

# The Hidden Killer:

## *Towards Regulating Railyard Diesel Particulate Matter Emissions in Oregon*

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*Diesel engines are the predominant choice when moving freight, particularly for the railroad industry. Compared to gasoline engines, diesel emits relatively few of the toxic compounds generally associated with internal combustion. However, diesel engines produce a disproportionate quantity of particulate aerosols. Airborne pollutants from locomotives and freight transferring equipment in railyards significantly impact the air quality of surrounding neighborhoods. We summarize the health impacts of diesel particulates emitted from railyards in Oregon. Using the most conservative range of the EPA's assessment, we calculate a Pigouvian Tax for the railroad companies to pay, totaling \$624.24 per  $\mu\text{g}/\text{m}^3$  for each person in the affected area.*



## Fine Particulates from Diesel

Diesel exhaust is a complex mixture of gases and particles, including those that have contributed to historic air pollution problems like ozone (commonly referred to as smog). Diesel engines are relatively low emitters of carbon monoxide and hydrocarbons, major constituents of traditional air quality issues. Diesel engines, however, are disproportionate emitters of fine (less than 2.5 microns) and ultrafine (less than 0.1 microns) particulate aerosols. Heavy duty diesels for instance represent 9.8 percent of the total Oregon motor vehicle fleet but are responsible for about 46 percent of all fine particulate emissions from motor vehicles in Oregon.<sup>5</sup> A diesel particulate is anywhere from 10 to 2,000 times more powerful a health risk than the gases found in vehicle exhaust that have been typically the focus of concern.<sup>6</sup> Diesel exhaust is characterized as being 100 times more toxic than gasoline exhaust.<sup>7</sup>

Fine particulates are very small, about 1/25<sup>th</sup> the diameter of a human hair. Although these particles are small, they have a large surface area relative to their mass, making them an excellent medium for adsorbing other toxic organics like formaldehyde, acetaldehyde, benzene, 1-3 butadiene and trace metals of toxicological significance like chromium, manganese, mercury and nickel.<sup>8</sup> The small size also makes them highly respirable, able to penetrate into the deepest parts of the lungs and evade the body's normal mechanisms for protection against aerosols. Although a solid material, the particulates can also act like a gas passing through the lungs transporting the particles and adsorbed toxics directly into the bloodstream.<sup>9</sup>

Diesel particulates have been associated with a number of chronic and acute health effects including premature mortality, aggravation of respiratory tracts and cardiovascular disease (as indicated by increased hospital admissions, emergency room visits, school absences, lost work days and restricted activity days), changes in lung function with an increase in respiratory symptoms, altered respiratory defense mechanisms and chronic bronchitis and asthma. For instance, the California Office of Environmental Health Hazard Assessment listed diesel exhaust among the five most hazardous substances to children because of its potent contribution to asthma and other respiratory illnesses among children.<sup>10</sup>

Several international, federal and state public health and environmental protection agencies, including the Oregon Environmental Quality Commission, have also determined that diesel exhaust particulates are a probable or known human carcinogen at environmental levels of exposure.<sup>11</sup>

Retrospective studies of occupational exposures, including railroad workers, have supported these findings.<sup>12</sup>

In addition to the public health impacts associated with diesel exhaust, there are additional environmental impacts. Perhaps the most significant of these is the contribution to climate change from black carbon, recently proposed as the second largest human influence on climate change.<sup>13</sup> Black carbon is the soot that results from the incomplete combustion of fossil fuels and biomass. Black carbon has an impact on the climate estimated at up to 2000 times that of carbon dioxide compared on an equivalent basis.<sup>14</sup> 60 percent of black carbon emissions in the United States are from diesel engines, about four percent from locomotives.<sup>15</sup> Since black carbon particles have a much shorter atmospheric residence time (weeks and months as compared to 60 to 100 years for carbon dioxide) reductions of black carbon are identified as a priority first step to buy time while more challenging reductions of carbon dioxide are secured.<sup>16</sup>

## Emission Sources in Railyards

The mix of emission sources from a railyard depends upon the type of activity that occurs there. For instance, in a classification yard, trains are assembled and disassembled by individual railcars (e.g., box car, tanker car, flatbed car) requiring movement by switch locomotives. In an intermodal yard, freight is transferred between rail and trucks by container or truck trailer without individually handling the contents any freight container when changing modes. The difference in impacts between classification and intermodal facilities can vary considerably and is illustrated in a generic example presented in Table 1. Locomotives can represent a larger portion of emissions from classification yards while intermodal facilities can show significant impacts from equipment and vehicles that service the yard in support of the intermodal functionality. In this example, total emissions from an intermodal facility far exceed that from a classification yard.

*Table 1 Emissions from Railyard with Existing Equipment, 2005 Baseline<sup>17</sup>*

PM <sub>2.5</sub> , tons/year	Very Large Intermodal Yard	Very Large Classification Yard
Locomotive Servicing	0.0	9.8
Switch Engines	1.8	5.5
Cargo Handling Equipment		
Yard Tractors	12.5	0.0
Cranes	7.5	0.0
Forklifts	4.9	0.0
Main Line Train Operations	3.5	11.8
Estimated Truck Drayage	28	0.0
Total	58.2	27.1

Railyards, from an air quality perspective, can be a collection of older, high emitting equipment and vehicles in each emission source category.

Table 2 presents more a specific emission inventory for intermodal railyards from the Health Risk Assessment completed under the California Memorandum of Agreement. These were selected for potential comparability to the Brooklyn railyard in SE Portland, where container lift activity is approaching 400,000 per year.<sup>18</sup>

The California assessment not only developed emission inventories, but also completed a risk assessment. Focusing solely on diesel particulate, each assessment also included an estimate of excess risk for cancer over a lifetime exposure, solely from railyard activity, as opposed to other background sources. In the case of these three railyards, considering emissions from railroad activities alone, for the estimated cancer risk to drop to 10 in a million (1 in a million-cancer risk is considered a public health benchmark), a resident would have to live at least 2 to 4 miles from the facility.

Table 2 Select California Intermodal Railyards with Health Risk Assessments<sup>19</sup>

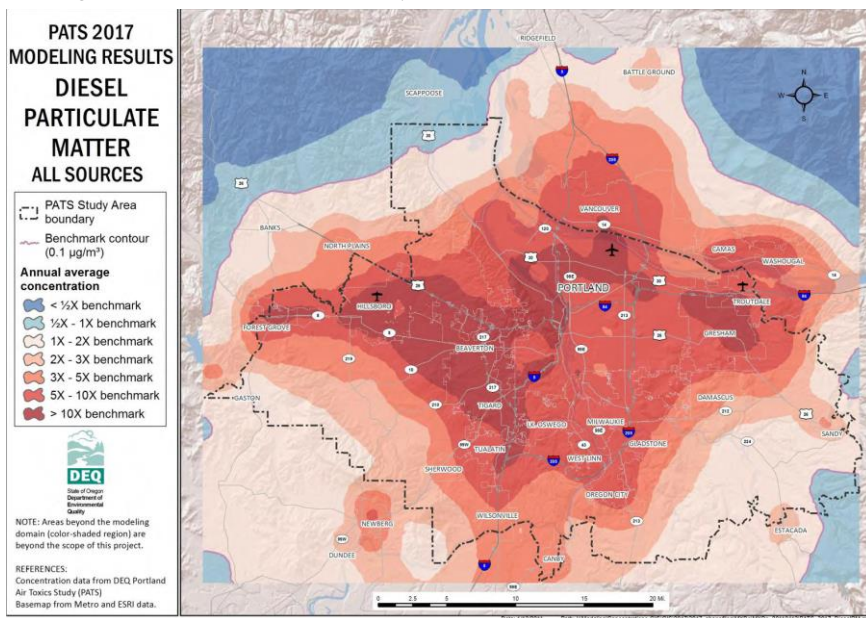
	Commerce Railyard	Los Angeles Transport ation Center	Oakland Railyard
Container Lifts – per year	350,000	250,000	350,000
Diesel PM Emissions – per year (tons)			
Locomotive	4.9	3.19	3.9
Line haul	3.0	0.73	1.6
Switch	1.9	2.46	1.9
Trailer Refrigeration Units, Reefer cars	0.4	0.46	3.2
Cargo Handling Equipment	4.8	2.67	2.2
On-Road Trucks	2.0	0.99	1.9
Total PM Emissions	17	10.5	14.7
Distance from railyard to experience cancer risk at 10 in million <sup>i</sup>	4 miles	2 miles	4 miles

<sup>i</sup> Based on the state of California risk factor for diesel PM, 0.003  $\mu\text{m}^3$ , which is also used for planning purposes in Washington state and the Greater Vancouver Regional District. The Oregon benchmark at 0.1  $\mu\text{m}^3$  is significantly less protective.  
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## Diesel Toxic Risk Assessment in the Portland Area

Diesel particulate is identified as a toxic air issue in Oregon, based on ambient concentrations and exposures. These toxics increase risk for incidence of cancer and other serious health effects. Based on the EPA assessment of direct and indirect environmental and public health costs associated with diesel particulates, the annual impact in Oregon is estimated at up to \$3.5 billion.<sup>20</sup> Over 90 percent of Oregonians live in areas where lifetime exposure results in excess risk for cancer above 1 in a million based on the Oregon benchmark concentration of  $0.1 \mu\text{m}^3$  (micrograms per cubic meter air). To complement risk reduction in the federal program, Oregon initiated a state-based air toxics reduction program. In one of the first steps the Air Toxics Science Advisory Committee recommends air toxic benchmark concentrations for adoption by the Environmental Quality Commission.<sup>21</sup> Benchmarks are not standards but rather planning goals and triggers for subsequent air quality protection measures and programs.

The Oregon DEQ convened the Portland Air Toxics Solutions Advisory Committee in 2009 to consider air toxic risk in the Portland metropolitan area. In support of that effort, DEQ completed the Portland Air Toxics Assessment (PATs) to model air toxic concentrations and risk for a planning target year of 2017. The study modeled air toxics concentrations using local meteorology, topography and emission information about population, neighborhood, car, truck, industrial and smaller sources based on projections for growth including the implementation of regulations in place as of 2011. The study identified 15 pollutants above benchmarks with eight showing the most risk: 1,3 butadiene, benzene, diesel particulate, 15 polycyclic aromatic hydrocarbons, naphthalene, cadmium, acrolein and formaldehyde.<sup>22</sup> While each of these pollutants is emitted from a variety of sources at varying concentrations, all of them are emitted from diesel engines. Of course, diesel particulates are singularly peculiar to diesel engines. The projected ambient concentrations from all sources of diesel particulate are portrayed in Figure 2 showing that the entire region exceeds the benchmark for exposure to diesel from all sources including trucks and buses, non-road equipment, ships and tugboats and locomotives.

Figure 2 Portland Air Toxics Study 2017 Diesel PM Cancer Risk – Overall<sup>23</sup>

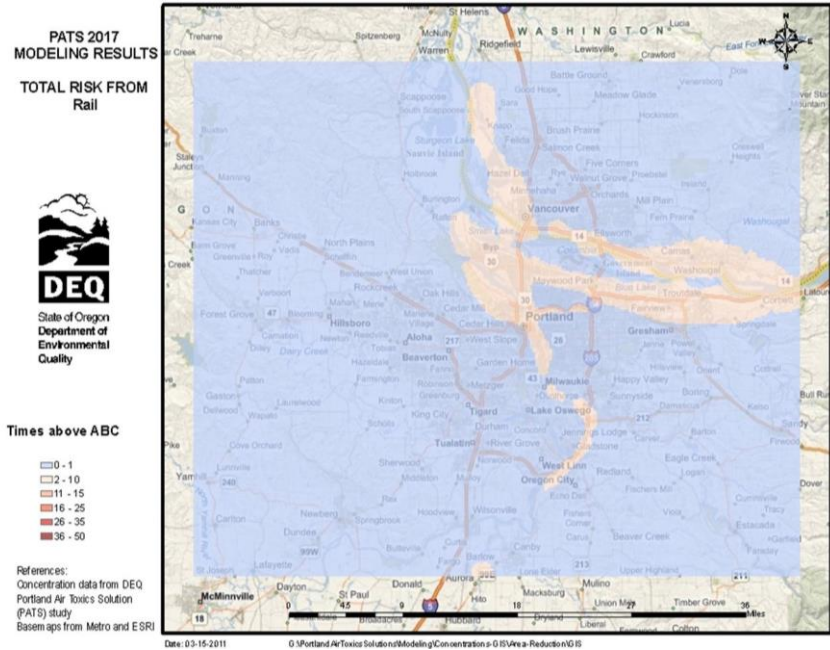
While emissions from construction equipment and highway trucks and buses are major sources of the impact in the region, localized impacts from railroad activity are also evident from the analysis.

Figure 3 shows total risk from locomotive operation in the Portland metro area. Diesel particulate matter and 15 PAH are the major drivers for this increased risk, both of which are products of incomplete combustion. The U.S. Environmental Protection Agency completed an assessment of the economic value of the direct and indirect public health costs associated with exposure to diesel particulate matter. These values can be determined for a given project in a specific location using the Diesel Emission Quantifier.<sup>24</sup> Relying on the earlier estimate of emissions based on the comparable activity level at the Los Angeles Transportation Center, the neighborhood impact from exposure to diesel particulate from activities at the Brooklyn Yard could be as high as \$11 million each year.<sup>i</sup>

<sup>i</sup> Calculated as 10.5 tons PM per year (Table 2 LATC) \* \$1,074,626 (derived from EPA Diesel Emission Quantifier health value of 1 ton PM in Multnomah County).



Figure 3 Portland Air Toxics Study 2017 Total Cancer Risk – Railroad<sup>25</sup>



Other toxics, acrolein, 1,3-butadiene, formaldehyde, naphthalene and benzene were also identified as contributing to above benchmark concentrations beyond background levels. The study concluded that reduction targets of between 84 and 96 percent from projected levels would be necessary to meet benchmarks by 2017. This was a worst-case scenario analysis but was intended to protect sensitive populations including medically vulnerable populations, the elderly and children.

Figure 4 shows the Brooklyn Raillyard and surrounding area. Within 1 mile of the Brooklyn Yard are five elementary schools and three retirement facilities. Five percent of the city's population live in the neighborhoods that adjoin the Brooklyn Yard on all sides. Utilizing EPA's EJSCREEN tool reveals that these neighborhoods are in the 93<sup>rd</sup> percentile statewide for diesel PM and air toxics cancer risk with levels in these factors placing this area in the 90-95<sup>th</sup> percentile nationwide.<sup>26</sup> Further emission reductions to meet benchmarks will result in health improvements for sensitive populations and others.

## Pollution Reduction Strategies for Railyards

Moving freight by rail is an efficient mode, consuming as little as 10 percent of the fuel per ton mile carried as compared to trucks.<sup>27</sup> While locomotives may be efficient fuel users, the emission rates for respirable pollutants can still be high. The engines are larger, older and otherwise subject to lower emission standards than heavy duty trucks.<sup>28</sup> Railyards can thus represent a significant source of respirable pollution with known myriad adverse impacts on human health.

*Figure 3 Brooklyn Rail Yard and Adjoining Area*<sup>29</sup>

Strategies have been identified and evaluated to address all aspects of emissions from railyards, including repowering and remanufacturing engines, installing exhaust controls, eliminating unnecessary idling and replacing older equipment altogether.

Repowering means replacing an existing engine with an altogether new engine. This strategy is most effective for use in diesel-powered

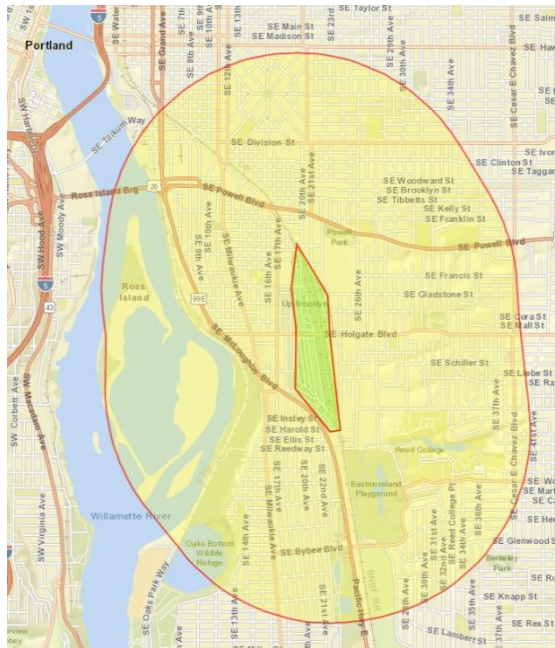
equipment, like locomotives and non-road equipment, with a useful life longer than that of the engine. Repowering in this context results in a new, lower emitting engine (or a new engine equipped with exhaust emission controls) than the original engine. This upgrade often results in fuel economy benefits and lower maintenance costs. Repowering can also include converting diesel-powered equipment to electrical power or other alternate fuels like natural gas and propane.

Remanufacturing retains the original engine but overhauls and upgrades

worn parts along with the installation of new parts, typically offered as a

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package specifically intended to reduce emissions from the original certified engine.

Retrofit involves the addition of an aftermarket emission control device on the tailpipe to remove emissions from the engine exhaust. Retrofits can be very effective at reducing emissions, eliminating up to 90 percent of pollutants in some cases. Exhaust control technology is being developed for locomotives but is not common. Space constraints on locomotives tend to make aftermarket exhaust controls challenging to install. Otherwise exhaust retrofits have been installed on truck and other non-road engines.

Replacement is also an effective strategy, although it can be costlier solely for air quality purposes because the costs of entire replacement go beyond systems intended solely for pollution reduction. In this case, though, the new equipment begins a duty cycle that returns other operational benefits for many years.<sup>30</sup>

Each strategy requires evaluation within the specific constraints of the intended application whether locomotive, drayage truck or cargo handling equipment, requiring a more detailed description than can be conveyed here of the advantages and disadvantages of each strategy in each application.

However, there are several notable examples of successful applications in other locations across the country. For instance, idle controls on switch engines have been shown to reduce fuel consumption by as much as 15,000 gallons per year with concomitant emission reductions.<sup>31</sup> In a case study analysis for a Class 2 railroad operating in the Portland metropolitan area, it was determined that automatic engine start/stop systems installed on six locomotives would cost in total \$120,000 resulting in annual fuel savings of \$26,250. The resulting reduced pollution provides an estimated annual human health and environmental benefit of \$480,000.<sup>1</sup> Or, to consider it another way, previous and ongoing uncontrolled idling results in extensive human health and welfare impacts well beyond the cost of the control technology.

Switch engines can be repowered in a “genset”<sup>32</sup> configuration in which the main locomotive engine is replaced with two or three smaller engines monitored by advanced computer controls that allows for precise control,

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<sup>1</sup> In 2018, one author, (KD), completed an assessment based on operational data and estimated fuel reductions received from a Class II railroad for installing Automatic Engine Start Stop systems on six locomotives. Resulting pollution reductions and associated health benefits were calculated using EPA’s Diesel Emission Quantifier; Diesel Emissions Quantifier (DEQ), U.S. Environmental Protection Agency, accessed July 2019, <http://cfpub.epa.gov/quantifier/>.

starting and stopping only as power is needed. Fuel savings as much as forty percent and emission reductions up to 70 percent have been reported.

Replacement can be an expensive strategy for locomotives considering the large initial capital costs involved but could be a very cost-effective strategy to upgrade trucks in drayage service. Typically, these trucks are very old but are used by businesses in short distance hauling because the business model does not warrant or support acquisition of brand-new trucks.<sup>33</sup> The Port of Seattle presents a model for drayage truck replacement by offering financial incentives for scrapping. This is also complemented by requirements established by the Port to limit access over time to port facilities to progressively newer trucks.

Many of these strategies have been evaluated by the California Air Resources Board as part of their program to further reduce emissions from locomotives and railyards. While some of these strategies may face operational and other challenges, they are almost universally cost effective at reducing diesel particulate at costs ranging from \$8,000 to \$194,000 per ton reduced.<sup>34</sup> This compares very favorably to the estimated impact costs associated with particulates emitted from diesel locomotives at up to \$407,000 per ton.<sup>35</sup>

## Emission Regulations for Railyards

The Environmental Protection Agency most recently adopted emission standards for new locomotives in 2008. The requirements phase in over four years, beginning in 2011.<sup>36</sup> Since locomotives have replacement cycles of 30 to 40 years, emission equipment upgrades are also required in some cases when locomotives are remanufactured, possibly every 4 to 8 years. When fully phased in, EPA estimates a reduction in particulate emissions by 88 percent as compared to the standards in place at the time of adoption.<sup>37</sup> Relying on normal turnover of locomotives may not be the only strategy possible to provide achievable air quality benefits in the near term.

Effective technologies are available now to reduce pollution impacts on communities near railyards. However, cost effective they may be when considering the value of pollution externalities, they still require a capital investment. Public funding assistance has been used in several parts of the United States, most notably in California which has substantial state originated funding streams like the Carl Moyer program, Prop 1B funding,

and most recently the greenhouse gas cap and trade program.<sup>i</sup> Other states, like Oregon that do not have dedicated funding, must rely on federal programs like DERA (Diesel Emissions Reduction Act) or the funds allocated from the Volkswagen settlement. Even with these funds, program guidelines that require 60 percent of project costs for engine repowering to come from recipients do not align with at least one railroad's expectation to contribute only 25 percent.<sup>38</sup> Despite some constraints and challenges other approaches relying on regulatory authority offer additional possibilities.

While states have general authority to enact laws and regulations to protect public health, in the case of railroads, several federal laws are in place that constrain states from taking action. The Interstate Commerce Commission Termination Act (ICCTA) effectively deregulated the rail industry, replacing the Interstate Commerce Commission with the Surface Transportation Board (STB). As interpreted by the courts and the STB, states cannot adopt regulations that unduly burden national railroad transportation. The jurisdiction of STB is regarded as exclusive as noted in Section 10501(b)(2)<sup>39</sup> that says:

*...Except as otherwise provided in this part, the remedies provided under this part with respect to regulation of rail transportation are exclusive and preempt remedies provided under Federal or State law.*

Nonetheless, the Act also proscribes a policy goal of the federal government in regards to rail transportation policy that "transportation facilities and equipment [operate] without detriment to the public health and safety."<sup>40</sup> While the STB is mainly an economic regulatory agency, concerted and coordinated effort among states could raise attention to incorporating this policy goal more seriously into decisions by the board. Additional avenues to focus action also exist within the current legal framework.

As noted in California ARB's analysis, courts and the STB have acknowledged that the ICCTA does not prevent states and local governments from all regulations affecting railroads in matters of traditional local concern such as protection of public health and safety.<sup>41</sup> A critical factor in determining whether state and local governments can act in this area is whether the regulation discriminates and unduly burdens rail transportation.

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<sup>i</sup> The Carl Moyer Program provides grant funding for cleaner-than-required engines and equipment. Prop 1B is a partnership between the State Air Resources Board (ARB) and local agencies (like air districts and seaports) to quickly reduce air pollution emissions and health risk from freight movement. And, California's cap and trade policy was passed in September 2006 to create a market for trading carbon emission credits.

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Courts have ruled that states and local jurisdictions may exercise authority under prior federal statutes such as the Clean Air Act as amended in 1990. In these circumstances, action by traditional rights and obligations of states would be weighed against the preemption authority established in the ICCTA.

The Clean Air Act is the primary federal law concerning air quality protection and regulation of sources contributing to pollution. The Clean Air Act generally outlines a partnership between the federal government and states in protecting and enhancing air quality giving the states significant responsibility and authority to take action. In the matter of motor vehicle emission standards generally and locomotives, in particular, the Act prescribes authority to set engine emission standards to that of the EPA. In Section 209 (e) the Congress expressly preempted all states from adopting emission standards for “new locomotives or new engines used in locomotives.”<sup>42</sup> New was defined by EPA in subsequent rulemaking as newly manufactured and not yet in use by the consumer. The preemption window was defined for these new engines to be within 133 percent of their useful life (estimated to be about 10 years or longer). Locomotive engines can also renew useful life when remanufactured or refurbished.<sup>43</sup> With this rule, EPA also determined that locomotives owned by Class 1 railroads<sup>44</sup> manufactured before January 1, 1973 and not remanufactured to Tier 0 or higher emission standards after January 1, 2000 could not be considered new and thus be preempted. This creates an opportunity to address emissions from the oldest and still operating locomotives.

A further evaluation of the type of equipment that can be regulated by a state under the limitations in ICCTA and the CAA requires a fuller evaluation that can be offered here. It is likely that a strong case can be made for locomotives primarily used only in intrastate service and either beyond useful life or qualifying under the 1973 model provision outlined above. Such state and local requirements on locomotives operating beyond their useful life may include several options including simply reporting when these locomotives are operating in the state, prohibiting these locomotives from operating in the state, mandating the immediate installation of idle control systems, and/or mandating the immediate remanufacture.

Another option that would necessarily address emissions in railyards holistically is the adoption of indirect source review requirements for freight handling facilities. As defined in the federal Clean Air Act, an indirect source is “a facility... which attracts...mobile sources of pollution.”<sup>45</sup> While the facility itself may not produce pollution, it increases air pollution by attracting motor vehicles. In practice an indirect source review requires a determination that a given facility will in normal operation result in pollution emissions

above a defined threshold requiring the facility to undertake and implement steps to reduce the impact below specified targets.

A program in California's San Joaquin Valley provides an example. Parties responsible for construction and development sites of a certain size must present information on projected emissions. If the development site cannot meet required emission reductions, a plan must be implemented to reduce emissions by using add-on controls, cleaner fuels or advanced equipment. Alternatively, the development may pay fees to the air district authority that then uses the money to fund emission reductions elsewhere in the area.<sup>46</sup> An application to a railyard could avoid specific requirements for locomotives that are otherwise preempted but would holistically address the multiple sources of emission sources, drayage trucks, yard hostlers, cargo lift cranes, reach stackers that collectively contribute to the pollution burden that particularly intermodal rail yards like Brooklyn produce.

## A Recommended Solution

Oregon could use similar siting authority to regulate railyards by imposing a direct Pigouvian tax on railyard diesel particulate emissions.<sup>i</sup> Like cameras in an intersection, emission monitors could be placed directly on the site of operations or closely nearby.

To be fully congruent with the EPA's emissions standards, the basis for Oregon's tax ought to be the EPA's December 2000 cost / benefit analysis that was used to set trucking standards.<sup>47</sup> Though this study is now nineteen years old, it remains the most consensus laden research on this topic. Its science advisory board vetted the study's methodology, carving out a very conservative approach. For instance, while the analysis identified seventy-eight health and welfare effects attributable to exposure to diesel engine exhaust, the analysis monetized only twenty-one, not including significant health effects like cancer and infant mortality due to uncertainties associated with factors like concentration-response function, lagged effects and economic valuation.

For that reason, this study remains the benchmark for mainstream estimates of the economic cost of diesel emissions. Ninety percent of the

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<sup>i</sup> Arthur Cecil Pigou (1877-1959) was an influential economist who proposed that negative externalities should be taxed at a rate that reflects the externality's cost to society; Encyclopedia Britannica, "Arthur Cecil Pigou – British Economist," accessed 2019, <https://www.britannica.com/biography/Arthur-Cecil-Pigou>.

EPA's estimation of diesel's cost, as a negative externality, was made up of the statistical value of human life lost from premature death.

The results of the EPA's survey of the epidemiological literature on premature death from diesel emissions is easily applied to Oregon empirically by regressing local mortality data on local diesel consumption. Annually, the Oregon Health Administration issues a report named Oregon Vital Statistics Annual Report in two volumes. The second volume identifies deaths by select causes by county. A variety of possible causes were considered for this scoping analysis and heart disease was selected for further analysis.

The basic model is very simple. The dependent variable was the difference between the Oregon death rate from heart disease and the national death rate from heart disease. The independent variables were Oregon sales of diesel and a simple trend variable.

$$(\text{Oregon Death Rate} - \text{National Death Rate}) = \beta_1 + \beta_2 (\text{Diesel use in thousands}) + \varepsilon$$

The estimated results were significant at a 99 percent confidence level with a  $R^2$  of .82 using Multnomah County. Bruesch Godfrey and Bruesch Pagan tests do not reject the null hypothesis that the time series were *not* autocorrelated or that the residuals were homoscedastic.

$$(\text{Oregon Death Rate} - \text{National Death Rate}) = -.004870536 + 4\text{E-}9 (\text{Diesel use in thousands of gallons})$$

Multnomah County has a lower death rate than the rest of the country. These results show as more diesel is consumed; the county's death rate converges with the national rate.

Most Oregon counties also were significant at 99 percent with the exception of Gilliam, Sherman, and Wheeler counties. We also modeled two other time series – railroad diesel alone, and highway diesel.<sup>i</sup> The results for all three sets of independent variables were consistently significant.

This model is too imprecise to gauge an exact marginal effect per gallon of diesel to impose a Pigouvian tax on Oregon's railyards. A modest approach would be to use the lower end of the EPA's range of literature estimating the

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<sup>i</sup> Railroad diesel data for Oregon had doubtful values for 2015, 2016, and 2017. These years were removed from the railroad diesel regression.  
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increase in premature death per 1 Micrograms per Cubic Meter of Air ( $\mu\text{g}/\text{m}^3$ ) increase in ambient concentration of Diesel  $\text{PM}_{2.5}$ . The EPA's science advisory board identified research showing a death rate of 68 per one million residents.<sup>48</sup> The Railyards should then be taxed at the EPA's statistical value of human life (\$7.4m as of 2006, indexed for inflation) multiplied by the expected death rate of 68/1,000,000.<sup>49</sup> The resulting tax per  $\mu\text{g}/\text{m}^3$  in 2019 should be:

$$(\text{The size of the effected population}) * \$624.24$$

The actual form of the tax is important. Traditionally taxes have been applied directly to fuels rather than their impacts. While this is generally easy to apply, our research identified some problems with identifying the location of fuel purchases. This is even more so for railroads who may make fuel purchasing decisions in different cities or even different states in order to minimize costs. The Energy Information Administration provides state by state diesel use for railroads. Surprisingly, Oregon railroads reduced their reported diesel purchases by over 99 percent between 2014 and 2017.<sup>i</sup> Basing the tax on actual monitoring at the site would be a more effective solution since the railroads could not simply evade the tax by shifting purchases of diesel to other jurisdictions.

Rather than impose standards on Portland's railyards, this Pigouvian approach would merely make them pay the negative externality of their operations. By putting a price on diesel particulate matter, the value of these operations may be so great to society that they should continue to pollute. The railroad companies may become incentivized to adopt technology that reduces emissions. The tax may motivate these companies to move their operations to less dense population areas. By taxing the externality rather than imposing command-and-control regulations, the socially optimal outcome, whatever it ultimately is, becomes more likely to be discovered through market forces.

## Conclusion

Portland, Oregon is a major transportation hub for the west coast. Railroad operations in particular are emitting a large amount of diesel particulate matter into the lungs of the residents of Oregon's largest city.

<sup>i</sup> In 2014, Oregon railroads purchased 106,299,000 gallons of diesel. In 2017, they reported purchases of only 795,000 gallons. Purchases in neighboring states increased; U.S. Energy Information Administration, "Adjusted Sales of Distillate Fuel Oil by End Use," [https://www.eia.gov/dnav/pet/pet\\_cons\\_821dsta\\_dcu\\_SOR\\_a.htm](https://www.eia.gov/dnav/pet/pet_cons_821dsta_dcu_SOR_a.htm).  
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There is robust evidence this is imposing a significant negative externality. Both the EPA and some state governments, particularly California, have taken steps to proscribe operational practices and vehicle standards to reduce emissions. We propose the more market-orientated solution of imposing a direct tax on this externality by setting up detection equipment in railyards that will meter the emissions, billing the railroad companies \$624.24 per person in the affected area for every  $\mu\text{g}/\text{m}^3$  of ambient concentration.

## Notes

- <sup>1</sup> Diesel Technology Forum, "Diesel-Powered Machines and Equipment: Essential Uses, Economic Importance and Environmental Performance," DieselForum.org, 2003, <https://www.dieselforum.org/files/dmfile/Diesel-PoweredMachinesandEquipment.pdf>.
- <sup>2</sup> U.S. Environmental Protection Agency, "2014 NATA: National Air Toxics Assessment," 2014, <https://www.epa.gov/national-air-toxics-assessment/nata-overview#self>.
- <sup>3</sup> Department of Environmental Quality, "The Concerns About Diesel Engine Exhaust," Oregon.gov, February 2015, <https://www.oregon.gov/deq/aq/programs/Pages/Diesel-Health-Effects.aspx>.
- <sup>4</sup> Oregon Department of Transportation, "2010 Oregon Rail Study," August 2010, 29.
- <sup>5</sup> Oregon Department of Transportation, "2014 Vehicle County Registration," 2015, [https://www.oregon.gov/ODOT/DMV/docs/2014\\_Vehicle\\_County\\_Registration.pdf](https://www.oregon.gov/ODOT/DMV/docs/2014_Vehicle_County_Registration.pdf); Environmental Protection Agency, "2014 National Emissions Inventory Data," 2015, <https://www.epa.gov/air-emissions-inventories/2014-national-emissions-inventory-nei-data>.
- <sup>6</sup> McCubbin, Donald and Mark Delucchi, "The Health Costs of Motor-Vehicle-Related Air Pollution," *Journal of Transport Economics and Policy*, September, Vol. 33, Part 3 (1999), 253-86.
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