Diesel Emission Reduction Analysis in Support of Utah S. B. 136

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Introduction:

Anyone who has lived through a Wasatch Front inversion knows Utah struggles with air pollution. In reality, a hazy winter day's true identity has sparkling blue skies, but only above a specific elevation. Residents who never leave the valley floor are left breathing higher concentrations of particulate matter (PM) for days until a storm system blows the inversion away.

Inversions happen when atmospheric thermal patterns flip, or invert; usually, air temperatures cool as elevation increases. The mountains surrounding Utah's population centers trap this cold air and prevent winds from blowing the stagnant air away. During the winter, long nights increase the amount of time ground level cooling occurs, and because the sun is at a lower angle, it heats the atmosphere more than the earth's surface. Furthermore, snow covering valley floors cools air even more while clear skies allow the atmosphere to heat. The longer and stronger the inversion is, the higher its capacity to trap pollutants from the affected area. PM levels increase as the inversion continues, specifically PM2.5, which is less than 2.5 microns in diameter. PM2.5 is generated both from direct sources of combustion, such as gasoline burning in a vehicle or wood burning in a fireplace, and from chemical reactions between its precursor pollutants, nitrogen oxides (NOx), volatile organic compounds (VOCs), sulfur dioxide (SO2), and ammonia (NH3). The longer an inversion lasts, the unhealthier the PM2.5 levels become (UDAQ, 2022c).

And this air pollution is quite visible to the human eye. Ground-level ozone (ozone) events, while rarer than winter inversions, occur along the Wasatch front, and while less visible on hot summer days, they still lead to respiratory challenges. Ozone does not regularly exist at ground-level; it is a chemical reaction between NOx and VOCs originating from fossil fuel combustion and evaporation of liquids like solvents, personal care products, and gasoline. The relationship between ozone and these two compounds, or contributors, is generally linear, meaning that ozone levels are higher when more contributors are present. Urban areas, where more contributors are present simply because there are more people, generally have higher ozone levels. Finally, ozone production is highest in hot, sunny environments, so urban areas are most at risk for unhealthy ozone levels in the summer (USEPA, 2022c).

The American Lung Association rates Salt Lake City, Provo, and Orem as the 10th most polluted metropolitan area in the United States for ozone and the 20th most polluted for short-term PM

(American Lung Association, 2022)[1]. PM2.5's primary danger is because of its small size. It can travel to the farthest reaches of human lungs, with the ability to even transfer to the bloodstream, causing respiratory and cardiovascular concerns (USEPA, 2022d). Though Utah currently is in attainment status, or meets federal standards, for PM2.5, this pollutant is still affecting the state. Experts estimate that 55% of Utah's annual air pollution-related health and economic costs are attributed to PM2.5, meaning 1,364-4,400 premature deaths and $0.4-$1.8 billion in costs (Errigo et al., 2020)

Ozone irritates human respiratory systems and aggravates existing lung conditions like asthma and emphysema. It can especially impact children whose lungs are still developing. Ozone exposure can lead to increased school absences, doctor visits, and hospital admissions (USEPA, 2022a). Experts estimate ozone accounts for 10% of health and economic impacts caused by air pollution in Utah, indicating a range of 248-800 premature deaths each year and $75-$330 million in annual costs (Errigo et al., 2020).

Currently, the Northern Wasatch Front (NWF), which includes Davis, Salt Lake, Utah, and parts of Tooele and Weber counties, is in nonattainment status for ozone (UDAQ, 2022b), meaning the air quality does not meet the Environmental Protection Agency's (EPA) standards, and current air quality regulations are insufficient to achieve these standards.

[1] The American Lung Association uses Combined Metropolitan Statistical Areas (CMSA) as defined by the White House Office of Management and Budget for their Most Polluted Cities rankings. Even though the name of this CMSA is Salt Lake City-Provo-Orem, Utah, the area includes eleven counties in the northwest corner of Utah. Ogden, Utah, is included in this CMSA (US Census Bureau, 2020).

Figure 1 Utah's Wasatch Front Nonattainment Area

Required by the Clean Air Act, the EPA sets National Ambient Air Quality Standards (NAAQS) for six pollutants, ozone and PM2.5 included (USEPA, 2022e). The NWF is currently classified as moderate nonattainment for the 2015 8-hour ozone standard but will likely slip to serious nonattainment based on recent monitoring trends (UDAQ, 2022B). In this case, the Utah Division of Air Quality (UDAQ) staff must find new ways to reduce ozone, as UDAQ is the responsible agency for designing regulations and incentive programs to mitigate air pollution problems. As pollution increases and EPA's standards decrease, solutions must become more creative and far-reaching, adding to an already diverse set of regulations, from controlling emissions for large electric generating facilities to curtailing residential wood burning.

A recent response to Utah’s air quality issues comes from the 2022 Utah State Legislature General Session, with the passage of S. B. 136 Air Quality Policy Amendments (S. B. 136). S.B. 136 requires UDAQ to study diesel emission reduction programs in other states and, based on this research, present a plausible framework to reduce diesel emissions from mobile sources in Utah (Utah State Legislature, 2022). Diesel combustion from mobile sources along the Wasatch Front contributes 24,010 tons annually of combined NOx and VOCs, or 25% of these two ozone creating pollutants in the NWF. Diesel fuel combustion also creates PM, ninety percent of which is PM2.5 (CARB, 2022). PM2.5 emissions from mobile source diesel combustion in the NWF total 1,016 tons per year, or 10% of all NWF PM2.5 emissions (UDAQ, 2022a). Finally, diesel combustion also creates numerous other pollutants, over forty of which are known to cause cancer (CARB, 2022).

Mobile sources are comprised of a wide range of on-road vehicles, including passenger and commercial cars, trucks, and motorcycles, while nonroad vehicles and engines range from aircraft, bulldozers, and locomotives, to snowblowers and weed eaters (USEPA, 2022b). Therefore, a diesel emission reduction program targeted at mobile sources could potentially remove large quantities of ozone and PM2.5 precursors available in the air. This program, combined with other targeted sources to reduce ozone, might allow Utah to meet EPA’s standards, and regain attainment status. In addition, though the NWF was redesignated to attainment status for the PM2.5 NAAQS in November 2020 (Maffly, 2020), further diesel emissions reductions will aid in maintaining the standard. Finally, though there are no NAAQS to determine healthy levels of less common but cancer-causing pollutants, diesel emission reductions will simply reduce their concentrations as well.

An additional requirement of S. B. 136 requires UDAQ to investigate possible emissions reductions specifically from Utah’s Inland Port area. In 2018, S. B. 234 created the Inland Port and the Inland Port Authority to capitalize on West Salt Lake City’s intersection of interstates, rail lines, and the airport (Utah State Legislature, 2018). By concentrating cargo infrastructure in this area, the Inland Port’s purpose is to create an inland redistribution center where goods arriving by rail from coastal ports can be repackaged for further distribution via truck, rail, or plane. With this increased movement of goods comes more emissions from freight handling equipment including locomotives, trucks, and cranes, in the NWF nonattainment area. The Utah Inland Port Authority (UIPA) is a state entity devoted to “smart, sustainable, and equitable” planning for the Inland Port (Utah Inland Port, n.d.), therefore S. B. 136 specifically requests recommendations for programs UIPA could implement to minimize the increase of emissions caused from this development.

This analysis project addresses questions asked by S. B. 136. First, it will investigate other state or municipality diesel reduction incentive, registration, and prohibition programs. S. B. 136 specifically requires a study of the Texas Emissions Reduction Plan (TERP), but this analysis will also examine programs in California and Canada. Next, analysis concerning the economics, efficiency, and efficacy of the three types of diesel emission mitigation programs is addressed. The analysis concludes with policy suggestions for Utah lawmakers and DAQ staff on a framework to reduce mobile diesel emissions in the state based on this project's findings of fact. In doing so, the intended outcome is to address specific programs that can be implemented statewide, in targeted airsheds, and at the Inland Port.

Literature review

Responding to mounting pressure from environmental advocates, President Richard Nixon created the EPA on July 9, 1970. Among other items, this legislation tasked EPA with establishing standards to protect the environment, research environmental issues, and assist other entities in their efforts to reduce pollution. The EPA combined portions of federal agencies already working on reducing pollution and housed them under one entity that could be unbiased and objective in its mission (Lewis, 1985).

Later that year, passage of the Clean Air Act (CAA) improved upon several earlier pieces of legislation and existing federal air quality efforts. The CAA created a strategy for the EPA to work with state, local, and tribal governments towards improving air quality, as is common with many environmental laws. As Denise Scheberle writes in *Federalism and Environmental Policy: Trust and the Politics of Implementation*, "Environmental laws are almost always based on the premise that states will do the on-the-ground work to implement and maintain the program while their federal counterparts oversee states efforts." (Scheberle, 2004) As required by the CAA, the EPA sets air quality standards to protect the public. States mostly, with some local and tribal governments taking responsibility for their lands, must create and enforce plans to meet the standards set by the EPA. The EPA assists states in creating these plans, and ensures they comply with the CAA (USEPA, 2022f).

This structure, with EPA acting as an advisor while states, localities, and tribes (SLT) create solutions, makes sense; each SLT has its own air pollution issues to solve. Each SLT has different sources of air pollution; Utah may have the world's largest copper mine, but California has the nation's largest ports. Each SLT also has different conditions, like climate and topography, that impact air pollution; Utah has the Wasatch Mountain Range that prevents air pollution from escaping, while Nebraska is flat, so air pollution passes more easily without accumulating. These differences lead each SLT to different solutions for their air pollution problems. Therefore, when identifying different ways to solve air pollution problems, the answers are as numerous as the SLTs facing those problems. Many SLTs combine efforts through imposing regulations to control emissions from specific sources and offering incentive programs that provide applicants with grant funds to buy cleaner emitting equipment. For example, UDAQ has implemented nearly 100 regulations which cover a wide range of topics, from controlling the VOC content in paints to when a resident can have a fire in their fireplace (UDAQ, 2022d). To assist in complying with their regulations, UDAQ also offers nine incentive programs, ranging from providing residents money to switch their wood burning fireplaces to natural gas inserts to replacing older, higher emitting vehicles with newer, cleaner ones (UDAQ, 2023).

Despite these efforts, Utah still struggles to meet the NAAQS for ozone and PM 2.5. S.B.136 is an unusual effort to mitigate pollution as it comes from the Utah State Legislature and requires UDAQ to research how other SLTs reduce emissions. S.B.136 specifically requires an examination of Texas's diesel emissions reduction program ,TERP, as well as other efforts to reduce diesel emissions in targeted airsheds. This analysis will also investigate state and local efforts in California, as well as local efforts in Vancouver, Canada. Below are several examples of financial incentive programs, registration programs, and prohibitions.

Financial Incentive Programs

Texas Emissions Reduction Plan (Texas Commission, 2022)

In 2001, the Texas Commission on Environmental Quality implemented TERP to reduce NOx emissions from mobile sources in Texas's nonattainment areas. Businesses and individuals apply for grants and rebates from TERP to replace or upgrade vehicles and equipment with cleaner technology. TERP has an impressive record of reducing 200,000 tons of NOx since its inception, including replacing nearly 8000 school buses, providing rebates for 4,607 electric and hybrid vehicles, and 265 natural gas vehicles. TERP is especially important to TCEQ's emissions reduction strategy, since mobile sources are not under their authority; they are still able to impact NOx reductions from mobile sources because of the financial incentives offered through TERP (TCEQ, 2020).

Fees from vehicle titles, registrations, and inspections fund TERP, resulting in $505,936,438 for the most recently reported fiscal year, FY 2020-2021 (Texas Commission, 2020). In both FY 2020 and 2021, TERP spent approximately $77 million on grant projects. TERP's most cost-effective program is $6257 to reduce a ton of NOx, and it places limits on cost effectiveness for its programs: $12,500/ton of NOx reduction for marine and locomotive engines and $17,500/ton reduced for all other programs. TERP projects its programs will become less cost effective, meaning it will become more expensive to reduce fewer tons of NOx, because the proverbial "low hanging fruit" is gone. Many of the older, dirtier engines have already been replaced, therefore the engines left to replace have fewer NOx emissions to reduce (TCEQ, 2020).

TERP currently offers ten incentive programs to achieve its goals; a comparison table for the programs follows below. The programs range from direct replacement of older diesel equipment to less direct, but still emission reducing, implementation of newer technology at stationary sources. The programs generally specify the type of equipment eligible for replacement, the entities eligible to apply, and the qualifications for replacement technologies. Where new equipment shall be powered by alternative fuels, TERP specifies which fuels qualify, but always includes compressed natural gas (CNG), hydrogen, and electric. Each program lists the total amount of funding available, and specifically how much funding is available per application. Funding for some programs is first-come, first-served, while other programs are competitive, based on criteria such as the amount of proposed emissions reductions, number of vehicles to be replaced, and where the project is located. Most programs also list what commitments come with the funding, such as how long the equipment must remain operational, the percentage of time the equipment must operate in Texas and/or designated airsheds, and what reports the recipient must provide to prove compliance with the funding criteria.

TERP Comparison Table

Program	Goals/Targets	Eligibility	Funding
Alternative Fueling Facilities Program	• Provide fuel access for alternative fuel vehicles • Stimulate market	• Construction/ reconstruction of alternative fueling facility	• ⅓ funds for small businesses • CNG or LNG = $400K • CNG & LNG = $600K
Emissions Reduction Incentive Grants	• Upgrade, replace equipment • Rail relocation /improvement	• On-road >= 8501 lbs • non-road, stationary >= 25 HP	• $35.5 million available • >= 80% of cost to purchase + install - scrap
Governmental Alternative Fuel Fleet Grant Program	• Help agencies purchase/lease alternative fuel vehicles, refueling infrastructure	• Government entity must own/operate >= 15 vehicles	• $6 million available • Competitive process
Light-Duty Motor Vehicle Purchase or Lease Incentive Program	• Rebates for purchase/lease of alternative fuel vehicle	• New purchase • Alternative fuels include: CNG, LPG, Hydrogen, Electric(plug-in/plug-in hybrid)	• <= $5000 CNG, LPG • <=$2500 hydrogen, electric
New Technology Implementation Grant Program	• Implement technology to reduce emissions at stationary sources	• Renewable electricity storage projects • Not eligible if required by law	• >= $1 million for Electricy Storage Projects • Reimbursement <=50% of cost
Rebate Grants Program	• Repower, replace diesel mobile equipment	• On-road > 8500 pounds • Non-road >= 25 HP	• >= $1 Million small businesses >= 1 must be diesel • <= 80% of cost
Seaport and Rail Yard Areas Emissions Reduction Program	• Replace drayage and heavy-duty, non-road, self-propelled cargo handling equipment	• Retiring equipment >= 26,000 lbs, routinely used, capable of operating for >= 5 more years	• Receive less of maximum grant amount (see table) or 80% of eligible costs • First come/first served
Texas Clean Fleet Program	• Replace diesel vehicles with alternative/hybrid fuels	• Fleet must be >= 75 on-road vehicles	• $7.8 million available • <= 80% of total cost - scrap value -

Program	Goals/Targets	Eligibility	Funding
	• Targets Large fleets	• New vehicle must be new, powered by alternative fuel	additional incentives
Texas Clean School Bus Program	• Reduce exposure to children from diesel school bus emissions • Replace with newest model	• Pre-2007 diesel-fueled • Must operate daily route during school year	• Replacement <= 80% of cost • Retrofit <= 100% of cost • First come/first served
Texas Natural Gas Vehicle Grant Program	• Repower/replace vehicles with natural gas engines (CNG, LNG, or LPG)	• New vehicle/engine: on TCEQ eligibility list, >=25% less NOx,	• $15.4 million available • First come/first served • <= 90% of eligible costs

San Joaquin Valley Air Pollution Control District Grants & Incentives (San Joaquin, n.d.)

California structures its air pollution efforts differently than Utah. While the California Air Resources Board (CARB) is the equivalent to UDAQ and oversees and orchestrates the entire state's efforts to reduce air pollution (CARB, 2022a), there are also 35 local air districts throughout the state that manage their own facility permitting, air monitoring, and planning (CARB, 2022b). The San Joaquin Valley Air Pollution Control District (SJVAPCD), which covers the southern half of California's Central Valley, is one of these local air districts. SJVAPCD offers a wide variety of grants and incentives to Public Agencies, Residents, and Businesses; a comparison table of diesel-reducing programs follows below.

In Fiscal Year 2021-22, SJVAPCD funded $243 million in grant projects, reducing 10,307 tons of NOx, 4,935 tons of VOCs, and 6,105 tons of PM2.5 emissions. This was matched by $471 million from grant recipients (San Joaquin, 2022). The programs range from direct replacement of older diesel equipment to less direct alternative fuel infrastructure funding and mechanic training. The programs generally specify the type of equipment eligible for replacement, the entities eligible to apply, and qualifications for replacement technologies. Most programs have tables detailing how much funding is available per application, which is often based on dollars per horsepower. Funding for some programs is first-come, first-served, while other programs are competitive and ranked on cost-effectiveness. Most programs also require the existing equipment to be destroyed by a certified dismantler and may require an inspection by District Compliance staff.

SJVAPCD Comparison Table

Program	Goals/Targets	Eligibility	Funding	Commitments
Charge Up!	• Funding for EV chargers to support growth of clean technology	• public agencies, businesses, multi-unit dwelling property owners	• Based on charger type (see table) • Can be paired with additional funding opportunities	• possible visits by District staff
Drive Clean	• provide rebates for clean-air vehicles	• residents or businesses • Eligibility list	• purchase or lease • <=$3000 based on vehicle (see table) • Can be paired with additional funding opportunities	
Alternative Fuel Mechanic Training	• Develop education for alternative fuel vehicles • Applies to mechanics, safe operation, and maintenance	• Government, private companies, public educational institutions	• <= $15,000/training	
New Alternative Fuel Vehicle Purchase	• Provide funding to purchase new alternative fuel vehicles	• alternative fuel = electric, plug-in hybrid, CNG, LNG, LPG • cities, counties, districts, public education institutions	• 1st come/1st served • <= $20K/vehicle • <= $100K/agency/year	
Alternative Fuel Infrastructure	• Alternative Fuel Infrastructure Projects	• cities, counties, districts, public education institutions		

Clean Vehicle Fueling Infrastructure Program: Private Use	• Private use:
	  ○ new stations
	  ○ conversion
	  ○ expansion
		• Heavy-duty Hydrogen, Natural gas, or electric battery charging
		• Public or Private entities
			• 1st come/1st served
			• >= 50% baseline
			• >=65% solar/wind
			• <=100% public school buses	

Program	Goals/Targets	Eligibility	Funding	Commitments
Hybrid Voucher Program	• increase market for clean, low-carbon hybrid/electric trucks, buses	• any size fleet • public or private		
Emergency Vehicle Replacement Program	• Replace In-use diesel with cleanest technology for Cities, counties, fire protection districts, etc.	• Existing equipment: diesel <= 2009 model year, >= 14,000 lbs • Operate 75% in CA, 50% in District • New vehicle: <= CARB 2010 emission standard	• 1st come/1st served • max amount calculated by cost-effectiveness and percentage limits	• Existing vehicle must be destroyed • Subject to pre-purchase, post-dismantler, and post-purchase inspections
Zero-Emission School Bus Replacement Incentive Program	• Replace existing school buses with zero-emissions buses • Disadvantages/low-income communities	• public school districts, joint Power Authorities, privately owned school buses that transport public school children • Diesel	• <= 100% of purchase/installation of charging equipment • <=$400K • <= 10 buses per entity	• District or self-inspection • Existing equipment must be destroyed
Heavy Duty Waste Haulers	• replace engine with >=2011 engine (.2 g/bhp-hr NOx, .01 g/bhp-hr PM)	• Solid waste to landfill, NOT garbage/recycling collection trucks) • Diesel, 1996-2003 model year, >= 26,001 lbs • >= 75% in District	• prioritize 100% in District • <=$50K/truck	• Existing equipment must be destroyed
Trucks: Prop 1B	• reduce air pollution, health risks along trade corridors through truck replacements, retrofits	• Heavy duty diesel trucks • Based on weight, model year, and miles/year (see table)	• Based on Engine class, model year, and replacement technology chosen (see table)	• Operate >= 90% in CA • Register with CARB

Program	Goals/Targets	Eligibility	Funding	Commitments
		• Operate 75% in CA, 10% in District		
Truck Replacement	• replace on-road diesel trucks with alternative fuel	• standard truck: 2010-2016 model year, class 4-8. • New truck = EV or Low-NOx • Operate 75% in CA, 50% in District	• priority for low-income/disadvantaged locations • Funding based on existing truck class and new truck technology	• Existing equipment must be destroyed • 75% in CA, 50% in District • Register with CARB
Locomotives: Proposition 1B	• reduce air pollution, health risks along trade corridors through locomotive replacement/retrofit	• Existing equipment: • uncontrolled • Tier 0, 1, or 2 • diesel • >= 2 years prior in CA • ~20,000 gal/year prior 2 years	• Based on year project becomes operational, type, and future CA operation (see table) • applications ranked	• Existing equipment either destroyed or banned from CA
Locomotive Program	• replace older locomotives with Tier 4 engines, including switchers	• Operate 100% in CA, 50% in District • Class 3, passenger, military, and industrial	• <= 85% of cost	• Remain owner for 15 years
Off-Road Replacement	• Incentives to replace heavy-duty off-road mobile equipment	• self-propelled • diesel • >=25 HP • Operate 75% in CA, 50% in District • New engine = newest model year	• <= 80% of cost • Amount of funding based on new engine HP	
Off-Road Repowers	• Funding for non-road mobile engine replacements	• Existing equipment: • Diesel • > 25 HP	• First-come, first-served • 80% of Tier 2 cost • 85% of Tier 3, Tier 4i, Tier 4	• Existing equipment must be destroyed

Program	Goals/Targets	Eligibility	Funding	Commitments
		• Operate 75% in CA, 50% in District		
Farmer Ag Truck Replacement Program	• replace heavy-duty diesel ag trucks	• Operate 100% in CA, 75% in District • >= 14,001 lbs • <= 2009 model year • New truck <= .2 g/bhp-hr	• first-come, first-served • 65% of replacement cost	• Existing equipment must be destroyed
Ag Pump Program	• replacement/repower of engines for ag pumps	• Diesel-Diesel • Diesel/NG -Electric • Diesel/NG -Electric w/ line extension	• 1st come/1st served • Amount of funding based on new engine HP • Line extension = 50% cost	
Small Farmer Certified Pre-Owned Agricultural Equipment Pilot Program	• replace in-use, off-road, self-propelled, compression-ignition mobile ag equipment	• Total acreage <= 100 • Existing equipment = Tier 0 or 1, >= 25 HP • Operate 75% in CA, 50% in District • New equipment >= pre-owned Tier 3	• first-come, first-served • <= 80% of cost • purchased through Original Equipment Manufacturer	• Existing equipment must be destroyed
Agricultural Tractor Replacement Program	• replace in-use, off-road, self-propelled, compression-ignition mobile ag equipment	• Existing equipment = Tier 0 or 1, >= 25 HP • Operate 75% in CA, 50% in District • New equipment = newest model year	• first-come, first-served • Funding based on farm acreage (see table)	• Existing equipment must be destroyed
Agricultural Tractor Trade-Up Program	• Award $ to farmers for Tier 4 Final purchase, who pass Tier 3 tractor to farmer that destroys Tier0/1 tractor	• Mobile, off-road, in-use, self-propelled, diesel tractor • Operate 100% in CA, 100% in District • Tier 3 < 10,000 hours	• <= 72% of Tier4f cost • based on $/hp (see table) • Applications ranked on cost-effectiveness	• Existing equipment must be destroyed

Program	Goals/Targets	Eligibility	Funding	Commitments
		• Like-for-like replacement		
Zero-Emission Ag Utility Terrain Vehicle (UTV) Voucher Program	• provide monetary incentives to replace ATVs, UTVs, or tractors	• diesel or gasoline powered • < 25 HP • New equipment = ZEV, towing capacity >= 500 lbs, weight >= 700 lbs • agricultural operations	• first-come, first-served • <= 75% of cost • Maximum $13,500	• 100% in District

Registration Programs

CARB Diesel Off-Road Online Reporting System

In 1967, California Governor Ronald Reagan signed legislation to create the California Air Resources Board. California's geography, weather, and population create prime conditions for air quality episodes, and the state had suffered from such incidents since 1943. This legislation merged the existing Bureau of Air Sanitation and California Motor Vehicle Pollution Control Board to create a statewide effort to reduce air pollution. CARB's creation occurred the same year as the Federal Air Quality Act of 1967 was implemented, and because of California's previous efforts, knowledge, and experience, the federal government allowed CARB more autonomy in their creation of air pollution regulations (CARB, 2022c).

Today, while California's local air districts manage stationary sources, air monitoring, and planning, CARB manages pollution sources that cross district boundaries, such as vehicles, fuel, and consumables. CARB has two applicable registration programs, one of which is CARB DOORS, short for Diesel Off-Road Online Reporting System. CARB requires all self-propelled, off-road diesel vehicles of 25 horsepower or greater to register in DOORS, an online reporting system. Vehicles must be registered within 30 days of purchase. Registration information includes owner, vehicle, and engine data, and if necessary, the Verified Diesel Emission Control System (VDECS). Once registered, each vehicle has an Equipment Identification Number (EIN). The vehicle's owner must label both sides of the equipment with the EIN within 30 days.

Annually by March 1st, owners must review and update contact and fleet information, and report any retired or sold vehicles. Some special designations, like low-use and agricultural equipment, must also submit hour logs. Owners must also show compliance with the fleet average target, which is based on the horsepower and model year for each engine in the fleet. If the fleet is over their target, owners must install VDECS on a percentage of the engines.

Regularly, fleet owners must reduce emissions by retiring, replacing, and repowering old engines. The table below illustrates a phased in ban on adding Tier 2 powered vehicles, based on fleet size:

<table>
<tr><th>Fleet Size</th><th>2014</th><th>2015</th><th>2016</th><th>2017</th><th>2018</th><th>2019</th><th>2020</th><th>2021</th><th>2022</th><th>2023</th></tr>
<tr><td>Medium/ Large</td><td colspan="4">T2</td><td colspan="6">T3</td></tr>
<tr><td>Small</td><td colspan="2">T1</td><td colspan="7">T2</td><td>T3</td></tr>
</table>

For fleets smaller than a combined 500 horsepower, CARB offers an alternative schedule for all units to be Tier 3 and above:

Compliance Date: January 1 of Year	Percent of Fleet (by hp)
2019	25
2022	50
2026	75
2029	100

Finally, owners must limit vehicle idling to five minutes. There are several exceptions to types of engines that are regulated (see “Background”).

CARB Portable Equipment Registration Program

CARB’s other applicable registration is CARB’s PERP, or Portable Equipment Registration Program. This program exists for diesel-fueled portable engines over 50 horsepower that are not subject to DOORS, primarily because they do not propel mobile equipment. A few examples of the purposes for these types of engines include power generation, well drilling, and pumps. Engine owners are classified into either small fleets (total horsepower < 750) or large fleets (total horsepower > 750). Small fleet owners must follow CARB’s Tier Phase-out Schedule:

Tier Phase-out Schedule (required for small fleets, default option for large fleets)			
Engine Certification	Engines rated 50 to 750 bhp		Engines rated >750 bhp
	Large Fleet	Small Fleet	
Tier 1	1/1/2020	1/1/2020	1/1/2022
Tier 2 built prior to 1/1/2009	1/1/2022	1/1/2023	1/1/2025
Tier 2 built on or after 1/1/2009	NA	NA	1/1/2027
Tier 3 built prior to 1/1/2009	1/1/2025	1/1/2027	NA
Tier 3 built on or after 1/1/2009	1/1/2027	1/1/2029	NA
Tier 1, 2, and 3 flexibility engines	December 31 of the year 17 years after the date of manufacture. This provision shall not apply to any engine operation before the effective date of this regulation.		

Large fleet owners can either follow this schedule, or apply to follow the Fleet Average Standards schedule:

Compliance Date	Fleet PM Standard (g/bhp-hr)
1/1/2020	0.10
1/1/2023	0.06
1/1/2027	0.03

The fleet owner must keep records proving compliance with the fleet PM standards and make the records available to local districts or CARB upon request.

MetroVancouver Non-Road Diesel Engine Regulatory Program

MetroVancouver provides a planning entity for 21 municipalities in the Vancouver, British Columbia, Canada, area. It provides a multitude of services, including drinking water, solid waste management, and affordable housing. MetroVancouver's air quality program focuses on monitoring and reducing air pollution through regulations and incentives. Their guiding document, the Clean Air Plan, proposes a reduction 7,500-ton reduction of combined PM, NOx, and VOCs by 2030 (MetroVancouver, 2021).

As part of their Clean Air Plan, MetroVancouver implemented their Non-Road Diesel Engine Regulatory Program (NDERP), which is similar to CARB's DOORS program. Initially, Tier 0 and 1 engines were not allowed to be registered, but updates to the regulation in 2021 allowed for their operation over 100 meters from sensitive receptors. Sensitive receptors include hospitals, elementary schools, and day care facilities. MetroVancouver uses the following fee structure to determine registration fees for each engine:

Annual Fee Rate	BYLAW 1329 FEE SCHEDULE.								
	2021	2022	2023	2024	2025	2026	2027	2028	2029 & later
Tier 0 $/HP	20.00	20.00	20.00	33.79	39.42	45.05	50.69	56.32	57.44
Tier 1 $/HP	10.00	10.00	10.00	12.56	14.65	16.74	18.83	20.92	21.35
Tier 2 $/HP	0.00	0.00	1.55	2.45	4.71	5.38	8.44	9.38	9.57
Tier 3 $/HP	0.00	0.00	0.00	1.65	3.22	3.68	5.80	6.44	6.57
Tier 4 $/HP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.94

Discounts are offered for installing approved control devices. Previously unregistered engines face a 300% surcharge, or installation of a control device to meet Tier 2 emission standards. If an owner retires an engine, they can be reimbursed up to 80% of the previous 3 years payments. There is an exception for moderate use engines that operate less than 500 hours per year; they are allowed to pay only 60% of the annual fee.

<u>Prohibitions</u>

CARB's regulation outlining PERP, the "Airborne Toxic Control Measure for Diesel Particulate Matter from Portable Engines Rated at 50 Horsepower and Greater", requires a prohibition of sale. It prohibits the sale or offer for sale or either uncertified portable diesel-fueled engine, or certified engines according to the following schedule:

Engine Certification	Engines rated 50 to 750 bhp	Engines rated >750 bhp
Tier 1	1/1/2020	1/1/2022
Tier 2 built prior to 1/1/2009	1/1/2023	1/1/2025
Tier 2 built on or after 1/1/2009	NA	1/1/2027
Tier 3 built prior to 1/1/2009	1/1/2027	NA
Tier 3 built on or after 1/1/2009	1/1/2029	NA
Tier 1, 2, and 3 flexibility engines	December 31 of the year 17 years after the date of manufacture. This provision shall not apply to any sale of an engine before the effective date of this regulation.	

Analysis in the Context of Utah S.B. 136

Hypotheses

H-1 Financial incentive programs become more expensive every year, increasing the cost to reduce each ton of pollution.

H-2 Diesel equipment registration programs demonstrate more non-road engines operating in jurisdictions than current models can provide.

Methodology and Data

To test H-1, I requested financial incentive program data from TERP, SJVAPCD, and UDAQ. Of the data TERP provided, I was able to use the Texas Clean Fleet Program (Clean Fleet) and Texas Clean School Bus Replacement Program, both of which only replace existing diesel equipment. I combined these data sets with filtered versions of the Rebate Grants Program (DERI), Seaport and Rail Yard Areas Emissions Reduction Program (SPRY), and Texas Natural Gas Vehicle Grant Program (TNGLVP), only including projects where the original equipment was diesel powered. I extracted the pertinent variables from each program: Program ID, Contract Fiscal Year, Total Grant Amount, and Total NOx Reduction (Tons). I removed projects with “0” for Total NOx Reduction to avoid an error when I created a new variable, Cost Per Ton, which divides the total grant amount by the total NOx reduction. I combined all five programs into one data set.

SJVAPCD provided the previous ten years of all their incentive programs. From that set I was able to use the Off-Road, On-Road, School Bus, and Locomotive data sets, where every piece of original equipment replaced was diesel. I also used the Agricultural Engine (Ag Engine) dataset and removed any programs where the original equipment was not diesel. I combined all five datasets, and created a new variable, Cost Per Ton, which divides the Total Grant Paid variable by the Lifetime NOx Reduced variable. SJVAPCD provided an actual date each project was executed. I converted these dates to years in order to compare with TERP data more easily.

UDAQ provided their Grants Accomplishments file for 2008-2021. I added the Federal U.S. Environmental Protection Agency Grant Funding and State/Local/Other Funding columns to create a Total Grant Amount variable. I removed all projects from the dataset with “0” for Lifetime NOx reductions to avoid errors when creating the Cost Per Ton variable from dividing Total Grant Amount by Lifetime NOx.

Once these steps had been taken, I combined the TERP and SJVAPCD datasets and ran a linear model to test the dependence of cost per ton on year, each program, and the entity. I created dummy variables for the entities and programs to try in the model, with a “1” indicating the data comes from that program or entity, and a “0” meaning it does not. I also tried a linear model for each entity separately between the independent variable of Contract Fiscal Year and the dependent variable of Cost Per Ton.

To test H-2, I requested registration data from MetroVancouver’s NDERP and CARB’s DOORS and PERP programs. From MetroVancouver, I received their entire registration set. Using a pivot table in Microsoft Excel, I listed the count of Registration Numbers by the MachineTypeID variable to see how many of each type of equipment is registered. I next found the population of MetroVancouver’s jurisdiction by using their list of 21 municipalities (MetroVancouver, 2023), Canadian Census data (Statistics Canada, 2023), and specific population data for Electoral Area A (MetroVancouver, 2023). To achieve a ratio of number of units per person, I divided the number of each machine type by the total population.

To compare this ratio to what is predicted to exist in Utah, I used a 2022 run of the EPA Nonroad MOVES (Motor Vehicle Emissions Simulator) (USEPA, 2016a) model provided by UDAQ. MOVES is how many scientists predict the amount of emissions originating from mobile equipment. This particular output was for the NWF nonattainment area. It provided the Source Classification Code (SCC), EPA’s four-level classification system that categorizes air emissions. I matched the SCC codes with their descriptions using EPA’s Complete SCC list (USEPA, 2016b), then filtered the descriptions to only diesel-powered equipment. I used a pivot table to sum the data in the Activity variable to show the number of each unique SCC code and found the ratio for number of units per person by dividing the activity sum by Salt Lake County’s 2021 populations (US Census Bureau, n.d.). I then matched SCC descriptions manually with the MetroVancouver data.

Analysis

Incentive Programs, Descriptive Statistics

The TERP datasets show all programs funded since the inception of each program, with the earliest projects funded in 2002. The combined data set created for the analysis lists 10,010 projects funded, and while a project is for one entity, it often includes multiple equipment replacements or retrofits.

SJVAPCD’s projects are listed in the same manner, and the combined data set created for the analysis lists 13,433 projects funded. Utah’s dataset shows an overview of each project funded since 2008. It differs from the TERP and SJVAPCD datasets because it does not list the project by the grant recipient, but by the total program output for the fiscal year. This provides 23 projects funded to analyze.

Since its inception, TERP has removed 182,445 tons of NOx from the five programs used for this analysis. SJVAPCD removed 67,718 tons of NOx in the last ten years of their incentive programs. They also include reductions for PM and VOCs, which were 3,169 and 5,876 tons, respectively. Since 2008, Utah has removed 2,533 tons of NOx, 589 tons of PM, 149 tons of VOC, 1,086 tons of Carbon Monoxide, and 4,018 tons of Carbon Dioxide.

Adding only the projects TERP funded during the same amount of time as SJVAPCD’s data set, or its last 10 years 2011-2021, TERP removed 51,869 tons of NOx. In Utah’s last 10 years of data, 2009-2019, it removed 1,688 tons of NOx.Since its inception, TERP has paid $1,297,233,199.88 in grants, averaging $11,436.59 to remove one ton of NOx. In its last 10 years, SJVAPCD has spent $826,513,469.84 in grants, averaging $93,325.26 to remove one ton of NOx. Since 2008, Utah has paid $44,378,657, averaging $320,936 to remove one ton of NOx. The cost for all pollutants combined is $382 per ton.

Adding only the projects TERP funded during its last 10 years, TERP paid $604,729,089 in grants, averaging $14,799 to remove one ton of NOx. In Utah’s last 10 years, it funded $42,882,157 in grants, averaging $335,443 to reduce a ton of NOx.

Program	Projects Funded	First Contract Year		Grant Amount		Total NOx Reductions (Tons)		Cost per Ton
SJVAPCD	**13,433**	**2004**	**Min**	**$2,923.48**	**Min**	**0.00**	**Min**	**$849.38**
			Max	**$2,667,220.95**	**Max**	**315.52**	**Max**	**$249,873,987.14**
			Mean	**$61,528.58**	**Mean**	**5.04**	**Mean**	**$93,325.26**
			Total	**$826,513,469.84**	**Total**	**67,717.91**	**Total**	
Ag Engine	709	2011	Min	$2,923.48	Min	0.07	Min	$849.38
			Max	$189,800.75	Max	77.96	Max	$128,571.43
			Mean	$22,909.98	Mean	3.86	Mean	$14,103.41
			Total	$16,243,178.66	Total	2,739.51	Total	
Locomotive	35	2012	Min	$864,500.00	Min	43.22	Min	$4,120.13
			Max	$2,667,220.95	Max	315.52	Max	$43,602.64
			Mean	$1,791,896.72	Mean	119.56	Mean	$18,602.65
			Total	$62,716,385.20	Total	4,184.65	Total	
Off-Road	9,110	2004	Min	$4,868.78	Min	0.02	Min	$955.79

			Max	$537,500.00	Max	101.19	Max	$2,086,016.67
			Mean	$60,491.34	Mean	5.40	Mean	$22,022.17
			Total	$551,076,133.55	Total	49,218.22	Total	
On-Road	3,421	2012	Min	$3,100.00	Min	0.01	Min	$1,974.46
			Max	$196,146.35	Max	22.48	Max	$19,614,635.00
			Mean	$51,346.42	Mean	3.30	Mean	$94,154.28
			Total	$175,656,087.77	Total	11,293.06	Total	
School Bus	158	2014	Min	$38,445.00	Min	0.00	Min	$8,250.00
			Max	$400,000.00	Max	9.18	Max	$249,873,987.14
			Mean	$131,782.81	Mean	1.79	Mean	$4,558,633.12
			Total	$20,821,684.66	Total	282.47	Total	
TERP	**10,010**	**2002**	**Min**	**$1,625.88**	**Min**	**0.19**	**Min**	**$594.78**
			Max	**$43,845,596.12**	**Max**	**14,561.07**	**Max**	**$373,236.28**
			Mean	**$129,593.73**	**Mean**	**18.23**	**Mean**	**$11,436.59**
			Total	**$1,297,233,199.88**	**Total**	**182,445.43**	**Total**	
Clean Fleet	37	2011	Min	$486,569.50	Min	3.09	Min	$24,249.70
			Max	$5,900,000.00	Max	82.92	Max	$373,236.28
			Mean	$1,874,692.83	Mean	18.90	Mean	$126,839.97
			Total	$69,363,634.56	Total	699.48	Total	
Clean School Bus Replacement	71	2018	Min	$28,000.00	Min	0.34	Min	$28,366.37
			Max	$473,995.00	Max	3.64	Max	$197,916.67
			Mean	$194,921.03	Mean	1.81	Mean	$110,216.03
			Total	$13,839,393.27	Total	128.76	Total	
DERI	9,642	2002	Min	$1,625.88	Min	0.23	Min	$594.78
			Max	$43,845,596.12	Max	14,561.07	Max	$76,842.60
			Mean	$118,034.19	Mean	18.56	Mean	$9,548.42
			Total	$1,138,085,671.41	Total	178,911.20	Total	
SPRY	126	2015	Min	$17,833.86	Min	1.03	Min	$11,569.16
			Max	$960,407.70	Max	60.79	Max	$27,146.84
			Mean	$174,976.37	Mean	8.22	Mean	$23,510.66
			Total	$22,047,023.04	Total	1,035.83	Total	
TNGLVP	134	2013	Min	$12,194.33	Min	0.19	Min	$6,315.32
			Max	$2,250,000.00	Max	76.06	Max	$183,112.92
			Mean	$402,219.98	Mean	12.46	Mean	$51,743.61
			Total	$53,897,477.60	Total	1,670.15	Total	
Total	**23,443**			**$2,123,746,669.72**		**250,163.34**		

Incentive Programs, Linear Regression

I ran linear regressions for the incentive program data with the contract year being the independent variable, and cost per ton for NOx reduction as the dependent variable. The school bus data for SJVAPCD was removed from this combined dataset because it contained three outlier values that skewed the data. Because these purchases were so different than the rest of the data, they were removed for analysis purposes. SJVAPCD responded the existing vehicles for these projects had significantly lower mileage than other projects (R. Delmanowski, personal communication, April 11, 2023).

For the entity dummy variables, I chose to include SJVAPCD guessing that California programs would cost more than Texas programs. For the program dummy variables, I excluded the locomotive program as it only has 36 of the nearly 14,000 SJVAPCD projects. The most inclusive resulting model therefore was:

Cost per ton = y + a(Contract Year) + b(Clean Fleet) + c(DERI) +d(SPRY) + e(TNGLVP) + f(Off Road) + g(Ag Engine) + h(On Road) + i(SJVAPCD)

Where y is the intercept and each program and entity is multiplied by a rate of change.

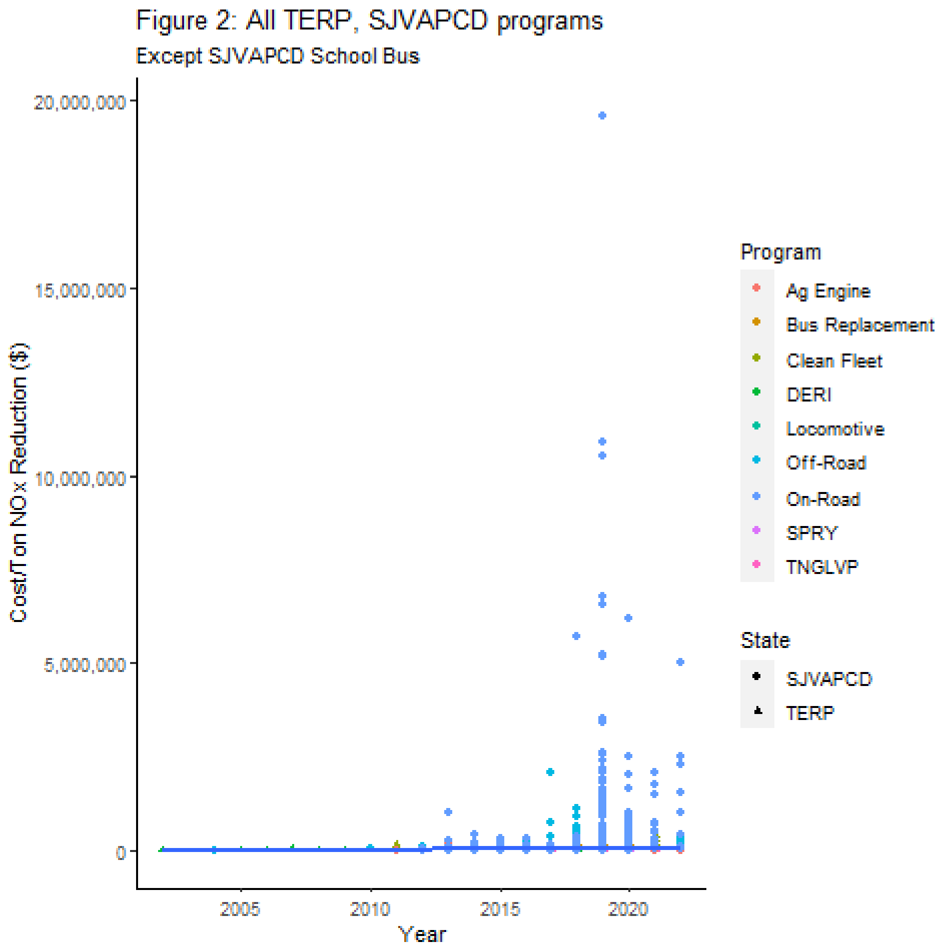
The model shows three significant results. The contract year is significant at less than 0.001, and its rate of change is $3,993.30, meaning that every year increase means the cost to reduce a ton of NOx will be this much more. The Clean Fleet and On-Road programs were also significant between 0.05 and 0.01 with a positive rate of change for the Clean Fleet program of $114,830.10 and $82,301.00 for the On-Road program, meaning after determining the cost to reduce a ton of NOx based on the year, this much more would be added to the total cost to reduce a ton of NOx for these programs.

With only significant variables included, the model appears as:

Cost per ton = -$7,953,318.50 + $3,993.30(Contract Year) + $114,830.10(Clean Fleet) + $82,301.00(On Road)[2]

With the values for Clean Fleet and On-Road being either 0 or 1 since these are dummy variables. Figure 1 shows the model results in graph format.

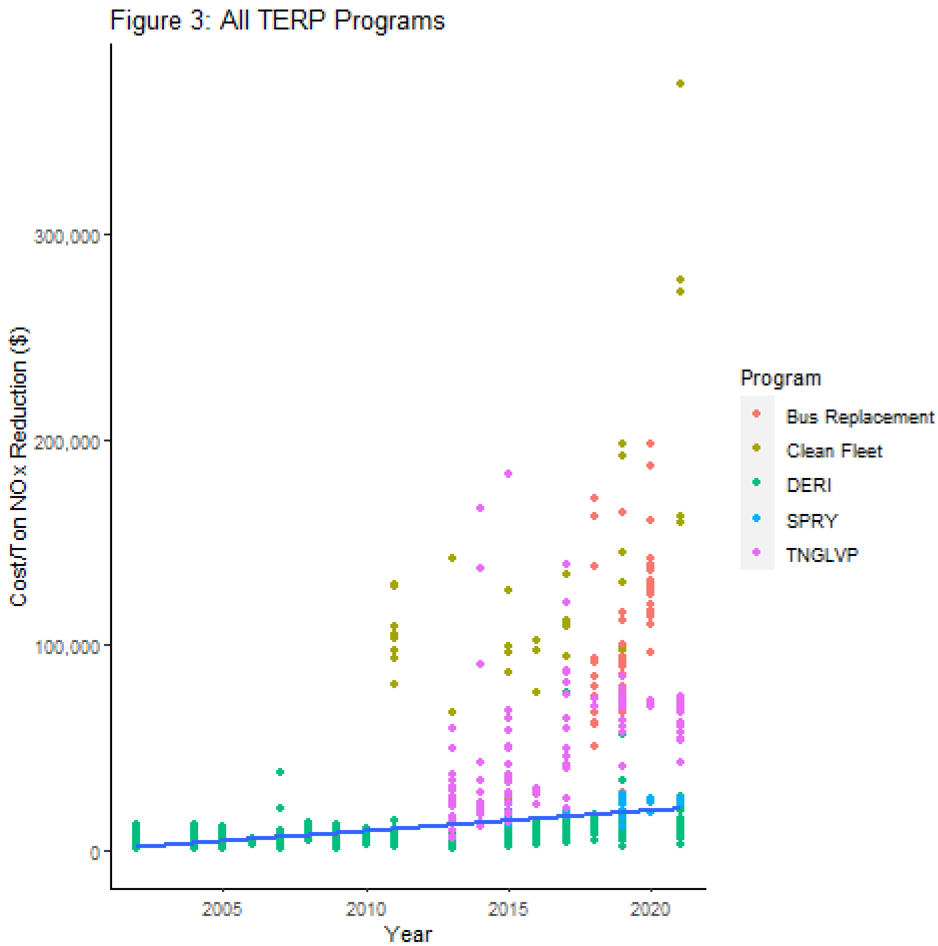
[2] While these costs reflect actual dollar amounts at the time, projections based on economic indicators are only guesses because economic conditions change over time.



The adjusted R^2 is low for this model at 0.01955, and when plotted, it is evident that cost per ton outcomes in SJVAPCD were higher than TERP because one cannot see any individual TERP values. Because of this, I decided to try running the regressions for each entity separately as well.

TERP Results

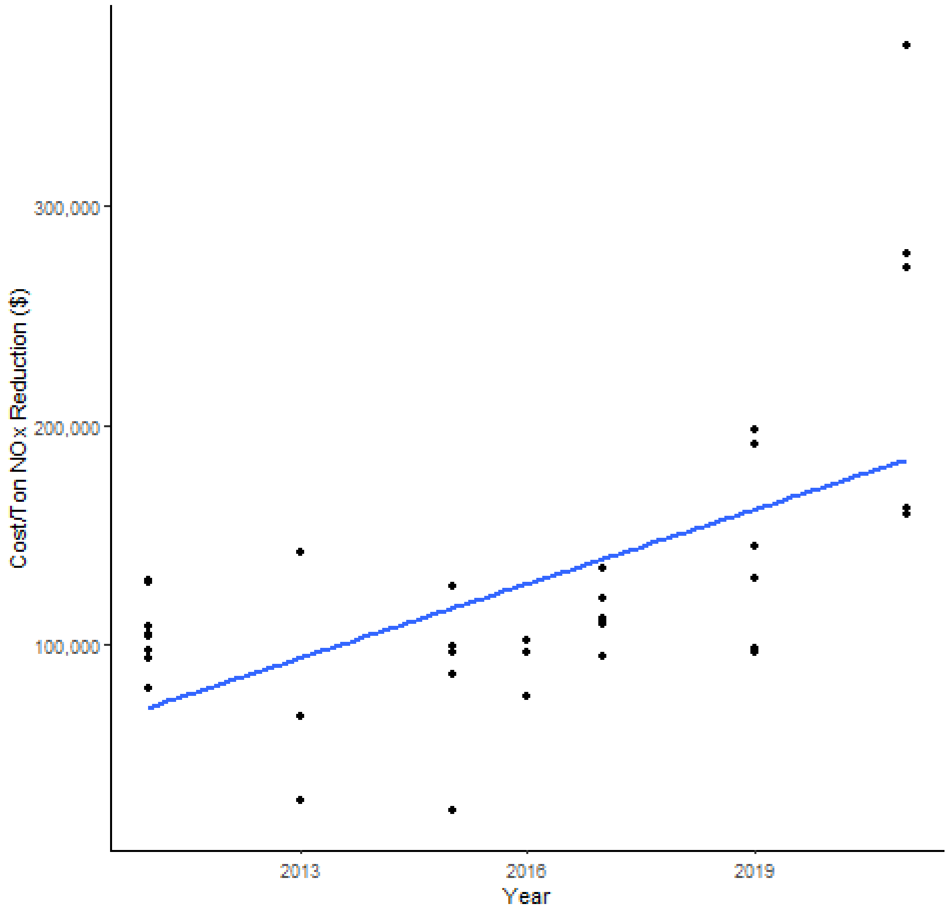
For all TERP data combined, the p-value is statistically significant at 2.2×10^{-16}, with a coefficient of $993 per ton NOx reduced. This means for every year increase, TERP programs can expect the cost to reduce a ton of NOx to increase by $993.



However, the adjusted R-squared value is 0.112, indicating these two variables only explain 11% of the variation. Because the plot indicates the cost per ton for each program, it is more similar within the program than compared to the other programs, I ran linear regressions for the most expensive cost per ton, the Clean Fleet program, and the least expensive cost per ton, the DERI program.

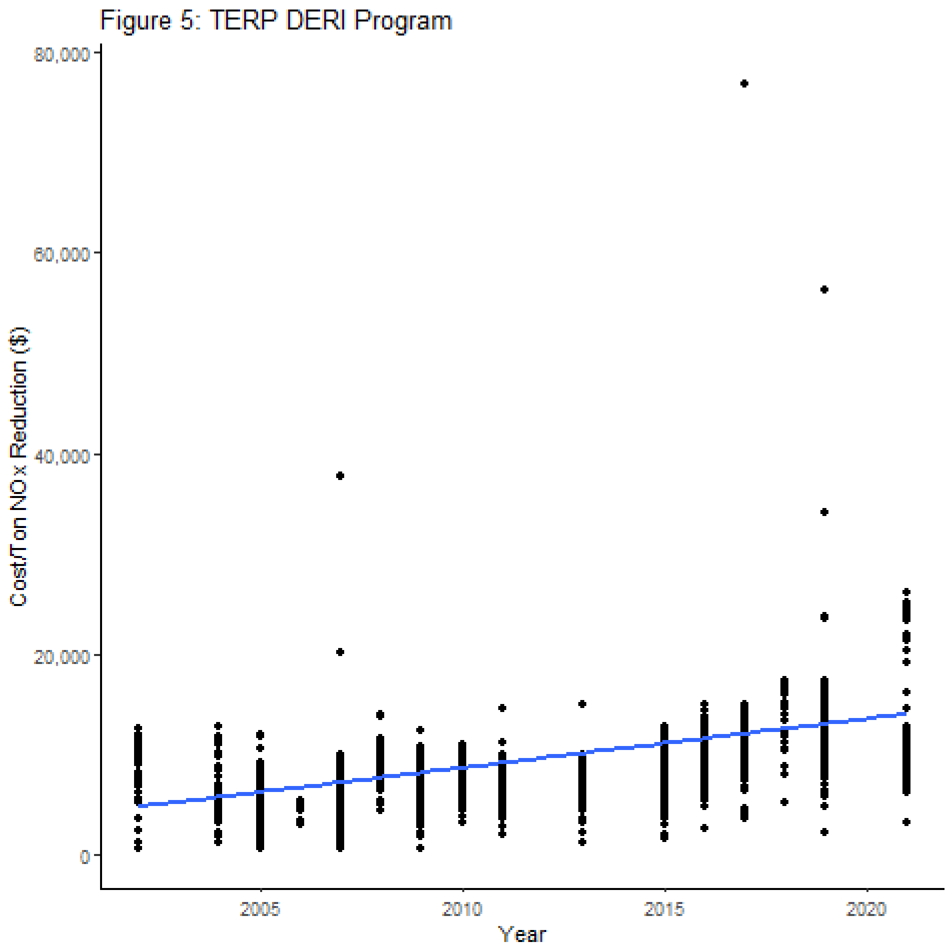
The Clean Fleet data also had a statistically significant p-value at 0.0001538, and a coefficient of $11,296, meaning for every year increase, the Clean Fleet program can expect to see a $11,296 increase in the cost to reduce a ton of NOx.

Figure 4: TERP Clean Fleet Program



The adjusted R-squared value is better at 0.3208, meaning these two variables explain 32% of the variation.

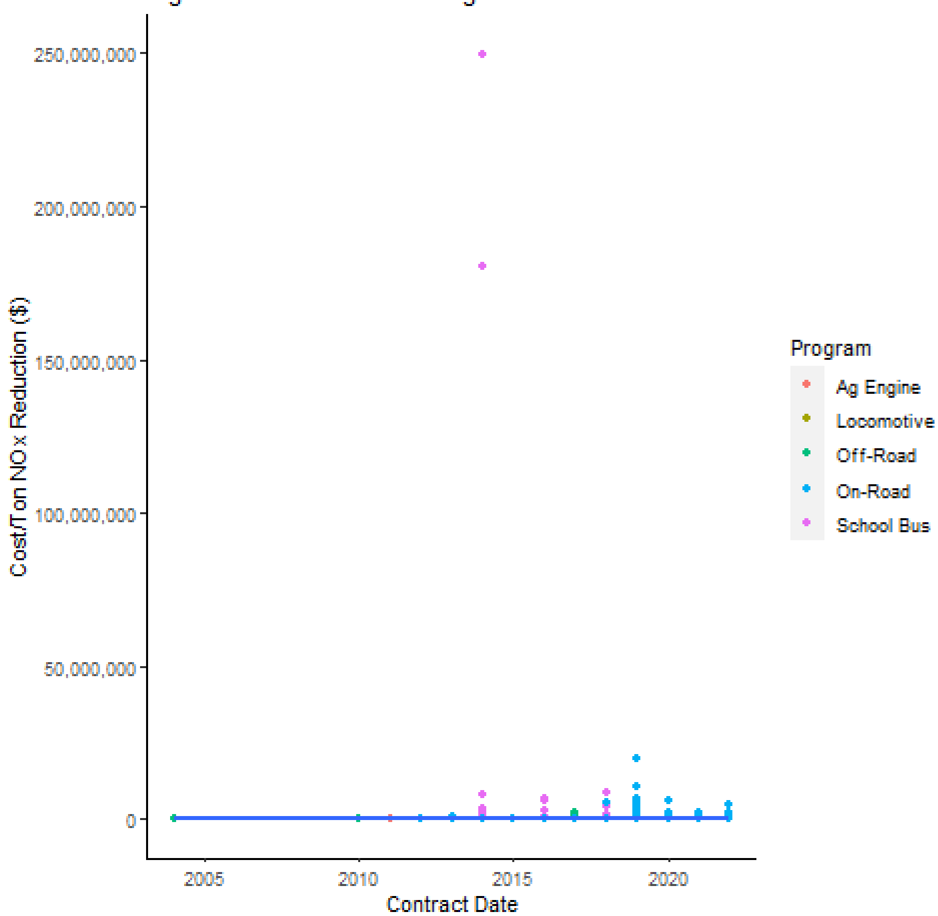
The DERI program model has the best adjusted R-squared of 0.4211 and is still significant with the same p-value as all TERP data combined, 2.2×10^{-16}. The coefficient is a $486 increase in the ton of NOx reduced for each year.



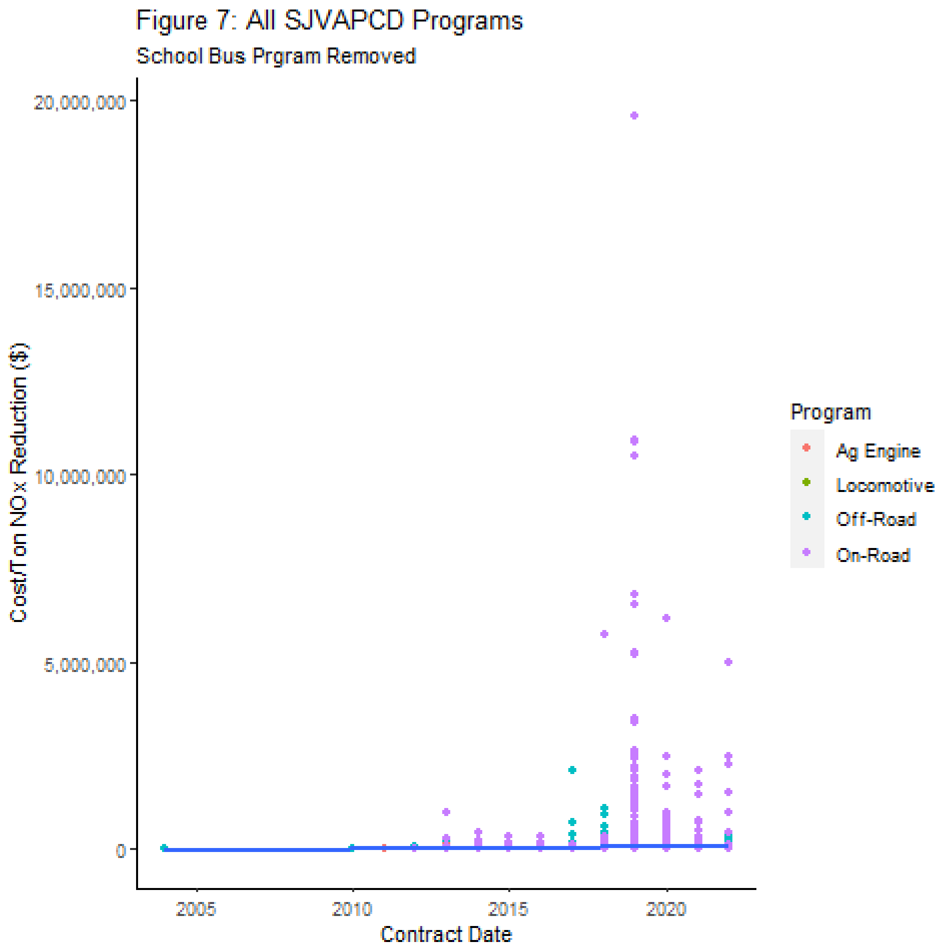
SJVAPCD Results

For all SJVAPCD data combined, the p-value is 0.2376, with a coefficient of -$10,903 per ton of NOx reduced. The following plot shows that School Bus data outliers skew the data.

Figure 6: All SJVAPCD Programs



Without including the school bus data, the p-value is statistically significant at 9.165e-14, with a coefficient of $6729, meaning the remaining SJVAPCD grant programs (On-road, Off-road, Locomotive, and Ag-engine), can expect to see a $6729 increase in the cost to reduce a ton of NOx every year.



The adjusted R-squared value is 0.004051, however, meaning these two variables only explain 0.4% of the variation.

For Utah, the linear regression result was not statistically significant with a p-value of 0.585.

Registration Program, Descriptive Statistics

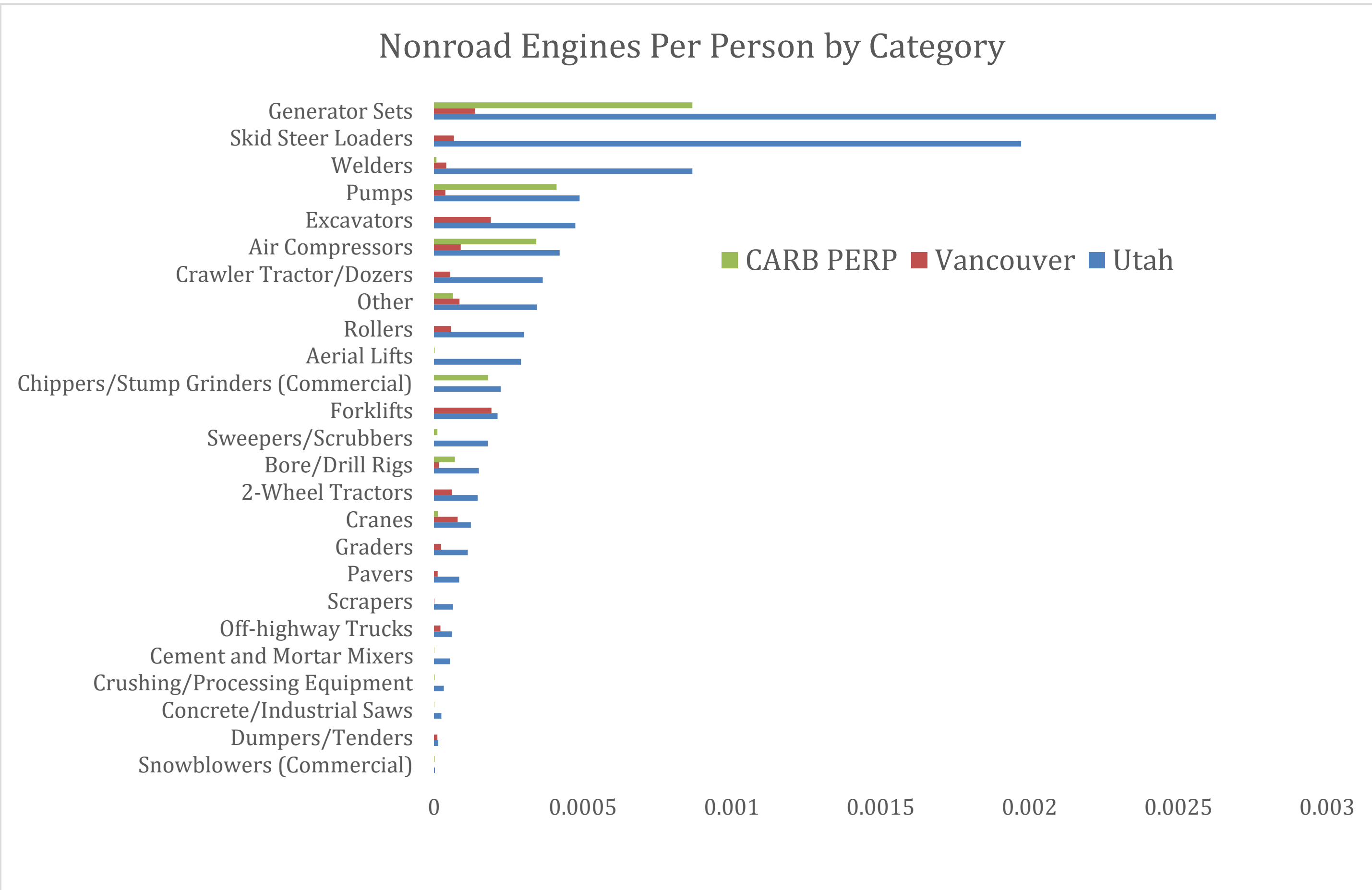
Utah's Nonroad MOVES model output predicted 38,813 nonroad engines in the NWF Nonattainment Area counties (Davis, Salt Lake, Tooele, Utah, and Weber Counties) for 2022. The population for these counties for 2021, the most recent Census data available, is 2,582,398 people (US Census Bureau, n.d.).

MetroVancouver's NDERP program shows 4,616 engines registered as of February 3, 2023. The population for MetroVancouver's service area for 2022, the most recent Statistics Canada data available, is 2,832,760 people (Statistics Canada, 2023).

CARB PERP's program shows 83174 engines registered since its inception. The population for California as of 2020, the most recent Census data available, is 39,538,223 (US Census Bureau, n.d.).

Registration Program, Ratio Comparison

The nonroad MOVES model predicted 922% more nonroad engines per person than NDERP has registered, 714% more engines than CARB PERP has registered. The figure below shows in every comparable engine category the Utah Nonroad MOVES model predicts more engines per people than either NDERP or CARB PERP.



Discussion

The regression analyses for TERP and SJVAPCD incentive programs (without SJVAPCD school bus data), combined and separate, show an increase in the cost to reduce a ton of NOx every year.

These statistically significant results mean we can accept H-1: Financial incentive programs become more expensive every year, increasing the cost to reduce each ton of pollution.

There are multiple implications for this finding. First, air entities must recognize these programs are becoming less cost effective. This is most likely because as older, more polluting equipment is replaced, there is less of it to incentivize, meaning the programs are constantly targeting a pool of newer equipment. The “low hanging fruit” is gone. Therefore, with finite funding available, air entities must ask themselves what is the most responsible use of these funds?

In considering the TERP data, one might conclude that the Clean Fleet program is too expensive to continue, as its cost to reduce a ton of NOx increases $11,296 per year, and an average grant amount per project of $1.9 million. But examining the program recipients, the majority are school districts, which operate on tax-payer dollars and generally tight budgets. Most school districts would probably not be able to prioritize replacing their entire school bus fleet on their own. Therefore, despite the large cost increase every year, perhaps these funds are well spent because the upgrades would not happen without them.

In contrast, the TERP DERI program appears much more cost effective, with only a $486 increase annually in the cost to reduce a ton of NOx. The program recipients in DERI are diverse and numerous, with over 9,000 projects funded since the inception of the program. However, the first replacement project was for Dallas Fort Worth International Airport to replace a street sweeper and a backhoe. The total cost of the grant was $66,033, which is not much compared to the Clean Fleet average price. But, considering the applicants, an airport, has alternative economic mechanisms to leverage the funds needed to make these engine replacements. For example, compared to the school districts reliance on taxpayer dollars, the airport could increase parking fees for a finite amount of time to raise the money. As the second busiest airport in the United States with 62.4 million passengers a year (World Atlas, 2023), it would likely not take long to raise the amount needed to replace two vehicles. Therefore, perhaps incentives going forward should be awarded to the marginalized or municipalities that do not have mechanisms for economic leverage.

Because the SJVAPCD data’s R^2 value is not as good as the TERP data, the relationship between the contract year and cost per ton is less reliable, but without the school bus data the relationship also shows cost per ton increases each year.

It is also evident that SJVAPCD is spending much more to reduce a ton of NOx as their average cost/ton is $81,889 more than TERP. As mentioned previously, TERP places cost/ton limits on their projects: $12,500/ton of NOx reduction for marine and locomotive engines and $17,500/ton reduced for all other programs. In conversation with SJVAPCD staff, they sometimes struggle to spend all the available grant money, and have to work with grant recipients to find more projects (J.Tackett, personal communication, March 15, 2023). This could have two implications; either cost per ton is not as important to consider, or entities should focus more on advertising their programs to encourage a more competitive grant application process that will drive down the cost to replace a ton of NOx and make programs more cost effective.

The data UDAQ could provide for their incentive programs was difficult to use in the data analysis. UDAQ does not have a database to facilitate their grants programs, therefore staff utilizes Microsoft Excel spreadsheets to record data. The best data source they could provide was their Achievements file, which is a high-level summary of each fiscal year's funding. This file only has 23 rows, therefore 23 data points to use in an analysis. This is not enough data points to conclude trends for their programs.

The unit per person ratio comparison between Utah, NDERP, and CARB PERP shows the Nonroad MOVES model far out predicts the number of engines in the NAA compared to the registration programs. This means we cannot accept H-2: Diesel equipment registration programs demonstrate more non-road engines operating in jurisdictions than current models can provide. Neither MetroVancouver nor CARB PERP provided SCC codes, which made the comparison of engine categories extremely manual, aligned by what I interpreted as the best match. Overall, though, the total number of nonroad engines predicted by Nonroad MOVES equaled 0.015 units per person, while MetroVancouver's total nonroad engines registered equals 0.0016 units per person, and CARB PERP's total engines registered equals 0.0021 units per person.

Recommendations

I attempted to include a Gross Domestic Product (GDP) variable in the models to test its effect on adjusted R^2 value, and possibly control for economic factors, swings, and implications. I have not used GDP variables previously, and felt my efforts were unsuccessful, but further research should utilize a GDP variable matched to the contract year and the state.

This analysis also only focused on programs in Texas, California, and Vancouver. Future research should build upon this analysis to include more entities and more data points.

Because the Utah data was not possible to analyze, it is evident that UDAQ needs a grants and incentives database to track its data more efficiently. Such a database should be able to log the pertinent variables per project, including total grant amount and total NOx reduced. Through the process of providing data for this project, UDAQ staff have seen this problem and begun conversations with TERP, SJVAPCD, and multiple database vendors to obtain an effective database.

More effort should be placed on understanding the differences between what is registered through NDERP and CARB PERP and how MOVES makes its predictions to determine if the field were accurately compared. Regardless, this analysis may have identified that comparing registration programs to Nonroad MOVES is challenging, especially registration programs from another country that does not even use SCC codes. Perhaps the best way to conduct this comparison is to compare California MOVES to California registration programs, if California still conducts Nonroad MOVES.

Also, this analysis focused on comparing number of engines in a model versus a registration program. Future research should investigate what emission reductions have been made from registration programs, and at what cost.

Finally, this analysis focused on costs of incentive programs and accuracy of registration programs. Future analysis should go further to determine what impacts these incentive programs and registration programs have had on human health, including a comparison of the costs of these incentive programs against the costs for the incentive programs.

Limitations

The biggest limitation to this analysis is the lack of registration program data from CARB DOORS. Though the data request was made to CARB January 5, 2023, the DOORS data never arrived. This made inclusion of this data into the analysis impossible. This is especially frustrating because I believe the CARB DOORS registration data will be more aligned with Utah’s Nonroad MOVES model than either NDERP or CARB PERP.

SJVAPCD’s datasets do not include grant recipient names, therefore the analysis could not provide as in depth analysis at the recipients’ level, as was the case with TERP DERI and Clean Fleet data.

Conclusion

This analysis concludes the cost to reduce a ton of NOx increases annually for grants and incentive programs, a fact that air pollution control agencies should consider. Because of this, in competitive grant situations, the ability for grant recipients to achieve reductions without government assistance should weigh into the awarding process. This should specifically be considered in lean funding years.

This analysis of registration programs also concludes that currently Nonroad MOVES predicts more engines than registration data can provide, but more research is needed once CARB DOORS data is available.

For Utah legislators, this analysis concludes that UDAQ should be provided adequate funds to obtain a grants and incentives database similar to TERP and SJVAPCD systems, doing so will allow UDAQ to conduct analyses on their data. Until then, no conclusion can be made on UDAQ incentive programs. But Utah legislators can take lessons learned from analyzing TERP and SJVAPCD programs to use incentive money wisely as costs to reduce NOx are only increasing. Grants funded should focus on the marginalized or municipalities that do not have mechanisms for economic leverage. These efforts are best directed in Utah’s nonattainment areas and Utah’s Inland Port, though consideration should be made as to which recipients can make upgrades on their own.

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