Freight and Climate Change

Background Paper for the Oregon Freight Plan

prepared for

Oregon Department of Transportation

prepared by

Cambridge Systematics, Inc.

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1.0 Introduction

Public concern about climate change has risen dramatically over the last several years. There is an emerging consensus that increasing emissions of greenhouse gases (GHG) is contributing to climate change. In fact, the United Nations Intergovernmental Panel on Climate Change (IPCC) estimates that in the absence of additional climate policies to reduce GHG emissions, baseline global GHG emissions will increase between 25 percent and 90 percent between 2000 and 2030.[1] Increases in GHGs are expected to result in climate change increases in extreme weather events, sea level rise, and other impacts.

Transportation is recognized as a significant source of GHG emissions. However, most research and analysis have focused on passenger movements rather than freight – despite the fact that freight emissions comprise close to one-third of U.S. transportation GHG emissions, and have grown by more than 50 percent since 1990.[2] In addition, freight transportation is much more energy intensive than passenger transport, due to the large weights involved.

There are many ways to reduce the climate change impact of freight operations. These approaches typically revolve around three targets:

1. **Reduce emissions produced by freight carriers per mile of travel** by improving freight carrier fuel efficiency through technological improvements, better maintenance, improved road system operations, driver behavior modification, and other techniques. Emissions per mile can also be reduced by reducing the carbon content of fuels.
2. **Reduce miles traveled by freight carriers**, for example, by enacting land use and development policies that reduce the distance goods must travel to reach market, or by increasing the cost of travel through pricing.
3. **Shift freight to modes with less climate change impact.** The most well-known example of this method is shifting truck freight to rail, but freight can also be shifted to other modes, such as barge or short-sea shipping, where appropriate.

This report presents an overview of the connections between climate change and freight transportation at the national level and in Oregon specifically. It explores and presents a variety of options the Oregon Department of Transportation (ODOT) can explore to reduce freight-sector GHG emissions in Oregon. The report is organized as follows:

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[1] United Nation Intergovernmental Panel on Climate Change, *Fourth Assessment Report*, 2007.

[2] Federal Highway Administration, *Freight and Air Quality Handbook*, June 2009.

- **Section 1.0, Introduction** (this section) discusses the relationship between freight and climate change and provides context on recent Oregon policies.
- **Section 2.0, Freight Impact on Climate Change** discusses emissions from freight vehicles and their climate impacts and describes emerging trends in freight technology that effect emissions rates.
- **Section 3.0, Opportunity Type 1: Operations Improvements and Education** introduces possible operations and educational strategies to reduce climate change impacts from freight.
- **Section 4.0, Opportunity Type 2: Tolling and Pricing** covers possible tolling and pricing strategies to reduce climate change impacts from freight.
- **Section 5.0, Opportunity Type 3: Transportation Project Prioritization** considers how freight project selection processes in Oregon could incorporate GHG impacts as a prioritization metric.
- **Section 6.0, Climate Change Impacts on Freight** describes the types of climate change impacts likely to affect freight movement in Oregon and discusses adaptation strategies.
- **Appendix A** provides background information on possible regulatory changes at the Federal level that could affect greenhouse gas emissions from freight in Oregon.

1.1 OREGON POLICY CONTEXT

The State of Oregon already is active in efforts to mitigate climate change. Through interagency collaboration, legislation, regulation, policy initiatives, and partnerships with nonprofits and other western states, Oregon has developed a multipronged approach to climate change monitoring, emissions reduction, and mitigation. Major elements of the Oregon policy context are outlined below.

Governor's Advisory Group on Global Warming

In late 2004, the Governor's Advisory Group on Global Warming published its recommended strategy for reducing GHG emissions in Oregon. This report laid out concrete emissions reduction goals for Oregon (later adopted by state law), along with recommended actions across seven key areas, including one for transportation. Two of the transportation recommendations were freight-specific, one for reduced truck idling and another for setting and meeting goals for truck and rail freight transport efficiency. Others (such as transportation/ land use coordination) could have an impact on freight.

The 2007 Legislature established the Oregon Global Warming Commission to continue the Advisory Group's work and provide progress updates to the Legislature on a regular basis. ODOT's director, Matthew Garrett, is an ex officio member. This group has recommended that Oregon adopt various GHG reduction strategies, including the establishment of a fund for nonhighway

transportation needs, supporting investment in nonhighway modes including ports and freight rail, and providing additional funding for Oregon's Clean Diesel Program.[3]

Climate Change Actions

Oregon is actively pursuing reductions in GHGs from the transportation sector through a variety of methods. This section highlights several examples of the measure taken to reduce GHGs from transportation in the State. This list is not comprehensive – other strategies that Oregon has pursued are discussed throughout the report.

ConnectOregon Program

*Connect*Oregon I (approved in 2005),*Connect*Oregon II (approved in 2007), and *Connect*Oregon III (currently in project selection phase) are funding programs helping to advance transportation projects for nonhighway modes, including seaports and rail. The first two programs helped fund a total of 68 projects. A substantial majority of these projects have been for freight, including several rail expansion or rehabilitation projects and port upgrades, some of which may reduce GHGs. *Connect*Oregon is discussed in more detail in Section 5.0 of this report.

GHG Reporting Rules

In 2008, the Oregon Environmental Quality Commission (EQC) approved GHG mandatory reporting rules. These rules allow better data collection on sources of GHG emissions and create data for better tracking of progress toward meeting GHG reduction goals. Facilities required to report their GHG

Oregon's Strategy for Greenhouse Gas Reductions – Freight-Related Actions

Oregon's *Strategy for Greenhouse Gas Reductions*, published in 2004, laid out a number of actions to address climate change. The following have specific relevance to freight:

- Set and meet goals for reduced truck idling at truck and safety stops (TRAN-10); and
- Set and meet goals for freight (truck/rail) transportation efficiency (TRAN-13).

The following goals could also impact freight:

- Recommend a proposal to adopt more stringent emissions standards for vehicles (TRAN-1);
- Integrate land use and transportation decisions with GHG consequences (TRAN-2);
- Promote biofuel use and production (TRAN-3);
- Incorporate GHG emission impacts into transportation planning decisions (recommendation TRAN-5);
- Adopt state standards for high efficiency/low rolling resistance tires (TRAN-7); and
- Set up traffic flow engineering best practices (TRAN-12).

[3] Oregon Global Warming Commission Report to the legislature, 2009. http://www.keeporegoncool.org/view/ogwc-reports.

emissions include those that have a Title V permit and emit 2,500 metric tons of combined greenhouse gases measured as CO2 equivalents per year.[4]

Efficient Vehicles

Around 2004 California, Oregon and several other states voluntarily adopted standards setting limits on the greenhouse gases emitted from new vehicles. In 2010, National Corporate Average Fuel Economy (CAFE) standards (which only apply to light-duty vehicles) were updated to be consistent with Oregon and California's standards.

In addition, Oregon has been selected by the U.S. Department of Energy as one of five test markets for the largest deployment of electric vehicles and the associated charging infrastructure. Approximately 9,000 Nissan electric cars will be deployed in Oregon in 2010, with about 2,100 charging stations at homes and businesses in Portland, Eugene, Salem, and Corvallis areas.

Alternative Fuels and Cleaner Engines

The Oregon Department of Energy provides business or residential tax credits to generators and providers of alternative fuels. This is meant to encourage the use of alternative fuels for transportation. The DEQ also provides a tax credit to owners of older, high-polluting trucks who replace their trucks with cleaner-burning engines.[5]

Additionally, with the passage of HB 2210 and 3463, the state legislature has taken steps to require the use of alternative fuels (specifically bio diesel) under certain conditions.

House Bill 2186

In 2009 the Oregon state legislature passed HB 2186, aimed specifically at reducing GHG emissions from transportation. Key measures in the bill that will contribute to GHG reductions from freight include:

1. A low-carbon fuel standard that would reduce life-cycle GHG emissions from gasoline and diesel fuel by 10 percent by 2020;
2. A study of potential requirements regarding the maintenance and retrofitting of truck to reduce aerodynamic drag and otherwise reduce GHG emissions;

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[4] Oregon Department of Environmental Quality: http://www.deq.state.or.us/aq/climate/howreport.htm#keep.

[5] Source: Oregon Department of Environmental Quality Truck Engine Tax Credit Program: http://www.deq.state.or.us/msd/taxcredits/factsheets/TruckEngineTCfactsheet.pdf.

3. Authority to DEQ to ensure vehicle emissions control systems perform properly;
4. Authority to DEQ to require automobile mechanics check that tires on motor vehicles are properly inflated, thereby improving fuel efficiency;
5. Authority to restrict engine use by commercial ships while at port, and require ports to provide alternative power; and
6. Creation of a task force to study and evaluate alternative land use and transportation scenarios to accommodate planned growth in areas served by MPO's while reducing greenhouse gas emissions, among other related items. Senate Bill 1059 is a result of the work of this task force.

House Bill 2001

House Bill 2001, passed in 2009, directs ODOT to work with local governments and metropolitan planning organizations to develop a model for least-cost planning to use a decision-making tool in the development of plans and projects at both the state and regional level. Least-cost planning is a process of comparing direct and indirect costs of demand and supply options to meet transportation goals, policies or both, where the intent of the process is to identify the most cost-effective mix of options. Least-cost planning approaches can be coordinated with development of climate change strategies to ensure adoption of the most cost-effective approaches to greenhouse gas mitigation, regardless of whether they are supply or demand-side measures.

As a consequence of this bill, Metro (the Metropolitan Planning Organization for the Portland area) is required to develop transportation and land use scenarios designed to reduce GHGs while accommodating population and economic growth, with technical and financial assistance from ODOT and the DLCD. Additionally, a task force has been formed to evaluate road user fees to replace the gas tax and income tax credits for companies that offer pay-as-you-drive auto insurance in Oregon.

House Bill 3463

House Bill 3463, passed in 2009, relates to biodiesel use in Oregon. First, the bill directs the State to monitor use, production, sales, and certificates of analysis in the state. In addition, the bill states that all diesel sold in the state must contain at least two percent biodiesel by volume. Once state production of biodiesel reaches 15 million gallons, diesel must contain at least five percent biodiesel by volume.

Senate Bill 1059

Senate Bill 1059, passed March of 2010, directs the Oregon Transportation Commission to adopt a statewide strategy on greenhouse gas emissions to aid in achieving emissions reduction goals. It directs ODOT and DLCD to establish

guidelines for developing and evaluating alternative transportation scenarios to reduce greenhouse gas emissions from transportation in metropolitan areas and to create a toolkit for local governments to use in developing actions to reduce greenhouse gas emissions.

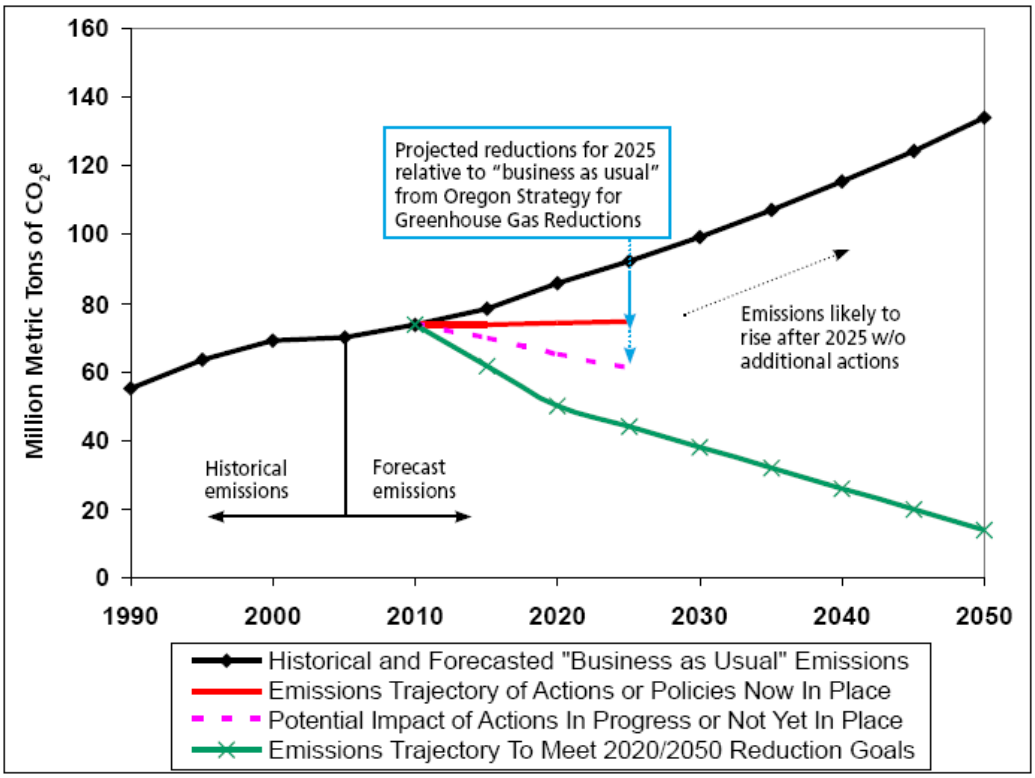
Climate Change Partnerships

Oregon has actively partnered with other western states and various nonprofits to advance GHG reduction goals. Chief among these is the Western Climate Initiative, a cooperative of Western U.S. states and Canadian provinces that work together to address climate change at the regional level. Among other things, the group has been exploring a regional target for GHG emissions reduction, and is working to implement a market-based, cap-and-trade program (to be fully operational by 2015). Oregon is also active with The Climate Registry, the International Carbon Action Partnership, and The Climate Trust.

Progress in Meeting GHG Reduction Goals

As shown in Figure 1.1, Oregon expects to make substantial progress in meeting its GHG reduction goals in part through the adoption of transportation strategies now in place. Once further actions are implemented, total GHG emissions are expected to decline on a yearly basis.

Figure 1.1 Oregon's Progress Towards GHG Reduction Goals



Source: Oregon Global Warming Commission, January 2009 Report to the Legislature.

2.0 Freight Impacts on Climate Change

Although there is little documentation of the specific effects of freight movement on climate change, much work has been done on the transportation sector's contribution as a whole to climate change, including freight. Recent estimates suggest that direct transportation emissions are responsible for 29 percent of total U.S. GHG emissions. Of that total, approximately one-third comes from freight sources.[6] In Oregon, transportation accounts for 34 percent of total GHG emissions.[7] This higher share could be partially tied to the importance of trade to the Oregon economy; it could also reflect fewer emissions from other sectors (such as coal-fired power plants), which would make transportation's share larger.[8] Comparable figures for freight's share of Oregon GHG emissions are not available, but the combustion of on-road diesel (mainly freight trucks) accounted for about 8 percent of the State's total GHG emissions in 2005.[9] The following section describes greenhouse gas emissions from freight in more detail.

2.1 GHG AND RELATED EMISSIONS PRODUCED BY FREIGHT TRANSPORTATION

There are many types of freight emissions that have climate impacts.[10] The following are the four primary GHGs produced by the transportation sector (including freight):

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6 Cambridge Systematics, Inc. analysis of the U.S. EPA emissions data.

7 Governor's Climate Change Integration Group, *A Framework for Addressing Rapid Climate Change*, January 2008.

8 In Oregon approximately 34 percent of GHG emissions are from transportation; 32 percent are from electricity consumption; and 11 percent are from industrial fuel combustion. Other categories each comprise less than 10 percent of the total. More detail is available on page 36 of *A Framework for Addressing Rapid Climate Change*: http://www.oregon.gov/ENERGY/GBLWRM/docs/CCIGReport08Web.pdf?ga=t.

9 Oregon Department of Energy, *Revision and Update to Oregon Greenhouse Gas Inventory*, May 28, 2008.

10 Not all GHGs have the same global warming potential (GWP), a measure of relative radiative forcing compared to CO_2. Therefore, figures in this report are presented in terms of CO_2 equivalents, or CO_2e (i.e., non-CO_2 gases are converted into the amount of CO_2 that would cause a similar degree of warming).

1. **Carbon dioxide (CO_2)** is the most well-known GHG, and indeed it accounts for 95 percent of total transportation-related GHG emissions. Most human-produced CO_2 is the product of fossil fuel combustion, including freight transportation.
2. **Hydroflourocarbons (HFC)** comprise 3 percent of overall transportation-related GHGs. HFCs are used extensively in truck and rail refrigeration systems, as well as automobile air conditioners.
3. **Nitrous oxide (N_2O)** is an ozone-depleting compound that represents approximately 2 percent of total transportation GHG emissions. Although ozone depletion does not have a direct effect on climate, climate change may accelerate ozone depletion, which has various negative effects, such as increased exposure to harmful ultraviolet-B (UVB) radiation.
4. **Methane (CH_4)** is a potent GHG (it has more than 20 times the heat-trapping capability of CO_2), so even though it represents less than 1 percent of transportation-related GHG emissions, it can have a significant effect on climate change patterns.

Black carbon (commonly known as soot) is another important climate forcing agent that often comes from freight sources. It is formed through incomplete combustion of fossil fuels and biomass. Like CO_2, black carbon traps heat in earth's atmosphere. When it is deposited on snow and ice, its dark color also reduces the planet's albedo, or ability to reflect sunlight, which also contributes to warming. It has been estimated that black carbon is the third largest contributor to warming after CO2 and methane, and recent science suggests its impact may be even greater.[11] In contrast to CO_2, black carbon only remains in the atmosphere for a few weeks, so reducing soot emissions may provide a quick payoff in terms of combating climate change.[12]

Freight's primary contribution to black carbon emissions is particulate matter (PM). PM is divided into two subcategories: PM_{10} (particles less than 10 microns in diameter, but larger than 2.5 microns); and $PM_{2.5}$ (particles less than 2.5 microns in diameter). Freight is a source of PM. The transport sector is responsible for over one-half of all PM_{10} emissions, and freight sources comprise 51 percent of that total (not including off-road diesel equipment; some of which is used for freight applications). Some freight vehicles in Oregon have recently been equipped with a particulate trap that reduce particulate matter by 95 percent.

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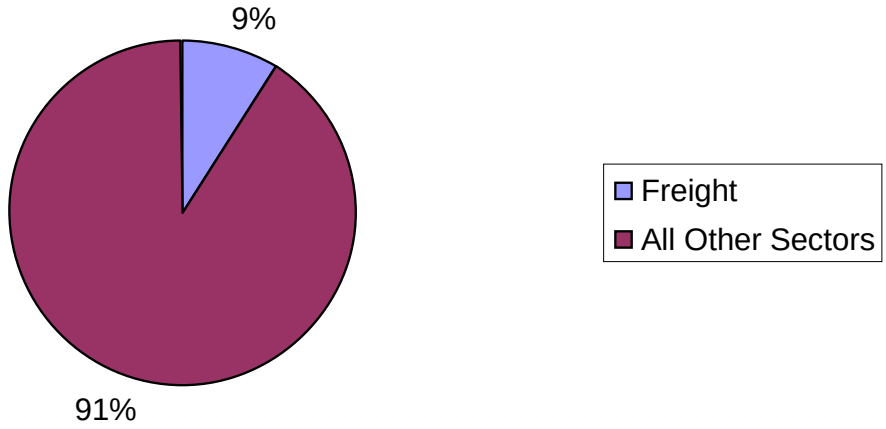
[11] International Council on Clean Transportation, 2009. *A policy-relevant summary of black carbon climate science and appropriate emission control strategies.* http://www.theicct.org/documents/0000/1022/BC_policy-relevant_summary_Final.pdf.

[12] Ibid.

Figure 2.1 shows emissions from the freight sector as a percentage of GHG emissions from other sectors. As the chart demonstrates, emissions from freight sources accounted for nine percent of overall U.S. GHG emissions in 2006; the equivalent of 608 million metric tons of CO_2 (MMT CO_2e).

Figure 2.1 Freight GHG Emissions as a Percentage of total Greenhouse Gas Production in the United States
2006



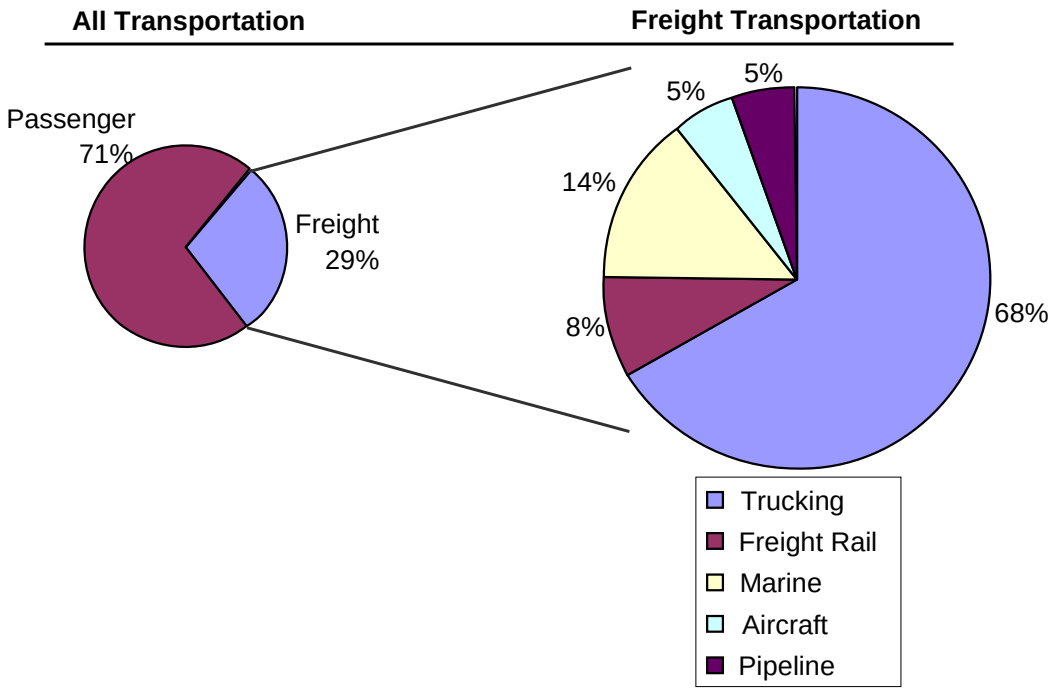
Source: Cambridge Systematics, Inc. analysis of U.S. EPA emissions data.

Figure 2.2 shows U.S. transportation-sector GHG emissions in 2006 for the passenger and freight modes, and highlights the contribution of each freight mode to the freight-sector share. Overall, passenger modes (including passenger cars and light trucks, buses, passenger rail, motorcycles, recreational boats, and domestic and international passenger aircraft) accounted for 71 percent of GHG emissions from transportation (1,515 MMT CO_2e), with freight modes comprising the remaining 29 percent (608 MMT CO_2e).

Of the freight-sector share, trucks accounted for the majority of GHG emissions (68 percent, or 405 MMT CO_2e). This is because trucks carry the vast majority of the nation's freight by both weight and value. In 2007, trucks handled 61 percent of total freight tonnage in the United States, and more than 65 percent of total freight value.[13] Marine sources (including ocean-going cargo ships using bunker fuel) made up the next largest share (14 percent, or about 87 MMT CO_2e). The remaining freight GHG emissions came from freight rail (8 percent), followed by air cargo and pipelines (5 percent each).

[13] Federal Highway Administration (FHWA), 2007. Freight Analysis Framework (FAF). http://www.ops.fhwa.dot.gov/freight/freight_analysis/faf/index.htm.

Figure 2.2 U.S. Transportation-Sector GHG Emissions by Mode
2006



Source: Cambridge Systematics, Inc. Analysis of 2006 U.S. EPA emissions data. Note that EPA emissions data usually excludes bunker fuel used in international shipping.

Different freight modes vary in terms of the amount of GHG emitted per mile. Table 2.1 presents 2006 total emissions, ton-miles, and emissions per ton-mile for each freight mode. As the table demonstrates, air cargo has by far the highest rate of emissions (1,472 grams CO_2e per ton-mile), but it also comprises the smallest share of GHG emissions and ton-miles. This is because moving cargo by air is expensive, and is therefore limited to light, time-sensitive, and very high-value commodities.

Of the remaining modes, trucking has the next highest emissions rate at 313 grams CO_2e per ton-mile. This relatively high emissions rate, combined with the fact that trucks are second only to rail in ton-miles of freight moved, explains why trucks are responsible for most freight GHG emissions. Domestic marine freight, which includes Columbia River barge traffic, as well as coastwise shipping, has the third highest emissions rate at 54 grams CO_2e per ton-mile. Note that this does not include ocean-going cargo vessels, which typically burn residual fuel and, therefore, may have higher emissions rates. The pipeline and freight rail modes have the lowest emissions rates at 35 grams CO_2e per ton-mile and 28 CO_2e per ton-mile, respectively.

Table 2.1 Emissions Rates by Freight Mode
2006

Mode	GHG Emissions (Teragrams)	Ton-Miles	Emissions Per Ton-Mile (gCO_2e)
Domestic Aircraft[a]	22.60	15,357	1,472
Trucking	405.49	1,294,492	313
Domestic Marine[a]	30.20	561,629	54
Pipelines	32.40	913,202	35
Freight Rail	51.50	1,852,833	28

Source: Cambridge Systematics, Inc. analysis of the U.S. EPA emissions data.

[a] International air cargo and marine GHG emissions are excluded because of the lack of ton-mileage data for these modes. For the marine mode, it is likely that large ships burning bunker fuel would have a higher emissions rate than domestic cargo ships, which typically use cleaner distillate fuel.

2.2 TRENDS IN FREIGHT EMISSIONS

Trends in freight vehicle emissions are an important consideration in assessing policy options for reducing greenhouse gas (GHG) emissions from the freight sector. New vehicles are often cleaner than the in-use vehicle fleet, and as technology advances, new options to reduce GHG emissions become more readily available. Table 2.2 provides estimates of the changes in GHG per ton-mile that could be achieved as the freight vehicle fleet is replaced. It includes estimates of GHG emissions per ton-mile for the existing fleet, new vehicles, and the best available technology for road, rail, marine, and air freight modes. This section explains assumptions used in Table 2.2.

Table 2.2 Range of Near-Term GHG Per Ton-Mile Emissions for Truck and Rail Sectors by Technology

Technology Option	Description	Emissions (g CO_2e/Ton-Mile)		Percentage Reduction in GHG/Ton-Mile from Existing Fleet	
		Low	High	High	Low
Heavy-Duty Diesel Trucks					
Existing	Existing truck fleet (2008)	313			
New	New truck	310	310	1%	1%
Best Available	Best available new truck, aerodynamic and weight reduction only	266	282	15%	10%
	Best available new truck, engine improvements only	284	287	9%	8%
	Best available new truck, combined	242	259	23%	17%
Rail					
Existing	Existing rail fleet (2008)	28			
New	New locomotive	27	27	3%	3%
	New locomotive, Tier 4-compliant	27	27	2%	2%
Best Available	Best available new locomotive	25	25	12%	12%
	Best available new locomotive and cars	22	23	21%	16%
Marine					
Existing	Existing domestic marine fleet	54			
New	New engine	53	53	2%	1%
	New engine, Tier 4-compliant	53	55	1%	-1%
Best Available	Best available engine (diesel-electric)	43	49	20%	10%
	Best available propeller (nozzle or winglets)	51	52	5%	4%
	Best available technology, combined	41	47	25%	13%
Air					
Existing	Existing commercial aircraft fleet	1,472			
New	New commercial aircraft	1,407	1,407	4%	4%
Best Available	Best available commercial aircraft	1,178	1,178	20%	20%

Sources: Cambridge Systematics analysis of Annual Energy Outlook, 2009; U.S. DOT Report to Congress *Transportation's Role in Reducing U.S. Greenhouse Gas Emissions*, 2010; U.S. EPA RIA for Diesel Engines less than 30L; Boeing; and General Electric.

A major assumption in Table 2.2 is that any improvements in vehicle fuel efficiency will generate proportional improvements in GHG emissions per ton-mile. This implicitly assumes that all other operational characteristics (such as load, speed, and travel conditions) will remain the same. As discussed separately in this report, many operational strategies to reduce emissions from freight travel exist.

Three main factors were taken into account in estimating changes in GHGs per ton-mile:

1. **New vehicle improvements**. The analysis takes into account a trend toward slightly improved fuel efficiency in new diesel engines. In general, diesel engine technology has become more efficient on a fuel per horsepower basis over time, although the gains have sometimes been put toward increasing power rather than saving fuel.
2. **Regulations.** There are not yet any regulations for freight vehicle GHG emissions or fuel efficiency. The 2007 Energy Independence and Security Act (EISA) gave the U.S. DOT authority to set fuel consumption standards for medium- and heavy-duty trucks beginning in the 2016 model year; currently no standards have been proposed, but the National Academy of Sciences has completed a study requested by Congress on regulatory options and the Obama administration has stated its intent to promulgate standards.[14] Existing and future U.S. EPA regulations to reduce particulate matter (PM) and nitrogen oxides (NO_x) have the potential to reduce diesel engine fuel efficiency, but the net effect on GHG production is complex. In particular, there is evidence to suggest that the benefits of removing black carbon[15] more than offset the increased CO_2 emissions due to implementing PM controls.[16] New trucks already need to comply with more stringent PM and NO_x regulations phased in over the past few years, and U.S. EPA has promulgated PM and NO_x regulations for locomotives and marine diesels as well to take effect in 2014 and 2015. This analysis includes the effect of current and pending NO_x and PM emission standards for trucks, rail, and marine engines (no standards exist for aircraft); the effects of black carbon are not included in the analysis at this time, but are worth further scrutiny.

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[14] Committee to Assess Fuel Economy Technologies for Medium- and Heavy-Duty Vehicles, 2010: *Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles*. Committee to Assess Fuel Economy Technologies for Medium- and Heavy-Duty Vehicles; National Research Council; Transportation Research Board. National Academies Press, Washington, D.C.

[15] Black carbon, a component of diesel particulate exhaust, warms the atmosphere because its dark color absorbs sunlight and radiates heat back into the atmosphere, and because black carbon deposits darken snow and ice surfaces, absorbing heat and accelerating spring melt. Diesel particulate filters can remove virtually all of the black carbon from diesel exhaust. Although black carbon is not one of the six primary "Kyoto" gases examined in the U.S. EPA's annual national inventory of GHGs, it may provide important opportunities for near-term reductions in global warming agents.

[16] Hill, L. Bruce, 2009, *The Carbon Dioxide-Equivalent Benefits of Reducing Black Carbon Emissions from U.S. Class 8 Trucks Using Diesel Particulate Filters: A Preliminary Analysis*, Clean Air Task Force, Boston Massachusetts, http://www.catf.us/publications/reports/CATF-BC-DPF-Climate.pdf.

3. **Best available technology**. More advanced technologies are available for trucks, rail, marine, and aircraft to reduce GHG emissions. This analysis provides estimates for fuel efficiency improvements associated with technologies that already are commercialized or entering the market in the next several years. More speculative technologies, or those not yet ready for commercialization, are not included in this analysis.

Further discussion of emissions trends for major freight modes is provided below.

2.3 TRUCK GHGS

Heavy-duty trucks have shown only very modest gains in fuel economy over the past few decades. The fleet of combination (Class 8)[17] trucks experienced an average annual fuel economy improvement of about 0.2 percent per year between 1970 and 2006, but recent years have shown the fleet average fuel efficiency declining from 6.1 miles per gallon (mpg) in 1998 to 5.1 in 2007.[18] Another measure of fuel economy, the fuel efficiency per ton-mile, shows essentially stagnant fuel efficiency. For medium- and heavy-duty trucks, on average 1 gallon of fuel moved one ton of freight 35.6 miles in 1998, but only 34.1 miles in 2006. This is the combined effect of changes in vehicle fuel efficiency and changing operations (including potentially the effects of congestion). The overall picture shows that fleetwide heavy-duty vehicle efficiency has not been making improvements in recent years.

However, this does not mean that individual new trucks do not perform better than the fleet average. According to the U.S. Annual Energy Outlook (AEO), model year 2008 Class 8 trucks are approximately 0.9 percent more efficient than the current heavy-duty truck fleet; this is the assumption applied for new trucks in Table 2.2. These trucks are assumed to be compliant with the newest U.S. EPA emission standards for PM and NO_x.[19] Heavy-duty trucks can remain on the road for up to 30 years, so turnover is relatively slow; this 0.9 percent improvement is compared to a fleet spanning many model years. (On the other hand, older trucks are driven significantly fewer miles than newer trucks – a 10-year-old truck puts on only 40 percent of the miles a new truck drives annually, and a 20-year-old truck drives less than 20 percent of the miles.[20])

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[17] Class 8 trucks are defined as having a gross vehicle weight rating (GVWR) of 33,000 pounds or above. This class includes all tractor-trailers.

[18] Davis, S., S. Diegal, and R. Boundy, 2009, *Transportation Energy Data Book: Edition 28*, U.S. Department of Energy, Oak Ridge National Laboratory, Knoxville, Tennessee.

[19] U.S. Department of Energy, Energy Information Administration, 2008, *Annual Energy Outlook 2009*.

[20] U.S. Department of Transportation, 2010, *Transportation's Role in Reducing U.S. Greenhouse Gas Emissions: Report to Congress*, Washington, D.C., April 2010.

There is also aerodynamic, weight reduction, and improved engine technologies available today or in the next few years that can be examined for a "best available technology" option. There are no regulations in place to require original equipment manufacturers (OEM) or truck owners to buy or implement these options, but they will be available in the market. Many ports, however, are developing "clean truck" programs – including the Ports of Long Beach and L.A., Seattle/ Tacoma, and New York/New Jersey.

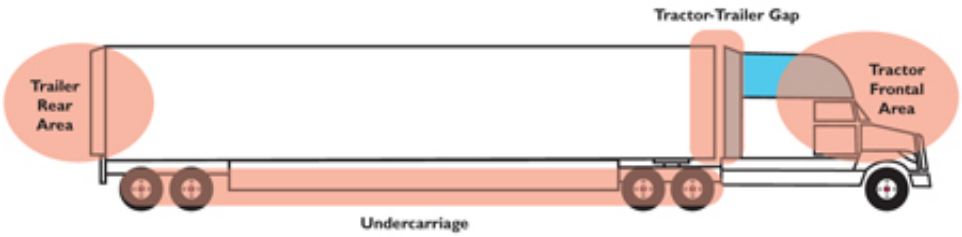
Oregon already is underway studying several of these technology options. As mentioned in the introduction to this report, House Bill 2186 directed the Department of Environmental Quality to evaluate requirements to reduce greenhouse gas emissions from commercial heavy- and medium-duty vehicles. DEQ formed a study group to provide input on evaluating potential requirements to reduce aerodynamic drag and unnecessary long duration idling by commercial vehicles, thereby decreasing resultant greenhouse gas emissions.[21]

The option packages for best available technology examined in Table 2.2 include aerodynamic, weight reduction, and engine improvement options, as discussed below.

Aerodynamic Improvement and Weight Reduction

There are several improvements to vehicle aerodynamics (similar to the U.S. EPA's SmartWay package) already on the market; either for retrofit or in new vehicles. These strategies focus on reducing areas of aerodynamic drag on moving trucks (see Figure 2.3).

Figure 2.3 Main Areas of Aerodynamic Drag on a Moving Truck



Source: Natural Resources Canada: http://fleetsmart.nrcan.gc.ca/index.cfm?fuseaction=rfet.2.

[21] Source: Oregon Department of Environmental Quality Truck Efficiency and Reduced Idling Study Group http://www.deq.state.or.us/aq/committees/TruckEfficiency StudyGrp.htm.

Examples of SmartWay approved technologies that will reduce drag include:

- **Trailer Gap Reducers –** Gap reducers are meant to reduce drag caused by space between the tractor and the trailer as shown below.

Figure 2.4 Picture: Trailer Gap Reducers

Source: Picture taken from Utility Trailer web site: http://www.utilitytrailer.com/files/UT_Smartway_Data_Sheet.pdf.

- **Trailer Boat Tails –** These devices are meant to reduce drag in the trailer rear area shown below.

Figure 2.5 Picture: Trailer Boat Tails

Source: Picture taken from Utility Trailer web site: http://www.aerovolution.com/information.shtml.

- **Trailer Skirts –** Skirts reduce drag coming from the open space between the road and the bottom of the trailer, as shown in Figure 2.6. Trailer skirts should be used in conjunction with trailer boat tails and gap reducers. See below.

Figure 2.6 Picture: Trailer Side Skirt

Source: Picture taken from Utility Trailer web site: http://www.utilitytrailer.com/files/UT_Smartway_Data_Sheet.pdf.

To make these types of aerodynamic adjustments legal in terms of truck size and weight regulations, the Federal Motor Carrier Safety Administration (FMCSA) excludes aerodynamic devices, such as those discussed above, from length and width measurements on the National Network (which includes interstate freeways, national highways and state highways).[22]

Table 2.3 provides a complete list of aerodynamic improvements and summarizes their effectiveness in improving fuel economy.

Table 2.3 Aerodynamic Improvement Effects on Fuel Efficiency

Improvement type	Fuel efficiency Impact	Notes
Basic cab improvements[23]	1-2%	Includes cab top fairings, sloping hoods, and cab side flares. Many trucks already contain these features.
Enhanced cab improvements[24]	2.4%	Includes gap reduction between tractor and trailer, fuel tank fairings, and wheel well covers
Basic trailer improvements[25]	1.3%	Includes rounding of front and back edge curvatures
Enhanced trailer improvements[26]	Up to 7.8%	Includes trailer fairings and side skirts
Next generation improvements[27]	2.8-4%	Planar boattail plates (reduce trailer drag)
Low rolling resistance tires[28]	2.7-4.8%	

[22] FMCSA, Part 658: Size and Weight, Route Designations – www.fmcsa.dot.gov/rules-regulations/administration/fmcsr/fmcsrguidedetails.asp?menukey=658.

[23] Schubert, R., and M. Kromer, 2008, Heavy-Duty Truck Retrofit Technology: Assessment and Regulatory Approach, TIAX LLC, prepared for the Union of Concerned Scientists.

[24] Ibid.

[25] California Air Resources Board (CARB), 2008, *CARB Staff Report, Initial Statement of Reasons for Proposed Rulemaking: Public Hearing to Consider the Adoption of the Regulation to Reduce Greenhouse Gas Emissions from Heavy-Duty Vehicles*, October 2008.

[26] Ibid.

[27] Vyas, A., C. Saricks, and F. Stodolsky, 2002, *The Potential Effects of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks*, Argonne National Laboratory, ANL/ESD/02-4.

[28] Frey, H.C., and P. Kuo, 2007, *Best Practices Guidebook for Greenhouse Gas Reductions in Freight Transportation*, North Carolina State University, Center for Transportation and the Environment, prepared for the U.S. Department of Transportation.

Weight Reduction

For weight reduction strategies, the U.S. EPA estimates that a 3,000-pound reduction in truck weight increases its fuel economy by 1.8 percent.[29] This is consistent with other studies that show weight reduction to improve fuel economy by 2 to 5 percent.

Depending on the mix of strategies adopted, the combination of aerodynamic and weight reduction strategies on Class 8 trucks is estimated in the analysis presented in Table 2.2 to range from a 10 to 15 percent reduction in per vehicle fuel consumption.

Engine Improvement Potential

There are a variety of engine improvements currently on the market or expected to be on the market within a few years. Options included in these estimates are engine friction reduction (better lubricants), improved fuel injection with common rail systems,[30] and reduced engine accessory loads by electrifying accessories (rather than powering them via drive belts). Per U.S. Department of Energy research (DOE), reducing engine frictional losses and improving fuel injection may reduce fuel consumption up to seven percent.[31] The combination of engine improvement strategies applied on Class 8 trucks range from eight to nine percent reduction in per vehicle fuel consumption.

Figure 2.7 compares estimates of GHG emissions per ton-mile from the existing truck fleet, new trucks, and improved trucks (based on information in Table 2.2).

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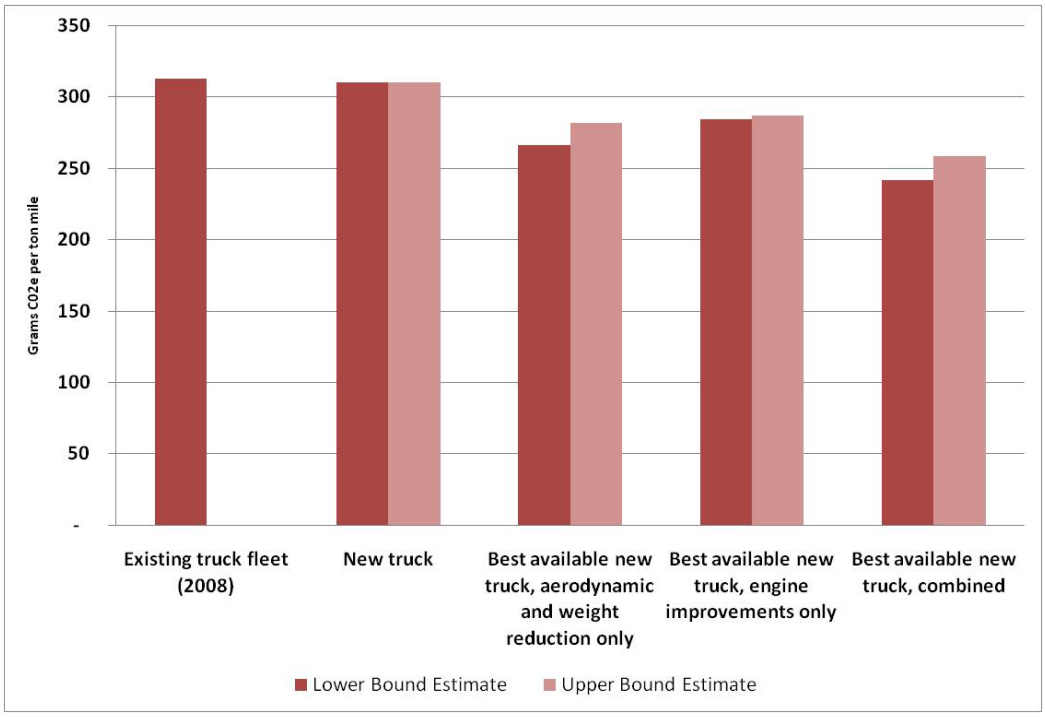
[29] U.S. Environmental Protection Agency, 2004, *A Glance at Clean Freight Strategies: Weight Reduction*, Office of Transportation and Air Quality, EPA420-F-04-005.

[30] Common rail systems store pressurized fuel along a "common rail" connected to each cylinder to allow for better fuel injection control than is present in conventional diesels, optimizing the fuel injection rate for each engine speed and the timing and duration of fuel injection.

[31] U.S. Department of Energy, 2009, *NEMS Transport Module Documentation,* DOE/EIA-0554.

Figure 2.7 Near-Term GHG Emission Reduction Potential for Heavy-Duty Diesel Trucks



2.4 RAIL GHGS

Unlike heavy-duty trucks, rail has shown a clear trend toward increasing fuel efficiency in the past decades, improving 16 percent per ton-mile from 1990 to 2006 – about 1 percent per year.[32,33]

A number of locomotive improvements contributed to this trend. Foremost among them is the increasing size of line-haul locomotive engines, yielding significant economies of scale and efficiency, and resulting in fewer locomotives needed per train. The average locomotive increased from about 3,000 horsepower in the mid-1990s to almost 3,500 horsepower in the mid-2000s, and new locomotives are generally 4,000 to 4,500 horsepower.[34] Other locomotive improvements included more advanced electronics, dynamic braking, and three-phase Alternate Current traction motors. In addition, many of the larger

[32] U.S. Environmental Protection Agency, 2007, *SmartWay Tractors and Trailers*, Office of Transportation and Air Quality, EPA 420-F-07-033.

[33] Stodolsky, F., 2002, *Railroad and Locomotive Technology Roadmap*, Argonne National Laboratory, Center for Transportation Research, ANL/ESD/02-6.

[34] Shughard, L., and H. Nulkar, 2005, *Improving Railroad Financials: The Facts on Pricing, Network Efficiency, and Cost Control*, presented at INFORMS 2005.

railroads have upgraded their tracks to take heavier 286,000-pound railcars, which have a higher ratio of payload to empty weight, increasing operational efficiency. Many regional and shortline railroads have not upgraded their tracks to support heavy, 286,000-pound railcars. The railroads also made improvements to operations over the period, including better signal control systems, more cargo per train, and reduced empty mileage.

As with trucks, recent U.S. EPA regulations for rail locomotives do not address CO_2. U.S. EPA applied emissions standards for criteria pollutants to locomotives in 2000, and proposed more stringent standards in 2008. Both rules apply not just to new engines, but also to older engines when they are rebuilt (as is common with locomotive engines). U.S. EPA projects these regulations will reduce locomotive efficiency by about 1 percent for both new engines and remanufactured engines (primarily because of backpressure created by the new PM filters).[35] However, new locomotives often include other efficiency improvements that allow them to meet U.S. EPA standards while still improving fuel economy.[36] The emissions shown for new locomotives in the table include the effect of these regulations.

Technologies are available to further improve rail efficiency. The analysis in Table 2.2 examines options for line-haul locomotives only. (There are also new technologies available for switchyard locomotives, such as gensets[37] and hybrid engines, which can yield significant reductions in GHG emissions. However, because switchyard locomotives do not contribute directly to ton-miles of freight moved, they are not examined here.)

The option package examined in Table 2.2 includes:

- **New locomotive**. Fuel efficiency for new locomotives is based on the GE Evolution Series locomotive, which according to GE is 3 percent more efficient than older locomotives. New locomotives in compliance with the more stringent ("Tier 4") U.S. EPA emission standards are assumed to be 1 percent less efficient due to backpressure from the PM filter.[38] This is a conservative

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[35] U.S. Environmental Protection Agency, 2008, *Regulatory Impact Analysis: Control of Emissions of Air Pollution from Locomotive Engines and Marine Compression Ignition Engines Less Than 30 Liters Per Cylinder*, EPA420-R-08-001a, Washington, D.C.

[36] General Electric, 2009, *The Evolution Series Locomotive: Moving Rail Power Forward.* Brochure.

[37] Genset locomotives use multiple smaller diesel engines (around 700 horsepower) rather than one large engine for power. Electronic engine controls match engine operations with power needs – when power demand is low, some of the engines are shut off to save fuel.

[38] U.S. Environmental Protection Agency, 2008, *Regulatory Impact Analysis: Control of Emissions of Air Pollution from Locomotive Engines and Marine Compression Ignition Engines Less Than 30 Liters Per Cylinder*, EPA420-R-08-001a, Washington, D.C.

assumption, as engine manufacturers may be able to meet the more stringent standards with no loss of fuel efficiency.

- **Best available technology**. For the "best available" technology, the table shows locomotive improvements by themselves and in combination with railcar weight reduction.
  - **Locomotive improvements**. Common-rail diesel technology (which results in more efficient fuel injection) and hybrid line-haul locomotives are entering the marketplace. Common rail injection systems are estimated to provide fuel and GHG emission reductions between five and 15 percent.[39] For the most part, hybrid locomotives are primarily used for yard activities, though GE has recently developed a 4,400 horsepower hybrid for line-haul operations providing a 10 to 15 percent reduction in fuel usage and GHG emissions.[40] For this analysis, we have assumed that using some combination of these options yields the equivalent of a 10 percent reduction in emissions per ton-mile.
  - **Railcar weight reduction**. Aluminum railcars (which already are in use, for instance, by the Canadian Pacific Railway) yield significant weight reductions, as compared to steel railcars. These translate into fuel reductions of five to 10 percent.[41]

Figure 2.9 (based on data presented in Table 2.2) compares estimates of GHG emissions per ton-mile from the existing rail fleet, new locomotives, new Tier 4-compliant locomotives, best available new locomotives, and best available new locomotives and cars. These estimates reflect line-haul travel; actual per-trip emissions will be higher due to drayage movements on either end of the trip.

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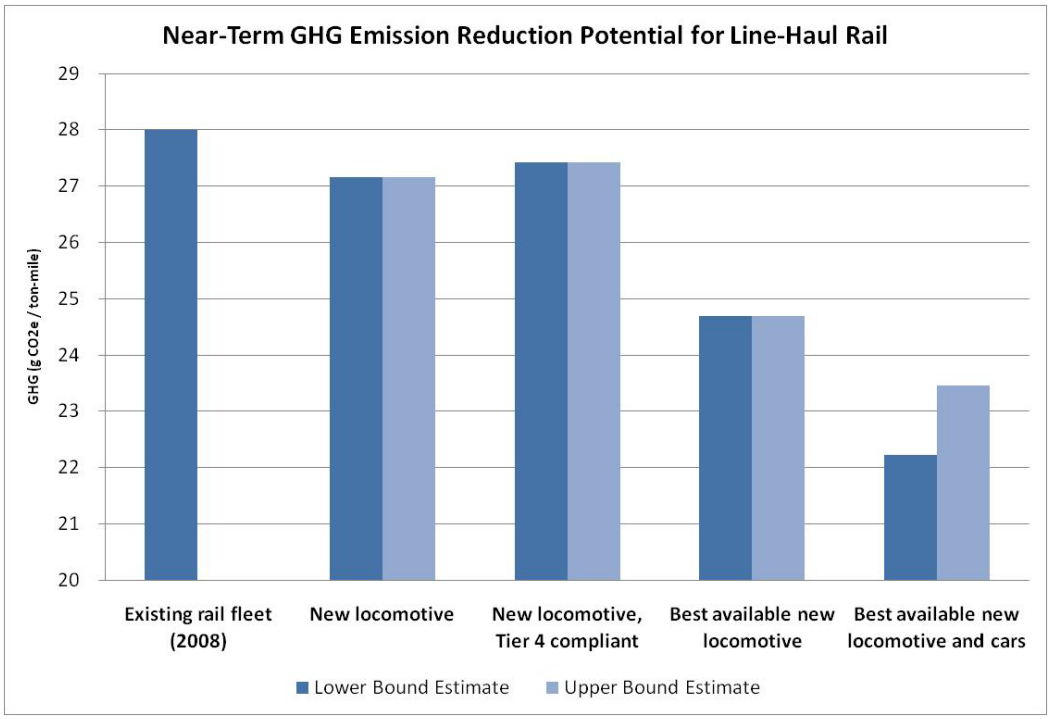
[39] California Energy Commission (CEC), 2008, Analysis of Transportation Options to Improve Fuel Efficiency and Increase the Use of Alternative Fuels in Freight and Cargo Movement in the California/Mexico Border Region, CEC-600-2008.

[40] General Electric (GE), 2005, *Hybrid Locomotive*, Press Release, May 4, 2005.

[41] Northeast States for Coordinated Air Use Management (NESCAUM) (2006), Scoping Study to Evaluate Locomotive Emissions Operating in New Haven, Connecticut and Potential Control Options.

Figure 2.8 Near-Term GHG Emission Reduction Potential for Line-Haul Rail



2.5 MARINE GHGS

According to the U.S. EPA's national inventory, domestic marine GHGs per ton-mile have not shown a clear trend since 1990. However, this most likely reflects difficulties in differentiating domestic and international fuel consumption, resulting in significant year-to-year variations in the official estimates.[42] As a result, it is not possible to draw strong conclusions regarding trends in marine GHG per ton-mile.

However, technologies are available to improve propulsion efficiency for the domestic marine sector. In this table, we have examined potential propulsion efficiency improvements for towboats to identify options for reducing GHG emissions per ton-mile for the Columbia River inland waterway.

The option packages considered in this table are:

- **New engines**. Comprehensive data on the efficiency of new marine diesels compared to the existing domestic inland waterway fleet was not available. For this analysis, new marine diesels are assumed to incorporate a common

[42] U.S. Department of Transportation, 2010, *Transportation's Role in Reducing U.S. Greenhouse Gas Emissions: Report to Congress*, Washington, D.C., April 2010.

rail and turbocharging enhancements (improvements which are now being offered by engine manufacturers), resulting in a 1 to 2 percent fuel efficiency gain.[43] New marine engines built to meet the upcoming U.S. EPA "Tier 4" NO_x and PM regulations are assumed to experience fuel efficiency losses of about 1 percent for new engines, and 2 percent for remanufactured engines (primarily because of backpressure created by the new PM filters),[44] essentially negating these gains. As is the case for rail locomotives, this is a conservative assumption, since engine manufacturers may be able to meet the Tier 4 standards with no loss in fuel efficiency.

- **Best available technology**. Best available technology is split into engine improvements and propeller improvements:
  - **Diesel-electric engines**. Diesel-electric engines function like a railroad locomotive – a diesel engine powers an electric motor, which in turn drives the propellers (in contrast to conventional direct drive marine diesels, which are directly coupled to the propellers). For tugs on the inland waterways that operate with varying loads and at varying speeds navigating the river and its locks, this increases efficiency by 10 to 20 percent by allowing the diesel generators to run at optimized levels.[45]
  - **Propeller improvements**. Propeller nozzles and propeller winglets increase propeller efficiency by smoothing turbulent water flow at the tip of each blade, generating fuel efficiency improvements of about 4 to 5 percent.[46] It should be noted that some tugs in the Columbia River fleet already may be using advanced propeller technologies, particularly because existing tugs can be easily retrofitted with them; data on the current market penetration of this technology was not available.
  - **Shore Power (Cold Ironing)**. Shore power systems provide electricity to container and freight ships while docking. This results in less fuel consumed by the ships, which equates to lower GHG emissions.

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[43] U.S. Department of Transportation, 2010, *Transportation's Role in Reducing U.S. Greenhouse Gas Emissions: Report to Congress*, Washington, D.C., April 2010.

[44] U.S. Environmental Protection Agency, 2008, *Regulatory Impact Analysis: Control of Emissions of Air Pollution from Locomotive Engines and Marine Compression Ignition Engines Less Than 30 Liters Per Cylinder*, EPA420-R-08-001a, Washington, D.C.

[45] U.S. Department of Transportation, 2010, *Transportation's Role in Reducing U.S. Greenhouse Gas Emissions: Report to Congress*, Washington, D.C., April 2010.

[46] U.S. Department of Transportation, 2010, *Transportation's Role in Reducing U.S. Greenhouse Gas Emissions: Report to Congress*, Washington, D.C., April 2010.

2.6 AIRCRAFT GHGS

Although there are no GHG regulations on airplanes, airlines and cargo aircraft operators have a strong incentive to buy fuel-efficient aircraft to cut operating costs and increase payloads, and the airline manufacturers have continually improved aircraft fuel efficiency over the years as a result. As a result, according to AEO, on average a new aircraft in 2008 is 4 percent more efficient than the existing fleet.[47]

The best available technology is equated to the Boeing 787 Dreamliner, which made its first test flight in December 2009. According to Boeing, the 787 will be 20 percent more fuel efficient than existing aircraft due to advances in jet engine technology and extensive use of lightweight composite materials in the airframe. The first 787s are scheduled to be delivered to customers in April of 2011.[48]

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[47] U.S. Department of Energy, Energy Information Administration, 2008, *Annual Energy Outlook 2009*.

[48] Boeing Corporation, 2010, *Boeing 787 Dreamliner Will Provide New Solutions for Airlines, Passengers*, http://www.boeing.com/commercial/787family/background.html.

3.0 Opportunity Type 1: Operations Improvements and Education

Operations improvements and driver education efforts can go a long way towards achieving the goal of reduced emissions of GHG and other pollutants. Many states, including Oregon, have realized environmental and economic benefits by pushing promising new freight operations and education ideas. This document highlights those strategies that, individually or collectively, can work to reduce freight-related GHG emissions in Oregon. The four types of strategies include the following:

1. Port operations and equipment improvements;
2. Idling reduction;
3. Improved driving efficiency; and
4. Improved routing efficiency

The sections below provide a brief overview of each strategy; describe related deployments, applications, and activities; identify, at a qualitative level, potential impacts on GHG emissions, and provide case study descriptions of where these strategies have been implemented across the United States.

3.1 PORT OPERATIONS AND EQUIPMENT IMPROVEMENTS

Ports and intermodal terminals are the hubs of the freight system, and the presence of numerous mobile and stationary emissions sources at these facilities can often turn them into hot spots for emissions of GHG and other pollutants. Exacerbating matters is the fact that much of the supporting equipment used at ports – particularly drayage trucks and shunting locomotives – are older, less efficient, and more polluting. There are a number of operational and equipment-related strategies that ports in Oregon and throughout the United States are using to improve port efficiency and reduce GHG (and other) emissions. These include the following:

- Extended gate hours and pricing techniques;
- Internet container matching service (Virtual Container Yard);
- Common chassis pools;

- Appointment systems for truck visits;
- Electric and alternative energy cargo-handling equipment; and
- Radio Frequency Identification (RFID)/Global Positioning System (GPS) tags.

It is important to note that not all of these strategies may be applicable or necessary at Oregon facilities. Rather, ODOT and ports/intermodal facilities should consider a range of different strategies that are in line with transportation, environmental, and economic goals.

Extended Gate Hours and Pricing Techniques

Extending gate hours and/or using pricing techniques and fees can more evenly distribute container pick-up times at ports, reducing truck queues and idling times, and improve air quality. Although these techniques have been employed at many ports across the country, the most successful example is the PierPass program at the Ports of Los Angeles (POLA) and Long Beach (POLB), as described below.

Case Study: PierPass

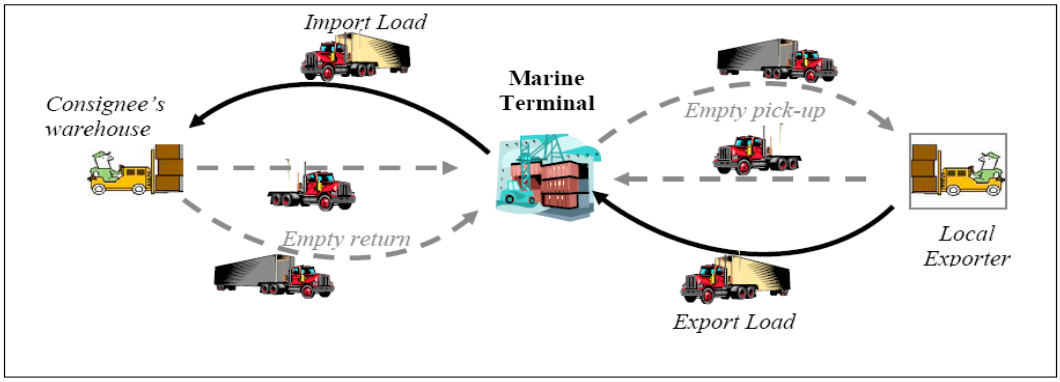
In response to Bill AB 2041 introduced in the California legislature that would have imposed a peak-hour surcharge on all containers entering or exiting POLA and POLB between the hours of 8:00 a.m. and 5:00 p.m., terminal operators at these Ports developed the nonprofit entity PierPass. The PierPass program (known as OffPeak) provides incentives for shippers to move cargo at night and on weekends, rather than during congested daytime hours. The incentive is in the form of a "traffic mitigation fee" imposed on all cargo imported and exported through the Ports. The fee varies according to business conditions and the actual costs of running the OffPeak program, but is currently $50 per TEU. Cargo owners then receive a refund for all loads that are handled during off-peak hours, which are defined as 6:00 p.m. to 3:00 a.m. on Monday through Thursday, and 8:00 a.m. to 6:00 p.m. on Saturday. Revenues from the traffic mitigation fee are used to support the operating costs associated with maintaining extended port gate hours.

OffPeak usage of the marine terminals has grown steadily since the program was implemented in late 2005. On days with peak and off-peak shifts, off-peak traffic comprised nearly 40 percent of total usage by the end of 2008.[1] Approximately 68,000 truck trips each week occur during OffPeak shifts; and in three years of operation, OffPeak removed more than nine million truck trips from local freeways during peak commuting hours. Since trucks represent a large share of the traffic mix on area freeways (especially near the ports), this shift to off-peak traffic leads directly to fewer trucks idling in traffic during the day, wasting fuel and increasing emissions. It also means shorter queues at the port gates, reducing the amount of time trucks must idle while waiting to access the terminals. The survey found that 67 percent of the drivers experienced reduced traffic congestion, and that 45 percent were able to complete more trips per shift. One-half of those familiar with OffPeak reported less congestion on the I-110 and I-710 freeways serving the Ports. The program also has benefited truckers who access the ports; two-thirds of whom have a positive opinion of OffPeak.

Virtual Container Yards

Another way to reduce emissions in port areas is to improve the efficiency of freight movements and eliminate unnecessary, empty truck trips into and out of the port. Often, trucks pick up a shipment at the port, deliver it, and then make an empty, or "deadhead," trip back to the port, as shown in Figure 3.1.

Figure 3.1 Empty Truck Movements To/From the Port



Source: Hanh, Le Dam, "The Logistics of Empty Cargo Containers in the Southern California Region."

One way to eliminate some of these empty truck trips, and lower GHG emissions, is the implementation of an Internet container matching service, also called a Virtual Container Yard (VCY). A VCY is essentially a "computer clearinghouse" or "bulletin board" containing information about containers transporting goods to and from marine terminals. VCYs can reduce empty truck trips by:

- Providing information about containers and their status and location.
- Facilitating communication between parties (motor carriers, ocean carriers, leasing companies, chassis pool operators) with a view to matching their needs.
- Permitting equipment interchange and other processes to take place without moving the empty container back to the marine terminal.
- Assisting the parties to make optimal decisions regarding container logistics (return, reuse, interchange, etc.); rationalize moves; and plan ahead.[49]

The case study below provides information about the VCY implemented by the Port of Oakland.

[49] *Empty Ocean Container Logistics Study*, TIOGA Group, 2002.

Case Study: Port of Oakland VCY

In 2003, the Port of Oakland implemented VCY software in order to improve port operations. This software connects ocean carriers with motor carriers in an attempt to reduce congestion and costs for all parties involved. All operators can access a public web site, where empty containers are posted. For example, after a truck completes a shipment from Oakland to San Luis Obispo, the driver can post the truck as being empty on a secure server. The VCY provides backhaul information to the Port of Oakland from a Central Coast provider.

Trucking companies have expressed satisfaction with the implementation of the system, and have indicated that the system saves them money and time. One Oakland-based carrier commented that the VCY has allowed them to meet their export demand when all of their other trucks are tied up in congestion.

Common Chassis Pools

Promoting centralized chassis pools at ports is another strategy that can reduce GHG emissions. A chassis, in this context, is a specialized highway trailer used to carry shipping containers. The chassis does not include the tractor. Figure 3.2 below shows available chassis to move goods to and from the port. Examples of chassis are the upright trailers in the middle of the picture and the line of trailers shown in the lower left corner of the picture.

Figure 3.2 Chassis Pool Example

Source: Picture from the Hampton Roads Chassis Pool web site. (www.hcrp2.com).

Typically, each shipping line requires truckers to use only their chassis for their containers. The container is delivered to the final destination by the trucker, after

which the chassis is brought back to the shipper at the marine terminal.[50] Often, truck operators move short distances and deliver goods from multiple shippers per day, which means that a trucker must find another chassis for each shipment.

If a common chassis pool is created, a trucker can use one chassis for delivering shipments for all shippers at the port; regardless of what shipping line's container is being transported. Not having to change chassis several times throughout the day saves time (up to one hour per trip),[51] thus reducing congestion, improving efficiency, and reducing overall GHG emissions. According to the U.S. EPA, drayage trucks using pooled chassis could save up to 0.8 gallon per trip, reducing carbon dioxide (CO_2), nitrogen Oxide (NO_x) and Particulate Matter (PM) emissions. The following case study provides an example of a common chassis pool implementation at the Port of Virginia.

Case Study: Port of Virginia

The Port of Virginia was the first U.S. port that required all on-site chassis (approximately 15,000) to participate in its Hampton Roads Chassis Pool. The number of chassis stored on site was reduced by 20 percent after one year, equaling 40 to 60 acres of recaptured land for the terminals. Local trucking firms indicated satisfaction with the program, indicating that they are now able to ship up to 10 containers a day, up from two or three daily trips. It was reported to have reduced the required chassis inventory by 23 percent, and increased asset utilization by 27 percent. The system received the 2006 IANA Intermodal Achievement Award.

While the benefits of increased port acreage may be minimal to GHG emissions, the key here is that the chassis pool had port management support, and was accepted by the trucking firms. Additional land for other uses is a side benefit to the chassis pool, as are the reduced GHG emissions that come from less congestion due to the simplified chassis-usage process.

(http://www.epa.gov/SmartwayLogistics/transport/documents/drayage/420f06002.pdf), Virginia Port Authority News Release, November 21, 2006.

Appointment Systems for Truck Visits

Gate appointment systems require that truckers pick up containers from the terminal during a specific time window. An efficient appointment system helps the terminal operator achieve better utilization of labor and equipment by balancing the flow of truck arrivals throughout the work day. Harbor truckers benefit if long queues at terminal gates are eliminated and their turn times are shorter.[52]

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[50] *Into the Pool*, Journal of Commerce, June 29, 2009.

[51] http://www.epa.gov/SmartwayLogistics/transport/documents/drayage/420f06002.pdf.

[52] *Truck Appointments Boost Port Efficiency*, The Journal of Commerce Online, Mongelluzo, October 23, 2009.

Gate appointment systems can be particularly effective since most of the drayage trucks used to move containers short distances (for example, from the port to an intermodal rail yard) are older and more polluting. In addition, this strategy is less capital intensive than other strategies and is feasible in the short term. If the port is able to control pick-up schedules, the port could work to reduce queues at the gate, which in turn would reduce unnecessary truck idling that leads to additional GHG emissions.

Abuses of the appointment system can occur. Truckers may overbook appointments to ensure favorable gate times, which forces other truckers into less favorable time slots, and compromises the utilization of equipment and labor at the terminal. This problem has been addressed at some terminals by applying a fee for no-shows. Additional problems with the appointment system can occur when shippers affiliated with the terminal operator receive preferential treatment for appointments.[53] It is necessary to avoid these pitfalls to ensure efficiency benefits and GHG emissions reductions.

Case Study: Port of Seattle

The Port of Seattle has also developed a RFID Pilot program at its Terminal 18 facility, through which more than 1,500 trucks have been outfitted with RFID tags. These RFID tags are installed on truck cabs and linked to a database that validates truck authorization for access onto terminals and expedited routing through the terminal. Because of this technology, 40 percent of trucks that call Terminal 18 are able to receive an "auto out gate," which means that no verbal contact is required before exiting the Port. Through August 2007, nearly two-thirds of truckers indicated that these tags saved time at the gates by streamlining the egress process. For ports, less time spent at gates means less idling, which has a significant impact on the GHGs emitted in the port area.

RFID/GPS Tags

Some container terminals now require trucks to be fitted with (RFID) tags so that the position of the truck can be monitored within the terminal, enabling terminal operators to better direct truckers to the appropriate place to pick up the right container(s). The adoption of this technology is usually driven by shippers in an attempt to speed up their processes and reduce cost. An added advantage of this technology is a reduction of idling time at the port entrance for trucks, since RFID tags only take a moment to scan, as opposed to the time spent showing papers to identify those entering the port. A more efficient entry process will reduce idling, which will lower GHG emissions from trucks.

RFIDs on containers, combined with GPS technology, may also be beneficial to track the location of containers. As container yards are increasing in size and as

[53] Ibid.

containers are stacked higher and higher, it can become difficult to quickly and efficiently locate containers for pick up. Several technologies exist that allow a container to be tracked throughout its stay at the port. This can have significant benefits for truck drivers, and can help GHG emissions. When a truck driver is in port and needs to find a container for delivery, he/she can simply be directed to the right container, as opposed to having to search around for the correct container parking space. This improves the ingress/egress process, reducing congestion, idling, and therefore GHG emissions.

Electric/Alternatively Fueled Cargo-Handling Equipment

The strategies discussed to this point refer to port technologies or operations changes to improve port efficiency and GHG-emissions. A more direct emissions-reduction strategy is replacing diesel-fueled vehicles and equipment with electric or alternatively fueled container handling equipment, such as hydraulic hybrid vehicles or electric gantry cranes. The Port of Portland has taken steps to reduce air pollution by switching to using ultra low-sulfur diesel for marine terminal equipment in 2005. The following case study provides an example of another program at the POLB and POLA, which aims to replace older drayage trucks.

Case Study: POLB/LA

The operations at the POLB/LA are the single largest source of diesel emissions in the Los Angeles area, with drayage equipment responsible for two-thirds of the diesel PM emissions at the Ports. This is of particular concern, as diesel PM have a significant impact on public health. In response to the situation, the Clean Trucks Program was established, which has a goal of reducing port truck emissions 80 percent by 2012.

Older drayage trucks have already begun to be banned from the Ports. The timeline for updating drayage truck fleets at the Ports has several key milestones:

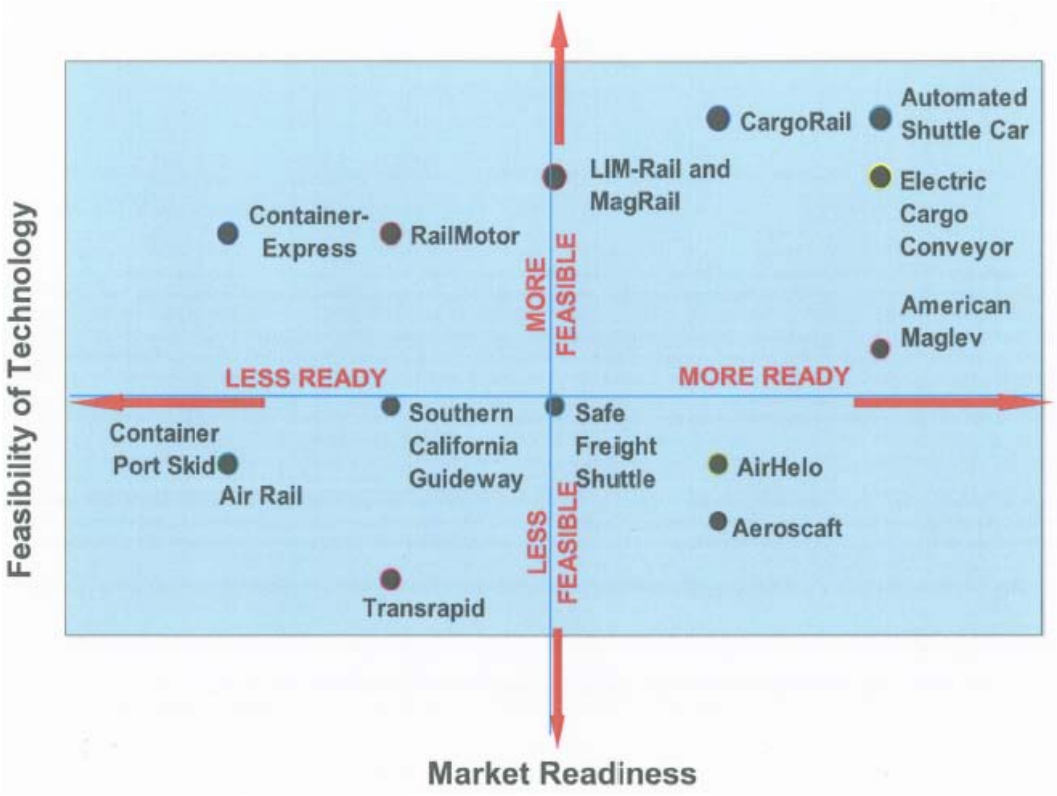
- **October 1, 2008.** All pre-1989 trucks have been banned;
- **January 1, 2010.** 1989 to 1993 trucks will be banned from port terminals, along with unretrofitted 1994 to 2003 trucks; and
- **January 1, 2012.** All trucks that do not meet the 2007 Federal clean truck emission standard will be banned from port terminals.

To finance truck replacement and offer financial assistance to truckers looking to replace their older drayage trucks, the Ports are collecting a fee on loaded containers ($35 per loaded TEU and smaller).
In its first year, the program has achieved significant results. POLA reported in a press release that the program has reduced emissions nearly 70 percent from the previous year. POLB reported that the goal of 80 percent emissions reduction by 2012 had nearly been achieved one year into the program.

Another more direct emissions-reduction strategy is to implement advanced freight guideway systems to move freight throughout the port. This can come in

the form of fixed guideway systems (e.g., cargo rail, magnetic levitation (maglev), linear induction) and air-based container movement systems. POLB recently analyzed the feasibility of developing advanced freight guideway systems at the Port. Analysis was performed by Cambridge Systematics to determine which technologies are most technologically feasible and the most market ready. Figure 3.3 highlights the results of this analysis.

Figure 3.3 Selection of Potential Green Freight Technologies and Operational Concepts



Of the numerous technologies that exist, the automated shuttle car, electric cargo conveyor, and cargo rail appear to be the most market ready. Implementation of these types of freight movers at ports would be a major investment and overhaul of current processes. However, emissions and efficiency benefits will be gained over the long term, if replacing old diesel-powered, cargo-hauling equipment.

3.2 TRUCK, RAIL, AND SHIP-IDLING REDUCTION STRATEGIES

The previous section described strategies to improve port efficiency, which has a significant impact on GHG emissions. Here, we specifically focus on the reduction of idling, which is an especially important topic. Long-duration idling of

trucks and trains in the U.S. consumes over 1 billion gallons of diesel fuel, and emits 11 million tons of CO_2; 200,000 tons of NO_x; and 5,000 tons of PM.[54] This estimate does not take into consideration short-term idling or marine vessel idling, which also contribute significant amounts of GHG emissions.

The State of Oregon already has taken steps to reduce truck idling. One of the recommendations in Oregon's Strategy for Greenhouse Gas Reductions, published in 2004 was to "set and meet goals for reduced truck idling at truck and safety stops." In 2004, a program was launched to reduce truck idling along I-5 by providing electrified truck stops.[55] In 2009, the State passed HB 2186, which increases the State's authority to restrict unnecessary idling of trucks and ships, except for when needed to run electrical and mechanical equipment and for reasonable periods of time during normal operation.

Detail on truck idling reduction strategies are provided below.

Truck-Idling Reduction Strategies

As a result of congestion, idling is a common occurrence at ports and intermodal stations. Nationally, idling long-haul trucks are estimated to consume 20 million barrels of diesel fuel, and generate 10 million tons of CO_2; 50,000 tons of NO_x; and 2,000 tons of PM annually.[56] Many of the strategies discussed in the first section of this chapter are aimed at reducing truck idling at ports by creating more efficient processes at port facilities. Here, we discuss two strategies that can prevent idling of trucks while truckers are parked away from the terminal. Truckers require power while sleeping in the cab, which often results in trucks idling for hours at rest areas and truck parking lots. Truck stop electrification (TSE) and auxiliary power units (APU) are technologies that will reduce GHG emissions from idling trucks.

Truck Stop Electrification (TSE)

TSE is a method to provide electricity to trucks at rest stops and other areas where truckers may stop. As mentioned above, efforts to electrify truck stops already are well underway in Oregon, but could be expanded to increase emissions reduction benefits.

Truck stop electrification reduces the idling that occurs when trucks wait at rest station. Since the Federal Motor Carrier Safety Administration (FMCSA) regulations restrict the number of consecutive hours drivers may operate heavy trucks,

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[54] U.S. EPA, http://www.epa.gov/otaq/smartway/transport/what-smartway/idling-reduction.htm.

[55] http://governor.oregon.gov/Gov/p2004/press_093004.shtml.

[56] Argonne National Laboratories, *Reducing Heavy Truck Idling*, http://www.transportation.anl.gov/engines/idling.html.

drivers often rest at truck stops or rest areas.[57] Truckers have historically left their vehicles idling during these rest stops to use electric power for in-cab heating, air conditioning, and other functions. A number of private companies offer TSE technology for fleet owners, independent truck owner-operators, and travel plazas. The systems can be as simple as an extension cord hookup running from a parking space power station into the truck cab. Other systems use a window hookup to provide climate control, power outlets, Internet access, and other amenities. Some trucks are now being built with TSE hookups; others can be retrofitted to accept the appropriate connections. It is important to note TSE requires buy-in from truck operators as well as a change in behavior. Truck operator education about the benefits of TSE may improve understanding of TSE's benefits and the likelihood for behavioral change.

Case Study: Shorepower Technologies

Shorepower Technologies originated from a TSE pilot project in New York State, when that State was pioneering TSE implementation on its I-90 and I-87 corridors. The company has the goal of deploying electrified parking spaces (EPS) at truck stops, rest areas, travel plazas, warehouses, truck depots, terminal, shopping malls, businesses, and other parking areas.

Recently, Shorepower was in the news with Cascade Sierra Solutions (CSS) because $22 million of Federal stimulus funds were allocated in August 2009 to the firm to create truck EPS at 50 rest areas and truck stops nationwide. Shorepower charges $1 per hour for electricity, saving the truckers money and preventing unnecessary GHG emissions into the air around truck stops. The development director for CSS believes that over 10 years, the new EPS systems will save approximately 35 million gallons of fuel.

For electrified truck parking spaces, there is an additional infrastructure cost for parking space construction that varies between $6,000 and $17,000, depending on the type of electrification service offered that is born by the property owner. The truck owner will see no up-front cost (for single-system hookups), but will pay an hourly fee between $2.50 and $3.00 for use of the system. Because of the operating-cost savings from this strategy, the truck owner would see net savings in the range of approximately $1,000 to $4,000 annually with electrified parking spaces.[58] A recent analysis of EPA data estimated national GHG reductions between 0.4 and 1.3 million metric tons (mmt) from truck stop electrification

[57] Federal regulations require truckers to take 10 hours of rest for every 11 hours on the road.

[58] Gaines et al., *Energy Use and Emissions Comparison of Idling Reduction Options for Heavy-Duty Diesel Trucks*, Argonne National Laboratory, 2009.

depending upon the extent of deployment (ranging from 1,500 to all 5,000 truck stops in the United States).[59]

One limitation of TSE is that truckers often rest at decentralized locations such as rest areas or parking lots, which cannot be efficiently electrified. As of October 2008, less than 3 percent of the nation's 5,000 truck stops were electrified.[60] Although 300,000 truck parking spots are eligible for electrification, it will not be feasible to electrify the vast majority of truck parking spots, which are often simply the highway shoulder. As a result, the most significant gains from reduced idling will need to result from on-board technologies such as diesel fired heaters and storage cooling air conditioning units.

Auxiliary Power Units (APU)

APUs are portable climate control and power systems that can be mounted on the side of trucks. The primary benefit is that these systems can power trucks without idling, thus reducing GHG emissions. These units tend to have small diesel engines to perform necessary functions. However, some are battery powered. In addition, APUs save fuel costs and reduce unnecessary engine wear. The upfront cost is significant (between $8,000 to 12,000 per truck on average).[61]

Auxiliary Power Unit (APU) Installation: CSS

CSS is a nonprofit organization operating in Oregon, Washington, and California, primarily along the I-5 corridor. The organization is dedicated to saving fuel and reducing emissions from heavy-duty diesel engines. The organization started as a program called "Everybody Wins," which coordinated a grant and tax credit with a lease-to-own contract to help finance APUs. By 2006, the idea had grown and CSS was formed to expand the program to the entire region and I-5 corridor. In addition, other products aside from APUs that saved fuel and reduced GHG emissions were introduced.

CSS estimates that every truck retrofit will reduce emissions by an average of 50 metric tons per year. NO_x and PM emissions will also be reduced. To date (October 20th, 2009), CSS has through its efforts saved nearly 6.7 million gallons of fuel, equaling nearly 68,000 metric tons in CO_2 reductions.

https://secure.cascadesierrasolutions.org/index.php.

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59 Moving Cooler Study.

60 U.S. Department of Energy, Energy Efficiency and Renewable Energy Information Center.

61 Federal Highway Administration (FHWA), 2010, *Freight and Air Quality Handbook*, Office of Freight Management and Operations, FHWA, U.S. Department of Transportation, Washington, D.C., May 2010.

Rail-Idling Reduction Strategies

Genset Locomotives

Genset yard locomotives use multiple smaller diesel engines to provide only the power that is needed and have electronic engine controls to better match locomotive activities to operating conditions. This technology can save between 15 and 24 gallons of diesel fuel per locomotive, per day, with accompanying emissions reductions. Genset locomotives reduce NO_x emissions (which contribute to smog and ozone formation) by up to 80 percent and PM by 90 percent compared to older switching locomotives. Genset locomotives also use up to 37 percent less fuel than older locomotives, and have emissions levels 50 percent better than current EPA limits for new locomotives.[62] Any reductions in fuel use translate proportionally into reduced greenhouse gas emissions, since carbon dioxide is emitted for every gallon of fuel consumed. The major downside to this option is the relatively high cost of the technology.

Union Pacific Railroad's Genset Fleet

Union Pacific Railroad (UP) has been a worldwide leader in adopting cleaner genset locomotives to operate in its railyards. As of June 2009, UP's fleet of Genset locomotives totaled 165, which is the world's largest fleet, and nearly one-half of all Genset locomotives built. The UP General Director of car and locomotive engineering said: "Genset locomotives can handle all rail yard duties and continue to be the standard bearer for new U.S. yard locomotives…. This next-generation Genset technology is maturing while being able to reduce GHG emissions by 37 percent compared to older switching locomotives."

Idling Limit Devices

Idling-limit devices automatically turn off a locomotive's engine if it is idle for a certain period of time, thus reducing unnecessary emissions that come from idling engines. These devices achieve their maximum benefit in warm climates, since locomotives typically must be kept running in cold weather to keep the engine from freezing up.

[62] http://www.uprr.com/newsinfo/releases/environment/2009/0611_genset.shtml.

Case Study: Idling Limit Devices at POLA/POLB

The POLB/LA are leaders in the area of implementing rail idling restrictions. By the beginning of 2009, all the switch/helper locomotives providing switching services to the ports (Pacific Harbor Line) had to be equipped with 15-minute idle limit devices. By 2011, all Class I switchers are required to have this technology, followed by line-haul locomotives in 2014.

(Ports of Los Angeles and Long Beach, "San Pedro Bay Ports Clean Air Action Plan Source Specific Standards.")

Another method to encourage railroads to install idling limit devices is to offer grants or other assistance to install these devices. For example, the Texas Commission on Environmental Quality (TCEQ) offers grants of up to $5,000 per ton of NO_x emissions reduced by idle-reduction technology.

Marine-Idling Reduction Strategies

Shore Power (Cold Ironing)

It is standard practice for ships to switch to their auxiliary engines while in port, which is beneficial to the environment. However, auxiliary engines still contribute to local air pollution and GHG emissions. One solution is to provide shore power systems that provide electricity to the ships while docking. This would result in less fuel consumed by the ships, which equates to lower GHG emissions.

Cold ironing requires a large up-front capital investment both for ships and landside hookups. Retrofitting a containership can cost up to $500,000. A 2004 study conducted for the POLB concludes that it would be cost-effective for ships to use shore power if they spend much time at the port. It would not be cost-effective to retrofit vessels for shore power if the vessel visits the port infrequently.

Shore Power (Cold Ironing) Regulation and Incentives: POLB/LA

The POLB/LA have been a leader in developing shore power technology in the United States. This technology is also a key part of the San Pedro Bay Ports Clean Air Action Plan. At the POLA, all major container terminals will have shore power within five years. In addition, the California Air Resources Board is requiring all container, passenger, and refrigerated cargo ships to turn off their auxiliary engines while in port.

Another best practice is for the Ports to offer incentives for shippers to adopt shore power technology. The POLB, for example, signed an agreement with a shipping company to retrofit five of its ships with shore power equipment in return for discounted tariffs and tax incentives.

3.3 EFFICIENCY ENHANCEMENT

Another way to improve freight efficiency and reduce GHG emissions is to implement systemwide freight improvements. Strategies described earlier focused on facility- and vehicle-specific improvements, while this section focuses on ways to make the freight system as a whole more efficient and less polluting. Improvements in freight system efficiency and throughput can reduce idling, travel time, and minimize GHGs and other emissions. The following strategies are discussed in more detail:

- Virtual Weigh Stations;
- Speed Reduction;
- Improved Truck Aerodynamics;
- Driver Training Efforts; and
- Signal Optimization and Signage.

Virtual Weigh Stations

Remote, unstaffed roadside enforcement facilities (commonly known as virtual weigh stations (VWS)) are becoming useful tools for improving roadside commercial vehicle enforcement programs. VWSs augment a state's existing fixed weigh stations, where trucks pull over to be weighed and occasionally inspected, and mobile patrols. Weigh-in-Motion (WIM) devices are typically used for measuring truck weight at VWS. WIM devices consist of a scale or a set of sensors installed in the pavement which communicate a vehicle's downward pressure to a roadside cabinet, which then estimates the gross weight and axle weights of the vehicle. Dial-up, DSL, or wireless communication is used to transmit this data to enforcement personnel or to a database management system.

Below is the description of a basic operational VWS scenario, followed by Figure 3.4, which visually depicts the basic VWS physical layout:

- As a commercial vehicle approaches the virtual weigh station, it is weighed while in motion on the WIM scales (see 2A in Figure 3.4).
- A picture of the commercial vehicle is taken for identification purposes (see 2B in Figure 3.4).
- Screening software integrates data from the WIM and camera system (see 2C in Figure 3.4).
- A mobile enforcement officer positioned downstream from the VWS accesses the VWS data (e.g., photo of commercial vehicle, WIM data) and makes a screening decision (see 3 in Figure 3.4). Another option is that enforcement

personnel at a fixed site (such as 1 in Figure 3.4) access the VWS data (e.g., photo of commercial vehicle, WIM data) and make a screening decision.

- Overweight commercial vehicle is intercepted for weighing/inspection.[63]

VWS provide numerous operational benefits, including increased pavement/ infrastructure protection, improved efficiency of enforcement assets, improved safety, and improved freight data, among others. VWS deployments support a reduction in GHG emissions through reduced truck idling as compared to fixed weigh stations. Trucks are not required to wait in queue at a VWS, and therefore do not idle while waiting for roadside inspections. While no formal evaluation of VMS and its benefits has been completed to date, anecdotal information is available to gain an understanding of environmental benefits of VWS. A national electronic preclearance program, which is deployed at more than 280 sites and has nearly 425,000 commercial vehicles enrolled, estimates that a total of 316,666 metric tons of carbon emissions have been prevented through its bypass program (49,436 metric tons in 2008 alone).[64]

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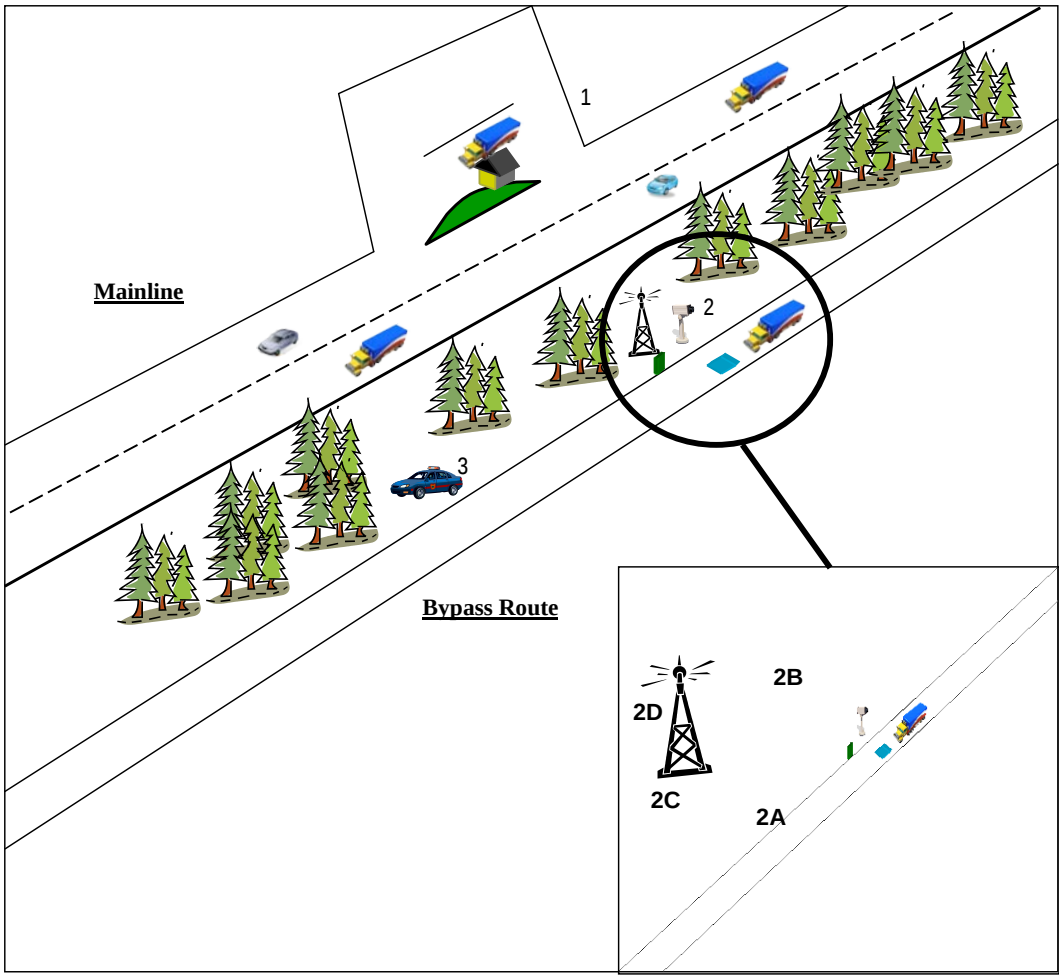
[63] Cambridge Systematics, Inc., *Concept of Operations for Virtual Weigh Station, Final Report*, Cambridge, Massachusetts, June 2009, page 4-6.

[64] PrePass web site: http://www.prepass.com/Pages/Home.aspx, October 27, 2009.

Figure 3.4 Basic Virtual Weigh Station Physical Layout



Speed Reduction

Freight operators will generally go as fast as the limits allow. While this may make sense from a time perspective, fuel economy and GHG emissions generally worsen at high speeds. Fuel efficiency can be improved and greenhouse gases reduced by increasing the time that trucks operate at the most fuel-efficient speeds. Gas mileage usually decreases rapidly at speeds above 60 miles per hour.[65]

Truck Speed Reduction

The American Trucking Association (ATA), in its 2008 sustainability program "Trucks Deliver a Cleaner Tomorrow," recommended the use of governors (a technology that limits speed) on trucks. The suggested ATA maximum speed of trucks was 68 mph. Fleet managers often opt to combine this technology with driver training to encourage driving at slower speeds. In parallel, a recent U.S. Department of Energy (DOE) evaluation estimated that a 55 mph speed limit implemented at the national level could result in a fuel consumption savings between 175,000 and 275,000 barrels of oil per day, or about 27 to 43 million metric tons (mmt) of CO_2e per year, which represents about 1.6 to 2.4 percent of on-road vehicle fuel consumption and emissions.

There are some disadvantages to limiting the speed of truckers through governors or training. Primarily, many hours of travel time are lost because of decreased speed. However, the cost of fuel is likely to increase into the future, which will reduce the marginal benefit of higher travel speeds and reduced travel time. Fleet managers will need to consistently analyze cost and benefits of varying speeds as fuel prices change to find optimal speeds within Oregon's legal limits.

Oregon currently has a maximum truck speed of 55 mph, which puts it at the low end in terms of maximum truck speeds compared to other states.

Marine Vessel Speed Reduction

A large number of ports are requiring ships nearing the port area to reduce speeds. For example, the POLA/LB have a voluntary speed reduction program, in which vessels approaching the Port are encouraged to reduce their speed to 12 knots. Reduced vessel speeds demand less power from the main engine, which reduces GHG emissions and lowers fuel consumption.

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[65] U.S. EPA Fuel Economy Guide, http://www.fueleconomy.gov/feg/driveHabits.shtml.

In 2007, the POLA/LB estimate that the VSR program resulted in the reduction of 1,345 tons of NO_x; 832 tons of Sulfur Oxide (SO_x); 112 tons of PM; and 52,502 tons of CO_2.[66]

Driver Training

Driver training programs can be used to educate truck drivers on how to drive in an environmentally friendly way. There are a number of driving techniques that truckers can employ to reduce emissions and save fuel. Effective trip planning, use of cruise control, avoiding rapid acceleration and deceleration, and up shifting as soon as practicable are all ways that drivers can improve fuel economy while reducing freight vehicle emissions. Another strategy that can be used in conjunction with driver training is to provide in-vehicle instrumentation that provides drivers with immediate feedback on fuel economy. Finally, incentives can be offered for "eco-driving." For example, a trucking company could pay bonuses to truckers that regularly conserve fuel through efficient driving practices.

Driver Training: CSS

Along with supporting a number of other GHG emission reduction initiatives, the nonprofit organization CSS also offers driver training to help reduce GHG emissions on the West Coast. CSS conducts approximately three to four training sessions per month, with a varying number of attendees. The course is flexible to accommodate different types of truck driving, including drayage truck driving, long-haul truck driving, and others. The course covers emissions-friendly driving habits, including progressive shifting, engine speed optimization, idle reduction, smoother braking and acceleration, anticipatory driving, speed control, and optimal gearing. The course also teaches truck drivers how to use GPS for route selection, important GHG emissions regulations in California and Washington State, the importance of tire inflation, and other topics. This class has been offered by CSS since the organization's inception in 2006.

CSS believes that even experienced truck drivers can boost their driving skills and reduce fuel consumption by 5 percent or more. Some fleets have seen reductions in fuel consumption of up to 20 percent. The potential to reduce GHG emissions through the type of training CSS offers is substantial, if enough drivers are exposed to such training.

Information taken from www.cascadesierrasolutions.org and phone interview with CSS COO Bill Harris.

Driver training can reduce fuel consumption by 5 percent or more; saving more than $1,200 in fuel costs, and eliminating about eight metric tons of GHG emissions per truck each year. Driver training may generate larger efficiency gains

[66] San Pedro Bay Ports Clean Air Action Plan.

for vehicles in urban service, where shifting practices have more influence on fuel economy (EPA, 2004).

Signal Optimization and Improved Signage

Adjusting signal timing to optimize traffic flow on busy truck routes and improving signage near ports or intermodal facilities are effective strategies to reduce freight emissions. A truck traveling at 55 mph that must stop at a light, and then reaccelerates loses 60 to 80 seconds.[67] Time spent idling at a traffic signal increases emissions, and reaccelerating increases them even more because the engine must work harder. Signal coordination has relatively modest costs, and could be more broadly deployed within the next 5 to 10 years; yielding short-term GHG reductions that may be significant at a local scale. Therefore, it can be beneficial to ensure efficient signal coordination to better facilitate freight flows.

A recent bottom-up attempt was made to estimate GHG benefits from signal optimization in Portland, Oregon. This study estimated that approximately 50 metric tons of CO_2 were saved each year per traffic signal retimed in the City. With approximately 3,300 traffic signals in the State of Oregon, of which 70 percent could benefit from retiming, the potential statewide CO_2 savings would be 115,000 metric tons in one year.[68] Note that this study includes all motor vehicles, not just trucks.

Improved signage to and from port facilities, intermodal facilities, logistics parks, and other major freight distribution facilities will reduce unnecessary VMT and acceleration around ports. This is a very simple solution which can have an impact in reducing unnecessary VMT by truckers.

Intelligent Transportation Systems

Intelligent Transportation Systems (ITS) strategies are a family of strategies that involve using technology to improve operations and reduce congestions along corridors. These strategies can reduce greenhouse gas emissions by reducing the time vehicles spend in stop-and-go traffic conditions, which cause a decline in fuel efficiency. Several of the most prominent ITS strategies for emissions reduction include the following:

- **Ramp metering**. This strategy involves the placement of a stoplight on freeway on-ramps to regulate or space out traffic during periods of heavy congestion. Controlled highway entry can reduce traffic and heavy backup on the freeway, thereby reducing GHG emissions.

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[67] Eyler, D., *Traffic Responsive Signal Coordination*, presentation given to the Transportation Research Board (TRB) Traffic Signal Systems Committee, July 2003.

[68] Peters, J., R. McCourt, and R. Hurtado, 2009, Reducing Carbon Emissions and Congestion by Coordinating Traffic Signals, ITE Journal, April 2009.

- **Incident management.** Improved incident management results in quicker identification of accidents, improved response times, and more effective incident scene management. This strategy reduces congestion from incidents, which could reduce GHG emissions in congested corridors.
- **Integrated Corridor Management (ICM).** Within an ICM system, the various institutional partner agencies manage the transportation corridor as a system – and not as individual assets. This improves travel time, helps manage congestion and empowers travelers through better information and more choices.[69] As a result of ITS technology advancements, integration of the transportation system is much more feasible.

Of these options, ramp metering and incident management appear to be the most cost-effective ways to reduce GHG emissions. At a high level, a ton of reduced emissions would cost between $10 and 40 over the 2010 to 2050 timeline. ICM systems would cost around $100 per ton. One serious concern with these strategies is the potential for induced demand. In other words, the congestion savings that these systems bring about may trigger additional demand, thereby reducing much of the benefit. Up to 90 percent of all GHG reduction benefits could be offset by induced demand.[70]

Improved Routing Efficiency

In order to save fuel and reduce GHG emissions, it is important for trucks to take the most efficient route to get to their destinations. In this section, we will describe two strategies to improve routing efficiency for freight shippers, including freight route management systems and urban consolidation centers.

Freight Route Management Systems

Freight route management systems are critical in helping carriers make more efficient routing and scheduling decisions in order to avoid congestion, reduce freight vehicle mileage, and increase load factors. Common uses of private-sector GPS systems are the following:

- Help track truck locations;
- Provide weather/traffic information; and
- Identify alternative routes.

The limited evaluation data on freight route management systems has not been able to quantify a VMT, fuel savings, or GHG benefit. However, truck highway information systems have been found to be beneficial to truckers. In one study, 75 percent of carriers believed Freight Route Management Systems are a valuable

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[69] http://www.its.dot.gov/icms/about_icm.htm.

[70] Cambridge Systematics, Inc., 2009.

tool to identify congestion, and 33 percent believed that on-time delivery and/or estimated time of arrival improved.[71] If these responses are accurate, GHG emissions would have been reduced due to less delay and avoidance of congestion.

Case Study: Port of Wilmington (Delaware Freight Route Management

The Port of Wilmington, Delaware, is a full-service deepwater Port located at the confluence of the Delaware and Christina Rivers, 65 miles from the Atlantic Ocean. The Port is the number one U.S. importer of fresh fruits, bananas, and juice concentrate. The Port of Wilmington has implemented several strategies that help carriers make efficient routing decisions.

First, the Port of Wilmington, in cooperation with the Delaware DOT (DelDOT), created an information kiosk in the trucker lobby of the Port. Truck drivers can use this facility to check traffic conditions along I-95 through web cameras. This gives drivers the option of seeking alternate routes or waiting in the lobby for traffic congestion to ease. This prevents unnecessary fuel consumption and GHG emissions through idling in heavy traffic.

Urban Consolidation Centers (UCC)

These facilities exist to consolidate freight on the urban fringe before final delivery to the more populated, congested urban core. The focus of the trip from the consolidation center to the final destination is that the trip should be low emissions, and have high load utilization. These centers can be located on the urban fringe at places such as airports or other appropriate location. Two key objectives of UCCs are:

- To reduce/eliminate the number of large trucks moving into the urban core; and
- To reduce congestion by delivering full loads (no partial loads).

UCCs are beneficial for nonperishable items, and in areas where truck congestion and overcrowding is a problem. In addition, places where large trucks cannot maneuver well would make a UCC attractive. With regards to GHG emissions reductions, UCCs could result in the following three primary outcomes:

1. Reduced urban road freight traffic levels through consolidation or modal shift;
2. Improved efficiency of operations and therefore less fuel consumed; and
3. Greater use of environmentally friendly vehicles.

[71] Cambridge Systematics, Inc., and SAIC, 2000.

4.0 Opportunity Type 2: Tolling and Pricing

4.1 INTRODUCTION

Tolling was traditionally a means of financing highway construction. Recent technological advances create the possibility of using tolling and road pricing to accomplish other public objectives, including reduction of greenhouse gas (GHG) emissions from transportation. Tolling and pricing can reduce greenhouse gases by reducing congestion, and thus improving fuel efficiency, reducing VMT, or encouraging the shifting of travel to more efficient modes.

Although Oregon has a limited history of tolling (essentially restricted to bridges), state policy and legislation has begun to address tolling options more comprehensively in recent years. The 2003 state legislature established the Oregon Innovative Partnerships Program (OIPP) to allow private firms to build and operate toll roads, and rules for developing tolling projects were revised as recently as 2007. The Oregon Transportation Plan (OTP) includes a strategy encouraging consideration of tolling and congestion pricing to raise revenues for transportation system improvements, and the Oregon Highway Plan (OHP) supports demand management strategies and high-occupancy toll (HOT) lane facilities.[72] Tolling has been studied extensively by the ODOT, most recently with a series of white papers published in 2009.[73] In the same year, state legislation directed ODOT in conjunction with Portland Metro to study congestion pricing – pilot projects may include time-of-day pricing with variable tolls. A pilot tolling project will be up and running by 2013. Oregon also has extensively studied the possibility of VMT fees.[74]

The purpose of this chapter is to further explore possible tolling and pricing mechanisms, focusing specifically on their potential to reduce greenhouse gases from the freight sector and their applicability in the Oregon context. The aim is not to recommend specific mechanisms, but to explore their relative effectiveness in influencing highway freight miles of travel, number of trips, mode shift, and operational conditions; and consequently impacting GHG emissions. Pricing of

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[72] Parsons Brinckerhoff and David Evans & Associates, 2009, *Tolling White Paper No. 2, Geographical and Situational Limits*, prepared for ODOT.

[73] http://www.oregon.gov/ODOT/TD/TP/Tolling_Background.shtml.

[74] For example, see ODOT's 2007 Report, *Oregon's Mileage Fee Concept and Road User Fee Pilot Program*.

nonhighway modes (e.g., rail, air, and barge shipping) is not considered here as ODOT's ability to price or toll these modes is limited.

Section 4.2 discusses factors affecting the potential response of the trucking sector to tolling mechanisms, Section 4.3 examines the effect of different types of tolling mechanisms on GHG emissions from truck travel, and Section 4.4 provides a summary of findings.

4.2 FACTORS AFFECTING FREIGHT SECTOR RESPONSE TO ROAD PRICING

Price Signals Sent to Truckers

Most studies of pricing relate to its effect on general travel or passenger travel, not truck travel. For passenger travel, road pricing can cause drivers to travel fewer miles, drive at different hours if prices change by time of day, or shift to unpriced roadways.

Truckers' response to road pricing depends on many factors, and there may be large variations within the trucking fleet. Long- and short-haul trucks operated by fleets, in-house operations, and owner operators all have different incentive structures. Some of the factors influencing truckers' responses include:

- **Cost**. The cost of a toll affects trucker travel patterns, with higher costs generally causing a greater response. However, the response will not be homogenous across the trucking sector, and will depend in part on ability to pass costs on to the customer, shipper, or receiver.
- **Travel-time savings**. Tolls may affect trucker travel patterns by providing travel-time savings on the tolled route. The Federal Highway Administration's (FHWA) Highway Economics Requirement System (HERS) estimates truck driver's value of time at $31.58 per hour (in 1995 dollars). However, for freight shipments the value of time includes not just driver's wages, but also costs related to missed shipments, loss of sales, need for additional trucks, spoilage, etc. Studies have estimated these costs to range from 2.5 times the value of the driver's time (e.g., less than $80 per hour) to as much as $371 per hour.[75] The importance of travel-time savings achieved from using a tolled facility varies for truckers. For instance, it is more important for truckers when it will allow them to make an extra paying trip (as for drayage trucks) or meet hours of service regulation. For truckers paid

[75] EDRG and Parametrix, 2009, *Tolling White Paper No. 6, Economic Comparison of the Alternatives for Tolling Projects*, prepared for ODOT.

by the mile who will not be able to make an additional revenue trip by saving a few hours, the time savings will have limited value.[76]

- **Travel-time reliability**. Improvements in travel-time reliability on a tolled route can be important to truckers needing to deliver within a certain time window, and can reduce the need to plan for "buffer" time in truck trip scheduling.
- **Time-of-day considerations**. Truckers' ability to respond to time-of-day price signals varies and is limited for many. Pick-up and delivery times are dictated by the needs of shippers or receivers who are usually not open 24 hours a day. Many trucks will not be able to shift deliveries to off-peak hours if they need to be at a business before it closes, for instance. The majority of companies that have implemented off-peak deliveries (such as Wal-Mart and 7/11) are served by private carriers – companies that provide freight transportation services only to a parent or related company. In these cases, the company considers trucking part of its own operations, and therefore is willing to optimize delivery times for overall cost-effectiveness. Common carriers, who serve unrelated customers, have had less success. Through trucks may have more leeway in what time they transit areas with time-of-day pricing.[77]

How Road Pricing Affects GHG Emissions

Road pricing can affect GHG emissions from the trucking sector in a number of different ways:

- **Trip reduction (elimination of trips).** For passenger travel, trip reduction can be achieved in a number of ways, such as carpooling, trip chaining – and trips not taken. For freight travel, trip reduction can come in the form of productivity increases: better consolidation of freight loads to ensure trucks are always full, better logistics management to reduce empty backhauls, and drayage strategies such as common chassis pools to eliminate the extra trips needed to bring empty chassis's back to the port. For instance, a study of a time-of-day pricing program at the Port Authority of New York and New Jersey found that more than 40 percent of the carriers who made changes to their trip schedules increased productivity, so that they carried the same cargo in fewer trips or miles.[78] Where the cost of the tolls exceeds the value of shipping a good, and costs cannot be mitigated by productivity increases

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[76] Cambridge Systematics, Inc., 2009, *Tolling White Paper No. 7, Truck-Only Toll (TOL) Lanes*, prepared for ODOT.

[77] Holguin-Veras, Jose, 2006, *The Truth, the Myths, and the Possible in Freight Road Pricing in Congested Urban Areas*, Association for European Transport.

[78] Holguin-Veras, Jose, 2006, *The Truth, the Myths, and the Possible in Freight Road Pricing in Congested Urban Areas*, Association for European Transport.

or passed on to consumers, the supply chain will be adjusted to eliminate the truck trip.

- **Trip length change.** Road pricing can have both positive and negative effects on GHG emissions in regards to trip length. Mileage-based pricing can encourage shorter trips to reduce costs. For instance, an increase in costs per mile would incentivize better route management, and in the long run could encourage shippers to locate distribution facilities closer to the markets they serve. Location-specific pricing (e.g., tolling) can incentivize truckers to divert to free facilities, potentially increasing GHG emissions by causing truckers to take longer and more circuitous routes. For instance, modeling for the Columbia River Crossing showed that implementing tolls only on the I-5 bridge would cause some trips to divert to the I-205 bridge via east-west routes in Vancouver and Portland; however, the amount of diversion depends greatly on the toll levels and level of congestion present.[79] Metro is beginning another round of analysis that includes an econometric model and may produce different results.
- **Mode shift.** Road pricing will increase the cost of trucking compared to other modes. As such, it could shift some freight to rail or barge, which have lower GHG emissions per ton-mile. Less desirably, it could shift high-value goods to air cargo, which has considerably higher emissions. Depending on how the tolls are structured, road pricing could also shift freight to longer combination vehicles (LCV), which have lower emissions per ton-mile than trucks. As discussed in Section 6.0 of this report, there are many barriers to mode shift beyond simply cost (such as time, reliability, and convenience); and relatively small changes in cost may not be sufficient to overcome these barriers for many shippers.
- **Operational improvements (smoother travel speed).** Road pricing and time-of-day pricing can result in decreased congestion and improved traffic flow, which increase the fuel efficiency of trucks traveling on previously congested roads. However, as discussed above, truckers are beholden to the needs of their customers in making time-of-day decisions. Truck drivers that have the choice already avoid traveling during peak periods in congested urban areas.

[79] Columbia River Crossing Tolling Study Committee, 2010, *Columbia River Crossing: Report to the Washington and Oregon Legislatures*, prepared by the Washington State Department of Transportation and the Oregon Department of Transportation, January 2010.

4.3 GHG IMPLICATIONS OF DIFFERENT TYPES OF PRICING ON FREIGHT SECTOR

This section examines in more detail the freight GHG emission implications of different tolling mechanisms that could be considered in Oregon. Five categories of tolling mechanisms are discussed here:

1. Conventional (static) tolls;
2. Managed lanes;
3. Truck-only toll (TOT) lanes;
4. Cordon pricing; and
5. Mileage-based fees.

Conventional Tolls

Conventional tolling uses static toll rates that do not vary by level of congestion. Traditionally, static tolls were used to raise revenue to pay for the facility or other transportation improvements. The ability to charge conventional tolls electronically eliminates the extra emissions associated with toll plazas and their associated stopping, starting, and idling.

Conventional tolls send the equivalent of a simple price per mile for travel on the tolled facility only, effectively making shipping goods by truck on that facility more expensive.

- **Trip reduction.** By increasing the price per mile, conventional tolls can encourage truckers to eliminate extra trips to compensate for increased costs.
- **Trip length**. Conventional tolling will motivate both shorter trips on the tolled facility and diversions to nontolled facilities. The net effect depends on the specific facilities and routes, but could very well lead to increased GHG emissions if total truck VMT increases due to longer routes. There is anecdotal evidence that long-haul truckers will divert significant distances to avoid the cost of tolls; on a multiday trip, a few extra hours may be less "costly" than a toll. Oregon's geography and road network is a limiting factor for diversion – it has no real parallel north-south expressways to I-5 in the Willamette Valley, and limited east-west routes across the Cascades – but options still exist, depending on the location of tolled roadways and trucker's origin and destination points.
- **Mode shift.** By increasing the price per mile, conventional tolls can encourage mode shift to nonroad modes. As discussed above, this can reduce emissions for freight shifted to rail or barge, but increase emissions for freight shifted to air cargo.
- **Operational improvement.** Static tolls will have limited effect on peak congestion issues because they do not increase during congested periods. To

the extent that congestion is reduced on the facility, truck fuel efficiency will increase as traffic flow smoothes out.

Managed Lanes

Managed lanes are lanes in which some restriction is applied to vehicles entering – as opposed to general purpose lanes, which are open to all. Managed toll lanes, which include a variety of concepts such as HOT lanes and Electronic Toll Lanes (ETL), generally are conceived with some kind of dynamic pricing to prevent congestion. This could be as simple as tolls that vary by time of day to discourage peak-period travel or true dynamic pricing, in which tolls are raised and lowered based on real-time traffic conditions to ensure that the managed lanes maintains free-flowing traffic conditions.

Heavy-duty trucks are usually prohibited from HOT lanes, but may be allowed in express toll lanes. ETLs may be a set of managed lanes on a facility that also provides general purpose lanes, or the facility can be entirely composed of ETLs, with no "free" option. ETLs have the potential to reduce truck GHG emissions, both by sending a price signal to incentivize less truck travel and by smoothing traffic flow to increase the fuel efficiency of trucks operating in the ETL. However, because tolling one lane of facility will likely impact traffic in the nontolled lanes, the effectiveness of ETLs at reducing GHG emissions varies depending in the layout of the particular facility. For instance, if an existing general purpose lane is converted to an ETL (so that no capacity is added), congestion may increase on the remaining general purpose lanes, increasing emissions from trucks that use the general purpose lanes. On the other hand, adding new capacity in the form of an ETL may have net benefits by reducing overall congestion.

- **Trip reduction**. By increasing the price per mile, ETLs can encourage truckers to eliminate extra trips to the degree to compensate for increased costs. However, if the lanes are provided as extra capacity added to a general purpose facility, there will be no additional incentive to reduce trips.
- **Trip length**. Where no general purpose lanes are provided, ETLs will simultaneously motivate shorter trips for trucks traveling on the tolled facility, and longer diversions to nontolled facilities for trucks choosing not to pay the toll. The net effect depends on the specific facilities and routes, but could very well lead to increased GHG emissions if total truck VMT increases due to longer routes. On the other hand, if adjacent general purpose lanes are provided, diversions will not lead to any net increase in emissions.
- **Mode shift.** By increasing the price per mile, ETLs can encourage mode shift to nonroad modes. However, this again depends on whether general purpose lanes are also provided. As discussed above, mode shift can reduce emissions for freight shifted to rail or barge, but increase emissions for freight shifted to air cargo.

- **Operational improvement.** ETLs are managed specifically to provide free-flow conditions, and will thus improve truck fuel efficiency. For Oregon, this will apply largely to trucks traveling in the Portland metropolitan area, where conditions can be congested. Trucks are not likely to be responsive to time-of-day price signals; however, as noted above, the schedule for many truck movements is determined by customer needs.

Cordon Pricing

Cordon pricing is designed to address urban congestion by charging a toll to vehicles entering a city or some portion of the urban area. The system can be designed to charge for entry during the day with free or discounted entry at night or weekends, when traffic is light. In Oregon, cordon pricing could take the form of a toll on traffic entering downtown Portland, or be expanded to put the cordon at the urban growth boundary.[80] Cordon pricing therefore only affects urban movements, and in the case of the freight sector would have the largest impact on trips with an origin or destination within the cordon. (Through-traffic would probably be routed around the cordon.) Cordon pricing can include any number of exemptions, and trucks with pickups or deliveries inside the cordon could even be exempted from the toll in the interest of promoting business.

- **Trip reduction.** If trucks are not exempted from cordon pricing, it would strongly incentivize reduced truck trips into the urban core. As shown by Table 4.1, London's cordon pricing scheme generated a 13 percent reduction in truck trips in its first four years of operation. However, truck miles decreased by about one-half that amount (7 percent), suggesting that carriers sent fewer trucks into the cordon, but increased each truck's productivity in part by making more stops within the cordon. GHG emission reductions will be approximately proportional to the reduction in truck miles traveled, rather than the reduction in trips.

Table 4.1 Impact of London Congestion Pricing Program on Truck Traffic

Concept	2002-2003	2003-2004	2004-2005	2005-2006	2002-2006
Trucks Entering the Charge Zone	-11%	-5%	-4%	6%	-13%
Truck-Miles in the Charge Zone	-7%	-8%	8%	2%	-7%

Source: Cambridge Systematics, Inc., 2007, *Congestion Mitigation Commission Technical Analysis: Night Delivery Incentives*, prepared for New York City Economic Development Corporation and New York City DOT.

[80] Cambridge Systematics, Inc., 2009, *Tolling White Paper No. 5, Assessing the Economic Effects of Congestion Pricing*, prepared for ODOT.

- **Trip length.** As noted above, cordon pricing will lead to fewer but longer trips for trucks going to destinations inside the cordon. The cordon toll has little effect on trip length for other trucks, other than to force through trips to route around the cordon. If a cordon's boundaries enclosed a closed-access freeway, traffic on the freeway could be exempted to avoid the emissions associated with long detours (e.g., vehicles exiting the freeway inside the cordon would be tolled, but not through traffic remaining on the freeway).
- **Mode shift.** Cordon pricing would not likely affect mode choice, since ultimately trucks are the only mode that could deliver goods to final destinations within the cordon.
- **Operational improvement**. Cordon pricing is designed to reduce congestion, and therefore would improve truck fuel efficiency inside the cordon. For instance, London's cordon pricing scheme reduced peak-period congestion delays by 30 percent, and increased average traffic speed by 37 percent, from 8 miles per hour to 11 miles per hour.[81] The effects would be most pronounced for urban delivery vehicles, rather than the large Class 8 combination trucks.

Mileage Fees

Most states have a fuel tax to help fund transportation improvements, but Oregon has in place a weight-distance fee for trucks instead, currently charging 0.4 to 18.51 cents per mile, depending on weight (the higher figure is for a 5-axle truck operating between 96,001 and 98,000 pounds); mileage is self-reported by trucking companies. (These fees will be raised to 0.498 to 23.04 cents per mile on October 1, 2010.) Similarly, VMT fees could be imposed and collected through global positioning system (GPS), hubodometer systems, or other ways of reporting mileage (In Oregon's VMT fee pilot, fees were collected at the gas pump.). For instance, in Germany a truck VMT fee of 10 to 15 Euro-cents per kilometer (about 24 to 36 U.S. cents per mile) is collected with GPS and wireless network technologies installed in all foreign and domestic trucks.[82] VMT fee systems could be devised to charge higher fees during peak periods, different fees for urban and rural travel, as well as on different types of facilities (expressways versus other types of roads, for instance).[83] Rates could also vary by size or

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[81] Cambridge Systematics, Inc., 2007, *Congestion Mitigation Commission Technical Analysis: Night Delivery Incentives*, prepared for New York City Economic Development Corporation and New York City DOT.

[82] Cambridge Systematics, Inc., 2009, *Task 8 Technical Memorandum: Analysis of Freight User Fee Funding Sources (Draft)*, prepared for the Washington State Legislature Joint Transportation Committee.

[83] Whitty, James M., 2007, *Oregon's Mileage Fee Concept and Road User Fee Pilot Program: Final Report*, Oregon Department of Transportation, November 2007.

weight of truck and even GHG emissions; tolls in the German system vary by number of axles and emission category. Such a fee structure is another way to price truck travel, and has the distinct advantage that it is completely comprehensive – it can cover travel on all roads within the State.

- **Trip reduction.** By increasing the price per mile, VMT fees can encourage truckers to eliminate extra trips to compensate for increased costs.
- **Trip length.** VMT fees will incentivize reducing miles traveled. Since a VMT fee is comprehensive, there will be no incentive for diversion.
- **Mode shift.** By increasing the price per mile, VMT fees can encourage mode shift to nonroad modes. As discussed above, this can reduce emissions for freight shifted to rail or barge, but increase emissions for freight shifted to air cargo.
- **Operational improvement.** If VMT fees were structured to discourage peak-period travel by passenger vehicles, the resulting decrease in congestion could improve truck's operational fuel efficiency for travel in urban areas. Trucks are not likely to be responsive to time-of-day price signals; however, as noted above, the schedule for many truck movements is determined by customer needs.

Truck only Toll (TOT) Lanes

TOT lanes, which are really another kind of managed lane, are lanes dedicated for the exclusive use of trucks. Currently, there are a handful of truck-only facilities in the United States, among them the I-5 climbing lane in Oregon, but there are no TOT lanes. TOT lanes can be designed as long-haul (for instance, the proposed I-70 truck-only lanes from Missouri to Ohio); or as urban corridors (for instance, proposed TOT lanes in Southern California and in Miami, both intended to allow port-related truck traffic to bypass urban congestion). Long-haul, truck-only facilities encourage the usage of longer combination vehicles (LCV), which are prohibited in many states, by separating freight and passenger traffic, while urban facilities are designed to improve freight mobility in metropolitan areas. TOT lanes can also be voluntary (in which case, trucks will use them if the operational benefits outweigh the toll costs); or mandatory (in which case trucks would be banned from the parallel general purpose lanes and required to pay the tolls).

The LCV issue is particularly significant for GHG reductions, because LCVs have lower ton-mile emissions than conventional combination trucks – but may also attract freight from rail. However, Oregon already allows LCVs on its National Network facilities (which includes interstates), eliminating much of the rationale for long-haul TOT lanes within the State and making it unlikely that any Oregon-only TOT proposal will increase LCV usage. (Given the cost of constructing TOT lanes, this also make it unlikely that long-haul TOT facilities would be constructed in Oregon.) Urban TOT lanes could be used to provide congestion-free freight travel in the Portland metropolitan area, or other congestion-prone areas in Oregon; or to provide better access to port facilities.

- **Trip reduction.** Voluntary TOT lanes would have no influence on trip reduction, since truckers that would not receive enough benefits to offset the costs would simply use the free lanes. Mandatory usage could reduce the number of trips by increasing trip costs.
- **Trip length.** Voluntary TOT lanes would have no influence on trip length, again because truckers could simply chose not to use the lanes. Mandatory TOT lanes could incentivize reduced trip lengths on certain facilities, but could also motivate diversions to nontolled facilities; increasing mileage driven. The net effect depends on the specific facilities and routes.
- **Mode shift.** Voluntary TOT lanes would not influence mode shift, nor would they result in freight shifting to LCVs, as they already are allowed on the major Oregon highways. If TOT lanes were made mandatory, the resulting increase in per-mile costs might result in some shift to other modes.
- **Operational improvement.** Free-flowing TOT lanes will allow for smoother truck operation, and improve truck fuel efficiency for those vehicles that use the TOT option.

4.4 SUMMARY AND CONCLUSIONS

Although the potential effects of these different tolling and pricing mechanisms are complex and difficult to generalize, it is evident that more comprehensive fees, especially mileage-based charges, avoid some of the drawbacks of point-based fees. In particular, mileage-based charges avoid the possible increase in VMT and associated GHGs that would occur if truckers detour around a tolled route. Tolls must be geographically comprehensive to prevent diversion to longer, free routes. To be effective at reducing GHGs, tolling networks will need to be comprehensive enough to eliminate diversion to nontolled routes, or carefully chosen in areas in which free routes are not practical for trucker diversion.

Other points to consider when analyzing options for tolling and pricing to reduce GHG include:

- **The magnitude of the toll has a strong effect on GHG reduction impacts.** Tolls will be just one element of operating costs, and shippers and carriers will not make decisions based solely on tolls. The higher the toll, the more likely become a factor in their decision-making process. However, toll magnitude must be weighed against other factors, such as political acceptability (see below for more discussion).
- **Mode shift is a potential effect of all truck tolling mechanisms, but is limited if similar fees are not applied outside Oregon.** Any tolling mechanism will promote mode shift to the extent that it raises trucking per-mile costs relative to other modes – as long as the tolls are high enough to significantly impact truck shipping costs compared to other modes. The effect would still be limited to commodities and origin-destination pairs that

are conducive to mode switching, limiting the overall impact. Problematically, (assuming current fuel prices) mode shift is most likely for shipments over 500 miles – an interstate move for Oregon. Since Oregon road tolls can only apply to the in-Oregon segment, mode shift incentives may be limited if neighboring states do not apply similar fees. In addition, the net effect on GHGs will depend on whether the shift to more efficient modes (rail and barge) outweighs the potential shift to air cargo. For Oregon, only a few origin-destination pairs are close enough for air and truck to be competitive, so this could be empirically estimated for any given tolling mechanism.

- **Dynamic pricing will be more effective at reducing GHG emissions than static tolling.** Dynamic pricing designed to maintain constant free-flow conditions will improve fuel efficiency for the segment of trucks that have to travel during peak periods due to schedule or route limitations. Static tolling, on the other hand, will not result in significant operational benefits for trucks.
- **Benefits of TOT lanes are limited in Oregon.** TOT lanes managed to maintain free-flow conditions will improve truck fuel efficiency by allowing trucks to travel at constant speed, but no more so than in any other managed lane concept. In Oregon, LCVs will not derive any special benefit from TOT lanes because they already are allowed on the National Network within the State. Thus, there will not likely be any emission reductions gained from freight shifting from regular trucks to LCVs.
- **Parallel general purpose lanes will undermine price incentives, but prevent diversion to longer routes.** The effect of managed lanes (ETL or TOT) in reducing GHG emissions from trucks will depend in part on whether free general purpose lanes are also provided in the facility. The provision of free lanes will effectively eliminate the price signal being sent to truckers, because drivers for whom the toll costs outweigh the benefits will simply opt out – as though there were no toll in place. As a result, the only GHG reductions will be derived from improved traffic flow – and that only for the trucks using the priced facility.

Challenges of Using Tolling As a GHG Reduction Policy

As with all GHG reduction policies, there are a number of implementation concerns that should also be considered in choosing among GHG reduction strategies:

- **Political.** To achieve significant GHG reductions, tolls will need to be higher than the public and businesses are used to seeing, and on many more roadways than Oregonians currently experience. Truck operators generally do not favor fee increases unless they receive direct benefits as a result, and tolling may be a tough sell for politicians; on the other hand when there is a clear plan for use of the revenues, greater support can be achieved.
- **Cost-effectiveness.** In theory, pricing strategies represent the most economically efficient way to implement GHG reduction strategies. Tolling strategies

have the potential to be a cost-effective emission reduction strategy requiring relatively little infrastructure, but there are still significant costs involved. Collecting tolls is considerably more expensive than collecting motor fuel taxes: collection costs at traditional toll facilities range from $0.10 to $0.60 per transaction, and London's area-pricing scheme spends about one-half its toll revenue on the cost of toll collection.[84] Improvements in electronic tolling are likely to bring costs down, but for the near future electronic tolling still has large "back office" labor requirements that keep costs up.

- **Equity impacts.** Equity discussions in tolling primarily concern passenger vehicle drivers being tolled off roadways. Equity concerns also exist in the freight sector, where small trucking companies (independent operators) may have more difficulties in responding to operating cost increases. Mode shift also presents concerns for small businesses, since by the nature of the industry makeup, a shift from trucks to rail or marine would likely result in small businesses losing revenue to large corporations.
- **Legal challenges.** The Oregon weight-distance fee was challenged in court by the American Trucking Association (ATA). Although it survived, a slightly different weight-distance tax in Idaho was repealed after the ATA successfully sued over a provision that reduced tax rates for natural resource commodities.[85] Most tolling mechanisms will likely survive legal challenges, but care will need to be taken in constructing them.
- **Eligibility**. Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) considerably expanded eligibility for toll roads. Currently, existing non-Interstate, Federal-aid highways can be converted to toll roads when rehabilitation or capacity expansion occurs, and high-occupancy vehicle (HOV) lanes on all interstate highways can be converted to HOT or ETLs. Federal-aid funds can also be used for new toll roads.[86]

As with any greenhouse gas reduction strategy, the potential benefits from tolling or road pricing need to be weighed against the potential economic impacts to the trucking industry, political acceptability, and implementation issues. Ultimately, pricing and tolling strategies may be considered as just one of many potential GHG strategies that could be pursued.

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[84] Cambridge Systematics, Inc., 2009, *Tolling White Paper No. 5, Assessing the Economic Effects of Congestion Pricing*, prepared for ODOT.

[85] Cambridge Systematics, Inc., 2009, *Task 8 Technical Memorandum: Analysis of Freight User Fee Funding Sources (Draft)*, prepared for the Washington State Legislature Joint Transportation Committee.

[86] Parsons Brinckerhoff and David Evans & Associates, 2009, *Tolling White Paper No. 2, Geographical and Situational Limits*, prepared for ODOT.

5.0 Opportunity Type 3: Transportation Project Prioritization

5.1 INTRODUCTION

According to the *Oregon Strategy for Greenhouse Gas Reductions,*[87] the incorporation of greenhouse gas (GHG) emissions into the Oregon transportation planning decision-making process is a cost-effective solution to help reduce Oregon's GHG emissions. The report also lists this strategy as one of several recommended "immediate actions" to help reduce transportation's contribution to GHG emissions. Specifically, it suggests "developing a method to account for GHG emissions and use it as a ranking criterion in transportation planning decisions."

As mentioned in the introduction of this report, freight movements result in a substantial portion of total transportation-related GHG emissions. Considering GHG emissions when selecting freight-related projects for funding is one way to achieve lower transportation GHG emissions. Several types of freight-related projects are more likely than others to lead to a reduction in GHGs, particularly those that reduce freight system fuel consumption. Some examples include the following:

- **Highway Bottleneck Relief –** Highway and road bottleneck mitigation through increased lanes or intersection redesign – however, the impacts of this strategy depend on other factors including land use, location (urban/rural), and other factors. In addition, induced auto/truck travel demand that result from bottleneck relief may offset some of the benefits;
- **ITS Improvements –** Further installation of ITS on roads, such as Weigh-in-Motion (WIM) technology;
- **Truck Idling Reduction –** Investment in widespread idle-reduction technology for trucks, including truck stop electrification (TSE) and auxiliary power units (APU);

[87] Governor's Advisory Group on Global Warming, *Oregon Strategy for Greenhouse Gas Reductions*, State of Oregon, December 2004.

- **Rail Mobility Improvements –** Investment in rail infrastructure to reduce at-grade interchanges, bottlenecks, and other upgrades to improve rail freight mobility; and
- **Port and Marine Operations Improvements –** This includes land-side and marine-side improvements to improve efficiency and reduce GHGs, including truck idling and VMT reduction through technologies in the terminal and shore-side power for ships.

Determining the relative impact that each of these strategies has on GHG reduction is a complex and difficult task. However, several methods exist that can help Oregon Department of Transportation (ODOT) assess GHG emissions from potential projects. This chapter provides background information that can help inform the discussion of how best to incorporate climate change considerations into the project prioritization process. It is divided into two sections:

- Overview of the current ODOT freight transportation project selection process; and
- Methods to analyze the impact of freight investments on GHG emissions.

5.2 BACKGROUND: OREGON FREIGHT PROJECT SELECTION AND FUNDING

Several transportation project selection and funding mechanisms are in place in Oregon which utilize prioritization factors to assist decision-makers with selecting projects. This section focuses on the Statewide Transportation Improvement Program (STIP) and *Connect*Oregon program while briefly discussing additional freight funding sources.

STIP Overview

The STIP is ODOT's short-term, four-year capital improvement program for the transportation system. It is the mechanism for funding and scheduling of Oregon transportation projects and programs, including freight, highway, rail, public transit, bicycle, and pedestrian projects, among others. By adopting the STIP, the Oregon Transportation Commission (OTC) allocates state and Federal funds to selected projects, having undergone discussions with metropolitan planning organizations (MPO), Federal and state government agencies, interest groups, and others to select priority project in the upcoming four-year period. The 2010 to 2013 STIP contains more than $1 billion in projects and programs (subject to change). A wide variety of projects funded by local, state, and Federal dollars are included in the program.

STIP Project Selection Process

The OTC has created a list of prioritization factors to help MPOs, ACTs, and other OTC STIP advisory bodies select projects for the STIP for certain

development and construction projects. This includes factors such as project readiness, projects that leverage other funds, and projects that support freight mobility. Greenhouse gas impact is not currently included among prioritization criteria.[88] However, the OTC is currently working with STIP stakeholders to update the STIP to include the criteria: "Is consistent with the State's greenhouse gas reduction goals and reduces the State's dependence on foreign oil." The STIP process is also being revised to better incorporate the principles of least cost planning, which could have implications for any efforts to further include greenhouse gases as a prioritization criteria.

STIP and Freight

No separate project selection or prioritization process exists specifically for freight projects in the STIP. The STIP is intended to guide funding and scheduling of all types of transportation projects, including freight projects. The Oregon Freight Plan, currently being developed, will provide guiding principles on the topic of freight project prioritization.

The Oregon Freight Advisory Council (OFAC), as a part of its effort to give freight more visibility in ODOT policy, planning, and programming, plays an important role in advising the OTC on freight-related topics in the STIP. In this role, OFAC helps decision-makers, including ACTs and ODOT, better understand how potential STIP projects may impact freight mobility, and whether projects meet the prioritization factor of "projects that support freight mobility."

OFAC acts as an important resource to advise and inform decision-makers concerning the level of benefit from each freight-related project. In 2004, OFAC created a prioritized list of freight projects for earlier STIPs. Neither freight-specific nor other transportation projects are currently analyzed in the STIP for their potential to reduce GHGs.

Additional Oregon Freight Prioritization Processes

Other Oregon freight funding sources exist which have eligibility or prioritization criteria. Several examples include the following:

- ***Connect*Oregon Program –** This program provides funding for rail, public transit, and air and marine ports through lottery-backed bonds. The most recent version, ConnectOregon III, provided $100 million in funds to improve the multimodal transportation system in Oregon. After public hearings on the recommended projects, the OTC makes the final decision on the projects

[88] However, the STIP guidelines indicate that if the greenhouse gas impacts of a particular project are analyzed, the project description should include a statement regarding how greenhouse gas reduction was considered and what impact this had on project selection.

to be included. Currently, there is no separate project selection or prioritization process for freight projects within the program.

*Connect*Oregon III has a detailed four-step project selection and prioritization process, which involves scoring, tiering, identifying project rank, and project prioritization. Scoring of projects involves considerations of transportation cost reductions; economic benefit to the State; whether a project is a critical link connecting elements of the State's transportation system; how much cost can be borne by the grant/loan applicant; and whether a proposed project is ready for construction. In the current scoring process, no criterion exists that prioritizes projects which may result in GHG reduction.

- **Oregon Transportation Infrastructure Bank (OTIB) –** This is a statewide revolving loan fund designed to promote innovative financing solutions for transportation needs, including highway projects, transit capital projects, and bicycle/pedestrian projects.[89] No criterion is currently in place that require applicants to estimate the impact on GHG emissions, but there is a requirement for applicants to discuss the environmental impact of proposed projects.
- **Immediate Opportunity Fund (IOF) –** This program provides grant funding needed for street or road improvements to influence the location, relocation, or retention of a firm in Oregon; revitalize business or industrial centers; and prepare project-ready industrial sites. There is no GHG criterion for this funding source.
- **Marine Navigation Improvement Fund –** This is a loan and grant program for which only the 24 port districts in Oregon are eligible. Several criteria are in place for receiving this funding, including whether or not the proposed project is listed in the port's business or strategic plan.
- **Port Revolving Fund –** This funding source is intended for the planning and construction of facilities and infrastructure that promote maritime shipping, aviation, and commercial/industrial activity of ports. A number of selection criteria exist, but none that involves the reduction of GHGs.

5.3 METHODS TO ANALYZE THE IMPACT OF FREIGHT INVESTMENTS ON GHG EMISSIONS

As described previously, GHG impacts are not currently considered in Oregon's project selection processes. This section describes alternative methods for analyzing and including GHGs within the current project selection framework. In Oregon, the STIP and *Connect*Oregon are two of the likely project funding and prioritization programs in which GHG analysis could occur. To address the

[89] http://www.oregon.gov/ODOT/CS/FS/otib.shtml.

impacts of GHGs, climate change prioritization criteria could be created and added to the current list of criteria evaluated for the STIP and *Connect*Oregon. In the STIP, a separate prioritization factor (such as the existing factor that encourages freight mobility) could be created to increase the priority of projects that reduce greenhouse gases. In *Connect*Oregon, a separate consideration for GHG reduction potential could be added to the current considerations, and projects that are likely to reduce GHGs could be assigned additional points. One challenge of integrating a GHG prioritization factor into these processes is that, as described above, they are decentralized. There may be obstacles associated with imposing GHG analysis requirements on MPOs and ACTs.

The ideal metric for representing climate change impact is amount (e.g., tons of CO_2e) of GHG produced by the transportation project relative to a no-project scenario during a specific timeframe (e.g., in 2025). If such a metric were available for every candidate transportation project, it would allow projects that result in the greatest net reduction in GHGs to receive the highest priority. In practice, this type of analysis is not always practical, cost-effective, or even analytically possible for all projects.

Instead, a programmatic or categorical approach is more practical, especially for projects that have little impact on GHGs. The Washington State DOT, for example, has stated that it believes the most informative GHG emissions information will be developed at the planning/regional level.[90]

This section discusses limitations to conducting accurate project-level GHG analyses, as well as the range of modeling and other options, to help decision-makers obtain necessary information about potential projects and their ability to help reduce GHGs. The following options are discussed:

- **Existing information and research –** For this method, the GHG prioritization criteria would be based on existing information and national research.
- **Sketch planning –** In this method, the GHG prioritization criteria would be based on Oregon-specific sketch planning analysis of the GHG impacts of different transportation project types.
- **Modeling –** In this method, the GHG prioritization factor would be based on project-level analysis where possible.
- **Programmatic / Plan-level analysis –** This method would not involve the creation of a GHG prioritization criteria for specific projects. Instead, packages of transportation projects at the metropolitan/regional level would be analyzed together, and certain packages that appear to have a greater greenhouse gas reduction impact could be given higher priority.

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[90] Source: Washington State DOT's preliminary guidelines on project level GHG analysis see: http://www.wsdot.wa.gov/NR/rdonlyres/73ADB679-BDA6-4947-93CA-87C157862DD7/0/WSDOTprojectLevelGHG.pdf.

These types of analysis would include all types of transportation projects, not just freight projects. No examples were identified where freight projects were analyzed separately from other transportation projects for GHG emissions evaluation. Many freight projects may be analyzed for GHG impact using the same tools used for other types of transportation projects; however, challenges are discussed below.

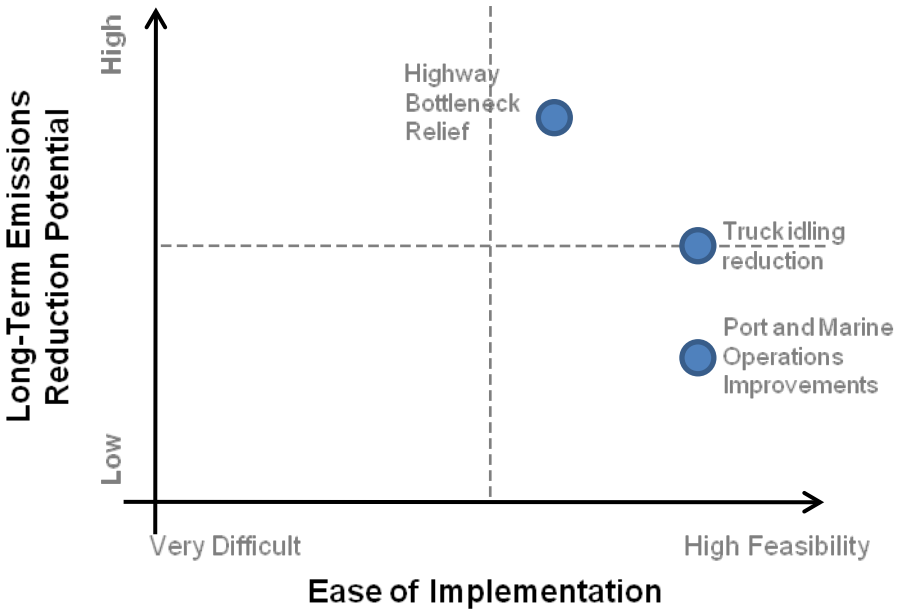
Existing Information and Research

As described previously, Oregon's current transportation project prioritization processes (e.g., STIP and Connect Oregon) do not require systematic analysis for all project selection criteria. For example, freight mobility is a consideration in project prioritization for the STIP, but quantitative analysis is not required. It is a judgment based on qualitative factors and existing information about the project.

If climate change were to be added as a criterion in the project selection process, a similar qualitative approach could be used. Guidelines based on existing research and data would need to be developed to help inform decision-makers on GHG impacts of potential project types. Figure 5.2 illustrates an example comparison of strategies based on national research.

Qualitative, judgment-based analysis of candidate project's likely impact on climate change is the least costly approach to project prioritization, but also the least objective. It is difficult to generalize GHG impacts by project type, and national research may not be applicable to Oregon.

Figure 5.1 Comparing Three Strategies for Reducing GHG Emissions



Note: Estimates of relative impacts based on Cambridge Systematics' analysis of the U.S. EPA data.

Sketch Planning Analysis

The likely greenhouse gas effects of certain types of transportation projects can be estimated using sketch planning analysis. This strategy is more labor-intensive than using qualitative information, but may be less labor-intensive than attempting to use travel demand modeling tools for all candidate projects.

Sketch planning methodologies and tools produce general order-of-magnitude estimates of travel demand and operations in response to transportation improvements. They are being used at the national and state level to estimate greenhouse gas impacts for a variety of project types. One example is Oregon's GreenSTEP tool, which was developed to help the Oregon Global Warming Commission (OGWC) develop a statewide strategy on how to meet targets for reducing GHG emission. GreenSTEP is a GHG planning model with sensitivity to a large number of land use, transportation, vehicle, price, fuels and other inputs. The model helps estimate the impact of various scenarios on GHGs.[91]

Cambridge Systematics developed a sketch planning tool to estimate greenhouse gas reduction impacts from a variety of transportation project types at the national level,[92] and has developed locally tailored versions of the tool in Maryland and currently in the Los Angeles metropolitan area. The national analysis included multiple types of multimodal freight strategies, including:

- Rail system bottleneck removal;
- Restoring major elements of the marine transport system;
- Requiring overweight load permits for trucks carrying shipping containers;
- Requiring overweight load permits for longer combination vehicles carrying natural resources;
- Weigh-in-motion screening at weigh stations;
- Electronic credentialing to bypass weigh stations;
- Truck stop electrification;
- Auxiliary power units for sleeper cabs;
- Truck-only toll lanes; and
- Urban consolidation centers.

Sketch planning methods could be developed using Oregon-specific inputs to roughly estimate the expected greenhouse gas reduction impacts of freight and other types of transportation projects, and the results could be used to inform project prioritization. Projects could be categorized by their ability to reduce

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[91] http://www.oregon.gov/ODOT/TD/TP/docs/HB2186page/General.pdf?ga=t.

[92] For *Moving Cooler,* a national study completed in 2009 for a multiclient consortium.

GHGs; and could be combined with other criteria, such as ease of implementation, as follows:

- High reduction potential, easy to implement (best);
- High reduction potential, hard to implement;
- Low reduction potential, easy to implement; and
- Low reduction potential, hard to implement (worst).

These were the categories used by Maryland's Commission on Climate Change to classify 42 measures under consideration for their potential to reduce greenhouse gas emissions within the State.

Travel Demand Modeling

Travel demand modeling, coupled with air quality analysis, is one of the most rigorous available approaches to estimating the greenhouse gas impact of some types of major transportation investments and packages of projects at an area-wide level (e.g., region or state).

While most travel demand models are capable of estimating changes in VMT and operating conditions resulting from highway investments, some also include portions of the nonhighway transportation network. Oregon's integrated statewide travel demand model, SWIM2, is one of the more sophisticated in its ability to model changes affecting freight travel. However, most transportation project analysis is done at the regional level, where there are much greater variations in the capabilities of travel demand models.

Travel demand model output can be linked to an air quality analysis tool to translate the results into greenhouse gas impacts. The U.S. EPA's MOVES Tool, for example, takes inputs such as change in VMT and vehicle fleet mix and outputs greenhouse gas effects. MOVES cannot model GHG effects associated with nonhighway freight transportation improvements.[93]

However, travel demand modeling has drawbacks. It is typically performed at the regional level, and greenhouse gas emissions can occur anywhere, not just in major metropolitan regions. It is also time-consuming and labor-intensive. For that reason, few states or metropolitan agencies use their travel demand models to analyze the impacts of a long list of individual transportation projects. As mentioned above, the state of Oregon and other states and regions are addressing this issue by identifying and modeling the GHG impacts of categories of projects (see box below on the modeling efforts of the San Francisco Bay Area Metropolitan Transportation Commission (MTC). The Portland region is also

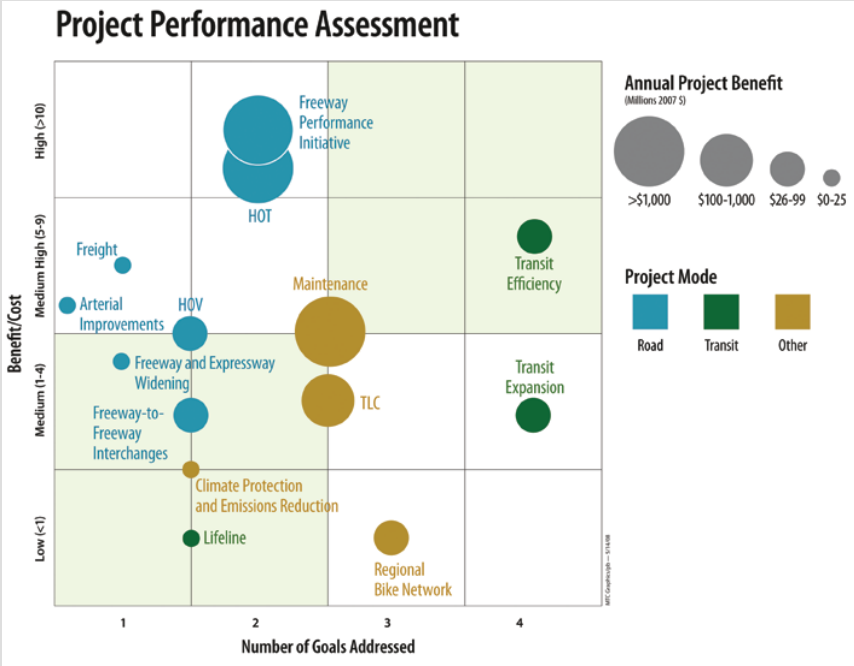
[93] Recommendations from ICF's *Assessment of Greenhouse Gas Analysis Techniques for Transportation Projects* for the American Association of State Highway and Transportation Officials (AASHTO) in May 2006.

becoming actively involved in measuring GHG impacts of transportation projects.

Programmatic / categorical modeling of transportation projects is beneficial in that it less labor intensive than attempting to model projects individually, and more accurately captures the effects of interactions between projects. Some sketch planning tools are also able to represent some of the interactions between different types of transportation investments.

San Francisco Bay Area MTC

MTC, the MPO for the San Francisco Bay Area, evaluates the GHG impacts of individual highway and transit projects. As a part of the Transportation 2035 Regional Transportation Plan (RTP) process, MTC developed a performance-based approach to help inform project selection. The RTP seeks to achieve three principles referred to as the Three Es: Economy, Environment, and Equity. Individual projects were measured against these three principles, which helped identify and advance high performing, cost-effective projects for consideration in the plan. Using outputs from the regional travel demand model, the projects were quantitatively analyzed for costs and benefits (including impact on GHG emissions). After the projects were analyzed, they were compared to each other based on the number of plan goals the project addressed and the Benefit/Cost ratio of the project. Below is an initial summary of some of the results:



One of the "goals addressed" is "particulate matter emissions (based on health effects) and GHG emissions."

FHWA, "Metropolitan Transportation Commission, San Francisco Bay Area: Developing Regional Objectives and Performance Measures to Improve System Operations," April 2009, http://ops.fhwa.dot.gov/publications/fhwahop09047/fhwahop09047.pdf.

New York State

New York State's 2002 Energy Plan integrated energy conservation and GHG emissions with transportation planning. One of the recommendations of the Energy Plan is that MPOs, in conjunction with the State, assess the GHGs expected to result from the implementation of transportation plans and programs. The New York State DOT has drafted guidance to help MPOs fulfill this recommendation. All MPOs in the State have estimated carbon dioxide emissions from the long-range transportation plans (LRTPs) and their transportation improvement programs.

FHWA, completed by ICF International. "Integrating Climate Change Into the Transportation Planning Process," July 2008.

Puget Sound Regional Council (PSRC)

The PSRC, the MPO for the Seattle area, is using the U.S. EPA's MOVES model to analyze GHG emissions from its LRTP at a regional level. Output from this model will feed into GHG emissions analysis.

Recommendations from ICF's "Assessment of Greenhouse Gas Analysis Techniques for Transportation Projects" for the AASHTO in May 2006.

5.4 SUMMARY

In seeking to link broad state climate change goals with transportation investment decisions, many states, including Oregon, are considering how to analyze the greenhouse gas impacts of transportation investments and use the results in project prioritization.

Quantitative greenhouse gas analysis is possible for certain types of projects, but not all, and can be labor intensive. When it is possible, it is limited by the fact that individual projects may have impacts well beyond the project boundaries and may interact with other projects. As a result, many states and regions, including some in Oregon, are moving towards planning-level analysis of categories of transportation investments and their effect on greenhouse gas reductions.

6.0 Opportunity Type 4: Modal Shift

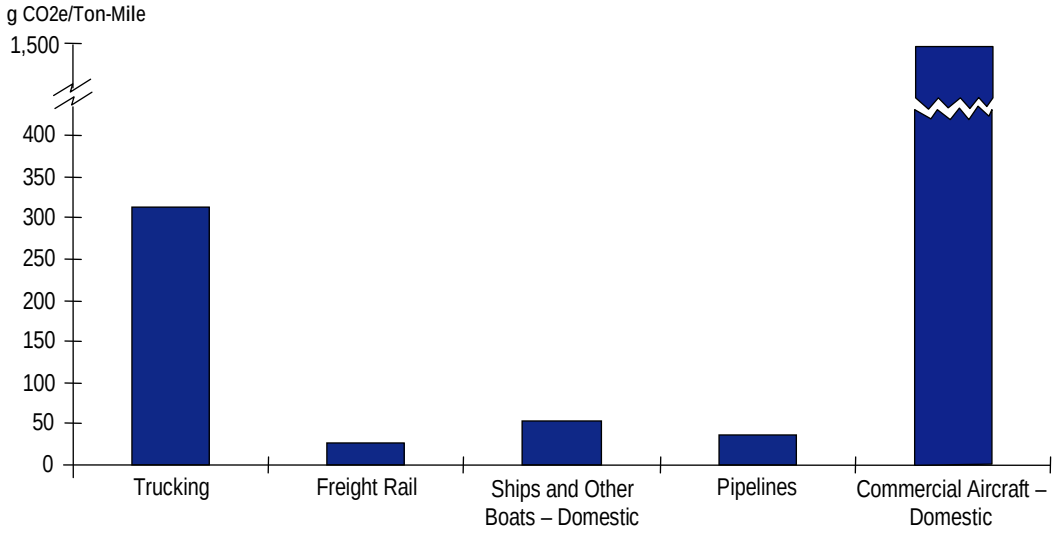
Shifting freight to more efficient modes represents an important tool for reducing freight GHG emissions. However, it will require care and study to successfully achieve mode shift, because shippers have cost, time, and reliability constraints that determine their choice of modes.

This section introduces the types of mode shift that can reduce GHG emissions, discusses some of the factors affecting the ability to shift freight to different modes in general and in Oregon specifically, and then describes the policy options available to affect mode shift.

Benefits of Mode Shifts

In the hierarchy of freight modes, GHG emissions are directly proportional to modal energy efficiency. As shown in Figure 6.1, moving cargo by air has by far the highest GHG emissions per ton of freight moved on average; more than four times those of truck. Trucking, in turn, emits GHG at more than five times the rate of marine or rail modes, on average.

Figure 6.1 Average GHG Emissions per Freight Ton-Mile by Freight Transportation Mode in the United States
2006



Source: U.S. EPA, 2008, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 to 2006*; and Bureau of Transportation Statistics, National Transportation Statistics.

It follows, then, that shifting freight to modes with lower emission rates can reduce GHG emissions. The major mode shifts that could result in reduced energy usage and GHG emissions reductions include the following:

- Truck to rail;
- Truck to short-sea shipping; and
- Air cargo to truck.

It is important to note that these mode shifts are not easy to implement in practice. The truck mode offers significant flexibility and time savings that make it difficult for other modes to compete. In addition, the lack of significant rail infrastructure and remote locations of industries make many goods dependent on truck movements. However, some commodities in certain locations may see benefits from mode shifts to more energy-efficient modes. The mode shifts that could result in reduced GHG emissions are discussed in greater detail below.

Shipper Perspectives on Modal Shift

As part of the development of the Oregon Freight Profile, a portion of the Oregon Freight Plan, 20 shippers were interviewed about several topics including modal shift. Five of those interviewed indicated recently shifting modes, with truck to rail being the most commonly cited type of shift. Some of the reasons listed for shifting included rising or falling fuel prices making rail or truck more attractive; closure of certain rail lines forcing a shift to truck; or closure of the Columbia River locks forcing a shift from barge to rail.

Truck to Rail and Truck to Short-Sea Shipping

The magnitude of the benefits achieved from switching from truck to rail and marine modes will vary depending upon factors, such as the length of the haul and the type of cargo. A review of recent estimates from the U.S. EPA SmartWay program, U.S. Maritime Administration, North American Commission for Environmental Cooperation, and Australian Network Access suggests that reductions on the order of 60 percent per ton-mile are feasible for shifts from trucking (trailers or containers) to long-haul intermodal rail, with reductions decreasing with shorter distances.[94]

Marine transport can, in some cases, produce even fewer carbon emissions per ton-mile than rail, although again this depends on the type of shipment and vessel. One study comparing inland waterway shipments with rail and truck estimated that inland towing (barge tows) uses 28 percent less fuel per ton-mile than rail and 73 percent less than truck.[95] An international study[96] found that

[94] U.S. Department of Transportation, 2010, *Transportation's Role in Reducing U.S. Greenhouse Gas Emissions: Report to Congress*, Washington, D.C., April 2010.

[95] Kruse, J., et al., 2007, *A Modal Comparison of Domestic Freight Transportation Effects on the General Public*, prepared by Texas Transportation Institute for U.S. Maritime Administration and National Waterways Foundation.

ocean-going and coastwise shipping is typically in the range of 16 to 56 grams of CO_2 per ton-mile for general cargo and container ships (compared with 56 to 80 grams per ton-mile for intermodal trains and more than 300 grams per ton-mile for trucks). However, it should be noted that marine diesels burn extremely low-grade fuel oil (bunker fuel), which could result in increased black carbon emissions, as compared to other modes.

Simply comparing emissions per ton-mile does not tell the whole story, however. Whereas trucks can move goods all the way from point of origin to final destination, rail and marine modes often involve drayage movements – additional truck movements – to get goods from the shipper to the rail and marine terminals. Terminal equipment, including yard trucks, straddle carriers, and other lifting devices, then transfer the container or truck trailer to flat cars or ships; in railyards, there also are emissions from switchyard locomotives. The very efficient rail line-haul (the long-distance portion) or water movement must then be followed by the terminal and drayage activity on the destination end. In many cases, these movements are made by the oldest and most polluting vehicles in the fleet, often in urban areas. Water and rail movements will, in most cases, also follow more circuitous routes than trucking movements because the rail and marine networks are less dense than the highway network. Thus, the relatively lower emissions per ton-mile may occur over a greater number of miles.

As a result, the greatest reductions per ton-mile occur for the longest-distance moves. For instance, because of the drayage moves in particular, which may range from 50 to more than 200 miles, most of the GHG emissions advantage of rail disappears at distances less than 400 to 500 miles, and the maximum benefits are only gained at over 1,000 miles.[97] Of course, the economic incentives driving shipper and carrier decisions on mode choice are sensitive to fuel cost, and can vary as the price of fuel rises and falls.

Air Cargo to Truck

Modal diversions from truck to rail or marine are not the only potential freight mode-shifts with GHG benefits. For a limited portion of air cargo shipments, there also may be potential for GHG benefits from shifting air cargo to truck primarily for shipments between city pairs that are relatively close together. For instance, overnight deliveries shipped by truck between cities within a few hundred miles of each other can arrive in time for morning delivery with significantly less GHG emitted than if sent by air.

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[96] Buhaug, Ø., J. J. Corbett, Ø. Endresen, V. Eyring, J. Faber, S. Hanayama, D. S. Lee, D. Lee, H. Lindstad, A. Mjelde, C. Pålsson, W. Wanquing, J. J. Winebrake, K. Yoshida, 2008, *Updated Study on Greenhouse Gas Emissions from Ships: Phase I Report*, International Maritime Organization (IMO) London, United Kingdom.

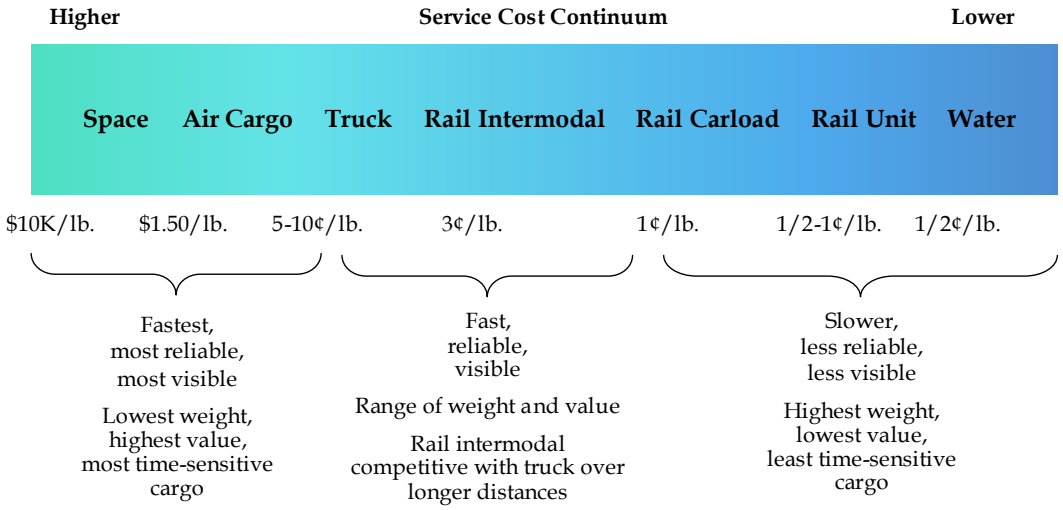
[97] U.S. Department of Transportation, 2010, *Transportation's Role in Reducing U.S. Greenhouse Gas Emissions: Report to Congress*, Washington, D.C., April 2010.

Potential for Mode Shift

The portion of freight that could be shifted to more fuel efficient modes depends on many factors; not just relative fuel efficiency. To further define the market for mode shift, the following would need to be considered:

- **Commodity types.** Only a limited number of commodities are amenable to shifting from truck to rail or water, given the current range of fuel and other costs. Most heavy commodities move by rail or water, which are engineered to carry larger, heavier loads, and realize economies of scale. For these goods, the costs savings of moving by rail or water offset slower and sometimes less reliable transit times. Lighter, high-value commodities travel by truck because they are dependent upon trucks' higher speeds and reliability (except perhaps for transcontinental movements). Thus, only commodities with more moderate weights and values are candidates for shipment by both modes. Figure 6.2 shows the types of commodities moved by the various modes:

Figure 6.2 Freight Transportation Service Spectrum



Source: Freight Rail Bottom Line Report – AASHTO.

- **Commodity volumes.** An individual railcar or marine vessel carries the equivalent of many truck loads. If the total volume of a commodity moving between a pair of cities is low, or the shipments are infrequent, it may not be economical or convenient for the shipper or the railroad to switch from truck to rail/marine. For instance, a study of potential short-sea shipping between Vancouver, British Columbia and Seattle/Tacoma concluded that short-sea

shipping needs to be scheduled daily to be competitive with trucking.[98] At lower frequencies, the service is less attractive to shippers, who are offered the option of very frequent service by the truck mode; low frequencies of service effectively increase dwell time – and costs. (As noted, significant changes in fuel costs could shift these economic incentives.)

- **Network connectivity.** The rail and waterway networks do not directly reach all destinations in the United States. Any point in the United States can be reached with a combination of rail/marine and truck modes, but on routes with long drayage legs, the added costs and time of intermodal transfers could simply make it more desirable to ship by truck. The rail system has been rationalized to allow the railroads to best serve their core markets. In addition, the railroads have made significant infrastructure, operations, and equipment investments to allow them to handle significant rail traffic. Future investment in rail capacity could change this equation, but would take decades to appreciably change the structure of the national network.
- **Reliability of service.** Trucking's more direct and timely service has become increasingly important with the rise of "just-in-time" supply chains. Just-in-time delivery refers to a logistics management system that relies on trucking's ability to deliver inventory quickly when needed, instead of stockpiling reserves of goods or materials to meet upcoming needs. This system gains efficiency by reducing the need to pay for warehousing, but it also requires fast, reliable service. Logistics providers are less willing to incorporate rail and water modes when just-in-time supply chains are involved. For instance, it takes about 47 hours to cover the 360 water miles from Lewiston, Idaho, to Portland by container barge and less than 10 hours by truck. A shipper with time-sensitive goods would choose truck. To address this issue, the rail industry has developed dedicated "expedited" container trains for certain high-volume routes (such as BNSF's "Z" train) that that run on regular schedules at higher speeds than average freight trains, carrying UPS deliveries and other less-than-truckload deliveries.

Oregon Modal Characteristics Relevant for Mode Shifting

A detailed origin-destination survey of freight movements in Oregon would be needed to assess which commodities move on routes and distances amenable to mode shifting. The discussion below provides an introduction to the factors that would need to be considered, given Oregon's commodity mix.

As shown in Figure 6.3, forestry and paper products together account for more than one-half the rail tonnage originating in Oregon. Lumber and wood prod-

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[98] Cambridge Systematics, Inc., 2007, *Cross Border Short-Sea Shipping Study: Phase II*, prepared for the International Mobility and Trade Corridor (IMTC) Project, January 2007.

ucts alone accounting for 5.7 million tons in 2007, or 42 percent of rail tons originating in Oregon (in fact, Oregon is the largest originator of rail tons of lumber and wood products in the country). Although intermodal (e.g., shipping containers) accounts for only 7 percent on tonnage, goods shipped by container generally have higher value per ton than other rail commodities. Tons terminating in Oregon are more diverse, reflecting both commodities consumed in the State and commodities shipped out internationally from Portland. Chemicals are the leading commodity with 28 percent of tons terminated. Grain and field crops account for another 21 percent; much of these are sent to Portland for transfer to ocean-going cargo ships. Coal (primarily for power production) accounts for 11 percent of inbound rail shipments.[99]

Figure 6.4 shows 2002 share of Oregon truck tonnage for selected commodities that could fit the time and bulk constraints of travel by rail or water. Clay, concrete, glass, or stone products are the dominant commodity by tonnage (34 percent) carried by trucks. Much of this trucking tonnage is likely to be relatively short moves bringing construction materials on-site, and not amenable to mode shift. Farm, lumber, and wood products also comprise a large share of truck tonnage in Oregon. These relatively low-value, high-weight commodities are generally amenable to travel by rail or water if accessible by those modes, and if the trip length is of sufficient distance to warrant shipping by rail.

A complication, however, is that 75 percent of Oregon's trucking tonnage are moved within the State. (By comparison, only 4 percent of waterborne tonnage and 3 percent of rail tonnage are internal to the State; reflecting the long-distance moves that are most economical by water and rail.) Since the GHG benefits of rail and water moves are gained primarily at distances of greater than 400-500 miles in part due to associated drayage moves, shifting these internal truck moves to other modes will likely have limited or no GHG benefits, depending on the emissions associated with drayage for those particular origin-destination pairs. Of the commodities relevant to potential mode shift, only about 23 percent of the tonnage originate or terminate outside Oregon. Overall, approximately 20 percent of Oregon's truck tonnage both originate and terminate outside the State, and are commodities amenable to mode shifting (such as farm, lumber, and wood products).

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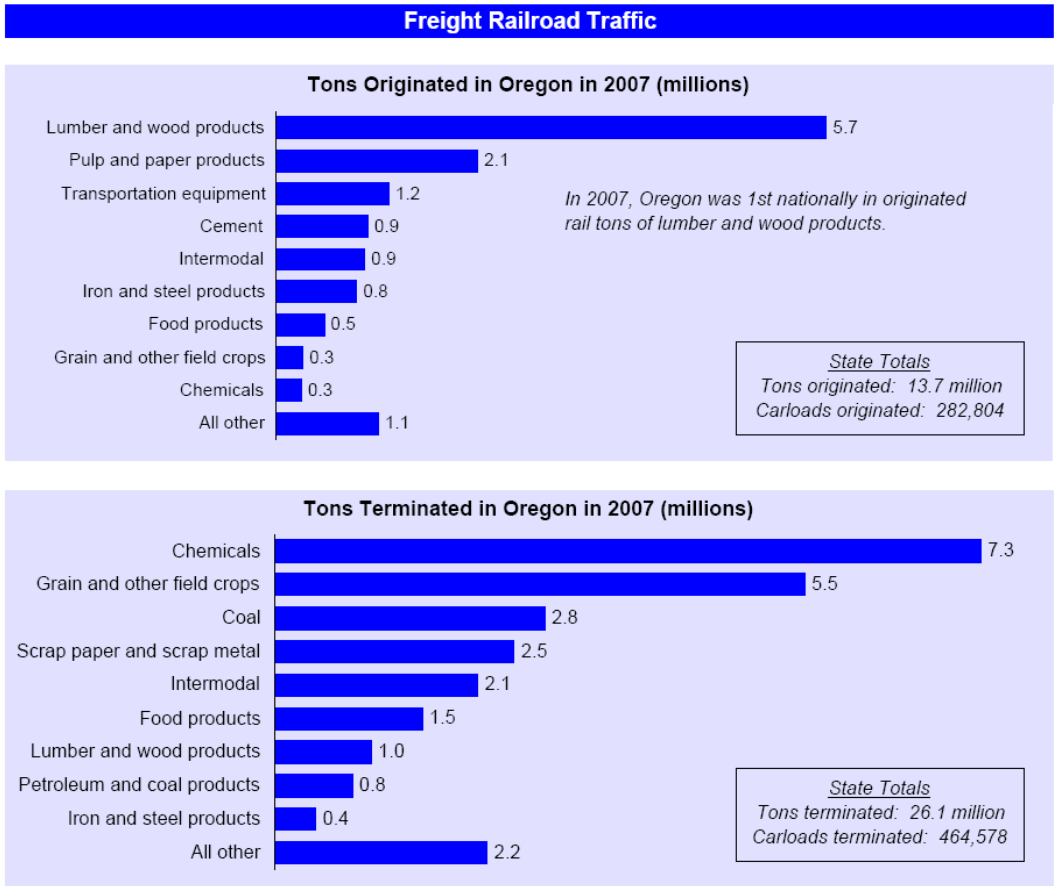
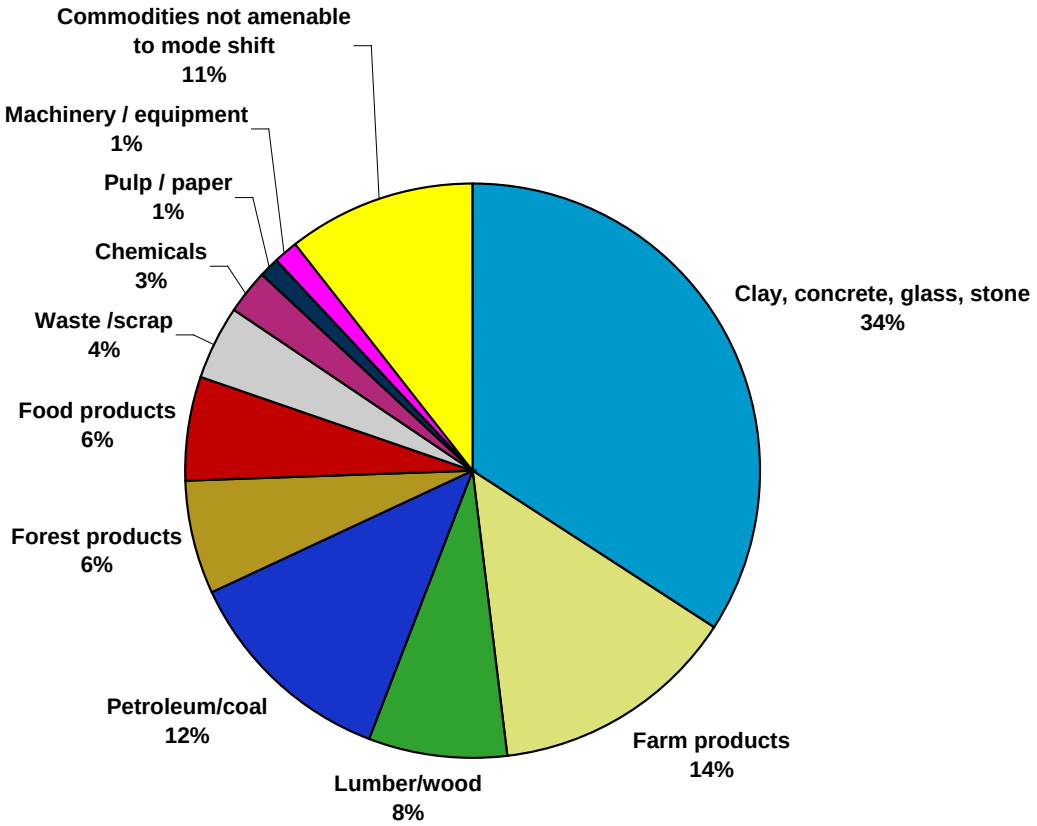
[99] Association of American Railroads, 2009, *Railroads and States – 2007: U.S. Freight Railroad Service on a State-by-State Basis*, March 2009.

Figure 6.3 Freight Railroad Tonnage Originated and Terminated in Oregon *2007*



Source: Association of American Railroads, 2009.

Figure 6.4 Oregon Truck Commodity Flows Most Relevant to Mode Shift *2002*



Source: Draft Oregon Commodity Flow Forecast, August 21, 2009.

The following are a few instances where shifting internal truck movements to rail and water modes could still be beneficial in terms of reduced GHG emissions; primarily where the drayage movements at either end are limited:

- **Shipments arriving via water to the Port of Portland.** Because the Port has on-dock rail and easy access to inland barges, drayage emissions for transfers from ocean-going ships to rail or barge at Portland would be minimal, preserving the GHG benefits of rail and barge movements even with Oregon. However, there may still be a relatively high financial cost to the transfer that could discourage shippers. In addition, not all commodities are amenable to on-dock rail. There may also be possibilities for shifting some truck tonnage to water at the ports of Astoria and Coos Bay (especially for forest products), although these ports are considerably smaller than the Port of Portland.
- **Shipments moving between locations directly on the rail or waterway network.** Where drayage moves are very short at both ends, it may be beneficial both from a GHG emissions point of view and economically to shift to rail or water. In some cases, an enabling factor, such as construction of a new intermodal facility (i.e., a new access point to the network) or a market incentive/subsidy may be what is needed to make a given move viable.

Short-Sea Shipping Routes Relevant to Oregon

In some cases, trucked commodities may be moved by short-sea shipping. Oregon's geography presents it with both opportunities and challenges for short-sea shipping. It has a major port accessible to ocean-going vessels and access to the inland waterway system of the Columbia and Snake Rivers. On the other hand, the location of ports in the Pacific Northwest means that sea routes to Portland are significantly longer than land routes; reducing the cost advantage of water and further increasing shipment time. In addition, ocean-going vessels cannot transit the Columbia River locks; necessitating cargo transfers at Portland from inland to ocean-going vessels. (The Port of Portland does in fact already offer container barging to accomplish this.) Nonetheless, several studies have assessed some potential opportunities for short-sea shipping in the region:

- **Container feeder service to Puget Sound.** Of the roughly 500,000 container 20-foot equivalent units (TEU) that arrive or depart the Columbia/Snake region by sea, 50 to 60 percent do so via Portland's Terminal 6, but the remainder are sent by truck or rail to the Puget Sound Ports of Seattle and Tacoma. Short-sea service has been suggested as a way to take some of those containers off the highways. A major obstacle to such service, however, is the relatively short surface distance between Portland and Puget Sound – around 140 to 170 miles – compared to the more than 300 miles by water. Moreover, containers traveling down the Columbia by barge would need to be transshipped to an ocean-going barge to make the trip; adding significantly to the costs of such a move. Ocean-going barges capable of transiting the Columbia River locks (e.g., narrower than 85 feet) could eliminate this problem, but do not currently exist.[100]
- **Coastwise service to California.** Coastwise service to southern California could preserve some of the cost advantages of water transport, due to the length of the haul. It could be most appropriate for movement of bulk agricultural and forest products from the Columbia River or southern Oregon. However, a suitable backhaul would also need to be found.
- **Solid waste shipments.** Portland area waste is trucked to the Columbia Ridge Landfill 140 miles east of Portland on the Columbia River; more than 500,000 tons are trucked out annually. Construction of a barge dock at the landfill (which already has rail access) could permit the waste to be sent by barge instead. It could also open up the possibility of taking waste by water

[100] Center for Economic Development Education and Research (CEDER), 2005, *Columbia Snake River System and Oregon Coastal Cargo Ports Marine Transportation System Study*, prepared by Pacific Northwest Waterways Association, June 2005.

from other areas, such as Seattle and California.[101] The current truck hauling contract for Portland – which was won as the low bid in a competition with rail and marine bids – expires in 2010.[102]

- **Coastwise service to Vancouver**. Waterborne shipments from Vancouver can bypass border delays faced by trucks crossing the U.S.-Canadian border. However, a study of this option found that this service would not be viable without subsidies, even if 10 percent of the truck movements between Vancouver and Portland shifted to water, because there would not be enough commodities moving between the two cities to economically justify daily service.[103]

Policies to Enable Mode Shift

The public sector can play a role in encouraging the shifting of freight to less energy-intensive modes of transport. Possible strategies include investing in the rail and marine transportation systems, pricing, and incentives. These strategies are covered in detail elsewhere in the Freight and Climate Change study, and are summarized briefly below.

Rail System Investment

Strategic investments to relieve rail bottlenecks in Oregon could encourage additional freight movement by rail. According to the Association of American Railroads (AAR),[104] two major rail segments in Oregon already are operating near or at capacity. The north-south Union Pacific (UP) line from Klamath Falls to Chemult operates near capacity (with volume-to-capacity ratios ranging from 0.7 to 0.8), while the east-west UP and Burlington Northern Santa Fe (BNSF) lines through the Columbia River Gorge from Portland to The Dalles operate at capacity (volume-to-capacity ratios ranging from 0.8 to 1.0). If rail's mode share remains constant over the next 30 years and capacity is not expanded by 2035, both of these segments would be operating above capacity, resulting in unstable

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[101] Center for Economic Development Education and Research (CEDER), 2005, *Columbia Snake River System and Oregon Coastal Cargo Ports Marine Transportation System Study*, prepared by Pacific Northwest Waterways Association, June 2005.

[102] Harder, Paul B., 1994, *Night And Day, Large-Scale System Keeps On Truckin' Trash*, Waste Age, September 1994.

[103] Cambridge Systematics, Inc., 2007, *Cross Border Short-Sea Shipping Study: Phase II*, prepared for the International Mobility and Trade Corridor (IMTC) Project, January 2007.

[104] Association of American Railroads, 2007, National Rail Freight Infrastructure Capacity and Investment Study, prepared by Cambridge Systematics, Inc., September 2007.

flows and service breakdowns. In addition, by then, the UP line continuing east through Pendleton, La Grande, and Idaho would also be operating at capacity.

This suggests that capacity may already be limiting rail's share of Oregon's freight flows. Therefore, if Oregon's goal is not just to maintain rail mode share but to increase it, significant investment in the rail network will be needed. Possible investments include the following:

- Upgrades to mainline tracks and implementation of more advanced signal control systems to increase throughput;
- Improvements to significant bridges, tunnels, and other chokepoints;
- Upgrades to secondary mainlines, branch lines, short lines, and regional railroad tracks and bridges to accommodate the heavier 286,000-pound railcars;
- Expansion of carload terminals and intermodal yards to increase freight-handling capacity and increase network access points; and
- Expansion of support facilities, such as fueling stations and maintenance facilities.

In addition, some of the short-sea shipping opportunities identified above could free up some rail capacity that may be better suited to capturing goods currently transported by truck.

There could be a role for the State of Oregon in to support identification of financing for some of these investments. Many states have rail/economic development programs to pay for rehabilitation of rail sidings and upgrade of short-line tracks and bridges to maintain rail connections between major businesses and Class I railroads; Oregon's *Connect*Oregon, program, for example, has provided funds to help upgrade shortline railroads.

Marine System Investment

Investing in marine waterways, intermodal terminals, and their operations could help eliminate chokepoints, reduce delays, and improve the speed and reliability of the marine freight transport, or expand the reach of the network. For instance, ro-ro[105] terminals for short-sea shipping could be constructed to facilitate inception of these services. Additional intermodal terminals or transload facilities (for bulk materials) could be established to serve markets where demand has not been sufficient to support private-sector investment.

The cost structure of short-sea shipping suffers from Federal requirements to buy U.S. built vessels for domestic shipping – which can double or triple the cost of

[105] Roll-on/roll-off (RORO or ro-ro) ships are vessels designed to carry wheeled cargo, such as automobiles, trucks, semi-trailer trucks, trailers, or railroad cars, which are driven on and off the ship on their own wheels. This is in contrast to lo-lo (lift-on/lift-off) vessels, which use a crane to load and unload cargo.

acquiring vessels, as compared to foreign-built vessels.[106] Financial assistance could be provided in acquiring equipment to incentivize starting short-sea services. In the long run, options for enabling the larger vessels useful for short-sea shipping to transit the Columbia River locks could also be explored.

Oregon may be able to seek Federal funds for marine improvements in the future. Maritime Administration's (MARAD) Marine Highway Program was established in 2007 to designate marine highway corridors, make these corridors eligible for support for improvements, and provide assistance in coordinating with and obtaining funding from existing sources. The Congestion Mitigation and Air Quality (CMAQ) program represents another potential source of funds; New York used CMAQ dollars to subsidize a river barging service from the Port of New York and New Jersey to Albany for several years.

Incentives and Pricing

Incentives can be developed to encourage shippers and carriers to switch freight to rail and water:

- **Shipper Incentives.** Providing subsidies or incentives (such as new-user discounts) for shippers to use rail or water in markets that are marginally competitive with trucking. This particular strategy is little used in today's economically deregulated freight markets, although the Port Authority of New York and New Jersey recently announced that it will reduce fees from $52 to $27 per container shipped by ExpressRail to any ocean carrier that increases the number of containers it transports over its 2008 levels (Journal of Commerce On-Line, 2009).
- **Diesel Fuel Pricing.** Increasing the price differential between truck and rail service by increasing the cost of on-road diesel fuel. For long-haul truckload carriers, the cost of fuel approaches (and sometimes exceeds) the cost of driver labor. When fuel costs rise, truckload carriers, shippers, and third-party logistics providers (who act as agents for shippers) may move longer-haul shipments from truck to rail. In Oregon, this could be enacted through differences in state taxing structures.
- **Air Cargo Pricing.** Domestic air cargo shipments are quite sensitive to fuel prices, which account for a relatively high share of air travel costs. Public-sector initiatives could shift cargo from air to truck if they affected fuel costs such as by reducing the tax on diesel relative to jet fuel.

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[106] U.S. Department of Transportation, 2006, *Four Corridor Case Studies of Short-Sea Shipping Services: Short-Sea Shipping Business Case Analysis*, prepared by Global Insight for U.S. DOT Office of the Secretary, August 15, 2006.

Other

One option to make rail modes more desirable and convenient is to facilitate development of logistics parks. Logistics parks, sometimes dubbed "freight villages," cluster distribution and assembly facilities around a rail terminal to minimize the amount of time and truck travel needed to collate goods arriving from global and national suppliers, and by train and dispatching loads tailored to the needs a specific store by truck. There are a number of examples of logistics parks in Europe, and CSX is pursuing this strategy in the southeastern U.S.

Other actions that have been proposed, but received little study, include local zoning policies or "land banks" to preserve land around rail sidings for the exclusive use of rail-using businesses; and working with Class I railroads to provide trackage rights for short-line railroad operators to expand the reach of their service and reduce the number of separate movements involved in a particular shipment.

Summary

Approximately 20 percent of Oregon's truck tonnage both originate/terminate outside the State, and also are a commodity amenable to mode shifting; in part this reflects Oregon's geographic position as a bridge state with a high volume of through traffic, limiting the freight mode shift achievable by Oregon-only initiatives. From a practical point of view, this represents an upper bound to the share of truck tonnage in Oregon that could be shifted to other modes without major changes to the freight network and its cost structure. Shippers choose the modes that seem the most cost-effective for their needs; they need to be provided with incentives or perceived benefits to change their practices. Aspirational studies of major national or regional investments in rail and marine infrastructure have estimated mode diversion ranging from 10 to 60 percent.[107]

Enabling mode shift would require more investment in the rail network, marine waterways, and their services to be successful. Such infrastructure and operations investment can involve significant sums of money, but would reap gains not just in GHG reductions, but also in improved freight service and decreased highway congestion.

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[107] U.S. Department of Transportation, 2010, *Transportation's Role in Reducing U.S. Greenhouse Gas Emissions: Report to Congress*, Washington, D.C., April 2010.

7.0 Climate Change Impacts on Freight

In spite of efforts to avoid the effects of climate change, some climate change impacts are occurring now and will increase in intensity in the future. Even if all anthropogenic GHG emissions were to completely cease today, the climate would continue to warm for many years from the gases already in the atmosphere.

Government agencies need to plan for how they will adapt to these impacts – a process referred to as adaptation planning. In the area of transportation, adaptation planning involves developing plans to enhance the resilience and flexibility of the transportation system, so it is better able to withstand the effects of climate change.

Several studies have found that it is more cost-effective to address climate change impacts in advance rather than taking a reactive stance. For instance, Kirshen, et al. (2004) studied the economic effects of increased flooding in the Boston area due to future climate changes, and found that aggressive adaptation strategies proved less costly in the long run than doing nothing.[108] Similarly, Kinsella and McGuire (2005) estimated the costs of retrofitting or redesigning New Zealand's bridges to accommodate increased precipitation (and higher stream flows).[109] They found that, although designing for climate change increased initial costs by about 10 percent, over the life of the structure the incremental cost was small (less than 1 percent) due to the decreased probability of climate-related damage.

Oregon has taken initial steps towards exploring adaptation issues in *A Framework for Addressing Rapid Climate Change* (2008).[110] The Oregon Climate Change Research Institute (OCCRI), administered by Oregon State University (OSU) and the Oregon University System (OUS), is charged by the state with assessing the likely effects of climate change on Oregon every two years and is currently conducting an updated statewide assessment of climate change risks.

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[108] Kirshen, P.H., M. Ruth, W. Anderson, and T.R. Lakshmanan, 2004, *Infrastructure Systems, Services, and Climate Change: Integrated Impacts and Response Strategies for the Boston Metropolitan Area (CLIMB Final Report)*, U.S. Environmental Protection Agency, Washington, D.C., August 13.

[109] Kinsella, Y., and F. McGuire, 2005, *Climate Change Uncertainty and the State Highway Network: A Moving Target*, Transit New Zealand, Auckland, New Zealand.

[110] Governor's Climate Change Integration Group, 2008, *A Framework for Addressing Rapid Climate Change: Final Report to the Governor*, State of Oregon, January 2008.

In addition, in partnership with the OCCRI, the University of Oregon Climate Leadership Initiative is leading Climate Preparedness Planning Projects in regions throughout the state, including examinations of impacts to built infrastructure such as transportation.[111]

The subsections below discuss climate projections relevant for the Oregon freight network, resulting impacts, and some implications for future environmental, planning, and management decision-making.

Climate Impacts in Oregon

Climate change will have a number of impacts on the Pacific Northwest, as described in the U.S. Global Change Research Program's *Global Climate Change Impacts in the United States*, the first major synthesis of U.S. climate impacts released since 2000.[112] According to this report, temperature is projected to increase 3 to 10° Fahrenheit by the year 2100 in the Northwest. Increases in winter precipitation and decreases in summer precipitation are likely; and changes in snowpack, streamflows, sea level, and ecosystems will be significant to the region. For Oregon's freight network, a number of climate impacts described in the report are of particular concern:

- **Changes in streamflow.** The Northwest will experience major changes in streamflow patterns due primarily to changes in the timing of spring snowmelt in the mountains, and an increase in winter precipitation falling as rain instead of snow. Over the past 50 years, the peak of spring runoff has shifted earlier, as increasing temperatures cause earlier snowmelt. This trend is projected to continue in the future, with runoff shifting 20 to 40 days earlier by the end of this century. Even as early as the 2040s, scientists expect the April 1 snowpack in the Cascades to have declined by as much as 40 percent compared to today.[113] In addition to earlier streamflow peaks, this will result in considerably lower summertime flows. A 30 percent reduction in warm season (April through September) runoff on the western slopes of the Cascades is projected by 2050.
- **Precipitation**. Between 1958 and 2007, there has been a 12 percent increase in days with very heavy precipitation in the Northwest; this trend is expected to continue.[114] In addition, increased winter rainfall (instead of snowfall) is expected to lead to more winter flooding on the west side of the Cascades;

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[111] http://climlead.uoregon.edu/node/9.

[112] U.S. Global Change Research Program (USGCRP) (2009), *Global Climate Change Impacts in the United States*, T.R. Karl, J.M. Melillo, and T.C. Peterson, (editors), Cambridge University Press, New York.

[113] Ibid.

[114] Ibid.

both from the rain itself and the rain-on-snow melting effect that can significantly increase runoff from a single storm. The increase in winter rainfall may also result in increased landslides along coastal bluffs due to an increase in saturated soils.

- **Sea level rise and coastal erosion.** Global sea levels are projected to rise as little as 8 inches and as much as 4 feet by the end of this century, with evidence suggesting that 6.5 feet represent an upper bound that is very unlikely to be exceeded. In some coastal areas, particularly those with sedimentary soils, this can be compounded by local subsidence. In addition, the Northwest may experience more southwesterly winter wind patterns in the future. Combined with higher sea levels, this could accelerate coastal erosion along the Pacific Coast.
- **Impacts to agriculture and forestry.** Climate change also will impact demand for freight services by affecting agriculture and forestry production in Oregon. In the short run, high-elevation forests on the west side of the Cascades are expected to grow faster due to milder conditions, but in the long run all forests are projected to see decreased growth due to summertime soil moisture deficits. Trees also will suffer from pests, such as the mountain pine beetle that in the past were killed off by cold winters; for instance in British Columbia, the mountain pine beetle outbreak has destroyed 40 percent of marketable pine trees in the province.[115] In the long run, forest succession will lead to species more appropriate for the warmer climate. Agricultural production in general also is likely to be negatively impacted by decreasing irrigation supplies during the summer growing season, as well as increasing pests and weeds.
- **Extreme temperatures.** Average temperatures rose 1.5°Fahrenheit for the region as a whole over the past century, with some areas experiencing up to 4 degree increases. Projections show that by the end of this century, average temperatures will rise 3 to 10°Fahrenheit.[116] More significantly for transportation infrastructure and operations, high temperature extremes – very hot days – are expected to occur with greater frequency. Very hot days that now occur once every 20 years are projected to occur every 2 years in much of the country by the end of this century. In addition, these very hot days are projected to be about 10°Fahrenheit hotter than they are today.

The effect of these changes on the Oregon freight network is discussed below.

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[115] Ibid.

[116] Ibid.

Streamflow Changes

These changes have potentially major implications for Oregon's freight network, especially impacts to waterborne commerce and flooding on road and rail networks. Water levels in navigable rivers, and thus the ability to move freight, would be affected by the changes in streamflow. Barge travel can be restricted during periods of both excessively high or low water flows, and lower water levels can also limit the tonnage carried on a given barge.[117] Although the timeframe and magnitude of impacts to the Columbia River systems is uncertain, significant shifts in streamflow could be taking place by the 2040s.

The Columbia River system above Portland is one of the nation's major inland waterway systems and an important conduit for agricultural products from the Northwest, especially grain. Barges transit the system from Portland as far inland as Lewison, Idaho. Four major multipurpose dams in Oregon (and more upstream on the upper Columbia and the Snake River) along this route control water flow. Climate change will result in much greater volatility in streamflows on the system, with higher flows in wintertime and lower flows in summertime. Given the competing demands for water resources on the dam system – power generation, irrigation, and flood control, as well as navigation – it may be more difficult to maintain navigable depths at all times. For instance, flood control needs could make it difficult to store up adequate supplies from the higher wintertime flows to make it through the lengthening dry season (by letting water over the spillway rather than storing it). There can also be impacts on barge travel from excessively high streamflows, which can render some inland waterways temporarily unnavigable. Although throughout much of the system there is more than adequate depth available, the U.S. Army Corps of Engineers (USACE) shows it having a controlling depth of 14 or 15 feet (typical barges may have drafts in the order of 10 feet); bottlenecks may develop that will require dredging or other channel maintenance.[118]

The volatility in streamflows and water levels also may present problems for port infrastructure along the inland waterways. Wharfs may not have been built to handle the range of water levels that could be experienced in the future, or may not be located in adequate depth during times of very low streamflow. Dredging operations and changes in water control facilities and marine terminals at upriver ports could be needed to maintain access. If river transport is curtailed, shippers may choose to increase use of truck and rail, with resulting

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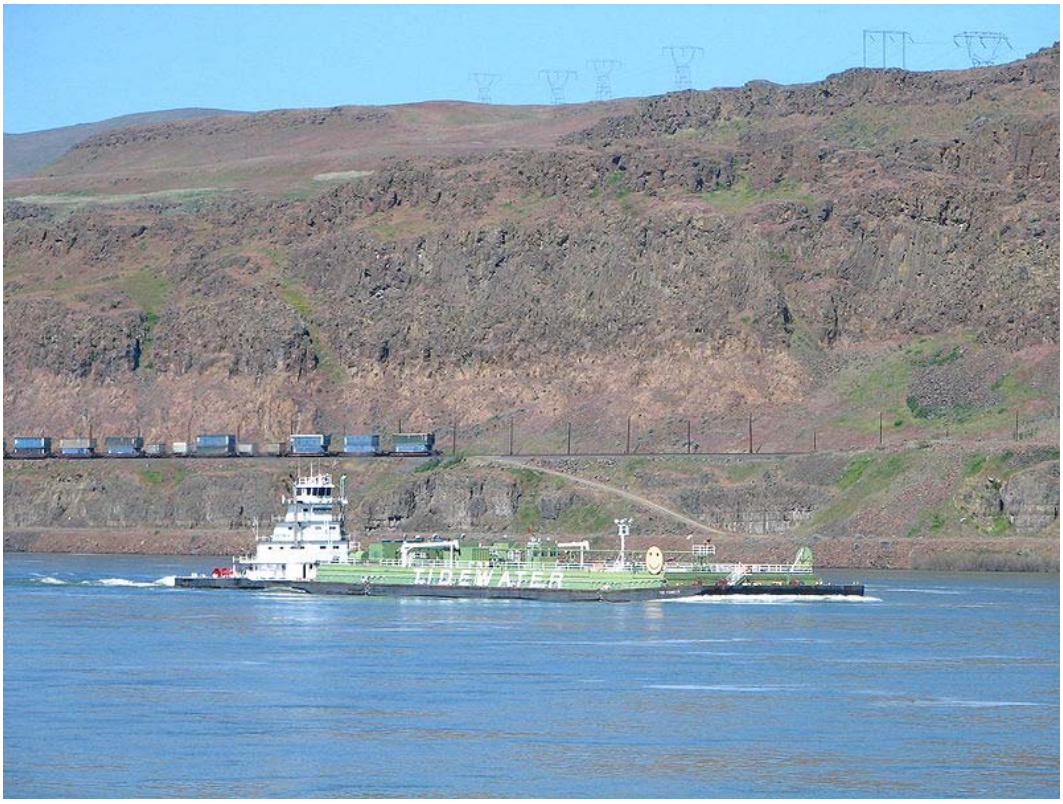
[117] Olsen, J. R., L. J. Zepp, and C. Dager, 2005, *Climate Impacts on Inland Navigation*, Conference Proceeding: Environmental and Water Resources Institute of ASCE: Impacts of Global Climate Change.

[118] U.S. Army Corps of Engineers, 2006, *Waterborne Commerce of the United States: Calendar Year 2006: Part 4 – Waterways and Harbors, Pacific Coast, Alaska and Hawaii*, Institute for Water Resources, Alexandria, Virginia.

implications for traffic on these networks both inside and outside of Oregon. Further climate and engineering studies are needed to quantify potential future changes to the depth and navigability of the Columbia River system.

Figure 7.1 Columbia River Barge



Volatile water levels and increasing competition for water due to climate change may make it more difficult to maintain navigable depths at all times. Image source: Flickr/Dave O. http://www.flickr.com/people/56205607@N00 Dave O.

Heavy Precipitation and Flooding

While changes in annual average precipitation may have some effects, an increase in the intensity of individual rainfall events may have even more significant implications for the transportation system. An increase in the intensity or frequency of heavy downpours may require redesign of stormwater management facilities for highway, bridges and culverts, ports, aviation, and rail. Severe weather events are correlated with higher incidences of crashes and delays, affecting both safety and mobility. Aviation services can be disrupted by intense rainfall events, as well as an increase in the probability of severe convective weather such as thunderstorms.

An increase in the frequency of extreme precipitation events will result in more frequent short-term flooding and bridge scour, as well as more culvert washouts; and could exceed the capacity of stormwater management infrastructure in some cases – depending on the maximum flow rates the systems were designed for. It

could also result in more scour to bridge piers in rivers and streams, and contribute to more frequent slides, requiring increased maintenance. Practices such as pavement grooving, may need to be adopted to increase traction and safety. Stormwater management systems may need to be redesigned for increased capacity; and technologies such as porous pavements could be considered.[119]

For railways, more intense rainfall events could result in increased erosion of the track subgrade, which washes away ballast and weakens the foundation, making the track unstable for passage of heavy locomotives and railcars. Increased inspection and maintenance would be needed to address this risk.

Increased extreme precipitation events also would affect commercial service aircraft operations. Navigation in heavy precipitation is possible and currently occurs on a daily basis in the national air system. However, intense precipitation almost always creates delays, particularly at congested airports.

Flooding from rivers and streams overtopping their banks has major impacts on affected transportation networks, making roads and railways impassable. Even facilities that are high enough to stay above water can be rendered useless if their access points are underwater. In addition, data from the Louisiana Department of Transportation and Development (DOTD) suggests that prolonged inundation (as could happen during severe river flooding) can lead to long-term weakening of roadways. A study of pavements submerged longer than three days during Hurricane Katrina (some were submerged several weeks) found that asphalt concrete pavements and subgrades suffered a strength loss equivalent to two inches of pavement. Portland concrete cement pavements suffered little damage, while composite pavements showed weakening primarily in the subgrade (equivalent to one inch of asphalt concrete) (Gaspard, et al., 2007).[120] Once waters recede, cleanup of debris and silt left behind is a time-consuming and expensive proposition.

These impacts will be felt most strongly on road and rail lines west of the Cascades. Bridges may need to be redesigned to allow debris through. For instance, in another example from King County, Washington, the County will be replacing 57 "short-span" bridges with wider spans that allow debris to pass more easily, preventing backups and jams that can cause river flooding. Water-

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[119] For instance, King County, Washington, has begun incorporating porous concrete and rain gardens into road projects to manage stormwater runoff from heavy rains. Source: U.S. Global Change Research Program (USGCRP) (2009), *Global Climate Change Impacts in the United States*, T.R. Karl, J.M. Melillo, and T.C. Peterson (Editors), Cambridge University Press, New York.

[120] Gaspard, K., M. Martinez, Z. Zhang, and Z. Wu, 2007, *Impact of Hurricane Katrina on Roadways in the New Orleans Area*, Technical Assistance Report No. 07-2TA, LTRC Pavement Research Group, Louisiana Department of Transportation and Development, Louisiana Transportation Research Center, March.

level transportation through the Columbia River Gorge, particularly the UP rail lines, could potentially be vulnerable to fluctuations in the river level, if winter-time flood control becomes more difficult in the future.

Sea Level Rise and Coastal Erosion

Fortunately for Oregon, much of its major freight infrastructure – and development in general – is not located on the ocean coastline (as compared to the Gulf Coast, where major interstates and rail lines are within the hurricane storm surge zone). For instance, I-5 and the north-south rail lines move through the Willamette Valley. Moreover, much of Oregon's coast is rocky, rather than flat plains vulnerable to rising sea levels. However, sea level rise and coastal erosion could have an impact on the smaller ports located on the Pacific Coast, and on freight moving in and out of low-lying developed areas. Moreover, sea level rise compounds vulnerability to surge from coastal storms, which will now be overlayed onto relatively higher water levels.

A greater impact will be felt on the tidal portion of the Columbia and Willamette Rivers, which are at sea level. Port facilities, which by definition are at water's edge, are particularly vulnerable to the effects of sea level rise. Although wharfs are unlikely to be affected, landside facilities may not be adequately protected from the rising waters. On the other hand, sea level rise could improve channel depths for ocean-going vessels in the Columbia River channel to Portland and in other harbors. This could reduce the future need for projects such as the Columbia River Channel Deepening, which is increasing the depth of the channel from 40 to 43 feet to accommodate larger ocean-going cargo vessels.[121] However, the effect of sea level rise in river channels and harbors will, in part, depend on how local patterns of currents, siltation, and scouring are affected by sea level rise; hydrodynamic studies would need to be done at each location to predict whether the net result will be channel deepening. Low-lying roads and rail lines could also be affected; but as a practical matter there may not be that much freight infrastructure in such low-lying areas in Oregon.

There are a variety of adaptation measures to address sea level rise. Roads, rail lines, and airports can be protected with seawalls, dikes, and levees (and in fact levees already exist along portions of the Columbia and Willamette). Facilities also can be raised when necessary (either as a retrofit or more likely when replacement facilities are built at the end of its design life), or even relocated to higher ground. For new facilities, expected sea level rise over the design life of the structure may need to be taken into account when building next to or over the water – roadways may need to be built higher to avoid future flooding, and bridges over navigable waterways may also need extra elevation to ensure adequate clearance for marine vessels in the future.

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[121] http://www.channeldeepening.com/channel_projoverview.asp.

Demand Impacts

Negative impacts to productivity in the agricultural and forestry sectors could have very significant impacts to waterborne and rail freight in Oregon. These commodities comprise large shares of the cargo carried on these modes, particularly for waterborne cargo.

The Columbia River is the third largest grain exporting center in the world, and the Port of Portland exports the largest volume of wheat in the United States. Changes in grain productivity or product mix due to climate change could have major impacts on the tonnage sent to Portland for export.

Waterborne traffic on the Columbia River system will be particularly vulnerable to potential declines in Northwest agricultural production. Grain – primarily wheat – accounts for more than one-half the tonnage carried on the Columbia River segments in Oregon.[122] Because these products comprise such a large share of inland waterway traffic, declines in production could be detrimental to the viability of barge traffic on the Columbia River system.

Forest products are also important to some waterways. Forest products (mostly wood chips) account for virtually all of the tonnage that departs Coos Bay, for instance. A decline in forestry in the region could negatively impact the viability of port operations there. (Forestry products are not, however, a major commodity on the Columbia, adding up to less than 5 percent of tonnage.)[123]

Rail traffic could face similar disruptions to demand, although the effects will not be as dramatic. Grain accounts for more than one-fifth of rail tonnage terminating in Oregon (as noted above, much of this is being sent to Portland for export). Even more significant could be changes to the forestry sector – lumber, wood, pulp, and paper products account for almost 60 percent of the rail tonnage originating in Oregon.[124] In addition, GHG controls will make coal considerably less attractive as a source for electric power generation; as discussed above national estimates project a 17 percent reduction in rail ton-miles due to a shift away from bulk fossil fuel shipments. By contrast, Oregon's waterways carry very little coal. However, petroleum products account for around one-quarter of barge tonnage on the Columbia River – primarily going upriver – and this traffic could also be affected by GHG regulations, although not as severely as coal

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[122] U.S. Army Corps of Engineers, 2006, *Waterborne Commerce of the United States: Calendar Year 2006: Part 4 – Waterways and Harbors, Pacific Coast, Alaska and Hawaii*, Institute for Water Resources, Alexandria, Virginia.

[123] U.S. Army Corps of Engineers, 2006, *Waterborne Commerce of the United States: Calendar Year 2006: Part 4–Waterways and Harbors, Pacific Coast, Alaska and Hawaii*, Institute for Water Resources, U.S. Army Corps of Engineers, Alexandria, Virginia.

[124] Association of American Railroads, March 2009, *Railroads and States – 2007*, Policy and Economics Department, Washington, D.C.

shipments. All of these changes could greatly reduce rail traffic in Oregon. However, this could be partly offset by mode shift from inland waterways, if the Columbia River system becomes less reliable as a shipping route due to changes in streamflow, as discussed above.

It also is possible that production of commodities amenable to rail or water shipping could increase as a result of climate change, or as a result of climate change policies. It is difficult to predict what those might be, but one possibility could include biomass products for biofuels or renewable power generation. For instance, ethanol is difficult to transport by pipeline due to its corrosive effects, and might instead move by rail or barge in Oregon.

Effects of Temperature increases

While changes in average temperatures have some implications for Oregon's freight sector, the more significant consideration is the potential change in temperature extremes. As the number of very hot days rises, stress will increase on infrastructure and on the people who provide freight transportation services. Impacts might include the following:

- **Need for design changes.** Steel and concrete bridges and pavements are generally designed for maximum temperatures appropriate for the region. Although the increase in record temperatures due to climate change may not exceed the design temperature, it would be prudent for future designers of highway facilities to ensure that joints in steel and concrete bridge superstructures and concrete road surfaces can adequately accommodate thermal expansion resulting from these temperatures. As temperatures increase, there may well be more failures of aging infrastructure, even if the maximum design temperature is only approached and not exceeded. Design standards may need to be changed so that new facilities are designed for higher maximum temperatures.
- **Construction impacts.** The projected increases in average temperature and number of hot days, coupled with possible increases in humidity, create added safety concerns for construction and maintenance workers in the field, and increase the number of work stoppages due to extreme heat events. (Evening hours and larger work crews to allow for more frequent recovery breaks are both solutions, but will increase labor costs.) Offsetting this would be a lengthening of the construction season as spring comes earlier and fall ends later.
- **Pavements.** Higher temperatures cause some pavement materials (particularly asphalt binders) to degrade faster, leading to rutting, cracking, potholing, and bleeding. This will require earlier replacement or rehabilitation of pavements. In the long run, pavement engineers will need to make changes in the pavement mixes typically used in Oregon to reduce future temperature-induced maintenance costs. For example, the Louisiana DOTD has begun to use asphalts with a higher polymer content, which helps

pavement better handle higher temperatures, although at a higher initial cost than standard asphalt.[125]

- **Rail buckling.** The increase in temperature extremes could increase the incidence of track buckling or "sun kinks." This occurs when compressive forces in the rail, due to restrained expansion during hot weather, exceed the lateral stiffness of the track, causing the track to become displaced laterally, up to 30 inches or more. Track buckling is most prevalent on an isolated hot day in the springtime or early summer, rather than mid to late summer when temperatures are more uniformly hot. To prevent derailments due to undetected sun kinks, in hot weather (more than 95°Fahrenheit), railroads typically issue blanket slow orders (generally to reduce all train speeds by 10 miles per hour). This has several negative consequences, such as longer transit times, higher operating costs, shipment delays, reduced track capacity, and increased equipment cycle time leading to larger fleet sizes and costs.[126]

  Several options exist to prevent buckling, including the use of concrete rather than wooden crossties, and prestressing the rail during installation to a target neutral temperature, generally 75 percent of the expected maximum temperature. (This is done by stretching or heating the rail to put it under tension when installed.) Engineers may need to consider raising that neutral temperature for new track to accommodate future temperatures.

- **Cooling and Refrigeration Needs.** Increases in temperatures also are likely to increase energy consumption for cooling. This applies particularly to refrigerated freight traveling in containers, railcars, and trucks (as well as refrigerated warehouses at intermodal facilities). This will increase costs and emissions from the sector.

- **Decreased winter maintenance.** A decrease in winter snowstorms and winter weather could reduce winter maintenance costs in Oregon's mountainous areas, reduce the environmental damage caused by use of anti-icing liquids and sand on roadways and de-icing chemicals at airports, and decrease accident rates.[127] For instance, an early study of the effects of climate change on

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[125] CCSP, 2008a: U.S. Climate Change Science Program, *Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I*, prepared by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research, 2008.

[126] CCSP, 2008a, U.S. Climate Change Science Program, *Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I*, prepared by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research, 2008.

[127] Warren, F., E. Barrow, R. Schwartz, J. Andrey, B. Mills, and D. Riedel, 2004, *Climate Change Impacts and Adaptation: A Canadian Perspective*, [Lemmen, D. S., and

Footnote continued

Cleveland estimated that increases in winter temperatures and decreases in snowfall would reduce Cleveland's snow and ice control budget by 95 percent.[128]

Figure 7.2 Asphalt Rutting

High temperatures can lead to faster asphalt rutting and cracking. Image source: FHWA.

Summary and Implications

For the Oregon freight system, the most important impact of climate change will not be temperature itself, but will be its impacts on the State's water resources – changes to streamflow, flooding, and sea level rise. Most of the impacts described above have engineering solutions of some kind – dikes, reconstructed bridges, etc. On the other hand, demand shifts, combined with streamflow variability, could impact the economic importance and viability of Columbia River system.

The likely impacts of climate change can be addressed through improved planning. The planning process should incorporate an understanding of expected future changes – for instance, future infrastructure might not be

F. J. Warren, Editors], Climate Change Impacts and Adaptation Directorate Natural Resources Canada, Ottawa, Ontario, 2004.

[128] Hyman, W., T. R. Miller, and J. C. Walker, 1989, *Impacts of the Greenhouse Effect on Urban Transportation*, Transportation Research Record 1240, Transportation Research Board, National Research Council, Washington, D.C., pages 45-50.

planned for locations (such as floodplains) that may become more vulnerable in the future. When designing new infrastructure, there will be a need to switch from designing with standards developed for historic climate trends to designing for future (and uncertain) climate projections – transportation infrastructure is sufficiently long-lived that it will not be prudent to base plans on historic averages. Operations are more easily adapted to a changing climate, but there should be an effort to monitor how conditions are changing, so as to plan for future operations in an effective manner, rather than relying on past information.

Some states, including Oregon, have begun grappling with the issue of adaptation to climate change. A survey of state DOTs, conducted for the FHWA in 2008, found that the amount of activity on adaptation varies: 13 state DOTs had some kind of action or activity underway regarding adaptation, 15 had discussions on the issue taking place, and another 24 had no action or activity related to adaptation at all.[129] For instance, California has begun requiring state agencies – including California DOT (Caltrans) – to plan for sea level rise, shifting precipitation, and extreme weather events; and is developing a statewide information strategy to support infrastructure vulnerability assessment. Alaska, which is already experiencing climate impacts, has set up a state-level Adaptation Advisory Group, which includes a Public Infrastructure Technical Working Group, and the state Department of Transportation and Public Facilities (DOTPF) is actively involved in community relocation and seeking enhanced data collection and collaboration across agencies.[130]

Most state DOTs, as well as the FHWA, regard development of an infrastructure inventory and vulnerability assessment as one of the first steps that will be needed in developing a comprehensive approach to adaptation. Although still in the beginning stages, the State of Oregon has already taken strategic planning steps in that direction, documenting existing knowledge about climate change impacts and summarizing data that can lead to the development of a full vulnerability assessment of transportation infrastructure. That risk and vulnerability assessment will be critical to identifying the highest priorities for protection, which may include elements of Oregon's freight network, and the most critical areas for further study.

Unfortunately, climate changes are uncertain, and there is no way to know exactly what will happen. There will be a need to leave room for this uncertainty in future freight planning to ensure that the freight network will be robust under a wide range of possible future scenarios.

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[129] FHWA, 2008, Summary Report: Peer Workshop on Adaptation to Climate Change Impacts, http://www.fhwa.dot.gov/planning/statewide/pwsacci_c.htm.

[130] Ritter, R., 2009, *Adaptation to the Impacts of Climate Change: Transportation State of the Practice*, presentation at the American Planning Association annual conference, FHWA Office of Planning, April 27.

Appendix A – Structure of Possible Federal GHG Regulations

This appendix provides background information on the structure of possible Federal greenhouse gas regulation. Any Oregon strategies for pursuing GHG reductions in the freight sector will take place in the context of potential Federal action on GHGs. There are several actions the Federal government could take to address GHG emissions from the transportation sector, such as the following:

- **Pricing carbon** through a cap-and-trade system, carbon tax or increased motor fuels tax, which could affect vehicle fuel efficiency, encourage use of low-carbon fuels, and encourage more energy-efficient travel patterns;
- **Enhancing transportation planning and funding** efforts, which could improve the operating efficiency of the multimodal transportation network, and integrate transportation and land use planning to reduce travel distances; and
- **Improving technology and increasing fuel standards**, which would ensure that the fuel efficiency of vehicles manufactured increases, and that alternative low-carbon fuels are available.

More detail on these strategies is provided below.

Price Carbon

There are two primary mechanisms to price carbon emissions; both of which act effectively like a fuel tax for the transportation sector:

- **Cap-and-trade**. Recent developments in Congress suggest a market-based approach to GHG reductions is likely.[131] For instance, the American Clean Energy and Security Act (ACESA, also called the Waxman-Markey Bill), proposed in Congress in 2009, included a cap-and-trade provision. A national cap-and-trade system would set up a market in which GHG emissions allowances up to a certain limit (the cap) could be traded. Allowances can be distributed initially through a government auction, free of charge, or a combination of the two. Since the overall number of GHG credits is capped, this approach should guarantee GHG emissions are reduced

[131] In fact, a cap-and-trade bill was introduced in the Oregon 2009 Legislature, but lacked support to make it out to committee.

by the amount required by regulation. The price of carbon would be set on the market, and would vary depending on actual economy-wide emission reduction costs. To limit adverse economic impacts if the price becomes too high, some proposals, including ACESA, include a "relief valve" in the form of extra allowances to be released if the carbon price exceeds some specified level. For the transportation sector, a cap-and-trade program would be implemented "upstream" on petroleum refineries; increasing the cost per gallon of fuel in the same manner as a tax.

- **Carbon tax.** A national carbon tax would be imposed in proportion to the carbon content, or CO_2e emissions, of the fuel. As compared to a cap-and-trade program, a carbon tax provides more certainty regarding economic impacts, but does not guarantee the level of emission's reduction achieved. A carbon tax does have some implementation advantages, such as greater transparency, reduced administrative burden, and ease of modification.[132] For the transportation sector, a carbon tax would be applied as a fuel tax proportional to the net carbon content of fuel (alternative fuels would therefore have lower taxes).

Either a cap-and-trade system or a carbon tax approach would create a consistent set of prices across all sectors of the economy to encourage actions to reduce GHG emissions. Within the transportation sector, these actions would increase the cost of carbon-fueled transportation, and would therefore create incentives for developing and purchasing more efficient vehicles and alternative fuels, implementing more efficient operating practices, reducing travel, and shifting to more efficient modes. In addition, revenue collected by pricing carbon can be invested in actions that further reduce ca**rbon emission**s – for instance, in infrastructure for more efficient transportation.

Further, the establishment at the Federal level of a cap-and-trade system or carbon tax would create the expectation in the market of long-term, sustained increases in fuel price. The recent, short-term fuel price volatility may have distracted from the likely long-term rise in fuel prices predicted over the next several decades.[133] Achieving a policy environment with greater certainty in long-term price trends may encourage long-run technological innovation and greater investment in more energy-efficient and reduced emissions vehicles and capital equipment in the transportation sector.

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[132] Congressional Research Service, 2009, *Carbon Tax and Greenhouse Gas Control: Options and Considerations for Congress*, February 23, 2009.

[133] For example, the U.S. Energy Information Administration reports that world marketed energy consumption is projected to grow by 44 percent over the 2006 to 2030 period, assuming current laws and policies remain unchanged. Source: EIA International Energy Outlook 2009. http://www.eia.doe.gov/oiaf/ieo/highlights.html.

Impacts of Carbon Pricing on the Transportation Sector

In the transportation sector, the impact of a cap-and-trade system would be felt in the form of increases in fuel prices in the short term; rising over time as the cap tightens. Fuel importers and refiners would be required to hold allowances for each ton of CO_2e contained in the fuel they sell. The U.S. EPA's modeling analysis of the cap-and-trade system, proposed in the ACESA of 2009, estimated allowance prices of $13 per metric ton CO_2e in 2015, $16 in 2020, $27 in 2030, and $70 in 2050 in the core policy scenario.[134] The estimates are based on a system that would cover 85 percent of total U.S. GHG emissions, impose a cap starting in 2012 at 3 percent below 2005 covered emissions, and then gradually reduce emissions to 17 percent below 2005 levels by 2020, and 83 percent below 2005 levels by 2050.

As shown in Table A.1, an allowance price of $15 per ton of carbon equivalent translates into an increase in the price of diesel fuel of $0.15 per gallon, based on its carbon content; a price of $30 per ton is equivalent to a $0.30 per gallon of diesel and $50 is equivalent to $0.51 per gallon.

Table A.1 Cap-and-Trade/Carbon Tax Price Impacts

	Gasoline	Diesel	Jet Fuel
Carbon Content kg CO_2/gallon	8.81	10.15	9.57
Allowance Price or Carbon Tax/ton CO_2	Gasoline $ Per Gallon	Diesel $ Per Gallon	Jet Fuel $ Per Gallon
$10	$0.09	$0.10	$0.10
$15	$0.13	$0.15	$0.14
$20	$0.18	$0.20	$0.19
$30	$0.26	$0.30	$0.29
$40	$0.35	$0.41	$0.38
$50	$0.44	$0.51	$0.48

Source: Carbon content from U.S. EPA, 2007, *Inventory of Greenhouse Gas Emissions and Sinks: 1990 to 2005*, Annex 2.1.

$/gallon = kg CO_2/gallon * 1 metric ton/1,000 kg * allowance price or carbon tax.

These prices are smaller than the increase in diesel fuel prices experienced in the 2004 to 2008 period, which did not result in steep declines in diesel use. As a result, the modest increase in near-term fuel prices caused by a cap-and-trade

[134] U.S. Environmental Protection Agency, 2009, *EPA Analysis of American Clean Energy and Security Act of 2009, H.R. 2454 in the 111th Congress*, June 23, 2009, page 3, page 12, http://www.epa.gov/climatechange/economics/economicanalyses.html.

system is not expected on its own to spur large reductions in transportation GHG emissions. Under both the U.S. EPA and Energy Information Administration's (EIA) modeling conducted for draft cap-and-trade legislation, the electricity sector provides the vast majority of GHG reductions in the early years – on the order of 80 percent or more. Transportation and energy-intensive manufacturing see more emissions reductions in later years, as the cap tightens and allowance prices rise.[135]

Analysis by the EIA of ACESA provides more insight into understanding the impact of these pricing measures on the freight sector. According to EIA's analysis of the "basic" ACESA bill, it would have only slight impacts on freight trucking, as compared to the reference case, with freight truck VMT only 2 percent lower in 2030 and fuel efficiency less than.1 percent higher, as compared to the reference case. Interestingly, much larger impacts are experienced by the rail and marine sectors – but not due to the increased cost of fuel for travel. Instead, their ton-miles are reduced significantly (17 percent for rail, 6 percent for marine) by reduced volume of bulk fossil fuel shipments, particularly coal, because of the shift away from coal-fired power plants.[136] (Coal supplies 41 percent of Oregon's electricity, and accounts for 11 percent of rail tonnage terminating in the State.)[137],[138]

Cap-and-trade, carbon tax, and motor fuel taxes all have the potential to generate large revenues for the Federal government through the sale of allowances or carbon- and fuel-tax receipts. The equivalent of a $1 per gallon increase in fuel taxes, for instance, would generate more than $150 billion per year.[139] Revenues raised from the transportation sector could be reinvested by the Federal government in strategies to further reduce GHG emissions from transportation. For instance, Congress has considered investing cap-and-trade revenues in research on energy efficient vehicles, development of low-carbon fuels, and investment in public transportation; revenues could also be used to compensate consumers facing higher fuel prices.

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[135] U.S. Environmental Protection Agency, 2009, *EPA Preliminary Analysis of Waxman-Markey Discussion Draft, The American Clean Energy and Security Act of 2009, in the 111th Congress*, April 20, 2009, page 14.

[136] U.S. Department of Energy, Energy Information Administration, 2008, *Energy Market and Economic Impacts of S. 2191, the Lieberman-Warner Climate Security Act of 2007*, http://www.eia.doe.gov/oiaf/service_rpts.htm.

[137] Oregon Department of Energy, March 2008, *State of Oregon Energy Plan, 2007-2009*, Salem, Oregon.

[138] Association of American Railroads, March 2009, *Railroads and States – 2007*, Policy and Economics Department, Washington, D.C.

[139] U.S. Department of Transportation, 2010, *Transportation's Role in Reducing U.S. Greenhouse Gas Emissions: Report to Congress*, Washington, D.C., April 2010.

Planning-Based Approaches

The Federal government provides nearly $40 billion in funding for surface transportation annually, and Federal statute and regulations establish requirements for states and MPOs to undertake planning in order to determine how to use these resources. These regulations could be changed to influence GHG reductions through a number of avenues, primarily:

- **Increased planning requirements**. As part of a GHG reduction package, Congress or the U.S. DOT could establish explicit requirements to consider GHG within the statewide and/or metropolitan planning process. The current Federal transportation planning statutes and regulations include a number of requirements that generally align with climate change, such as requiring that plans "protect and enhance the environment [and] promote energy conservation" and that plans discuss "potential environmental mitigation activities"; these could be expanded to more explicitly include climate change. There are a range of possibilities for how this could occur:
  - **Require consideration of GHG emissions in planning**. At the simplest level, this could be merely incorporating climate change as a transportation planning factor without including any specific requirements as to how GHG should be addressed. At a more stringent level of regulation, this could be a requirement to develop GHG inventories and forecasts for plan alternatives, and to consider GHG mitigation measures in plan development.
  - **Require scenario planning or visioning efforts** focused on a longer timeframe (30 to 50 years) than the standard 20-year transportation planning horizon. MPOs and/or DOTs could be required to develop forecasts of GHGs under different transportation and land use scenarios, and to undertake a planning process with this broader focus. For instance, Congressman Oberstar's proposed Federal surface transportation reauthorization bill[140] would have EPA and the U.S. DOT establish national transportation-related greenhouse gas emissions reduction goals. The existing transportation planning process would be expanded to require States and metropolitan regions would be required to develop surface transportation-related greenhouse gas emission reduction targets and incorporate strategies to meet these targets into their transportation plans; progress towards these goals would be verified by DOT. Because of the much shorter planning horizon of private-sector freight operators – who are much more focused on the outlook for the next five years, not a period 30 or 50 years in the future – incorporating freight into such visioning efforts can be challenging.

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[140] The *Surface Transportation Authorization Act of 2009: A Blueprint for Investment and Reform,* presented by Chairman James Oberstar, June 2009.

- **Increased requirements for intermodal planning and megaregion approaches**. Better intermodal infrastructure planning can encourage the utilization of the most efficient combination of modes for any particular trip, shift travel to more efficient modes, or increase tonnage per mile. Better freight planning would likely also involve "megaregion" or multistate planning approaches, which are already a topic of discussion at the FHWA.[141] This could involve establishing a new planning structure and process for megaregions or multistate geography. The Federal government has taken some steps toward intermodal planning with the Passenger Rail Investment and Improvement Act of 2008 (PRIIA), which – though passenger focused – for the first time established a requirement for a National Rail Plan that would consider GHG benefits as one of several criteria for prioritization. PRIIA also requires state rail plans, which are to be coordinated with the existing transportation planning process for highway investments. Similar requirements could be instituted for better incorporation of port operations into transportation planning processes. For instance, such a requirement could result in more serious examinations of short-sea shipping as a way to reduce highway congestion (as was done in the IMTC project in Washington State and British Columbia.)

- **Metropolitan Planning Organization and Department of Transportation Greenhouse Gas Goals.** The Federal government could require state DOTs or MPOs to set state or regional GHG reduction targets for the transportation sector through the transportation planning process. The purpose of this would be to force inclusion of GHG mitigation strategies in transportation planning. State and regional transportation plans would be compared against these targets.

- **Performance-Based Funding**. Performance-based approaches could range from a modest amount of funding to reward certain projects to completely changing how Federal funding is directed. The goal would be to reward activities resulting in the most cost-effective GHG reductions, or areas achieving the greatest GHG reductions. A programmatic approach could, for example, take the form of a highway formula factor that is based on transportation GHG per capita, or is based on achieved reductions in GHG per capita over time. In a performance-based funding approach, GHG is likely to be one of a number of performance measures, which may also include factors such as mobility/accessibility, safety, economic development, air quality, and livability. Resource decisions could be required to achieve certain performance targets in several areas. A performance-based funding approach would likely benefit rail and marine modes because of their lower emission

[141] For example, see the FHWA's National Roundtable on Institutions for Improving Freight Movement: ops.fhwa.dot.gov/freight/documents/mscrt/sec6.-htm.

profiles compared to trucking. This could represent a source of additional funds for port and rail improvements, as well as initiatives such as short-sea shipping.

Resource Implications

State and local transportation agencies already have experience integrating air quality into transportation planning that will prove valuable in finding ways to reduce GHG emissions. For instance, a regional-level analysis of transportation-related GHG emissions and reduction strategies analysis may be appropriate at the planning stage. Some states already have requirements to conduct GHG analysis for projects subject to state environmental review requirements. Where such requirements are in place, or where voluntary regional analyses are conducted, NEPA documents could summarize information regarding regional-level analysis of transportation-related GHG emissions and reduction strategies from transportation plans and associated studies.

These types of planning regulations have a number of implications for resources, data gathering efforts, and the planning process. More quantitative planning regulations would probably require DOTs and MPOs to develop: 1) a baseline inventory of existing GHG emissions from transportation sources in their state or region; and 2) GHG forecasts associated with each alternative evaluated in the long-range transportation plan. For some MPOs, the requirement could be relatively straightforward, as the MPO already prepares baseline and plan alternative model runs using its regional travel demand model, and a first-level GHG analysis could be added without much effort. However, data and modeling improvements might be needed in many metropolitan areas to develop better GHG estimates from freight intermodal improvements, which many of today's models are not designed to analyze. The requirements would have more significant implications for state DOTs, which typically do not develop a full network model with a comprehensive set of statewide projects to analyze plan alternatives. The inclusion of nonhighway modes (rail and marine) in the inventory requirement also would add another level of data collection and analysis that does not currently exist at either level.

Air quality has always been a challenge for freight planning because much of the freight sector is not under the planning authority of state or local governments. A rail intermodal yard, for instance, could conceivably be built without ever going through an environmental review or appearing in a TIP. Similar challenges will arise in dealing with climate change, and a key question in implementing any of the planning mechanisms outlined above will be how the private sector is integrated into the process.

Technology and Fuel Standards

New Federal standards for fuels and vehicles can achieve significant reductions in carbon emissions from transportation. Two types of standards are likely to be considered: 1) fuel efficiency standards for vehicles using carbon-based fuels;

and 2) standards for alternative and low-carbon fuels. Such standards would likely be applied to diesel engine manufacturers and the energy industry, and not come under the control of ODOT. Therefore, this report only summarizes them briefly.

Fuel Efficiency Standards

Strong standards for fuel efficiency can help achieve GHG reductions in the near to midterm, as the vehicle fleet turns over, by decreasing the amount of carbon consumed per mile of travel. Equally important, these standards would help stimulate the research and development that will be required for future progress.

Congress has required the U.S. DOT to study and issue standards for work truck and medium- and heavy-duty vehicles. The NHTSA will take action based on the findings of a study underway by the National Academy of Sciences, and a subsequent study by the DOT; new standards are likely to be announced in approximately 2012.

Although not currently proposed, fuel economy standards also could be considered for rail, air, and marine modes in the future; although such standards would likely be more difficult to apply. An alternative to fuel economy standards would be to require the use of certain technologies that have been proven feasible and cost-effective in reducing fuel consumption (such as drag reduction on trucks or trains).

Low-Carbon Fuel Standards or Renewable Fuel Mandates

Fuel standards or mandates provide certainty over future demand for low-carbon fuels for vehicle manufacturers, encouraging them to design and market vehicles that support the use of such fuels (such as bi-fuel or flex-fuel vehicles capable of running on both gasoline and ethanol). This could be implemented in the form of a volumetric fuel mandate – requiring that a certain amount of alternative fuels be produced – or in the form of a low-carbon fuel standard, which requires manufacturers to meet an average fuel carbon content. The renewable fuel standard, passed by Congress in December 2007, is an example of the former – it mandates that 36 billion gallons of renewable fuel be in use in the U.S. by 2022; the U.S. EPA has already issued a proposed regulation on implementing this standard. A low-carbon fuel standard is more flexible, allowing fuel suppliers to determine how to cost-effectively meet the carbon standard through combinations of fuel strategies. This fuel-neutral approach rewards lowest carbon results without choosing winners and losers in the development of improved fuels and technologies. Implementing both types of standards simultaneously could effectively reduce flexibility for fuel suppliers, leading to increased compliance costs.

Oregon is in the process of adopting a low-carbon fuel standard that would reduce life-cycle emissions from gasoline and diesel 10 percent by 2020.[142] The present Federal volumetric fuel mandates would not conflict with this Oregon standard, but if Congress chooses to establish national low-carbon fuel standards, it may choose to prohibit states from enacting their own standards to preserve maximum flexibility for industry.

Any low-carbon approach for freight vehicles would most likely apply to on-road trucks, but Congress would need to decide if marine or other off-road fuels would be included. The broader the scope of the rule, the more opportunity for substituting low-carbon fuels and the lower the cost per gallon in cross-subsidy for a given volume of low-carbon fuels.

[142] Oregon DEQ, 2009: *HB 2186 Reducing Greenhouse Gas Emissions from Transportation*, Fact Sheet, State of Oregon Department of Environmental Quality.