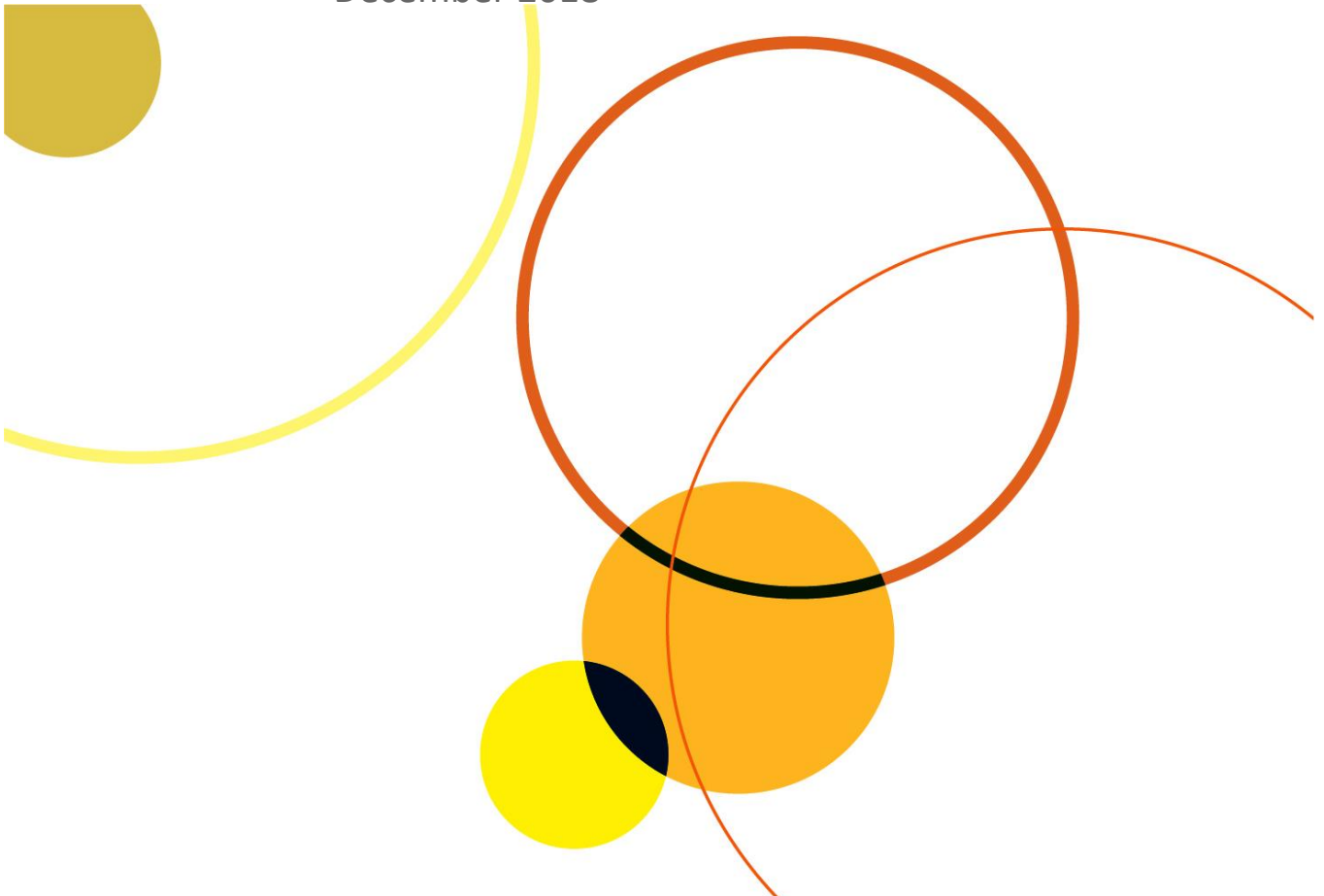


# Oregon Sectoral Competitiveness under Carbon Pricing

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Final Report  
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## Executive Summary

**Oregon has a competitive manufacturing and industrial sector, as evidenced from robust employment growth recently.** The state is highly diversified with both high-tech and natural resource manufacturing in its top value-adding sectors. Oregon currently has its lowest unemployment rate in decades, in part due to manufacturing employment growth over 2010–17 that was more than double the national average.

**However, many industrial activities generate greenhouse gas (GHG) emissions and current trajectories suggest that Oregon will not achieve its reduction targets without additional effort.** In 2016, Oregon emitted 61.9 million metric tons of carbon dioxide equivalent (MtCO<sub>2</sub>e), 20% of which came from industrial activity. The state's 2007 House Bill 3543 established targets for it to achieve emissions levels 10% below 1990 levels by 2020, and to achieve emissions levels 75% below 1990 levels by 2050. However, these targets will likely be missed if emissions continue at the current trajectory.

**As a result, the state is considering a cap-and-trade program as part of a strategy to drive cost-effective emissions reductions.** In the industrial sector, the proposed cap-and-trade would impose a price on direct emissions from entities with emissions greater than or equal to 25,000 tCO<sub>2</sub>e per year. This mechanism would directly regulate about 30 manufacturing and mining sector facilities in Oregon whose emissions exceeded this threshold in at least one year over 2014–17. A cap-and-trade drives economic decarbonization by providing price incentives for both producers and consumers to undertake less emissions-intensive activities. It also provides regulated entities the flexibility of a market-based mechanism to determine how to reduce emissions. Moreover, carbon pricing can stimulate innovation and low-carbon investment.

**However, if the cap-and-trade is not designed to maintain industrial competitiveness, it can also lead to the risk of carbon leakage in covered emissions-intensive and trade-exposed (EITE) sectors.** While carbon pricing is spreading globally, differences remain in carbon price levels, both within the US and with international competitors. This leads to divergences in compliance costs for the same industry in different locations, increasing production costs of companies in regulated jurisdictions in the short term. Sectors with high emissions and with few emissions reduction opportunities, and which compete strongly with facilities in non-regulated jurisdictions may, as a result, be at risk of reduced competitiveness. Carbon leakage occurs when this leads to production or investment shifting from jurisdictions with carbon pricing to more emissions-intensive jurisdictions, raising net global emissions.

**While the evidence is mixed, the risk of associated negative environmental, economic, and socio-political outcomes makes preventing carbon leakage central to any cap-and-trade mechanism design.** While *ex ante* analyses predict carbon leakage impacts in EITE sectors, *ex post* evaluations have not yet found evidence it has occurred. This is because of low carbon prices and also, importantly, because carbon policy is designed to prevent carbon leakage. In addition, environmental compliance costs tend to be a minor component of production and investment decisions. However, when implementing a carbon price, policymakers have been careful to ensure carbon leakage risk is addressed given it implies an increase in global emissions, in addition to economic activity and employment shifting to external jurisdictions.



**There are two central elements – carbon cost exposure and cost pass-through capacity – that influence whether an industrial sector is EITE, and thus at risk of carbon leakage.** Carbon cost exposure examines the impact that carbon pricing has on a facility or sector. Cost pass-through capacity determines whether the facility or sector can pass through carbon costs to their consumers without significant loss of market share. The EITE identification methodology in this report follows a dual quantitative–qualitative approach to offer a holistic understanding of these two elements. Quantitative analysis provides initial insight into sectors’ carbon cost exposure. Qualitative analysis offers deeper insights on cost pass-through capacity by evaluating competitive dynamics, profitability and emissions reduction opportunities. The low number of facilities in Oregon means that the qualitative analysis is more important to offer a final assessment of leakage risk.

*Table 1.* All potentially covered sectors in Oregon are at risk, or likely at risk, of carbon leakage

NAICS 4 code	Sector description	Number of potentially covered facilities	Carbon leakage risk assessment
3273	Cement and Concrete	1	At risk
3251	Chemicals	2	Likely at risk
3114	Food Manufacturing	5	At risk
3315	Foundries	1	At risk
3272	Glass	1	At risk
3311	Iron and Steel	2	At risk
3274	Lime and Gypsum	1	Likely at risk
2123	Non-metallic Mineral Mining	1	At risk
3279	Other Non-metallic Mineral Products	1	At risk
3261	Plastics	2	Likely at risk
3221	Pulp, Paper, and Paperboard	5	At risk
3211	Sawmills and Wood Preservation	1	At risk
3344	Semiconductors	6	At risk
3212	Wood Products	2	At risk

*Note:* NAICS denotes North American Industrial Classification System

*Source:* Vivid Economics

**The assessment for Oregon shows that all potentially covered manufacturing and mining sectors are either at risk, or likely at risk, of carbon leakage if the cap-and-trade is not designed to safeguard competitiveness.** Table 1 illustrates the findings from the overall leakage risk assessment for all potentially covered Oregon sectors. The distinction between the results of the assessment is:

- At risk: while there are competing factors increasing and decreasing risk, the sector is at risk of carbon leakage on the balance of evidence;
- Likely at risk: while there are competing factors increasing and decreasing risk, the sector is likely at risk of carbon leakage on the balance of evidence. However, a lack of evidence on cost pass-through capacity from one or more sectoral stakeholders prevents a more definitive conclusion.

**A cap-and-trade program in Oregon should nevertheless cover all EITE sectors, and a program designed to prevent carbon leakage is likely to successfully reduce emissions while also safeguarding competitiveness.** Although the analysis finds that all potentially covered manufacturing and mining sectors are EITE, these



sectors still have some opportunities to reduce emissions, suggesting a carbon price will drive decarbonization at the margin. Furthermore, as more jurisdictions across the US and the world begin pricing carbon in their industrial sectors, long-run leakage risk to these jurisdictions will decline. In the short term, however, leakage risk will remain, and as such the cap-and-trade should be designed to safeguard industrial competitiveness. Economic theory and evidence from other jurisdictions strongly suggests that the twin objectives of emissions reductions and safeguarding competitiveness can be achieved through appropriate design.

**The most prevalent policy option to prevent leakage risk is providing free allowance allocations; other options, including exemptions, are not recommended for Oregon.** Instead of purchasing allowances through an auction, free allocation involves issuing facilities with a proportion of their emissions allowances for free using any of four mechanisms: grandfathering, fixed sector benchmarking, output-based allocation and facility level benchmarking, which is a type of output-based allocation. Other options include tax reductions, subsidies, or other programs which reduce carbon cost impacts if benefits scale with output; however, the leakage risk reduction evidence for these is mixed. Exempting EITE sectors entirely fails to provide marginal emissions reduction incentives. Furthermore, for a given economy-wide emissions reduction target, exempting certain sectors would require an increase in stringency for non-exempted sectors which could shift, rather than reduce, carbon leakage risk.

**This report recommends that Oregon provides output-based free allowance allocation as it safeguards EITE competitiveness while also maintains incentives to reduce emissions through efficiency measures or innovation.** The benefits of output-based allocation are that when facilities increase or decrease their output, the amount of allowances they receive rises or falls correspondingly. Thus, it maintains domestic production incentives and reduces leakage risk. The use of pre-defined emissions intensity benchmarks, at the facility or sectoral level, maintains marginal incentives for facilities to improve emissions efficiency and increase investment in low-carbon processes and technologies. This form of carbon leakage risk reduction has been successfully implemented in California, Quebec, and Alberta, with the EU moving closer towards this policy over time.

**Benchmarks are an essential aspect of any output-based allocation policy option and are integral to improving emissions efficiency.** Benchmarks are a technically feasible level of emissions efficiency, designed with respect to high-performing comparable producers and used to incentivize emissions reductions. Most jurisdictions have both product benchmarks, incentivizing efficient production, and fall-back benchmarks, incentivizing the efficient use of inputs in more complex sectors. The stringency of benchmarks can be developed in different ways: relative to a specific best-available technology (BAT) level; relative to a 'best-in-class' performer in the pre-defined group of comparable activities; or relative to an average level or a subset percentile of high performers.

**A well-designed output-based free allocation mechanism will require the development of an appropriate set of emissions intensity benchmarks for Oregon sectors.** Oregon faces three options when developing emissions benchmarks:

1. Developing benchmarks from first principles, although this can be a time-consuming and resource-intensive process, both for policymakers and industry stakeholders.

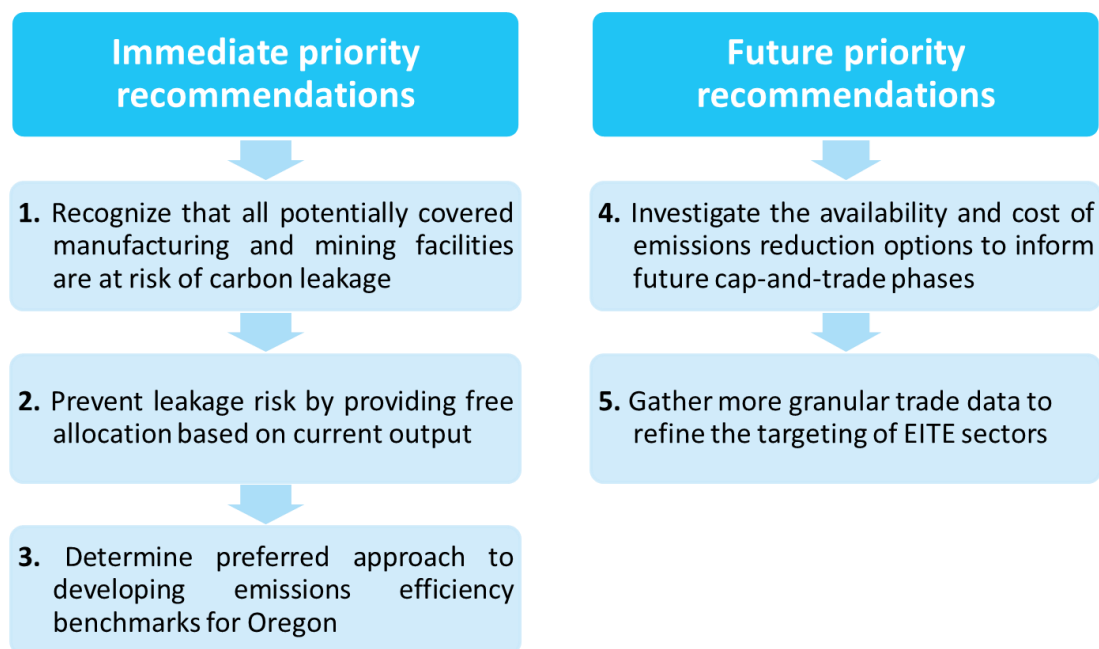


2. Adopting benchmarks developed in other jurisdictions – this has precedent and significantly reduces resource requirements.
3. Following a blended approach entails developing new benchmarks for some sectors and adopting and adjusting benchmarks for others.

Approaches used in jurisdictions such as California, Quebec or Ontario could be suitable for Oregon. Quebec’s experience could be particularly instructive: it developed product benchmarks based on average historical emissions intensity of sectoral production, in some cases at the sector-level and others at the individual facility level.

**This analysis thus offers five recommendations for the design of Oregon’s cap-and-trade which achieves a sustainable path forward for the economy, while also safeguarding domestic competitiveness, production and employment.** Per Figure 1, the first three recommendations should be implemented in the immediate term as the program is being designed, while recommendations 4 and 5 should be implemented in later stages of the program to improve its effectiveness. These last two recommendations stem from sectoral analysis which suggests a gap in research on the availability and cost of sectoral emissions reduction opportunities and regarding the level of granularity available on trade data to help determine cost pass-through capacity.

*Figure 1.* Three recommendations are for immediate prioritization, while two are for future prioritization



Source: Vivid Economics

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## List of Abbreviations

Acronym	Full Name
ASM	Annual Survey of Manufactures
BAT	Best-available technology
CARB	California Air Resources Board
CCIR	Carbon Competitiveness Incentive Regulation
CGE	Computable general equilibrium
CPO	Carbon Policy Office
DE	Diatomaceous earth
DEQ	Department of Environmental Quality
EBITA	Earnings before interest, taxes and amortization
EITE	Emissions-intensive and trade-exposed
ETS	Emissions Trading System
EU	European Union
GDP	Gross Domestic Product
GHG	Greenhouse gas
GVA	Gross value added
kWh	kilowatt hour
MtCO <sub>2</sub> e	Million (metric) tons of carbon dioxide equivalent
n.e.c	Not elsewhere classified
NACE	Classification of Economic Activities in the EU (Nomenclature des Activités Economiques dans la Communauté Européenne)
NAICS	North American Industrial Classification System
TE	Trade-exposed
UK	United Kingdom
US	United States
WCI	Western Climate Initiative

# 1 Introduction

**Oregon has committed to reduce emissions as part of a strategy to improve the local environment and reduce the risk of climate change.** In 2007, Oregon's House Bill 3543 established targets for the state to achieve emissions levels 10% less than 1990 levels by 2020, and to achieve emissions levels 75% below 1990 levels by 2050 (Oregon Legislative Assembly, 2007). However, the current trajectory of Oregon's annual emissions reductions suggests that the state will not achieve its targets without additional effort.

**Oregon is examining the use of carbon pricing as an instrument for cost-efficient mitigation.** Carbon pricing, such as a cap-and-trade, enables industry and society to respond flexibly to market signals to internalize the environmental costs of emissions. As a result, the State of Oregon is exploring the design and potential implementation of a statewide carbon pricing program, an effort led by the Carbon Policy Office (CPO). The program would likely directly regulate large sources of emissions, such as those that exceed a threshold of 25,000 metric tons of carbon dioxide equivalent (tCO<sub>2</sub>e) annually, as reported to the Department of Environmental Quality (DEQ) in the state's GHG Reporting Program.

**However, the cap-and-trade should be designed to safeguard the competitiveness of Oregon's EITE sectors.** Variation in jurisdictions' ambition on emissions reduction speed gives rise to differences in carbon pricing stringency between jurisdictions and thus to differences in compliance costs for the same industry in different locations. In such a world of differential carbon pricing, the introduction of carbon pricing in Oregon will increase the production costs for many sectors relative to international and domestic US peers who do not face carbon pricing, at least in the short term. Competitiveness impacts may be a particular concern in sectors with significant external and internal competition, and thus with limited ability to pass through costs, and those with high carbon cost exposure.

**Safeguarding the competitiveness of EITE sectors reduces their risk of carbon leakage, which occurs when economic activity and associated emissions shift to another jurisdiction as a result of differences in carbon pricing between jurisdictions.** If an Oregon carbon price reduces the competitiveness in covered sectors, production or investment could shift to external jurisdictions. The associated decrease in emissions in Oregon could then be partly or more than offset by higher emissions in a jurisdiction with lower or no carbon price. In this case, the intended reduction in emissions from the Oregon carbon price would not be achieved at the global level. Equally important, a key implication of carbon leakage is a reduction of EITE sectoral production and employment.

**This report identifies Oregon's manufacturing and mining sectors at risk of carbon leakage, and details policy options and benchmarking approaches the state could take to reduce leakage risk.** This report focusses on the carbon leakage risk of potentially covered manufacturing and mining sectors, as detailed in Box 1. The report undertakes a quantitative and qualitative approach to identify sectors and facilities at risk of carbon leakage and adverse competitiveness impacts. The approach is based on methodologies developed across jurisdictions that have implemented carbon pricing and tailored them to the context of Oregon, with increased emphasis on the qualitative analysis given the low number of potentially covered facilities and sectors as well as data limitations. It subsequently details the policy options and benchmarking approaches

that have been used across international jurisdictions to maintain EITE sector competitiveness. Finally, the report offers recommendations on the optimal leakage reduction policy option and benchmarking approach for Oregon, while highlighting priorities for future research.

**Box 1. The competitiveness and carbon leakage analysis focusses on manufacturing and mining sectors potentially directly regulated under Oregon's cap-and-trade program**

**The Oregon carbon price would directly regulate all entities with annual direct anthropogenic emissions greater than 25,000 tCO<sub>2</sub>e.** This covers around 30 facilities in the manufacturing and mining sectors, but also 23 facilities in the power generation, natural gas pipelines, waste management and educational services sectors.

**This report focusses on identifying directly regulated manufacturing and mining sectors which are at risk of carbon leakage.** Manufacturing and mining sectors are the most exposed sectors to competitiveness impacts and are generally the primary focus of competitiveness and carbon leakage risk assessments. Further, this focus reflects the fact that separate work is under way in Oregon that will recommend preferred approaches in the other sectors with directly regulated facilities. As such, all subsequent references to potentially covered sectors in this report refer only to directly regulated manufacturing and mining sectors.

**The remainder of the report is structured as follows:**

- Section 2 provides background on Oregon's economy and emissions profile and discusses the rationale for carbon pricing;
- Section 3 introduces the concept of carbon leakage and presents the evidence to date;
- Section 4 details the methodology and results of the quantitative and qualitative leakage risk analyses;
- Section 5 presents policy options to reduce leakage risk and approaches to benchmarking; and
- Section 6 sets out conclusions and recommendations.



## 2 Cap-and-Trade Context

**This section provides a background to Oregon’s economy and its proposed cap-and-trade regulation:**

- Section 2.1 provides an overview of Oregon’s economy and its competitive strengths;
- Section 2.2 discusses Oregon’s emissions profile and introduces the proposed mechanism to reduce emissions; and
- Section 2.3 discusses the rationale for a cap-and-trade.

### 2.1 Economic Overview

**Oregon’s Gross Domestic Product (GDP) was \$227 billion in 2017 and the state has recently experienced strong employment growth.** Oregon’s 2017 GDP comprised 1.2% of the overall US GDP, ranking it the 25th largest US state economy (BEA, 2018c). Its economy recently experienced significant growth in employment and now benefits from its lowest unemployment rate in decades. In 2018, Oregon’s unemployment rate was around 3.8%; just above that of the US at large of 3.7% (State of Oregon Employment Department, 2018). In 2017, Oregon’s per capita personal income level (\$48,137) was ranked 25th across US states, reflecting an improvement from its ranking of 43 in 2010 (BEA, 2018a).

**Oregon’s manufacturing sector has grown strongly since the 1980s and comprises 14% of the state’s GDP.**

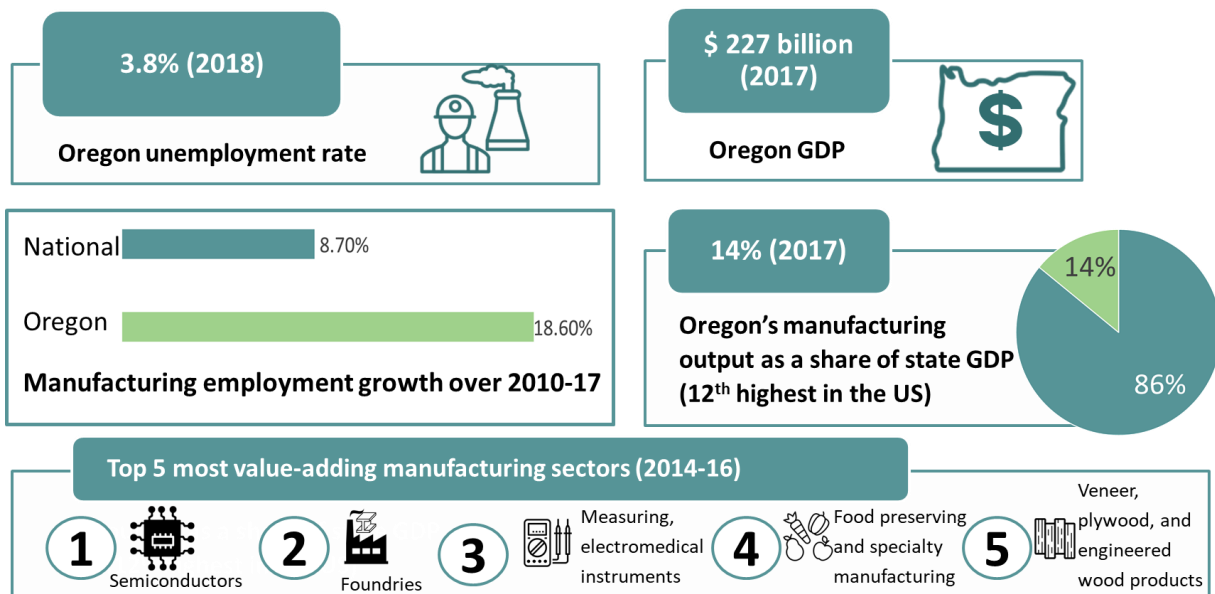
Prior to the 1980s, the primary state industries were forestry, farming and fishing. Wood products comprised 10% of Oregon’s GDP in the 1970s. However, manufacturing has since grown significantly, and with it Oregon’s manufacturing sector employment has grown more quickly and comprises a larger portion of the economy than the national average. Over 2010–17, Oregon’s manufacturing employment grew by 18.6% relative to the national average of 8.7%. In 2017, manufacturing employment represented 10% of Oregon’s total employment relative to the national average of 8.5% (Bechtoldt, 2017a). In 2017, Oregon’s manufacturing GDP was 14% of total state GDP (\$32 billion), ranking it as the state with the twelfth-highest manufacturing share of state GDP (BEA, 2018b).

**The state’s main value-adding manufacturing sector is in high-end technology, such as semiconductor and electronic components manufacturing.**<sup>1</sup> Figure 2 illustrates the top five Oregon value-adding manufacturing sectors over 2014–16 at the North American Industrial Classification System (NAICS) 4-digit level, and highlights the significance of the semiconductor sector to Oregon’s economy. Oregon has become a globally renowned location for semiconductor and electronics manufacturing and the state now hosts 479 facilities, including Intel’s largest global manufacturing facility. This industry benefits from Oregon’s high-tech ecosystem and highly skilled workforce (Business Oregon, 2018b).

<sup>1</sup> The definition of value added is the total value of final production minus the value of inputs (such as cost of materials, fuel, electricity, and labor) (US Census Bureau, 2017).



Figure 2. Oregon has a strong economy and has experienced robust growth in manufacturing



Source: Vivid Economics

**Oregon is highly dependent on trade and relies on trade flows with both foreign countries and other US states.** It is the most trade-dependent state in the US, with major foreign trading partners including Canada, China, Malaysia, Japan and South Korea (Oregon Secretary of State, 2018). In particular, exports to South Korea have reflected the most significant growth over 2007–17 (ITA, 2018). However, Oregon's trade with other US states is significantly greater than its trade with other international jurisdictions. The most recent available data suggests that Oregon's manufacturing trade with other US states was at least double that of its trade with international jurisdictions (U.S. Department of Commerce, 2018; U.S. Department of Transportation; Bureau of Transportation Statistics; and U.S. Census Bureau, 2014).

**Oregon's overall competitiveness is mainly driven by the lack of a general sales tax, low energy costs, and access to major export markets.**

1. The lack of a general sales tax supports business competitiveness in Oregon and the state also offers incentives to support business growth, including low effective business tax rates, property tax abatement measures, and income tax credits (Business Oregon, 2018a).
2. Oregon maintains low energy costs which lower the costs of doing business. It has electricity tariffs (especially industrial tariffs) that are among the lowest in the US and has highly competitive natural gas rates relative to neighboring states (Business Oregon, 2018a). Oregon has also invested heavily in energy efficiency and has provided tax credits for implemented energy efficiency and renewable measures to eligible entities in the past (ODOE, 2018).
3. Oregon has easy access to important final markets. The state borders California, which is now the fifth-largest economy in the world (Corcoran, 2018), and thus will reflect a significant final market for many Oregon sectors. Additionally, Oregon benefits from the strategic port of Portland, which is the fourth-

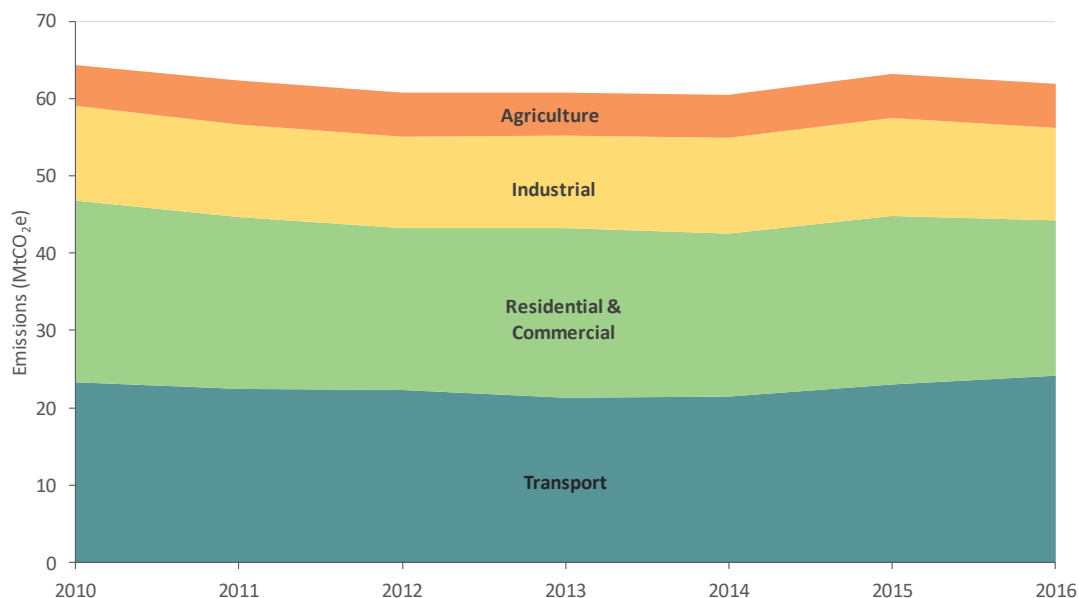
largest export port on the West Coast. Its major trading partners are Japan, South Korea, China, Taiwan and Mexico (WPS, 2018).

## 2.2 Emissions Profile

Many types of economic activity produce GHG emissions which generate economic, social, and environmental costs not captured by market prices. The 4th National Climate Assessment (USGCRP, 2018) estimates that unmitigated climate change will incur significant costs for the US economy in the form of destruction of infrastructure and property, which will slow economic growth and cost some sectors hundreds of billions of dollars by the end of the century. The extent of these potential costs is central to justifying action to curb dangerous climate change.

In 2016, Oregon emitted 61.9 million metric tons of carbon dioxide equivalent (MtCO<sub>2</sub>e),<sup>2</sup> 20% of which came from industrial activity. Figure 3 shows the trajectory of Oregon's emissions pathway over 2010-16 and illustrates that while total (direct and indirect) emissions are not increasing, industrial activity alone generates one-fifth of all Oregon's total (direct and indirect) emissions on average. While industrial activity generates a significant portion of Oregon's emissions, transportation sector emissions are even more significant, averaging 36% of total annual emissions over 2010–16.

Figure 3. 21% of Oregon's total (direct and indirect) emissions were generated from industrial activity over 2010-16



Source: Vivid Economics based on DEQ (2018b)

<sup>2</sup> Throughout this report, volumes are in metric tons unless otherwise stipulated.



**Oregon requires additional measures to achieve commitments to statewide emissions reduction targets.**

Oregon's legislature has committed to achieving emissions levels 10% and 75% below 1990 levels in 2020 and 2050, respectively. It appears to have achieved its 2010 target to stop emissions growth (ODOE, 2018). However, Oregon's emissions trajectory will not be sufficient to meet either the state's 2020 target or its 2050 target. The Oregon Global Warming Commission (2017) projected that the state's emissions will likely exceed the targeted 2020 emissions level by 11 MtCO<sub>2e</sub> given its current trajectory.

## 2.3 Using Cap-and-Trade to Reduce Industrial Emissions

**Carbon pricing is central to any cost-effective, market-oriented strategy to drive a deep decarbonization of the economy.** A cap-and-trade program is a form of carbon pricing that puts a price on emissions allowances, which are then traded in the market. There is inherent uncertainty in many decisive factors affecting production and emissions reductions, such as technological development and innovation, prices for fossil fuels and renewables, and demand trends. Direct government regulation alone is unlikely to achieve decarbonization efficiently as the necessary information to do so is not accessible to policymakers. A cap-and-trade:

1. Allows private economic agents to flexibly respond to new information, as well as reaching decarbonization targets;
2. Incentivizes companies to supply low-emissions goods and services: carbon costs will be treated like other business costs and reduced to increase profit margins and/or gain market share;
3. Incentivizes end-users to demand low-emissions goods and services as these will have a cost advantage.

**A cap-and-trade can also incentivize industrial investment into innovation while maintaining economic growth.** The development of green technology often requires ongoing investment and a carbon price could help the development of cleaner technologies by providing a price signal that generates returns to low-emissions investment. Evidence from the EU Emissions Trading System (ETS), the world's largest cap-and-trade, suggests that carbon pricing induced regulated companies to increase low-carbon patenting by up to 10% and increase patenting for other technologies by close to 1% (Calel & Dechezleprêtre, 2016). Further, evidence on patent applications under China's regional pilot carbon pricing instruments suggests that carbon pricing effectively induced low carbon innovation (Cui, Zhang, & Zheng, 2018). Siegmeier et al. (2018) investigate the macroeconomic impacts of carbon pricing and find that induced investment shifts towards low-carbon technologies may enhance economic efficiency without constraining economic growth. A recent Information Technology & Innovation Foundation (ITIF) (Kennedy, 2018) report contains similar findings on the innovation and economic growth impacts of carbon pricing.

**Carbon pricing can also generate positive technology spill-overs by catalyzing low-carbon investment.**

Jurisdictions with stringent carbon prices can create an environment conducive to emerging low-carbon technologies. This could lead to lower global emissions if low-carbon technologies become the cost-effective production method: facilities in stringent climate policy jurisdictions would increase their international market share or low-carbon facilities would choose to relocate there (PMR, 2015).



## 3 Carbon Leakage Theory and Evidence

**Even though more countries are moving towards carbon pricing, coverage remains uneven globally and there is variation in jurisdictions' climate ambition and emissions reduction speed.** Some jurisdictions have relatively ambitious climate targets and longstanding carbon pricing systems, such as the EU and California. Other regions are at earlier stages of planning or implementing carbon pricing nationally, such as Brazil, China and South Korea. Finally, some regions – such as Saudi Arabia or Russia – generally lack climate ambition and are unlikely to implement carbon pricing nationally in the near term.

**This variation gives rise to asymmetries in carbon pricing stringency, both within the US and with international competitors, and thus to differences in compliance costs for the same industry in different locations.** Carbon pricing, and regulation more generally, can increase the production costs of companies in the regulated jurisdiction in the short term. This is particularly relevant if facilities have no cheaply available emissions reduction options. Facilities in the regulated jurisdiction that face significant compliance costs and compete strongly with facilities in non-regulated jurisdictions may be at risk of reduced competitiveness. Yet while environmental regulations can affect competitiveness, research indicates that the broader business and trade environment has a greater impact on large-scale competitiveness in the long term (Ambec et al. 2013; Dechezleprêtre and Sato 2017).

**This section introduces the theory underpinning the carbon leakage debate and presents key experiences.** It is structured as follows:

- Section 3.1 explains the theoretical link between carbon pricing and carbon leakage;
- Section 3.2 looks at experiences in jurisdictions outside of Oregon.

### 3.1 Theory of Carbon Leakage

**The impact of production cost bases on a companies' competitiveness varies across sectors, but EITE sectors will be more susceptible to the risk of carbon leakage.** In some sectors other factors are more important, such as the ability to innovate, increase product differentiation or react to changes in consumer preferences. For many EITE sectors, however, the size of the production cost base is a key determinant of competitiveness since:

- They often produce a relatively homogeneous good, such as cement or steel products, making customers sensitive to price movements;
- These markets tend to be highly internationalized, and thus companies in these sectors are typically price-takers;
- As a result, in the absence of low-cost emissions reduction opportunities, these sectors could lose significant market share if they pass through the costs associated with carbon pricing.

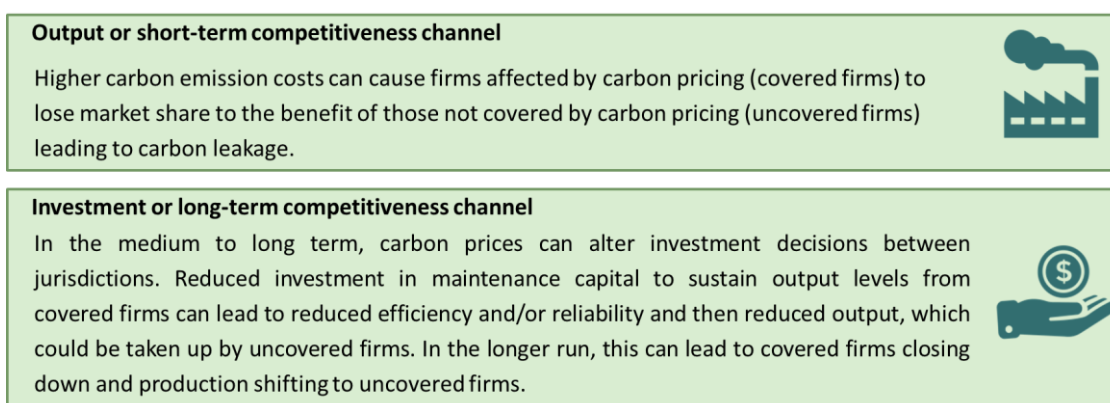
This final point is key: carbon cost pass-through is a desirable element of carbon pricing in order to induce demand-side substitution from emissions-intensive products. However, if a sector is EITE, carbon cost pass-through can lead to carbon leakage.



**Carbon leakage occurs when carbon pricing induces production to shift to jurisdictions with less stringent carbon pricing.** With carbon leakage, some of the reduction in emissions in the jurisdiction where carbon pricing is implemented inadvertently causes production to shift to jurisdictions with less ambitious emissions reduction policies. If the emissions intensity of production in jurisdictions that see an increase in production is greater than in jurisdictions where production falls, it is conceivable that this could lead to a net increase in global emissions.

**There are two channels through which carbon leakage could occur in Oregon.**<sup>3</sup> These are the output or short-term competitiveness channel, and the investment or long-term competitiveness channel.<sup>4</sup> Figure 4 details each potential channel of carbon leakage.

Figure 4. **Types of carbon leakage relevant to Oregon**



Source: Vivid Economics

**Carbon leakage has potentially undesirable environmental, economic, and socio-political consequences and is therefore a major concern for policymakers and industry.** There are three reasons for this:

- 1. Carbon leakage could undermine the environmental objective of carbon pricing by causing emissions to increase in regions beyond the reach of the policy.** A shift of production and therefore emissions to an uncovered jurisdiction would lower a country's effective contribution to the reduction of global emissions. Since the gains of GHG emissions reduction materialize mostly on a global level this would jeopardize the overall benefits of the policy.

<sup>3</sup> Carbon pricing may also lead to technological spill-overs in the regulated jurisdiction and thus could improve covered facilities' international competitiveness, leading to increases in output and investment. This is termed 'reverse leakage' in academic literature.

<sup>4</sup> A third channel is also relevant on a more global scale: the fossil fuel price channel. In this channel, facilities subject to carbon regulation reduce fossil fuel use, which can reduce the price of globally traded fossil fuels. Demand for these fuels in jurisdictions without carbon pricing could then increase, resulting in carbon leakage.

2. **Furthermore, carbon leakage raises the economic costs of reaching a certain emissions reduction objective.** Firstly, to reach a certain global reduction the (indirect) carbon price must be higher when leakage occurs, increasing the compliance costs for covered companies. Secondly, the difference in carbon price between jurisdictions creates an economic distortion between competing companies, leading to a reduction in social welfare compared with the undistorted case.
3. **At the same time, the decline in domestic production and employment can create significant political and social challenges.** Increasing economic output and especially employment are key objectives for policymakers. If carbon pricing induces carbon leakage, it can cause economic challenges and unemployment, which in turn can present significant social and political challenges.

This confluence of potentially undesirable outcomes makes leakage one of the most controversial and important aspects of carbon pricing design.

## 3.2 External Experiences of Leakage

**The experiences of carbon leakage across jurisdictions that have implemented carbon pricing are split between identification and evidence of carbon leakage in jurisdictions outside of Oregon.**

- Section 3.2.1 discusses how jurisdictions have identified sectors at risk of carbon leakage; and
- Section 3.2.2 details the existing *ex ante* and *ex post* evidence for carbon leakage in international jurisdictions.

### 3.2.1 Identification of sectors at risk

**Policymakers in international jurisdictions have typically used two main metrics to estimate leakage risk: trade exposure and emissions intensity.** Trade intensity intends to capture the facility's capacity to pass through carbon costs to consumers without losing profit margins or market share to international competitors. The emissions intensity metric aims to reflect a sector's cost exposure to a carbon pricing mechanism. Box 2 explains why these two metrics have been favored over other indicators.



**Box 2. Theoretical indicators of carbon leakage risk may not be feasible for practical analysis****The academic literature identifies two main considerations for assessment of sectoral leakage risk:**

1. Carbon cost impact: the impact that carbon pricing has on a particular facility or sector; and
2. Whether the facility or sector has the capacity to pass through carbon costs to consumers without loss of market share or profit margin (carbon cost pass-through capacity).

**Each of these channels is difficult to observe in practice given data limitations, and is therefore often estimated through use of a proxy:**

- Carbon cost impact can be measured by volume of emissions created per unit of output, revenue, value added, and profit. While this is often quite easy to capture, on some occasions emissions data may be challenging to gather.
- Measuring cost pass-through capacity is more challenging. A wide range of factors can be important including market power, sensitivity of demand, the sensitivity of domestic supply, and sensitivity of foreign supply. However, these are difficult to observe or measure and policymakers have tended to approximate through measurable drivers – most notably measures of trade intensity.

**Carbon price differentials and emissions reduction potential have not been used in practice to quantitatively measure carbon leakage risk, but are used in this analysis within the qualitative assessment:**

- Emissions reduction potential and cost can influence investment decisions and leakage. If a facility can reduce emissions at low cost it will be able to cost-effectively reduce the carbon cost it faces, thus reducing the risk of leakage. However, this can vary significantly by facility;
- As carbon leakage is driven by carbon price differentials, competing countries introducing carbon pricing policies of equivalent stringency should lessen the risk of leakage. However, prices can change quickly and so risk can be highly variable.

**Different jurisdictions use largely similar definitions of emissions intensity and trade exposure.** Table 2 shows the four main definitions of emissions intensity and trade exposure that jurisdictions have used as metrics of carbon leakage risk. Trade exposure is largely measured as the share of a sector's total trade over its local market, except in the former Australian policy wherein it was measured as a sector's total trade over local production. Jurisdictions either define emissions intensity as a sector's carbon cost share relative to its value added using an assumed carbon price, or a sector's CO<sub>2</sub>e emissions volume per dollar of value added. Box 3 provides additional aspects of how some jurisdictions have identified EITE sectors.



Table 2. There are four main definitions of emissions intensity and trade exposure

System	Emissions intensity definition	Trade exposure definition
EU ETS Phase III		
South Korea ETS		
Alberta Carbon Competitiveness Incentive Regulation (CCIR)	$\frac{\text{direct carbon costs (\$)*} + \text{indirect carbon costs (\$)**}}{\text{value added (\$)}}$	$\frac{\text{imports (\$)} + \text{exports (\$)}}{\text{imports (\$)} + \text{production (\$)}}$
EU ETS Phase IV		
California ETS		
Australia Carbon Pricing Mechanism (former)	$\frac{\text{direct} + \text{indirect emission (tCO}_2\text{e)}}{\text{value added (\$)}}$	$\frac{\text{imports (\$)} + \text{exports (\$)}}{\text{production (\$)}}$

Note: \*assumed carbon price  $\times$  emissions; \*\*electricity consumption  $\times$  carbon intensity of production  $\times$  carbon price

Source: Vivid Economics

### Box 3. Some jurisdictions have used or proposed alternative methodologies to identify EITE sectors

#### Canadian provinces and the Waxman/Markey bill use or propose alternative methodologies to identify EITE sectors.

- Some Canadian provinces have followed a less publicly transparent methodology; and
- The Waxman/Markey bill also identified sectors using energy intensity as an indicator.

**Quebec, Ontario, and British Columbia identify EITE sectors in a variety of ways, although the process followed is not always clear from publicly available information.** Ontario identified all industrial sectors as EITE but excluded fuel suppliers/distributors, electricity importers and most electricity generators. This transitional measure aims to support industries competing with jurisdictions that do not yet price carbon. Quebec identifies all manufacturing and mining sectors and some electricity producers (under certain conditions)<sup>5</sup> as eligible for free allowance allocation prior to 2020 (Government of Quebec, 2011). British Columbia does not determine EITE sectors but exempts certain sources from the carbon tax under various conditions.

**The Waxman/Markey bill identified sectors using an energy intensity indicator.** The bill allowed for certain sectors to receive emission allowance rebates. The criteria for rebate eligibility were: having an energy or GHG intensity of at least 5% AND having trade intensity of at least 15%. If a sector has an energy or GHG intensity of at least 20% it would also qualify for rebates, regardless of trade intensity (US Congress, 2009).

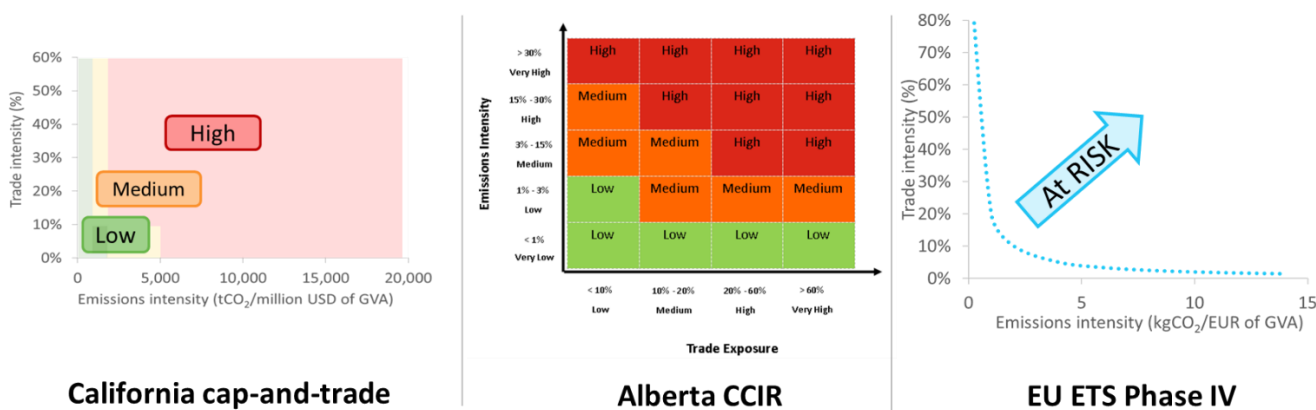
<sup>5</sup> Free allocation to electricity producers is only provided if the generator has signed a contract before 2008 in which the sales price is fixed and cannot be adjusted to account for carbon cost increases. Free allocation also covers power consumed in Quebec but generated in another jurisdiction that has implemented a cap-and-trade system .



**Jurisdictions have combined indicators in different ways to identify sectors at risk of carbon leakage, as shown in Figure 5.**

- **California** uses trade intensity and emissions intensity but determines leakage risk in a tiered manner based on combinations of the two metrics. This allows a more granular identification of risk rather than reducing it to a binary assessment as with Phases III and IV of the EU ETS.<sup>6</sup> However, recent legislation requires that all leakage risk categories will receive the same level of support as the highest category (100% of the output-based benchmark allocation level). These amendments will effectively make California’s carbon leakage risk identification a binary system.
- **Alberta’s Carbon Competitiveness Incentive Regulation (CCIR)** combines trade intensity and emissions intensity to identify tiered EITE categories, but provides support only to sectors in the High EITE category.
- **EU ETS Phase IV** multiplies trade intensity with an estimate of emissions intensity and compares this product against a threshold.<sup>7</sup> While this removes the reliance on a carbon price assumption as in Phase III, it still relies on the choice of an explicit threshold. This new method ensures that a sector’s cost increase and trade intensity are considered together, which is also attractive. Moreover, the methodology is easy to implement.

**Figure 5. Major international methodologies combine emissions intensity and trade intensity measures differently to determine carbon leakage risk**



*Note:* California currently uses a tiered approach to determine leakage risk, although ARB398 will effectively impose a binary system. GVA, gross value added.

*Source:* Vivid Economics

<sup>6</sup> The EU ETS is currently in its third phase. Phases I and II ran over 2005–12; the third phase runs from 2013–20; while the fourth phase will run from 2021–30. Subsequent phases have expanded the scope of the system in terms of sectors and GHGs covered. The system has also become increasingly nuanced over time, particularly in terms of allocation support to EITE sectors and market stability measures.

<sup>7</sup> The European Commission, in conjunction with the European Parliament and Council of Ministers, determines the choice of a 20% threshold under EU ETS Phase IV. The basis for the choice is ultimately a political one rather than an economic one: policymakers made the choice with reference to which sectors were previously on the carbon leakage list.



**The EU ETS also uses qualitative assessments to identify borderline EITE sectors, focusing on market characteristics, profitability and emissions reduction opportunities (European Commission, 2018a).**

- Market characteristics take into account the possibility that companies in more competitive sectors may face a high carbon cost burden relative to margins and find it harder to pass through costs. The EU ETS looks at carbon pricing of key imports and exports competitors, as well as output prices compared with production costs (which include the carbon costs) to determine the extent to which this will affect a company.
- More profitable companies will find it easier to absorb the cost of a carbon price and retain incentives to invest. Hence the EU ETS aims to assess the extent of this profitability by looking at publicly available financial performance metrics, transport costs to proxy for ease of relocation, as well as recent investment and trade trends.
- The EU ETS also assesses emissions reduction opportunities, as emissions reduction cost and potential can influence the impact of carbon emission costs, investment decisions and leakage. It looks at facilities' emissions intensities compared with international benchmarks, absolute emissions and/or electricity consumption, as well as the impact of adopting BAT.

**In general, jurisdictions often identify similar sectors at risk of carbon leakage.** Across California, the EU ETS, Alberta and Quebec, sectors such as pulp and paper, basic chemicals manufacturing, cement manufacturing, lime manufacturing and iron and steel manufacturing are consistently identified as at risk of carbon leakage. Other sectors such as wood product manufacturing and plastic manufacturing have been identified as at risk in some jurisdictions and not at risk in others. Table 3 summarizes the identification of key sectors in different jurisdictions.

### 3.2.2 Evidence of carbon leakage

**To be properly classified as carbon leakage, any shift of emissions needs to be caused by a difference in stringency in emissions regulation.** A change of emissions or output alone does not qualify as carbon leakage. In a globalized world, production may shift due to various reasons, and environmental compliance is only one factor in a company's complex decision-making about where to produce and how much. This makes the *ex post* observation and quantification of carbon leakage challenging. The counterfactual – how the company would have produced in the absence of carbon regulation – remains unobservable.

**Isolating the causal factors behind output or emissions changes is highly challenging, but in general there are two approaches to estimating prospective or past carbon leakage:**

- An *ex ante* or theoretical approach where the effects of a carbon pricing policy are modelled before the (potential) implementation;
- An *ex post* approach where the effects of a carbon pricing policy are estimated after implementation.

Table 3. Key sectors' EITE identification in different jurisdictions

Sector description	California <sup>o</sup>	EU ETS Phase IV	Alberta	Quebec
Mining and Quarrying	High	X	X	✓
Food Manufacturing	Medium	✓	✓	✓
Sawmills	Medium	X	X	✓
Wood Product Manufacturing	High	✓	X	✓
Pulp and Paper	High	✓	✓	✓
Chemicals	High	✓	✓	✓
Plastic Manufacturing	Medium	✓	X	✓
Glass Manufacturing	High	✓	X	✓
Cement Manufacturing	High	✓	✓	✓
Lime Manufacturing	High	✓	✓	✓
Iron and Steel Manufacturing	High	✓	✓	✓
Semiconductors	N/A <sup>8</sup>	X*	X**	✓***

Note: X indicates sectors not identified as at risk of carbon leakage, while ✓ indicates sectors identified as at risk. This table offers a high-level understanding of leakage risk as determined by the local factors in each jurisdiction and it should not be interpreted as a definitive leakage risk indicator for Oregon. <sup>o</sup> Based on current tiered Californian identification, although this will no longer be applicable in future phases. \* Eligible for qualitative assessment of EITE; however, the EU ETS does not cover F-gases. \*\* While Alberta covers F-gases, the semiconductors sector was assessed and either found not to be highly EITE or did not have any facilities exceeding the 50,000 tCO<sub>2e</sub> eligibility threshold. \*\*\* Quebec covers F-gases and has one semiconductor fabrication plant, owned by [Teledyne DALSA](#).

Source: Vivid Economics

**Ex ante** approaches generally use either computable general equilibrium (CGE) or partial equilibrium models to estimate risk of carbon leakage, and predict levels of leakage in the absence of measures to protect against it. In general, CGE models predict relatively low levels of carbon leakage, while partial equilibrium models estimate higher rates and higher variation in rates. One reason for this structural difference in results is that partial equilibrium models assume perfect substitutability between domestic and foreign goods, and therefore that economies are more vulnerable to changes in costs by design. By contrast, CGE models use trade elasticities to account for intangible trade barriers, and also account for dynamic shifts between sectors. A third methodology has emerged in recent years which first estimates econometrically the historical relationship between energy prices and trade and production, and then extrapolates these estimates while accounting for carbon prices.

**Ex post** approaches have generally not yet found significant evidence of carbon leakage, although crucial qualifications suggest caution is required when interpreting these findings. These empirical evaluations usually employ econometric techniques to isolate the effect of carbon pricing from other prevalent

<sup>8</sup> California's cap-and-trade does not directly cover the semiconductors sector, but rather regulates large facilities through emissions standards (discussed further in Section 4.4.11).



developments. Competitiveness effects tend to be mild, and even in cases where regulated and unregulated facilities are directly compared, typically no significant impact is seen (Flues & Lutz, 2015). A recent major OECD study, comparing financial data from close to 2,000 companies with facilities covered by the EU ETS, the world's largest cap-and-trade, with similar sized unregulated companies from the same countries and sector, found that the EU ETS had no negative effect on revenue, profits, jobs or fixed assets (Dechezleprêtre et al., 2018). Indeed, revenues of facilities subject to the ETS were 7% to 18% higher at the end of the period studied than what they would have been without the EU ETS, and their fixed assets grew by 6%-10% compared to control firms. However, there are 2 crucial qualifications required when considering these approaches:

1. **Most existing carbon pricing systems are characterized by low prices.** This means that the *ex post* studies of carbon leakage risk consider only moderate carbon prices; there is very little empirical evidence on the competitiveness impacts of ambitious carbon pricing.
2. **Cap-and-trade policies are usually designed to prevent carbon leakage or other competitiveness impacts, such as free allocation in the EU ETS.** It is therefore challenging to determine whether carbon leakage does not occur because the prevention mechanisms are working, or because carbon leakage is generally unlikely.

An overview of recent *ex ante* and *ex post* evidence of carbon leakage is provided in Appendix 2 – Academic Evidence on Carbon Leakage.

**A further significant reason for the low occurrence of carbon leakage may be that the costs of environmental compliance are only one factor in the multidimensional production decision.** Purchasing emission permits or paying a carbon tax is only one part of the cost function and other contributors such as resource prices or labor costs are often more significant. In addition, facilities have long been observed to compete not only on costs, but also on the efficiency of converting inputs into high-value outputs. In this process, factors such as access to a qualified labor force, stable institutions, and innovation and technological development are often more important than mere cost competition, and are crucial to Oregon's state competitiveness. These findings are in line with a longstanding and large body of research on the effects of environmental policies and the optimal location of production (Yoon & Hwang, 1985; Tole & Koop, 2011; Bolscher et al., 2013; Dechezleprêtre and Sato 2017) .

**Even though there is little previous evidence on economy-wide carbon leakage, the potential impacts of carbon pricing on competitiveness and emissions need to be assessed carefully.** There is no significant evidence from published research thus far of a large-scale shift of economic activity, employment or emissions as a result of carbon pricing. However, there are limitations to the *ex post* research as outlined above. Input prices, the role of different sectors in the global economy, and the current technological advancements in the production process are more important than prospective carbon prices in the short term. However, policymakers must engage with stakeholders to understand leakage risk, and whether it is necessary to reduce that risk given the deleterious consequences associated with it.



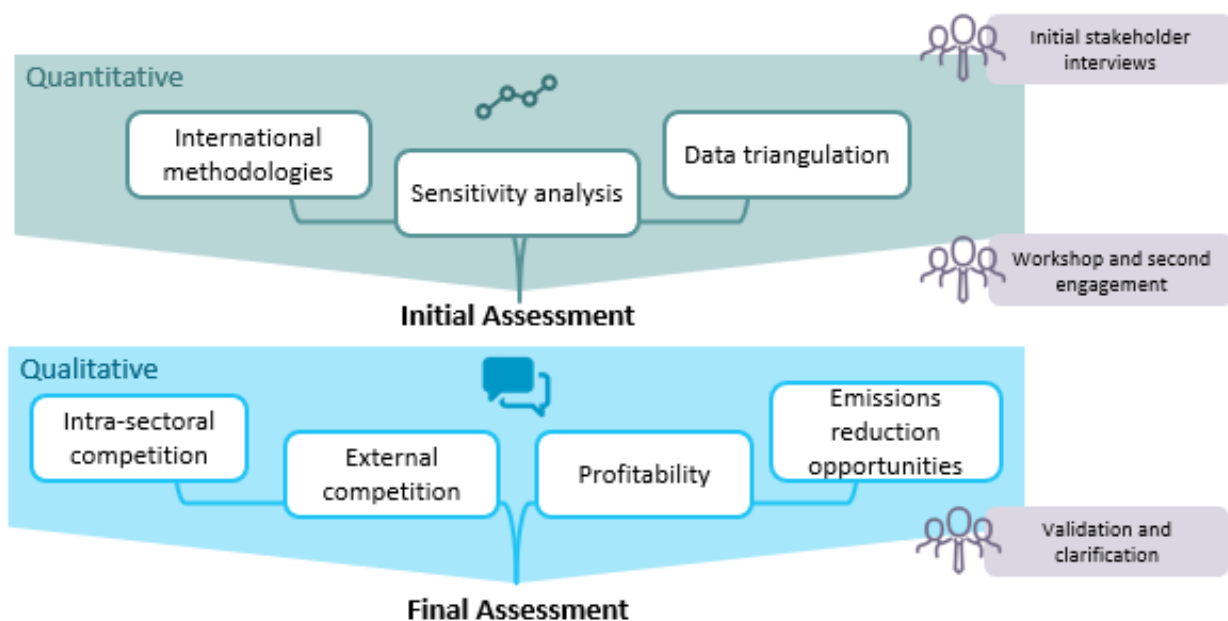
## 4 Methodology and Results

The methodology combines quantitative and qualitative analysis of each directly regulated sector to offer a final assessment of carbon leakage risk across Oregon sectors. The program would likely directly regulate large sources of emissions, such as those that exceed a threshold of 25,000 tCO<sub>2</sub>e annually as reported to DEQ in the state’s GHG Reporting Program. This covers around 30 manufacturing sector facilities and one mining sector facility when observing emissions data over 2014–17. There are two key elements to the analysis, per Figure 6:

- Quantitative analysis provides initial insight into sectors’ carbon cost exposure at the NAICS 4 sector level;
- Qualitative analysis develops the final risk assessment through the evaluation of competitive dynamics, profitability and emissions reduction opportunities.

For Oregon, the qualitative analysis is the most important component of the approach and yields key insights that determine sectoral assessments. The low number of facilities potentially directly covered under an Oregon cap-and-trade mean that a qualitative analysis can uncover more nuance than an approach reliant on quantitative analysis alone. The quantitative trade exposure metric is a proxy for cost pass-through capacity, while the qualitative analysis reveals factors influencing cost pass-through directly. Furthermore, the lack of granular trade data limits the usefulness of the trade exposure metric in the context of Oregon.

Figure 6. Quantitative and qualitative analysis are the two key elements of the risk assessment



Source: Vivid Economics

The summary findings of the carbon leakage risk assessment for Oregon show that all potentially covered manufacturing and mining sectors are either at risk of carbon leakage or likely to be at risk. Table 4 illustrates the high-level findings from the overall leakage risk assessment for all investigated Oregon sectors. The distinction between the results of the assessment is:

- At risk: while there are competing factors increasing and decreasing risk, the sector is at risk of carbon leakage on the balance of evidence;
- Likely at risk: there are competing factors increasing and decreasing risk, the sector is likely at risk of carbon leakage on the balance of evidence; however, a lack of evidence on cost pass-through capacity from one or more sectoral stakeholders prevents us from reaching a more definitive conclusion.

*Table 4.* The carbon leakage risk assessment for Oregon finds that all potentially covered sectors are at risk of carbon leakage

NAICS 4 code	Sector description	Number of potentially covered facilities	Carbon leakage risk assessment
3273	Cement and Concrete	1	At risk
3251	Chemicals	2	Likely at risk
3114	Food Manufacturing	5	At risk
3315	Foundries	1	At risk
3272	Glass	1	At risk
3311	Iron and Steel	2	At risk
3274	Lime and Gypsum	1	Likely at risk
2123	Non-metallic Mineral Mining	1	At risk
3279	Other Non-metallic Mineral Products	1	At risk
3261	Plastics	2	Likely at risk
3221	Pulp, Paper, and Paperboard	5	At risk
3344	Semiconductors	6	At risk
3211	Sawmills and Wood Preservation	1	At risk
3212	Wood Products	2	At risk

Source: Vivid Economics (based on 2014–17 data)

This section details the quantitative and qualitative methodological approaches and the accompanying results from each analysis. The section first details the methodology and results of the quantitative analysis and then details the methodology and results of the qualitative analysis. The structure is as follows:

- Section 4.1 describes the methodology of the quantitative analysis;
- Section 4.2 explains the results of the quantitative analysis;
- Section 4.3 details the methodology of the qualitative analysis; and
- Section 4.4. explains the results of the qualitative analysis.



## 4.1 Quantitative Analysis Methodology

The scope of this analysis is limited to sectors which contain a potentially covered facility in the manufacturing and mining sectors. Facilities are identified as potentially covered under a future Oregon cap-and-trade mechanism if their annual emissions breached 25,000 tCO<sub>2</sub>e in any single year over the period 2014–17. The quantitative analysis for Oregon calculates metrics using average annual data over the period 2014–16 and at the NAICS 4 level.<sup>9</sup> It calculates carbon leakage risk metrics using publicly available data sources from the US Census Bureau and the Oregon DEQ, detailed in Table 5.

Table 5. Summary table of data sources used for quantitative analysis

Data	Source	Unit	Granularity	Most recent year
<b>International trade</b>	U.S. Department of Commerce (2018) USA Trade Online	\$	Oregon level NAICS 4	2017
<b>Trade with other US states</b>	U.S. Department of Transportation and U.S. Department of Commerce (2015) Commodity flow survey	\$	Oregon level NAICS 2	2012
<b>Value added</b>	U.S. Department of Commerce (2017) US Census Bureau: Annual Survey of Manufactures	\$	Oregon level NAICS 4	2016
<b>Production</b>	U.S. Department of Commerce (2017) US Census Bureau: Annual Survey of Manufactures	\$	Oregon level NAICS 4	2016
<b>Direct emissions</b>	DEQ (2018a) Greenhouse Gas Emissions Reported to DEQ	tCO <sub>2</sub> e	Oregon level NAICS 6	2016
<b>National electricity intensity of production</b>	U.S. Department of Commerce (2017) US Census Bureau: Annual Survey of Manufactures	kWh/\$	National level NAICS 4	2016
<b>Carbon intensity of Oregon's electricity grid</b>	DEQ (2018b) Oregon Clean Fuels Program: Calculating the Carbon Intensity of Electricity used in the CFP	tCO <sub>2</sub> e/MWh	Oregon wide	2016

Source: Vivid Economics

**Policymakers in other jurisdictions have typically used two main metrics to estimate leakage risk: trade exposure and emissions intensity.** Trade intensity is intended to capture facilities' capacity to pass through

<sup>9</sup> While new 2017 emissions data is now available, 2017 value-added data is not yet available from the US Census Bureau. As such, the quantitative analysis has been limited to period 2014–16.





carbon costs to customers without significant loss of market share to external competitors. Emissions intensity is intended to capture a sector's direct (and indirect) cost exposure to a carbon pricing mechanism.

**Quantitative analyses of carbon leakage risk tend to utilize commonly used emissions intensity and trade exposure methodologies, such as those defined in the EU ETS Phase IV and the Californian ETS.** Table 6 provides the definition of the emissions intensity and trade exposure metrics. Indirect emissions are defined as electricity consumption (kWh) multiplied by the emissions factor of the electricity grid (tCO<sub>2</sub>e/kWh). The trade exposure metric should capture both international trade flows and trade flows with other US states.

*Table 6. Definition of carbon leakage risk indicators*

Carbon leakage risk indicator	Formula
1. Emissions intensity	$\frac{\text{Direct emissions (tCO}_2\text{e)}}{\text{value added (\$)}} + \frac{\text{Indirect emissions (tCO}_2\text{e)}}{\text{value added (\$)}}$
2. Trade exposure	$\frac{\text{Imports (\$)} + \text{Exports (\$)}}{\text{Production (\$)} + \text{Imports (\$)}}$

Source: Vivid Economics based on CARB (2010a) and Bolscher & Graichen (2018)

**To calculate indicators, direct emissions data is available publicly, and a series of assumptions facilitate data approximation for all sectors' indirect emissions and certain sectors' value-added and production data.**

- DEQ publishes facility-level direct emissions publicly on an annual basis for facilities emitting more than 2,500 tCO<sub>2</sub>e.
- Indirect emissions data was approximated for all sectors assuming they reflected their national level of electricity intensity of production over 2014–16.<sup>10</sup> This intensity was combined with Oregon production data and Oregon's average emissions intensity of the statewide electricity mix over 2014–16, 0.36 kgCO<sub>2</sub>e/kWh, to approximate sectoral indirect emissions (DEQ, 2018b).
- Certain sectors had withheld value-added and/or production data for confidentiality reasons. To approximate these datapoints, this analysis assumed Oregon sectors reflect past or national relationships between labor, production, and value added (Appendix 1 – Data Approximation Process details each data approximation).

**However, to calculate the trade exposure indicator, data limitations and conceptual issues present three significant challenges.** These challenges relate to:

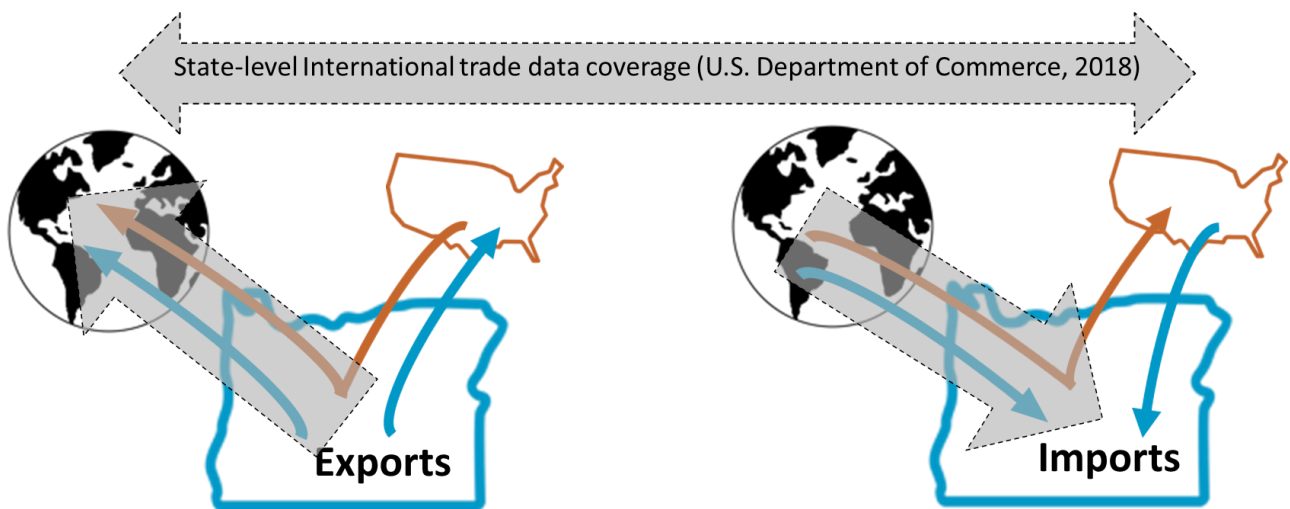
1. Limitations of international trade data;
2. Lack of inter-state trade data; and
3. The imperfection of trade exposure as a measure of cost pass-through capacity.

<sup>10</sup> For the Non-metallic Mineral Mining and Quarrying sector (NAICS 2123), national electricity intensity was calculated from the most recent available source, the US Census Bureau's (2016) Economic Census: Mining: Summary Series.



1. Oregon-level **international trade data** from the U.S. Department of Commerce (2018) has limitations, such as overestimating international trade flows to and from Oregon. This limitation derives from not disaggregating goods that move through Oregon from those that would be considered true Oregon-based trade. As such, the data does not isolate exports produced in Oregon (or imports destined for Oregon) from all trade flows moving through Oregon (Export.gov, 2016). Figure 7 illustrates how the available state-level trade data misrepresents true Oregon trade with international jurisdictions.

*Figure 7.* Existing state-level trade data misrepresents true trade flows of exports originating in Oregon and imports destined for Oregon



*Note:* The blue arrow reflects Oregon's actual exports and imports, while the gray arrow reflects what is provided by the US Census Bureau's USA trade data, and the brown arrow reflects the inter-state trade flows being misrepresented as Oregon international trade.

*Source:* Vivid Economics

2. The lack of Oregon-level **inter-state trade data** further limits the capacity to calculate the trade exposure metric. The US Census Bureau's (2012) Commodity Flow Survey includes goods flows from Oregon to other US states, but does not disaggregate beyond the NAICS 2-digit level. Some datasets available for purchase offer more estimates of Oregon sectors' trade with external jurisdictions. However, these datasets, while useful for much economic analysis, do not provide sufficient disaggregation for the current task of identifying EITE sectors. This is due to the fact that they do not indicate how much each sector trades with individual jurisdictions that have implemented carbon pricing, such as California. However, Oregon's manufacturing trade with California is likely significant, as Figure 8 illustrates for 2012. This is important as the presence of a cap-and-trade in that state significantly reduces leakage risk to it. Furthermore, it may not be possible to address this issue with a simple correction factor across all sectors: proportions of trade with California will vary across sectors. The limitations of both international

and state-level trade data limit the ability of the trade flow analysis to accurately determine export competitors' jurisdictions, detailed in Box 4.

- Furthermore, the **trade exposure metric itself** is an imperfect indicator of cost pass-through capacity. During Phase III of the EU ETS, sectors could be identified as at risk of carbon leakage using a trade intensity metric alone, among other methods. As illustrated in Figure 9, 79% and 85% of NACE<sup>11</sup>-4 sectors identified on the EU ETS's Phase III leakage lists were identified based on the trade exposure metric alone (European Commission, 2015d). However, *ex post* analysis showed some EU sectors identified in this way had significant cost pass-through capacity (Vivid Economics & DECC, 2014; CE Delft & Oeko-Institut, 2015).

*Figure 8.* In 2012, Oregon manufacturing trade with California represented the destination market for 47% of all its intra-US exports and the source market for 18% of all intra-US imports



Source: Vivid Economics based on US Census Bureau's (2012) Commodity Flow Survey

<sup>11</sup> Classification of Economic Activities in the EU (Nomenclature des Activités Economiques dans la Communauté Européenne).

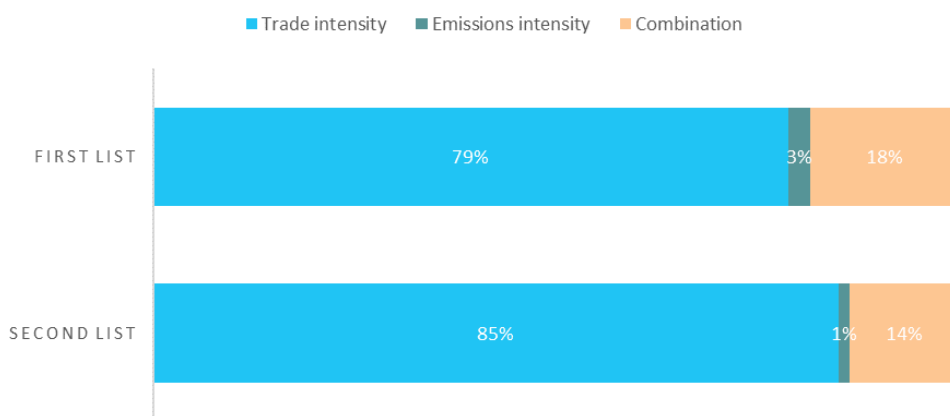
**Box 4. The analysis of competitive dynamics would ideally identify key export competitor jurisdictions**

**Ideally, the analysis of competitive dynamics for Oregon sectors potentially covered under a carbon price would take into consideration key export competitor jurisdictions.** This would require a full dataset on Oregon’s trade flows to and from export markets (both international and other US states), local production in those markets, and trade flows of competitor jurisdictions also exporting into those markets. This allows for the identification of key export competitor jurisdictions. For example, if an Oregon sector sells widgets to Californian markets, then it competes not only with Californian widget producers, but also with second-order competitors in other jurisdictions that export into the Californian market. The presence of carbon pricing in these second-order competitors also influences the extent to which an Oregon sector can pass through carbon costs.

**However, this identification is not possible with available data.** As discussed above, state-level international trade data may misrepresent individual state trade levels, and purchased datasets cannot identify individual Oregon sectors’ trade flows to individual states, such as California. Similarly, this data does not allow the identification of which other states export into California. The nature and location of second-order competitors will vary across export markets and across different sectors, and as such, it would not be possible to generalize any pattern across export markets and sectors. This data limitation emphasizes the importance of the qualitative analysis to generate insights on competitive dynamics.

**This is a further reason for carrying out a qualitative analysis to understand potential competitiveness impacts.**

*Figure 9. Most sectors on the EU ETS (current) Phase III carbon leakage list are identified based solely on trade intensity*



*Note:* The first carbon leakage list was in effect from 2013–14; the second, current, carbon leakage list is in effect from 2015–19. Data for NACE-4 sectors assessed, Prodcom-level assessments excluded.

*Source:* Vivid Economics based on (European Commission, 2014) and Juergens et al. 2013 (first list)



**These data challenges reduce the capacity of this quantitative analysis to offer insights on leakage risk and increase the importance of the qualitative analysis to determine cost pass-through capacity.** The emissions intensity metric offers insights on relative carbon cost exposure, and the results of this are discussed in the following section. However, challenges in calculating the trade exposure metric mean that it is not pursued as an indicator for understanding cost pass-through capacity. This highlights the importance of the supplementary qualitative assessment, contained within the sector briefs and detailed in Section 4.3, to directly identify the potential capacity for sectors to pass through carbon costs.

## 4.2 Quantitative Analysis Results

**The quantitative analysis focusses on sectoral (direct and indirect) emissions only.** The results present the analysis of Oregon sectoral emissions in three ways:

1. Direct emissions levels;
2. Emissions intensity of Oregon sectors relative to each other, using direct emissions; and
3. Emissions intensity of Oregon sectors relative to the categories used in California, which include indirect emissions for comparability with the Californian method.

### 4.2.1 Direct emissions levels

**Pulp, paper and paperboard mills, cement and concrete, and semiconductors would face large carbon costs, in the absence of measures to reduce carbon cost exposure, given high direct emissions levels.** Table 7 illustrates the key average annual data points over 2014–16 used to calculate the emissions intensity metric for Oregon sectors potentially covered under a carbon price. The pulp, paper, and paperboard and the cement and concrete sectors<sup>12</sup> were the highest direct emitters

<sup>12</sup> The scope of this analysis is at the NAICS 4-digit level given this would be the regulatory scope. Thus, for example, while there are no concrete facilities regulated under the potential carbon pricing instrument, the analysis nevertheless refers to the cement and concrete sector.



*Table 7. Emissions intensities vary by an order of magnitude between sectors, and pulp and paper has the highest total emissions*

NAICS 4 code	Sector description	Abbreviation	Number of potentially covered facilities	Average annual direct emissions (tCO <sub>2</sub> e)	Average annual indirect emissions (tCO <sub>2</sub> e)	Average annual value added (\$1,000)	Direct and indirect emissions intensity (tCO <sub>2</sub> e/(\$M) value added)	Direct-only emissions intensity (tCO <sub>2</sub> e/(\$M) value added)
3221	Pulp, Paper, and Paperboard	P&P	5	898,994	451,629	1,150,702	1,174	781
3273	Cement and Concrete	Cem	1	670,127	62,297	326,139	2,246	2,055
3344	Semiconductors	Sem	6	645,883	1,089,585	3,716,560	467	174
3212	Veneer, Plywood, and Engineered Wood Products	WdP	2	251,548	410,961	1,040,567	637	242
3114	Food Manufacturing	Food	5	245,679	108,616	1,058,599	335	232
3251	Chemicals	Chem	2	230,354	95,596	343,142	950	671
3311	Iron and Steel	I&S	2	178,280	173,553	292,877	1,201	609
3211	Sawmills and Wood Preservation	Saw	1	120,083	254,734	1,023,214	366	117
3261	Plastics	Plas	2	104,203	105,879	659,986	318	158
3315	Foundries	Fnd	1	61,820	225,294	1,174,574	244	53
3274	Lime and Gypsum	L&G	1	51,996	3,541	13,896	3,997	3,742
3279	Other Non-metallic Mineral Products	ONMP	1	43,727	20,060	141,383	451	309
3272	Glass	Gls	1	42,942	64,427	252,952	424	170
2123	Non-metallic Mineral Mining and Quarrying	NMMi	1	42,137	36,145	231,476	338	182

*Note:* Direct emissions from all facilities reporting emissions in the sector and indirect emissions approximated.

*Source:* Vivid Economics based on DEQ (2018a) and U.S. Department of Commerce (2016, 2017)

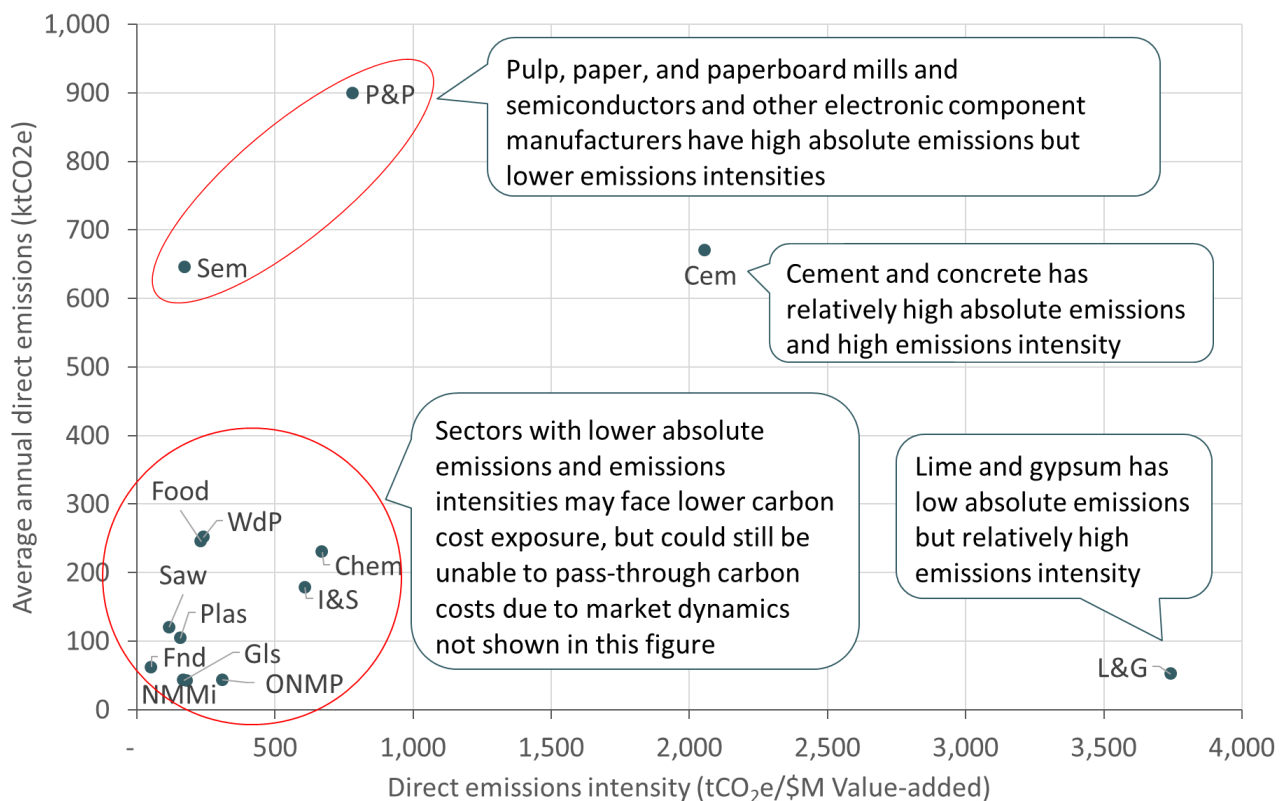


#### 4.2.2 Relative direct emissions intensity across Oregon sectors

**Highly emissions-intensive Oregon sectors may face particular risk of carbon leakage since their carbon cost relative to value added implies a higher exposure to carbon costs:**

- Figure 10 plots sectors' direct emissions intensities against their absolute direct emissions. However, this figure does not account for trade exposure or market environments that impact a firm's ability to pass through a carbon cost.
- If a sector lies in the upper-right corner of this figure, it has high absolute emissions and high emissions intensities, reflecting a high exposure to carbon costs.
- Sectors towards the left-hand side of the graph have lower emissions intensities, suggesting lower exposure to carbon costs relative to value added.

*Figure 10. Average annual direct emissions intensity of Oregon sectors plotted against average annual direct emissions over 2014–16 illustrates potential exposure to carbon costs, but not cost pass-through capacity*



*Note:* Pulp, Paper, and Paperboard (P&P); Cement and Concrete (Cem); Semiconductors (Sem); Veneer, Plywood, and Engineered Wood Products (WdP); Food Manufacturing (Food); Chemicals (Chem); Iron and Steel (I&S); Sawmills and Wood Preservation (Saw); Plastics (Plas); Foundries (Fnd); Lime and Gypsum (L&G); Other Non-metallic Mineral Products (ONMP); Glass (Gls); Non-metallic Mineral Mining (NMMi).

*Source:* Vivid Economics

**Lime and gypsum, cement and concrete, and pulp, paper, and paperboard are the most emissions-intensive sectors in Oregon and may face particular exposure to carbon costs:**

- Lime and gypsum, and cement and concrete are by far the most emissions-intensive sectors in Oregon.

- Pulp, paper, and paperboard is the most emissions-intensive sector out of the remaining sectors, and has the highest level of absolute direct emissions in the state, making the sector potentially exposed to significant carbon costs.
- Basic chemicals and iron and steel are the only other sectors with emissions intensities above 500 tCO<sub>2</sub>e/\$M value added and may thus also face potential exposure to carbon costs.

**Sectors with lower absolute emissions and emissions intensities may have lower carbon cost exposure, although this does not account for their capacity to pass through costs.** Figure 10 above suggests that sectors with lower relative carbon cost exposure may be non-metallic mineral mining and quarrying, other non-metallic mineral products, foundries, and glass. However, these sectors may still not be able to pass through their carbon costs, as the emissions intensity analysis does not consider sectors' trade exposure and thus their ability to pass through costs.

#### 4.2.3 Total emissions intensity relative to Californian thresholds

**California classifies sectors into four categories of emissions intensity.** Table 8 sets out the thresholds for classifying high, medium, and low, and very low emissions intensity. In the California method, emissions intensity categories were calculated by using both direct and indirect emissions in the emissions intensity calculation. As such, comparing Oregon sectors to the Californian thresholds requires including indirect emissions in Oregon sectors' emissions intensity metrics.<sup>13</sup>

*Table 8. In the California cap-and-trade, sectors are classified into four categories of emissions intensity*

Category	Emissions intensity (direct and indirect tCO <sub>2</sub> e/\$M value added)
High	≥ 5,000
Medium	1,000 to 4,999
Low	100 to 999
Very Low	< 100

Source: Vivid Economics

#### **Four Oregon sectors would be classified as medium emissions intensity under the Californian method:**

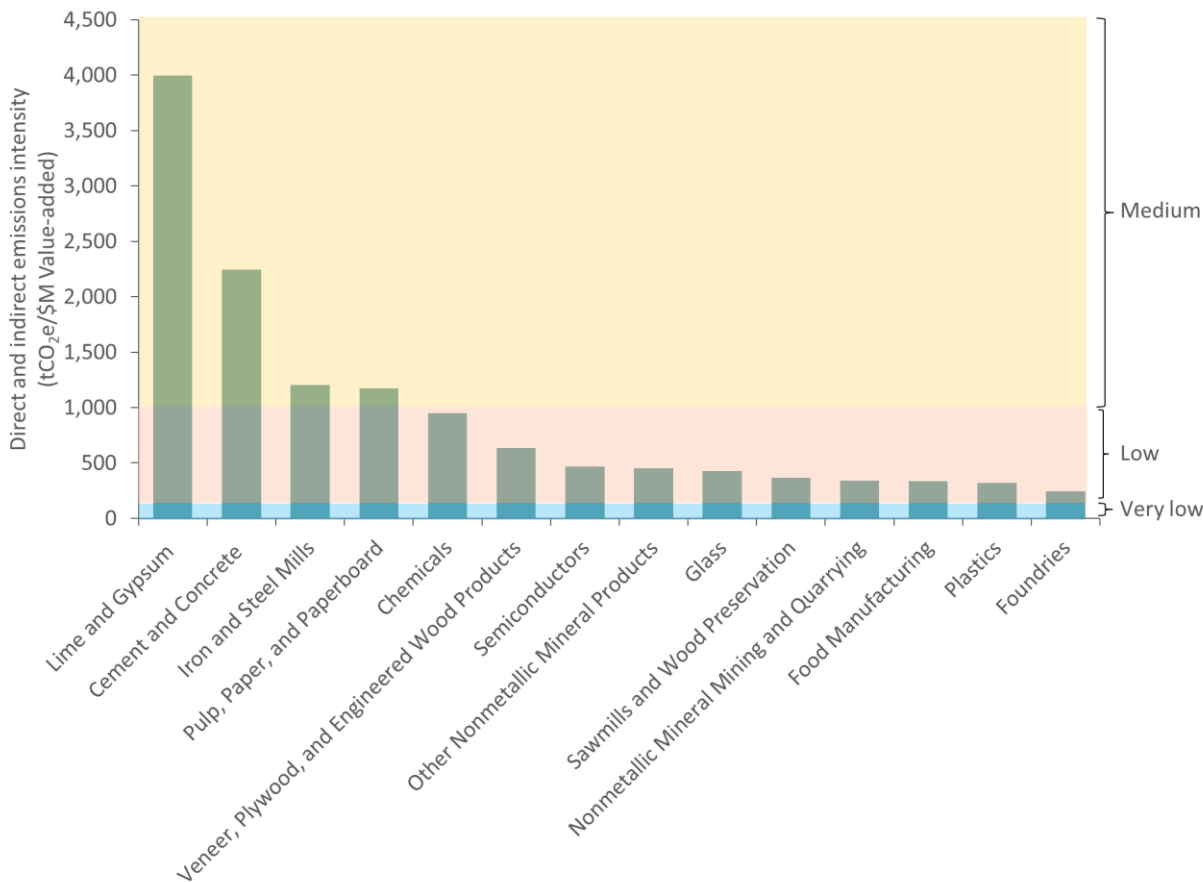
- No Oregon sectors would be considered highly emissions-intensive under the Californian method.
- Figure 11 shows that only lime and gypsum, cement and concrete, iron and steel, and pulp, paper and paperboard would be considered to have a medium emissions intensity under Californian thresholds.
- All other potentially covered Oregon sectors have an average emissions intensity that would be considered low under California's approach.
- No sectors would be considered to have a very low emissions intensity.

<sup>13</sup> The comparison with Californian thresholds is only indicative considering California's EITE identification is undertaken at the more disaggregated NAICS 6 industry level, and that the emissions factor for the electricity grid is higher in California relative to Oregon.





Figure 11. Oregon sectors’ direct and indirect emissions intensity relative to Californian categories



Notes: This figure plots Oregon sectors’ total (direct and indirect) emissions intensity against Californian thresholds. Californian thresholds, however, are only indicative of relative emissions intensity and are not being recommended as categorizations. Californian thresholds were developed specifically for California, taking into consideration the state’s higher electricity grid emissions factor and the higher level of disaggregation of their carbon leakage assessment.

Source: Vivid Economics

### 4.3 Qualitative Analysis Methodology

The qualitative analysis offers deeper insights on underlying risk. Box 5 details the European Commission’s approach to qualitative analysis of carbon leakage risk, which provides further guidance and an internationally applicable method for carrying out such an assessment. The intention is to provide a holistic picture of the drivers of leakage risk for each sector. In particular, such an analysis provides additional insight which is unavailable due to the data limitations in Oregon. The qualitative analysis takes place at the NAICS 4-digit level, but insights are tailored specifically to the facilities potentially covered under a carbon price within each sector.



**Box 5. The European Commission uses qualitative assessments to determine the carbon leakage risk status of sectors close to being identified by the quantitative assessment**

**Under the EU ETS Phase IV, sectors may also be identified as at risk of carbon leakage on the basis of a qualitative assessment using three criteria.**<sup>14</sup> In such circumstances, sectors can be deemed at risk of carbon leakage on the basis of a qualitative assessment and the following criteria (Council of the European Union, 2017):

- a) The extent to which it is possible for individual facilities in the sector or subsectors concerned to reduce emission levels or electricity consumption;
- b) Current and projected market characteristics, including any common reference price where relevant; and
- c) Profit margins as a potential indicator of long-run investment or relocation decisions, taking into account changes in costs of production relating to emission reductions.

**Sectors may be eligible under three circumstances for either the qualitative assessment or further quantitative assessment at a disaggregated level** (European Commission, 2018a):

- The qualitative assessment alone is available for sectors close to being identified by the quantitative assessment: if their quantitative indicator lies between 0.15 and 0.2;<sup>15</sup>
- The sector has an emissions intensity that exceeds 1.5; or
- The sector would receive free allocation calculated based on refineries benchmarks.

**In the EU ETS methodology, the qualitative argument for a sector's leakage risk status is put forward by the sector itself.** A sector eligible for a qualitative assessment must first confirm its NACE code and list all facilities covered under the EU ETS. Subsequently, the sector develops an argument as to why it should be considered at risk of carbon leakage, based on the three criteria described above. The sector must use its own reasoning and evidence and submit independently verified data to enable the Commission to carry out the assessment. The European Commission provides an analytical framework for each criterion as guidance for sectors submitting an application for qualitative assessment (European Commission, 2018a).

**In addition to emissions intensity and trade intensity, theoretical literature and international experience suggest there may be several additional indicators of relevance to leakage risk assessment that are harder to quantify:**

1. Domestic competition: competitive dynamics between Oregon facilities, and between Oregon facilities and facilities in other US states.
2. International competition: competitive dynamics between Oregon facilities and foreign facilities in export markets or from imports.
3. Profitability: profit margins of Oregon companies in the sector.
4. Emissions reduction opportunities: a set of feasible opportunities to lower emissions intensities.

<sup>14</sup> The same three qualitative criteria were used under Phase III to supplement the carbon leakage list; however, there was less of a clear quantitative boundary to determine sectors eligible to undertake a qualitative assessment.

<sup>15</sup> Based on 2014–16 data (Council of the European Union, 2017).



**The process developed for Oregon sectoral assessments incorporates best practices.** It consists of five steps to create sector briefs and a qualitative assessment of carbon leakage risk:

1. **Initial research:** Background research captured initial insights into potentially covered Oregon sectors. This incorporated summary data from the US Census Bureau, publicly available information on Oregon sectors and academic and gray literature on the sectors at large.
2. **Interviews:** Stakeholder interviews by teleconference covered key themes. They provided: an understanding of the sector's production processes and sources of emissions; available options to reduce emissions; competitive dynamics with other US states and international jurisdictions; and sectoral profitability. In-person meetings were held during the project workshop with stakeholders who requested follow-up.
3. **Workshop:** A workshop with stakeholders offered the opportunity to discuss the assessment methodology and key findings from other jurisdictions, as well as undertake in-person follow-up interviews with stakeholders who requested it.
4. **Sector briefs:** Initial stakeholder insights from interviews and the workshop were incorporated into sector briefs, with information verified through triangulation with academic and gray literature. Secondary literature provides an impartial picture of competitive trends in each sector, as well as the set of feasible emissions reduction opportunities. These sources include regional or global sectoral organizations such as Business Oregon, Global Cement, and the World Steel Manufacturers' Association, as well as academic and official studies on the feasibility of emissions reduction opportunities such as those carried out by the European Commission.
5. **Input and validation:** Stakeholders were given the opportunity to offer comments on sector briefs before their finalization. Further research was then undertaken to either verify or reject suggestions made by sector stakeholders.

The sector analyses are contained in Appendix 3.

#### 4.3.1 Domestic US competition

**The analysis of domestic US competition focusses on the competitive dynamics between Oregon producers, and between Oregon producers and producers in other US states.** Competition from international importers in Oregon is covered in the next section.

**The nature of competition between Oregon producers will affect facilities' exposure to carbon leakage.** Concentration ratios have been found to be influential in determining exposure to leakage. Carbon cost pass-through capacity in product prices will partially depend on the competitive nature of the relevant market. More competitive markets lead to higher rates of cost pass-through if all producers face the same cost increases (Reinaud, 2008). By contrast, if relationships with customers are based on long-term contractual agreements, this would be indicative of low cost pass-through since facilities are unable to adjust their prices as conditions change. Highly concentrated production in particular geographies could be another indicator of strong competition.

**The extent to which Oregon producers compete with producers in other US states without carbon pricing also impacts a sector's ability to pass through costs.** As discussed, if Oregon producers compete with producers in locations without carbon pricing, this gives rise to asymmetric carbon costs. This could disadvantage the competitiveness of Oregon producers, particularly if the nature of product markets constrain their ability to pass through costs to consumers. In Oregon, competition from producers in other



US states may be more acute than competition from producers in international jurisdictions. It is this sub-national context that makes the carbon leakage risk assessment inherently different for US states compared with assessments undertaken at the national level. Figure 12 illustrates that, in 2012, Oregon's manufacturing sectors' trade flows with other US states were at least double the value of their international trade flows.

**Figure 12. In 2012, Oregon's manufacturing sectors (NAICS 31–33) had significantly greater intra-US trade flows relative to international trade flows**



*Note:* Oregon international trade flows may be overestimated, as discussed in Section 4.1

*Source:* Vivid Economics

**To assess the nature of domestic competition in a sector, this analysis considers the following variables:**

- The location and extent of competitor producers within Oregon and in other US states; and
- The nature of relationships with customers, including contracts.

**These are proxies for the domestic competitive dynamics and hence the way in which domestic competition constrains or facilitates cost pass-through.** This analysis was supplemented by *ex post* evidence of the impacts of the EU ETS on the relevant sectors' range of cost pass-through rates (CE Delft & Oeko-Institut, 2015). While cost pass-through rates will depend on many factors which will likely be different between those observed in Europe and those in Oregon, especially market scope and competitive dynamics, the insights from this source are instructive as it presents one of the few examples of observed experiences of carbon cost pass-through capacity under a cap-and-trade.

#### 4.3.2 International competition

**Competition with facilities in international jurisdictions without carbon pricing mechanisms could result in significant loss of market share and profitability for Oregon facilities.** Many Oregon sectors trade to a significant extent with countries in Asia, North America, and Central and South America that do not have



carbon pricing mechanisms in place. The importance of these trading partners for each sector should therefore be considered separately.

**However, if a highly trade-exposed sector is trading mostly with countries under a carbon price, this could significantly reduce the risk of carbon leakage to that competitor.** It is important to note that the scope of this reduction depends critically on several factors, including:

- Whether the relevant sector in that jurisdiction is receiving cost containment measures such as free allowances, and if so, how many and on what basis;
- The eventual relative stringency of the carbon pricing mechanisms or the carbon price differential of that jurisdiction compared with Oregon;
- The nature and extent of key export market competitors. For example, leakage risk for Oregon sectors exporting to California would not be reduced if they compete in the Californian market with other international exporters without carbon pricing. This is discussed in more detail in Box 4 above.

**Trade exposure to California and/or the EU would reduce leakage risk; however, trade exposure to China suggests leakage risk in the short term at least.** California and the EU price carbon, which means that competitors in these jurisdictions face a marginal carbon cost, even though they provide free allocation to EITE sectors. This reduces asymmetries in carbon cost, which reduces leakage risk in the short and long run. However, trade exposure to jurisdictions that do not currently price industrial emissions, including most US states and China, implies leakage risk. China has launched a national cap-and-trade program and is expected to gradually increase its coverage over the years to eventually cover industrial sectors (ICAP, 2018),<sup>16</sup> reducing long-run leakage risk for those sectors planned for eventual coverage. However, policy uncertainty around mechanism design, coverage and timing mean that leakage risk remains, at least in the short run.

#### 4.3.3 Profitability and sector dynamics

**More profitable companies with positive sector dynamics will find it easier to absorb the cost increase associated with the introduction of a carbon price.** While a carbon price may incentivize long-run innovation (discussed in Section 2.3) and there is no evidence of large-scale competitiveness impacts (discussed in Section 3.2.2), it will increase compliance costs for emissions-intensive industries with few low-cost emissions reduction opportunities. If a sector has not been profitable in recent years, the introduction of a carbon price could negatively impact industry and, by extension, the Oregon economy. Sector profitability is a key consideration in the qualitative assessment of carbon leakage risk used in Phases III and IV of the EU ETS for sectors at the margin of the leakage risk metrics. This analysis also observes recent market trends and market outlooks, particularly in terms of production and employment. This provides an indication of the likely robustness of a sector and consequently its ability to absorb carbon costs.

**A lack of data for smaller companies relative to large, publicly listed enterprises in Oregon represents a challenge for the profitability analysis.** Whether information on the profitability of the sectors is available is often dependent on the nature of competition in the sector; larger companies with high market share, and a stock market listing, are more likely to publicly report granular information on profitability. Since, on balance, these are more likely to be profitable, their publicly reported financial performance may not be indicative of smaller companies' profitability. Additionally, if a sector comprises mostly small companies, there may not

<sup>16</sup> The industrial sectors to be covered are petrochemicals, chemicals, building materials, steel, nonferrous metals, paper, and aviation (ICAP, 2018).



be any information on profitability. As a result, this analysis was carried out only for those sectors for which meaningful statements on profitability could be made given available information.

#### 4.3.4 Emissions reduction opportunities

**The availability and cost of emissions reduction opportunities will influence the impact of carbon pricing on investment decisions and leakage.** If a facility can reduce emissions at low cost it will be able to cost-effectively reduce the carbon cost increase it faces, reducing the risk of leakage. Following this logic, a lack of emissions reduction opportunities is sometimes argued to lead to loss of market share and therefore warrant preferential policy treatment (Okereke & McDaniels, 2012). Availability of emissions reduction options depends on a variety of factors, such as the time required to develop less carbon-intensive technologies, and the stringency and credibility of the carbon price signal in the context of the cost of the emissions reduction option. Technically feasible emissions reduction opportunities are those for which the technology is proven and exists. Economically feasible opportunities are those that are both technically feasible and make economic sense to implement given capital requirements and return on investment. Ideally, the introduction of a carbon price will increase the availability of economically feasible emissions reduction opportunities by increasing the returns of avoided emissions.

**This analysis compares the relative emissions intensity of the Oregon sectors using stakeholder interviews and secondary literature in order to evaluate the significance of available emissions reduction opportunities.** In practice, whether facilities in an Oregon sector have a significant set of feasible emissions reduction opportunities available to them may be difficult to establish in the absence of detailed data on implemented emission reduction options. However, direct stakeholder interviews, secondary literature on best practices, and comparisons of the emissions intensity of sectors in Oregon relative to other jurisdictions can provide an indication of the scale of emissions reductions options available.

## 4.4 Qualitative Analysis Results

**This section presents the qualitative sectoral carbon leakage risk assessments for potentially covered Oregon sectors.** Sections 4.4.1 to 4.4.12 provide more detailed conclusions of the carbon leakage risk assessments for each of the potentially covered sectors. These conclusions are drawn from the 12 sector briefs, which can be found in Appendix 3.

**Results of the analysis show that all potentially covered Oregon sectors are at risk or likely at risk of carbon leakage.** The findings suggest that 11 of 14 sectors are at risk of carbon leakage if Oregon introduces a carbon price without measures to secure competitiveness. The remaining three sectors are also likely at risk:

- cement and concrete; food manufacturing; glass; iron and steel; foundries; non-metallic mineral mining and quarrying; other non-metallic mineral products; pulp, paper and paperboard; semiconductors; and veneer, plywood and engineered wood products; and sawmills.
- Chemicals, lime and gypsum, and plastics sectors are likely at risk, but further research is necessary to ascertain the nature and extent of risk.

The results are detailed in the following sections.



#### 4.4.1 Cement

**Other jurisdictions have identified their cement sectors as at risk of carbon leakage.** Analysis of the cement sector in different jurisdictions produced the following results:

- EU ETS Phase III metric: European cement sector identified based on the cost increase metric;
- EU ETS Phase IV metric: European cement sector identified;
- California metric: Californian cement sector identified to exhibit “high” leakage risk based on high emissions intensity.

*Table 9. Treatment of the cement sector in external jurisdictions*

Metric	EU ETS Phase III				EU ETS Phase IV	California		
	Trade intensity	Cost increase	Joint metric	Identified	Identified	Trade intensity	Emissions intensity	Level of risk
Initial assessment	No	Yes	Yes	Yes	Yes	Medium	High	High

*Note:* This table shows how external jurisdictions classified their own particular sector. The identification and classification process has been developed specifically for these jurisdictions and their sectors. It serves as an indication of whether sectors in Oregon are at risk. Furthermore, there are differences in sector scope between jurisdictions which also limits the predictive power of leakage risk in Oregon.

*Source:* Vivid Economics

**There are several factors that suggest the cement and concrete manufacturing sector in Oregon is EITE:**

- The sector’s emissions intensity is one of the highest in the state;
- The sector’s cost pass-through capacity may be limited due to a growth in competition from Chinese manufacturers;<sup>17</sup>
- Most emissions are process emissions inherent to the production of clinker that are technically very challenging to abate;
- Precedent from the EU and California suggests that the sector may be at risk of leakage.

**However, there are several factors which reduce underlying carbon leakage risk:**

- The sector has seen robust demand growth in recent years, with consumption rising by almost 50% during 2012–16, although still below the peak levels experienced before the financial crisis;
- US domestic competition from states further away from Oregon may be limited due to road transport cost constraints within the sector;
- Emissions intensities may be higher than European benchmark levels, indicating the technical potential for efficiency improvements;
- Chinese competition will become less of a concern as China’s national cap-and-trade begins imposing compliance obligations and gradually expands its coverage to industrial sectors;

<sup>17</sup> This will become less of a concern as China’s national cap-and-trade begins imposing compliance obligations and gradually expands its coverage to industrial sectors. However, timing and mechanics of China’s expanded cap-and-trade system are unclear at this time.



- Some evidence from the EU suggests that cement producers may have high carbon cost pass-through capacity.<sup>18</sup>

**On balance, the sector is at risk of carbon leakage if Oregon introduces a carbon price without measures to protect against possible adverse competitiveness impacts.** A carbon pricing instrument for this sector should be designed to ensure that innovation and emissions reduction incentives remain, while also incorporating measures to protect against the risk of carbon leakage and other competitiveness impacts.

#### 4.4.2 Chemicals

**The chemicals manufacturing sector has been identified as at risk of leakage in other jurisdictions:**

- EU ETS Phase III metric: European chemicals sector identified based on the trade intensity metric;
- EU ETS Phase IV metric: European chemicals sector identified;
- California metric: Californian chemicals sector identified to exhibit “high” leakage risk based on high trade intensity.

*Table 10. Treatment of the chemicals sector in external jurisdictions*

Metric	EU ETS Phase III				EU ETS Phase IV	California		
	Trade intensity	Cost increase	Joint metric	Identified	Identified	Trade intensity	Emissions intensity	Level of risk
Initial assessment	Yes	No	Yes	Yes	Yes	High	Medium	High

*Note:* This table shows how external jurisdictions classified their own particular sector. The identification and classification process has been developed specifically for these jurisdictions and their sectors. It serves as an indication of whether sectors in Oregon are at risk. Furthermore, there are differences in sector scope between jurisdictions which also limits the predictive power of leakage risk in Oregon.

*Source:* Vivid Economics

**There are several factors that suggest that the Oregon basic chemicals manufacturing sector is at risk of carbon leakage:**

- The sector is relatively emissions-intensive and has few emissions reduction opportunities for the near future, especially with respect to process emissions;
- The sector competes externally with other US states and other countries. Some of these external jurisdictions are not subject to a carbon price, which limits the sector’s ability to pass through costs;
- The facilities potentially covered are part of larger companies with facilities in states with no carbon price, where production relocation could occur;
- Precedent from the EU and California suggests the sector may be at risk.

<sup>18</sup> While cost pass-through rates will depend on many factors which will likely be different between those observed in Europe and those in Oregon, especially market scope and competitive dynamics, this data point is instructive as it presents one of the few examples of observed experiences of carbon cost pass-through capacity under a cap-and-trade.





**However, two factors reduce underlying leakage risk.**

- There is likely to be energy efficiency options available to reduce emissions. Facilities can optimize their equipment and processes and implement heat recovery systems to improve efficiency and lower the carbon cost faced;
- Evidence from Europe suggests fertilizer producers may have high cost pass-through capacity.

**The sector is likely at risk of carbon leakage if Oregon introduces a carbon price without measures to protect against possible adverse competitiveness impacts; however, further research is required to understand these risk factors more conclusively.** A carbon pricing instrument for this sector should be designed to ensure that innovation and emissions reduction incentives remain, while also incorporating measures to protect against the risk of carbon leakage and other competitiveness impacts. Further research is necessary to understand the nature and extent of these risks.

**4.4.3 Food Manufacturing**

**The facilities potentially covered under a carbon price in the Oregon food manufacturing sector all involve potato processing.** As such, the assessment of carbon leakage for the food manufacturing sector focusses on potato processing in Oregon.

**In the EU ETS Phase III, potato processing facilities are identified as at risk of carbon leakage based on the joint criteria, and in Phase IV they qualify for assessment at a disaggregated level; California identified the food processing sector as a whole at medium risk of carbon leakage:**

- EU ETS Phase III metric: the European potato processing sector was identified as at risk of carbon leakage at the 8-digit level and received free allocation support;
- EU ETS Phase IV metric: as the European potato processing sector was determined as at risk of carbon leakage at the 8-digit level during Phase III, under the Phase IV methodology, the sector qualifies for a second-level assessment of its carbon leakage risk at a disaggregated level;
- California metric: the Californian food manufacturing sector as a whole is identified as at medium risk of carbon leakage. It had a medium trade intensity (12%) and a low emissions intensity (608 tCO<sub>2</sub>e/\$M value added), leading to an overall categorization of medium carbon leakage risk. However, recent legislation requires this leakage risk category to receive the same level of support as all other categories on the carbon leakage list (100% of the output-based benchmark allocation level). Importantly, the Californian sector has a number of higher-margin and -value fruit and vegetable products that generally are not grown or produced in other places in the US. The Californian sector does not include frozen potato processing which is conducted in numerous other jurisdictions.



Table 11. Treatment of the food manufacturing sector in external jurisdictions

Sectors	Metric	EU ETS Phase III				EU ETS Phase IV	California		
		Trade intensity	Cost increase	Joint metric	Identified	Identified	Trade intensity	Emissions intensity	Level of risk
Frozen potatoes, prepared, or preserved	Initial assessment	No	No	Yes	Yes	Qualifies for quantitative assessment at a disaggregated level*			
Food manufacturing	Initial assessment						Medium	Low	Medium

Note: \* Under the EU ETS Phase IV, sectors that are listed in the EU ETS 2015–20 carbon leakage list at a 6-digit or 8-digit level qualify for a second-level quantitative assessment at a more disaggregated level (Criteria D). Phase III of the EU ETS finds the aggregated sector of food manufacturing to not be at risk of carbon leakage, but does identify the subsector of frozen potatoes, prepared, or preserved as at risk. California undertakes its carbon leakage assessment at a higher level of sectoral aggregation for this sector.

This table shows how external jurisdictions classified their own particular sector. The identification and classification process has been developed specifically for these jurisdictions and their sectors. It serves as an indication of whether sectors in Oregon are at risk. Furthermore, there are differences in sector scope between jurisdictions, which also limits the predictive power of leakage risk in Oregon.

Source: Vivid Economics

### There are several factors that suggest this Oregon sector is EITE:

- While the sector’s carbon cost relative to its value added is low, carbon costs fall solely on potato processing facilities which may have limited potential for further emissions reductions;
- The ability for potato processing facilities to pass through costs without losing market share is also likely inhibited by the existence of significant competitive pressures from other US states and international competitors. Leakage to sister plants in Idaho and Washington is also a risk; and
- Precedent from the EU and California suggests that the sector may be at risk of leakage.

### However, several factors reduce underlying carbon leakage risk:

- Emissions reduction opportunities may exist in terms of fuel-switching and energy efficiency;
- International competitors are largely European producers which also face a carbon cost compliance regulation, suggesting that asymmetric carbon pricing may not present competitiveness challenges in the long term; and
- Recent employment, value added and investments planned suggest the sector is operating in a positive market environment and may be able to pass through some carbon costs without significant loss of market share.

**On balance, the sector is at risk of carbon leakage if Oregon introduces a carbon price without measures to protect against possible adverse competitiveness impacts.** A carbon pricing instrument for this sector should be designed to ensure that innovation and emissions reduction incentives remain, while also incorporating measures to protect against the risk of carbon leakage and other competitiveness impacts.



#### 4.4.4 Glass

##### Three key international carbon leakage identification metrics put the glass sector at risk of carbon leakage.

Analysis of the glass sector in other jurisdictions produced the following results:

- EU ETS Phase III metric: the European hollow glass manufacturing sector was identified based on the trade intensity metric;
- EU ETS Phase IV metric: the European hollow glass manufacturing sector was identified; and
- California metric: the Californian container glass sector was identified as exhibiting “high” leakage risk based on high trade intensity and medium emissions intensity.

*Table 12. Treatment of the glass sector in external jurisdictions*

Sector	Metric	EU ETS Phase III				EU ETS Phase IV	California		
		Trade intensity	Cost increase	Joint Metric	Identified	Identified	Trade intensity	Emissions intensity	Level of risk
Container glass	Initial Assessment	Yes	No	No	Yes	Yes	High	Medium	High

*Note:* Container glass in the EU is identified by NACE 23.13, manufacture of hollow glass. This table shows how external jurisdictions classified their own particular sector. The identification and classification process has been developed specifically for these jurisdictions and their sectors. It serves as an indication of whether sectors in Oregon are at risk. Furthermore, there are differences in sector scope between jurisdictions, which also limits the predictive power of leakage risk in Oregon.

*Source:* Vivid Economics

##### There are several factors that suggest the glass and glass product manufacturing sector in Oregon is EITE:

- The sector faces competition from other US states and countries without carbon pricing and may thus have limited cost pass-through capacity;
- The substitutability of glass container products exposes producers in the sector to competition from other types of packaging manufacturers, further reducing cost pass-through capacity;
- *Ex post* evidence from the EU shows the glass sector may have low cost pass-through capacity; and
- Precedent from the EU and California suggests the sector may be at risk of leakage.

##### However, the sector has relatively low emissions intensity and may have additional emissions reduction opportunities, which reduce the underlying carbon leakage risk:

- The emissions intensity of the sector is low relative both to other Oregon sectors and to California thresholds; and
- While the sector already uses a significant proportion of cullet in the production process and relatively efficient furnaces,<sup>19</sup> there may be further scope for emissions reduction through higher cullet usage, utilizing waste heat recovery and implementing other efficiency measures.

<sup>19</sup> Cullet is waste glass that is used in glass manufacturing. Its use reduces the emissions intensity of glass production.



**On balance, the sector is at risk of carbon leakage if Oregon introduces a carbon price without measures to protect against possible adverse competitiveness impacts.** A carbon pricing instrument for this sector should be designed to ensure that innovation and emissions reduction incentives remain, while also incorporating measures to protect against the risk of carbon leakage and other competitiveness impacts.

#### 4.4.5 Iron and Steel, and Foundries

**Several other jurisdictions identify their metals manufacturing subsectors as at risk of carbon leakage.**

Analysis of the metals sector in other jurisdictions produced the following results:

- EU ETS Phase III metric: the European metals subsectors were identified based on the trade intensity metric;
- EU ETS Phase IV metric: the European metals subsectors were identified;
- California metric: the Californian metals subsectors were identified as exhibiting “high” leakage risk based on high trade intensity.

*Table 13. Treatment of the metals sector in external jurisdictions*

Sector	Metric	EU ETS Phase III				EU ETS Phase IV	California		
		Trade intensity	Cost increase	Joint metric	Identified	Identified	Trade intensity	Emissions intensity	Level of risk
Metals sector	Initial assessment	Yes	No	Yes	Yes	Yes	High	Medium	High

*Note:* This table shows how external jurisdictions classified their own particular sector. The identification and classification process has been developed specifically for these jurisdictions and their sectors. It serves as an indication of whether sectors in Oregon are at risk. Furthermore, there are differences in sector scope between jurisdictions, which also limits the predictive power of leakage risk in Oregon.

*Source:* Vivid Economics

**There are several factors that suggest the Oregon iron and steel subsector is at risk of carbon leakage:**

- It is emissions-intensive with few opportunities for further emissions reductions;
- There may be limited ability for the subsector to pass through costs due to strong domestic and international competition, although some competitors are located in the EU where there is a carbon price;
- Precedent from the EU and California suggests that the sector may be at risk of leakage.

**However, there are other factors which reduce underlying leakage risk:**

- An EU study looking at the cost pass-through ability of flat steel products determined that some products had the capacity to pass through 55–100% of carbon costs, although further research is required on whether this would be the case for Oregon producers.
- Profit margins have improved in recent years, suggesting the sector is operating in a positive economic environment, although the cyclical nature of the steel industry implies this may not be indicative of long-term profitability.



**While the foundries subsector may be at risk of leakage, recent data suggests facilities in the sector may not be covered under the carbon price.** The sector has relatively low emissions intensity, suggesting carbon cost increase risk is low. However, both national and international competition faced by the foundries sector could result in the facility having relatively low capacity to pass through its carbon costs without facing significant competitiveness impacts. That said, the Oregon foundry, which was above the carbon pricing threshold in 2014, did not breach it in 2015 or 2016, and thus may not face a carbon price under the proposed regulations.

**However, the risk of threshold impacts may apply to this foundry and lead to leakage.** There is a risk that the facility may maintain production below the threshold in order to avoid compliance costs. If demand for avoided production is met by external competitors with higher emissions intensities, this implies carbon leakage. The risk is acute for this foundry given it operates sister plants in Nevada and Utah – states without carbon pricing – and so could relatively easily expand production, or investment, in those facilities.

**On balance, the sector is at risk of carbon leakage if Oregon introduces a carbon price without measures to protect against possible adverse competitiveness impacts.** A carbon pricing instrument for this sector should be designed to ensure that innovation and emissions reduction incentives remain, while also incorporating measures to protect against the risk of carbon leakage and other competitiveness impacts.

#### 4.4.6 Lime and Gypsum

**The gypsum manufacturing sector is commonly identified as an at-risk sector in other jurisdictions, as illustrated in Table 14:**

- EU ETS Phase III metric: the European lime and plaster sector was identified based on the trade intensity metric;
- EU ETS Phase IV metric: the European lime and plaster sector was identified;
- California metric: the Californian gypsum product manufacturing sector was identified as at medium risk of carbon leakage based on low trade intensity and medium emissions. However, recent legislation requires this leakage risk category to receive the same level of support as all other categories on the carbon leakage list (100% of the output-based benchmark allocation level).



Table 14. Treatment of the lime and gypsum sector in external jurisdictions

Sector	Metric	EU ETS Phase III				EU ETS Phase IV	California		
		Trade intensity	Cost increase	Joint metric	Identified	Identified	Trade intensity	Emissions intensity	Level of risk
Gypsum products	Initial assessment	Yes	No	No	Yes	Yes	Low	Medium	Medium

*Note:* Gypsum products in the EU are covered in NACE 23.52, manufacture of lime and plaster. This table shows how external jurisdictions classified their own particular sector. The identification and classification process has been developed specifically for these jurisdictions and their sectors. It serves as an indication of whether sectors in Oregon are at risk. Furthermore, there are differences in sector scope between jurisdictions which also limits the predictive power of leakage risk in Oregon.

*Source:* Vivid Economics

#### There are several factors that suggest that the Oregon sector may be EITE:

- The sector has the highest emissions intensity in Oregon;
- Precedent from the EU and California suggests the sector may be at risk of leakage;
- There may little ability for the sector to pass through costs, but further research is required to identify competition.

**However, one factor does reduce the underlying risk of carbon leakage:** the sector may have emission reduction opportunities, although further research is required in this area.

**The sector is likely at risk of carbon leakage if Oregon introduces a carbon price without measures to protect against possible adverse competitiveness impacts; however, further research is required to understand these risk factors more conclusively.** A carbon pricing instrument for this sector should be designed to ensure that innovation and emissions reduction incentives remain, while also incorporating measures to protect against the risk of carbon leakage and other competitiveness impacts. However, further research is required to understand the nature and extent of these risks.

#### 4.4.7 Non-metallic Mineral Mining and Quarrying

**Diatomaceous earth (DE) producers are identified as at risk of carbon leakage in the EU and in California (although not initially), as illustrated in Table 15:**

- EU ETS Phase III metric: the European other mining and quarrying sector was identified based on a trade intensity metric of close to 173%;<sup>20</sup>
- EU ETS Phase IV metric: the European other mining and quarrying sector was identified (again, due to a very high trade intensity);
- California metric: the Californian DE mining facilities were not initially classified in the leakage analysis due to a lack of information (CARB, 2010b). The subsector (DE mining in particular) was then determined to be at high risk of carbon leakage in subsequent iterations of the cap-and-trade regulation, without detail on the individual EITE metrics (CARB, 2011a).

<sup>20</sup> Other mining and quarrying in the EU includes mining activities relating to diatomite beds.



**Table 15. Treatment of the non-metallic mineral mining and quarrying sector in external jurisdictions**

Sector	Metric	EU ETS Phase III				EU ETS Phase IV	California		
		Trade intensity	Cost increase	Joint metric	Identified	Identified	Trade intensity	Emissions intensity	Level of risk
All Other Non-metallic Mineral Mining	Initial assessment	Yes	No	No	Yes	Yes	-	-	High

*Note:* Other non-metallic mineral mining covered in the EU by NACE 08.99, other mining and quarrying n.e.c. This table shows how external jurisdictions classified their own particular sector. The identification and classification process has been developed specifically for these jurisdictions and their sectors. It serves as an indication of whether sectors in Oregon are at risk. Furthermore, there are differences in sector scope between jurisdictions, which also limits the predictive power of leakage risk in Oregon.

*Source:* Vivid Economics

#### **There are several factors that suggest that the non-metallic mineral mining subsector is EITE in Oregon:**

- The nature of the product and pricing environment suggest a limited cost pass-through capacity;
- The subsector has implemented a range of measures to reduce emissions;
- Precedent from the EU and California suggests the subsector may be at risk of leakage;
- The owners of the Oregon covered facility also own a very similar ore resource, mine and manufacturing in plant in Nevada where production could be relocated.

#### **However, several factors reduce the underlying risk of carbon leakage:**

- Emissions intensity is relatively low, suggesting a carbon price will represent a relatively low-cost burden;
- Competition from external locations is concentrated in jurisdictions with, or considering implementing, carbon prices, suggesting that asymmetric carbon pricing may not present competitiveness challenges in the long term;
- The location of facilities is primarily dictated by the location of resources, which reduces the number of feasible locations that reflect relocation risk.

**On balance, the sector is at risk of carbon leakage if Oregon introduces a carbon price without measures to protect against possible adverse competitiveness impacts.** A carbon pricing instrument for this sector should be designed to ensure that innovation and emissions reduction incentives remain, while also incorporating measures to protect against the risk of carbon leakage and other competitiveness impacts.

#### **4.4.8 Other Non-metallic Mineral Products**

**The glass fiber manufacturing sector is commonly identified as an at-risk sector in other jurisdictions, as illustrated in Table 16:**

- EU ETS Phase III metric: the European glass fiber manufacturing sector was identified based on the trade intensity and joint metrics;
- EU ETS Phase IV: the European glass fiber manufacturing sector was identified;
- California metric: the Californian mineral wool manufacturing sector was identified as at “medium” risk of leakage based on medium trade intensity and emissions intensity. However, recent legislation requires this leakage risk category to receive the same level of support as all other categories on the carbon leakage list (100% of the output-based benchmark allocation level).



Table 16. Treatment of the “other non-metallic mineral products” sector in external jurisdictions

Sector	Metric	EU ETS Phase III				EU ETS Phase IV	California		
		Trade intensity	Cost increase	Joint metric	Identified	Identified	Trade intensity	Emissions intensity	Level of risk
Mineral Wool Manufacturing	Initial assessment	Yes	No	Yes	Yes	Yes	Medium	Medium	Medium

*Note:* Mineral wool manufacturing covered in the EU by NACE 23.14, manufacture of glass fibers. This table shows how external jurisdictions classified their own particular sector. The identification and classification process has been developed specifically for these jurisdictions and their sectors. It serves as an indication of whether sectors in Oregon are at risk. Furthermore, there are differences in sector scope between jurisdictions, which also limits the predictive power of leakage risk in Oregon.

*Source:* Vivid Economics

### Several factors suggest the facility covered within the non-metallic mineral product subsector is EITE in Oregon:

- The sector’s emissions intensity is near the median value for all covered sectors in Oregon;
- Emissions reduction opportunities for the covered facility may be limited due to requirements on product specifications;
- Precedent from the EU and California suggests the subsector may be at risk of leakage;
- Evidence from the EU suggests cost pass-through capacity is low;
- The potentially covered facility competes in US and international markets against facilities located in jurisdictions without carbon pricing.

### However, several factors reduce underlying carbon leakage risk:

- Further research is required to determine if there are opportunities for emissions reductions;
- Many products within the sector are highly engineered, suggesting scope for product differentiation, which in turn offers greater scope for cost pass-through.

**On balance, the sector is at risk of carbon leakage if Oregon introduces a carbon price without measures to protect against possible adverse competitiveness impacts.** A carbon pricing instrument for this sector should be designed to ensure that innovation and emissions reduction incentives remain, while also incorporating measures to protect against the risk of carbon leakage and other competitiveness impacts.

#### 4.4.9 Plastics

**Three key international carbon leakage identification metrics put the plastics sector at risk of carbon leakage.** Analysis of the plastics sector in other jurisdictions produced the following results:

- EU ETS Phase III metric: the European plastics product manufacturing sector was identified based on the trade intensity metric;
- EU ETS Phase IV metric: the European plastics product manufacturing sector was identified;
- California metric: the Californian polystyrene foam product manufacturing sector was identified as “medium” leakage risk based on medium trade intensity, but low emissions intensity. There are no battery separator manufacturers operating in California.





Table 17. Treatment of the plastics sector in external jurisdictions

Sectors	Metric	EU ETS Phase III				EU ETS Phase IV	California		
		Trade intensity	Cost increase	Joint metric	Identified	Identified	Trade intensity	Emissions intensity	Level of risk
Manufacture of plastics in primary forms	Initial assessment	Yes	No	No	Yes	Yes			
Polystyrene Foam Product Manufacturing	Initial assessment						Medium	Low	Medium

*Note:* The EU identified the plastics sector at the level of the manufacture of plastics in primary forms, NACE 20.16, which contains polystyrene foam manufacturing. This table shows how external jurisdictions classified their own particular sector. The identification and classification process has been developed specifically for these jurisdictions and their sectors. It serves as an indication of whether sectors in Oregon are at risk. Furthermore, there are differences in sector scope between jurisdictions, which also limits the predictive power of leakage risk in Oregon.

*Source:* Vivid Economics

#### The high degree of trade exposure increases the Oregon plastics sector's risk of carbon leakage:

- The battery separator market is largely global and Oregon's plastics producers are facing increasing competition from producers in Asian countries as well as existing competition from domestic producers. The polystyrene foam manufacturing sector may face significant external competition from other US states, although further research is required in this regard.
- Precedent from the EU and California suggests the plastics sector may be at risk of carbon leakage.

#### However, there are several factors which reduce underlying carbon leakage risk:

- There may be scope for product differentiation, reducing consumers' price sensitivity;
- The sector as a whole has a relatively low emissions intensity and may have additional opportunities to undertake emission reductions, particularly in terms of energy efficiency, albeit that some entities have already invested significantly in equipment upgrades and replacement.

**The sector is likely at risk of carbon leakage if Oregon introduces a carbon price without measures to protect against possible adverse competitiveness impacts; however, further research is required to understand these risk factors more conclusively.** A carbon pricing instrument for this sector should be designed to ensure that innovation and emissions reduction incentives remain, while also incorporating measures to protect against the risk of carbon leakage and other competitiveness impacts. Further research is necessary to understand the nature and extent of these risks.

#### 4.4.10 Pulp, Paper, and Paperboard

**The paper manufacturing sector is commonly identified as an at-risk sector in other jurisdictions, as illustrated in Table 18:**

- EU ETS Phase III metric: the European pulp and paper sector was identified based on the trade intensity metric;
- EU ETS Phase IV metric: the European pulp and paper sector was identified;



- California metric: the Californian pulp and paper sector identified the sector as “high” leakage risk based on high trade intensity and medium emissions intensity.

*Table 18. Treatment of the pulp, paper and paperboard sector in external jurisdictions*

Metric	EU ETS Phase III				EU ETS Phase IV	California		
	Trade intensity	Cost increase	Joint metric	Identified	Identified	Trade intensity	Emissions intensity	Level of risk
Initial assessment	Yes	No	Yes	Yes	Yes	High	Medium	High

*Note:* This table shows how external jurisdictions classified their own particular sector. The identification and classification process has been developed specifically for these jurisdictions and their sectors. It serves as an indication of whether sectors in Oregon are at risk. Furthermore, there are differences in sector scope between jurisdictions, which also limits the predictive power of leakage risk in Oregon.

*Source:* Vivid Economics

#### **There are several factors that suggest the pulp and paper industry should be designated as EITE:**

- The sector is relatively emissions-intensive in Oregon, and would have a “medium” emissions intensity classification under California’s methodology;
- There may be limited ability to pass through carbon costs as the sector mainly competes with other US domestic producers on the basis of price and, with the exception of California, other US states do not price these carbon emissions;
- Evidence of decreasing production and value added over recent years, combined with mill closures, suggests the sector faces competitiveness challenges;
- Precedent in other jurisdictions suggests the sector may be at risk of leakage.

#### **Several factors reduce underlying carbon leakage risk:**

- The subsector in the region may have significant energy savings potential and facilities could make use of BAT to improve efficiency;
- The sector’s use of biomass is lower than the national average, suggesting its uptake is prevented by relative cost considerations and regulatory constraints rather than technical barriers;
- Exposure to Chinese competition for waste paper as a raw material may be decreasing, although there is a risk it could quickly change its policies on imports of collected waste paper.<sup>21</sup>

**On balance, the sector is at risk of carbon leakage if Oregon introduces a carbon price without measures to protect against possible adverse competitiveness impacts.** A carbon pricing instrument for this sector should be designed to ensure that innovation and emissions reduction incentives remain, while also incorporating measures to protect against the risk of carbon leakage and other competitiveness impacts.

#### **4.4.11 Semiconductors**

**Some jurisdictions have identified the semiconductor and other electronic component sector as at risk of carbon leakage, while others regulate it separately:**

<sup>21</sup> Competition with China in general will become less of a concern as China’s national cap-and-trade begins imposing compliance obligations and gradually expands its coverage to industrial sectors. The details of the timing and mechanism to be used in China remains uncertain.



- EU ETS Phase III metric: European electronic components manufacturers, which include semiconductors, have been identified as EITE based on their exposure to trade with external jurisdictions;
- EU ETS Phase IV metric: the European sector did not qualify for EITE support based on the quantitative analysis, but it is eligible for qualitative assessment, of which the result will be known in 2019;
- California metric: the Californian sector is regulated separately from the cap-and-trade, CARB implemented the Regulation to Reduce Greenhouse Gas Emissions for Semiconductor Operations which aims to reduce F-gases from the sector. The regulation requires all facilities to abide by reporting guidelines and applies emission standards to operations that emit more than 800 tCO<sub>2</sub>e annually (CARB, 2018). The emissions standard ranges from 0.2 – 0.5 kgCO<sub>2</sub>e/cm<sup>2</sup> depending on the annual wafer surface area processed at the facility (CARB, 2009).

*Table 19. Treatment of the semiconductor and other electronic components sector in external jurisdictions*

Sectors	Metric	EU ETS Phase III				EU ETS Phase IV	California		
		Trade intensity	Cost increase	Joint Metric	Identified	Identified	Trade intensity	Emissions intensity	Level of risk
Manufacture of Electronic Components	Initial assessment	Yes	No	No	Yes	Qualifies for qualitative assessment as indicator > 0.15	Semiconductor manufacturers regulated separately		

*Note:* This table shows how external jurisdictions classified their own particular sector. The identification and classification process has been developed specifically for these jurisdictions and their sectors. It serves as an indication of whether sectors in Oregon are at risk. Furthermore, there are differences in sector scope between jurisdictions, which also limits the predictive power of leakage risk in Oregon.

*Source:* Vivid Economics

### **There are several factors that suggest the semiconductors and other electronic components subsector should be designated as EITE in Oregon:**

- Emissions reduction options for the sector may be limited due to the non-substitutability of F-gases and widespread uptake of energy efficiency options. Indeed, given F-gases are relatively expensive and are used as an input, facilities are already incentivized to minimize their use.
- Competition is strong both domestically and internationally, especially in jurisdictions without carbon pricing, limiting the sector's ability to pass through carbon costs without losing long-term market share.
- The rate of change of technology in the sector suggests that the risk of leakage through the investment channel could be high, especially within companies with plants in multiple jurisdictions. This risk remains even for companies with plants in Europe: the carbon pricing system there does not cover F-gases. It is also possible for fabrication plants to outsource parts of the production process.



**However, several factors reduce underlying carbon leakage risk:**

- The sector's emissions intensity is moderate to low relative to other Oregon sectors;
- Some facilities in the sector enjoy relatively high profit margins which reduces relocation risk;<sup>22</sup>
- Evidence from other jurisdictions suggests that emissions benchmarking could raise technical efficiency in the sector, although further research is required on this in Oregon's context.

**On balance, the sector is at risk of carbon leakage if Oregon introduces a carbon price without measures to protect against possible adverse competitiveness impacts.** A carbon pricing instrument for this sector should be designed to ensure that innovation and emissions reduction incentives remain, while also incorporating measures to protect against the risk of carbon leakage and other competitiveness impacts.

**4.4.12 Wood Products and Sawmills****Other jurisdictions have identified engineered wood product manufacturers, such as reconstituted wood products, and veneer and plywood manufacturers at risk of carbon leakage:**

- EU ETS Phase III metric: the European sector was not identified as EITE;
- EU ETS Phase IV metric: following a change in methodology from Phase III, the European sector was identified as at risk of carbon leakage;
- California metric: the Californian reconstituted wood product manufacturing sectors were identified as highly at risk of carbon leakage, with a medium emissions intensity and a high trade exposure.

**The sawmills sector is not always identified as at risk of carbon leakage:**

- EU ETS Phase III and Phase IV metric: the European sector falls below the quantitative thresholds, which means that the sector does not receive full benchmark allocation for free, but rather an annually declining portion (in 2018, this portion was 44.29% of the benchmark level);
- California metric: the Californian sector is deemed to be at medium risk of carbon leakage. While this sector is determined to be only at medium risk, amendments to the cap-and-trade regulations will ensure this sector will receive the same level of support as all other sectors on the carbon leakage list (100% of the output-based benchmark allocation level).

<sup>22</sup> Margins are a key indicator of long-run investment or relocation decisions and, as such, the EU uses profitability as one of three criteria to assess leakage risk under its qualitative assessment: "If profit margins are positive, high and sustained in the domestic market, that increases the incentive to invest in the domestic market and reduces the incentive to relocate. In contrast, if profit margins are continually low or negative, the cost of complying with the ETS is a sizeable share of profit margins, and/or profit margins are higher in third countries outside of the ETS, the incentive to invest in the domestic market is low and the incentive to relocate, to serve the overseas market and/or export back to the EU, is high." European Commission (2018a)



**Table 20. Treatment of the wood product manufacturing sector in external jurisdictions**

Sectors	Metric	EU ETS Phase III				EU ETS Phase IV	California		
		Trade intensity	Cost increase	Joint Metric	Identified	Identified	Trade intensity	Emissions intensity	Level of risk
Sawmills	Initial assessment	No	No	No	No	No	High	Low	Medium
Engineered Wood Products	Initial assessment	No	No	No	No	Yes	High	Medium	High

*Note:* This table shows how external jurisdictions classified their own particular sector. The identification and classification process has been developed specifically for these jurisdictions and their sectors. It serves as an indication of whether sectors in Oregon are at risk. Furthermore, there are differences in sector scope between jurisdictions which also limits the predictive power of leakage risk in Oregon.

*Source:* Vivid Economics

### **There are several factors that suggest the wood products and sawmills sectors are EITE in Oregon:**

- While the sectors' carbon cost relative to their respective value added is relatively low, they each may have limited further emissions reduction potential;
- Similarly, companies covered in these sectors may have the ability to shift production to different facilities within Oregon or to facilities out of state;
- The ability of the sectors to pass through costs to their consumers is also likely inhibited by the existence of significant competitive pressures from both other US states, such as Georgia, and South American producers currently without carbon pricing; and
- Precedent from the EU and California suggests that engineered wood products and, to a lesser degree, sawmills may be at risk of leakage.

### **However, there are several factors which reduce underlying carbon leakage risk:**

- Wood products manufacturing facilities located in Oregon benefit from the state's significant wood resources and innovative expertise;
- There may also be significant and cost-effective energy efficiency potential in the wood products sectors over 2021–35; further research could shed light on whether the investment necessary to achieve these savings is economic;
- Furthermore, the optimal location of wood products manufacturers may be determined by proximity to adequate lumber resources, and this limits the number of states that pose a relocation risk.

**On balance, the sectors are at risk of carbon leakage if Oregon introduces a carbon price without measures to protect against possible adverse competitiveness impacts.** A carbon pricing instrument for these sectors should be designed to ensure that innovation and emissions reduction incentives remain, while also incorporating measures to protect against the risk of carbon leakage and other competitiveness impacts.



## 5 Policy Options and Benchmarking

**As all potentially covered Oregon sectors are likely at risk of carbon leakage, policy needs to be designed to safeguard competitiveness.** These measures must safeguard the competitiveness of local emissions-intensive industries vulnerable to external competition, while retaining the carbon price's incentive to invest in innovative, low-carbon technologies and processes. This section discusses policy options commonly used across jurisdictions to secure the competitiveness of EITE sectors, and details different approaches to benchmarking.

**For cap-and-trade programs, the most common policy option to address leakage risk is free allowance allocation.** Other policy option such as complementary (e.g. rebates, transfers or exemptions, as discussed in Box 6) or external mechanisms (e.g. border carbon adjustments, linking) can also reduce competitiveness impacts and carbon leakage risk. However, free allowance allocation is by far the most prevalent policy option for leakage risk reduction and represents the focus of analysis in this section.

**The most effective forms of free allocation support rely on benchmarking.** This is a mechanism by which free allowance support is offered relative to a facility's emissions intensity when compared with sectoral peers. The remainder of this section is structured as follows:

- Section 5.1 assesses the benefits and challenges of different forms of free allowance allocations;
- Section 5.2 discusses different approaches to benchmarking across jurisdictions.

**Box 6. Rebates, transfers, or exemptions are additional complementary policy options but are not recommended for Oregon**

**Complementary options are measures which may reduce leakage risk, but are not an explicit part of the carbon pricing mechanism.** These options compensate industry for the impacts of the carbon price – such as rebates and other transfers including direct financial support – or entirely protect industry from the effects of the carbon price – such as an exemption. They can apply to an ETS or any other form of carbon pricing.

**Transfers and rebates can potentially reduce leakage risk and preserve emissions reduction incentives, although evidence on their impact is limited.** Tax reductions, subsidies, or other programs can theoretically reduce some carbon cost impacts if benefits scale with output. These mechanisms can also preserve emissions reduction incentives if not linked to emissions levels.

**Exemptions may result in carbon leakage elsewhere in the economy and undermine the emissions reduction incentives of a carbon price.** Exemptions effectively reduce the carbon cost for targeted sectors, thereby reducing leakage risk. However, for a given emissions target, exempting some sectors may require an increase in ambition in the other regulated sectors that would increase leakage risk. Exemptions also undermine a carbon price's emissions reduction incentive by not providing relative incentives for more efficient companies, and not facilitating any demand-side emissions reduction.




## 5.1 Free Allowance Allocation Mechanisms

There are four key free allocation policy mechanisms to address carbon leakage risk, and these can be used in combination with each other. Free allowance allocation involves facilities receiving a percentage of their emissions allowances for free using any of four mechanisms: grandfathering, fixed sector benchmarking, output-based allocation and firm-specific benchmarking. A summary of the differences between the allocation mechanisms is provided in Figure 13. More than one type of allocation mechanism can be used within the same cap-and-trade, with different mechanisms applying to different sectors. Facility specific benchmarking is a subset of output-based allocation and so is treated with that approach below.

This section offers a framework against which to assess policy options to address carbon leakage risk based on trade-offs across three policy objectives:

1. *Leakage protection*: policies should effectively address leakage risk in exposed sectors;
2. *Emissions reduction incentives*: policies should maintain incentives to reduce emissions to ensure environmental integrity;
3. *Policy efficiency*: policies should be technically viable and avoid administrative complexity.

Figure 13. There are two key considerations when designing free allocation mechanisms



		Do allocations vary in proportion to a firm's current output?	
		Yes – allocation in line with current output	No – allocation in line with historic output
Do allocations vary in proportion to a firm's own emissions intensity?	Yes – firm's own emissions intensity	Facility Level Benchmarking	Grandfathering
	No – sector's emissions intensity	Output Based Allocation	Fixed Sector Benchmarking

Source: Vivid Economics

### 5.1.1 Grandfathering

**Grandfathering allocates free allowances in proportion to an individual facility's historical emissions.** This approach determines historical emissions either directly or by multiplying past output by a relevant emissions factor. Allocation is independent of current production. Facilities can sell unutilized permits or purchase allowances depending on the relationship between historical and current emissions. Prominent examples of systems using grandfathering include the first two phases of the EU ETS (from 2005–07 and 2008–12), the first phase of the South Korea ETS (for most sectors), and Chinese ETS pilots.



### *Leakage protection*

**Grandfathering may be less effective at addressing leakage in exposed sectors and disincentivizes output growth.** Under grandfathering, a facility's allocation of allowances would remain independent of changes to output. This allocation mechanism disincentivizes growth for covered sectors, as future allowances would remain constant despite increasing output. If domestic growth arises through production increases from facilities outside the cap-and-trade, this may result in carbon leakage. Furthermore, as allowances are not linked to emissions intensity, more efficient facilities may receive the same support as less efficient facilities, which lowers the effectiveness of leakage protection.

**To address leakage concerns under grandfathering, other jurisdictions with cap-and-trade programs adjust allocations over time and implement closure rules.** Rather than maintain fixed assistance levels, programs tend to adjust allocation decisions periodically. Updating creates a link between current output – and therefore emissions – and future allocations. Facilities will know that reduced output and emissions in one phase of the system is likely to result in less assistance in the next phase. This creates an incentive for continued production and hence reduces the risk of carbon leakage. Adjustments are typically made every three years, such as in the early phases of the EU ETS. Systems have also implemented a variety of closure rules. These rules make the allocation of allowances contingent on a minimum level of production, thus reducing the risk of carbon leakage beyond a certain threshold.

### *Emission reduction incentives*

**Grandfathering can provide facilities with strong short-run emission reduction incentives as assistance levels are fixed over time and based on historical emissions.** As a facility's free allowances are independent of changes in emissions intensity and output, any growth in output and hence emissions would not generate additional allowances for the facility. As such, growing facilities are incentivized to reduce their emissions intensity of production to lower their carbon cost. If a facility lowers its emissions intensity, it could sell its surplus allowances and use the profits to pay off its investment in emissions reduction.

**However, grandfathering may jeopardize long-run emissions reduction efficiency and can create perverse incentives.** Providing free allowances based on historical emissions supports efficient and less-efficient facilities equally, and prevents innovative companies from expanding. In addition, free allowances can be used by incumbents to prevent market entry. Moreover, facilities face an incentive to not reduce output and emissions as future free allowances depend on current production. Grandfathering has also been widely criticized in the EU for providing greater support to facilities with greater absolute historical emissions, effectively punishing early emissions reduction (European Commission, 2015a).

### *Policy efficiency*

**Grandfathering is an administratively efficient solution due to its ease of implementation.** The calculation of assistance levels based on historical emissions presents a significantly smaller administrative burden than the determination of product- or sector-level benchmarks.

**The mechanism can be effective at generating industry stakeholder buy-in, but the risks of overcompensation could raise other challenges.** There are two mutually counteracting forces with grandfathering:





1. The retention of strong emissions reduction incentives and the capacity to generate stakeholder buy-in can be key advantages to support cap-and-trade phase-in. Prior to its repeal, the Australian Carbon Pricing Mechanism included a one-off, non-updating allocation of allowances to electricity generators. These allocations were offered as one-off support to those exposed to the system, even though generators had not been identified as at risk of leakage.
2. Grandfathering may be fiscally challenging if sectors misidentified as at risk of carbon leakage receive overcompensation. These sectors receive free allowances as they are thought to be at risk of exposure, but ultimately do not face a significant leakage risk. In these cases, facilities may have capacity to pass through carbon costs without significant loss of market share. As such, their free allocation may have a value higher than their actual carbon cost exposure. Such facilities would then earn “overcompensation” from their free allowance. This occurred in the power sector under the early phases of the EU ETS: electricity generators received free allowances but were able to pass through the full carbon costs to customers. The UK power sector alone made a €1 billion overcompensation in 2005 from the implementation of grandfathered free allocation (Grubb & Neuhoff, 2006).

#### *Implications*

**In summary, grandfathering is unlikely to address leakage concerns.** The grandfathering approach does not effectively address growth and carbon leakage risk in exposed sectors and is rarely adopted as a long-term solution for carbon leakage. Furthermore, improving its effectiveness at targeting leakage risk by implementing updating or closure rules compromises emissions reduction incentives, as facilities would then expect future assistance levels to be based on current emissions.

#### **5.1.2 Fixed sector benchmarking**

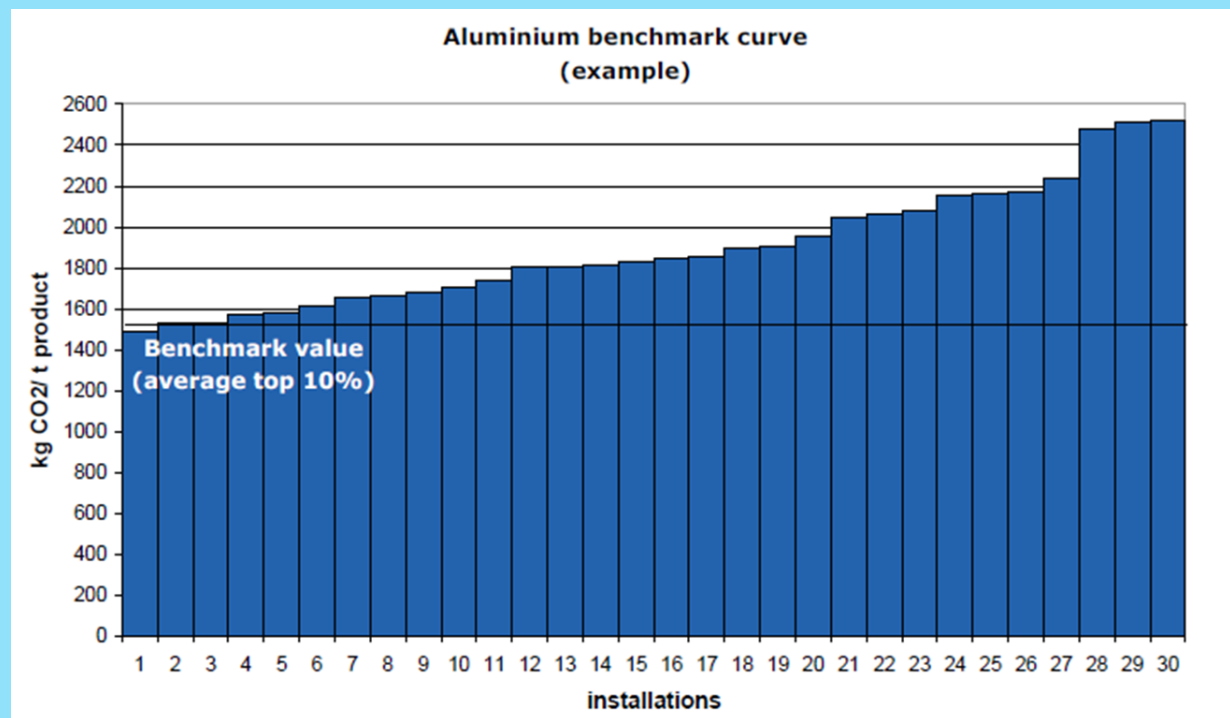
**Fixed sector benchmarking allocates allowances to facilities based on a function of their past production and product- or sector-level emissions intensity benchmarks.** As with grandfathering, levels of assistance are infrequently updated as facilities change their output and emissions. However, in contrast to grandfathering, assistance levels are determined with reference to product- or sector-level benchmarks rather than by reference to historical emissions intensities at the individual facility level. This is the approach adopted under EU ETS Phases III, per Box 7.



### Box 7. Fixed sector benchmarking under EU ETS Phase III

The fixed sector benchmarking allocation approach under EU ETS Phase III uses product-related emissions benchmarks to determine the free allocations of each facility. These benchmarks are set using the average emissions intensity of production of each sector's 10% most-efficient installations (facilities), as illustrated in Figure 14. Where possible, product benchmarks encompass direct emissions from all production processes used in the manufacture of a product. Where this is not possible, fallback benchmarks based on heat production, fuel consumption or process emissions are used (European Commission, 2015a).

Figure 14. The EU ETS Phase III developed product benchmarks according to the average efficiency of the top 10% most efficient facilities in the sector



Source: European Commission (2015a)

### Leakage protection

As with grandfathering, the effectiveness of fixed sector benchmarking in addressing leakage depends on closure rules and updating. While it would be possible to create a fixed sector benchmarking system where the level of assistance would not be altered over time, this would result in a similar dynamic as under grandfathering – namely that, if facilities are exposed to international competition, they may still be disincentivized to grow production and lose market share to competitors not facing carbon prices. Accordingly, policymakers using fixed sector benchmarking have supplemented it with closure rules and periodic updating to reduce the risk of leakage. However, output thresholds to reduce leakage risk can create further challenges, as Box 8 illustrates.

**Box 8. Advantages and disadvantages of fixed sector benchmarking**

**Fixed sector benchmarking actively aims to incentivize emissions efficiency improvements within a sector, while reducing the sector's risk of carbon leakage.** This system is designed to reward efficient facilities and incentivize emissions reductions in less-efficient facilities. This is achieved by providing free allocation support to all facilities in a sector at the level of a subset of efficient facilities. This requires less-efficient facilities to purchase allowances for their emissions above the benchmark level.

**Fixed sector benchmarking in the EU ETS Phase III has a long period in which the output basis of the allocation is not updated.** While the benchmark factors in historical production, the amount of free allocations received by a facility does not change over the period of Phase III. In the absence of other measures, this weakens its effectiveness in preventing leakage. To help address this challenge, adjustments have been made to create a stronger link between allocations and output, subject to a minimum threshold of output, which facilitates stronger protection against leakage. For example, facilities producing more than 50% of their historical level receive their full free allocation, including if their output exceeds their historical activity level.

**However, output thresholds for different allocation levels present incentive challenges.** By producing at a level just above a threshold, facilities may receive allocations that exceed their actual carbon costs. For example, at an output level of 51% of their historical activity level, facilities would be entitled to receive 100% of their allocation (Branger et al., 2014). Interviews with cement facility managers in the EU, carried out by Neuhoff et al. (2014), confirm that these practices have been implemented in the past.

**The change of allocation rules from Phases I and II to Phase III reduced the scope for overcompensation while also reducing leakage risk.** Benchmarking further improves the harmonization of free allocation levels between countries relative to Phase II. However, it does not remove the possibility of overcompensation and other internal market distortions, as benchmarks are calculated according to *ex ante* output levels.

**Changes in allocation rules from Phase III to Phase IV aim to further improve the targeting of leakage risk.** While fixed sector benchmarking will still determine allocation, allocation levels will annually account for significant changes in production. This moves allocation rules closer to an output-based allocation approach (discussed in section 5.1.3). Furthermore, this phase will update all product benchmark values twice over Phase IV (2021–30) to reflect technological improvements over time (European Commission, 2018b).

*Emission reduction incentives*

**Fixed sector benchmarking preserves incentives for facilities to improve their emissions intensity by severing the link between an individual facility's own emissions intensity and the allowances it receives.** Under a grandfathering approach with periodic updating, facilities may be incentivized not to reduce their emissions intensity as this would reduce their future allowances. This challenge is largely eliminated by fixed sector benchmarking: rather than facility-specific emissions, it is the industry-wide benchmark that determines the amount of the facility's future free allowances.



**The stringency of a benchmark should have limited effects on emissions reduction incentives.** The benchmark level determines the level of a particular facility's carbon costs and the average carbon costs of the sector. However, the benchmark itself preserves the marginal incentive to reduce emissions. A facility will be incentivized to reduce emissions regardless of whether its emissions are above or below the benchmark. This is because if it is more efficient than the benchmark implies, it would be able to sell excess allowances for cash were it to reduce emissions further. This incentivizes innovative companies that are below the benchmark by rewarding them with surplus allowances. Similarly, if a facility is less efficient than implied by the benchmark, it could reduce the cost it faces from allowance purchases by increasing efficiency.

#### *Policy efficiency*

**The fixed sector benchmarking approach's reliance on past output levels could deliver overcompensation if applied to sectors that can pass through carbon costs.** As the level of allocation is independent of current output levels, facilities that compete only domestically will have an incentive to respond to a carbon cost by reducing output and raising prices. As under grandfathering, this increase in prices could lead to overcompensation.

**Fixed sector benchmarking requires a lot of data to create product benchmarks.** Similar products with different production processes or multi-output production processes could result in complications and require significant and potentially protracted discussion with industry. However, the successful development of benchmarks under fixed sector benchmarking in the EU, and output-based allocation mechanisms in New Zealand, the former Australian system, and California indicates that these technical challenges can be overcome. Section 5.2 comprises a more extensive discussion of these issues.

#### *Implications*

**In summary, fixed sector benchmarking entails challenges due to the reliance on historical output that results in weaker carbon leakage protection relative to policy options based on current output levels.** Key implications are:

- Fixed sector benchmarking maintains emissions reduction incentives more effectively than grandfathering. This is achieved by severing the link between individual facility emissions and allowances received.
- However, without the implementation of closure rules and updating, fixed sector benchmarking will still face the same challenges as grandfathering in terms of leakage prevention, and overcompensation and reduced production are still possible.
- Furthermore, the reliance on historical output results in weaker leakage protection relative to policy options based on current output levels.
- Fixed sector benchmarking may still be useful in sectors where leakage risk is more uncertain, as support provided maintains emissions reduction incentives.

### **5.1.3 Output-based allocation methods**

**Output-based allocation methods provide free allowances according to a pre-determined emissions intensity benchmark and adjusts allocations if facilities change their output.** This system is similar to fixed sector benchmarking as the initial allowance allocation is determined by multiplying an emissions intensity benchmark by each facility's individual output level. Facility level benchmarking is a form of output-based allocation; the only difference is that benchmarks are determined at the facility level with the former, and at the sectoral level with the latter.



**However, unlike fixed sector benchmarking, subsequent changes in facility production are incorporated into future allocation decisions with only a small lag.** This means that when facilities increase or decrease their output, the amount of allowances they receive rises or falls correspondingly, according to the pre-defined emissions intensity benchmark. Variants on this basic model are used to provide assistance in California, per Box 9, and Alberta, per Box 10. Phase IV of the EU ETS moves closer to this system by annually taking into consideration significant changes in output when determining free allowance allocations.

*Box 9. California's cap-and-trade offers assistance based on output-based allocation*

**The California cap-and-trade uses a form of output-based allocation to reward efficiency and reduce the potential for thresholds to influence incentives.** Facilities that are more efficient than their competitors are rewarded using benchmarking, and the system ensures that an entity cannot increase its allocation by artificially increasing or decreasing production because allocation is directly linked to current output levels (EDF, CDC Climate, & IETA, 2015).

**Allocation is calculated through a combination of industry- and facility-level data.** For the operator of an industrial facility, allowance allocations are determined by multiplying total product output or energy consumed by an emissions benchmark, an industry assistance factor and cap-adjustment factor (a fraction that decreases over time to reflect a tightening emissions cap). While product output or energy consumed is calculated at the facility level, the remaining variables are determined at the sector level.

**To determine the amount of free allowances distributed to industry, the California Air Resources Board (CARB) created the industry assistance factor.** Assistance is provided for sectors in three leakage classifications, which were initially planned to receive varying levels of support:

- High risk, which includes oil and gas extraction, paper mills, and chemical, cement, iron, steel, and lime manufacturing;
- Medium risk, which includes petroleum refineries and food and beverage manufacturing; and
- Low risk, which includes pharmaceutical and aircraft manufacturing.

**However, California will be essentially moving away from free allocation based on tiered leakage risk determination.** For the first and second compliance periods (2013–14 and 2015–17, respectively), all leakage classifications received 100% of their benchmarked allowances for free. It was initially planned that for the third compliance period, entities in the medium and low categories would receive 75% and 50%, respectively, of their allowances freely allocated. However, recent proposed amendments would see all leakage risk classifications retain 100% of benchmarked free allowances through 2018–20 and 2021–30 (CARB, 2018).



*Box 10. Output-based allocation under the Albertan carbon pricing system*

**Output-based allocation under the Carbon Competitiveness Incentives Regulation (CCIR) came into effect in the Canadian province of Alberta in early 2018.** This was the second component of its carbon pricing system (following a levy applied to heating and transport fuels). The plan encourages the use of the least-emissions-intensive process for production. Final products are judged against peers, with more emissions-intensive production processes facing compliance obligations to broaden the use of cleaner technologies (Monahan, 2017).

**More specifically, the following aspects characterize the CCIR framework:**

- Free allocations of performance credits up to the product benchmark are distributed to EITE industries;
- Benchmarks are set to reward producers with cleaner production processes with excess performance credits that they can sell for cash;
- Facilities with more emissions-intensive production processes for the same products will face obligations to comply and be required to purchase performance credits from other facilities (among other costly alternatives);
- The system covers large emitters with annual production volumes above 100,000 tons as well as the coal-intensive electricity producers, despite their low trade exposure.

**Output-based allocation is fixed sector benchmarking with more frequent output updating, and as such has largely the same attributes in terms of leakage protection, emissions reduction incentives, and policy efficiency.** The following analysis therefore focusses on how using current production data for allocation influences transaction costs for regulated companies and administrative costs for the regulator.

*Leakage protection*

**Output-based allocation targets leakage more robustly through adjustment of allowances based on current output levels.** Under output-based allocation, when a facility produces an extra unit of output, this directly results in allocation of additional allowances, whereas this is not the case under grandfathering or fixed sector benchmarking systems. This feature offers more targeted leakage protection as additional allowances are provided in proportion to a facility's production changes.

*Emission reduction incentives*

**Output-based allocation also incentivizes emissions intensity reductions more strongly due to the use of current output levels.** As facilities' allocations change based on current production levels, incentives to increase production while reducing emissions intensity are greater than under any other policy option.

*Policy efficiency*

**In contrast to grandfathering and fixed sector benchmarking, output-based allocation reduces the risk of overcompensation.** As allocation varies according to current production levels, facilities can receive additional benefits from production changes only if this is accompanied by reductions in emissions intensity. This lowers the risk of overcompensation under an output-based allocation relative to grandfathering and fixed sector benchmarking.



**An output-based allocation approach entails marginally higher reporting costs for regulated facilities and higher administrative costs for the regulator in comparison to other free allocation policy options.** Under this approach, regulated facilities face additional costs in the form of more regular (annual) output data reporting. Similarly, administrative costs for the regulator are higher as they must collect a large amount of output data from regulated facilities each year and then update allocation levels for each regulated facility for the next year. However, considering Oregon's DEQ already collects annual GHG emissions data from facilities, the increase in costs associated with more data collection would likely be small.

### *Implications*

**In summary, output-based allocation may be an attractive option for Oregon as it provides targeted leakage protection, encourages emissions-intensity reductions, and reduces the chances of overcompensation.** The key implications are as follows:

- The output-based allocation approach uses current output data which can be more effective at tackling leakage than other policy options, provides strong incentives to reduce emissions intensity, and lowers the risks of overcompensation.
- The downside of output-based allocation is the requirement for industry to report output annually and the administrative costs for the regulator to collect and analyze a large amount of data each year.
- Nevertheless, it may be an attractive policy option for Oregon to implement and has been successfully introduced in other jurisdictions such as California, Alberta and New Zealand. Alternatively, the state could potentially begin with fixed sector benchmarking while putting in place the administrative requirements for more frequent output data collection. In particular, Oregon's DEQ already collects annual GHG emissions data at the facility level, and there would likely be efficiency gains by incorporating output data collection into this existing process.

## **5.2 Approaches to Benchmarking**

**Both fixed sector benchmarking and output-based allocation require the development of emissions benchmarks.** Emissions benchmarks are standard performance measures representing the amount of anthropogenic emissions associated with one unit of a product. Benchmarks can compare peers against each other or against certain reference levels such as BAT. Both fixed sector benchmarking and output-based allocation require emissions benchmarks against which to measure the emissions efficiency of different facilities, and thereby determine their free allocation levels. This section discusses different types and stringencies of benchmarks found across jurisdictions (Section 5.2.1); details options available to develop benchmarks (Section 5.2.2); and discusses implications for Oregon (Section 5.2.3).

### **5.2.1 Benchmark types and stringencies**

**Benchmarks determine an aspirational level of efficiency across a group of comparable producers in order to incentivize behavioral change with respect to facilities' emissions-intensive processes.** For benchmarks to adequately measure relative efficiency, they must compare similar activities and define relevant emissions boundaries as only those which facilities have control over. Benchmarks pertaining to comparable activities (e.g. output produced, processes used) ensures that different emissions intensities are due to differences in efficiency levels, rather than differences in the manufacturing objective. This ensures that inherently more emissions-intensive processes are not compared with those with lower emissions intensity (i.e. cement producers are not compared with plastics producers). Developing clear emissions boundaries ensures that



facilities are benchmarked only on the emissions from activities which they have control over to incentivize behavior change; as such, benchmark boundaries should focus on the most common and emissions-intensive activities in sectors (PMR, 2017).

**For the purposes of climate policy, there are two central categories of emissions benchmark: product and fallback benchmarks:**

- Product benchmarks reflect the emissions associated with the production of one unit of a particular product. Establishing this type of benchmark incentivizes emissions reductions during the production process. Often, but not always, this type of benchmark can be in comparison to different products produced.
- Fallback benchmarks (heat, fuel) reflect the emissions associated with the production of intermediary products (such as heat), or the consumption of inputs (such as fuel):
  - Fuel benchmarks incentivize the choice of low-emission fuel mix, but not the efficient conversion of fuel into final output;
  - Heat benchmarks reflect the efficiency with which a facility produces heat and incentivizes both low-emissions fuel mixes and efficient conversion of fuel into output;
  - However, fallback benchmarks largely do not capture process emissions which is why jurisdictions often use a combination of both product and fallback benchmarks as alternative approaches.

**Benchmark stringencies can also be calculated according to three main methodologies.** The choice of stringency levels depends on policy objectives as well as the potential impact on affected facilities. Jurisdictions define the benchmark level in three main ways:

- With reference to a specific BAT level;
- With reference to a “best-in-class” performer in the pre-defined group of comparable activities; or
- With reference to the average level or a subset percentile of high performers.

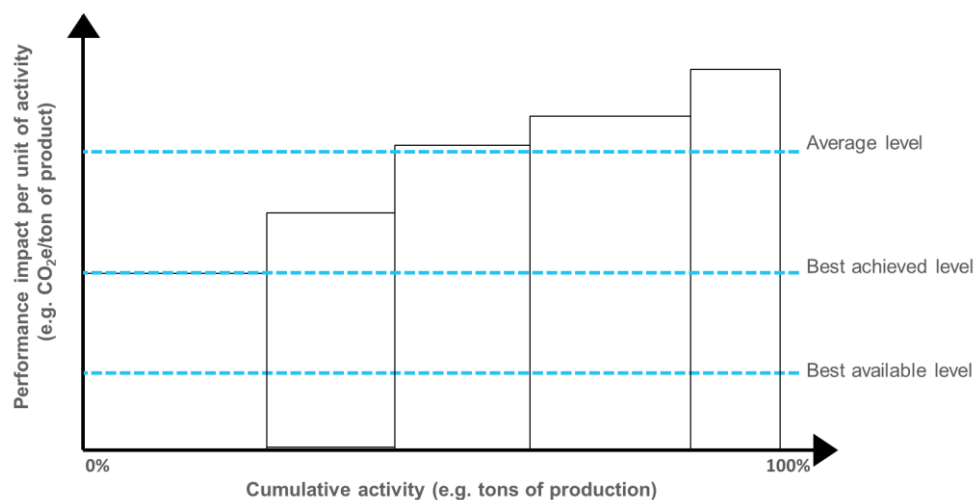
**Figure 15 illustrates a stylized benchmark curve with the three main potential benchmark level methodologies.** This figure illustrates that the methodology chosen significantly influences the stringency of the benchmark, with two facilities performing better than the average level, but no facilities performing near the best available level. When determining the benchmark level, it is essential to engage widely with stakeholders and industry to take into consideration the emissions reduction potential of the sector and the representativeness of the benchmark curve (PMR, 2017).

**Most jurisdictions that have enacted cap-and-trade systems use both product and fallback benchmark types, per Table 21.** This allows cap-and-trade programs to benchmark a wide variety of sectors, even those in which defining a simple product is not straightforward. In particular, the jurisdictions of the Western Climate Initiative (WCI), California and Quebec, developed product benchmarks and, for sectors with more complex production processes, fuel fallback benchmarks. Alberta uses both product benchmarks and heat fallback benchmarks to calculate allowance allocations.





Figure 15. Different methodologies to determine the benchmark level can significantly influence the stringency of allocation



Source: Vivid Economics based on PMR (2017)

**Australia's current Safeguard Mechanism has proposed a reserve approach that calculates a benchmark value when data availability is low.**<sup>23</sup> This proposed approach would calculate a benchmark value based on a hypothetical facility assumed to have the least emissions-intensive technologies and practices currently implemented in the country. This approach uses conservative judgements to ensure that a benchmark value reflects existing deployed technologies in Australia or overseas (Australian Government, 2016a). While this has not yet been implemented, it is an option to consider to calculate benchmarks when there is insufficient data to plot a whole benchmark curve (PMR, 2017).

**There is a wide variety of methodologies to determine the benchmark stringency level.** Table 21 shows that some jurisdictions use the average emissions intensity of a subset of efficient facilities; others choose the production-weighted average emissions intensity of the sector (or some fraction of this); while other jurisdictions use a representative "best-in-class" facility. In practice, output-based allocation approaches have tended towards the use of benchmarks that are between the average and best practice of emissions intensity of the industry in the relevant jurisdiction. Jurisdictions also update benchmarks over time to reflect the tighter emissions targets or expected facility efficiency improvements.

**California, Quebec, Alberta and British Columbia all use different methods to determine benchmark stringency:**

- California defines benchmark stringency levels as 90% of production-weighted average emissions intensity for most sectors and as the best-in-class Californian facility for a subset of other sectors.
- Quebec defines its benchmark stringency as the level of historical average emissions intensity (or some fraction thereof) for either individual facilities or, in some cases, the sector as a whole.
- Alberta uses different benchmark stringency methodologies for different sectors: some are set at 80–90% of production-weighted average emissions intensity, some at best-in-class levels, and others based

<sup>23</sup> Australia's Safeguard Mechanism was launched in 2016 and is a baseline and credit system, whereby large emitters must purchase credits if their direct emissions exceed pre-defined baseline levels (Australian Government, 2016b).

on quartiles. For their assigned product benchmark, stringency levels are set for each individual facility (discussed further in Box 11).

- British Columbia’s carbon tax provides rebates to facilities that meet performance benchmarks set at the best performing facility in the sector globally (British Columbia, 2018).

**Table 21. Types of benchmark used and methods to establish stringency vary across jurisdictions**

Jurisdiction	Benchmarks used	Benchmark stringency methodology
EU ETS Phase III and IV	— Product — Fallback (heat, fuel, process)	— Average emission level of the 10% most efficient facilities within a sector
California cap-and-trade	— Product — Fallback (fuel)	— 90% of a sector’s production-weighted average emissions intensity — For some sectors, best-in-class Californian facility*
Alberta CCIR	— Established (and assigned) products — Fallback (heat)	— Different across sectors: 80–90% of production-weighted average emissions intensity; best-in-class; or quartile-based — For assigned benchmarks: stringency developed for each facility
British Columbia’s clean growth incentive program	— Product	— Best-in-class facility globally
Quebec cap-and-trade	— Product — Fallback (fuel)	— Historical average emissions intensity of facility or sector
Ontario	— Product — Fallback (fuel)	— Not detailed
Pan-Canadian Framework	— Product	— Initially, 70% of production-weighted national average of emission intensity
Australia (Safeguard Mechanism)	— Product — Reserve approach (proposed)	— Weighted average emissions intensity of tenth percentile
India’s energy efficiency certificate trading system	— Product	— Best-in-class facility
South Korea	— Product — Fallback (heat, fuel)	— Weighted average emissions intensity of eligible entities
New Zealand cap-and-trade	— Product — Fallback (electricity)	— Average emissions intensity of national sectors
Kazakhstan cap-and-trade	— Product — Fallback (fuel, electricity)	— Average emissions intensity of sectors
Tokyo cap-and-trade	— Floor area-based — Fallback (fuel, heat, electricity)	— Average emissions intensity of facilities covered in previous program

*Notes:* \* California uses the best-in-class facility when no one facility meets the 90% average benchmark; sectors that use this methodology include cement manufacturing and tomato processing (CARB, 2011b, 2014).

*Source:* Vivid Economics

## 5.2.2 Different options to develop benchmarks

**Jurisdictions can either develop benchmarks from scratch or adopt existing benchmarks with adjustments to accommodate local context:**

- Developing benchmarks for all covered sectors from first principles is costly and time-consuming;

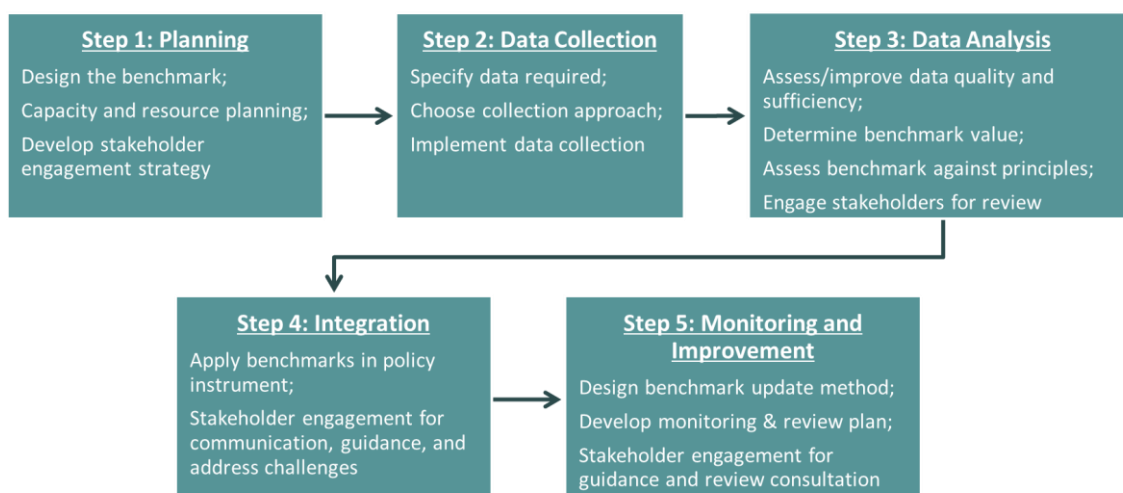


- Adopting and adjusting existing benchmarks is less resource-intensive and is particularly suitable if an economy is similar to one that has developed its own benchmarks.

**Developing benchmarks from first principles can be a time-consuming and resource-intensive process, both for policymakers and industry stakeholders.** Figure 16 indicates the key steps in benchmark development:

- California took at least six months for each step, with Step 4 taking 24 months. Each step required five full-time technical scientists or engineers and their corresponding salary costs and consultancy fees.
- Tokyo’s ETS also required numerous government staff and consultancy fees for each step.
- The European Commission (2015a) details a five-step process through which it developed benchmarks for the EU ETS, wherein it describes the early stages of developing a draft list of product benchmarks and a general data-collection methodology to be the most intensive stakeholder engagement process.

Figure 16. **Developing emissions benchmarks is a five-step process**



Source: Vivid Economics based on PMR (2017)

**Adopting benchmarks developed in other jurisdictions significantly reduces resource requirements.** Both South Africa and Kazakhstan adopted and adjusted benchmarks developed for other jurisdictions for the purposes of their domestic carbon pricing instruments. Kazakhstan adjusted the EU’s benchmark to take into consideration the relative economic burden and industrial development of the country relative to the EU. South Africa, meanwhile, is using EU and Australian benchmarks as a starting point for stakeholder consultation to calculate local benchmarks (Lozynskyy et al., 2014; PMR, 2017). Small economies may face particular challenges in developing local benchmarks, emphasizing the benefits of adopting the benchmarks of other jurisdictions, as discussed in Box 11.

**Box 11. Small economies face particular challenges in developing locally appropriate benchmarks**

**Alberta** developed an entire methodology to apply benchmarks in sectors with only one facility. Its CCIR uses an assigned benchmark approach for sectors that do not have established product benchmarks; typically this is used where a product is produced by only one regulated facility in the province. In cases with only one facility in a sector, assigned benchmarks are developed specifically for that facility. This benchmark takes the form of a production-weighted average emissions intensity benchmark that undergoes economic testing to determine the appropriate stringency.

Benchmark stringency is reduced for facilities in sectors categorized as highly EITE and with a proportion of production exceeding the sales test by more than 10%,<sup>24</sup> exceeding the profit test by more than 25%,<sup>25</sup> or with significant sector impacts estimated in sector-level macro-economic impact analysis (Alberta Government, 2018).

The sales and profit tests are measures of economic impact attributable to the net compliance costs under the CCIR relative to the compliance costs under the previous Specified Gas Emitters Regulation. A facility fails the sales test if its incremental compliance cost divided by its gross revenues is greater than or equal to 3%; while a facility fails the profit test if its incremental compliance cost is greater than or equal to 10% of its EBITA (Alberta Government, 2018). However, benchmark stringencies are reduced only if the percentage of facilities' production that fails the sales and/or profit tests exceeds the 10% or 25% thresholds.

**New Zealand's** Negotiated Greenhouse Agreements provided carbon cost relief for industries at risk of competitiveness impacts. Due to low numbers of regulated facilities, some sectors were not conducive to developing benchmarks from local data. As such, they developed benchmarks in comparison to prevailing international best practices (PMR, 2017).

**Benchmarks or approaches used in jurisdictions such as California, Quebec, or Ontario could be particularly suitable for Oregon.** To varying degrees, these economies may have similar structures, competitive dynamics, and regulatory ambition to Oregon. Adopting and adjusting the benchmarks or approaches from one of these jurisdictions could significantly reduce the resources required by Oregon to develop benchmarks. Box 12 provides an overview of Quebec's approach to benchmarking, which could hold specific potential for Oregon. Further research is required to determine which jurisdiction's benchmarks would be best to adopt, and how best to adjust them.

<sup>24</sup> The sales test is the ratio of a facility's incremental compliance costs to its gross sales revenues.

<sup>25</sup> The profit test is the ratio of a facility's incremental compliance costs to an estimate of its earnings before interest, taxes, and amortization (EBITA).



**Box 12. Quebec provides free allocations to facilities based on either facility- or sector-level benchmarks**

**Quebec identifies the majority of sectors covered under its cap-and-trade as eligible for free allowance allocation using benchmarks.** Quebec identifies all manufacturing and mining sectors and some electricity producers (under certain conditions)<sup>26</sup> as eligible for free allowance allocation (Government of Quebec, 2011). Allocations to facilities in these sectors are determined by facilities' performance against emissions intensity benchmarks, which helps maintain emissions reduction incentives. Emissions intensity is either calculated as emissions per unit of product or per unit of fuel input.

**Product benchmarks are based on average historical emissions intensity of production, either at the sector level, or at the individual facility level.** Both methods calculate emissions intensity using average data over a four-year period. Three elements of this approach are noteworthy:

1. Most activities use benchmarks developed according to **individual** facilities' historical emissions intensities;
2. Only a few activities are benchmarked using **sector-level** emissions intensity. These activities are lime production, cement production, and prebaked anode and aluminum production;
3. Further **nuances** to this methodology are included for facilities with missing data or those without a simple output product that can be used as a reference unit.

**1. Individual facility benchmarks, based on a facility's historical combustion, process, and other emissions efficiency, determine free allocation for most activities in Quebec.** For these activities, over 2013–14, free allocation was determined by multiplying a facility's current output volume by its emissions intensity target benchmark: its 2007–10 average historical emissions intensity (across combustion, process, and other emissions).<sup>27</sup> In later years of the cap-and-trade (2015–20), a facility's emissions intensity target benchmark declines annually until it reaches a specified 2020 target intensity level. The 2020 intensity targets are the same as the 2007–10 average for process emissions; and for combustion and other emissions are the lower of either 95% of the minimum emissions intensity over 2007–10, or 90% of the average emissions intensity over 2007–10. Quebec ensures that this methodology does not penalize facilities that have undertaken early emissions reductions by providing early reduction credits to account for early action.

**2. Sector-wide benchmarks determine free allocation to facilities in a subset of sectors in Quebec.** Facilities in the lime, cement, and aluminum sectors receive allowances based on current output volumes multiplied by an emissions intensity target benchmark. The criteria for eligibility for a sector-wide benchmark is that there are three or more facilities undertaking a common activity,

<sup>26</sup> Free allocation to electricity producers is only provided if the generator has signed a contract before 2008 in which the sales price is fixed and cannot be adjusted to account for carbon cost increases. Free allocation also covers power consumed in Quebec but generated in another jurisdiction that has implemented a cap-and-trade system.

<sup>27</sup> Combustion emissions intensity is adjusted by a multiplication factor determined by the ratio of a facility's combustion emissions attributable to fossil fuels (excluding refinery fuel gas) to its total combustion emissions. This ratio takes on a value of 1 in the case of the pulp, paper, and paperboard mills and the particle board and fiberboard manufacturing sectors.



either in terms of product or processes. For 2013–14, the target benchmark is the greater of either the facility-level average historical emissions intensity over 2007–10, or the sector-level emissions intensity target for 2020 for facilities in Quebec in the sector. The latter term is based on sector-level average emissions intensity over 2007–10 and is calculated in the same manner as the facility-level 2020 target. For 2015–20, this benchmark declines annually for a facility if its historical intensity is greater than the sector-level 2020 target, until the 2020 target intensity is reached.

- 3. Quebec uses nuances of this benchmarking methodology to account for facilities with missing data.** If emissions data is missing for 2007–10, then the 2013–14 intensity target calculation takes into account average emissions from two years before to one year after the facility exceeds the inclusion threshold.<sup>28</sup> Over 2015–20, the benchmark declines annually to reflect a 1% decline in the facility’s combustion and other emissions intensities.

**For sectors without simple output products that can act as reference units in the emissions intensity calculation, Quebec calculates free allocation based on energy-use benchmarks.** The combustion emissions benchmark is set against the emissions factor of natural gas in tCO<sub>2</sub>e/Gigajoule. A facility’s average historical total energy consumption (across all fuels used) is multiplied by this benchmark to determine free allocations. The implication is that if a facility uses fuels that are more emissions-intensive than natural gas, they will need to purchase allowances to cover the difference. Process and other emissions intensities are set at the facility’s average historical levels. Declining cap adjustment factors over 2018–20 are then applied to the facility’s benchmarks for combustion and other emissions intensities.

### 5.2.3 Implications

**Oregon could develop emissions benchmarks, adopt benchmarks or approaches used in other jurisdictions, or undertake a blended approach.** Table 22 details each possible approach, along with their advantages and disadvantages. While developing new benchmarks can allow for a tailored approach specific to Oregon, this can be costly and time-consuming and entail challenges for sectors with low numbers of facilities. Adopting and adjusting benchmarks or approaches from similar jurisdictions may be cheaper and quicker and allow for a wider comparison of Oregon sectors’ efficiencies, but may still require significant work to adjust to Oregon’s context. Following a blended approach entails developing new benchmarks for some sectors and adopting and adjusting benchmarks for others. This approach is pragmatic in the sense that it proposes to adopt well-suited benchmarks and develop benchmarks where existing benchmarks are less suited, thereby also building capacity to develop benchmarks. However, this approach could still require significant resources and time and requires some alignment of Oregon’s benchmarking methodology to that of another jurisdiction.

**When developing benchmarks, due regard must be given to prevailing industry efficiency levels to avoid perverse outcomes such as penalizing early adopters of emissions reduction options.** This is particularly important in sectors with low numbers of facilities. If a facility is benchmarked against its historical emissions intensity, but this is already low, the benchmark must be adjusted to account for existing efficiency to avoid

<sup>28</sup> Excluding the facility’s first year of operation.



penalizing the facility for early adoption of mitigation measures. This could be done by taking into account prevailing best-practice efficiency levels and global trends when calculating Oregon benchmarks.

*Table 22. Oregon could take three approaches to developing benchmarks for allowance allocation*

Benchmark development method	Advantages	Disadvantages
Develop new benchmarks from first principles	<ul style="list-style-type: none"> <li>— Tailored representation of Oregon sectors' relative efficiencies</li> <li>— Can explicitly introduce efficiency potential of Oregon sectors</li> </ul>	<ul style="list-style-type: none"> <li>— Costly and time-consuming process</li> <li>— May be difficult to develop benchmarks in sectors with low numbers of facilities</li> </ul>
Adopt and adjust the benchmarks or approaches of a similar jurisdiction (such as WCI jurisdictions)	<ul style="list-style-type: none"> <li>— Allows for comparison of Oregon sectors' efficiencies relative to similar jurisdictions</li> <li>— Cheaper and quicker process to adjust rather than develop afresh</li> <li>— International precedent illustrates feasibility and potential methodologies</li> </ul>	<ul style="list-style-type: none"> <li>— May require work to adjust benchmarks to reflect certain nuances of Oregon sectors that are not identical in similar jurisdictions</li> <li>— Benchmark updating may be dependent on other jurisdictions updating and Oregon's economy following a similar trajectory of economic structure over time</li> </ul>
Blended approach: develop new benchmarks for a subset of sectors and adopt benchmarks for other sectors	<ul style="list-style-type: none"> <li>— Can build capacity to develop benchmarks in a subset of more contextually unique Oregon sectors</li> <li>— Allows similar sectors to be benchmarked as in other jurisdictions and more novel sectors to follow a unique approach</li> </ul>	<ul style="list-style-type: none"> <li>— May still require relatively significant resources and time</li> <li>— Requires alignment of benchmarking methodologies</li> </ul>

Source: Vivid Economics



## 6 Conclusions and Recommendations

**Carbon pricing is a cost-effective, market-oriented approach to driving the decarbonization of the economy and is becoming increasingly used internationally.** The global implementation of carbon pricing has recently accelerated. As of 2018, carbon pricing initiatives cover jurisdictions accounting for about half of the global economy and almost a fifth of global emissions (World Bank, 2018). Carbon pricing:

- Is central to any strategy to prevent dangerous climate change at the global level and improve air quality at the local level;
- Allows stakeholders to respond flexibly to new information and helps ensure that emission reductions occur where they are cheapest;
- Can help drive innovation to more efficient production techniques as consumer behavior shifts towards low-emissions goods and services.

**Experiences from other jurisdictions suggest that when implementing a carbon price certain sectors may be susceptible to carbon leakage.** In the short term, carbon leakage can occur through a loss of market share to competitors in external jurisdictions without carbon pricing. In the longer term, it can arise through the shifting of new investment and/or the relocation of facilities to external jurisdictions. While there has been little empirical evidence of carbon leakage internationally, it is a serious policy concern. This is because it implies a loss of domestic competitiveness and a reduction in local production and employment, while also undermining the environmental impact of the carbon price.

**Two central elements determine the susceptibility of sectors to competitiveness impacts: (high) carbon costs and (low) cost pass-through capacity.** Jurisdictions commonly identify carbon cost exposure by estimating a sector's emissions intensity, and measure cost pass-through capacity using a sector's trade exposure as an indicator. Jurisdictions have also used qualitative analyses, in conjunction with quantitative measures, to identify sectors at risk of leakage and more directly reveal the underlying drivers of cost pass-through capacity of sectors. Qualitative analyses typically investigate the technical and economic feasibility of emissions reduction options; competitive dynamics between local and external producers; and sectoral profitability and market outlooks.

**Oregon's economy is reliant on trade, both inter-state and international; this implies a high carbon leakage risk for EITE sectors if policymakers do not design a carbon pricing mechanism to account for this.** The more a jurisdiction trades with jurisdictions that have not implemented carbon pricing, the greater its carbon leakage risk as domestic facilities face an additional carbon cost that their competitors do not. Oregon faces three general risk factors:

1. Oregon trades significantly with international jurisdictions that have not implemented carbon pricing. Portland is the fourth-largest export port on the West Coast and its major trading partners are Japan, South Korea, China, Taiwan and Mexico.
2. Its trade with other US states is a significant component of the economy's revenue. In 2012, Oregon's manufacturing trade with other US states was at least double its manufacturing trade with international jurisdictions (U.S. Department of Commerce, 2018; U.S. Department of Transportation; Bureau of Transportation Statistics; and U.S. Census Bureau, 2014). Currently, California is the only US state that prices industrial emissions. This means that Oregon sectors covered under a carbon price that compete





with producers in other US states would almost always be competing under conditions of asymmetrical carbon costs.

3. Competition between producers across different US states may be more acute than between producers across different national jurisdictions. This is due to relatively lower barriers to market entry and exit, a shared federal regulatory system, cultural values, and consumer preferences.

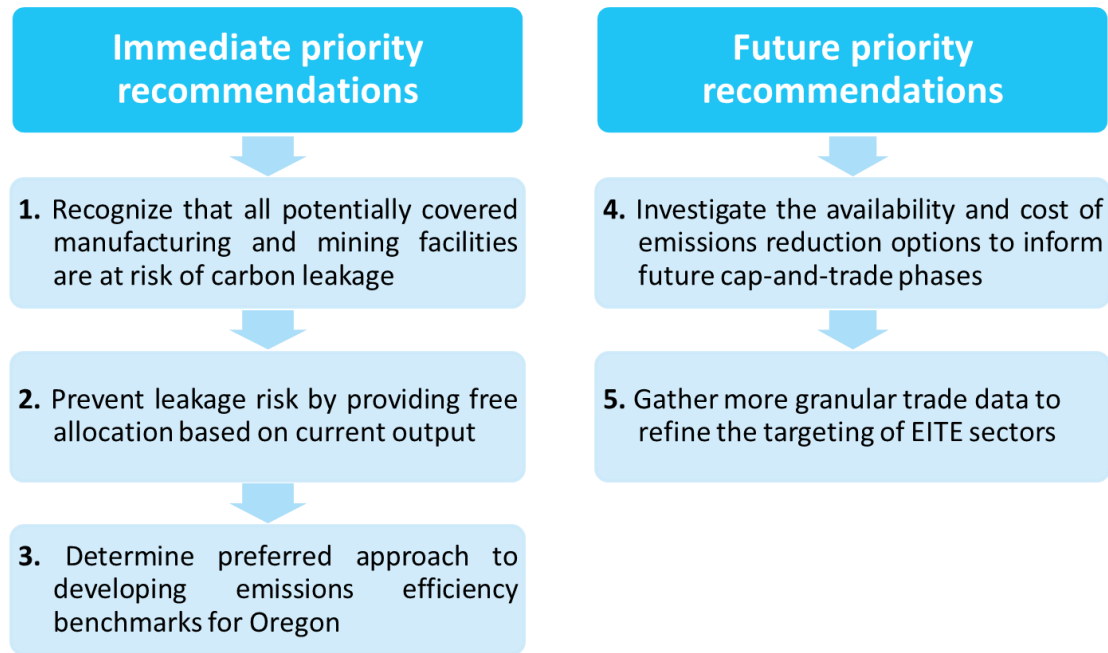
**However, a cap-and-trade program in Oregon should still cover all EITE sectors.** All jurisdictions that have implemented carbon pricing have included design elements that provide support to sectors identified as at risk of carbon leakage. The effectiveness of these measures is partly evidenced in most *ex post* evaluations finding little to no carbon leakage resulting from implemented carbon pricing instruments. While the analysis undertaken for Oregon finds that all potentially covered manufacturing and mining sectors face a degree of fundamental underlying carbon leakage risk, all sectors and facilities have some opportunities to reduce emissions. Furthermore, as more jurisdictions across the US and the world begin pricing carbon in their industrial sectors, long-run leakage risk to these jurisdictions will decline. As such, policy options should be designed to incentivize efficiency improvements across all sectors. Exempting EITE sectors outright fails to provide marginal emissions reduction incentives, and does not reflect the reality of existing emissions reduction opportunities. Moreover, for a given emissions reduction target, exempting certain sectors would require an increase in stringency for non-exempted sectors which could shift rather than reduce carbon leakage risk.

**Well-designed policy options can secure the competitiveness of EITE while maintaining incentives to reduce emissions.** Providing free allocation to EITE sectors using output-based allocation and appropriate benchmarks can effectively secure industrial competitiveness while maintaining marginal incentives for facilities to improve efficiency and increase investment into innovative emissions reduction technologies. This form of carbon leakage risk reduction policy has been successfully implemented in California and Alberta, with the EU ETS moving closer towards this model over time. A well-designed output-based free allocation mechanism will require an appropriate set of facility-level emissions intensity benchmarks for Oregon sectors, such that allocation provides sufficient support while incentivizing feasible efficiency improvements.

**The findings from the analysis provide the basis for the five recommendations.** Figure 17 summarizes the recommendations and categorizes them according to prioritization. Recommendations 1 to 3 are immediate priority, and must be implemented before the start of the cap-and-trade. Recommendations 4 and 5 should be prioritized in future reviews of the cap-and-trade program



Figure 17. Three recommendations are for immediate prioritization, while two are for future prioritization



Source: Vivid Economics

1. **Recognize that all potentially covered Oregon manufacturing and mining sectors face risk of carbon leakage, and should be considered EITE while still being part of the cap-and-trade program.** In particular, the high emissions intensities of the gypsum sector and the cement and concrete sector, the high absolute emissions levels of the semiconductor and other electronic components, and pulp, paper and paperboard mills sectors may suggest a specific exposure to carbon costs in these sectors. The supplementary qualitative analysis identifies Oregon sectors' ability (or lack thereof) to pass through carbon costs to consumers by assessing both domestic and international competitive dynamics, opportunities to reduce emissions, and sector profitability. The findings from the qualitative analysis suggest that all Oregon sectors face some risk of carbon leakage. As such, while all sectors should remain covered under the carbon price to help incentivize efficiency improvements, additional policies can support sectors through this transition by reducing carbon leakage risk. These transitional support policies should be designed to protect against the risk of carbon leakage and other competitiveness impacts, while also incorporating measures to ensure that innovation and emissions reduction incentives remain.
2. **Provide free allocations based on current output to at-risk sectors to safeguard competitiveness and reduce leakage risk, while retaining incentives to innovate in emissions reduction technologies and production processes.** This policy option is likely the optimal form of free allocation as it safeguards industrial competitiveness and provides incentives for efficiency improvements. This form of allocation is linked to a facility's relative efficiency and its frequently updated (ideally annual) output levels. Such characteristics make output-based allocation (whether at the sector or facility level) preferable to fixed sector benchmarking and grandfathering. It is less vulnerable to threshold effects and does not disincentivize output growth. Furthermore, as the proposed Oregon cap-and-trade would cover around

only 30 facilities, the administrative costs of collecting facility-level annual output data would be relatively low.

- 3. Determine the most appropriate approach to benchmarking: either developing specific benchmarks or adopt and adjust those of another jurisdiction.** Developing benchmarks for all potentially covered sectors in Oregon could be time-consuming and require significant resources. Adopting existing benchmarks from jurisdictions with similar economic structures such as California, Quebec, or Ontario could be quicker and less costly, but may require work to reflect the specific context of Oregon and may imply a degree of dependence on other jurisdictions in terms of updating benchmarks. Quebec’s approach may hold specific potential since it benchmarks most facilities against its own historical emissions intensities, and this may be particularly suited to sectors in which there are few facilities. This approach might require relatively few resources to develop and is capable of securing facility-level competitiveness while incentivizing efficiency improvements through benchmarks that decline annually until reaching a targeted intensity level. Research should be conducted on how to best adjust these benchmarks to Oregon’s context and on how to implement these.
- 4. Investigate the availability and cost of emissions reduction options for covered sectors to maximize the efficiency of future phases of cap adjustments and industrial allocations.** Future reviews should investigate the feasibility of emissions reduction options for covered manufacturing and mining sectors. This will help maximize the efficiency of a carbon price, by revealing technically feasible sectoral emissions reduction potential, such that optimal annual cap adjustments and levels of sectoral allocation can be determined. This analysis should take into consideration the context of Oregon – for example, supply-side availability of alternative fuels such as biomass, geographic solar irradiance levels, life-cycle emissions of natural gas, and the current state of implemented technologies.
- 5. Gather more granular trade data to more accurately define EITE sectors.** Existing trade data does not allow for a meaningful analysis of Oregon’s trade exposure to other US states and foreign jurisdictions, and this inhibits a quantitative leakage risk assessment. Future reviews would benefit from gathering data on the extent of Oregon’s trade with individual states and jurisdictions, allowing for a more sophisticated analysis of Oregon’s trade exposure, including key export competitor dynamics (discussed in Box 4).



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## Appendix 1 – Data Approximation Process

**The analysis approximated data for three NAICS 4 sectors that had withheld value added and/or production data for confidentiality purposes:**

- Pulp, Paper, and Paperboard Mills (3221)
- Non-metallic Mineral Mining and Quarrying (2123)
- Iron and Steel Mills and Ferroalloy Manufacturing (3311)

### **Production**

The US Census Bureau's Annual Survey of Manufactures (ASM) provided production for Oregon NAICS 4 sectors over 2014–16; however, data approximation was required for:

- Non-metallic Mineral Mining and Quarrying (2123)
- Iron and Steel Mills and Ferroalloy Manufacturing (3311)

**Non-metallic Mineral Mining and Quarrying.** We approximated annual production by using US Census Bureau employment data<sup>29</sup> for Oregon, and assuming the sector's correlation between employment to total production over 2014–16 is the same as was observed in Oregon in the US Census Bureau's (2012) Economic Census.

**Iron and Steel Mills and Ferroalloy Manufacturing.** We first estimated employment in the Oregon sector in 2014 and 2015 by using ASM employment data for Oregon in 2016, and assuming the Oregon sector employment growth changes over 2014–16 reflect the same annual rate changes over 2014–16 as the national sector. Subsequently, we approximated annual production by assuming the Oregon sector reflected the same average correlation between employment and production added over 2014–16, as found in the sector at the national level.

### **Value added**

The US Census Bureau's ASM provided value added data for Oregon NAICS 4 sectors over 2014–16; however, data approximation was required for:

- Pulp, Paper, and Paperboard Mills (3221)
- Non-metallic Mineral Mining and Quarrying (2123)
- Iron and Steel Mills and Ferroalloy Manufacturing (3311)

**Pulp, Paper, and Paperboard Mills.** We approximated annual value added by assuming the Oregon sector reflects the same average correlation between production and value added that is reflected in the national sector over 2014–16. We then multiplied this correlation to Oregon-level annual production over 2014–16 to approximate value added each year.

**Non-metallic Mineral Mining and Quarrying.** We approximated annual value added by using approximated annual production data and assuming the sector over 2014–16 reflects the same correlation between value

<sup>29</sup> US Census Bureau (2018), "Geography Area Series: County Business Patterns" - CB1600A11.



added and production as reflected for NAICS 212319 in US Census Bureau’s 2012 “Mining: Geographic Area Series: Industry Statistics for the State or Offshore Area: 2012”.<sup>30</sup>

**Iron and Steel Mills and Ferroalloy Manufacturing.** We approximated annual value added by using approximated annual employment data and assuming Oregon’s NAICS 3311 sector reflects the same average correlation between employment and value added over 2014–16, as found in the sector at a national level.

<sup>30</sup> US Census Bureau (2016), ‘Mining: Summary Series: General Summary: Detailed Statistics by Subsectors and Industries: 2012’



## Appendix 2 – Academic Evidence on Carbon Leakage

Table 23. *Ex ante* and *ex post* studies differ significantly in their findings on carbon leakage for key industrial sectors

Sector	<i>Ex ante</i>			<i>Ex post</i>		
	Author	Scope	Predicted carbon leakage rate (%)	Author	Scope	Strong evidence of leakage
Iron and steel	Gray, Linn, and Morgenstern (2016)	California; 1989-2009; carbon price \$15	Output loss: 12% Employment loss: 8%	Boutabba and Lardic (2017)	Phases I and II and part of Phase II of the EU ETS; 2005-15	No
	Ritz (2009)	EU ETS; calibration 2003-05; carbon price €20	9–75 (EU to ROW)	Branger, Quirion, and Chevallier (2017)	Phases I and II of the EU ETS; 2005-12	No
	Santamaría, Linares, & Pintos (2014)	EU ETS-covered part of steel in Spain; carbon price €5-35	18–95 (Spain to ROW)	Chan, Li, and Zhang (2013)	EU ETS before and after implementation; 2001-09	No
				Bruyn, Markowska, and Nelissen (2010)	EU ETS; 2005-09	No
				Ellerman, et al (2010)	Phase I of the EU ETS	No
Cement	Allevi et al. (2013)	EU ETS-covered part of cement (clinker) in Italy; carbon price €32-100	17–100 (Italy to ROW)	Boutabba and Lardic (2017)	Phases I and II and part of phase II of the EU ETS; 2005-15	No
	Healy, Quirion, and Schumacher (2012)	EU 2005-2012; gray clinker market; carbon price €20	22 (EU to ROW)	Branger, Quirion, and Chevallier (2017)	Phases I and II of the EU ETS; 2005-12	No
	Szabó, Hidalgo, Ciscar, and Soria (2006)	EU and Kyoto Protocol Annex B countries; 1990-97; carbon price €28-40	Carbon leakage: 29; production leakage: 33 (EU and Annex B countries to ROW)	Chan, Li, and Zhang (2013)	EU ETS before and after implementation; 2001-09	No
	Santamaría, Linares, and Pintos (2014)	EU ETS-covered part of cement in Spain; carbon price €5-35	35–80 (Spain to ROW)	Ellerman, et al (2010)	Phase I of the EU ETS	No
	Gray, Linn, and Morgenstern (2016)	California; 1989-2009; carbon price \$15	Output loss: 9% Employment loss: 6%			
Glass	Gray, Linn, and Morgenstern (2016)	California; 1989-2009; carbon price \$15; class containers only	Output loss: 17% Employment loss: 13%	Oberndorfer, Alexeeva-Talebi, and Loschel (2010)	EU ETS on prices in UK manufacturing; 2001-07; selected products only	Low cost pass-through indicates some effect on competitiveness
Pulp and paper	Gray, Linn, and Morgenstern (2016)	California; 1989-2009; carbon price \$15	Output loss: 14% Employment loss: 11%	Abrell, Zachmann, and Ndoye (2011)	EU ETS; 2005-08	No



Sector	<i>Ex ante</i>			<i>Ex post</i>		
	Author	Scope	Predicted carbon leakage rate (%)	Author	Scope	Strong evidence of leakage
Chemicals				Anger and Oberndorfer (2008)	EU ETS on competitiveness in Germany	No
				Yu (2013)	EU ETS on competitiveness in Sweden; 2004-06	No
	Gray, Linn, and Morgenstern (2016)	California; 1989-2009; carbon price \$15; only “all other basic inorganic chemical manufacturing”	Output loss: 7% Employment loss: 4%	Bruyn, Markowska, and Nelissen (2010)	EU ETS; 2005-09	No
				Oberndorfer, Alexeeva-Talebi, and Loschel (2010)	EU ETS on prices in UK manufacturing; 2001-07; selected products only	No
				Yu (2011)	EU ETS on competitiveness in Sweden; 2004-06	No

*Note:* Sector definitions might not exactly align with the granularity used in the sectoral analysis in Section 4. ROW, rest of world.

*Source:* Vivid Economics



## Appendix 3 – Sector Analyses

**The Oregon Carbon Policy Office (CPO) is undertaking technical work to understand the impacts of a cap-and-trade in the state.** The policy design under discussion would price greenhouse gas (GHG) emissions of facilities emitting more than 25,000 tCO<sub>2</sub>e annually.<sup>31</sup> Integral to this process is the determination of carbon leakage risk faced by potentially covered Oregon facilities.

**These briefs are central to qualitative analysis to understand leakage risk for each sector; quantitative analysis provides only a high-level assessment.** This project utilizes data on emissions and gross value added to understand a sector's exposure to a carbon cost. However, such quantitative analysis can provide only a partial understanding of leakage risk factors. As a result, the project has also involved interviews and workshop engagements to develop these briefs and offer a holistic understanding of whether a sector is EITE.

**These briefs offer analysis on the factors which determine carbon leakage risk faced by each manufacturing sector in Oregon.** They are structured as follows:

- An overview of the sector and key trends in the industry, including which relevant NAICS 4 subsectors would potentially be covered by a carbon price;
- The identification of the relevant subsector exposure to carbon costs by exploring products, processes, and key emissions reduction options;
- The market and competitive dynamics of the relevant subsector by considering both domestic competition with other US states and international competition;
- How key jurisdictions have classified the carbon leakage risk of the subsector; and
- Conclusions on the overall carbon leakage risk of the sector.

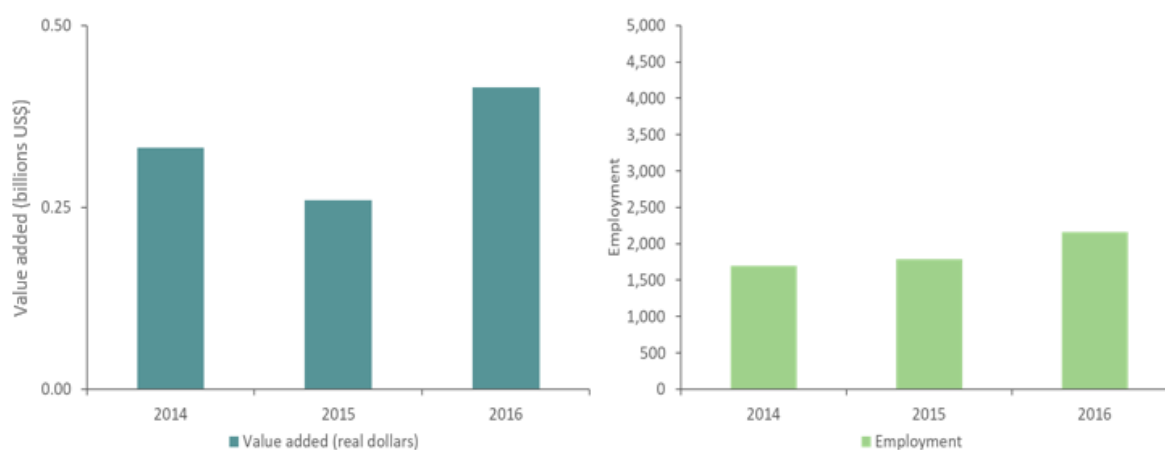
<sup>31</sup> tCO<sub>2</sub>e denotes one metric ton of carbon dioxide equivalent. All weights referenced in this brief are metric.

# Cement

## Sector background

**Cement and concrete manufacturing is a small but expanding sector in Oregon and gives rise to significant emissions.**<sup>32</sup> The sector employed just over 2,000 employees in 2016 in Oregon, which grew from 1,700 in 2014. Similarly, the Oregon sector's annual value added appears to be rebounding, as shown in Figure 18. Over 2012–16 cement consumption in Oregon increased by almost 50%, which has contributed to the sector's resurgence. However, Oregon's 2016 cement consumption levels of around 860,000 metric tons was still well below peak levels in 2006, before the financial crisis (Portland Cement Association, 2017). The sector was also one of the largest absolute emitters in Oregon's manufacturing sector over 2014–16, after the pulp and paper sector.

Figure 18. The Oregon cement and concrete sector experienced a net increase in value added over 2014–16



Source: Vivid Economics and US Census Bureau

**The facilities in this sector are part of international conglomerates.** The four Oregon cement and concrete facilities each belong to international conglomerates with facilities in different US states and countries mostly without a carbon price on the horizon. This poses a risk of production being reallocated to states with no carbon price, which, particularly if relocated to less-efficient facilities, could lead to carbon leakage.

**Only one Oregon facility in this parent sector would potentially be covered under a carbon price – a cement manufacturing plant.** This facility emits significantly more (between 150 and 400 times as much) than the other three facilities, which import cement and produce concrete. It directly employs around 100 workers and forms the focus of analysis for the remainder of this brief.

<sup>32</sup> Data in this subsection refers to this parent sector, while the scope of the remainder of the brief is for cement only.



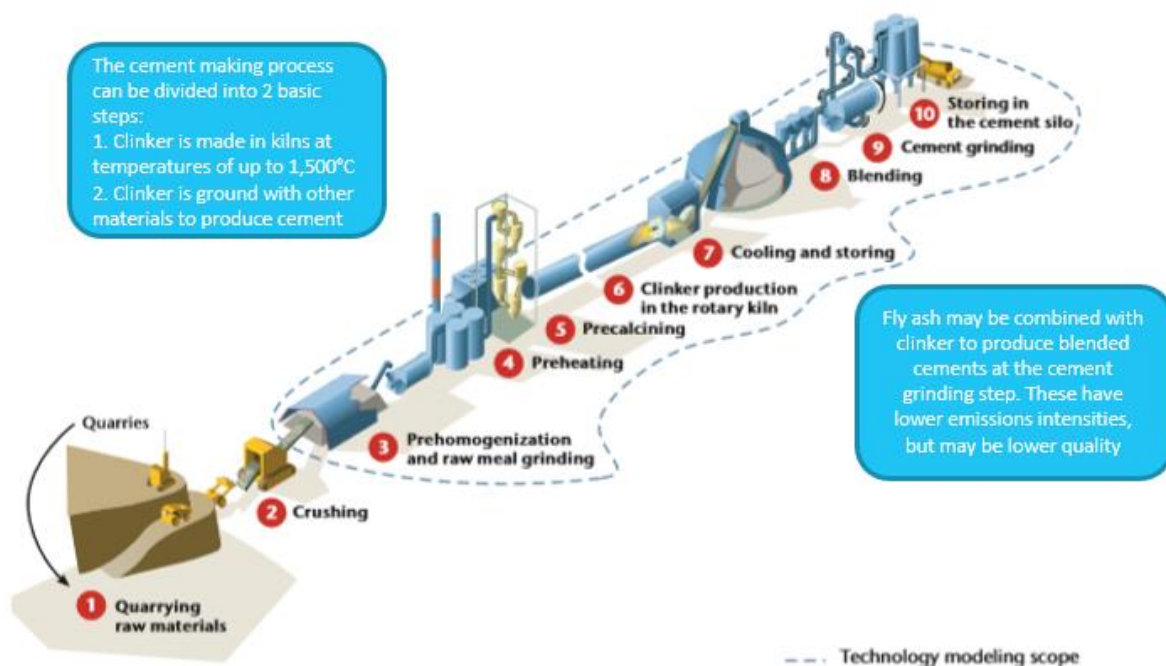
## Carbon cost exposure

### *Products and production processes*

The key direct emissions-intensive process in cement production is clinker production, with process emissions forming a significant share of the production of the material. Raw materials, primarily limestone and clay, are first blended and ground, then heated in kilns at temperatures of up to 1,500°C to make clinker. Producing Portland cement entails heating ground limestone to a very high temperature in kilns to produce calcium oxide, with carbon dioxide emitted as a result – a process emission inherent to the production of cement. The burning process takes several hours and produces clinker in the form of spherical pebbles. This burning process varies by type of limestone; some take longer than others and require greater heat inputs. Portland cement is the sector’s main product and the production capacity of the covered facility is around 1 million tons of clinker per year.

Cement types are generally distinguished by clinker concentration ratios. Clinker is ground and mixed with a small amount of gypsum or anhydrite to make Portland cement. To make blended cement, clinker and gypsum or anhydrite is ground with materials such as fly ash, limestone dust and granulated blast-furnace slag, also referred to as supplemental cementitious material (SCM). The lower proportions of clinker in blended cements make them less emissions-intensive. An integrated plant produces its own clinker and, from this, cement; whereas a grinding plant buys clinker from other producers and grinds it into cement without any direct emissions (although there are no standalone grinding plants in Oregon).

Figure 19. The production of clinker is the most energy-intensive process within cement production



Source: Vivid Economics and IEA

The cement manufacturing sector in Oregon does not buy fly ash to produce cement. Stakeholders suggest there is little to no availability of fly ash in Oregon, which makes blended cement production challenging. This has led the cement sector to focus on producing Portland cement.

### ***Emissions reduction opportunities***

**Cement manufacturing is highly energy-intensive, and most emissions stem from the calcination process, which have few economically viable abatement opportunities.** Process emissions stem from the burning of calcium carbonate in the production of clinker, while emissions from energy use are caused by the combustion of fuels. In general, heating of raw materials in the kiln constitutes around 75% of total cement manufacturing energy consumption (Radwan, 2012). However, most direct emissions are process emissions: on average, over 2011–15, the EU cement sector’s combustion emissions from energy use comprised 35% of total sectoral direct emissions (European Commission, 2015b), with the remainder being process emissions. There are a range of technically viable opportunities to abate these emissions; however, they are not economically viable in the short-to-medium term (Energy Transitions Commission, 2018).

**The cement sector in Oregon has been taking steps to limit its impact on the environment, and Oregon’s only cement manufacturing plant is in the top 25th percentile for energy efficiency nationally.** Following the federal Clean Air Act, the cement sector has invested in pollution controls. The sector has also been improving its energy efficiency – for example, the installation of technology to reduce energy use by fans by 50%. The covered facility in Oregon is an Energy Star-certified plant, meaning that it is in the top 25th percentile of energy efficiency for all US cement facilities. Further research is required on the capacity of the plant to continue to reduce emissions through efficiency measures.

**There are two key abatement opportunities in the production of cement generally; the applicability to the Oregon facility may be limited, however, and further research is required in this area** (European Cement Research Academy, 2017). The key areas are:

1. Increasing the production of blended cement
2. Switching away from coal through waste fuels or natural gas

**1. Blended cement contains smaller proportions of clinker and thus reduces the energy needed in production; however, further research is required on the viability of this option:**

- Customers tend to demand a specific cement quality, with stakeholders noting that the majority of the market currently demands ASTM C150 standard Portland cement, which has fixed content specifications (ASTM International, 2018). Production of this cement is thus demand-led.
- Including alternative materials may also be constrained by other quality standards limiting toxicity and product performance requirements.
- Stakeholders suggest that alternative cementitious materials such as fly ash and pozzolans are in limited supply in Oregon and have few long-term prospects for supply. In Washington and Oregon, the low levels of coal-fired power generation and impending closures of remaining facilities may result in a local supply shortage of fly ash, requiring the material to be transported from eastern states or Canada.
- Further research is required on whether importing fly ash from outside of the state to the Oregon cement facility is economically viable, or whether it would result in reduced life-cycle emissions once transport emissions are accounted for.

**2. A significant emissions reduction option for the cement sector is fuel-switching towards more recovered waste fuels, but this opportunity is limited in the US given recent legislation.** In the EU, a supportive regulatory environment has helped cement facilities increase their proportion of waste fuels consumed – by up to 80% in some facilities (European Commission, 2013). Non-hazardous waste sources frequently used as fuels include wood, paper and cardboard wastes; plastics; municipal sewage sludge; animal fats; rubber; and textiles. However, the use of household and commercial waste for US cement facilities is limited by federal rules. The 2011 Commercial and Industrial Solid Waste Incinerator Units (CISWI) rule passed by the Environmental Protection Agency (EPA) imposes stringent emission standards

for incinerators. This includes kilns that use commercial and industrial solid waste as fuel. Other recent regulations on non-GHG pollutants in Oregon also introduce uncertainty on their applicability. The potential to utilize non-CISWI regulated waste streams as a fuel-switching option may remain, although further research is required on the economic viability and environmental impact of such switches once life-cycle, including transport emissions are accounted for. The remote nature of the plant in Oregon is another factor which should be accounted for when considering processing and delivering such fuels.

**In the long run, increased use of natural gas has technical potential to reduce emissions (EPA, 2010).**

Stakeholders suggest that the price of natural gas is not currently favorable to such a switch and that they typically enter into 3–5-year contracts for coal. However, gas remains a technically feasible alternative, and the main constraint on its use is such economic considerations. A high degree of switching from coal to natural gas is technically feasible for cement facilities without a significant decline in plant performance, provided facilities optimize burner specifications to account for natural gas (Akhtar et al., 2013). However, stakeholders suggest that natural gas reliability is a current concern: since natural gas cannot be stored like coal, in times of outages this can limit production potential and damage equipment.

***Relative emissions intensity***

**The cement manufacturing sector in Oregon has one of the highest emissions intensities in the state.** Table 24 shows the sector to have an average emissions intensity over 2014–16 of 2,246 tCO<sub>2</sub>e/US\$ value added. California’s carbon leakage risk identification methodology would deem cement manufacturing as having a medium emissions intensity. However, in Oregon, this sector has the second-highest emissions intensity out of all NAICS 4 covered sectors, after gypsum manufacturing.

**The Oregon covered cement facility may be less efficient than EU product benchmark levels.** Assuming the facility ran at 80% capacity<sup>33</sup> (around 800,000 tons of clinker) over 2014–16 allows us to calculate the facility’s emissions intensity of production and compare these with EU benchmark levels. Over 2014–16, the covered facility in Oregon emitted on average 660 ktCO<sub>2</sub>e, which would imply an emissions intensity of 0.825 tCO<sub>2</sub>e/ton of clinker. This would make the facility less efficient than the EU Emissions Trading System (ETS) Phase III benchmark for gray cement clinker (0.766 allowances/ton) (European Commission, 2011b). While European benchmarks do not account for Oregon’s context, due to different local limestones potentially requiring longer burning periods, the benchmarks provide an order of magnitude comparison of the emissions efficiency potential of clinker production generally.

<sup>33</sup> 2017 US average capacity utilization was 78.9% . <https://www.cement.org/docs/default-source/market-economics-pdfs/issues-trends/us-cement-manufacturing-capacity-feb-2017.pdf?sfvrsn=2&sfvrsn=2>

**Table 24. One cement and concrete product manufacturing facility would potentially be covered by a carbon price**

NAICS code	Sector description	Average sectoral direct emissions (ktCO <sub>2</sub> e)	Average sectoral indirect emissions (ktCO <sub>2</sub> e)	Average value added (US\$ million)	Average direct emissions intensity of value added (tCO <sub>2</sub> e/value added US\$ million)	Average total emissions intensity of value added (tCO <sub>2</sub> e/value added US\$ million)
3273	Cement and Concrete Product Manufacturing	670	62	326	2,055	2,246

*Note:* Indirect emissions estimated assuming the subsectors reflect the electricity intensity of production of the subsector at a national level and all facilities' electricity has the average emissions factor of the carbon intensity of Oregon's electricity grid over 2014–16 of 0.3610 tCO<sub>2</sub>e/MWh (DEQ, 2018b).

*Source:* Vivid Economics, DEQ and US Census Bureau's "Annual Survey of Manufactures"

## Markets and competitive dynamics

**Oregon's cement sector serves Oregon and the states surrounding it.** The cement sector produces cement for roads, bridges and buildings. Stakeholders noted that a particularly significant market exists between Oregon, Washington, Montana and Utah. It is not economic to export cement further than this due to the high cost of road transport relative to the value of cement. Stakeholders suggested that the Oregon covered facility has historically served one third of the Oregon market and provides cement to residential, commercial, and domestic consumers.

**The cement manufacturing sector closely follows the trends in the construction sector.** Cement is primarily used in construction and hence demand increases when and where there is more construction.

### *Domestic competition*

**The cement sector in Oregon does not compete with other US states.** According to stakeholders, no US plant, other than the Durkee facility, supplies cement for Oregon. The high transportation costs of cement limit domestic competition from other US states.

**In the Oregon market, the cement sector also competes with engineered wood product manufacturers in Oregon and other states.** Oregon recently changed the law regarding the maximum allowable height of timber buildings. It is the first state to allow timber buildings to rise higher than six stories without special consideration (Hilburg, 2018). This opens up the construction market for engineered wood products, particularly cross-laminated timber (CLT). Cement is heavily used in the construction sector, so this sector may eventually face increasing competition from wood product manufacturers as CLT becomes more widely adopted in buildings.

### *International competition*

**The Oregon cement sector's main international competition comes from China.** Stakeholders note that Chinese producers are able to manufacture cement and ship to the US at very low prices. Shipping being less costly than road transport expands the reach of their exports cost-effectively. Stakeholders suggest that more than two thirds of the cement used in Oregon is imported and most of this comes from China. This is in line with overall national trends in cement imports from China to the US: they increased by almost 300% over 2012–15 (Portland Cement Association, 2016). If Chinese producers displace the domestic market share of

local Oregon producers, this could result in significant emissions leakage. This is particularly the case given the more emissions-intensive Chinese electricity grid and maritime shipping emissions resulting from greater transportation distances.<sup>34</sup>

### **Cost pass-through capacity**

**Competitive dynamics suggest the cement industry in Oregon may have limited cost pass-through ability.**

The sector faces domestic competition from other northwestern US states without carbon pricing and international competition largely from Chinese producers.

**However, the EU offers some evidence that cement producers' carbon cost pass-through capacity may be high.** An *ex post* investigation into the carbon cost pass-through capacity of different EU sectors found Portland cement producers to have significant cost pass-through rates in Poland and the Czech Republic of between 90–100% (European Commission, 2015c).<sup>35</sup>

## **Leakage risk identification in other jurisdictions**

**Other jurisdictions placed their cement sector at risk of carbon leakage.** Analysis of the cement sector in different jurisdictions produced the following results:

- EU ETS Phase III metric: cement identified based on the cost increase metric;
- EU ETS Phase IV metric: cement identified;
- California metric: cement identified to exhibit “high” leakage risk based on high emissions intensity.

*Table 25. Treatment of the cement sector in external jurisdictions*

Metric	EU ETS Phase III				EU ETS Phase IV	California		
	Trade intensity	Cost increase	Joint metric	Identified	Identified	Trade intensity	Emissions intensity	Level of risk
Initial assessment	No	Yes	Yes	Yes	Yes	Medium	High	High

Source: Vivid Economics

## **Conclusion**

**There are several factors that suggest the cement and concrete manufacturing sector in Oregon is EITE:**

- The sector's emissions intensity is one of the highest in the state.
- The sector's cost pass-through capacity may be limited due to a growth in competition from Chinese manufacturers.<sup>36</sup>

<sup>34</sup> In 2015, China's average electricity emissions factor was 0.66 tCO<sub>2</sub>/MWh relative to Oregon's average electricity sector emissions factor of 0.36 tCO<sub>2</sub>e/MWh over 2014–16 (IEA, 2017; DEQ, 2018).

<sup>35</sup> While cost pass-through rates will depend on many factors which will likely be different between those observed in Europe and those in Oregon, especially market scope and competitive dynamics, this data point is instructive as it presents one of the few examples of observed experiences of carbon cost pass-through capacity under a cap-and-trade.

<sup>36</sup> This will become less of a concern as China's national cap-and-trade begins imposing compliance obligations and gradually expands its coverage to industrial sectors.

- Most emissions are process emissions inherent to the production of clinker and are technically very challenging to abate.
- Precedents from the EU and California suggest that the sector may be at risk of carbon leakage.

**However, there are several factors which reduce underlying carbon leakage risk:**

- The sector has seen robust demand growth in recent years, with consumption rising by almost 50% during 2012–16, although it is still below the peak levels experienced before the financial crisis.
- US domestic competition from states further away from Oregon may be limited due to road transport cost constraints within the sector.
- Emissions intensities may be higher than European benchmark levels.
- Some evidence from the EU suggests that cement producers may have high carbon cost pass-through capacity.

**On balance, the sector is at risk of carbon leakage if Oregon introduces a carbon price without measures to protect against possible adverse competitiveness impacts.** A carbon pricing instrument for this sector should be designed to ensure that innovation and emissions reduction incentives remain, while also incorporating measures to protect against the risk of carbon leakage and other competitiveness impacts.

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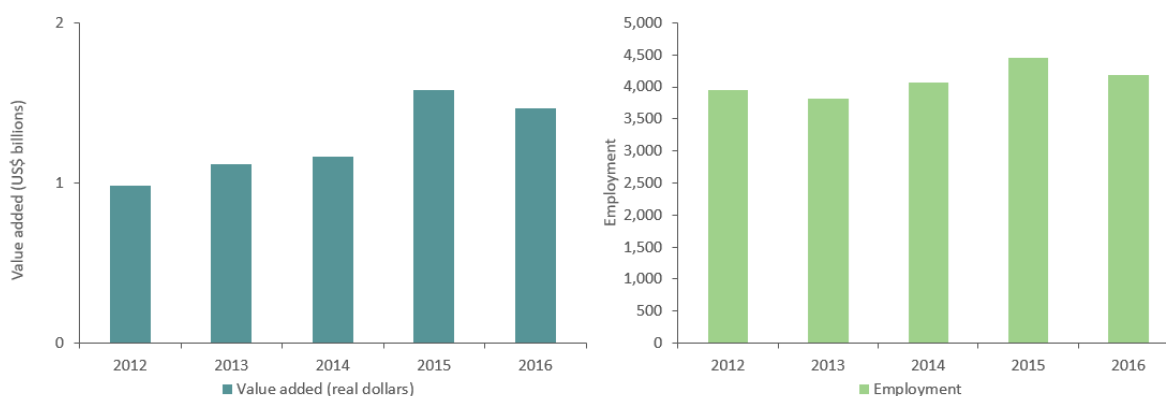
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# Chemicals

## Sector background

**Chemicals manufacturing (NAICS 325) is a small but growing sector in Oregon.** Figure 20 shows how the sector's value added has grown from just below US\$1 billion to around US\$1.5 billion over 2012–16 at an annual average growth rate of 10%, while employment has averaged at around 4,000 workers.

*Figure 20. The Oregon chemical manufacturing sector has experienced strong growth in value added over 2012–16*



Source: Vivid Economics and US Census Bureau

**The industry has been changing over time to meet demand.** Wood-related chemicals have been replaced by other products (such as basic organic chemicals or toilet preparation manufacturing). There has also been growth in supplements manufacturing for vegans and vegetarians (Rooney, 2018a).

**The basic chemical manufacturing subsector (NAICS 3251) is the only subsector that has facilities potentially covered under a carbon price.** In Oregon there are 12 chemical manufacturing facilities reporting emissions over 2014–16, only two of which from one subsector would potentially be covered under a carbon price. Table 26 shows the breakdown of the Oregon chemicals manufacturing sector at the NAICS 4 level.

**Table 26. Two basic chemical manufacturing facilities would potentially be covered under a carbon price**

NAICS 4 Code	Sector description	No. facilities reporting emissions over 2014–16	No. facilities emitting more than 25 ktCO <sub>2</sub> e over 2014–16
3251	Basic Chemical Manufacturing	4	2
3252	Resin, Synthetic Rubber, and Artificial Synthetic Fibers and Filaments Manufacturing	5	0
3253	Pesticide, Fertilizer, and Other Agricultural Chemical Manufacturing	0	0
3254	Pharmaceutical and Medicine Manufacturing	1	0
3255	Paint, Coating, and Adhesive Manufacturing	1	0
3256	Soap, Cleaning Compound, and Toilet Preparation Manufacturing	0	0
3259	Other Chemical Product and Preparation Manufacturing	1	0

Source: Vivid Economics and DEQ

## Carbon cost exposure

### *Products and production processes*

**Covered facilities in the Oregon basic chemical manufacturing subsector produce ammonium nitrate and ethanol, respectively.** Ammonium nitrate is used in fertilizers for agriculture, and ethanol is used in low-carbon renewable fuels and high-quality alcohol products.

**One covered facility emits significantly more emissions than the other potentially covered facility.** The facility producing ammonium nitrate emitted an average of 189,000 tCO<sub>2</sub>e between 2014 and 2016. The facility producing ethanol emitted an average of 38,000 tCO<sub>2</sub>e between 2014 and 2016.

**The majority of emissions in the production of ammonium nitrate come from chemical processes, which tend to be more difficult to abate.** Natural gas, steam and air are combined in catalytic reactors to produce nitrogen, hydrogen and carbon dioxide. The nitrogen produced reacts with hydrogen to produce ammonia, which then reacts with carbon dioxide to produce urea. The ammonia is also reacted with water and air to produce nitric acid, which then reacts with ammonia to produce ammonium nitrate. The creation of these products results in significant chemical process emissions and requires considerable energy consumption. However, the inherent emissions-intensity of the chemical process implies that process emissions will outweigh natural gas combustion emissions (Vivid Economics & DECC, 2014). In 2016, the Oregon ammonium nitrate facility chemical process emissions accounted for 58% of total anthropogenic emissions, while stationary combustion emissions accounted for 42% (Oregon DEQ, 2016).

**Emissions from the ethanol production process come primarily from natural-gas-fired boilers.** Corn is delivered to facilities via truck or rail and conveyed either to storage or to the scalping process, and for milling in the hammermills. The meal from the hammermills is mixed with water and enzymes and is heated to liquify the mixture. The resulting mash in the slurry tank is then mixed with yeast and additional enzymes in the fermentation process. The resultant liquid contains 10–15% ethanol. The carbon dioxide produced by the fermentation process is scrubbed in a packed tower scrubber. The ethanol is then separated, and the rest is processed into wet cake which is used as animal feed. The majority of emissions come from the use of natural-gas-fired boilers for the slurry tank, fermentation tanks and distillation columns.



### **Emissions reduction opportunities**

**There may be limited opportunity for emissions reductions through fuel switching in ammonium nitrate production, although further research is required in this area.** The use of natural gas is currently the most efficient production route (European Commission, 2007). There do not appear to be any fuel-switching opportunities in the short term. In the long term, options may include the gasification of biomass and electricity-based ammonia production. However, further research is required on the technical and economic viability of these options.

**Energy efficiency measures are potential avenues for emissions reductions.** There are improvements to be made in energy efficiency such as switching to light-emitting diode (LED) lighting, optimizing compressed air systems and installing variable frequency drives (VFDs) in electric motors. Similarly, some integrated EU chemical sites have implemented excess heat and steam recovery to improve energy efficiency (Vivid Economics & DECC, 2014).

### **Relative emissions intensity**

**The basic chemical manufacturing sector is relatively emissions-intensive in Oregon.** The sector was the fifth most emissions-intensive sector in the state over 2014–16. The total emissions intensity would be categorized as low under Californian cap-and-trade thresholds, but is on the verge of being “medium” ( $\geq 1,000$  tCO<sub>2</sub>e/value added US\$ million).

*Table 27. The basic chemicals subsector in Oregon has a relatively high emissions intensity*

NAICS code	Sector description	Average sectoral direct emissions (ktCO <sub>2</sub> e)	Average sectoral indirect emissions (ktCO <sub>2</sub> e)	Average value added (US\$ million)	Average direct emissions intensity of value added (tCO <sub>2</sub> e/ value added US\$ million)	Average total emissions intensity of value added (tCO <sub>2</sub> e/ value added US\$ million)
3251	Basic Chemical Manufacturing	230	96	343	671	950

*Note:* Indirect emissions estimated assuming the subsectors reflect the electricity intensity of production of the subsector at a national level and all facilities’ electricity has the average emissions factor of the carbon intensity of Oregon’s electricity grid over 2014–16 of 0.3610 tCO<sub>2</sub>e/MWh (DEQ, 2018b).

*Source:* Vivid Economics, DEQ and US Census Bureau

## **Markets and competitive dynamics**

**The market for ammonium nitrate fertilizers is largely US agriculture.** In particular, agricultural operations in the Midwest and northwest region of the US are significant market locations.

**The ethanol manufacturing facility is the only Oregon facility that supplies fuel companies to meet the low-carbon fuel mandate** (Borrud, 2016).

### ***Domestic competition***

**The US is the largest producer of ethanol worldwide, leading to domestic competition for the Oregon ethanol producing facility.** The US represents around 57% of fuel ethanol production (Renewable Fuels Association, 2016). Iowa, Nebraska, Illinois, Minnesota, Indiana and South Dakota each produce more 100 million gallons a year (Renewable Fuels Association, 2016).

**In particular, Oregon imports ethanol via rail from Minnesota, Kansas and Nebraska** (Borrud, 2016). These states do not have a carbon price and this could limit Oregon producers' ability to pass through costs without losing market share for ethanol.

**The ammonium nitrate producing facility competes with facilities in other states.** Oregon producers may face competition from other states. US ammonium nitrate producers are found in New Jersey, Texas, Pennsylvania, California, and Connecticut (USA Chemical Suppliers, 2018).

**Both chemical facilities potentially covered are owned by companies with additional facilities in other states not under a carbon price.** The company producing ammonium nitrate in Oregon also has a facility producing ammonium nitrate in Wyoming (Dyno Nobel, 2018). The company that owns the ethanol facility also has plants in Nebraska, Idaho, California and Illinois (Pacific Ethanol, 2018). This suggests that production could potentially be reallocated to facilities in states not subject to a carbon price.

### ***International competition***

**Brazil is a large ethanol producer and exports to the US.** Brazil produces ethanol from sugar cane and used to be the largest producer of ethanol in the world (Renewable Fuels Association, 2016). While the US is now the largest producer, it still faces competition from Brazil (Wisner, 2012).

**The US is a global net importer of ammonium nitrate fertilizer, but significant international competitors are increasingly subject to carbon pricing.** In 2012, the US imported more than double the ammonium nitrate than it exported. However, two of the top three importing countries, reflecting 56% of imports, were Canada and the Netherlands (US Department of Agriculture, 2013). These two countries are either covered under a carbon price or are moving towards greater use of carbon pricing. Similarly, Canada and Mexico were the two most significant destinations for US ammonium nitrate exports in 2012 (US Department of Agriculture, 2013).

### ***Cost pass-through capacity***

**The basic chemicals manufacturing subsector may have limited cost pass-through capacity given these competitive dynamics.** Competition from other US states without a carbon price could produce pricing asymmetries leading to loss of market share.

**However, evidence from the EU suggests that fertilizer producers have significant cost pass-through capacity.**<sup>37</sup> Fertilizers made from ammonium nitrate, calcium ammonium nitrate, and urea ammonium nitrate were found to have cost pass-through rates over 100% in the UK, Germany and France (European Commission, 2015c). Transportation costs (relative to product prices) of nitrogen fertilizer products have

<sup>37</sup> While cost pass-through rates will depend on many factors which will likely be different from those observed in Europe and those in Oregon, especially market scope and competitive dynamics, this data point is instructive as it presents one of the few examples of observed experiences of carbon cost pass-through capacity under a cap-and-trade.

been found to be higher than for products such as steel or refinery products in the EU (European Commission, 2015c). This could limit the scope for competition over large distances.

## Leakage risk identification in other jurisdictions

**The chemicals manufacturing sector has been identified as at risk of leakage in other jurisdictions:**

1. EU Emissions Trading System (ETS) Phase III metric: chemicals identified based on the trade intensity metric;
2. EU ETS Phase IV metric: chemicals identified;
3. California metric: chemicals identified to exhibit “high” leakage risk based on high trade intensity.

*Table 28. Treatment of the chemicals sector in external jurisdictions*

Metric	EU ETS Phase III				EU ETS Phase IV	California		
	Trade intensity	Cost increase	Joint Metric	Identified	Identified	Trade intensity	Emissions intensity	Level of risk
Initial assessment	Yes	No	Yes	Yes	Yes	High	Medium	High

Source: *Vivid Economics*

## Conclusion

**There are several factors that suggest that the basic chemicals subsector is at risk of carbon leakage:**

- The sector is relatively emissions-intensive and has few abatement opportunities for the near future, especially with respect to process emissions.
- The sector competes externally with other US states and other countries. Some of these external jurisdictions are not subject to a carbon price, which limits the sector’s ability to pass through costs.
- The facilities potentially covered are part of larger companies with facilities in states with no carbon price, and where production relocation could therefore occur.
- Precedents from the EU and California suggest the sector may be risk.

**However, several factors reduce underlying leakage risk:**

- There are likely to be energy efficiency options available to reduce emissions. Facilities can optimize their equipment and processes and implement heat-recovery systems to improve efficiency and lower the carbon cost faced.
- Some evidence from Europe suggests that fertilizer producers may have high cost pass-through capacity.

**The sector is likely at risk of carbon leakage if Oregon introduces a carbon price without measures to protect against possible adverse competitiveness impacts; however, further research is required to understand these risk factors more conclusively.** A carbon pricing instrument for this sector should be designed to ensure that innovation and emissions reduction incentives remain, while also incorporating measures to protect against the risk of carbon leakage and other competitiveness impacts. However, further research is necessary to understand the nature and extent of these risks.

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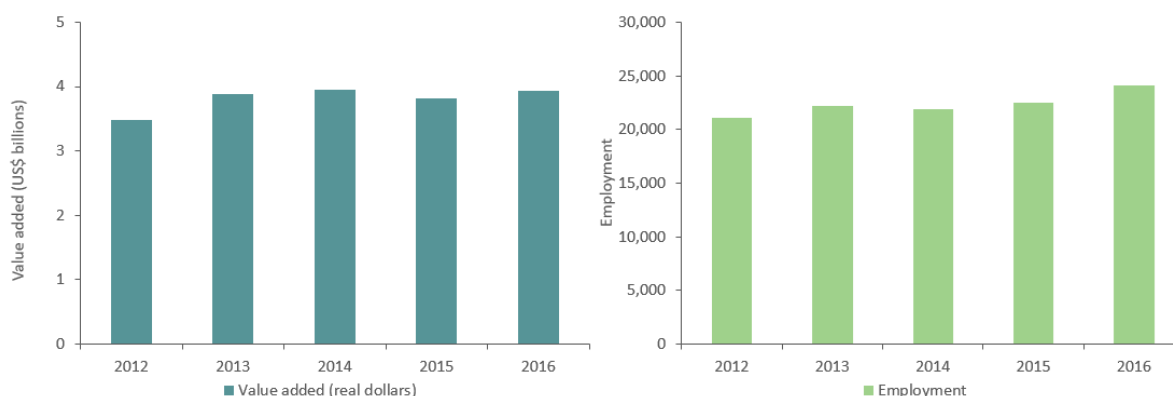
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# Food Manufacturing

## Sector background

The food manufacturing sector (NAICS 311) is a significant employer in the state and has recently experienced robust growth. There are 637 food manufacturing companies in Oregon and the food processing sector is the third-largest manufacturing sector in the state, with almost 25,000 employees. Food processing facilities are concentrated in Greater Portland, the Willamette Valley, the Columbia Gorge, the Oregon Coast and Southern Oregon. Food manufacturing was the only Oregon sector to have no significant job losses during the 2008 recession (Mortenson, 2016). This consistent performance is illustrated in Figure 21, which shows that the sector's employment and value added have been on an upward trajectory overall during 2012–16. The sector reflects around 14% of total manufacturing value added and grew on average 3% each year over 2012–16, which is roughly in line with the average growth of the rest of Oregon's manufacturing sectors.

Figure 21. Over 2012–16, Oregon's food manufacturing sector has grown overall



Source: Vivid Economics and US Census Bureau

**Oregon has 28 food manufacturing facilities reporting emissions over 2014–16, but only five of these from one subsector would potentially be covered under a carbon price.** Table 29 shows the breakdown of the Oregon food manufacturing sector at the NAICS 4 level. Only five facilities from the Fruit and Vegetable Preserving and Specialty Food Manufacturing (3114) subsector would be covered under the carbon price. This reflects only a third of the facilities in the NAICS 3114 subsector.

**Furthermore, the facilities within this sector covered under the carbon price are all potato processing facilities.** As such, this assessment of carbon leakage risk for the food manufacturing sector focusses on specific characteristics of potato processing in Oregon. The five facilities that would potentially be covered under the carbon price had emissions between 30,000 tCO<sub>2</sub>e and 50,000 tCO<sub>2</sub>e. These facilities are located in rural eastern Oregon and are key sources of employment in this region, with significant prospects for further employment growth given prospective food company expansions.

*Table 29. Five Fruit and Vegetable Preserving and Specialty Food Manufacturing facilities would potentially be covered under a carbon price*

NAICS 4 code	Sector description	No. facilities reporting emissions over 2014–16	No. facilities emitting more than 25 ktCO <sub>2</sub> e over 2014–16
3114	Fruit and Vegetable Preserving and Specialty Food Manufacturing	15	5
3115	Dairy Product Manufacturing	1	0
3116	Animal Slaughtering and Processing	2	0
3118	Bakeries and Tortilla Manufacturing	6	0
3119	Other Food Manufacturing	3	0

Source: Vivid Economics and DEQ

## Carbon cost exposure

### *Products and processes*

**At a high level, potato processing entails six stages:** peeling, blanching, cutting, drying, frying and freezing. The main final products are frozen potatoes and appetizers for restaurants and retailers.

**The major energy- and emissions-intensive processes are pre-heating for potato blanching, drying and frying, and refrigeration for potato freezing.** These processes use a combination of natural gas and electricity as fuel sources, and substitutability between these fuels is determined by economic, safety and feasibility considerations. Stakeholders claim that electric boilers require large amounts of electricity to operate their facilities; this high-capacity power in a wet environment increases safety risks. Furthermore, experience in Washington suggests that electric boilers are not compatible with the goals and capabilities of the power suppliers in the area. Stakeholders suggested that fuel, water, and electricity comprise approximately 7–11% of the total costs of the finished products.

### *Emissions reduction opportunities*

**Oregon potato processing facilities have taken action to increase efficiency, resulting in emissions reductions.** The majority of covered facilities are owned by one company which recently invested heavily into expanding a facility in Oregon, improving operational efficiency. This company has undertaken early abatement action, having reduced its electricity consumption by approximately 40 GWh over the past eight years through process upgrades and energy efficiency improvements. It is also working with the US Department of Energy, the Environmental Protection Agency, and its utility providers to seek additional energy efficiency savings. Furthermore, stakeholders noted that Food Northwest, of which this company is a member, was the first group of the food manufacturing sector in the country to adopt a voluntary goal to reduce energy intensity, and has already achieved a 25% reduction in ten years. Food Northwest analysis indicates that natural gas accounts for about 71% of the energy input across the frozen fruits and vegetables sector, and electricity represents about 28% of energy input on a Btu basis, with other energy sources making up the remaining 1%.

**However, there are two further emissions reduction opportunities that could be considered:**

- Switching to biomass fuel to operate boilers;
- Energy efficiency improvements – stakeholders note that under their sustainability goals, they are continuously seeking economically feasible opportunities to improve efficiency.

**Food processor stakeholders claim that biomass is not a viable abatement option due to high costs, although it has been successfully employed elsewhere.** While cogeneration is an abatement measure that is in use, switching to biomass is seen as too costly in the sector. However, Frito-Lay's processing facility in Topeka, Kansas, successfully abated 5,000 tCO<sub>2</sub>e and generated energy savings of 0.3 trillion Btu in 2011 by using biomass boilers, suggesting it is a technically feasible option (US Department of Energy, 2017). Despite this, costs to roll out the technology may be high in Oregon, especially in the short-to-medium term, and further research will be required to understand the feasibility. Stakeholders stated that, while technically feasible, biomass opportunities in the high desert environment of eastern Oregon are currently not economically feasible.

**Energy efficiency improvements could be a significant emissions reduction option for the food manufacturing sector.** A range of options could be considered:

- The introduction of automated controls on natural gas boilers, insulating pipelines and improving pump efficiency. Stakeholders noted that all of these actions have been implemented in their Oregon facilities. Every boiler in stakeholders' plans in Oregon, except for two in a plant that is now being upgraded, have been replaced and upgraded in the past several years.
- Stakeholders noted that while there are new, more efficient, boilers on the market, these are expensive and would require significant capital investment.
- Assessments undertaken by the Industrial Assessment Center (IAC) for the frozen fruit and vegetable sector in Oregon indicate that modifications to refrigeration systems to operate at lower pressure result in estimated average savings of US\$20,307 and a payback period of under a year. This recommendation has an implementation rate of about 56% after being proposed nine times in the subsector in Oregon (IAC, 2018).
- The Northwest Power and Conservation Council (2016) identifies the frozen and other foods manufacturing sectors as having significant energy savings potential by 2035 due to refrigeration loads. As such, there is likely potential room for improvement.

### ***Relative emissions intensity***

**The fruit and vegetable preserving and specialty food manufacturing sector as a whole has low emissions intensity, although it is likely the potato processing subsector has higher emissions intensity than its parent sector.** Table 30 shows the subsector to have an average emissions intensity over 2014–16 of 232 tCO<sub>2</sub>e/value added US\$ million. California's carbon leakage risk identification methodology would deem this sector as having a low emissions intensity, being between 100 and 999 tCO<sub>2</sub>e/value added US\$ million. However, further research is required to determine the emissions intensity of the potato processing subsector, which comprises the facilities that are potentially covered under the carbon pricing mechanism.

**Table 30. The fruit and vegetable preserving and specialty food manufacturing subsector as a whole has a low emissions intensity**

NAICS code	Sector description	Average sectoral direct emissions (ktCO <sub>2</sub> e)	Average sectoral indirect emissions (ktCO <sub>2</sub> e)	Average value-added (US\$ million)	Average direct emissions intensity of value added (tCO <sub>2</sub> e/value added US\$ million)	Average total emissions intensity of value added (tCO <sub>2</sub> e/value added US\$ million)
3114	Fruit and Vegetable Preserving and Specialty Food Manufacturing	246	109	1,059	232	335

*Notes:* Indirect emissions estimated assuming the subsectors reflect the electricity intensity of production of the subsector at a national level and all facilities' electricity has the average emissions factor of the carbon intensity of Oregon's electricity grid over 2014–16 of 0.3610 tCO<sub>2</sub>e/MWh (DEQ, 2018b).

*Source:* Vivid Economics, DEQ and US Census Bureau

## Markets and competitive dynamics

**The market for frozen potatoes is expanding and consumers are retail and food service companies across North America, parts of Asia the Middle East and Mexico.** Market demand for frozen potato products is growing at 2.3% annually – approximately 300 million lbs per year – which stakeholders note is comparable to the capacity of one full plant. Key producers are in North Dakota, Maine, Minnesota, Idaho, Oregon, Wisconsin and Washington State. International markets are worldwide and include China, Japan, and other Asian countries, the Middle East and Mexico. Food service industry consumers, in particular, source globally and demand global pricing, which makes Oregon potato processors price-takers in the overall market.

**Potato processors have a mix of long- and short-term supply contracts.** Stakeholders noted that they often enter into longer-term contracts, such as three years, with direct food service industry buyers. However, contracts with retailers are generally more short-term.

### **Domestic competition**

**Oregon potato processors directly compete in their final markets with companies based in states without carbon pricing.** Domestic competitors are companies such as Simplot (with operations in Idaho, North Dakota Oregon, and Washington), McCain (with operations across the US and globe), and Cavendish (with operations in North Dakota and Canada). The intensity of competition may inhibit facilities' ability to pass through carbon costs to their consumers without significant loss of market share. Additionally, producers in states closer to final markets on the east coast (comprising the bulk of Oregon facilities' markets) already have a cost advantage due to lower transportation costs. Stakeholders suggested that transportation costs already make up 10–12% of the overall cost of the final products.

### **International competition**

**Oregon potato processing facilities face significant international competition from Europe.** Belgian competitors are companies such as Ecofrost and Agristo. European producers have a cost advantage by



having cheaper raw input materials (potatoes can be bought in an open market)<sup>38</sup> and lower fertilizer costs. Transport costs to eastern US markets are also lower for these competitors, as international maritime shipping is less expensive than truck-based road transportation. As a result, European potato processing facilities (largely in Belgium) have increasingly taken US market share since 2000. US producers had a global market share of 62% in 2002 which declined to 39% by 2016; meanwhile EU processors (particularly Belgian and Dutch) had external export growth increase of 13% on average over the same period (Huffaker, 2018).

**European producers currently operate under the EU Emissions Trading System (ETS) and so already face some level of carbon pricing at the margin.** Potato processing facilities are regulated under the EU ETS, but have been identified as at risk of carbon leakage under Phase III. As such, they receive benchmarked emissions allowances for free, which still incentivizes emission reduction and prices emissions above benchmarks.

**Stakeholders noted some potential for product differentiation relative to these competitors.** US facilities produce more shoe-string fries compared with thicker fries in Europe, as a result of the US potato being larger on average.

### ***Cost pass-through capacity***

**The cost pass-through of Oregon potato processing facilities is inhibited by significant competitive pressures from both other US states and international producers.** Domestic competitive pressure arises from two sources: internal production substitution for large nationwide companies, and producers in other states. Oregon facilities owned by companies with footprints across the US could divert production to other states to lower their Oregon carbon cost. Competitor producers in other states without carbon pricing (and other lower-cost aspects) also exert pricing pressure in the final markets of Oregon facilities, constraining their ability to pass through costs. Moreover, international producers in Europe exert pressure on local markets, having already lower operational costs.

**Profits in the sector may be strong, yet stakeholders suggest profitability is dependent on consistently securing sales volume.** The company owning three out of five potentially covered potato processing facilities recently had a significant hike in its stock price after annual reports stated that it had considerably surpassed expectations of sales and profits (Kilgore, 2018). However, interviewed stakeholders noted that profit margins are dependent on securing sales volume.

## **Leakage risk identification in other jurisdictions**

**In the EU ETS Phase III, potato processing facilities are identified as at risk of carbon leakage based on the joint criteria, and in Phase IV they qualify for assessment at a disaggregated level.**

- Under Phase III, the sector was identified as at risk of carbon leakage at the eight-digit level and received free allocation support.
- As the sector was deemed at risk of carbon leakage at the eight-digit level during Phase III, under the Phase IV methodology, it qualifies for a second-level assessment of its carbon leakage risk at a disaggregated level.

**California identifies the food manufacturing sector as a whole as at medium risk of carbon leakage.** The Californian food manufacturing sector has a medium trade intensity (12%) and a low emissions intensity (608

<sup>38</sup> This is in contrast to US potato processors which are limited to purchasing potatoes through longer-term contracts.

tCO<sub>2</sub>e/US\$ million value added), leading to an overall categorization of medium carbon leakage risk. However, it should be noted that the differences in subsectoral composition between California and Oregon limit the applicability of this insight to Oregon. Importantly, the Californian sector has a number of higher-margin and -value fruit and vegetable products that are generally not grown or produced in other places in the US. The Californian sector also does not include frozen potato processing which is conducted in numerous other jurisdictions.

*Table 31. Treatment of the food manufacturing sector in external jurisdictions*

Sectors	Metric	EU ETS Phase III				EU ETS Phase IV	California		
		Trade intensity	Cost increase	Joint Metric	Identified	Identified	Trade intensity	Emissions intensity	Level of risk
Frozen Potatoes, Prepared, or Preserved	Initial assessment	No	No	Yes	Yes	Qualifies for quantitative assessment at a disaggregated level *			
Food Manufacturing	Initial assessment						Medium	Low	Medium

*Note:* \* Under the EU ETS Phase IV, sectors that are listed in the EU ETS 2015-20 carbon leakage list at a six-digit or eight-digit level qualify for a second-level quantitative assessment at a more disaggregated level (Criteria D).

*Source:* Vivid Economics

## Conclusion

### There are several factors that suggest this sector is EITE:

- While the sector's carbon cost relative to its value added is low, carbon costs fall solely on potato processing facilities which may have limited potential for further emissions reductions.
- The ability for potato processing facilities to pass through costs without losing market share is likely inhibited by the significant competitive pressures from other US states and international competitors. Leakage to sister plants in Idaho and Washington is also a risk
- Precedents from the EU and California suggest that the sector may be at risk of leakage.

### However, there are several factors which reduce underlying carbon leakage risk:

- Abatement opportunities may exist in terms of fuel switching and energy efficiency.
- International competitors are largely European producers which also face a carbon cost compliance regulation, suggesting that asymmetric carbon pricing may not present competitiveness challenges in the long term.
- Recent employment, value added and planned investments suggest the sector is operating in a positive market environment and may be able to pass through some carbon costs without significant loss of market share.

**On balance, the sector is at risk of carbon leakage if Oregon introduces a carbon price without measures to protect against possible adverse competitiveness impacts.** A carbon pricing instrument for this sector should be designed to ensure that innovation and emissions reduction incentives remain, while also incorporating measures to protect against the risk of carbon leakage and other competitiveness impacts.

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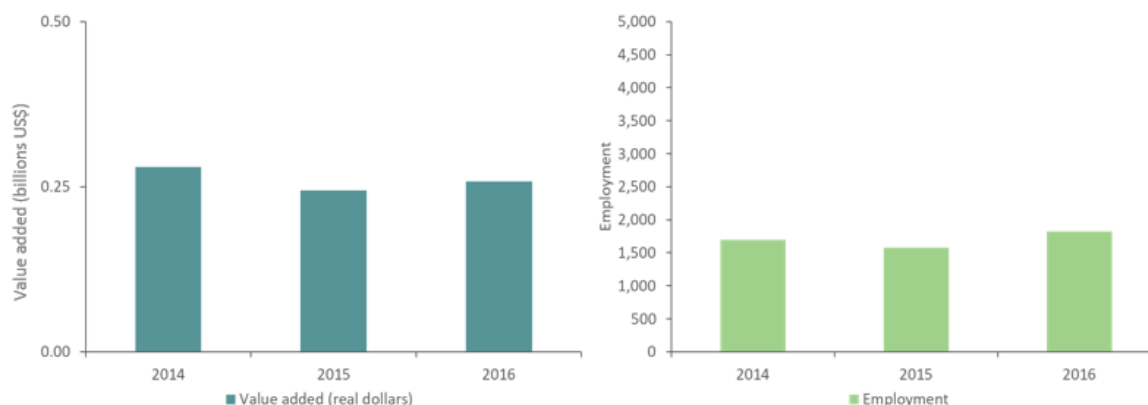
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# Glass

## Sector background

The glass sector faced a downturn in 2015, but recovered in 2016. Figure 22 shows that the Oregon glass sector has performed relatively consistently over 2014–16, with annual value added averaging around US\$260 million and annual employment steady at around 1,700 people.

Figure 22. The Oregon glass sector's value added and employment have been consistent over 2014–16



Source: Vivid Economics and US Census Bureau

The glass industry in Oregon has benefitted from a bottle deposit system and a re-usable bottle program. Glass-recycling rates in the state are higher than in many other US states, largely due to an industry-run bottle deposit system. This provides the sector with a substantial supply of recycled glass to use in the production process, which lowers costs and emissions.

## Carbon cost exposure

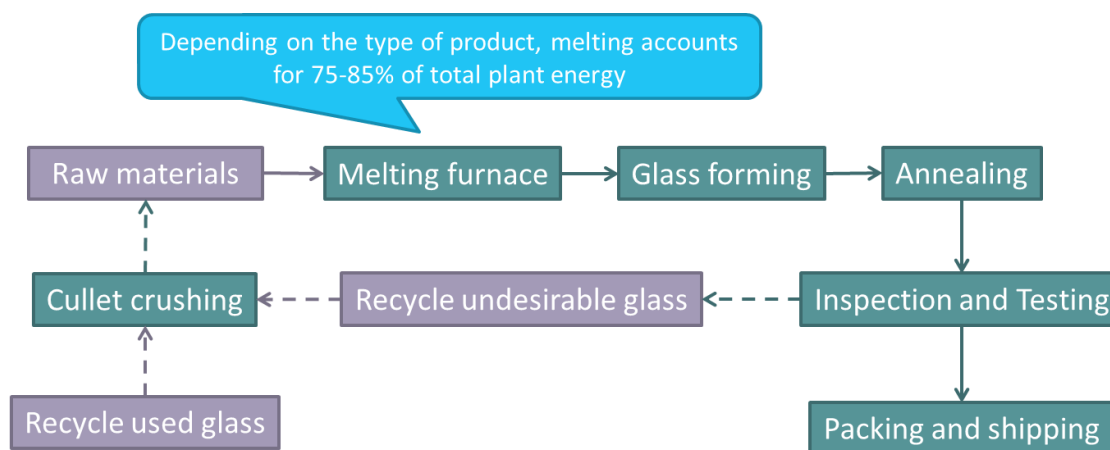
In Oregon there are two glass manufacturing facilities reporting emissions over 2014–16, only one of which would potentially be covered under a carbon price. This facility specializes in container glass manufacturing.

### Products and production processes

The container glass sector in Oregon manufactures containers for food and beverages. Products made in Oregon include beer bottles, wine bottles and food packaging containers.

The most emissions-intensive step in the glass production process is the melting and refining of raw materials in melting furnaces. This process accounts for 75–85% of total energy consumption, with furnaces operating at temperatures of up to 1,600–1,700°C. Melting furnaces account for 80–90% of emissions from typical glass production facilities (IFC, 2007). Furnaces require continual operation. As a result, production is not flexible and cannot adjust quickly in response to energy price or exchange rate fluctuations. Figure 23 illustrates the production process. Energy use in glass forming is variable by product, but the energy required to heat and maintain the melting furnaces and refining is comparable across subsectors.

Figure 23. **Most emissions in glass production arise during the melting process**



Note: Purple elements denote inputs; green elements denote processes.

Source: Vivid Economics

**A significant amount of energy is consumed during production by the glass container manufacturer potentially covered under the carbon price.** Energy costs typically account for 10–20% of the facility’s total manufacturing costs, depending on the price of energy, the type of energy available, the factory location and the particular energy requirements. The percentage of total cost related to energy can vary significantly because of the volatility in market prices. However, for the company owning the Oregon facility potentially covered under the carbon price, more than 90% of North American sales volume is represented by customer contracts containing provisions that pass the commodity price of natural gas to the customer, effectively reducing the North America segment’s exposure to changing natural gas market prices (O-I, 2017).

### **Emissions reduction opportunities**

#### **Typical abatement opportunities for GHG emissions from the sector are:**

- Use lower-carbon fuels in furnaces where available;
- Maximize cullet use to increase energy efficiency and lower GHG emissions;
- Use waste heat recovery from furnace flue gases for batch or cullet preheating.

**The Oregon facility also uses energy-efficient continuous regenerative furnaces.** The majority of emissions from the facility derive from two glass-melting furnaces, both of which are continuous regenerative furnaces. Regenerative furnaces are more energy-efficient than recuperative furnaces due to higher preheat of combustion air (IFC, 2007). The two furnaces were installed in 1956 and 1970, respectively, and primarily burn natural gas and use electric boost to reach more difficult areas of the glass melt. There may be additional energy conservation potential from the older furnace. However, both plants have been modified since 1979 and are therefore subject to the Standards of Performance for Glass Manufacturing Plants regulation.

**The glass container manufacturer in Oregon already uses large amounts of cullet in its production processes, although there is technical scope to increase this.** The utilization of cullet reduces the emissions intensity of production. For every 10% of cullet used in manufacturing, energy costs drop by 2–3%, while 1 ton of carbon dioxide is reduced for every 6 tons of cullet used during manufacturing (Glass Packaging Institute, 2014). The state of Oregon is particularly advanced in this regard, with a mandate to use 50% of cullet in production, compared with, for example, California’s 35% minimum cullet content mandate for glass manufacturers (CalRecycle, 2018). This is due, in part, to the Oregon beverage recycling cooperative which has encouraged the use of re-usable bottle products. In 2015, the comparable EU average use of cullet in

production was 52% (The European Container Glass Federation (FEVE) & EY, 2015). However, both Maine and British Columbia outperform Oregon's impressive glass-recovery rates, implying that there is potential for improvement (Collins, 2017).

**The use of waste heat recovery and other energy efficiency measures could significantly decrease energy demand and associated costs.** Recovered heat can be used to preheat the batch and cullet, but retrofitting preheaters may be economically challenging due to high capital costs. Additional techniques that could increase the energy efficiency of melting furnaces include using more effective sensors, control systems and refractors. Energy management systems implemented across facilities can help identify shortcomings in energy efficiency performance.

### **Relative emissions intensity**

**The emissions intensity of glass producers in Oregon may be relatively low.** Table 32 illustrates that the average emissions intensity of the glass sector in Oregon is 424 tCO<sub>2</sub>e/value added US\$ million. Under the California methodology, this would be classified as low emissions intensity.

*Table 32. The glass manufacturing sector has a relatively low emissions intensity*

NAICS code	Sector description	Average sectoral direct emissions (ktCO <sub>2</sub> e)	Average sectoral indirect emissions (ktCO <sub>2</sub> e)	Average value added (US\$ million)	Average direct emissions intensity of value added (tCO <sub>2</sub> e/value added US\$ million)	Average total emissions intensity of value added (tCO <sub>2</sub> e/value added US\$ million)
3272	Glass and Glass Product Manufacturing	43	64	253	170	424

*Note:* Indirect emissions estimated assuming the subsectors reflect the electricity intensity of production of the subsector at a national level and all facilities' electricity has the average emissions factor of the carbon intensity of Oregon's electricity grid over 2014–16 of 0.3610 tCO<sub>2</sub>e/MWh (DEQ, 2018b).

*Source:* Vivid Economics, DEQ and US Census Bureau

## **Markets and competitive dynamics**

**For the US as a whole the glass container industry remained stable in 2016–17 with growth opportunities in 2018.** Beer is largest market segment, representing 56% of glass container industry sales volume, then food products, then non-alcoholic beverages. Exports of beer and other non-alcoholic beverage containers reflect high demand for glass packaging outside the country (Bragg, 2018). Oregon has strong demand for glass beer containers, with close to 40% of beer shipments in Oregon packaged in glass, ranking the state seventh in terms of share of glass-packaged beer in 2017 (Beer Institute, 2018).

**The Oregon facility potentially covered under a carbon price is part of a large international company, with a significant regional footprint largely producing beer bottles for microbreweries.** The company which owns this glass container producer has the leading market share of US rigid packaging products and has 19 production facilities across the US and Canada, with additional facilities in Europe, South America, and Asia Pacific. The Oregon facility produces 1 million bottles per day – primarily beer bottles for local microbreweries (Gerlat, 2013), but also for wineries and food companies. Stakeholders suggest that the Oregon glass

containers market is similar to the markets of California, Quebec and Ontario. They make the same containers and have similar trade exposure, and these markets can be supplied from outside the country or state, which can create competitive pressures from packaging produced outside of the jurisdiction, particularly if they are not covered by a carbon price.

**The US beer market is facing a decline, but spirits and food packaging markets are looking up.** Across the US, beer is losing market share as younger consumers change consumption habits (Bragg, 2018). Stakeholders also noted that more customers are switching to aluminum cans. However, the food and spirits glass container markets, particularly for non-alcoholic beverages, is picking up. Despite this, stakeholders from the Oregon company noted that this uptick in alternative markets still reflects only a small percentage of their total business.

### ***Domestic competition***

**While there is relatively little competition in the glass sector in Oregon, with only one facility producing glass container products, the sector also competes with other packaging products.** These competing products are packaging containers made from plastic, aluminum or paper. Stakeholders suggest that, in Oregon, this type of competition is growing for the glass sector. For instance, in the beer packaging segment, aluminum cans represent 44.5% of the packaging mix, while glass represents 41.3% (Beer Institute, 2018).

**There is strong competition from other states in the US for Oregon's glass industry.** There is competition from glass container manufacturers in other states, many of which do not have any carbon pricing mechanism in place or planned. Competition in this sector also comes from other states' manufacturers producing plastics, metal and paper packaging.

### ***International competition***

**There is significant competition for the glass sector coming from China.** As the wine industry grows in the Pacific Northwest region, Chinese imports have been flowing into Oregon through the Port of Seattle. Chinese imports have been increasing recently and, stakeholders suggest, now serve up to a quarter of total glass demand in Oregon. This is significantly more than the share of Chinese imports in the national market, which stakeholders suggest is around 15%. In support of this, producers in the Asia Pacific region (mainly China, India, Japan and Australia) had the highest global glass container market share in 2016 and are forecast to have the highest compound annual growth rate on the back of good supply of raw materials, low labor costs, and advanced manufacturing technology (Reuters, 2018).

### ***Cost pass-through capacity***

**The glass sector in Oregon may have little cost pass-through capacity given competition and the substitutability of glass containers.** The packaging sector competes on prices, making it difficult to pass through costs. Previous studies support this finding in the EU,<sup>39</sup> wherein it was found that glass container manufacturers may have the ability to pass through only 20–50% of their carbon costs to consumers (Vivid Economics & DECC, 2014; Oberndorfer et al., 2010). The substitutability of glass container products for alternatives such as aluminum, cardboard, and plastic packaging containers further inhibits the sector's cost pass-through capacity.

<sup>39</sup> While cost pass-through rates will depend on many factors which will likely be different between those observed in Europe and those in Oregon, especially market scope and competitive dynamics, this data point is instructive as it presents one of the few examples of observed experiences of carbon cost pass-through capacity under a cap-and-trade.

## Leakage risk identification in other jurisdictions

### Four key international carbon leakage identification metrics put the glass sector at risk of carbon leakage.

Analysis of the glass sector produced the following results:

1. EU Emissions Trading System (ETS) Phase III metric: the European hollow glass manufacturing sector was identified based on the trade intensity metric;
2. EU ETS Phase IV metric: the European hollow glass manufacturing sector was identified; and
3. California metric: the Californian container glass sector was identified to exhibit “high” leakage risk based on high trade intensity and medium emissions intensity.

*Table 33. Treatment of the container glass sector in external jurisdictions*

Sector	Metric	EU ETS Phase III				EU ETS Phase IV	California		
		Trade intensity	Cost increase	Joint Metric	Identified	Identified	Trade intensity	Emissions intensity	Level of risk
Container glass (Manufacture of hollow glass)	Initial assessment	Yes	No	Yes	Yes	Yes	High	Medium	High

*Note:* This table shows how external jurisdictions classified their own sector. The identification and classification process has been developed specifically for these jurisdictions and their sectors. It serves as an indication of whether sectors in Oregon are at risk.

*Source:* Vivid Economics

## Conclusion

### There are several factors that suggest the glass and glass product manufacturing sector in Oregon is EITE:

- The sector faces competition from other US states and countries without carbon pricing and may thus have limited cost pass-through capacity.
- The substitutability of glass container products opens producers in the sector to other types of packaging manufacturers, further reducing cost pass-through capacity.
- *Ex post* evidence from the EU shows the glass sector may have low cost pass-through capacity.
- Precedents from the EU and California suggest the sector may be at risk of leakage.

### However, the sector has relatively low emissions intensity and may have additional abatement opportunities, which reduce the underlying carbon leakage risk:

- The emissions intensity of the sector is relatively low, in terms of both Oregon sectors and r California thresholds.
- While the sector already uses a significant proportion of cullet in the production process and relatively efficient furnaces, there may be further scope for emissions reduction through higher cullet usage, utilizing waste heat recovery and implementing other efficiency measures.

**On balance, the sector is at risk of carbon leakage if Oregon introduces a carbon price without measures to protect against possible adverse competitiveness impacts.** A carbon pricing instrument for this sector should be designed to ensure that innovation and emissions reduction incentives remain, while also incorporating measures to protect against the risk of carbon leakage and other competitiveness impacts.



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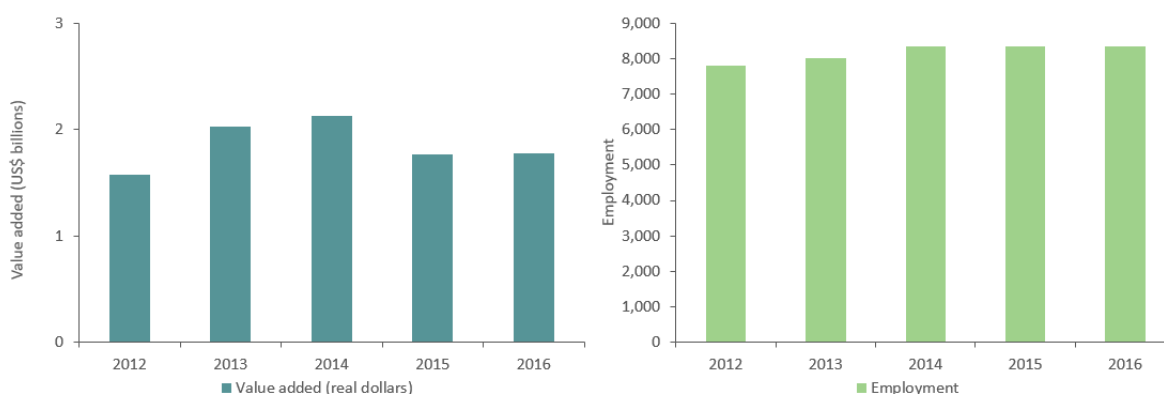
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# Iron and Steel, and Foundries

## Sector background

**The primary metals manufacturing sector is relatively significant to the Oregon economy.** In 2016, the sector contributed 6% of Oregon's total manufacturing value added, close to double the national sector's contribution to nationwide total manufacturing value added.<sup>40</sup> As shown in Figure 24, the Oregon sector's annual value added experienced a slight decline in 2015, but levels in recent years remain above those seen in 2012. Employment has been more stable over recent years, averaging around 8,000, with a slight increasing trend over 2012–16.

**Figure 24. Over 2012–16, metals manufacturing on average generated US\$1.8 billion in value added and employed around 8,000 workers in Oregon each year**



Source: Vivid Economics and US Census Bureau

### The metals manufacturing sector has five NAICS 4 subsectors:

- 3311 Iron and Steel Mills and Ferroalloy Manufacturing
- 3312 Steel Product Manufacturing from Purchased Steel
- 3313 Alumina and Aluminum Production and Processing
- 3314 Nonferrous Metal (except Aluminum) Production and Processing
- 3315 Foundries

**The foundries subsector (3315) accounts for the majority of the metals manufacturing direct value added and employment, while iron and steel mills (3311) are associated with high indirect impacts.** Over 2014–16, the foundries subsector accounted for, on average, 65% of the total metals sector's annual value added and 69% of the sector's employment. The iron and steel subsector made up on average 16% of the metals sector's annual value added, and 9% of its employment over the same period.<sup>41</sup> However, iron and steel mills may be associated with high indirect economic impacts, and local benefits in addition to direct employment and value added due to input purchases and employee expenditure. Industry figures suggest that the iron and steel mills subsector had an employment multiplier of 5.1 (American Iron and Steel Institute, 2018),

<sup>40</sup> Value added: a measure of the value of goods and services produced in an industry defined as total output minus the cost of inputs and raw materials.

<sup>41</sup> Iron and steel (3311) value added approximated for 2014, 2015, and 2016, while employment approximated for 2014 and 2015 – according to the methodology described in the main report.

against a weighted average employment multiplier for all industries within Oregon of 1.85 (ECONorthwest, 2012).

**The recent tariffs imposed on steel and aluminum imports have created uncertainty in the metals sector.**

The tariffs could impact the sector differently, even within the iron and steel subsector. For example, one facility makes its own steel from recycled steel and may be advantaged by tariffs, while another facility imports steel slabs from Russia, Mexico, and Canada and might face tariffs, potentially placing it at a competitive disadvantage due to increases in the cost of inputs.

## Carbon cost exposure

**Over the 2014–16 period, only three facilities from two metals subsectors could be covered under a carbon price.** Table 34 shows that while there are 11 metals manufacturing facilities in Oregon, only three would potentially be covered under a carbon price. The two facilities in the iron and steel manufacturing subsector annually emitted on average around 100 ktCO<sub>2</sub>e and 76 ktCO<sub>2</sub>e, respectively, over 2014–16. Over the same period the foundries subsector facility had annual emissions close to the threshold level, and breached the inclusion threshold of 25 ktCO<sub>2</sub>e only in 2014.

*Table 34. Two iron and steel facilities and one foundry facility would potentially be covered under a carbon price*

NAICS 4 code	Sector description	No. facilities reporting emissions over 2014–16	No. facilities emitting more than 25 ktCO <sub>2</sub> e over 2014–16
3311	Iron and Steel Mills and Ferroalloy Manufacturing	2	2
3312	Steel Product Manufacturing from Purchased Steel	0	0
3313	Alumina and Aluminum Production and Processing	1	0
3314	Nonferrous Metal (except Aluminum) Production and Processing	2	0
3315	Foundries	6	1

Source: Vivid Economics and DEQ

### **Products and production processes**

**The iron and steel sector in Oregon produces both long steel products and flat steel products.** Liquid steel is cast into semi-finished product, and then rolled into flat or long steel products. Long steel products are used in construction, engineering, heavy machinery and other similar applications. Flat steel refers to sheets and plates of steel that are used for cladding, decking, shipbuilding, tube- and pipe-making, white goods, car bodies, and so on.

**The foundries sector produces different types of products, notably investment cast products.** In Oregon, the foundries subsector focusses on aerospace and investment casting, and there is no forging process.

**The most emissions-intensive part of the steel production process is the melting of raw materials or scrap in furnaces, and Oregon steelmakers primarily use electric arc furnaces (EAFs).** There are two main ways to produce steel: in integrated plants using either basic oxygen furnaces (BOFs) or EAFs. The former use iron

ore and coking coal as raw materials to produce iron, while the latter mainly use recycled scrap metal to produce steel, requiring less energy and operating as the key type of furnace used in Oregon.

### ***Emissions reduction opportunities***

**Abatement opportunities for the iron and steel subsector are limited, although further research is required in this area.** One of the facilities already uses an EAF which is less emissions-intensive than BOFs, while the other facility does not have a furnace. Emissions from this sector stem predominantly from natural gas. Natural gas is also used in EAFs as the burner during the melting of scrap metal. There are also practical thermodynamic limits to emissions reductions in iron and steel production with existing technologies, and many modern steel plants operate close to this level (Worldsteel, 2018). Further research is required to determine the full extent of abatement options and costs.

**Moreover, each metals subsector has limited scope to improve energy efficiency, although options remain to optimize equipment.** The Northwest Power and Conservation Council identified foundries and the broader metals sector as having some of the lowest energy savings potential by 2035 (Northwest Power and Conservation Council, 2016). In another report looking at the metals sector in more detail, it found that energy efficiency improvements on primary equipment used in the production process are limited. However, there is potential to increase energy efficiency in support systems: facilities can optimize, and prevent leaks to, air compressors, change lighting systems from metal halide to LED (light-emitting diode), and install variable frequency drives to their pumps and fans (NWPPCC, 2016a). Stakeholders suggest that the potential for energy improvements in these support systems is minimal compared to overall emissions.

### ***Relative emissions intensity***

**The iron and steel subsector could face a significant carbon cost, whereas foundries likely would not.** Table 35 illustrates that iron and steel has a significant emissions intensity, while that of foundries is much lower. Under the California cap-and-trade emissions intensities categories, the Oregon iron and steel subsector would be classified as medium, while foundries would be low. This indicates that iron and steel facilities may face a significant carbon cost.

**Table 35. The emissions intensity of the Oregon iron and steel subsector is significant, while that of the foundries subsector is relatively low**

NAICS code	Sector description	Average sectoral direct emissions (ktCO <sub>2</sub> e)	Average sectoral indirect emissions (ktCO <sub>2</sub> e)	Average value added (US\$ million)	Average direct emissions intensity of value added (tCO <sub>2</sub> e/ value added US\$ million)	Average total emissions intensity of value added (tCO <sub>2</sub> e/ value added US\$ million)
3311	Iron and Steel Mills and Ferroalloy Manufacturing	178	172	293	609	1,201
3315	Foundries	62	225	1,175	53	244

*Note:* Indirect emissions estimated assuming the subsectors reflect the electricity intensity of production of the sector at a national level and all facilities' electricity has the average emissions factor of the carbon intensity of Oregon's electricity grid over 2014–16 of 0.3610 tCO<sub>2</sub>e/MWh (DEQ, 2018b). Value added data estimated for the iron and steel subsector.

*Source:* Vivid Economics, DEQ and US Census Bureau

## Markets and competitive dynamics

**Oregon iron and steel producers have predominantly North American markets, particularly for west coast states.** Stakeholders noted that most iron and steel products are consumed within the US, and major destinations for all products are the ten western states, like California. The feasibility of serving markets further away is limited by significant transportation costs. However, Canadian states are also a significant source of demand for some Oregon iron and steel facilities.

**Oregon iron and steel manufacturers have final consumers in many sectors.** Major facilities in the subsector produce different types of steel products, such as rebar, wire rod, steel plates and pipes. These products have different final markets such as construction, oil and gas, military and other equipment manufacturing, transportation, and renewable power.

**The consumers of foundries subsector products are primarily international aerospace companies.** Stakeholders suggested that the major market for the only foundries subsector facility potentially covered under a carbon price are large aerospace companies, such as GE, Pratt & Whitney, Rolls-Royce and Safran.

### **Domestic competition**

**The iron and steel mills subsector faces significant competition from domestic US producers.** Competition for long and flat steel products comes from states both with and without a carbon price. For example, stakeholders indicate that they face competition from producers in California, which has a carbon price on industrial emissions, as well from Midwestern, southern and eastern states which do not. Competition for hot rolled flat steel products comes primarily from states without a carbon price. Table 36 indicates key steel plate mill locations for domestic and international competitors. As this subsector is highly traded across states and competition is largely based on price, Oregon stakeholders are concerned about losing market share to other states where there is no carbon price.

**Table 36. Steel plate mill locations, furnace type, and carbon pricing mechanism**

Plate mill location	Furnace type	Carbon price
Alabama	EAF	No
Indiana	BOF	No
Iowa	EAF	No
North Carolina	EAF	No
Pennsylvania	EAF	No
Texas	BOF	No
Ontario, Canada	EAF	Under review
South Korea	BOF 70%	Yes
Mexico	EAF 70%	Yes*
Ukraine	BOF 95%	Yes*

*Note:* Ontario has a carbon pricing system in place, but the current government is withdrawing from the arrangement. Mexico and Ukraine's carbon price mechanisms do not yet cover industrial emissions.

*Sources:* Industry contact for locations and domestic furnace types; EUWID Recycling and Waste Management (2016); carbon pricing from [https://carbonpricingdashboard.worldbank.org/map\\_data](https://carbonpricingdashboard.worldbank.org/map_data)

**There is limited competition between foundries in Oregon but there is intense competition from other states.** Different facilities within Oregon serve different final markets, limiting the competition between foundries. Some facilities focus on products for industrial machinery, while others are producing for the aerospace industry. The foundries subsector, however, faces considerable domestic competition from foundries located in states with and without a carbon price, including in the Midwest, the east coast and California.

### **International competition**

**International competition in the subsector is significant.** Indicatively, the US as a whole is the world's largest importer of steel products, representing 9% of all steel imported globally in 2017. Canada (which has a carbon price in certain states), Brazil, and Mexico are the US's largest sources of steel imports in 2017. Oregon stakeholders suggest that foreign steel manufacturers tend to have lower labor costs and subsidized inputs. If Oregon producers passed through carbon costs, there is a risk they could lose market share to Chinese and other foreign producers which do not currently face carbon costs and, stakeholders suggest, primarily use more emissions-intensive BOF processes.

**The recent trade tariffs imposed by the Trump administration and regulatory uncertainty pose potential risks for competitiveness.** Some facilities in the sector import slabs of steel from outside the US, leading to increased production costs. Furthermore, certain facilities are export-oriented and retaliatory tariffs could also increase economic challenges. Stakeholders noted that, due to the fact that a new mill takes two years to construct, decisions such as this will not be made until there is more regulatory certainty and a more level regulatory playing field across competitors. Similarly, uncertainty associated with evolving carbon pricing policies delays investment decisions in this sector.

**International competition is also prominent in the foundries subsector.** The foundries subsector faces strong competition in the investment cast parts market from international businesses. Competitors are large multinational companies located in the US, Europe (where there is a carbon price) and Asia. Competition

between these international producers is relatively intense, with major players being global companies like Arconic and GF Precicast, which have manufacturing facilities in countries with and without a carbon price.

### **Cost pass-through summary**

**The iron and steel subsector may have a limited ability to pass through carbon costs without losing market share.** Producers in this subsector compete with producers in other jurisdictions without carbon pricing, and tend to compete on a price basis, particularly in commodities such as rebar and wire rod. However, further research is required on the level of exposure to jurisdictions with a carbon price.

**Some evidence from the EU suggest that cost pass-through rates for steel can be high.** The ability to pass through costs depends on the type of product and the end-market. For example, flat steel products destined for the automobile industry have relatively high cost pass-through potential. Estimates for the cost pass-through potential of EU cold rolled coil producers were 55–85%, while hot rolled coil producers had cost pass-through rates between 75–100% (European Commission, 2015c).

**Recent recoveries in the global steel market have improved average profit margins, although the nature of the industry is highly cyclical and these figures may not be indicative of long-term profitability.**<sup>42</sup> Average global profitability ratios (EBITDA<sup>43</sup> to sales revenues) have recovered recently, from record lows of 8% in 2012, to 13% in 2016. However there is significant heterogeneity in terms of net operating profit margins of different steel companies (Mercier et al. 2018), and the sector is a highly cyclical one, suggesting that these changes may not be indicative of long-term prospects.

**Foundries would likely be limited in their ability to pass through costs.** Competition is high in both domestic and international markets which limits their ability to pass through the costs without significant loss of market share.

## **Leakage risk identification in other jurisdictions**

**Several other jurisdictions identify the metals manufacturing sector as a whole as at risk of carbon leakage.** Analysis of the metals sector produced the following results:

- EU Emissions Trading System (ETS) Phase III metric: metals subsectors identified based on the trade intensity metric;
- EU ETS Phase IV metric: metals subsectors identified;
- California metric: metals identified to exhibit “high” leakage risk based on high trade intensity;
- Quebec cap-and-trade system identified the metallurgy sector as at risk of carbon leakage.

<sup>42</sup> While cost pass-through rates will depend on many factors which will likely be different between those observed in Europe and those in Oregon, especially market scope and competitive dynamics, this point is instructive as it presents one of the few examples of observed experiences of carbon cost pass-through capacity under a cap-and-trade.

<sup>43</sup> Earnings before finance costs, income taxes, depreciation, depletion, amortization, restructuring costs, asset write-downs and other costs, and other foreign exchange gains (losses).

Table 37. Treatment of the metals sector in external jurisdictions

Sector	Metric	EU ETS Phase III				EU ETS Phase IV	California			Quebec
		Trade intensity	Cost increase	Joint metric	Identified	Identified	Trade intensity	Emissions intensity	Level of risk	Identified
Metals sector	Initial assessment	Yes	No	Yes	Yes	Yes	High	Medium	High	Yes

Source: Vivid Economics

## Conclusion

### There are several factors that suggest the iron and steel subsector is at risk of carbon leakage:

- It is emissions-intensive with few opportunities for further emissions reductions.
- There may be limited ability for the subsector to pass through costs due to strong domestic and international competition, although some competitors are located in the EU where there is a carbon price.
- Precedents from the EU and California suggest that the sector may be at risk of leakage.

### However, there are other factors which reduce underlying leakage risk.

- An EU study looking at the cost pass-through potential of flat steel products determined that some products had the capacity to pass through between 55–100% of carbon costs, although further research is required on whether this would be the case for Oregon producers.
- Profit margins have improved in recent years, suggesting the sector is operating in a positive economic environment, although the cyclical nature of the steel industry implies this may not be indicative of long-term profitability.

**While the foundries subsector may be at risk of leakage, recent data suggests installations in the sector may not be covered under the carbon price.** The sector has relatively low emissions intensity, suggesting carbon cost increase risk is low. However, both national and international competition faced by the foundries sector facility could result in it having relatively low capacity to pass through carbon costs without facing significant competitiveness impacts. That said, the foundry, which was above the carbon pricing threshold in 2014, did not breach it in 2015 and 2016, and thus may not face a carbon price under the proposed regulations.

**The risk of threshold impacts may apply to this foundry and lead to leakage.** There is a risk that the facility may maintain production below the threshold in order to avoid compliance costs. If demand for avoided production is met by external competitors with higher emissions intensities, this implies carbon leakage. The risk is acute for this foundry given it operates sister plants in Nevada and Utah – states without carbon pricing – and so could relatively easily expand production or invest in those facilities.

**On balance, the sector is at risk of carbon leakage if Oregon introduces a carbon price without measures to protect against possible adverse competitiveness impacts.** A carbon pricing instrument for this sector



should be designed to ensure that innovation and emissions reduction incentives remain, while also incorporating measures to protect against the risk of carbon leakage and other competitiveness impacts.

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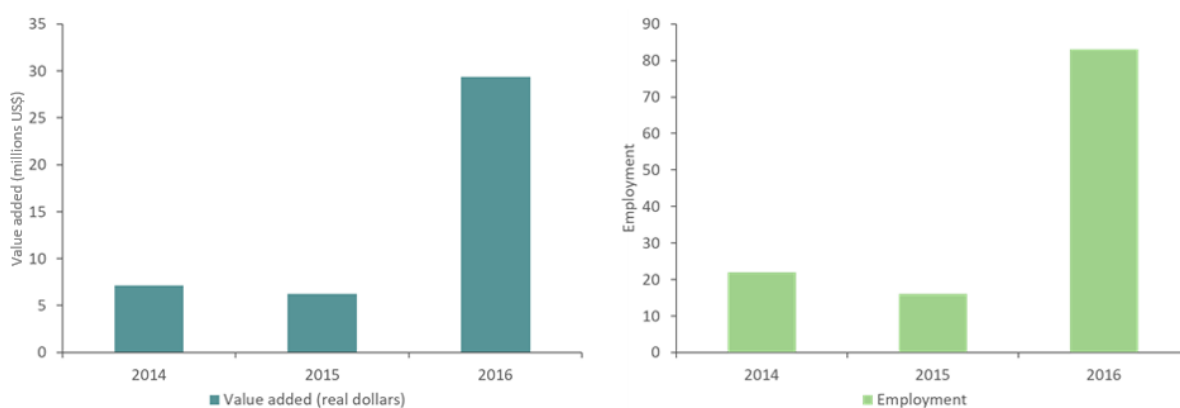
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# Lime and Gypsum

## Sector background

The Oregon lime and gypsum manufacturing sector is small, but increased significantly in size over 2015–16. Annual sectoral value added is below US\$30 million and the sector employs fewer than 100 people in Oregon. However, it experienced significant growth in one year over 2015–16, when value added and employment grew by almost a factor of five.<sup>44</sup>

Figure 25. The Oregon lime and gypsum sector experienced significant growth over 2015–16



Source: Vivid Economics and US Census Bureau

In Oregon there is one lime and gypsum manufacturing facility reporting emissions over 2014–16, and it would potentially be covered under a carbon price. This facility's annual emissions have consistently been around 50,000 tCO<sub>2</sub>e over 2014–16.

## Carbon cost exposure

### Products and production processes

The facility in Oregon manufactures wallboard from gypsum; the most emissions-intensive step in the manufacturing process is drying (Ecofys, 2009). Gypsum board is produced by mixing calcined gypsum with water and additives to form a slurry, which is fed between continuous layers of paper on a board machine. Along the production line, the calcium sulfate recrystallizes or rehydrates, reverting to its original rock state. The paper becomes chemically and mechanically bonded to the core. The board is then cut to length and conveyed through a natural gas-fired kiln dryer to remove any free moisture (Gypsum Association, 2018).

### Emissions reduction opportunities

The facility in Oregon recycles wallboard waste back into gypsum panels. The facility in Oregon has a new waste reclamation system that turns wallboard waste into gypsum panels. When new wallboard waste

<sup>44</sup> While the source of this ramp-up is uncertain, it is unlikely due to the expansion of the facility in the sector potentially covered under a carbon price, as this facility's emissions remained consistently close to 52 ktCO<sub>2</sub>e in all years over 2014–16.

arrives at the facility, the gypsum core is separated from the paper. The recovered gypsum is put back into the manufacturing process and recycled into new wallboard.

**Opportunities to reduce emissions exist in the form of reducing feedstock moisture, heat recovery, and fuel-switching.** In the EU, some gypsum manufacturers have combined heat and power (CHP) plants to recover heat and thereby increase energy efficiency (Ecofys, 2009). Variability in emissions from facilities in the sector is a function of the moisture content of the feedstock and the efficiency of the drying process, thus improvements to both could reduce emissions (DTI, 2006). Furthermore, fuel-switching for the kilns from natural gas to either biomass or electricity could potentially reduce emissions. More research is necessary to understand the economic feasibility of such measures in Oregon.

### **Relative emissions intensity**

**The gypsum manufacturing subsector has the highest emissions intensities in Oregon.** The impact of a carbon price is likely to be high for this sector as emissions are high and value added is low, as illustrated in Table 38. Emissions have been consistent throughout 2014 to 2016, but value added experienced a significant increase over 2015–16 (reflected in Figure 25).

*Table 38. The lime and gypsum sector in Oregon has a very high emissions intensity*

NAICS code	Sector description	Average sectoral direct emissions (ktCO <sub>2</sub> e)	Average sectoral indirect emissions (ktCO <sub>2</sub> e)	Average value added (US\$ million)	Average direct emissions intensity of value added (tCO <sub>2</sub> e/ value added US\$ million)	Average total emissions intensity of value added (tCO <sub>2</sub> e/ value added US\$ million)
3274	Lime and Gypsum Product Manufacturing	52	4	14	3,742	3,997

*Note:* Indirect emissions estimated assuming the sector reflects the electricity intensity of production of the sector at a national level and all facilities' electricity has the average emissions factor of the carbon intensity of Oregon's electricity grid over 2014–16 of 0.3610 tCO<sub>2</sub>e/MWh (DEQ, 2018b).

*Source:* Vivid Economics, DEQ and US Census Bureau

## **Markets and competitive dynamics**

**Oregon's gypsum manufacturing sector serves the domestic US housing and construction market.** This makes the Oregon gypsum sector vulnerable to the cyclicity of these sectors.

### **Domestic competition**

**Gypsum is mined in 17 US states.** Iowa, Texas, Utah and New Mexico are particularly important producers. Further research is needed to identify domestic competition with certainty.

### **International competition**

The US has started to apply a 10% tariff to mineral and other products from China. This includes gypsum products, and thus could reduce international competition (Global Gypsum, 2018).

### **Cost pass-through capacity**

The nature of products in the gypsum sector suggest it may have little cost pass-through capacity. There is little scope for product differentiation. However, further research is required on domestic and international competition to determine the capacity to pass through costs.

## **Leakage risk identification in other jurisdictions**

The gypsum manufacturing sector is commonly identified as an at-risk sector in other jurisdictions, illustrated in Table 39:

- EU Emissions Trading System (ETS) Phase III metric: lime and plaster identified based on the trade intensity metric;
- EU ETS Phase IV metric: lime and plaster identified;
- California’s cap-and-trade identified Gypsum product manufacturing as at medium risk of carbon leakage based low trade intensity and medium emissions.

Table 39. Treatment of the lime and gypsum sector in external jurisdictions

Sectors	Metric	EU ETS Phase III				EU ETS Phase IV	California		
		Trade intensity	Cost increase	Joint metric	Identified	Identified	Trade intensity	Emissions intensity	Level of risk
Lime and Plaster	Initial assessment	Yes	No	No	Yes	Yes			
Gypsum Products	Initial assessment						Low	Medium	Medium

Source: Vivid Economics

## **Conclusion**

**There are several factors that suggest that the sector may be EITE:**

- The sector has the highest emissions intensity in Oregon.
- Precedents from the EU and California suggest the sector may be at risk of leakage.

**However, one factor reduces the underlying risk of carbon leakage:**

- The sector may have emissions reduction opportunities, although further research is required in this area.

The sector is likely at risk of carbon leakage if Oregon introduces a carbon price without measures to protect against possible adverse competitiveness impacts; however, further research is required to understand these risk factors more conclusively. A carbon pricing instrument for this sector should be designed to ensure that innovation and emissions reduction incentives remain, while also incorporating measures to protect against the risk of carbon leakage and other competitiveness impacts. However, further research is required to understand the nature and extent of these risks.

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# Non-metallic Mineral Mining and Quarrying

## Sector background

**Over 2014–16, four mining sector facilities reported emissions, with only one stone mining and quarrying facility potentially being covered under the carbon price.**

- The potentially non-covered facilities in the sector are all construction sand and gravel mining facilities and emit significantly less than the covered facility, at below 5,000 tCO<sub>2</sub>e each.
- The potentially covered facility has also experienced a significant drop in emissions over time, from around 52,000 tCO<sub>2</sub>e in 2014 to just over the eligibility threshold at 27,000 tCO<sub>2</sub>e in 2016.

**Mining facilities generally develop close to raw materials.** Oregon's natural ore resources have contributed significantly to the development of the sector in the state.

## Carbon cost exposure

### *Products and process*

**The facility potentially covered under a carbon price mines ore to make diatomaceous earth (DE).** DE is the product of processing diatomite. The product has many different end-uses:

- A particulate filter for fruit juices, wine, beer, biodiesel, corn syrup and water;
- An additive to paint, rubber, paper and plastics;
- In other products such as absorbents, catalysts and carriers for pesticides.

**Drying and calcinating, the last steps of processing the ore to make DE, are energy-intensive.** The first step of DE production is the mining of diatomite ore. This is then transported from the mine to an outdoor stockpile to partially dry. Once the ore has attained the level of moisture desired, it is transferred to the mill where it is crushed, dried and calcinated. Drying and calcinating the ore are energy-intensive, with the drying furnaces using natural gas.

### *Emissions reduction opportunities*

**The potentially covered facility in Oregon has implemented several emissions reduction options (including ore moisture reduction through exposure to the sun, heat recovery, variable frequency drives (VFDs), more efficient furnace burners, and use of lightweight tractor trailers), although further research is necessary on whether there is scope for even greater reductions.** Key options include:

1. Reducing DE moisture levels before processing
  2. Improving energy efficiency
- 
1. **DE processing facilities can reduce emissions by decreasing the moisture in the ore before it arrives at the facility.** This can be achieved by exposing ore to the atmosphere until it reaches a lower pre-determined moisture level through solar drying. This reduces the amount of drying that is required in the facility, thereby reducing the amount of energy consumed.
  2. **DE processing facilities may have scope to improve their energy efficiency, although the levels are unclear.** These facilities can improve their energy efficiency with the implementation of VFDs in fans and pumps. There is also potential to improve heat recovery but stakeholders suggest this is currently high-cost. Further research is required to understand the full scale of emissions reductions available from energy efficiency and other measures.

### Relative emissions intensity

**Oregon’s non-metallic mining and quarrying subsector is one of the least emissions-intensive sectors in the state and has reduced its emissions significantly since 2014** (see Table 40). The sector’s emissions intensity would be classified as low according to California’s current thresholds. The facility that would potentially be covered under a carbon price has also taken steps to reduce emissions.

**Table 40. Over 2014–16, the non-metallic mineral mining and quarrying subsector in Oregon had a low emissions intensity**

NAICS Code	Sector description	Average sectoral direct emissions (ktCO <sub>2</sub> e)	Average sectoral indirect emissions (ktCO <sub>2</sub> e)	Average value added (US\$ million)	Average direct emissions intensity of value added (tCO <sub>2</sub> e/value added US\$ million)	Average total emissions intensity of value added (tCO <sub>2</sub> e/value added US\$ million)
2123	Non-metallic Mineral Mining and Quarrying	42	36	231	182	338

*Note:* Indirect emissions estimated assuming the sectors reflect the electricity intensity of production of the subsector at a national level and all facilities’ electricity has the average emissions factor of the carbon intensity of Oregon’s electricity grid over 2014–16 of 0.3610 tCO<sub>2</sub>e/MWh (DEQ, 2018b). Value-added data estimated for the non-metallic mineral mining and quarrying subsector.

*Source:* Vivid Economics, DEQ and US Census Bureau

## Markets and competitive dynamics

**The non-metallic mineral mining subsector in Oregon exports to over 100 countries.** Its largest market is the US, but there are also significant sales to Asia, Europe and South America.

### Competition

**The subsector in Oregon competes with producers in other US states.** Competition in the US is determined by the location of ore resources, although these are relatively abundant and could be found elsewhere in the US. Currently, competitor mines and processing facilities operate in Nevada, Washington and California – the only state with a carbon price.

**International competition comes primarily from Europe and Asia, leading to a competitive pricing environment.** In 2017, the US was the global leader in volume of diatomite mined, followed by Czech Republic, Denmark and China (King, 2018). However, stakeholders noted that it also faces competition from producers in France, Japan and Mexico. They also suggest that the international nature of competition and production leads to competition based on price.

### Cost pass-through exposure

**The subsector in Oregon may have limited ability to pass through costs.** The pricing environment and nature of the product suggest limited cost pass-through capacity. However, the risk of asymmetric carbon costs<sup>45</sup> is lessened given that many competitor mines are located in US states or international jurisdictions that either have a carbon price in place or are in the process of implementing one.

### Leakage risk identification in other jurisdictions

**DE producers are identified as an at-risk sector in the EU and in California (though not initially), as illustrated in Table 41:**

- EU Emissions Trading System (ETS) Phase III metric: other mining and quarrying identified based on a trade intensity metric of close to 173%;<sup>46</sup>
- EU ETS Phase IV metric: other mining and quarrying identified (again, due to a very high trade intensity);
- In California, DE mining facilities were not initially classified in their leakage analysis due to a lack of information (CARB, 2010b). The subsector (DE mining, in particular) was then determined to be at high risk of carbon leakage in subsequent iterations of the cap-and-trade regulation without detail on the individual EITE metrics (CARB, 2011a).

*Table 41. Treatment of mining sector in external jurisdictions*

Sector	Metric	EU ETS Phase III				EU ETS Phase IV	California		
		Trade intensity	Cost increase	Joint metric	Identified	Identified	Trade intensity	Emissions intensity	Level of risk
Other Mining and Quarrying	Initial assessment	Yes	No	No	Yes	Yes			
All Other Non-metallic Mineral Mining	Initial assessment						-	-	High

Source: Vivid Economics

## Conclusion

**There are several factors that suggest that the non-metallic mineral mining subsector is EITE:**

- The nature of the product and pricing environment suggests a limited cost pass-through capacity.
- The subsector has implemented a range of measures to reduce emissions.
- Precedents from the EU and California suggest the subsector may be at risk of leakage.
- The potentially covered facility also owns a similar ore resource, mine and manufacturing plant in Nevada where production could be relocated, and where it would not be subject to a carbon price.

**However, several factors reduce the underlying risk of carbon leakage:**

- Emissions intensity is relatively low, suggesting a carbon price will represent a relatively low-cost burden.

<sup>45</sup> Asymmetric carbon costs refer to a situation where producers in certain states are subject to a carbon price and incur a carbon cost, while other producers do not face a carbon price and therefore do not incur a carbon cost.

<sup>46</sup> Other mining and quarrying in the EU include mining activities relating to diatomite beds.



- Competition from external locations is concentrated in jurisdictions with, or considering implementing, carbon prices, suggesting that asymmetric carbon pricing may not present competitiveness challenges in the long term.
- The location of facilities is primarily dictated by the location of resources, which reduces the risk of production relocating.

**On balance, the sector is at risk of carbon leakage if Oregon introduces a carbon price without measures to protect against possible adverse competitiveness impacts.** A carbon pricing instrument for this sector should be designed to ensure that innovation and emissions reduction incentives remain, while also incorporating measures to protect against the risk of carbon leakage and other competitiveness impacts.

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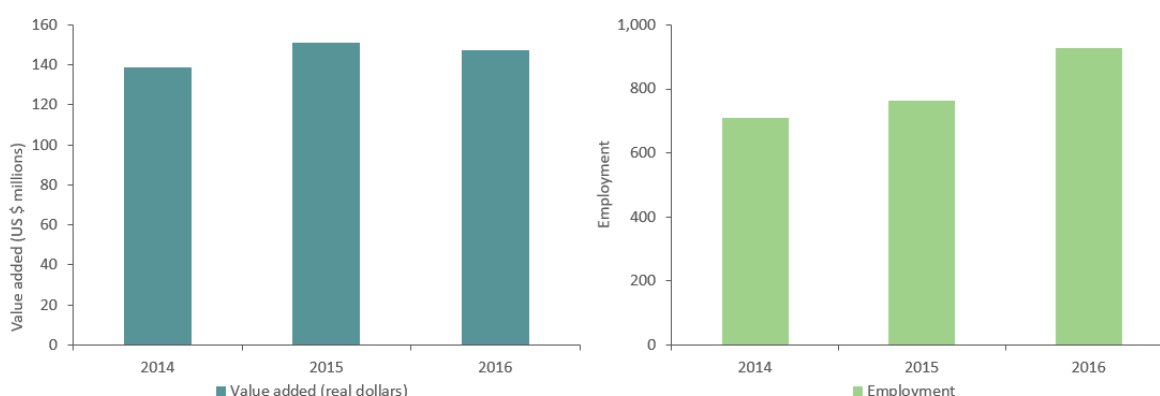
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# Other Non-metallic Mineral Products

## Sector background

The “other non-metallic mineral products” manufacturing sector is relatively small but has had growing employment. Figure 26 illustrates that, over 2014–16, the sector’s annual value added ranged from US\$130 million to US\$140 million, while employment grew steadily from around 700 to 930 workers over the same period. The sector includes the manufacture of abrasive products, cut-stone and stone products, ground or treated mineral earth products, and mineral wool.

Figure 26. Over 2014–16, the Oregon “other non-metallic mineral products” sector experienced relatively stable annual value added, an increasing employment growth



Source: Vivid Economics and US Census Bureau

There are two facilities in this sector reporting emissions over 2014–16, only one of which would potentially be covered by a carbon price. This facility, producing mineral wool, or glass fiber, emitted 40,248 tCO<sub>2</sub>e on average over 2014–16. The other facility emitted 3,479 tCO<sub>2</sub>e on average over 2014–16, and produces ground or treated mineral and earth products.

## Products and processes

### Products and production processes

The facility potentially covered under a carbon price manufactures glass fiber. The glass fiber produced at this facility is an interim product used in air and liquid filtration media and specialty battery separator media. It is highly engineered and has narrow specifications for its end use, suggesting scope for product differentiation, which offers greater scope for cost pass-through.

Emissions come primarily from the natural gas-fired fiberizers. The facility produces glass fiber from sand and soda ash. The inputs are melted in electric furnaces and are then processed in a natural gas-fired fiberizer, where the melted material undergoes a combination of extrusion and attenuation to become long, thin fibers.

### **Emissions reduction opportunities**

**There are limited emissions reduction opportunities as the glass fiber must have specific characteristics.** Stakeholders suggest the glass fiber produced in Oregon has stringent specification requirements dictated by its use in end products. This means that using recycled glass is not possible as it could alter the properties of the glass fiber and limit its use in the end products. Stakeholders suggested that any change in the glass fiber manufacturing process, including changes to combustion conditions, would require investment in R&D to maintain product specifications and quality.

Further research would be required to determine the economic and technical feasibility of improving energy efficiency in secondary equipment.<sup>47</sup> However, according to the stakeholder, the facility has made significant capital investments to improve energy efficiency throughout its plant, including in secondary equipment and the installation of new energy-efficient fans and pumps.

### **Relative emissions intensity**

**Jurisdictions classify “other non-metallic mineral products” manufacturing as low-to-moderate emissions intensity.** Table 42 shows that the sector has a total emissions intensity of 451 tCO<sub>2</sub>e/value added US\$ million, which would be categorized as a low-emissions intensity under current Californian emissions intensity thresholds. However, in Oregon, this emissions intensity is close to the median value for all potentially covered sectors and could be higher for individual companies (all calculations are based on aggregate data).

**Table 42. The “other non-metallic mineral products” subsector in Oregon has a relatively low-to-moderate emissions intensity**

NAICS code	Sector description	Average sectoral direct emissions (ktCO <sub>2</sub> e)	Average sectoral indirect emissions (ktCO <sub>2</sub> e)	Average value added (US\$ million)	Average direct emissions intensity of value added (tCO <sub>2</sub> e/value added US\$ million)	Average total emissions intensity of value added (tCO <sub>2</sub> e/value added US\$ million)
3279	Other Non-metallic Mineral Product Manufacturing	44	20	141	309	451

*Note:* Indirect emissions estimated assuming the sector reflects the electricity intensity of production of the sector at a national level and all facilities’ electricity has the average emissions factor of the carbon intensity of Oregon’s electricity grid over 2014–16 of 0.3610 tCO<sub>2</sub>e/MWh (DEQ, 2018b).

*Source:* Vivid Economics, DEQ and US Census Bureau

<sup>47</sup> Secondary equipment is the equipment in the facility that is not used as part of the production process, such as lights or heating for staff.

## Markets and competitive dynamics

**Glass fiber is an input for many end products.** The facility in Oregon exports products to China, the UK, and across the US. As mentioned above this is an interim product for liquid filtration media and specialty battery separator media.

### *Domestic and International competition*

**The owners of Oregon's potentially covered facility have a plant in another US state that is not subject to a carbon price.** The facility in Oregon is owned by a large conglomerate with facilities across the world and the US. It is possible that with a carbon price, production or investment could shift to other facilities.

**According to stakeholders, there are approximately ten global producers of similar glass fiber worldwide.** Other producers are primarily located in China, Europe, Russia and the Middle East. The EU already has a carbon price and China may be implementing one soon, while there are no plans for a carbon price in the Middle East or Russia.

**There is rising competition from China.** China has been a key driver in the growth of glass fiber since the early 2000s due to an increase in domestic production and rising demand. Stakeholders suggest that lower labor costs and favorable government export treatment supports Chinese production. In addition, Chinese glass fiber manufacturers have excess capacity, making the market competitive. Stakeholders suggest that Chinese production has become more competitive in the last five years as its glass fiber has improved in quality. China does not yet place a price on GHG emissions for the manufacturing sector.

**Some quantitative evidence suggests this sector has a high trade exposure, although exposure to jurisdictions which have carbon pricing is unclear, making inferences challenging.** The 2016 IMPLAN dataset for Oregon indicates that the state's non-metallic minerals plants' state and international trade exposure is high, at 49%.<sup>48</sup> However, the IMPLAN dataset does not offer insights on the nature of this trade exposure: if exposure is to jurisdictions which already apply a carbon price, this reduces underlying carbon leakage risk. Thus, this figure should be treated with caution.

### *Cost pass-through capacity*

**Market concentration may be relatively high, which increases cost pass-through capacity at the local level, although foreign competition is increasing.** The small number of global manufacturers suggests a concentrated market at a high level. However, stakeholders also suggest that recent Chinese competition has increased due to excess capacity and improvements in the quality of their glass fiber which may limit the potential to pass through costs. They also suggest that services to the automotive and heavy-duty truck industry are highly cost-competitive. Finally, there is evidence of low cost pass-through capacity in the sector under the EU Emissions Trading System (ETS) (European Commission, 2015c).<sup>49</sup>

<sup>48</sup> Trade exposure in this case is defined as the summation of state imports and exports divided by the summation of Oregon production plus imports.

<sup>49</sup> While cost pass-through rates will depend on many factors which will likely be different between those observed in Europe and those in Oregon, especially market scope and competitive dynamics, this data point is instructive as it presents one of the few examples of observed experiences of carbon cost pass-through capacity under a cap-and-trade.

## Leakage risk identification in other jurisdictions

The glass fiber manufacturing sector is commonly identified as an at-risk sector in other jurisdictions, as illustrated in Table 43:

1. EU ETS Phase III metric: manufacture of glass fibers identified based on the trade intensity and joint metrics;
2. EU ETS Phase IV: manufacture of glass fibers identified;
3. California identified: mineral wool manufacturing identified as at medium risk of leakage based on medium trade intensity and emissions intensity.

Table 43. Treatment of the “other non-metallic mineral products” sector in external jurisdictions

Sector	Metric	EU ETS Phase III				EU ETS Phase IV	California		
		Trade intensity	Cost increase	Joint Metric	Identified	Identified	Trade intensity	Emissions intensity	Level of risk
Manufacture of Glass Fibers	Initial assessment	Yes	No	Yes	Yes	Yes			
Mineral Wool Manufacturing							Medium	Medium	Medium

Source: Vivid Economics

## Conclusion

Several factors suggest the facility covered within the “other non-metallic mineral products” subsector is EITE:

- The sector’s emissions intensity is near the median value for all covered sectors in Oregon.
- Emissions reduction opportunities for the covered facility may be limited due to requirements on product specifications.
- Precedents from the EU and California suggest the sector may be at risk of leakage.
- Some evidence from the EU suggests cost pass-through capacity is low.
- The potentially covered facility competes in US and international markets against companies located in jurisdictions without carbon pricing.

However, certain factors may reduce the underlying carbon leakage risk:

- Further research is required to determine if there are opportunities for emissions reductions.
- Many products within the sector are highly engineered, suggesting scope for product differentiation, which offers greater scope for cost pass-through.

**On balance, the sector is at risk of carbon leakage if Oregon introduces a carbon price without measures to protect against possible adverse competitiveness impacts.** A carbon pricing instrument for this sector should be designed to ensure that innovation and emissions reduction incentives remain, while also incorporating measures to protect against the risk of carbon leakage and other competitiveness impacts.

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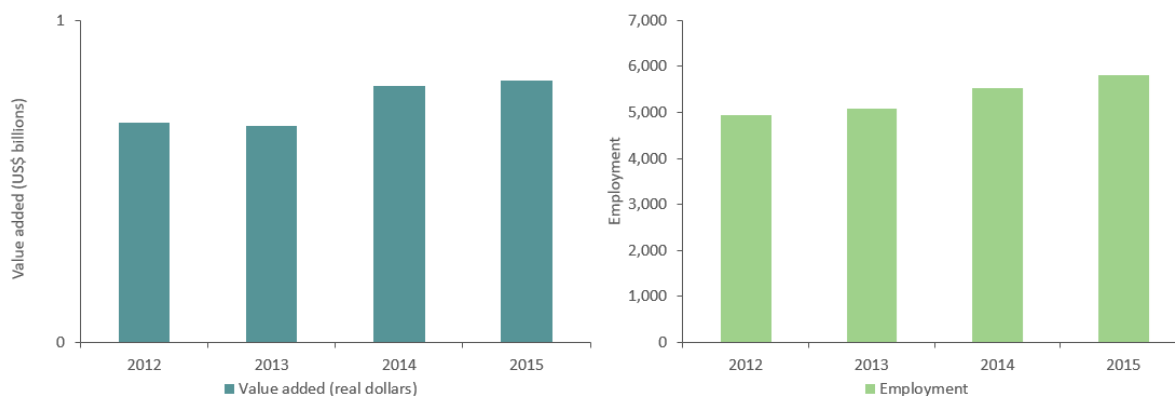
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# Plastics

## Sector background

The plastics and rubber products manufacturing sector in Oregon is relatively small. As Figure 27 shows, annual value added over 2012–15 ranged between US\$0.7–0.8 billion, or around 3% of Oregon’s total manufacturing value added.<sup>50</sup> Total employment in the sector averaged around 5,500 workers, or 3% of total manufacturing employment.

Figure 27. Plastics and rubber manufacturing value added and employment increased over 2012–15



Note: 2016 data not displayed as value-added data withheld for confidentiality purposes

Source: Vivid Economics and US Census Bureau

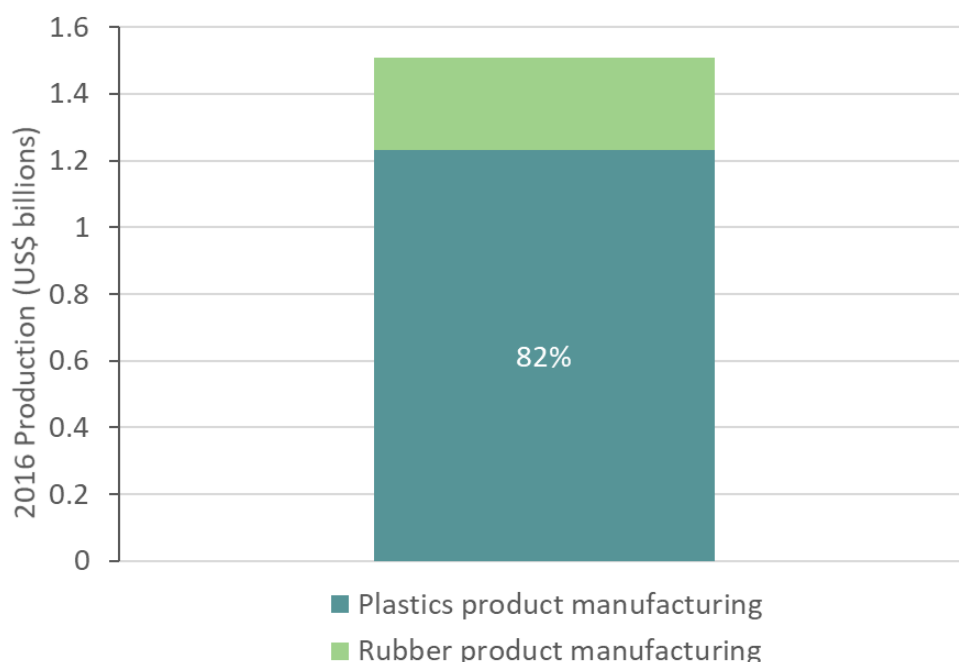
**The plastics and rubber manufacturing products sector contains two NAICS 4 subsectors, with plastics dominant:**

- 3261 Plastics Product Manufacturing
- 3262 Rubber Product Manufacturing

Figure 28 shows that the plastics subsector in 2016 produced 82% of the sector’s production, just over US\$1.2 billion. The market for battery separators is a key area within the plastics product sector, especially as the market for batteries grows.

<sup>50</sup> Value added: a measure of the value of goods and services produced in an industry defined as total output minus the cost of inputs and raw materials.

Figure 28. **Plastics product manufacturing comprised 82% of plastics and rubber product manufacturing production in 2016**



Source: Vivid Economics and US Census Bureau

## Carbon cost exposure

**In Oregon there are two plastics product manufacturing facilities reporting emissions over 2014–16, both of which would potentially be covered under a carbon price.** One of the facilities emitted on average 27,000 tCO<sub>2</sub>e over 2014–16, while the other emitted significantly more – on average 77,000 tCO<sub>2</sub>e over 2014–16.<sup>51</sup>

### Products and processes

**The plastics product manufacturing sector in Oregon covers a range of products.**

- One of the key products is battery separators manufacturing, which is a highly engineered polyethylene-based product for both lead-acid batteries and lithium-ion batteries. The separator is critical to the function of a battery as it separates the positive and negative electrodes which create a short, and therefore a battery failure, if they come into contact.
- Another key product manufactured is foam for the insulation of buildings. The main product is extruded polystyrene (XPS), a high-performance rigid insulation with a closed cell structure. It is a structural insulant which is available in various grades for specific applications requiring high loadings or resistance to excessive moisture levels. It is produced either as a standard construction product or a close tolerance version for panel-making applications.

**Battery separation facilities rely on the use of steam in production.** The process of making battery separators for lead-acid batteries starts with combining precipitated silica, ultrahigh molecular weight polyethylene, process oil and various minor ingredients to form a mixture that is extruded at an elevated temperature through a die to form an oil-filled sheet. The sheet is then passed through a solvent bath to remove the oil and then a dryer and hot-air oven to remove residual solvent and leave behind a porous

<sup>51</sup> An estimate which is biased downwards due more than a 99% drop in emissions from 2014–15, but then in 2016 emissions returned to around similar levels as seen in 2014 (+/- 100 ktCO<sub>2</sub>e).



structure. The solvent-laden air from the ovens and other production equipment is passed through a set of carbon beds to capture solvent for re-use and to avoid its emission to the atmosphere. This emission-control process relies on a steam cycle that also demands significant steam load from the boiler. The sheet is then slit and rolled for processing into batteries at the customers' facilities. The process for manufacturing lithium-ion battery separators is slightly different, but also relies heavily on steam in both the manufacturing process as well as the recycling process for TCE.

**Emissions from battery separator manufacturing come primarily from the use of a natural gas-fired boiler.**

The boiler is used for steam during the production process to remove the solvent from the final product, to operate the emission control systems, and to recycle and separate inputs. The oil, water, and solvent retrieved from this process are then re-used.

**Emissions from foam manufacturing arise mainly from the extrusion process.** XPS foam begins with solid polystyrene crystals. These crystals, along with special additives and a blowing agent, are fed into an extruder in which the mixture is combined and melted under controlled conditions of high temperature and pressure into a viscous plastic fluid (American Chemistry Council, 2018). The hot, thick liquid is then forced in a continuous process through a die. Further electro-intensive processes take place when it emerges from the die and expands to a foam, and is shaped, cooled, and trimmed to size.

***Emissions reduction opportunities***

**Fuel-switching opportunities may be limited in the sector due to regulatory constraints, although further research is necessary to understand fully the range of options available.** The use of biomass is prohibited in the battery separation facility's air permit, making it difficult to find an alternative to the natural gas used for the boiler. Similarly, stakeholders assert that substituting to electricity would be prohibitively expensive. The facility in the battery separator segment recently replaced its boiler with a more efficient unit. However, discussions with energy efficiency experts in Oregon suggest that there are abatement options available in the sector as a whole, especially from installing economizers and controls on boilers and thereby increasing their energy efficiency. Further research on the nature and cost of abatement options in the sector is required.

***Relative emissions intensity***

**The plastics subsector may have a relatively low emissions intensity.** Table 44 shows the Oregon plastics sector's average emissions intensity estimates over 2014–16. This sector had the second-lowest average emissions intensity of all assessed Oregon subsectors.

**Table 44. The plastics product subsector has a relatively low emissions intensity**

NAICS code	Sector description	Average sectoral direct emissions (ktCO <sub>2</sub> e)	Average sectoral indirect emissions (ktCO <sub>2</sub> e)	Average value added (US\$ million)	Average direct emissions intensity of value added (tCO <sub>2</sub> e/value added, US\$ million)	Average total emissions intensity of value added (tCO <sub>2</sub> e/value added, US\$ million)
3261	Plastics Product Manufacturing	102	106	660	158	318

*Note:* Indirect emissions estimated assuming the subsectors reflect the electricity intensity of production of the subsector at a national level and all facilities' electricity has the average emissions factor of the carbon intensity of Oregon's electricity grid over 2014–16 of 0.3610 tCO<sub>2</sub>e/MWh (DEQ, 2018b).

*Source:* Vivid Economics, DEQ and US Census Bureau

## Markets and competitive dynamics

**The market for Oregon plastics producers is largely export-based.** Oregon facilities export 100% of lithium-ion battery separators, while the market for lead-acid battery separators is relatively equally split between US domestic and international consumers. One of the companies owning a facility potentially covered under the carbon price is a leading global supplier of battery separators. Market forecasts predict that growing demand for automobiles in Asia will drive growth in the demand for separators produced in Oregon plants (Entek International Limited, 2014). Industry forecasts predict that the global battery separator market will grow at a compound annual rate of 12.5% from 2017 to reach over US\$5 billion in 2020, due to both movement towards electric vehicles and smartphone and electronic product demand (PR Newswire, 2018b). However, stakeholders suggest that their growth may be constrained in Oregon due to increasing competition from Asia, where production capacity of lithium-ion battery separators is growing.

### **Domestic competition**

**The battery separation segment of the sector has competition domestically from Tennessee and Indiana.** Stakeholders suggest that this part of the sector is very export-driven, with only a small proportion of production remaining in Oregon. Close to half of the production is for the domestic market, where the facilities in Oregon compete with those in Tennessee and Indiana – states without carbon pricing. These US facilities are owned by multinational companies with other facilities around the world, such as Microporous, Daramic and Celgard.

**The foam manufacturing segment competes primarily with manufacturers in the US.** The company that owns the facility in Oregon is North America's largest producer of residential, commercial and industrial insulation, and the second-largest producer of XPS foam insulation (Owens Corning, 2017). In 2017, major competitor states for insulation foam manufacturing, measured by employment in the subsector, were Ohio, Texas and Georgia, which are also states without carbon pricing. All of these states had employment at least an order of magnitude larger than Oregon (American Chemistry Council, 2018).

### **International competition<sup>52</sup>**

**The battery separation segment of the sector has increasingly significant competition from China, Korea, Thailand and India.** This part of the sector has been growing in Asia. Chinese producers have been expanding production capacity recently, with the largest of these being Suzhou GreenPower New Energy Materials Co., Ltd., having a wet-process separator capacity of 204 million m<sup>2</sup> (PR Newswire, 2017). Other key competitors are the Japanese Asahi Kasei company and the Chinese Cangzhou Mingzhu Plastic Co., Ltd. Stakeholders in Oregon suggest that this is impacting their profit margins. International competitors have also announced the expansion of lead-acid separator production facilities in India and Thailand. Stakeholders suggest that this expanded production capacity could impact export markets.

### **Cost pass-through capacity**

**The plastics sector in Oregon may have relatively low cost pass-through ability.** Stakeholders note that battery separators are increasingly becoming a price-driven decision for customers. Combining this with competition from Asia and from multinationals in other US states suggests that the Oregon sector may have limited cost pass-through capacity. This may be particularly true for the lithium-ion market wherein two Japanese competitors had 32% of the global market in 2016.

## **Leakage risk identification in other jurisdictions**

**Three key international carbon leakage identification metrics put the plastics sector at risk of carbon leakage.** Analysis of the plastics sector produced the following results:

- EU Emissions Trading System (ETS) Phase III metric: plastics product manufacturing identified based on the trade intensity metric;
- EU ETS Phase IV metric: plastics product manufacturing identified;
- California metric: polystyrene foam product manufacturing identified as “medium” leakage risk based on medium trade intensity, but low emissions intensity. There are no battery separator manufacturers operating in California.

*Table 45. Treatment of the plastics sector in external jurisdictions*

Sectors	Metric	EU ETS Phase III				EU ETS Phase IV	California		
		Trade intensity	Cost increase	Joint metric	Identified	Identified	Trade intensity	Emissions intensity	Level of risk
Manufacture of plastics in primary forms	Initial assessment	Yes	No	No	Yes	Yes			
Polystyrene Foam Product Manufacturing	Initial assessment						Medium	Low	Medium

Source: Vivid Economics

<sup>52</sup> This section focusses on battery separators due to limited engagement from the foam manufacturing facility.

## Conclusion

### **The high degree of trade exposure increases the Oregon plastics sector's risk of carbon leakage:**

- The battery separator market is largely global and Oregon's plastics producers are facing increasing competition from producers in Asian countries as well as existing competition from domestic producers. The polystyrene foam manufacturing sector may face significant external competition from other US states, although further research is required in this regard.
- Precedents from the EU and California suggest the plastics sector may be at risk of carbon leakage.

### **However, there are several factors which reduce underlying carbon leakage risk:**

- There may be scope for product differentiation, reducing consumers' price sensitivity.
- The sector as a whole has a relatively low emissions intensity and may have additional opportunities to undertake emissions reductions, particularly in terms of energy efficiency, noting that some entities have already invested significantly in equipment upgrades and replacement.

**The sector is likely at risk of carbon leakage if Oregon introduces a carbon price without measures to protect against possible adverse competitiveness impacts; however, further research is required to understand these risk factors more conclusively.** A carbon pricing instrument for this sector should be designed to ensure that innovation and emissions reduction incentives remain, while also incorporating measures to protect against the risk of carbon leakage and other competitiveness impacts. Further research is necessary to understand the nature and extent of these risks.

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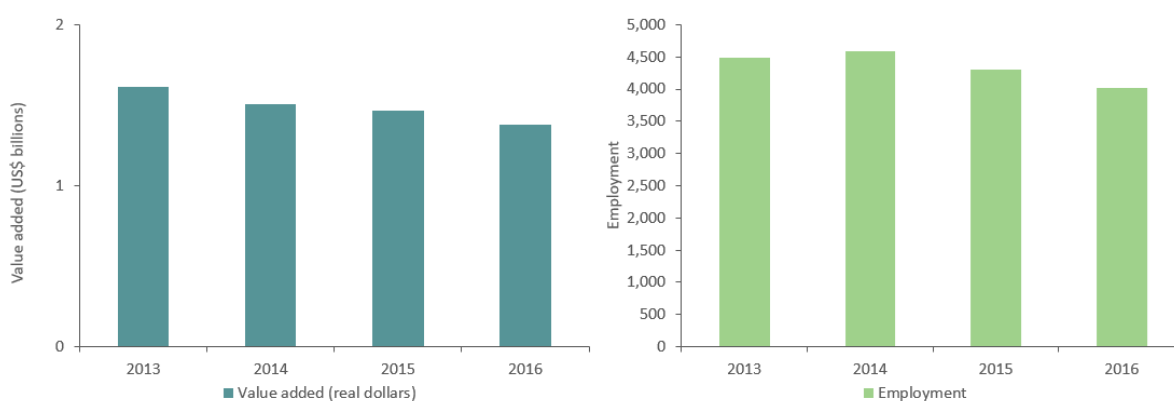
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# Pulp, Paper, and Paperboard

## Sector background

The paper manufacturing sector (NAICS 322) is a prominent industry in Oregon but is currently experiencing a challenging outlook. The sector is an important economic driver for Oregon, providing US\$1.5 billion in value added and around 4,000 jobs on average over 2014–16 to the Oregon economy. However, over 2013–16 the sector experienced a small decreasing trend in value added,<sup>53</sup> illustrated in Figure 29. Broader global market trends have seen recent declines in graphic paper and newsprint consumption, a positive outlook for packaging and containerboard/linerboard products, and a slightly more volatile tissue market.

Figure 29. The paper manufacturing sector has seen a small decreasing trend in terms of value added over 2013–16



Source: Vivid Economics and US Census Bureau

**Oregon's forest resources and low electricity prices are conducive to paper manufacturing.** The state is the largest lumber producer in the US, with 30.5 million acres of forest and 50% of its landmass covered by forests (OFRI, 2017b). Proximity to such significant forestry resources makes Oregon a natural location for pulp and paper facilities. Paper manufacturing in Oregon also benefits from the state's low average electricity prices. In June 2018, average electricity price to industrial sectors was 5.8 c/kWh, making Oregon the state with the seventh-cheapest average electricity price (US Energy Information Association, 2018).

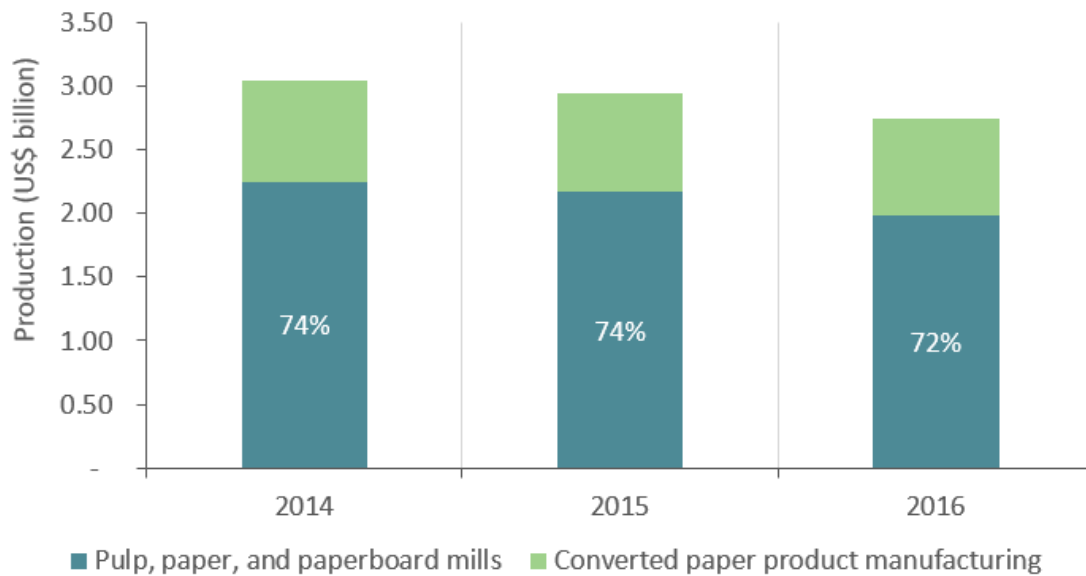
**The paper manufacturing sector comprises two NAICS 4 subsectors:**

- 3221 Pulp and Paper Manufacturing
- 3222 Converted Paper Products

**The pulp and paper subsector dominates paper manufacturing production in Oregon and manufacturing sector emissions.** Over 2014–16, the pulp and paper subsector comprised on average 73% of the total value of paper manufacturing production in Oregon, as shown in Figure 30. The subsector was also the largest absolute GHG emitter in the manufacturing sector over this period – third only to fossil fuel power generators and waste treatment and disposal facilities.

<sup>53</sup> Value added: a measure of the value of goods and services produced in an industry defined as total output minus the cost of inputs and raw materials.

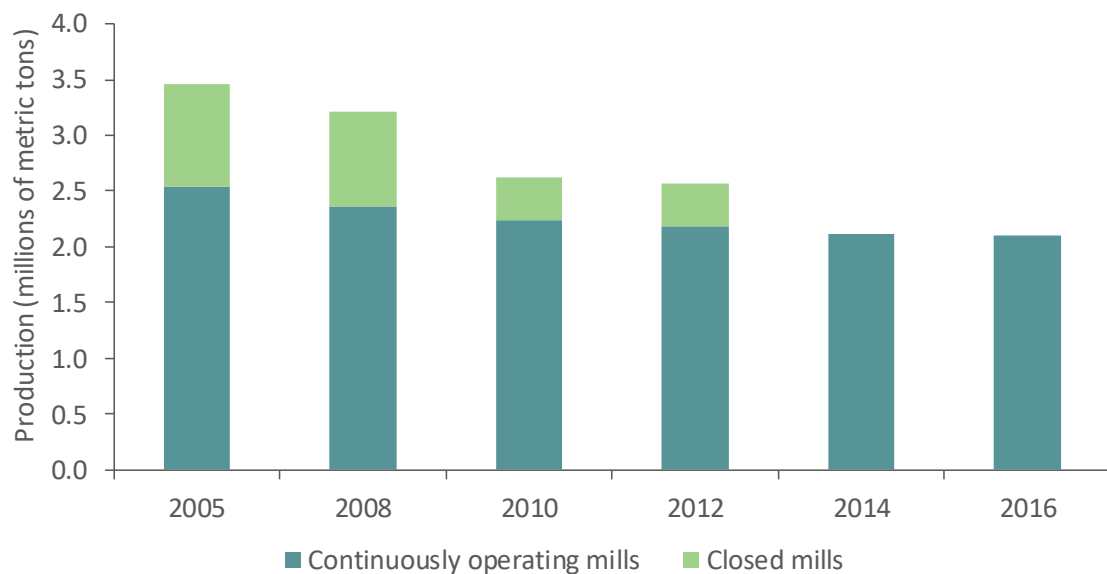
Figure 30. Pulp and paper manufacturing dominates paper manufacturing production in Oregon



Source: Vivid Economics and US Census Bureau

The pulp and paper subsector in particular experienced a decline in output volumes over 2014–16 and the closure of several facilities. Figure 31 shows that annual production declined from just above 3.5 million tons in 2005 to around 2 million tons in 2016. From 2005 to 2016, four pulp and paper facilities closed in Oregon, and one additional facility closed in 2017 (NWPPA, 2018).

Figure 31. The Oregon pulp and paper sector's annual production has declined since 2005 and several mills are now closed

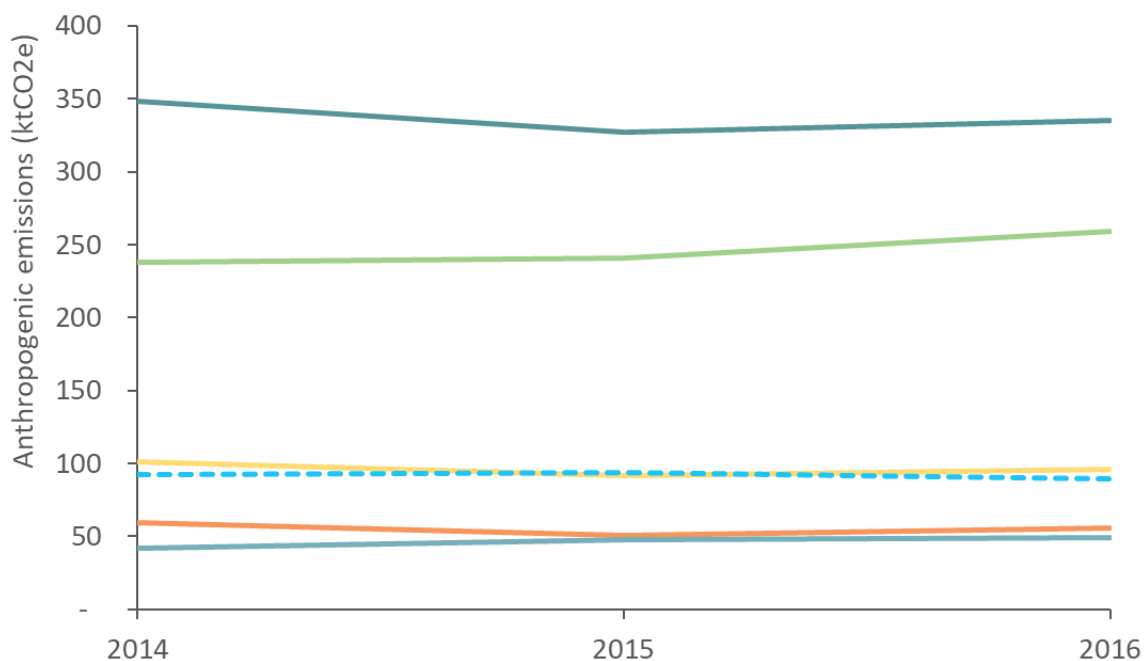


Source: Vivid Economics based on NWPPA (2018)

## Carbon cost exposure

In 2016, there were eight pulp and paper facilities in Oregon, five of which would have been above the proposed threshold to be covered under the carbon price. Six facilities located in Lincoln, Clatsop, Lane, Linn, Clackamas, and Columbia would have been covered, although stakeholders noted that in 2017 one of the potentially covered facilities closed down, leaving five remaining facilities under a possible carbon price. Two large facilities, owned by one company, emit significantly more than the other four covered pulp and paper facilities, as shown in Figure 32. While there are four converted paper products manufacturers (NAICS 3222) reporting emissions in Oregon over 2014–16, none of these was close to the eligibility threshold for coverage under the carbon price.

Figure 32. Over 2014–16, two of the six pulp and paper facilities covered under a carbon price emitted significantly more than the other facilities



Note: The dashed blue line represents the Oregon pulp and paper mill that closed in 2017.

Source: Vivid Economics and DEQ

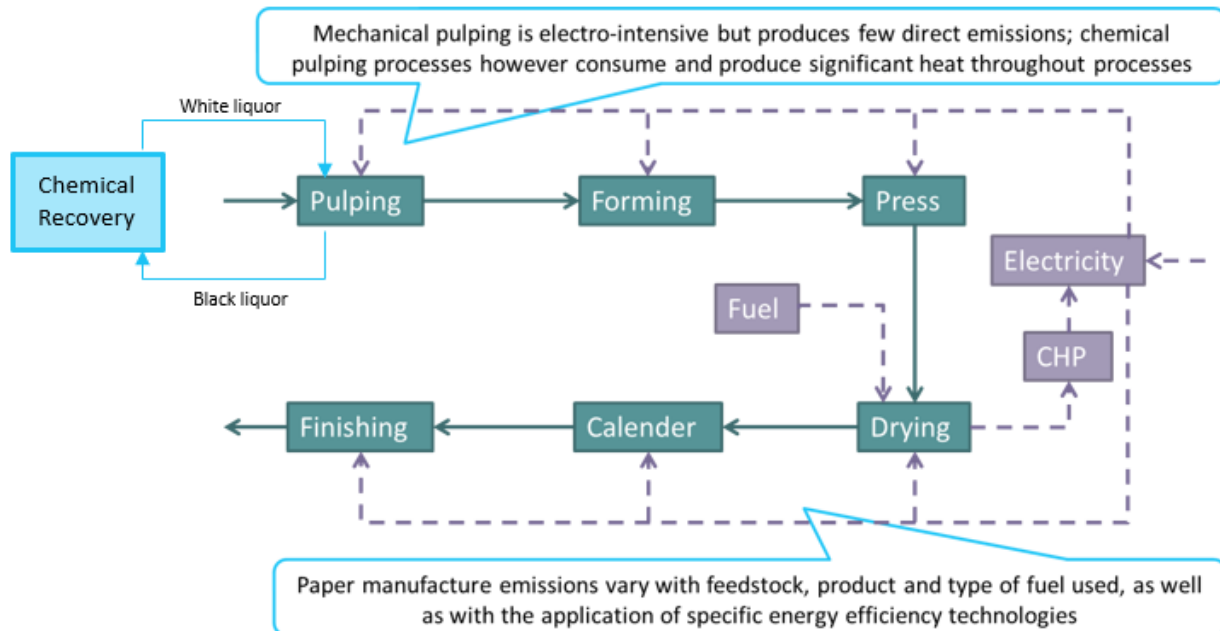
### Products and processes

Oregon's paper facilities produce a variety of products, including bleached and unbleached Kraft papers, and virgin Kraft market pulp. Pulp and paper facilities in Oregon create a variety of products ranging from linerboard for boxes, to tissue and paper towels.

The six basic steps of paper production are capital- and energy-intensive. To produce paper, pulp is mixed with water to produce a pulp slurry, which is then sprayed onto a screen. This web of slurry is subsequently pressed at high speed between large rolls that squeeze out the water. The pressed sheet is passed to heated cylinders for drying, after which the paper is rolled in the "calender", a series of high-pressure rollers to provide finish and ensure uniform consistency. The paper is rolled up at the end of the machine and later re-rolled into smaller reels ready for shipping. Figure 33 illustrates these six key processes. There is an additional

process in chemical pulp mills: the chemical recovery, during which spent cooking liquor (black liquor) used in the pulping process is recovered and converted back to cooking liquor (white liquor) to be re-used.

Figure 33. There are six key processes in the manufacture of pulp and paper products



Note: In the above diagram, pulping occurs only at a pulp mill or an integrated plant. Recovered paper can be incorporated in the pulping process once de-inked, or used in the forming process.

Source: Vivid Economics

**The most emissions-intensive process in paper production is the drying.** Emissions from paper production are dependent on feedstock, product type, fuel used and energy efficiency processes. However, in all cases the most energy-intensive step in production is the drying process. In chemical pulp mills, processes used during the chemical recovery are also highly energy-intensive.

**The level of biomass used and emissions profile of facilities in the sector are dependent on the products produced and the degree of integration.** Emissions from newsprint production stem largely from electricity use, whereas emissions from pulp, paper, and paperboard facilities are largely derived from biomass consumption which is considered carbon-neutral in Oregon. Within these sectors, non-integrated facilities generally have greater percentages of on-site fossil fuel consumption and electricity consumption. This is largely because integrated facilities have access to biomass from pulping residues (Schneck & Boyd, 2011).

### Emissions reduction opportunities

**Emissions intensity from Oregon's paper manufacturing sector benefits from biomass use and heat recovery, although it is likely to be technically feasible to increase the use of biomass.** Pulp facilities burn spent pulping materials in recovery boilers; this generates steam, which is used to run manufacturing processes. Excess steam is used to generate electricity through cogeneration or combined heat and power. The sector's share of biomass cogeneration from wood waste in Oregon (63%) is slightly lower than the national average of around two-thirds (AF&PA, 2014), suggesting that further use of cogeneration is technically feasible.



**Stakeholders suggest that the opportunity to increase biomass cogeneration is limited by costs and regulations.** Stakeholders suggest that in Oregon there is a limited supply of pulpwood, which is used for cogeneration, because wood processors are very efficient in the utilization of their inputs. Federal regulations may also limit the amount of biomass that can be used in boilers. The Environmental Protection Agency's standards, known as Boiler MACT,<sup>54</sup> impose limits on other hazardous pollutants that result from burning biomass (McCarthy, 2013).

**Facilities have various additional options for increasing energy efficiency.** The main electricity end-uses in the northwest region's pulp and paper sector are motors for pumps and fans, accounting for 35–75% electricity consumption (NWPPCC, 2017). Measures to optimize pumps and fans, particularly variable frequency drives (VFDs), and air compressor optimization have significant energy-saving potential, and have been cited as the two energy-efficiency options with the most potential across Oregon's industrial sector by 2021, followed closely by general energy management facilities (Northwest Power and Conservation Council, 2016).

**The major uses of steam in chemical pulp mills are in the digester, pulp and paper drying, black liquor evaporation and parasitic steam uses in the power island. These steam requirements are linked closely to process conditions such as water content, so there may be limited opportunities for energy efficiency improvements.** Pulp and paper facilities can also potentially make further use of excess heat to dry biomass or heat buildings; insulate steam and condensate pipe fittings to reduce heat loss; and match steam pressure levels with actual pressure needs (Suhr et al., 2015). The costs of investment in these energy efficiency measures require further research to determine economic feasibility.

**The Oregon pulp and paper subsector is relatively energy-efficient, although efficiency levels are heterogeneous, which leaves room for improvements.** While pulp and paper facilities in the northwest region are fairly old (+/– 75 years on average), many facilities have undergone frequent capital upgrades (NWPPCC, 2017). However, Northwest Power and Conservation Council (2016) estimates that the pulp and paper subsector in the northwest region still has some of the highest energy savings potential in the region. An Oregon energy sector expert noted that while the sector has experienced strong energy efficiency improvements over the recent past, different pulp and paper facilities in the state may still have heterogeneous levels of energy efficiency.

### ***Relative emissions intensity***

**Oregon's pulp and paper sector is relatively emissions-intensive.** The sector was the fourth most emissions-intensive sector in the state over 2014–16, implying that its carbon cost burden may be significant. Under the methodology currently used by California's cap-and-trade program, this would be classified as "medium" emissions-intensive.

<sup>54</sup> National Emission Standards for Hazardous Air Pollutants for Major and Minor Sources: Industrial, Commercial, and Institutional Boilers and Process Heaters.

**Table 46. The pulp and paper subsector in Oregon has a relatively high emissions intensity**

NAICS code	Sector description	Average sectoral direct emissions (ktCO <sub>2</sub> e)	Average sectoral indirect emissions (ktCO <sub>2</sub> e)	Average value added (US\$ million)	Average direct emissions intensity of value added (tCO <sub>2</sub> e/ value added US\$ million)	Average total emissions intensity of value added (tCO <sub>2</sub> e/ value added US\$ million)
3221	Pulp and Paper Manufacturing	899	452	1,151	781	1,174

*Note:* Indirect emissions estimated assuming the subsectors reflect the electricity intensity of production of the subsector at a national level and all facilities' electricity has the average emissions factor of the carbon intensity of Oregon's electricity grid over 2014–16 of 0.3610 tCO<sub>2</sub>e/MWh (DEQ, 2018b). Value-added data estimated for the pulp and paper sector.

*Source:* Vivid Economics, US Census Bureau and DEQ

## Markets and competitive dynamics

**The Oregon pulp and paper industry's primary markets are within the US but they also sell to European and Asian markets.** Markets are located particularly in the Pacific northwest, southern states and southeastern states. California and the West Coast are significant markets for all pulp and paper producers.

### **Domestic competition**

**Within the northwest region there is little competition among pulp and paper facilities, but external state competition is strong.** Northwest region companies do not compete as they generally produce differentiated products. However, the pulp and paper subsector in Oregon faces competition from other US states. Key competitive dynamics are between facilities owned by the same companies but located in different states. Stakeholders noted that particularly strong competition is evident from pulp and paper facilities in states such as Oklahoma that are in the west south central region of the US. For example, Georgia-Pacific has two facilities producing wallboard and tissue products, and International Paper has one corrugated-package facility located in Oklahoma.

### **International competition**

**International competition from China for input recycled paper and final paper products may be diminishing.** In recent years, it has been suggested that subsidized Chinese producers have been outbidding Oregon producers for recovered paper at the expense of Oregon and other states (Dudley, 2016). This has created a lack of supply of recycled paper which is a key input for certain Oregon facilities. However, in 2017, China banned imports of unsorted waste paper and growing domestic demand may turn China from a competitor to a significant new potential market (Elhardt, Min, & Lu, 2018). This growing domestic demand also means that the Chinese government encourages paper production for domestic markets (PR Newswire, 2018a).

### **Cost pass-through capacity**

**The pulp and paper industry may have limited cost pass-through capacity given these competitive dynamics.** Industry stakeholders suggest that they compete with external producers on prices rather than on

product differentiation. As some competitors, such as facilities in Oklahoma, are in jurisdictions without carbon pricing, this may limit the Oregon sector’s ability to pass through carbon costs without losing market share. However, some competitors are in California where there is a carbon price.

## Leakage risk identification in other jurisdictions

**The paper manufacturing sector is commonly identified as an at-risk sector in other jurisdictions, as illustrated in Table 47:**

- EU Emissions Trading System (ETS) Phase III metric: pulp and paper identified based on the trade intensity metric;
- EU ETS Phase IV metric: pulp and paper identified;
- California metric: pulp and paper identified the sector as at “high” leakage risk based on high trade intensity and medium emissions intensity.

*Table 47. Treatment of the pulp and paper sector in external jurisdictions*

Metric	EU ETS Phase III				EU ETS Phase IV	California		
	Trade intensity	Cost increase	Joint metric	Identified	Identified	Trade intensity	Emissions intensity	Level of risk
Initial assessment	Yes	No	Yes	Yes	Yes	High	Medium	High

Source: Vivid Economics

## Conclusion

**There are several factors that suggest the pulp and paper industry should be designated as EITE:**

- The sector is relatively emissions-intensive in Oregon, and would have a “medium” emissions intensity classification under California’s methodology.
- There may be limited ability to pass through asymmetric carbon costs<sup>55</sup> as the sector mainly competes with other US domestic producers on the basis of price.
- Evidence of decreasing production and value added over recent years, combined with mill closures, suggests the sector already faces competitiveness challenges.
- Precedents in other jurisdictions suggest the sector may be at risk of leakage.

**Several factors reduce underlying carbon leakage risk:**

- The subsector in the region may have significant energy-savings potential and facilities could make use of best-available technologies to improve efficiency.
- The sector’s use of biomass is lower than the national average, suggesting that its uptake is prevented by relative cost considerations and regulatory constraints rather than technical barriers.
- Exposure to Chinese competition for waste paper as a raw material may be decreasing, although there is a risk it could quickly change its policy on imports of collected waste paper.

**On balance, the sector is at risk of carbon leakage if Oregon introduces a carbon price without measures to protect against possible adverse competitiveness impacts.** A carbon pricing instrument for this sector

<sup>55</sup> Asymmetric carbon costs arise when some producers are faced with a carbon price while others either face no carbon price at all or face a smaller carbon price.

should be designed to ensure that innovation and emissions reduction incentives remain, while also incorporating measures to protect against the risk of carbon leakage and other competitiveness impacts.

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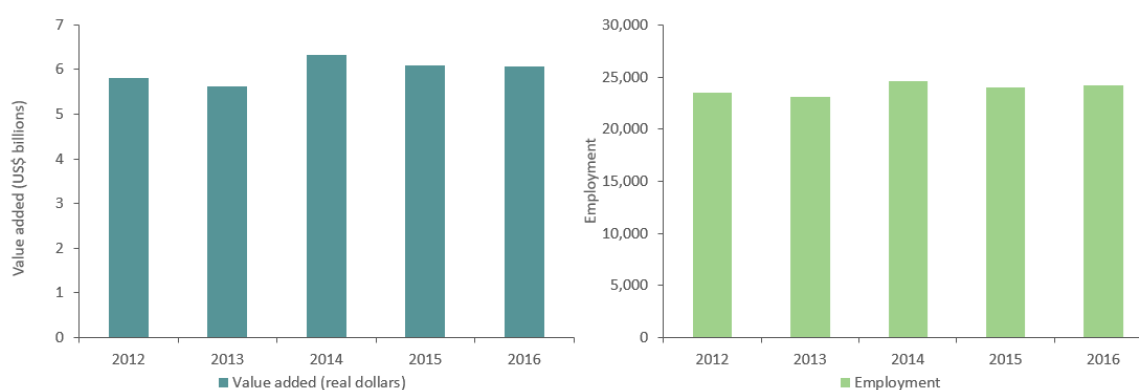
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# Semiconductors

## Sector background

**Computer and electronic component manufacturing is a very significant source of value added and employment in the Oregon.** Figure 34 indicates the sector's significant value added and employment contribution to Oregon's economy over 2012–16. The sector represents on average 22% of Oregon's manufacturing sector value added and 15% of total manufacturing employment. This makes the sector Oregon's top manufacturing industry. In 2017, the sector increased its share of manufacturing employment to 19%, whereas nationally, the sector represented only 8.4% of total manufacturing employment (Bechtoldt, 2017b).

**Figure 34. Over 2012–16, Oregon's computer and electronic component sector consistently generated around US\$6 billion in annual value added and employed on average around 24,000 people**



Source: Vivid Economics and US Census Bureau

### The computer and electronic components sector comprises of six NAICS 4 subsectors:

- 3341 Computer and Peripheral Equipment Manufacturing
- 3342 Communications Equipment Manufacturing
- 3343 Audio and Video Equipment Manufacturing
- 3344 Semiconductor and other Electronic Component Manufacturing
- 3345 Navigational, Measuring, Electromedical, and Control Instruments Manufacturing
- 3346 Manufacturing and Reproducing Magnetic and Optical Media

**The semiconductors and other electronic components manufacturing subsector (NAICS 3344) is particularly important for Oregon.** In 2016, this was the largest value-adding subsector in manufacturing in Oregon, with around US\$4 billion gross value added. Semiconductor manufacturers account for around two-thirds of total employment in the computer and electronic components sector in Oregon (US Census Bureau, 2017). Oregon accounts for 10% of America's output of semiconductors and is a major center for R&D in the sector.

**The sector is predominantly concentrated in the Portland metro region.** Initially, the sector comprised Tektronix, Intel, Hewlett Packard and Mentor Graphics. However, recently it has grown quickly, with the emergence of many start-ups. The largest cluster is found around the city of Hillsboro where Intel's largest global manufacturing facility is located. Oregon's low energy costs and low cost of doing business make the state a globally competitive location for semiconductors manufacturing (Business Oregon, 2017).

## Carbon cost exposure

**Ten semiconductor and other electronic component manufacturing facilities reported emissions during 2014–16, five of which would potentially be covered under a carbon price.** Table 48 shows the breakdown of the Oregon computer and electronic components manufacturing sector at the NAICS 4 level.

*Table 48. Five semiconductor manufacturing facilities would potentially be covered under a carbon price*

NAICS 4 code	Sector description	No. facilities reporting emissions over 2014–16	No. facilities emitting more than 25 ktCO <sub>2</sub> e over 2014–16
3344	Semiconductor and other Electronic Component Manufacturing	10	5

Source: Vivid Economics and DEQ

### **Products and processes**

**The semiconductor manufacturing sector produces a variety of electronic processing chips components.** These processing chips are largely silicone-based and tend to involve complicated production processes. Facilities in the sector produce a range of differentiated products, from 8-bit and 16-bit microcontrollers to microprocessors.

**Manufacturing semiconductor chips uses a production process known as fabrication.** At a high level, the production process entails many steps using both photogenic and chemical processing during which electronic circuits are gradually created on wafers made of semiconducting material. Silicon is the most common semiconducting material currently in use. In broad terms there are two main production phases: wafer production and processing. First, silicon wafers are produced from raw materials and sliced into discs. These discs then go through multiple rounds of processing. Different producers may use different types of intermediate processing steps (broadly grouped into front-end and back-end processes) depending on the type of chip being produced and the technological capabilities of the facility. However, in general, all types of processing incrementally prepare the silicon wafer and incorporate circuits to produce a final semiconductor chip.

### **Emissions reduction opportunities**

**Most emissions from semiconductor manufacturing arise from fluorinated-gas (known as F-gas) consumption during the process, for which there are no technically viable substitutes.** Around a quarter of direct emissions are from natural gas combustion. The main source of emissions, however, are F-gases which are necessary in the production of semiconductors and used to clean chambers in which silicon chips are made. These F-gases have high global warming potential (GWP) (Patel-Predd, 2008). Currently, there are no technically viable substitutes for F-gases in the production process (Intel, 2017)

**Despite this, the semiconductor industry has some limited options to reduce F-gas emissions, many of which have been implemented, and more research is required on the viability of further abatement options.** The industry as a whole has reduced the intensity of F-gas emissions over time. For example, Intel reduced its emissions per chip manufactured by 80% over 1996–2010. Indeed, given F-gases are relatively expensive and are used as an input, installations are already incentivized to minimize their use. These

reductions have been achieved through a variety of industry-driven options, such as point-of-use abatement,  $\text{NF}_3$  (nitrogen trifluoride) remote plasma chamber cleans, chemical substitution (i.e. from higher to lower GWP gases), process optimization and energy efficiency improvements (Intel, 2017). Stakeholders claim that many point-of-use abatement, tool modification or chemical substitution options are costly and require industry-level changes. Furthermore, point-of-use abatement often produces additional pollutants of concern including toxics and criteria pollutants. Further research is required on the economic and technical viability of these options.

**Manufacturing semiconductors requires large amounts of electricity and energy efficiency options may be limited.** Electricity accounts for around two-thirds of all energy use in the sector (NWPCC, 2016b). The sector consumes electricity for process equipment, maintaining optimal conditions, heating, ventilation, air conditioning and chillers. Layering and diffusing processes are particularly energy-intensive (Gopalakrishnan et al., 2010). However, the US industry as a whole has already achieved significant recent efficiency improvements, having reduced energy consumption by 34% over 2001–15 (Semiconductor Industry Association, 2017). Oregon stakeholders in the sector have worked closely with the Energy Trust of Oregon on incentivized energy efficiency projects and have installed updated equipment like efficient chillers and variable frequency drives (VFDs). However, stakeholders claim that they have nearly exhausted the low-hanging fruit efficiency options. Further projects may entail a step-change increase in costs and a low return on investment, such as pump improvements for over US\$1 million. The Northwest Power and Conservation Council's (2016) Seventh Conservation and Electric Power Plan supports this, indicating that the region's hi-tech chip and silicon manufacturing sectors have some of the lowest energy conservation potential by 2035 out of all sectors.

### ***Relative emissions intensity***

**The sector has moderate-to-low emissions intensity relative to other covered facilities in Oregon, but there may be limited opportunities to decrease emissions further.** The sector's direct emissions are largely derived from non-substitutable F-gas usage. California's current emissions intensity category thresholds would identify this Oregon sector as low emissions intensity. However, incentivizing efficiency improvements has been shown to be possible in other jurisdictions. *Ex ante* analysis of Taiwanese semiconductor manufacturers found that using emissions benchmarking could raise the technical efficiency of production and thereby boost sales revenue by US\$490 million (Liou et al. 2018). Further research is necessary to determine whether this would also drive emissions reductions in Oregon.

**Table 49. The semiconductors subsector in Oregon has moderate-to-low total emissions intensity**

NAICS code	Sector description	Average sectoral	Average sectoral	Average value-	Average direct	Average total
		direct emissions (ktCO <sub>2</sub> e)	indirect emissions (ktCO <sub>2</sub> e)	added (US\$ million)	intensity of value added (tCO <sub>2</sub> e/value added US\$ million)	intensity of value added (tCO <sub>2</sub> e/value added US\$ million)
3344	Semiconductor and other Electronic Component Manufacturing	646	1,090	3,717	174	467

*Note:* Indirect emissions estimated assuming the subsectors reflect the electricity intensity of production of the subsector at a national level and all facilities' electricity has the average emissions factor of the carbon intensity of Oregon's electricity grid over 2014–16 of 0.3610 tCO<sub>2</sub>e/MWh (DEQ, 2018b).

*Source:* Vivid Economics, US Census Bureau and DEQ

## Markets and competitive dynamics

**International consumers are the most important source of demand for the semiconductor manufacturing sector in the US.** In 2015, international sales made up 83% of US semiconductor manufacturing production, which reflects the fact that many end-use consumers such as computer assembly facilities are located in Asia (Platzer & Sargent, 2016). Oregon stakeholders noted that around 50% of their revenue came from the Asian market, while remaining demand was equally split between the domestic US market and the European market (where carbon emissions are priced). Global demand for semiconductors is also seen to be robust and growing due to their increasing use in a variety of products.

### **Domestic and international competition**

**Domestic semiconductor manufacturing facilities are largely located in the northwestern regions without carbon pricing.** In the northwest region, over half the semiconductor fabrication plants and 62% of regional employment in the sector are located in Oregon, with Washington and Idaho having six fabrication plants each (NWPCC, 2016b). Competitors outside the northwest region are in largely in states without carbon pricing. In 2015, there were 12 competitor facilities outside of Oregon producing 300mm silicon wafers, located in Arizona, New Mexico, New York, Texas, Utah and Virginia (Platzer & Sargent, 2016).

**The US is a key player in the global market of semiconductor manufacturing.** In 2015, the US-based companies had a 50% share of the global market in sales. These companies have a majority of the global market for integrated circuits design and fabrication, which makes up 80% of the global semiconductor market. Within integrated circuits, the US leads in logic and analog processors, notably high-end microprocessors, communication chips for smartphones and devices, and networking components for routers, the Internet, and landline exchanges (President's Council of Advisors on Science and Technology, 2017). However, these companies have fabs around the world and North America represented 14% of the world's fab capacity in 2015, down from 30% in 1990. US-based companies are increasingly moving fabrication facilities abroad, or even focus solely on the design while contracting out fabrication (fabless



companies). The next biggest competitors are based in South Korea (17%), Japan (11%), the EU (9%), and Taiwan (6%) (Hinnman & Kreps, 2016). There is a carbon price in South Korea and in the EU.

**The international environment has grown more challenging recently and tariff increases on Chinese goods may increase the costs of producing semiconductors in Oregon.** The US chip industry at large estimates the tariffs (and retaliatory action) will cost around US\$700 million annually, which would significantly impact sector profits (Chittooran, 2018). This is the case as China (along with Vietnam and Malaysia) is a vital part of the semiconductors value chain. Finished semiconductor chips are sent to Asian manufacturers for incorporation into devices, which are then exported back to the US (Rogoway, 2018).

**Some quantitative evidence suggests this sector has a high trade exposure, although exposure to jurisdictions which have carbon pricing is unclear, therefore making inferences challenging.** The 2016 IMPLAN dataset for Oregon indicates that its semiconductor manufacturing plants' state and international trade exposure is very high, at 91%.<sup>56</sup> However, the IMPLAN dataset does not offer insights on the nature of this trade exposure: if exposure is to jurisdictions which already apply a carbon price, this reduces underlying carbon leakage risk. Thus, this figure should be treated with caution.

### ***Cost pass-through summary***

**The semiconductors and other electronic components subsector has strong competition in international markets, but high margins reduce relocation risk for some facilities.** Competition from domestic and international producers in the major Asian market may limit the sector's ability to pass through carbon costs. However, some companies in the sector operate with high margins, which reduces relocation risk. Evidence and stakeholders suggest that gross margins in the sector may be as high as 60%.

**A carbon price may have the potential to influence investment decisions in the sector.** Some sector stakeholders note that it could take up to a year to ready their other facilities to produce what Oregon facilities produce. However, the rate of change of technology is such that decisions on investment in new plant and equipment are relatively frequent. As such, while short-term production shifts out of the state are less likely, a carbon price may change the relative return on capital in Oregon versus facilities that are out of state or outside the US.

## **Leakage risk identification in other jurisdictions**

**Manufacturers of electronic components, including semiconductors, have been identified as EITE under the EU Emissions Trading System (ETS).** As shown in Table 50, Phase III of the EU ETS identified electronic component manufacturers as at risk of carbon leakage based on their exposure to trade with external jurisdictions. However, under Phase IV the sector no longer qualifies for EITE support based purely on quantitative methods. The sector will instead be eligible for a qualitative assessment to determine carbon leakage risk as its quantitative carbon leakage indicator was between 0.15 and 0.20. The outcome of the assessment will be known in 2019.

**California regulates semiconductor manufacturers under a separate regulation to the cap-and-trade.** In 2010, the California Air Resources Board (CARB) implemented the Regulation to Reduce Greenhouse Gas Emissions for Semiconductor Operations, which aims to reduce F-gases from the sector. The regulation

<sup>56</sup> Trade exposure in this case is defined as the summation of state imports and exports divided by the summation of Oregon production plus imports.

requires all facilities to abide by reporting guidelines and implements emission standards on operations that emit more than 800 tCO<sub>2</sub>e annually (CARB, 2018). The emissions standard ranges from 0.2–0.5 kgCO<sub>2</sub>e/cm<sup>2</sup> depending on the annual wafer surface area processed at the facility (CARB, 2009).

*Table 50. Treatment of the semiconductors and other electronic components sector in external jurisdictions*

Sectors	Metric	EU ETS Phase III				EU ETS Phase IV	California		
		Trade intensity	Cost increase	Joint metric	Identified	Identified	Trade intensity	Emissions intensity	Level of risk
Manufacture of electronic components	Initial assessment	Yes	No	No	Yes	Qualifies for qualitative assessment as indicator > 0.15	Semiconductor manufacturers regulated separately		

Source: Vivid Economics

## Conclusion

**There are several factors that suggest the semiconductors and other electronic components subsector should be designated as EITE:**

- Emissions reduction options for the sector may be limited due to the non-substitutability of F-gases and widespread uptake of energy efficiency options. Indeed, given F-gases are relatively expensive and are used as an input, installations are already incentivized to minimize their use.
- Competition is strong both domestically and internationally, especially in jurisdictions without carbon pricing, limiting the sector’s ability to pass through carbon costs without losing long-term market share.
- The rate of change of technology in the sector suggests that the risk of leakage could be high, especially within companies with plants in multiple jurisdictions. This risk remains even for companies with plants in Europe: the carbon pricing system there does not cover F-gases. It is also possible for fabs to outsource parts of the production process.

**However, several factors reduce underlying carbon leakage risk:**

- The sector’s emissions intensity is moderate-to-low relative to other Oregon sectors.
- Some facilities in the sector enjoy relatively high profit margins which reduces relocation risk.
- Evidence from other jurisdictions suggests that emissions benchmarking could increase technical efficiency in the sector, although further research is required on this in Oregon’s context.

**On balance, the sector is at risk of carbon leakage if Oregon introduces a carbon price without measures to protect against possible adverse competitiveness impacts.** A carbon pricing instrument for this sector should be designed to ensure that innovation and emissions reduction incentives remain, while also incorporating measures to protect against the risk of carbon leakage and other competitiveness impacts.

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# Wood Products and Sawmills

## Sector background

**Oregon's wood products manufacturing sectors are an important part of the Oregon economy.** Despite having gone through significant losses in employment over 1990–2010, the sectors are still large and an important source of employment for the state (Rooney, 2018b). The sectors are more important in terms of employment for all Oregon counties relative to the national average, but in particular for counties such as Coos, Curry, Douglas, Baker, Union, Wallowa, Klamath and Lake (Business Oregon, 2016). Across the state as a whole, employment in these sectors makes up 1.2% of all state employment; in rural counties this proportion is often significantly higher, such as in Douglas where the sectors account for 8% of total employment (Rooney, 2018b).

**The sectors have recently experienced a slight improvement in performance with a more positive market outlook.** Since 2012, both value added and employment show a marginal increasing trend as illustrated in Figure 35.<sup>57</sup> The Oregon Employment Department forecasts growing employment in the sectors between 2014 and 2023 and growing demand for wood products due to a strong national economy and housing market (Rooney, 2018b). Furthermore, a recent Oregon building code amendment will allow timber buildings to rise higher than six stories, which could be a boost for the wood products manufacturing sectors (Hilburg, 2018). However, stakeholders suggest housing starts are expected to slow in the short term, curbing production. Wood products demand could also be boosted as states increasingly consider embodied carbon in public procurement, such as California's Buy Clean Act for state-funded infrastructure projects. In 2018, housing demand in the west region, along with lumber prices, reached highs not seen since 2007. In particular, Oregon construction grew by 5% in 2017 and by an expected 7% in 2018 (Oldcastle Business Intelligence, 2017; Northwest Farm Credit Services, 2018).

**Figure 35. Over 2012–16, Oregon's wood product manufacturing sectors have seen increasing annual value added and employment**



Source: Vivid Economics and US Census Bureau

**Oregon's natural resource base combined with innovative production processes makes it a well-suited location for wood product manufacturing.** Oregon's forestry base is substantial and the state is the largest

<sup>57</sup> Value added: a measure of the value of goods and services produced in an industry defined as total output minus the cost of inputs and raw materials.

lumber producer in the US. Nearly half – 30.5 million acres of the state’s 63 million acre total land mass – is covered by forests. About 18 million acres, or 60% of the state’s forestland, are owned by the federal government and have experienced declining harvest levels due to federal management changes (OFRI, 2013). Large private timber companies own about 6 million acres, while smaller private owners account for around 5 million acres (OFRI, 2010). Advanced technology has increased the competitiveness of the industry and allowed producers to make higher value-adding products, particularly with Oregon being home to a highly skilled workforce and leading forestry schools (Business Oregon, 2012). The innovation in the state can also be seen in the increasing use of cutting-edge cross-laminated timber (CLT) in new buildings (Stein, 2018).

**The wood products manufacturing sector comprises three NAICS 4 subsectors:**

- 3211: Sawmills and Wood Preservation
- 3212: Veneer, Plywood, and Engineered Wood Product Manufacturing
- 3219: Other Wood Product Manufacturing

**The veneer, plywood and engineered wood products subsector is particularly important for Oregon.** The Oregon sector makes up 29% of all US plywood production. Oregon is also a US leader in engineered wood and is home to the first mill in the US to manufacture certified CLT (OFRI, 2017a).

## Carbon cost exposure

**Oregon has 69 wood product manufacturing facilities reporting emissions over 2014–16, but only two companies emit above the threshold and would potentially be covered under a carbon price.** Of the two companies, one emitted over 25,000 tCO<sub>2</sub>e in only one year (2014) and so may not be covered moving forward. In 2017, an additional facility reached the emissions threshold and may potentially be covered in the future.

### *Products and processes*

**The key products produced by the companies potentially covered by a carbon price are particleboard, plywood and logs and lumber products.** The NAICS 3212 company produces additional products, such as engineered wood, lumber, plywood, laminate panels, veneer, chipboard and wood pellet fuel. The NAICS 3211 company largely processes pine logs to produce specialty and industrial lumber products (Interfor, 2017).

**A third of wood product emissions are biogenic, and are therefore not covered under the proposed carbon pricing mechanism; however, some manufacturing processes and some value-adding processes rely on natural gas combustion.** On average, across all wood manufacturing facilities reporting emissions in Oregon, around 32% of total emissions were biogenic over 2014–16, and thus not regulated under the proposed carbon pricing mechanism.<sup>58</sup> For wood product manufacturing, fuel use in the northwest region is split between electricity and natural gas in varying ratios, with many mills also supplementing fuel use with biomass mill residue. The most emissions-intensive production process is particle drying, which generally uses direct-fired dryers; however, one of the potentially covered facilities in Oregon does not use these (NWPPCC, 2016c). The majority of anthropogenic emissions from sawmills are derived from onsite natural gas cogeneration plants that produce electricity for internal use and steam to operate dry kilns. For sawmills, the energy intensity of operations also depends on the tree species which affects moisture content and wood

<sup>58</sup> Biogenic emissions are the result of biological processes in the global carbon cycle. Plants sequester atmospheric CO<sub>2</sub> through photosynthesis and when plant biomass burns or biodegrades this releases sequestered CO<sub>2</sub> back into the atmosphere.

condition, lumber thickness and the types of drying fans (Loeffler et al., 2016);(NWPPCC, 2016c). For example, Breiner et al. (1987) calculated the energy requirements of drying four softwood species and found that drying Douglas fir trees required around half the energy required to dry ponderosa pine.

### ***Emissions reduction opportunities***

**Wood products manufacturers in Oregon already comply with relatively stringent environmental regulation and may have little opportunity for further emissions reduction, including from fuel-switching.** Companies must adhere to other local air pollutant regulations which may limit their ability to increase the use of alternative fuels which emit other local air pollutants.<sup>59</sup> However, biomass burning as a GHG emissions reduction measure is already widely used in the region. For example, NWPPCC (2016) findings suggest that biomass accounts for almost 94% of the total energy requirement for producing plywood. Stakeholders also suggest that the processes that result in anthropogenic emissions would be difficult and costly to retrofit with pollution control devices, and report that most facilities in the sector use similar technologies and that many natural gas-fired burners are newer units with high levels of efficiency.

**The sectors have invested significantly in energy efficiency improvements in recent years.** Discussions with an Oregon energy efficiency expert indicated that the lumber sector has gone through significant efficiency improvements over the last 20 years, largely induced by energy efficiency incentives and federal standards for new equipment (Oregon Department of Energy, 2018). Although facilities are still heterogeneous in their levels of efficiency, many of the low-cost efficiency options may have already been implemented.

**However, evidence from state assessments suggests there may be some additional scope for energy efficiency improvements.** The majority of electricity consumed by panel manufacturers and sawmills is from motors process equipment (NWPPCC, 2016). The Northwest Power and Conservation Council's (2016) Seventh Conservation and Electric Power Plan forecasts that the wood products sectors may have achievable technical energy savings potential of 70 GWh, 149 GWh and 166 GWh in 2021, 2026 and 2035, respectively. These energy savings are also achievable at a negative abatement cost in 2021 and 2026 (–US\$64–68/MWh) and at a low positive abatement cost of US\$24/MWh in 2035. Similarly, the Industrial Assessment Center's energy conservation recommendations database shows that installation of variable frequency drives (VFDs) to motors, compressor controls, and behavioral changes to equipment use are the measures with the highest potential energy savings in the Oregon veneer, plywood, and engineered wood product manufacturing sectors (IAC, 2018). Indeed, NWPPCC (2016) identifies changing blowers to conveyers and installing VFDs as options that comprise a quarter of all energy savings potential in the region's sectors.

### ***Relative emissions intensity***

**Both wood manufacturing sectors (3211 and 3212) exhibit relatively low sectoral emissions intensity.** Both sectors have an emissions intensity that California's methodology would determine as low, being between 100 and 1,000 tCO<sub>2</sub>e/value added US\$ million, as illustrated in Table 51.

<sup>59</sup> For example, wood-fired biomass burners may also result in an increase in other local air pollutants which would increase the companies' compliance costs for other local air pollutant regulation.

*Table 51. While both sectors have relatively low emissions intensities, plywood and engineered wood product facilities are more emissions-intensive than sawmills*

NAICS code	Sector description	Average sectoral direct emissions (ktCO <sub>2</sub> e)	Average sectoral indirect emissions (ktCO <sub>2</sub> e)	Average value added (US\$ million)	Average direct emissions intensity of value added (tCO <sub>2</sub> e/value added US\$ million)	Average total emissions intensity of value added (tCO <sub>2</sub> e/value added US\$ million)
3211	Sawmills and Wood Preservation	120	255	1,023	117	336
3212	Veneer, Plywood, and Engineered Wood Product Manufacturing	252	411	1,041	242	637

*Notes:* Indirect emissions estimated assuming the subsectors reflect the electricity intensity of production of the subsector at a national level and all facilities' electricity has the average emissions factor of the carbon intensity of Oregon's electricity grid over 2014–16 of 0.3610 tCO<sub>2</sub>e/MWh (DEQ, 2018b).

*Source:* Vivid Economics, US Census Bureau and DEQ

## Markets and competitive dynamics

### **Wood product manufacturers covered under a carbon price in Oregon mainly serve the domestic market.**

Major US markets for wood products produced in Oregon are other western and Midwest/central states. The southeastern states have a growing demand for wood products that is associated with the housing industry (NWPCC, 2016), which tends to be cyclical. The growth in demand in these states is also likely to benefit competitors located closer to these markets. The Oregon Forest Resources Institute (OFRI, 2017) notes that as much as 75% of all products made in Oregon are sold outside of the state. This exposes the sectors to competition from other jurisdictions. Wood products are largely commodity products, and producers in the sectors must compete mainly on price as there are many competitors providing high levels of supply. Markets for wood products and sawmills products in the US are also frequently dependent on short-term contracts. However, the covered sawmill in Oregon also has a long-term contract with a pulp and paper producer for wood chips and other residuals sales (Interfor, 2017).

### ***Domestic and international competition***

**Both wood products companies covered under a carbon price are part of larger companies with other facilities located in neighboring states.** This entails a significant degree of leakage risk, as it may be feasible for the companies to substitute production in Oregon for out-of-state production. For example, one interviewed company recently invested in new production facilities in South Carolina and Ontario (Roseburg, 2018) and has acquired 158,000 acres of timberland in Virginia and North Carolina.

### **Stakeholders suggest that they face competition in Oregon and competition with producers in other states.**

Oregon and Washington contain 75% of sawmills and 94% of panel/veneer manufacturing facilities in the northwest region (including Idaho and Montana). Competition within Oregon between covered and uncovered facilities could pose an internal risk of leakage. Stakeholders noted that competitors from other regions are located in states that have no carbon price nor any plans to introduce carbon pricing, such as Georgia-Pacific, located in Atlanta, Georgia (IncFact, 2018). Other west region states face particular

competitive vulnerability for lumber and plywood products, while strong competition for particleboard is largely in the central north and southern regions of the US.

**Solid wood product manufacturers need to source raw materials nearby, which limits the domestic US competitive potential to a number of states.** As product transportation within the North American market is costly and largely dependent on truck and rail transport networks, to which Oregon is well connected, wood product manufacturers tend to settle near lumber resources. This limits the number of states in which there will be competition for Oregon producers. However, stakeholders suggest that states in the south central and southeastern US have a timber source with a competitive advantage, as their timber stands grow significantly faster relative to timber stands in Oregon.<sup>60</sup> This allows companies owning timberland in these states to rotate plantations more quickly.<sup>61</sup> However, stakeholders suggest that lifecycle emissions could increase if production was to relocate to states further away from lumber resources and transport emissions are accounted for.

**In addition to other US states, stakeholders noted that they face competition from South American producers.** These producers may face lower input costs due to lower labor and environmental regulation obligations. There is some evidence to suggest that the competitive position of South American facilities is improving, with one company recently opening a production facility within the US. Howard & McKeever (2016) also note that in 2015 US wood products manufacturers were faced with a surge of plywood imports from South American producers on the back of a strong dollar.

**Some quantitative evidence suggests these sectors (3211 and 3212) have a high trade exposure, although exposure to jurisdictions which have carbon pricing is unclear, making inferences challenging.** The 2016 IMPLAN dataset for Oregon indicates that the state's wood product manufacturing plants' state and international trade exposure is very high, at 72% for sawmills and 83% for wood products.<sup>62</sup> However, the IMPLAN dataset does not offer insights on the nature of this trade exposure: if exposure is to jurisdictions which already apply a carbon price, this reduces underlying carbon leakage risk. Thus, this figure should be treated with caution.

### ***Cost pass-through capacity***

**The ability of Oregon wood product manufacturers to pass through carbon costs is likely limited due to competition from producers in other US states and international jurisdictions without carbon pricing.** Profit margins may be relatively low for the wood manufacturing sectors, with one sawmill company having EBITDA<sup>63</sup> margins of sales of around 13% on average over 2016–17 for all its operations (not just in Oregon) (Interfor, 2017). Stakeholder sentiment supports this, noting that profit margins are low in the sectors and dependent on cyclical industries like housing that are sensitive to natural business cycles. In addition, stakeholders suggest that sawmills and processors have closed down in the state recently, suggesting that the outlook for investment is uncertain.

<sup>60</sup> Various studies support this, showing that timber growth rates are higher in moist, warmer areas, particularly just after logging (although the level of impact can vary by tree species) (Yeh & Wensel, 2000; Toledo et al., 2011).

<sup>61</sup> However, output and revenues, and hence the competitive dynamics of producers, will also depend on various other considerations such as state forestry regulations, land-ownership dynamics, predominant tree species, and soil quality.

<sup>62</sup> Trade exposure in this case is defined as the summation of state imports and exports divided by the summation of Oregon production plus imports.

<sup>63</sup> Earnings before finance costs, income taxes, depreciation, depletion, amortization, restructuring costs, asset write-downs and other costs, and other foreign exchange gains (losses).



## Leakage risk identification in other jurisdictions

Engineered wood product manufacturers such as reconstituted wood products and veneer and plywood manufacturers are deemed at risk of carbon leakage under both the EU Emissions Trading System (ETS) Phase IV and the California cap-and-trade. Table 52 presents the carbon leakage risk identification of the wood product manufacturing sectors in other jurisdictions' carbon pricing instruments. In the EU ETS, Phase III veneer and plywood manufacturers are not deemed EITE, but with the change of methodology for Phase IV, the sectors are recognized as at risk of carbon leakage. California determines the reconstituted wood product manufacturing sectors as at high risk of carbon leakage, with a medium emissions intensity and a high trade exposure.

The sawmills sector is determined to have medium carbon leakage risk only in California and not at all for the EU ETS Phases III and IV. The sawmills sector falls below the quantitative threshold for both the methodologies of the EU ETS Phases III and IV. This means that the sector does not receive for free the full benchmark allocation level of allowances, but rather an annually declining portion. In 2018 this portion was 44.29% of the benchmark level (European Commission, 2011a). However, California deems the sector to be at medium risk of carbon leakage. While this sector is determined only at medium risk, amendments to the cap-and-trade regulations will ensure this sector will receive the same level of support as all other sectors on the carbon leakage list (100% of the output-based benchmark allocation level).

Table 52. Treatment of the sawmills sector and the wood products sector in external jurisdictions

Sectors	Metric	EU ETS Phase III				EU ETS Phase IV	California		
		Trade intensity	Cost increase	Joint metric	Identified	Identified	Trade intensity	Emissions intensity	Level of risk
Sawmills	Initial assessment	No	No	No	No	No	High	Low	Medium
Engineered wood products	Initial assessment	No	No	No	No	Yes	High	Medium	High

Source: Vivid Economics

## Conclusion

There are several factors that suggest the veneer, plywood, and engineered wood product manufacturing and sawmills sectors are EITE:

- While the sectors' carbon cost relative to their respective value added is relatively low, they may each have limited further emissions reduction potential.
- Similarly, companies covered in these sectors may have the ability to shift production to different facilities within Oregon or to facilities out of state.
- The ability of the sectors to pass through costs to their consumers is also likely inhibited by the existence of significant competitive pressures from both other US states, such as Georgia, and South American producers currently without carbon pricing.
- Precedents from the EU and California suggests that engineered wood products and, to a lesser degree, sawmills may be at risk of leakage.

**However, there are several factors which reduce underlying carbon leakage risk:**

- Wood products manufacturing facilities located in Oregon benefit from the state’s significant forestry resources and innovative expertise.
- There may also be significant and cost-effective energy efficiency potential in the wood products sectors over 2021–35; however, further research is necessary on whether the investment required to achieve these savings is economic.
- Further, the optimal location of wood products manufacturers may be determined by proximity to adequate lumber resources, which limits the number of states that pose a relocation risk.

**On balance, the sectors are at risk of carbon leakage if Oregon introduces a carbon price without measures to protect against possible adverse competitiveness impacts.** A carbon pricing instrument for these sectors should be designed to ensure that innovation and emissions reduction incentives remain, while also incorporating measures to protect against the risk of carbon leakage and other competitiveness impacts.

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