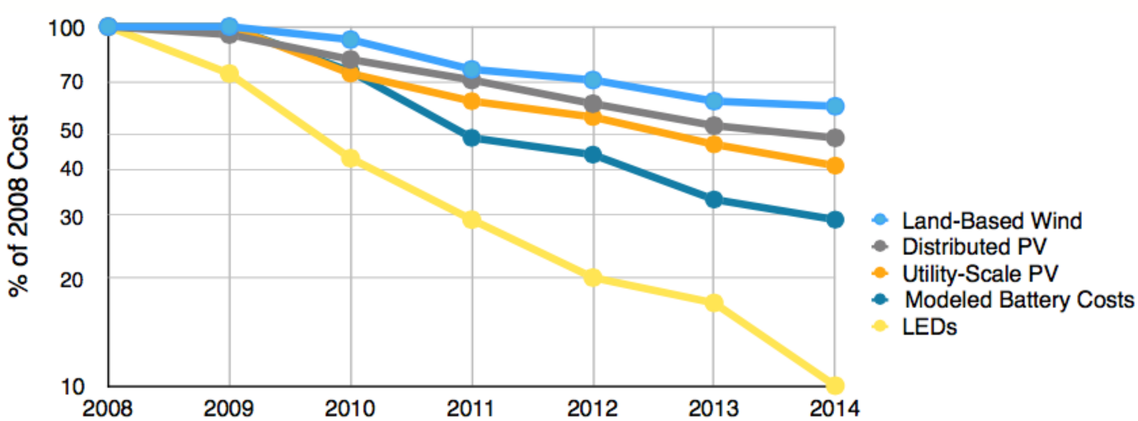

Figure 6. Recent cost trajectories of wind, solar, battery, and LED technologies. US DOE 2016

These cost trajectories can be extrapolated out at least five years because they are the result of learning more as we build more product. The related learning curves do not assume any technology breakthroughs; any breakthroughs that are commercially successful would only improve cost-performance beyond the industry's learning curve.

Such cost trajectories create a new complexity for buyers and policymakers—when is the optimal time to buy a new smartphone/car/truck/energy system, when each are getting cheaper? For example, LED lighting recently passed the tipping point of being preferred by consumers, but electric vehicles aren't there yet. How and when should policy prioritize ramping EVs vs. LEDs vs. energy efficiency upgrades at 3 cents/kWh? Subsidies to accelerate adoptions may be justified by the social costs of emissions, but the emissions impact per subsidy dollar may be much greater when a smaller subsidy can push a new technology over the cost tipping point. Past the tipping point, as LEDs are now, the need for a subsidy decreases and a mandate may be more effective, if necessary at all. Governance mechanisms need to anticipate such issues.

Thirdly, savings on fuel and maintenance make the transition a matter of financing and payback periods.
EVs are already cheaper to fuel and maintain than gas/diesel vehicles, and energy from the sun and wind are free. Transitioning to clean energy thus comes down to financing. The capital cost is still an important portion of the total lifetime costs of clean energy, and the cost of that capital is important. How can the state facilitate and accelerate financing of clean-energy deployments, without taking unreasonable risks? How can we optimally mix public and private financing? How can public financing optimally phase out as clean-energy options become as cheap as incumbent technologies without social costs? Who will pay for stranded assets?

Green banks in various states have demonstrated 3X to 12X leveraging of private spending with public dollars, even as the banks are or will be paying back the state's investment. Why should the state grant public money for cheaper private infrastructure, when the state could make money by loaning it out instead?

What financial policies help or hinder clean-energy investments? For example, the impacts of Home Energy Scores need to be more than just available to home buyers—they should be signed by all buyers, correctly accounted by appraisers, and respected by lenders as part of buyers' necessary expenditures.

Fourthly, the transition will create jobs and massive savings.
Oregonians spend over $10 billion per year on fossil fuels, almost all of which flows out of the state or country. The International Energy Agency estimated that global decarbonization would cost about $44 trillion for new infrastructure, resulting in $115 trillion of fuels savings by 2050. A study of the economic impacts of decarbonizing Oregon should demonstrate similar savings after transitioning, just as solar and electric vehicle (EV) owners already enjoy. Key deficiencies of macroeconomic modeling include the lack of technology cost trends or policies that can steer clean infrastructure adoptions. Various decarbonization studies find zero-emission scenarios to be cheaper and healthier, and many cities and architectural organizations are already mapping attractive approaches.

An Oregon transition would generate thousands of clean-energy jobs while eliminating far fewer fossil-fuel jobs. (Jacobson's study for Washington state doesn't assume or estimate a distribution of additional job creation from manufacturing the new technologies, as if all the equipment was purchased from other states.) The Northwest could clearly benefit from growing its clean-energy business segment, as noted by the Oregon Talent Council. The scope and scale of a clean-energy business cluster depends on how well we attract and develop the necessary talent, and how well policies facilitate those companies.

Fifthly, including the social costs of fossil fuels confirms that the transition is a bargain.
It's very clear that the clean-energy transition will be far less costly than the sixth great extinction or runaway planetary warming. But humans are wired to ignore distant threats, and financial tools like net present value calculations don't compel action. In this regard, focusing policy communication on the benefits of stopping the toxic emissions of fossil fuels addresses here-and-now impacts of friends and relatives suffering from respiratory diseases.

The estimated social costs of fossil fuels range from $12/ton to over $480/ton.

- In 2013 the federal government estimated the social cost of carbon (SCC), counting effects of GHG emissions only, to be $12 to $129/MTCO2e, depending upon the discount rate used.
- Using a different economic model in 2015, Moore and Diaz estimated SCC at $220/MTCO2e.
- In 2015 the International Monetary Fund estimated the global social costs of fossil fuels at $5.3 trillion annually, much higher due to the social costs of toxic emissions. That total corresponds to an average of about $110/MTCO2e if all the emissions were costed as a CO_2 equivalent; but for example, toxic emissions from coal are much more expensive than just the CO_2 emissions from coal.
- In 2015, Shindell estimated the social cost of atmospheric releases of various combustion emissions, conservatively estimating damages from gasoline at about $3.80 per gallon and diesel at about $4.80 per gallon.

These costs compare with Oregon's gas tax at $0.30 per gallon, approximately equivalent in pricing impact to a $30/MTCO2e carbon tax. $0.30 per gallon doesn't affect travel behaviors, but an extra $3.80 per gallon price signal certainly would.

Jacobson's study for Washington state estimated that decarbonization "will further result in each person in the state saving ~$85/year in direct energy costs and ~$950/year in health costs [eliminating ~830 (190-1950)/year statewide premature air pollution mortalities] while reducing global climate costs by ~$4200/person/year (all in 2013 dollars). Converting will therefore improve health and climate while reducing costs."

Can economic levers be useful to steer investments toward clean energy?
In theory the international community could partially level the playing field by charging ~$100/MTCO2e or more for emissions worldwide, and jurisdictions would use that to leverage clean infrastructure investments. $100/ton would generate about $6 billion annually in Oregon (similar to Oregonians paying an extra dollar per gallon for gasoline), and leveraging that by 3X with private money would decarbonize Oregon within roughly a decade, after which Oregonians would be saving $10 billion a year.

However, the efficacy of pricing current emissions hasn't been demonstrated. Many economists and climate advocates assert the obvious policy solution of putting a price on current GHG emissions, but real-world practicalities get in the way.

- A price signal large enough to affect purchasing behaviors is well over $150/ton. In 2014 gasoline prices effectively tested a $150/ton tax on driving vs. today's fuel costs, yet vehicle miles traveled have barely changed. The continuing gradual macroeconomic decline in energy costs of all types will further exacerbate the gap between prices paid for fossil fuels and their total costs to society.
- Numerous market failures with energy-efficient products are common, due partly to consumers considering only two or three years of operating expense, when the operating lifetime of the product is more like 5 to 20 years.
- Whether an economy-wide price on GHG emissions is enacted by a tax or a cap, the price is still set by policy. If the price were to exceed ~$30/ton in the foreseeable future, it would be dropped due to political pressures.
- Cross-border leakage has been demonstrated to be a problem as low as $12/ton. Hypothetical import/export price adjustments would require an unprecedentedly complex system to track embodied emissions throughout supply chains worldwide.
- Most people and businesses are trapped by the need to fuel their current infrastructure. It is counterproductive to punish users of dirty infrastructure with a price on their current emissions when they can't afford to change it with more efficient cars or buildings, green power, etc. In British Columbia, "Carbon taxes have not been demonstrated to reduce GHG emissions or gasoline consumption; working and middle-class families have no alternative but to drive."
- Refunding the fees through dividends or other taxes just dilutes the pricing incentive. "If everyone was given back the exact amount of carbon tax they paid there would be no incentive to use less fuel and reduce emissions."
- Cap-and-trade (C&T) systems fundamentally compound these problems by introducing adverse policy interactions whenever mandates change the available emissions supply in the emissions market. And "…economic cycles have an exceptionally strong impact on allowance prices, which therefore are inherently volatile."

Mandates work.
Many articles erroneously claim emissions reductions due to C&T systems in the RGGI states or California, but it's clear that $12/ton isn't a significant price signal. The reductions are the result of other policies.

Options for revenue to accelerate clean-energy deployment and help low-income families
A price on future emissions, such as a fee on new infrastructure purchases, may be useful for funding revenue-neutral rebates. This is claimed to be very successful in France. A price on future emissions, applied by vehicle registration or infrastructure location, enables a higher price per ton without leakage concerns. A policy forcing a high tax on future emissions could steer investments into cleaner infrastructure before the tax would be paid.

Oregon has a successful model of applying a 3% “public-purpose charge” for efficiency and renewable energy programs through ETO. Why not increase or share the public purpose charge to accelerate electrification of transportation, to create stable funding for higher efficiency vehicles and their new infrastructure, such as by initial funding of a green bank? And R&D on new technologies? An energy/climate board could periodically review the impacts of the public-purpose charges.

Economic models seem to disagree on the use of revenues for emissions projects, such as REMI’s study of a carbon tax for Vermont, which estimated that $15/ton spent on emissions projects was more effective than the $150/ton price signal (fig. 6.3). Other models conclude that using revenues for emissions projects has negligible effect on emissions.

Mandates vs. fees or subsidies
A central policy question is how much emission reduction should be done by mandates vs. the need for revenue for subsidies. As a clean technology passes the tipping point where it is preferred for cost (as LEDs did recently), that subsidy budget should be shifted to more effectively fund other financing needs. Such budget flexibility should thus span all agencies responsible for emission sectors. Appropriate metrics would facilitate budget prioritization, such as emission reduction per dollar spent.

Whether mandates or subsidies, the policies should be rooted in health and environment needs and not technology choices. Policies should set the table and allow players to respond with innovation and technology.

V. Sector emissions and illustrative policy options

Oregon's GHG annual emissions are dominated by transportation and electricity production. Oregon's most recent GHG inventory totaled 60.1 MMTCO2e in 2014, with 22.1 MMTCO2e from transportation, the largest emissions from gasoline (mostly light vehicles) at 11.5, from diesel and distillates (mostly freight transport) at 6.6, followed by aviation fuels at 1.8, and then miscellaneous. A sampling of policy options by transportation mode are listed here from a top-down perspective. An energy board could be responsible for these transportation transitions.

Passenger cars and light trucks must all transition to zero-emission vehicles (ZEVs), most likely electrified.

- CARB expects 85 models of EVs or pluggable hybrid vehicles (PHEVs) to be available in California by 2021, which would be 38% of all models available in the US today. Carmakers are already developing or have promised EV or PHEV models of minivans and pickups. The fuel and maintenance costs of EVs are already much lower than combustion vehicles; the capital cost crossover for EVs is expected to be happen around 2025 .
- The classic policy approach to transportation emissions has been cleaner fuels, more efficient vehicles, and reduced vehicle miles traveled (VMT). But ZEVs may shift these priorities by enabling vehicle travel that is far less polluting than air travel—the back of Sierra magazine should feature EV destinations instead of oversea expeditions.
- Oregon's Article 9 of the state constitution restricts the usage of fees on fuels, titles, and registration to the improvement and maintenance of roads. This is a narrow view of transportation that limits good policy choices. However, a high vehicle fee could go to highway maintenance and still achieve the purpose of steering purchases away from gas-guzzlers. The Clean Fuels program skirts this by creating a revenue-neutral fuel fee system.
- Europe is heading toward banning sales of new internal-combustion engine (ICE) cars by about 2030. Would it be impractical for Oregon to refuse to register ICE vehicles after some model year? Coordinate such restrictions across the west coast states? Some states and countries offer HOV/bus lane access only to ZEVs, along with parking priority. Could Oregon somehow ramp up registration fees on non-ZEV models after 2025 or some date? Ramping registration fees to ~$200/ton (by 2030?) for the average emissions of non-ZEV models during the registration period would cost about $1000 per year for a 30 mpg vehicle at 15,000 miles per year. Such fees or mandates would only be applied if there are reasonably equivalent ZEV options available in the vehicle category (e.g., don't penalize a farmer for buying a pickup unless he has a ZEV alternative). Ideally the fees could fund a pool for leveraging infrastructure investments or to help low-income families.
- Electric vehicles are already the lowest cost of ownership for commuting distances. Oregon could expand the EV fleet by helping low-income families afford leasing or buying such EVs.
- Autonomous vehicles (AVs) are likely to be even more disruptive than EVs. (AVs aren't necessarily electrified, but most AVs are being developed on EV platforms.) AVs will dramatically increase vehicle usage instead of being parked 96% of the time, implying major parking-space efficiencies. Vehicle miles traveled may also decrease as more rides are shared.

Buses and some medium-duty trucks already have multiple electrified options for urban uses.
Should Oregon mandate no registration of non-ZEVs after a 2025 model year, or some date?

Heavy-duty trucks must transition to carbon-neutral.
Some heavy trucks already use compressed natural gas (CNG), and the clean way to run them is on compressed renewable natural gas (RNG), or fuel cells running on hydrogen or RNG. How should Oregon evolve the Clean Fuels Program after 2025? Ramp fuel fees to the equivalent of ~$200/ton by ~2040?

Shipping must transition to carbon-neutral.
Some ships are being refitted for LNG to meet global environmental regulations for pollution near ports. A question for both shipping and heavy trucks is how we can source enough RNG—how much is available from methane digesters, water treatment plants, and landfills? Will power-to-gas (P2G) or other methane synthesis be a path to sufficient RNG for heavy trucks and shipping? In the meantime, should Northwest Natural or shipping fuels get a small tax for the purpose of research, development, and deployment (RD&D) of RNG infrastructure in Oregon? Should such a public purpose charge be directed to deploying more RNG instead of efficiencies of houses using natural gas, since new housing is more energy efficient with an electric heat pump (or district heating with heat pumps) than gas heating anyway?

Aviation fuels must transition to carbon-neutral.
Biofuels for aviation have been much slower to productize than EVs. Should Oregon create a small public purpose charge on aviation fuels, which funds RD&D of carbon-neutral or carbon-negative aviation fuels in Oregon? To minimize the administrative burden, such funding could be limited to matching private or federal funding of RD&D.

Should Oregon ramp up emission fees on air travel to and from Oregon airports after some date? Since jet aircraft create roughly twice as much warming effect as their fuel combustion, the fee should arguably start at a year that anticipates a practical but aggressive deployment schedule for carbon-neutral fuels, and ramp to ~$400/ton by 2035. Such a fee would be obviated to the extent that carbon-neutral fuels become adopted.

Rail emissions must be eliminated, probably electrified, possibly RNG.
All diesel locomotives use electric drive motors, and the most powerful locomotives are all electric. So technologies exist. If Union Pacific zeroed emissions in Oregon they could save millions on fuel, reduce their noise pollution, and eliminate their particulate and other toxic diesel emissions. Do they need a motivation to spend the capital necessary to transition?

Rail transportation is regulated by the FRA and states cannot tax railroads. However, just as Washington state taxes oil terminals to pay for safety measures, can Oregon charge an increasing tax on rail freight at shipping terminals? The funds could accumulate and earn interest in an escrow account until UP uses it to transition in Oregon. To keep freight business from just going across the Columbia, this policy could be coordinated and duplicated in

Washington, and also coordinate with ramping emissions fees on other modes of transport, especially trucking.

Oregon's 2014 GHG emissions from electricity use totaled 18.0 MMTCO2e.
7.3 MMTCO2e was from residential electricity usage, followed by 6.1 from commercial electricity usage. Industrial uses of electricity counted for 4.6. Illustrative options for electricity policies include:

- Increase the RPS to 100% by 2050, with linear milestones on the way.
- Unless RNG supplies allow it, plan to dismantle all electricity from gas generation by 2050, including who pays for the stranded assets. After legislative adoption of a zero-emissions goal, utilities should be forced to pay for stranding of any further fossil fuel assets they choose to install. The PUC would clearly be involved to transition out of fossil natural gas while controlling costs and ensuring sufficient supplies.
- Incentivize or mandate deployments of demand response that is functional on water heaters, EVs, and large industrial loads as available; and deployments of storage capacities.
- Specify the value that transmission access and distributed generation and storage assets bring to the grid. The PUC or energy/climate board should manage a third-party technical resource for distributed power projects, to keep the utilities from being biased gatekeepers. To what degree these generation and storage resources are centralized or distributed is a key policy question that affects utilities, residential and commercial power generators, and the resilience capabilities of communities.
- Microgrids that can both integrate with, and operate independently of, the grid will be critical for emergency power capabilities. Incentivize or mandate pilot installation and then deployment of many microgrids for resilience, in concert with EMS providers. Small cities and towns could prioritize emergency power for police, fire, and medical services, communications facilities, and EV charging. Neighborhoods and business parks should be able to recover from disasters with their own power supplies and energy storage.
- Neighborhoods and small-business parks should be able to benefit from community-owned generation and storage assets. Why should Ikea, Walmart, Google, and Target be able to negotiate low power rates with utilities, but small businesses can't?
- Consider planning dual use of small solar farms near urban areas for ultra-low income housing underneath the arrays. The arrays require footings, support structures, and power distribution, which is a subset of the needs of any type of housing. If Portland is going to continue to attract homeless people and the federal government is unwilling to fund sufficient social safety nets, then some sort of housing will be necessary.
- The electrification of petroleum combustion for industrial processes could be mandated by some date.

Current emissions from natural gas must be zeroed.
Residential natural gas usage was 2.3 MMTCO2e in 2014, commercial natural gas was 1.5, and industrial use was 3.0. Combustion for pipelines was 1.5 (natural gas pump stations?), and methane from solid-waste landfills was another 1.7. Potential policies include:

- RPS mandate to transition all natural gas to 100% RNG by 2050 and 50% by ~2035. Such a mandate would presumably encourage all landfills, water-treatment plants, and methane digesters to collect methane and sell it.
- Fugitive methane emissions from pipelines, landfills, and water treatment plants (including agricultural water treatment) could be monitored and fined.
- After P2G pilot projects demonstrate practical operation, mandate deployment targets for P2G or other RNG production technologies as necessary.
- Both electricity and gas emissions would be reduced by 1) upgrading state building codes to require electric heat pumps, heat-pump water heaters, smart thermostats, more efficient building envelopes, etc.; and 2) requiring landlords and tenants to share gas and electricity bills (such as 50/50), thus encouraging landlords to install more efficient infrastructure and tenants to use it efficiently.

Net-zero emissions from agriculture and forestry

Oregon's 2014 GHG inventory of agricultural emissions includes enteric fermentation at 3.0 MMTCO2e and soil management was 1.6. Agricultural emissions are complex and varied, and agriculture and forestry provide our only natural carbon sequestration processes.

The 5-6 ppm seasonal variation in atmospheric CO_2 concentration corresponds to the seasonal change in uptake of CO_2 by the world's land vegetation, indicating a need to better understand and harness the sequestration potential of agriculture and forestry. Agricultural emissions seem to attract the greatest controversies over the magnitude of the emissions and what to do about them. Mob grazing apparently improves grasslands and sequesters more carbon in the soil from the deep roots. Low-till and no-till farming methods have carbon sequestration potential, but "Additional investments in soil organic carbon research are needed to better understand the agricultural management practices that are most likely to sequester or at least retain more [carbon]." Carbon inventories in US forests are available but lack accuracy. Methane capture and sequestration may be the only way to continue cattle and sheep farming.

Policy makers should monitor global research while supporting studies on the yields, sustainability, and carbon sequestration of new processes for Oregon agriculture and forestry, targeting deployment of improved methods as soon as practical.

R&D recommendations

The federal government is the best source of research and development (R&D) funding, but the near future of climate funding is currently very uncertain. Could west-coast states collectively fund such R&D, or create some sort of investor program(s)? Even small R&D efforts funded by the state could significantly advance the technologies. In any case, Oregon should advocate federal R&D funding for climate and toxic emission mitigation, especially when the research addresses gaps in a comprehensive plan for the state. The state could match all related federal R&D grants to Oregon companies, thus providing significant leverage with minimal overhead for selecting and administering grants.

A high-leverage strategy to support a clean-energy industry cluster is a center of excellence with talent investment in Oregon. Such a policy innovation would attract outside investment from private sources and potentially from the federal government.

Specific areas urgently needing more R&D work include:

- Carbon-neutral fuels for heavy trucks, shipping, and aviation
- Low-carbon industrial processes, such as cement manufacture
- Carbon sequestration options in agriculture and forestry relevant to Oregon
- Atmospheric CO_2 capture and sequestration by any method

It is useful to commit to challenging goals where no one knows the solution—this drives innovation. We need to challenge Oregon's innovators to find new solutions to goals for which we don't yet see the path. We didn’t clearly see the path to put a man on the moon when JFK committed to it.

VI. Governance options

Background and gaps

The Green Energy Institute's 2015 report Countdown to 2050—Sharpening Oregon's Climate Action Tools provides a "comprehensive overview of Oregon's existing climate change laws and explains why these existing policies will ultimately fail to adequately achieve necessary emissions reductions. The report then recommends strategies for developing a comprehensive climate policy framework in Oregon that would establish binding emission reduction targets and address climate change mitigation opportunities for the energy, transportation, and land-use sectors."

GEI governance recommendations

A recent GEI report *Energy Governance in Oregon: Improving the Framework for Oregon's Energy Transition*, illustrates key components of effective energy governance:

Key Features	Energy-focused features
Future- and outcome-oriented	100% renewable energy (or carbon-free) system
Comprehensive and strategic	Long-term comprehensive plan for carbon-free system
Clear policies that promote certainty, but adapt	Long-term RPSs, fossil fuel retirement strategy, tailored incentives
Effective agency performance	Structure for collaborative inter-agency operations
Promotes stakeholder involvement, but not as the ultimate outcome	Input through PUC proceedings, comments, etc., but not at expense of objectives
Relies on data, analysis, and transparency	Front-end policy analysis + risk assessments + regular, publicly available progress reports
Values and uses expertise	Solicits and uses inputs from interdisciplinary independent experts

GEI further recommends that Oregon

- Convert Oregon's greenhouse gas goals into mandate and/or establish a 100% RPS;
- Use an energy czar, advisory body, or designated agency to lead the comprehensive planning strategy;
- Develop policies and create scenario models to project how policies will function;
- Prevent unnecessary investments while promoting desired ones;
- Create an ongoing data collection, analysis, and public information process; and
- Routinely evaluate progress and adjust policies as necessary.

- Explicitly authorize and expect ETO, PUC, ODOE, etc. to work with employers and other agencies to evaluate talent needs for the transition and fund talent development through the Oregon Talent Council, HECC, or other means.

ODOE Interim Oversight Committee recommendations
On October 31, 2016 the state's Joint Interim Committee on Department of Energy Oversight released a draft committee report with 9 findings and over 40 key recommendations related to

- the agency's charge, mission, and statutory responsibilities;
- the agency's organizational structure and funding streams;
- an assessment of the current gaps and deficiencies in the agency's operational structure and personnel capacity to fulfill its mission and programs; and
- an assessment of the agency's capacity to facilitate stakeholder relationships, both public and private, to fulfill its mission.

The draft report recommends the establishment of a "seven-member state Energy and Climate Board, appointed by the Governor and confirmed by the Senate, to oversee ODOE. The Board would oversee the operations and programs of the Department, including the preparation of a strategic energy and climate plan for legislative adoption which balances the interests and accountability for the state's energy and climate policy." And to "Direct the Governor to convene a work group comprised of the directors of the Departments of Energy, Environmental Quality, Transportation, Water Resources, the Public Utility Commission and Business Oregon; a representative of the Global Warming Commission; and stakeholders to evaluate and make recommendations to the Board and the Legislature on the establishment of a state agency coordinating body on energy and climate activities.

These recommendations have evolved into House Bill 2020, which proposes to:

- Establish the Oregon Energy and Climate Board as oversight and advisory body for Oregon Department of Energy and Climate.
- Establish the Interagency Climate Coordinating Committee to make recommendations to board on ways to coordinate state policies and programs related to energy and climate.
- Change the name of State Department of Energy to Oregon Department of Energy and Climate. Changes name of Director of State Department of Energy to Energy and Climate Director.
- Abolish the Oregon Global Warming Commission.
- Modify state energy policy.
- Modify general duties of department.
- Implement other provisions

This could be a clear and positive step toward more coordinated energy and climate governance, although of course dependent upon rulemaking and implementation.

Other recommendations

- The existing GHG inventory process provides quantitative, sector-specific guidance for each type of emission. This inventory must be continuously updated, and augmented with forecast data for state population, future reduction contributions from state and federal GHG policies, technology scenarios, and related tools. Oregon counties and cities need these to plan and quantify their progress.
- The legislature should create long-term goals for both climate and toxic emissions, and a comprehensive planning process for all sectors
- Effective agency missions and clear, measurable objectives, consistent with long-term GHG and toxic emissions goals
- Maximally motivate key agency managers based on measurable achievements toward long-term objectives. What motivates these key managers? Status? Recognition? Money? Breadth of charter or scope of authorities?

VII. Conclusions

The intent of this work is to provide a useful outline for planning.
This exploration is intended to holistically illustrate the scope, complexities, interactions, and potential solutions in the physical, economic, policy, and governance layers of Oregon's emissions challenges and opportunities. Concise brevity was favored over detailed analyses; thus none of the topics is addressed with a level of detail or scrutiny sufficient to warrant adoption as building blocks of a statewide plan. Only a few of the policy proposals from various constituencies are included herein, limited by lack of time and the brevity constraint. The aim of this work is to sketch a framework that spurs creativity and catalyzes wider and deeper studies as necessary, toward a comprehensive emissions plan for Oregon.

This exploration demonstrates several types of interactions between the physical, economic, policy, and governance layers:

- The physical constraints of zero GHG emissions by some date provide clearer policy guidance than reducing emissions to some number, since a zero target does not allow a strategy of hope for efficiencies or conservation or relief from other sectors.
- The clean-energy revolution is accelerating, but we're in a race to roll back global GHG emissions before they result in further ecological destruction or planetary thermal runaway. The new energy technologies will disrupt incumbent industries on an unprecedented scale, and those industries will use unprecedented means and resources to delay their inevitable demise. This resistance and the cost trajectories of new clean-energy technologies must be carefully considered by policy planners.
- A physical constraint of zero emissions drives transportation and building heating/cooling to either electrification or carbon-neutral fuels.
- A zero-emission constraint provides clear requirements for the future of natural gas uses and sources.
- Everything interacts with economics, but economic levers don't necessarily result in physical changes.
- Efficient deployment will require better governance structures and mechanisms.

Some of the elements of a sufficient planning process include:

- Addressing the constraints and interactions within and between the layers of the climate change problem: the science of GHG and toxic emissions and their physical and economic effects; the new technologies necessary to rebuild emitting infrastructure, their maturity levels and cost trajectories; the economic options and impacts of various new infrastructure scenarios; and the policies and governance necessary to efficiently steer new infrastructure.
- Metrics and quantified targets by sector and by agency, such as baseline and target emissions and costs to permanently cut emissions. It can't be improved if it's not measured.
- Analyzing policies for theoretical and empirical evidence of efficacy, potential adverse policy interactions, and ability to reach the overall long-term goals.
- Policy analyses that anticipate the full range of potential climate change scenarios, cost evolutions in clean technologies, and economic issues.

The scope, scale, and complexity of comprehensive emissions planning are challenging and thus worthy of careful forethought.

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