Project Report

Reducing Air Pollution at Land Ports of Entry: Recommendations for Canada, Mexico and the United States

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List of Abbreviations and Acronyms

Aduanas	*Servicio de Administración Tributaria*
BC	black carbon
BCC	Border Crossing Card
BECC	Border Environmental Cooperation Commission
BESTUFS	BEST Urban Freight Solutions
CBP	US Customs and Border Protection
CBSA	Canada Border Services Agency
CEC	Commission for Environmental Cooperation
CH_4	methane
CO	carbon monoxide
CO_2	carbon dioxide
CO_2e	atmospheric carbon dioxide equivalent
CV	commercial vehicle
e-Manifest	electronic manifest
EC	elemental carbon
EPA	US Environmental Protection Agency
FAST	Free and Secure Trade
FHWA	Federal Highway Administration
FRATIS	Freight Advanced Traveler Information Systems
GHG	greenhouse gas
GPS	global positioning system
HC	hydrocarbon
ITS	Intelligent Transportation Systems
JAC	Ciudad Juárez, Chihuahua/El Paso, Texas/Doña Ana County, and New Mexico Air Basin
MOVES	Motor Vehicle Emission Simulator
MSATs	mobile-source air toxics
N_2O	nitrous oxide
NAAEC	North American Agreement on Environmental Cooperation
NAFTA	North American Free Trade Agreement
NO_x	oxides of nitrogen
NPAH	nitrogenized polycyclic aromatic hydrocarbon
NY DEC	New York State Department of Environmental Conservation
opMode	operation modal
PAH	polycyclic aromatic hydrocarbon
PM	particulate matter
PM_{10}	particulate matter that are less than 10 micrometers (µm) in diameter
$PM_{2.5}$	particulate matter that are less than 2.5 micrometers (µm) in diameter
POE	port of entry
POV	privately-owned vehicle
RFID	radio frequency identification
Semarnat	*Secretaría de Medio Ambiente y Recursos Naturales*
SENTRI	Secure Electronic Network for Travelers Rapid Inspection
SO_2	sulfur dioxide
THC	total gaseous hydrocarbons
TTI	Texas A&M Transportation Institute
UFP	ultrafine particles
VMT	vehicle-miles traveled
VOC	volatile organic compounds
VSP	vehicle-specific power

Abstract

Increased traffic at North American land ports of entry (POEs) associated with transportation of goods affects air quality in border communities and beyond. In its 2013–2014 Operational Plan, the Commission for Environmental Cooperation (CEC) has provided support for researching and developing viable, integrated options for the implementation of vehicle emission-reduction mechanisms at selected land POEs. As part of the *Greening Transportation at North American Land Ports of Entry* project, this report presents a review of previous work related to air emissions at land POEs on the US-Canada and US-Mexico borders, classified by transportation mode, geographic region, pollutants analyzed, and the methodology that was followed. The report also highlights various strategies that reduce air emissions from transportation in general, with discussion on applicability to land POEs, as well as specific examples of interventions that have been implemented or recommended to reduce air emissions from the transportation sector at land POEs. The report concludes with recommendations for expanding best practices that deal with air emissions at North American borders.

Executive Summary

Increased traffic at North American land ports of entry (POEs) affects air quality in border communities and beyond. In its 2013–2014 Operational Plan, the Commission for Environmental Cooperation (CEC) has provided support for researching viable and integrated options for the implementation of vehicle emission-reduction mechanisms at selected land POEs as part of the project *Greening Transportation at North American Land Ports of Entry*.

The border-crossing process for commercial and privately-owned vehicles creates environmental challenges at some major North American land POEs. This report presents a review of previous work related to air emissions at land POEs on the US-Canada and US-Mexico borders and describes various air emission-reduction strategies from the transportation sector as the foundation to identifying best practices that have been implemented in North America and elsewhere to improve air quality and transportation flows at land POEs.

The literature review includes case studies that are classified by transportation mode, geographic region, pollutants analyzed, and the methodology that was followed, if applicable. Key findings are as follows:

- The majority of studies on emissions from the past 10 years were performed at the US-Mexico border. This could be because of the higher traffic volume growth rate at that border, compared to the US-Canada border, and because congestion issues are more prevalent at the US-Mexico border due to more stringent inspection processes.
- Because the US Environmental Protection Agency's (EPA's) MOBILE 6.2 was the official model used until December 2012, this tool was most commonly employed to analyze vehicle emissions at land POEs. Canada and Mexico follow similar methodologies with tools that are adapted to Canadian and Mexican conditions.
- Data integration and data collection on the Mexican side of POEs are difficult and create challenges to measuring vehicle emissions properly.

The report also describes eight best practices or recommendations to reduce air emissions, which are classified as vehicle technologies and system optimization/operation efficiencies. The table below describes the implementation status, environment and vehicle type associated with each practice.

Strategy Type	Best Practice	Status	Environment	Vehicle Type
Engine and Vehicle Technologies	Retrofit: Strategies to Reduce Particulate Matter at the Laredo/Nuevo Laredo Border Crossing	Recommendation	Border environment	Trucks
	Retrofit: San Diego-Tijuana Diesel Emissions Reduction Demonstration Project	Piloted	Border environment	Trucks
	SmartWay and *Transporte Limpio*	Implemented and operational	Urban and long-haul freight transportation	Trucks
System Optimization Operation Efficiencies	Washington State and British Columbia initiatives to reduce GHG emissions in the Cascade Gateway, Anti-idling program	Piloted	Border environment	Trucks and light-duty vehicles
	Port anti-idling program	In operation	Port drayage environment	Trucks
	Truck stop electrification	Implemented and operational	Urban and long-haul freight transportation	Trucks

	Border trusted-traveler programs	Implemented and operational	Border environment	Trucks and light-duty vehicles
	Eco-driving	Piloted	Border environment	Mainly trucks

This report also makes recommendations for expanding air emission-reduction best practices on North American borders, such as applying the BEST Urban Freight Solutions (BESTUFS) model, an international POE-related information network used by the European Union, to North America, under the leadership of the CEC.

Introduction

In 2013–2014, the Commission for Environmental Cooperation (CEC) supported work related to reducing air emissions from vehicles at land ports of entry (POEs) as part of its strategic objective to greening the North American economy. This report summarizes the work carried out as part of *Greening Transportation at North American Land Ports of Entry* project, whose objective is to research and develop viable, integrated options for implementing vehicle emission-reduction mechanisms at selected POEs.

The first outcome of this activity is a review and summary of all work related to air emissions at POEs on the United States (US)-Canada and US-Mexico borders and of best practices implemented in North America and elsewhere to improve air quality, transportation flows, and community and human health along the border. POEs on each border that may be used as demonstration projects were also identified, as well as sources of air quality data at or near US-Mexico and US-Canada POEs. The second outcome includes a description of best practices that have been implemented in North America and elsewhere to reduce air emissions and improve transportation flows and community health at land POEs.

This report is organized in seven sections, including: 1) a description of the international border-crossing process in North America; 2) data requirements to measure air emissions at land POEs; 3) the results of the literature review; 4) recommendations on potential measures and POE candidates for further analysis; 5) a description of various strategies to reduce air emissions from transportation; 6) several case studies of air emission-reduction best practices; and 7) a set of recommendations for expanding identified best practices on North American borders. The complete literature review can be found in Appendix I.

1. Border-Crossing Process in North America

The border-crossing process at North American land POEs entails the interaction of multiple stakeholders, sometimes with different objectives (see the location of land POEs in Figure 1). The commercial vehicle (CV) crossing process is more complicated than that for privately-owned vehicles (POVs) because it involves coordination and interaction of stakeholders from public and private sectors and from two different countries. Public-sector stakeholders include several federal agencies and state/provincial and local entities, while private-sector stakeholders include shippers, carriers, customs brokers, and third-party logistics providers. POV crossings between two countries usually involve only the participation of the immigration and customs agencies and the local authorities.

The interaction among stakeholders, particularly in the security inspection processes, creates vehicle delays and congestion, which increase vehicle emissions at POEs. The border-crossing processes for CVs and POVs at US-Mexico and the US-Canada land borders are described in this section.

Figure 1: Location of North American Land POEs (not showing POEs at the Alaska-Canada border)

Legend: ● indicates a border port

Source: US Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, Border Crossing/Entry Data; based on data from US Department of Homeland Security, Customs and Border Protection, OMR database.

Note: POEs shown are designated by US Customs and Border Protection. One POE could include more than one crossing.

1.1 Commercial Vehicle Border-Crossing Process[1]

The CV border crossing for US-bound shipments at the US-Mexico border requires additional steps than the one at the US-Canada border. The US-Mexico crossing is described first to contrast it with the US-Canada crossing.

Prior to entering the United States from Mexico through a land POE, carriers are required to file an electronic manifest (e-Manifest) with the US Customs and Border Protection (CBP) Automated Commercial Environment system for international truck shipments. The e-Manifests are filed at least 30 minutes prior to the estimated time of arrival for Free and Secure Trade (FAST) shipments and 60 minutes prior to the estimated time of arrival for non-FAST shipments. The e-Manifest enables the CBP to prescreen the shipper, carrier, driver, conveyance, equipment, and shipment information before the

[1] Much of the material in sections 1.1, 1.2 and 1.3 comes from Rajat R., Villa J., Macias, R., and W. Tate. 2012.

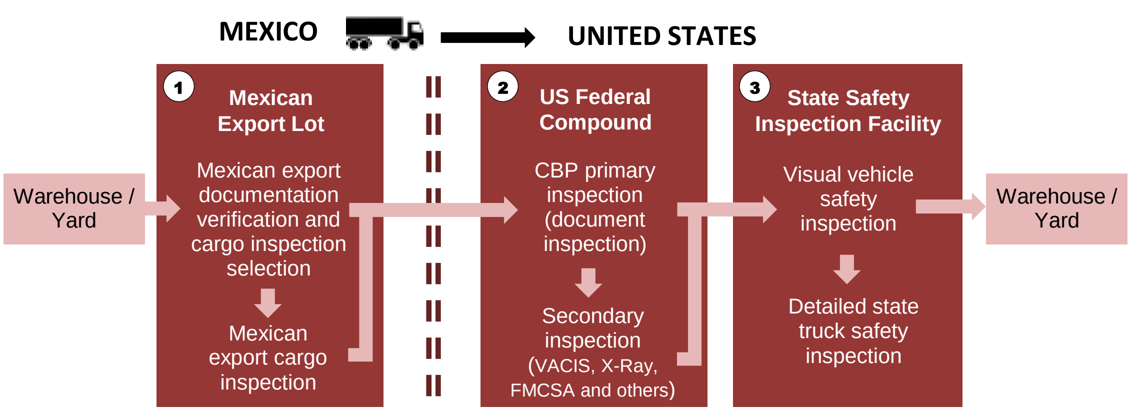
truck arrives at the border. This allows the CBP to focus its efforts on high-risk crossings and minimize unnecessary delays for low-risk crossings.

After submitting the e-Manifest at the US-Mexico border, the truck driver with required documentation proceeds to the Mexican customs agency (*Servicio de Administración Tributaria*, Aduanas) compound at the POE (Figure 2, step 1). For audit and interdiction purposes, the Aduanas staff conducts inspections, consisting of a physical review of the cargo of randomly selected outbound freight prior to export.

After clearing the Aduanas inspection, trucks head to the border toward CBP's primary inspection booth, where drivers present identification and shipment documentation to CBP officers (Figure 2, step 2). The officers at the primary inspection booth use computer terminals to cross-check the basic information about the driver, vehicle, and cargo with information sent previously by the carrier in the e-Manifest. The CBP officers then make decisions to refer trucks, drivers, or cargo for more detailed secondary inspections of any or all of these elements, or alternatively release trucks to the exit gate. Inside the federal facility, there are other US federal agencies, including Department of Transportation and agricultural agencies that could also perform inspections, as required.

After leaving the US federal facility, trucks enter the state's safety inspection facility, which is usually located adjacent to the federal facility (Figure 2, step 3). Typically, the state's safety agency inspects trucks to determine whether they are in compliance with US safety standards and regulations. If the initial visual inspection finds any safety or regulatory violations, the trucks are directed to proceed to a more detailed secondary inspection at a special facility. After leaving the state facility, trucks typically drive to the freight forwarder or customs broker yard to drop off the trailer for later pickup by a long-haul tractor bound for the final destination. This is illustrated in Figure 2.

Figure 2: Border-Crossing Process for a US-bound Commercial Vehicle from Mexico



Source: Villa 2006.

Commercial merchandise being exported from the United States into Mexico requires filing import documentation with Aduanas, and this is usually done by a Mexican customs broker, who is responsible for filing documentation with appropriate customs classification codes and, if necessary, for paying import duties. The truck driver has a copy of the documentation and the authorities at the border could request it. Once the truck arrives at the booth, there is only one inspection station at Aduanas. The process in Mexico is a red-light/green-light decision in which a loaded CV is randomly selected for a secondary inspection if it receives a red light. Empty vehicles cross with no need to stop at the Aduanas booths. An Aduanas algorithm determines the relative risks and needs to send a CV to secondary inspection. This probability is processed when the vehicle is detected and triggers a red-light/green-light decision.

At a few border crossings, the CBP has recently started to perform random manual inspections on the US side of the border for CVs crossing into Mexico, aiming to identify illegal shipments of money and weapons. The existing border crossings facilities are not designed for southbound commercial inspection on the US side of the border, and consequently this has created congestion at the POE and on approaching facilities.

US-bound CVs from Canada are also required to file the e-Manifest with the CBP prior to shipments arriving at the US-Canada border. The difference between the US southern and northern border-crossing processes is that at the northern border, there are no vehicle safety inspections, and the Canada Border Services Agency (CBSA) does not perform an inspection for exported goods.

The Canada-bound process for exports from the United States also requires one potential inspection at the CBSA facility. The CBSA has proposed regulations requiring all trucks carrying freight into Canada to provide advance conveyance and shipment information via an e-Manifest. Voluntary e-Manifest submissions began in October 2012, and the CBSA estimates that more than 95 percent of cross-border carriers are already using the system (International Trade Compliance Strategies 2014).

1.2 The Border-Crossing Process for Privately-owned Vehicles

Passenger vehicles entering the United States from Mexico or Canada proceed to the US federal facility where they go through primary and sometimes secondary inspections. At primary inspection booths, CBP officers must ask the drivers to show proper documentation (e.g., a US visa, proof of US citizenship, or a permanent resident card) and state the purpose of their visit to the United States. If necessary, vehicles are sent to secondary inspection, where a more thorough investigation is performed of the identity of those wanting to enter the United States, as well as of the purpose of their visit. During this step, individuals may also have to pay duties upon their declared items. Upon completion, access to the United States is either granted or denied.

Similar to the FAST program for CVs, the Secure Electronic Network for Travelers Rapid Inspection (SENTRI) at the US-Mexico border and the NEXUS at the US-Canada border are trusted-traveler programs that have been implemented. These programs provide expedited processing for pre-approved, low-risk travelers at the US borders with Canada and Mexico. Applicants must voluntarily undergo a thorough biographical background check against criminal, law enforcement, customs, immigration, and terrorist indices; a 10-fingerprint law enforcement check; and a personal interview with a CBP officer. Once an applicant is approved, he or she is issued a document with radio frequency identification (RFID) that will identify their record and status in the CBP database upon arrival at the border crossing. When an approved international traveler approaches the border in the SENTRI or NEXUS lanes, the system automatically identifies the vehicle and the identity of its occupant(s) by reading the file number on an RFID card. Participants in the program have much shorter wait times to enter the United States than those in regular lanes.

POV crossings from the United States into Mexico do not require filing documentation in advance; there is only one inspection station at Aduanas. The process at the US-Mexico border is a red-light/green-light decision in which passenger vehicles are randomly selected for a secondary inspection, indicated by a red light. An Aduanas algorithm determines the relative risks and needs to send a passenger vehicle to secondary inspection. This probability is processed when the vehicle is detected and triggers a red-light/green-light decision. Aduanas has also installed automatic license plate readers to verify individual license plates and identify violators with criminal records.

At the US-Mexico border, the CBP has recently started to perform random manual inspections on the US side of the border for POVs crossing into Mexico, aiming to identify illegal shipments of money and weapons. The POEs are not designed for southbound inspection on the US side of the border, and consequently this has created congestion.

For entry into the United States via land and sea borders, US citizens must present either a US passport, passport card, NEXUS card, Enhanced Driver's License, or another Western Hemisphere Travel Initiative–compliant document. The only exception to this requirement is for US citizens under the age of 16 (or under 19 if traveling with a school, religious, or other youth group), who need only present a birth certificate, Consular Report of Birth Abroad, or naturalization certificate.

POVs crossing from the United States into Canada have only one inspection station at the CBSA facility, and the process is very similar to the one performed entering the United States from Canada. At the primary inspection booth, a CBSA officer requests to see a passport and a valid visa. US citizens do not need a passport to enter Canada; however, proof of citizenship, such as a birth certificate, certificate of citizenship or naturalization, or Certificate of Indian Status, and a photo ID are required. At US-Canada POEs, there are NEXUS lanes that operate in a similar way to the US-bound ones, reducing wait times for enrolled users.

1.3 Pedestrian Border-Crossing Process

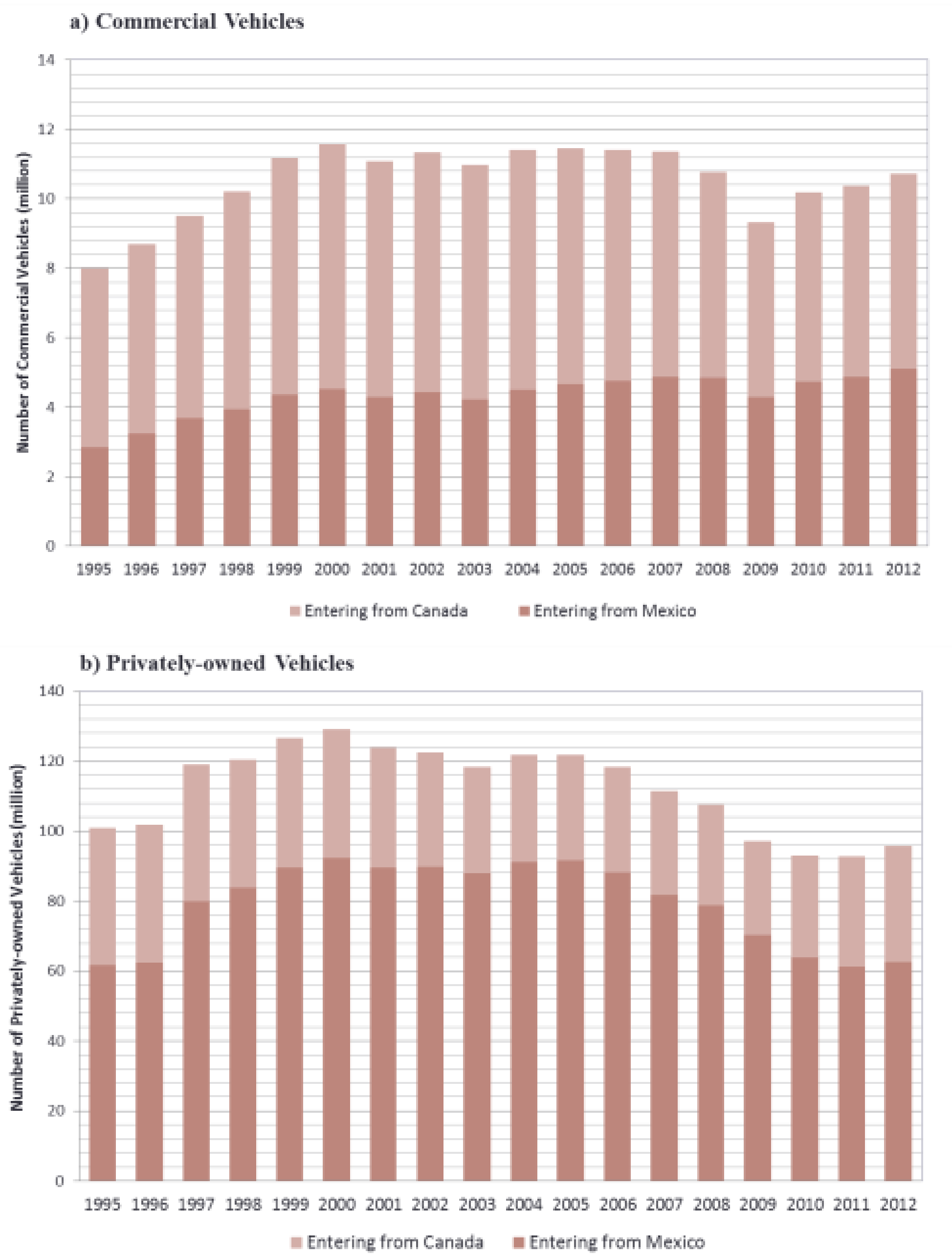
Pedestrians desiring to enter into the United States from Mexico proceed directly to the US federal facility, where pedestrians go through primary and sometimes secondary inspection. At the inspection facility, CBP officers must ask the individuals who want to enter the country to show proper documentation such as a visa, green card, or passport, and to state the purpose of their visit to the United States. A vast majority of Mexican nationals crossing through land border crossings carry border crossing cards (BCCs) to enter into the United States. A BCC may be issued as a laminated card, which has enhanced graphics and technology and is similar in size to a credit card, or a passport visa. BCCs and visas are valid for travel until the expiration date on the front of the card or on the visa, usually 10 years after issuance. US citizens and lawful permanent residents are required to carry US passports, "green cards," or Global Entry Cards to enter into the United States through the land border crossings. At some POEs and during high demand time periods, pedestrians trying to cross into the United States have to stand next to vehicles idling in line as they wait to cross into the United States.

Mexico-bound pedestrians that have indicated their Mexico citizenship are not subject to inspections on either the US side or the Mexican side of the border. Non-Mexican pedestrians are, however, required to show their visa documents at the Mexican immigration office. Pedestrians heading into Mexico rarely experience long queues.

1.4 North American Border-Crossing Volumes

In 2012, more than 95.5 million POVs and 10.5 million CVs crossed the border from Canada and Mexico into the United States. In the period from 1995 to 2012, the increase in commercial vehicles crossing from Mexico to the US grew 78 percent, with a 58 percent increase by 1999, while CV crossings from Canada into the US saw a more modest growth (10 percent), as shown in Figure 3a. POV cross-border traffic fluctuated slightly between 1995 and 2012; a maximum was reached in 2000 with close to 130 million crossings into the United States from Canada and Mexico. Since 1995, the number of POVs that crossed into the US from Mexico has been on average over twice the number that crossed from Canada, as shown in Figure 3b.

Figure 3: Commercial Vehicle Crossings (a) and Privately-owned Vehicle Crossings (b) from Canada and Mexico into the United States.



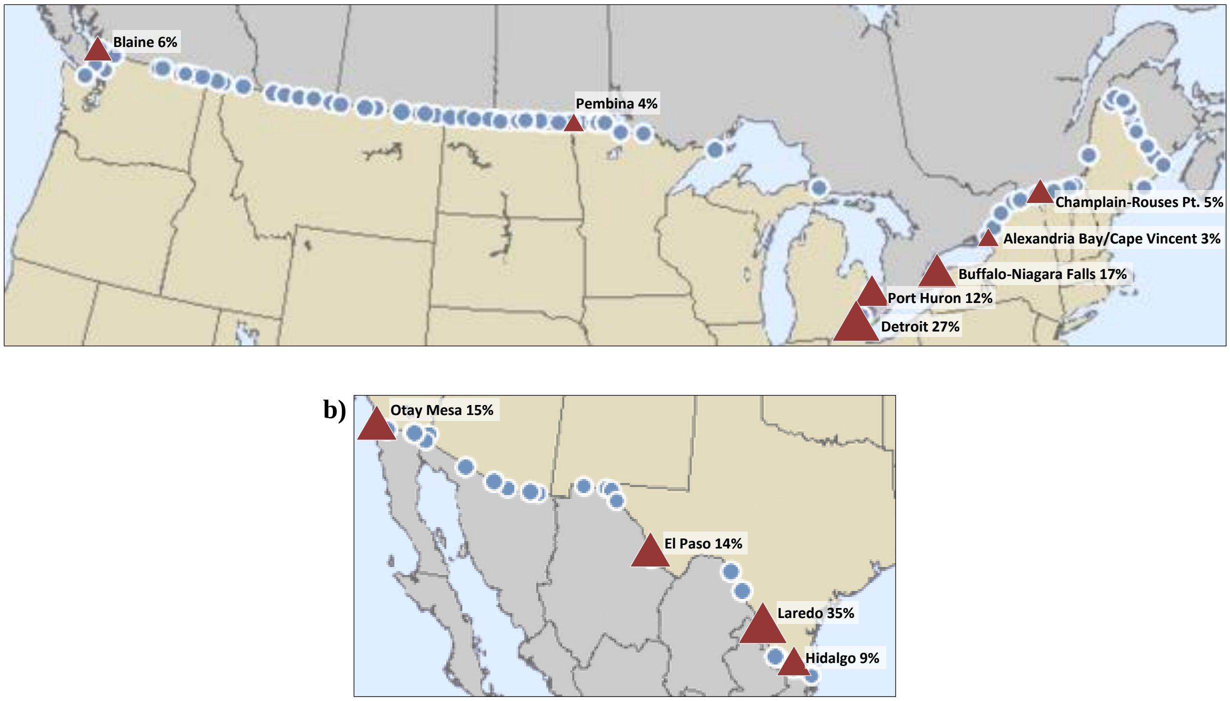
Source: US Department of Transportation, Bureau of Transportation Statistics, TransBorder Freight Data.

The data also show that there are 79 international POEs that processed trucks at the US-Canada border; however, seven POEs processed three-quarters of the total crossings into the United States (Figure 4a). At the US-Mexico border, the concentration is even higher, with four crossings concentrating three-quarters of the total commercial traffic (Figure 4b).

Figure 4: Percentage of Commercial Vehicle Crossings into the US, by POE, at (a) the US-Canada Border (not considering POEs at the Alaska-Canada Border), and (b) the US-Mexico Border, 2012 data

a)

b)



Note: POEs shown are designated by US Customs and Border Protection. One POE could include more than one crossing.

Source: US Department of Transportation, Bureau of Transportation Statistics, TransBorder Freight Data, 2012.

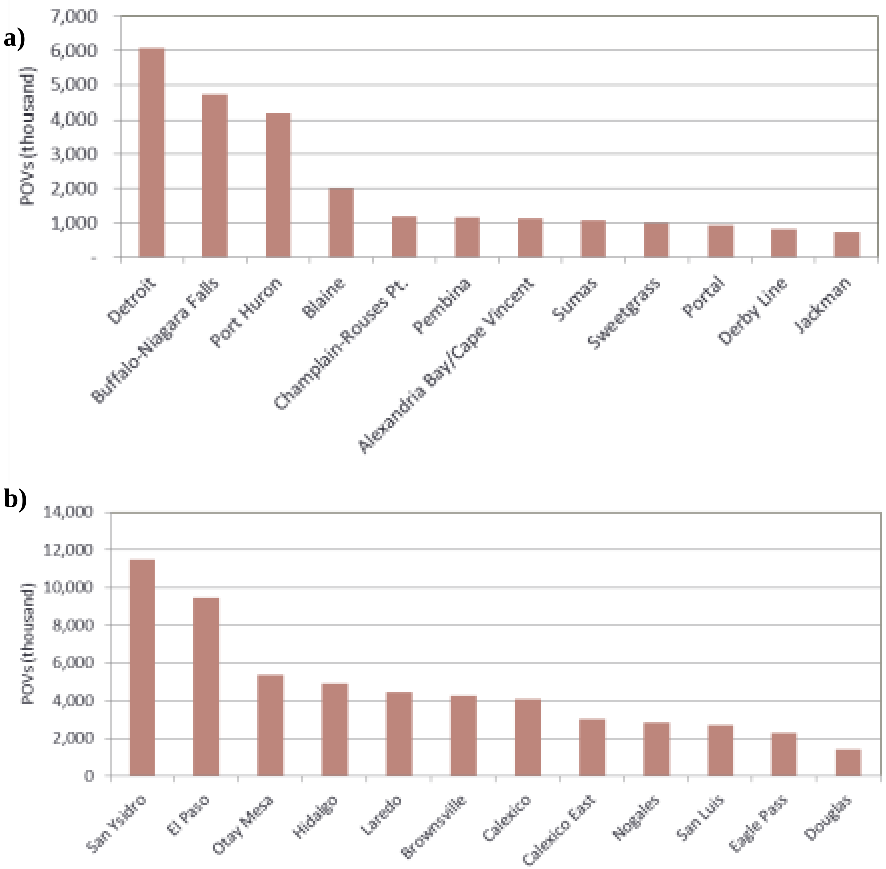
The concentration of POV crossings into the United States is similar, with 12 POEs concentrating three-quarters of the total crossings at the US-Canada border, and 12 POEs concentrating 90 percent of the total crossings at the US-Mexico border (Figure 5a and b).

The implications of this concentration of POVs and CVs at a few POEs are that even though there is ample infrastructure across the North American borders, a handful of them handle most of the traffic, creating congestion and delays. Vehicle delays, in most cases, cause additional emissions that impact the binational regions where POEs are located. Border crossing and wait times vary from crossing to crossing, but the most congested commercial vehicle POEs have reported crossing times of up to four hours, while POVs can experience crossing times of up to two hours. North American federal and local agencies are implementing technology to measure border-crossing volumes and wait times on a regular and systematic way. Wait-time data will provide decision makers with reliable information to identify solutions and reduce times at the border.

Figure 5: Number of Privately-owned Vehicle Crossings into the US at the Twelve Busiest POEs, (a) US-Canada Border and (b) US-Mexico Border, 2012 data

a)

b)



Note: POEs shown are designated by US Customs and Border Protection. One POE could include more than one crossing.

Source: US Department of Transportation, Bureau of Transportation Statistics, TransBorder Freight Data, 2012.

2. Data Requirements to Estimate Air Quality at Land Ports of Entry

2.1 General Data Requirements

Measurement of vehicle emissions is based on two key elements: the volume of vehicle activity per unit of time or distance, and emission factors in terms of mass per time or distance. These two key elements are estimated based on various input parameters such as fleet characteristics, roadway classification and grade, fuel formulation and market share, and meteorology.

Vehicle fleet characteristics are major input parameters and are determined by the make and model year of the vehicles operating in the area under consideration. In border regions, fleet characteristic information is difficult to estimate if vehicle registration information is not kept up-to-date or there is no reliable field information. Even when good record-keeping practices are followed, an effort to match records from the two neighboring counties is required in order to estimate the vehicle fleet that operates at the border region under analysis. The characteristics of the vehicles involved in border crossing might be different from the average vehicle fleet of both countries; e.g., border drayage vehicles tend to be older than the fleet average, and therefore local data are recommended.

The vehicle activity is usually obtained in the United States and Canada from local travel demand models. The models produce estimates of vehicle-miles traveled (VMT) on various roadway segments or links. For urban areas that do not have travel demand models in the United States, data from the Highway Performance Monitoring System are used to determine hourly VMT by roadway type for each county. Usually Mexican border regions do not have travel demand models; therefore, it is difficult to estimate VMT at the Mexican side of the border. Vehicle activity could be estimated based on roadway counts and specific origin-destination surveys.

Emission factors are estimated by vehicle type and for different pollutants. Emission rates in the United States are calculated with the EPA's Motor Vehicle Emission Simulator (MOVES) model. Emission rates are developed separately for freeway and arterial links and matched to the hourly VMT, based on average hourly operating speed. Input data for MOVES include local fuel formulation and market share, hourly temperature and humidity, and inspection and maintenance inputs based on locally observed data from specific time periods. This provides a more accurate characterization of emissions for the days chosen for modeling. A brief description of MOVES is presented in the following section.

2.2 Motor Vehicle Emission Simulator

EPA developed an emissions modeling system called MOVES to estimate emissions for mobile sources including automobiles, trucks, and motorcycles. MOVES was released in 2009 to replace MOBILE6.2, EPA's previous model for on-road mobile sources. Compared with the previous model, MOVES incorporates a more sophisticated modeling approach using new emissions test data, changes in vehicle technology and regulations, and an improved understanding of in-use emissions levels. Additionally, the software framework also includes many new features and provides more flexibility for input and output options than MOBILE6.2. The current version, MOVES 2010b, was released in June 2012.

The MOVES model is currently required for all new regional emissions analyses for transportation conformity and project-level hot spot analyses. New input options in MOVES and changes in the way MOVES handles existing information require the user to create local information for an accurate analysis (EPA 2009b). Users of the model specify vehicle types, time periods, geographical areas, pollutants, vehicle operating characteristics, and the road types being modeled. MOVES also incorporates estimates of energy consumption. The model was designed to work with databases, allowing for new and updated data to be more easily incorporated into the model. The default database summarizes emissions information for the entire United States and is drawn from EPA research studies, Census Bureau vehicle surveys, Federal Highway Administration (FHWA) travel data, and other federal, state, local, industry, and academic sources.

To use the model, the user prepares a Run Specification to define the place, time, vehicle, road, fuel, emission-producing process, and pollutant parameters. These specifications are described as follows:

- Place: Nation, state, and county levels can be selected.
- Time: Time can be aggregated into hour (default), day, month, or year.
- Vehicle: Mobile source types include motorcycle, passenger car, passenger truck, commercial truck, bus (intercity, transit, and school), and freight truck (short haul and long haul).
- Road type: The user can select from a list of roadway types in the database that represent urban and rural driving on roads with restricted and unrestricted vehicle access.

- Pollutants: The user can select from a list of pollutants, including total gaseous hydrocarbons (THC), carbon monoxide (CO), oxides of nitrogen (NO_x), sulfate particulate matter (PM), tire wear and brake wear particles of less than 2.5 or 10 µm in size ($PM_{2.5}$ and PM_{10}), methane (CH_4), nitrous oxide (N_2O), carbon dioxide (CO_2) on an atmospheric basis, and the CO_2 equivalent of CO_2 combined with N_2O and CH_4 (CO_2e).
- Processes: These refer to the mechanisms by which emissions are created, including evaporative permeation, evaporative fuel vapor venting, and evaporative fuel leaks.

The flexible configuration of MOVES, which is based on a database-centered structure, gives more flexibility to users to control the local parameters. Most importantly, the model does not specify a fixed coding for the driving patterns representing the different traffic conditions and average traffic speeds. Users can create and use local drive schedules (i.e., drive cycles) to perform an accurate analysis. This feature is especially critical for project-level and unique applications such as border crossings.

MOVES uses a disaggregate emissions estimation algorithm that enables it to perform estimation at different analysis levels such as at the national, state, and local level. The MOVES model is equipped with default drive cycles that are representative of driving patterns aggregated across different types of roadways, roadway characteristics, and driver behaviors for the United States. While these composite cycles are effective in large-scale emissions modeling, they are less effective in terms of micro-level analysis, such as for specific roadways (or border crossings) or specific vehicle classes.

MOVES uses a disaggregated measure for vehicle activity, called vehicle-specific power (VSP), which is a combined measure of instantaneous speed, acceleration, road grade, and road load (EPA 2009a). The emissions associated with a particular driving pattern are modeled, based on the distribution of time spent in operation modal (opMode) bins that are defined based on VSP bins and speeds. In addition to exhaust and evaporative emissions, MOVES also provides estimates of brake and tire wear emissions.

Drive schedules that represent typical operational states at different average speeds for each vehicle type operating on a road are used to translate average speed information into VSP values and then an opMode distribution. VSP is calculated on a second-by-second basis for a vehicle operating over these drive schedules.

3. Literature Review Analysis

3.1 Summary of Literature Consulted

A literature review of existing case studies related to the transportation impact of vehicle emissions on human health and the environment at land POEs is presented in Appendix I.[2] Most studies concerned vehicle emissions, with relatively few measuring air concentrations or effects on human health near the POEs. A relatively minor amount of information regarding the impact of emissions produced by motor vehicles at land POEs was found. The literature search did not find any experiences outside the US-Mexico or US-Canada borders. The documents that were found are organized in three categories: North American borders, the US-Mexico border, and the US-Canada border. Findings were also classified by vehicle category when possible.

A summary of the analyzed documents is presented in Table 1. The summary includes the transportation modes that were included in the analysis, the region for which the study or program was performed, the pollutants that were analyzed, the methodology, and general comments. A total of 21documents were identified and analyzed: four of them studying vehicle emissions at the North American level, 12 of them at the US-Mexico border, and five at the US-Canada border.

[2] The research team reviewed significant literature that was completed during the past 10 years. Texas A&M Transportation Institute (TTI) researchers made use of TTI's library and industry contacts to identify previous work at land POEs in North America and other parts of the world. The review was based on published studies, presentations, and any other documents containing keywords that would help identify the state of the practice in border crossing air emissions and their classification (vehicle type/POE).

Table 1: Summary of Literature Review

Study/Report	Transp. Modes	Region	Pollutants Analyzed	Methodology/Observations
Greening North American Transportation Corridors: Challenges and Opportunities (TTI 2010)	CV, rail	North America (Laredo-Nuevo Laredo, Detroit-Windsor, Port Huron-Sarnia)	CO_2, CO, NO_x and hydrocarbon (HC) PM	MOBILE6.2 data with *ad hoc* modeling. Vehicle activity data from FHWA's Freight Analysis Framework, border statistics, and other sources in Canada.
"Sustainability and Freight Transportation in North America" (Villa and Protopapas 2010)	CV, rail	North America (Canada-US-Mexico major land POEs)	GHG	Direct and indirect methods: MOBILE6, National Mobile Inventory Model, EMFAC2007, MOVES, US Inventory of Greenhouse Gases, and State Inventory and Projection Tool.
Environmental Assessment of NAFTA by the Commission for Environmental Cooperation: An Assessment of the Practice and Results to Date (Aguilar et al. 2011)	POV, CV, bus, rail, airplane	North America (Canada-US-Mexico major land POEs)	*N/A*	Environmental assessment covering the social and economic effects of the North American Free Trade Agreement (NAFTA)/air quality impact analysis (no specific pollutant was measured).
Greening Transportation at the Border (FHWA 2011)	POV, CV, bus, rail, airplane	North America (Canada-US-Mexico major land POEs)	*N/A*	Implementation of sustainable transportation options toward reduction of environmental impacts while improving air quality, public health, and wildlife and habitat connectivity/air quality impact analysis (no specific pollutants were measured).
Developing an Emissions Estimation Tool for El Paso Border Crossings. Draft (Farzaneh et al. 2013)	POV, CV, bus	United States-Mexico (El Paso region)	THC, CO_2, CO, NO_x, PM and PM-elemental carbon (EC)	Methodology to specifically estimate the emissions produced at border crossings using MOVES model to develop the emissions rates and construct a tool.
"United States-Mexico Land Ports of Entry Emissions and Border Wait-Time White Paper and Analysis Template" (Cambridge Systematics, Inc. 2013)	POV, CV, bus	United States-Mexico (Ysleta-Zaragoza)	NO_x and PM	VISSIM micro-simulation model combined with MOVES or EMFAC depending on the scenario.
US-Mexico Border Region Greenhouse Gas Inventories and Policy (Ross and Associates 2009)	POV, CV, bus	United States-Mexico (border region states: CA, AZ, NM, TX, Baja Calif., Son, Chih, Coah., N. León and Tamps.)	GHG	Measuring levels of pollution (GHG) using monitoring facilities and reports on both sides of the border.

Study/Report	Transp. Modes	Region	Pollutants Analyzed	Methodology/Observations
Greenhouse Gas Emissions Due to Vehicle Delays at the San Diego-Tijuana Border Crossings (Barzee 2010)	POV, CV, bus	United States-Mexico (San Diego County POEs: San Ysidro, Otay Mesa, Tecate)	GHG	Emission factors for each lane category (passenger, commercial, and bus) were obtained by running the EPA MOVES2010 project level model. Input parameters included vehicle age profiles and three second-by-second speed profiles. Data input for MOVES model were obtained using 2009 estimations. 2009 estimations are considered atypical due to economic recession and escalated violence in Mexico.
"Black Carbon and Polycyclic Aromatic Hydrocarbon Emissions from Vehicles in the United States-Mexico Border Region: Pilot Study" (Kerry et al. 2006)	POV, CV, bus	United States-Mexico (Calexico, Mexicali, El Paso, Ciudad Juárez POEs)	BC, CO_2 and PAH	Innovative method by implementing measurement systems along roadsides, monitoring vehicle emissions, and calculating a fuel-based emission factor.
Tier II Air Quality Technical Report for Construction Emissions for State Route 11 and the Otay Mesa East Port of Entry (Thompson 2010)	POV, CV	United States-Mexico (Otay Mesa)	BC, CO and PM	Concentration analysis using monitoring stations and US EPA's guidelines.
Mitigating Cross-Border Air Pollution: The Power of a Network (Cresswell et al. 2009)	POV, CV	United States-Mexico (Ciudad Juárez, Chihuahua/El Paso, Texas/Doña Ana County, New Mexico Air Basin region)	*N/A*	Exploration of best practices to mitigate air pollution/air quality impact analysis (no specific pollutant was measured).
Mariposa Port of Entry Bottleneck Study (Nogales Sonora-Nogales Arizona) (Golob et al. 2008)	POV, CV	United States-Mexico (Mariposa POE: Nogales, AZ-Nogales, Sonora)	*N/A*	Bottleneck identification at the POE's surrounding areas. Authors recommend a set of actions to improve congestion mitigation strategies (no specific pollutant was measured).
US-Mexico Border 2020 (EPA 2014a)	POV, CV, bus, rail, airplane	United States-Mexico (border region states: CA, AZ, NM, TX, Baja California, Sonora, Chihuahua, Coahuila., Nuevo León, Tamaulipas)	*N/A*	Development of guiding principles to support the mission statement of the Border 2020 binational program/air quality impact analysis (no specific pollutant was measured).
*Developing a Strategy to Reduce Particulate Matter as Part of the "*Transporte Limpio*" Program* (TTI 2013)	CV	United States-Mexico (Laredo/Nuevo Laredo region)	PM	Analyzed CV fleet and trip characteristics, and prepared a cost/benefit analysis to recommend technologies to reduce PM emissions. Diesel oxidation catalysts were recommended, and an implementation plan was developed.

Study/Report	Transp. Modes	Region	Pollutants Analyzed	Methodology/Observations
Quantification of Selected Sources for Emission Inventory Improvement in El Paso, Texas (Yang et al. 2012)	POV, CV, bus, rail, airplane	United States-Mexico (All four El Paso-Ciudad Juárez POEs)	CO, NO_x, PM and VOC	Emission factors by hour of the day were developed using the EPA's MOVES 2010b.
Impactos en la Salud de los Cruces Fronterizos En México—Estados Unidos Puertos de Entrada: Deficiencias, Necesidades y Recomendaciones para Acciones (EPA-SCERP 2012)	POV, CV, bus, rail	United States-Mexico	PM_{10}, $PM_{2.5}$, BC, NO_2, SO_2, VOC, CO and ultrafine particle (UFP)	Summarizes recommendations and findings regarding health impacts along the US-Mexico border and communities near the POEs after a two-day meeting in San Ysidro, California, in May 2012.
Interim Report: Phase 1 of the Air Quality Study of the Impact of the Peace Bridge Plaza on the Surrounding Neighborhood (NY DEC 2013)	CV	Canada-United States (Peace Bridge Plaza POE)	$PM_{2.5}$ and BC	Data collection at two different monitoring locations near the Peace Bridge Plaza and surrounding areas. Results indicated that, on average, there is no significant source of $PM_{2.5}$, and concentrations of black carbon (BC) were relatively small. National Ambient Air Quality Standards for Particulate Matter procedure was used to measure $PM_{2.5}$.
Greening the Border. Idle Reduction at the Peace Arch Border Crossing (BC Ministry of Transportation and Infrastructure 2014)	POV, CV	Canada-United States (British Columbia/ Washington State, Peace Arch Border Crossing)	GHG	The initiative includes installation of traffic signals to move waiting traffic in a series of pulses (vehicle coordinated platoon movements), allowing motorists to turn off their engines while waiting for traffic ahead to clear.
Air Toxics Exposure from Vehicle Emissions at a US Border Crossing: Buffalo Peace Bridge Study (Spengler et al. 2011)	POV, CV, bus	Canada-United States (Buffalo Peace Bridge)	VOC, PAH and nitro-polycyclic aromatic hydrocarbon	Measurements of a large number of compounds caused by diesel and gasoline vehicles.
Understanding Pacific Highway Commercial Vehicle Operations to Support Emissions Reduction Programs (Goodchild and Klein 2011)	CV	Canada-United States (Pacific Highway POE)	*N/A*	The logistic study (policy, border crossing procedures, and other factors considered in the research) was based on data collection and data analysis (including statistical). No air quality assessment was directly performed.
Preliminary Air Quality Assessment Related to Traffic Congestion at Windsor's Ambassador Bridge (Diamond and Parker 2004)	CV	Canada-United States (Ambassador Bridge POE, Windsor, Ontario)	PM_{10}, $PM_{2.5}$ and VOC	Researchers used short-term air quality surveys using a portable particulate monitor and VOC cartridge sampler. Data collection and analysis were performed in 2002 and 2003.

3.2 Literature Review—Findings and Recommendations

This section provides a summary of findings based on the literature review on air pollution measurements and methods in North America's land border regions:

- Even though MOVES is EPA's most recent on-road emissions model, emission analyses done with MOBILE 6.2 are the most commonly found in the existing literature reviewed. One reason could be that MOVES was launched in 2010, and some of the analyses were done prior or in that year. Most likely, future GHG emissions and energy consumption analyses will be done using MOVES.
- EPA's emission analysis procedures are typically originated and implemented in the United States and then adopted first by Canada and second by Mexico. As a result, approaches and methods/models are identical to the ones developed in the United States. Nevertheless, each country uses its corresponding data, such as fuel consumption rates and vehicle fleet characteristics, when data are available.
- Challenges were found in data integration and data collection (monitoring equipment) on the Mexican side of the border at US-Mexico POEs. Moreover, the United States and Mexico monitor different pollutants, making data integration difficult across the border.
- In general terms, studies and technical reports along the US-Mexico border were more common than along the US-Canada border, and the only health study was done at the US-Canada border. A possible reason could be that congestion levels at the US-Mexico border (at least for POVs) are much higher than at the US-Canada border due to traffic volume and inspection procedure differences. As described in Section 1, POV volume reported in 2012 indicates that the US-Mexico POEs had almost double the volume reported at the US-Canada POEs.
- Every POE has different characteristics in terms of layout, traffic volumes, vehicle category, geography, etc. Therefore, it would be difficult to replicate interventions without a detailed analysis of the specific characteristics of each POE. For instance, the Greening the Border Climate Action Initiative that contemplates the installation of traffic signals (stopping motor vehicle engines) could be extremely uncomfortable for motorists traversing a desert area POE when temperatures are very high.

Recommendations

- Ensure a unified North American approach to data quality and collection methods and, through publications on the CEC website, distribute necessary information and guidance to stakeholders and authorities.
- Carry out joint monitoring procedures, data collection, data inventories, and environmental planning at selected border regions to ensure high data quality.
- Verify POE characteristics with border agencies, provinces/states and local stakeholders to confirm the feasibility of implementing best practices and procedures, and potential adaptation processes.

4. Strategies to Reduce Air Emissions from Transportation[3]

General strategies to reduce air emissions from transportation vehicles can be organized in four broad categories, as shown in Figure 6:

- Fuel Technologies
- Engine and Vehicle Technologies
- System Optimization/Operational Efficiency
- Smart/Sustainable Growth

A positive step toward reducing air emissions would be to reduce dependence on highly polluting fossil fuels and consider alternatives that are less damaging to the environment. Owing to the fact that CO_2 makes up such a large percentage (95 percent) of the total greenhouse gases (GHGs) emitted by transportation modes, an effective mitigation strategy is to reduce CO_2 production from the source by shifting to low-carbon fuels (the higher the carbon content of a fuel, the greater the CO_2 emissions resulting from its combustion). The idea is to replace existing fuels with others of the same thermal efficiency but lower carbon content. A wide variety of alternative fuels have the potential to replace fossil fuels, although with varying degrees of success. Alternative liquid fuels include biodiesel, ethanol, methanol, synthetic gasoline, and diesel made from natural gas, coal, or other feedstocks. Gaseous fuels include compressed natural gas, propane (liquefied petroleum gas), dimethyl ether (a diesel substitute), and hydrogen.

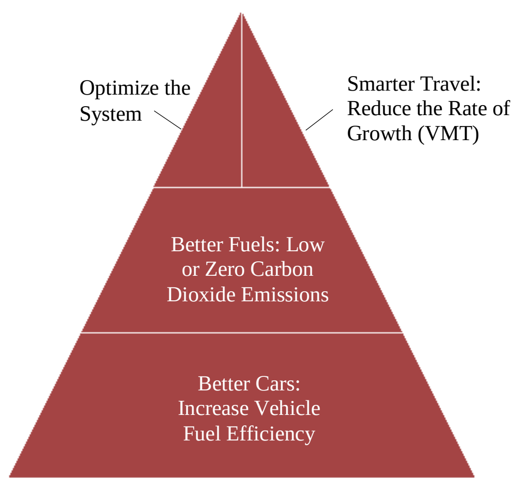


Figure 6: The GHG Emission Reduction Strategies Pyramid

The US–Mexico border environment presents an opportunity to implement programs with alternative fuels, particularly for cross-border truck transportation. Most US–Mexico cross-border freight transportation is performed by drayage trucks that operate within a specific well-defined region. Alternative, low-emitting fueling stations could be installed at major land POEs, and ideally, if resources are available, alternative fueling infrastructure could be installed upstream along major freight corridors leading to and from the POE on both sides of the border. The concept is less applicable to the US–Canada border. Unlike most of the US–Mexico cross-border freight transportation, cross-border trucking at the Canada–US border extends beyond a defined border zone.

A limited scope 'pilot project' might be considered in the future, where a small-fleet drayage operator that provides cross-border services could be equipped with alternative fueling stations at its operating base.

4.1 Engine and Vehicle Technologies

Air emissions associated with CVs or POVs can be reduced by one or a combination of the following means:

- reducing the loads (weight, rolling and air resistance, and accessory loads) on the vehicle, thus reducing the work needed for its operation

[3] Much of the material in this section comes from the authors' work published in Villa, J.C. and A. Protopapas 2010.

- increasing the efficiency of converting the fuel energy to work, by improving drive train efficiency and recapturing energy losses
- reducing emissions from vehicle exhaust and climate controls

The loads on the vehicle consist of the force needed to accelerate the vehicle to overcome inertia; vehicle weight when climbing slopes; the rolling resistance of the tires; aerodynamic forces; and accessory loads. There are a range of measures to improve engine efficiency, which indirectly impacts the amount of air emissions from the vehicle: increasing thermodynamic efficiency, reducing frictional losses, and reducing pumping losses (these losses are the energy needed to pump air and fuel into the cylinders and push out the exhaust). Each kind of measure can be addressed by a number of design, material, and technology changes.

Also, some of the energy used to overcome inertia and accelerate the vehicle—normally lost as heat when vehicle speed is reduced, aerodynamic forces take effect, rolling resistance increases, and mechanical brakes are applied—may be recaptured as electrical energy if regenerative braking is available.

The border operation environment, where CVs and POVs operate at low speeds, might not yield to reducing frictional losses, but there might be room for improvement in thermodynamics and pumping losses.

4.2 System Optimization/Operational Efficiency

System efficiency can be achieved through operational strategies that change the way vehicles are used, either within each modal system or across two or more modal systems. Strategies to promote system efficiency within each mode include reducing idling at origins, destinations, and intermediate points, through for example, electrification or auxiliary power units for CVs.

Other measures that have been implemented to reduce emissions from CVs include:

- improving driving practices
- optimizing routing to reduce backtracking and empty miles
- reducing shipment frequency
- decentralizing supply chain origins
- improving local distribution systems
- decreasing non-revenue-producing payload such as excess packaging
- increasing the use of longer/heavier trucks and longer trains
- increasing the use of double-stacked containers on trains

Tools such as Intelligent Transportation Systems (ITS) and global positioning systems (GPS) can aid in the implementation of operational changes and optimization to achieve system efficiencies.

The border environment presents an opportunity to implement operation efficiencies, both for CVs and POVs. Some border regions have more than one alternative to cross, therefore a routing system aided by GPS or ITS technologies could provide users with the route with less wait time and reduce idling at queues.

CVs represent the largest area of opportunity for system optimization or operational efficiency interventions at POEs. The US Department of Transportation has been conducting research-based pilot projects of Freight Advanced Traveler Information Systems (FRATIS) at marine ports. The experience from the FRATIS program could be expanded to land POEs.

Truck-stop electrification or auxiliary power units at points of origin or destination, and even at the border crossing facility itself, have been proposed. Trucks would stop at an "electrified" location, where engines could be switched off while awaiting their turn to cross the border. Coordination with various stakeholders from public and private sectors (shippers, carriers, and border inspection agencies) would be necessary for successful implementation of such initiatives.

4.3 Smart/Sustainable Growth

Activity reduction refers to direct or indirect reduction in vehicle-miles traveled, hence reduction of air emissions. Reducing overall congestion along a route or at border crossings through, for example, integrated transportation planning that better accounts for land uses and vehicle movements, can achieve overall air emission reductions. This class of mitigation strategies presents major future opportunities and, at the same time, challenges to the public sector as it requires redirecting overall focus toward sustainable transportation planning or "smart growth."

As mentioned earlier, decisions about border planning involve many stakeholders from two countries and different levels of government. Making changes to the planning process in a border region has proven to be a difficult task; therefore, the smart and sustainable growth initiatives are hard to implement.

The Northwest Ports Clean Air Strategy is a good example of international collaboration with maritime ports and environmental agencies. In addition, federal, regional and local air agencies collaborate across the US Northwest and Canada's southwestern regions to implement the Georgia Basin-Puget Sound International Airshed Strategy. These are strategies that could be analyzed to identify potential application at land POEs.

5. Air Emission-Reduction Best Practices at Ports of Entry

POEs are transportation system nodes where international security, safety, and immigration inspection take place. These inspection processes usually take time and could fluctuate, depending on such elements as POE configuration, vehicle demand, vehicle type, trip or shipment type, time of day, and even weather conditions. This creates bottlenecks and vehicle congestion that increases air emissions. Implementing emission reduction strategies is more challenging than any other measure in urban areas or corridors, given the interaction of various binational stakeholders who often have different priorities.

Negative impacts of cross-border congestion and delays not only affect the environment at border regions, but also have enormous impacts on the regional and national economies. The San Diego Association of Governments completed an extensive study to gauge the economic impacts of border wait times on the binational economy. Delays during border crossing negatively affect productivity, industrial competitiveness, and business income at the regional, state, and national level both for the United States and Mexico. The study concluded that "inadequate infrastructure capacity creates traffic congestion and delay that costs to the US and Mexican economies an estimated US$6 billion in gross output in 2005" (Sandag 2006). No information on the cost of congestion and delay to the US and Canadian economies was identitied during the course of this study, however due to the nature and volume of freight crossing that border, most likely it has a significant economic impact.

The economic impacts of delays and congestion at POEs are experienced by local residents and industry; therefore, most or all of the initiatives or interventions that were found in this research are directed toward reduction of congestion and delay at land POEs, or increase security, and not air emissions reduction. However, a reduction in border crossing time, traffic volumes, congestion, and delay has an associated air emissions reduction impact.

Few initiatives or best practices that were identified in this research are border-specific and have been implemented. Most of them are general recommendations that would still need to be implemented and tested in the border environment. Most of the measures that were identified are directed to both trucks and light vehicles, however the ones that have been implemented are directed at trucks.

From the four types of air emission-reduction actions described in Section 5, all the best practices that were identified were either vehicle technologies or system optimization/operation efficiencies (Table 2). Due to the nature of cross-border transportation practices, there is some overlap among best practices.

Table 2: Air Emission-Reduction Best Practices

Strategy Type	Best Practice	Status	Environment	Vehicle Type
Engine and Vehicle Technologies	Retrofit: Strategies to Reduce Particulate Matter at the Laredo/Nuevo Laredo Border Crossing	Recommendation	Border environment	Trucks
	Retrofit: San Diego-Tijuana Diesel Emissions Reduction Demonstration Project	Piloted	Border environment	Trucks
	SmartWay and *Transporte Limpio*	Implemented and operational	Urban and long-haul freight transportation	Trucks
System Optimization Operation Efficiencies	Washington State and British Columbia initiatives to reduce GHG emissions in the Cascade Gateway, Anti-idling program	Piloted	Border environment	Trucks and light-duty vehicles
	Port anti-idling program	In operation	Port drayage environment	Trucks
	Truck stop electrification	Implemented and operational	Urban and long-haul freight transportation	Trucks
	Border trusted-traveler programs	Implemented and operational	Border environment	Trucks and light-duty vehicles
	Eco-driving	Piloted	Border environment	Mainly trucks

5.1 Vehicle Retrofit: Strategies to Reduce Particulate Matter at the Laredo/Nuevo Laredo Border Crossing

With funding from the Border Environmental Cooperation Commission (BECC) and working in coordination with *Secretaría de Medio Ambiente y Recursos Naturales* (Semarnat) *Transporte Limpio* program, similar to SmartWay in the US, the Texas A&M Transportation Institute (TTI) analyzed various truck retrofit technologies to reduce PM from drayage trucks at the US-Mexico border (COCEF 2014). The analysis was concentrated in the Laredo/Nuevo Laredo POE, the largest commercial vehicle border crossing along the US southern border. The two technologies analyzed in detail were diesel oxidation catalysts and diesel particulate filters.

The diesel oxidation catalyst utilizes a chemical process in order to break down pollutants in the exhaust stream of a diesel engine, turning them into less harmful chemicals, similar to what happens in an automobile's catalytic converter. Diesel oxidation catalysts are normally honeycomb-shaped configurations coated with a catalyst designed to trigger a chemical reaction that will reduce gaseous emissions and particulate matter. Diesel oxidation catalysts typically reduce emissions of PM by 20 percent to 40 percent, or more, and gaseous emissions by 50 to 70 percent.

Diesel particulate filters, on the other hand, are systems that filter exhaust gas flow to capture solid PM, created as a byproduct of the internal combustion process. Diesel particulate filters have been used as pollution control devices for both on- and off-road vehicles and equipment since the 1980s.

The analysis concluded that the diesel oxidation catalyst was the better solution for the US-Mexico border environment. One key element in the recommendation was the lack of low sulfur diesel in Mexico, and most of the border drayage trucks are Mexico-domiciled vehicles that use Mexican fuel. The diesel particulate filters require low-sulfur diesel. The analysis included an estimation of the potential PM reduction in the area and an implementation plan.

Canada and the United States have regulations requiring low-sulfur diesel fuel and mandating compliance with vehicle emission standards, which result in manufacturers routinely installing various emission control technologies on new diesel vehicles. However, a retrofit approach may still be worth considering for the older diesel vehicles in these jurisdictions.

The present analysis estimated that installing diesel oxidation catalysts in a fleet of 1,700 trucks in the Laredo/Nuevo Laredo area could reduce annual PM emissions by approximately 12 tons.

5.2 San Diego-Tijuana Diesel Emissions Reduction Demonstration Project

The Otay Mesa POE is the largest POE along the California/Mexico border and serves the San Diego/Tijuana region. Diesel engines there contribute to unhealthy levels of ozone (i.e., smog), air toxics, and PM. Long-term studies of children's health conducted in California have demonstrated that particle pollution may significantly reduce the growth of lung function in children. Public health authorities associate exposure to PM with an increased risk of premature death, greater number of hospital admissions for heart and lung disease, and amplified adverse respiratory symptoms, such as asthma.

The EPA funded a scoping study to evaluate the costs and effectiveness of emission-control retrofit technologies on Mexican heavy-duty diesel vehicles operating in the San Diego County-Tijuana border region. The implementation phase of this study involved retrofitting approximately 127 Mexico-domiciled heavy-duty diesel trucks operating in the border region: 117 with diesel oxidation catalysts and 10 with diesel particulate crankcase filtration systems to demonstrate their viability under Mexican operating conditions (IEc 2007, EPA-Semarnat 2011, p. 59, EPA undated 1, undated 2).

5.3 SmartWay and Transporte Limpio

All three North American countries have implemented a version of the SmartWay® Program. In the US, the program was launched in 2004 by the EPA to reduce transportation-related emissions by creating incentives that would improve supply-chain fuel efficiency. The program is a public-private initiative between EPA, large and small trucking companies, logistics companies, commercial manufacturers, retailers, and other federal and state agencies. Its purpose is to improve fuel efficiency and the environmental performance (reduction of both GHG emissions and air pollution) of the goods movement supply chains (EPA 2014b).

In Canada, the SmartWay Transport Partnership is a collaboration designed to help businesses reduce fuel costs related to their transportation activities by working with freight carriers and shippers to benchmark their operations, track their fuel consumption, and improve their annual performance (NRCan 2014a). In addition to SmartWay, Natural Resources Canada has initiated the FleetSmart Program, which provides fleet managers with tools and resources to green their operations, including a Smart Driver Training program (NRCan 2014b).

The Mexican version is called *Transporte Limpio* (Clean Transport) and is managed by Semarnat and the Mexican Ministry of Communications and Transport (SCT and Semarnat 2014).[4]

[4] See "Transporte Limpio, Preguntas frecuentes" (Spanish only): <www.semarnat.gob.mx/temas/gestion-ambiental/calidad-del-aire/transporte-limpio/preguntas-frecuentes>.

The programs have a list of strategies that can help truck carriers save fuel and money, reduce air pollution, and cut carbon dioxide emissions that contribute to climate change. The list includes the following:

- idle reduction
- improved aerodynamics
- improved freight logistics
- automatic tire inflation systems
- single wide-base tires
- driver training
- low-viscosity lubricants
- intermodal shipping
- longer combination vehicles
- reducing highway speed
- weight reduction
- hybrid powertrain technology
- renewable fuels

SmartWay strategies are primarily aimed for long-haul trucking and not the short-haul operations found in border drayage vehicles. For example, the improved aerodynamics would not benefit low-speed operations and urban areas and lines at POEs. The longer combination vehicles are not allowed in the US, while in Mexico and Canada they are used in some states and provinces.

TTI analyzed various SmartWay technologies for border drayage trucks at the El Paso/Ciudad Juárez POE (TTI 2009). The project tested the applicability of three SmartWay strategies in the border drayage operations:

- use of lighter trailers
- modified driving behavior
- use of diesel oxidation catalysts

These SmartWay strategies were tested and evaluated for their emissions and fuel consumption impacts. The results of the research showed that diesel oxidation catalysts provide major THC and CO reduction benefits for drayage operations. Lightweight trailers and eco-driving were also found to decrease CO and THC emissions moderately. Only eco-driving appeared to have reduced CO_2 emission, fuel consumption and NO_x emissions. All the investigated strategies resulted in lowering PM emissions compared to the baseline. No similar analyses were identified at the US-Canada border.

5.4 Washington State and British Columbia Initiatives to Reduce Greenhouse Gas Emissions in the Cascade Gateway, Anti-Idling Program

As one part of a broad range of strategies for improving the border crossings, leaders from Washington State and British Columbia signed a memorandum on "greening the border." The long lineups at the border had become an environmental concern for regional governments. This initiative focused on reducing idling at the border as well as supporting the efforts of cross-border organizations and stakeholders in reducing congestion and environmental impacts. Some of the key elements that led to the greening the border memorandum are related to air pollution, health, and fuel economy:

Air Pollution

- An idling vehicle emits air toxics, chemicals, gases, and PM into the air, contributing to regional haze.
- An idling vehicle emits 20 times more pollution than one traveling at 30 mph.
- Every gallon of gas burned produces more than 20 lb of GHGs.

Health

- Breathing in exhaust can aggravate asthma, allergies, and cardiovascular disease.
- Exhaust emissions increase the risk of premature deaths in children.
- Emissions are still present and harmful, even when you cannot see the exhaust.

Fuel Economy

- For each hour spent idling, a typical truck burns approximately one gallon of diesel fuel, and a typical car wastes 1/5 of a gallon of gasoline.
- 10 seconds of idling uses more fuel than turning off and restarting the engine.

Idling occurs when a vehicle's engine is running but the vehicle is not in movement. At POEs, drivers commonly idle to run the air conditioner or heating, or to power other accessories while waiting for inspection. Idling reduction has become a popular initiative to reduce the amount of emissions, especially in large diesel engine vehicles (trucks).

Some efforts to reduce idling at land POEs have been implemented. The Peace Arch Border Crossing anti-idling initiative was proposed by the British Columbia Ministry of Transportation and Infrastructure and has as a goal to reduce emissions at the POE by one-third by 2020 without increasing border wait times. According to the Government of British Columbia, approximately three million vehicles pass through the Peace Arch Border Crossing every year and the average waiting time for southbound motorists is about half an hour. This means that the anti-idling program can reduce GHG emissions from southbound traffic and save nearly 0.132 gallons of fuel per vehicle per trip.

A traffic signal has been installed just north of the US Customs booth, and during periods of heavy traffic, motorists stop at the red signal and turn off idling engines. Once motorists ahead of the signal clear US Customs, the signal will turn green and another group of vehicles advances. While the total time to reach the customs booth will not change, it is estimated that this simple arrangement will result in a reduction of 639,000 million kilograms of GHG emissions annually (BC Ministry of Transportation and Infrastructure 2014).

This initiative might be applicable to other US-Canada border regions and might even be applicable to the US-Mexico region with some changes and adaptations. Before implementing this best practice, an analysis of the operations and infrastructure at a particular POE would be required to identify location of traffic signals and coordination with federal stakeholders.

5.5 Port Anti-idling Program

EPA, through the SmartWay initiative, launched the EModal Port Community System for Drayage. EModal reduces the amount of time trucks spend waiting in queues at terminal gates by establishing terminal appointments and eliminating delays caused by fee payments and incomplete information. This saves fuel, cuts pollution, and can reduce GHG emissions by over 200 metric tons per year at a typical port, while improving earnings for truck drivers/operators and terminal operators (EPA undated 3).

An appointment system to alleviate congestion at terminal gates just prior to opening time has been considered at the Ports of Los Angeles and Long Beach. This will complement the otherwise quite successful PierPass peak-pricing program.

PierPass is a not-for-profit company created by marine terminal operators at the ports of Los Angeles and Long Beach in 2005 to address multi-terminal issues such as congestion, security, and air quality. Under the program, all international container terminals in the two ports established five new work shifts per week. As an incentive to use the new off-peak shifts and to cover the added cost of the shifts, a Traffic Mitigation Fee is required for most cargo movement during peak hours (Monday through Friday, 3 a.m. to 6 p.m.) (PierPass 2014).

Although these two initiatives, appointment system and PierPass peak pricing program, have not been implemented at land POEs, there is a potential that similar strategies could be analyzed for implementation. Working with all stakeholders from public and private sectors would be needed to define the strategy specific to each POE, such as the lane configuration and hours of operation, which vary from POE to POE. The appointment system would need to be coordinated with POE security inspection agencies to assure that service could be provided at the time of the appointment.

5.6 Truck Stop Electrification

An initiative, known as electrified parking spaces, allows truck drivers to provide power to necessary systems, such as heating, air conditioning, or appliances, without idling the engine. The approach seeks to encourage truck drivers to turn off their engines instead of idling at a standstill or slow speeds.

Rules on hours of service in the US require drivers to stop and rest for a designated number of hours each day. Drivers often choose to leave their engines running while parked at truck stops to run air conditioning or heating systems, and communications and entertainment equipment. The typical US tractor-trailer idles between 1,800 and 2,400 hours per year (burning approximately one gallon of diesel fuel an hour). The truck stop electrification systems provide drivers with an appropriate resting environment, help them save fuel, and help them comply with anti-idling rules where they apply.

At land POEs, a combination of various initiatives such as the appointment system with truck stop electrification could achieve substantial air emissions reduction. Carriers and shippers can make an appointment and travel toward the POE and stop at the electrified facility while waiting for the inspection booths. The main issue with this proposal is to find additional land near the POE inspection booths. Most of the existing POEs in North America have space constraints, making this initiative more appropriate for new POEs.

5.7 Border Trusted-Traveler Programs

The US Department of Homeland Security has several trusted-traveler programs that provide an improved passenger experience, while enhancing security and increasing system-wide efficiencies (DHS 2014). Some of the relevant programs include:

- Global Entry. A CBP program that allows expedited clearance for pre-approved, low-risk travelers. All applicants undergo a rigorous background check and interview before enrollment. The program's goal is to speed travelers through the process.
- NEXUS. Program members use NEXUS cards in designated lanes to enter Canada or the United States. Members of this program have crossing privileges at air, land, and marine ports of entry.
- SENTRI. Similar to the NEXUS program, Secure Electronic Network for Travelers Rapid Inspection (SENTRI) allows travelers to cross the US border to and from Mexico through designated border crossing lanes.
- FAST. The Free and Secure Trade program is a commercial clearance program for known low-risk shipments entering the US from Canada and Mexico. FAST vehicle lanes process cargo at land border POEs that serve commercial cargo, with 17 participating ports on the northern border and 17 on the southern border (CBP 2014).

Even though these programs are not designed to reduce air emissions, by expediting processing at land POEs vehicle congestion and idling could be reduced. Another advantage of reducing delay at POEs is that users and inspection staff are less exposed to the toxic vehicle emissions. Although the goal of these trusted-traveler programs is to speed travelers through the process, members may still be selected for further examination when entering the United States, Canada or Mexico. Members of the trusted-traveler programs are issued a radio frequency identification card that grants them access to a special lane at participating border crossings. With fewer vehicles and the radio frequency identification card, inspection officers can process vehicles faster, and travel time for trusted-traveler program enrollees is lower than for those using general-purpose lanes.

At the Peace Arch Border Crossing, car owners enrolled in NEXUS amounted to 36 percent of the cross-border traffic in 2012 and closer to 40 percent in 2013. Analyzing the wait-time savings for NEXUS-enrolled drivers at the Peace Arch anti-idling initiative, the Whatcom Council of Governments calculated that over 4,800 metric tons of CO_2e emissions have been avoided. This is over 10 times the impact of the Cascade Gateway anti-idling program (Farzaneh et al. 2013).

5.8 Eco-driving

According to the United Nations Environment Programme (UNEP 2014):

> Eco-driving is a driving style that significantly reduces fuel consumption and thus emissions. The 'eco' in eco-driving refers to a driving style that takes into consideration ecological and economic benefits, which significantly reduces fuel consumption and GHG emissions at the same time. A variety of benefits can be realized by practicing eco-driving, including:
>
> - **Health Benefits:** Eco-driving reduces the emissions that cause air pollution. This has a positive impact on human health, and reduces health care costs.
> - **Environmental Benefits:** Vehicles produce emissions that adversely affect human health and contribute to climate change. These include BC, a component of soot, whose effects are linked with early death, cancer, heart disease, and respiratory problems; and CO_2, which contributes to climate change.
> - **Economic Benefits:** Simply by changing driving habits, fuel consumption can be cut by up to 25 percent. In addition to reductions in fuel use, which are quite substantial when considered over a one-year period, savings on vehicle maintenance can be significant. By practicing eco-driving, the wear-and-tear on a vehicle can be substantially lower, resulting in less damage to the vehicle and fewer trips to the repair shop.

In North America, several agencies and organizations have set up driver training and certification programs, e.g., SmartWay in the US and SmartDriver in Canada. At the US-Mexico border, the BECC, working with Semarnat and the Clean Air Institute, coordinated a train-the-trainer eco-driving program for CVs in September 2013 as part of the *Transporte Limpio* program. According to Semarnat, the eco-driving program has resulted in a reduction of 17 percent in fuel consumption in average, and some trucking companies have reported reductions between 44 and 49 percent in fuel consumption and air emissions (COCEF 2013). Unfortunately, there is little information on the penetration of the program, but the perception is that the participation of drayage carriers is limited, as there are no incentives for taking the courses.

Implementing driver performance monitoring following eco-driving training and including incentives for drivers who reduce fuel consumption would help sustain the program. Trainers can review detailed data on driver operating patterns from electronic engine monitoring and benchmark performance over time. If properly designed and implemented, incentive programs have been found to be very effective at changing driver behavior.

6. Recommendations for Expanding Best Practices on North American Borders

The objective of this research was to identify best practices implemented in North America to improve air quality, transportation flows, and border community and human health. As mentioned in the previous section, few best practices implemented at North American POEs were found. Most of the initiatives that were identified are general recommendations with some initiatives intended to improve security inspections at land POEs and secondarily benefit transportation flows.

It is possible that other initiatives to improve land border operations have been implemented but are not documented. A model that could be followed to expand best practices on North American borders would be to create a network similar to the European Union's BEST Urban Freight Solutions (BESTUFS).

BESTUFS was created in 2000 with funding from the European Commission (at that time, the Directorate-General for Energy and Transport) to identify, describe, and disseminate best practices, success criteria, and bottlenecks of urban freight transport solutions. Furthermore, BESTUFS maintains and expands an open European network of urban freight experts, user groups/associations, ongoing projects, the relevant European Commission Directorates, and representatives of national, regional, and local transport administrations and transport operators (BESTUFS undated).

The BESTUFS project team organizes regular workshops and conferences throughout Europe and reports on interesting urban commercial transport related developments, demonstrations, and events on European, national, regional, and local levels. BESTUFS received considerable attention from practitioners as well as from researchers, and all information is publicly available via their website <www.bestufs.net>.

Now in its second phase, BESTUFS II will strengthen and extend the promotion and dissemination of city logistics solutions in Europe and beyond by establishing new links with other networks, groups, and other international experts that interface with urban freight transport issues, among other solutions.

One recommendation is to use the BESTUFS model to disseminate best practices that reduce air emissions at North American border crossings via the leadership of the CEC. The CEC should undertake the following activities:

- Work with existing North American transportation planning groups (e.g., the US-Mexico Joint Working Committee and the US-Canada Transportation Working Group) to create an information-sharing network of best practices at land POEs that would be hosted on the CEC website.
- Disseminate and organize seminars or workshops on best practices in the three official languages in North America: English, Spanish, and French. Quantify the contribution of land border air emission-reduction initiatives to inform policy.
- Disseminate land border-crossing data through the network.
- Compile a list of existing working groups, bilateral or trilateral initiatives and projects, as well as active social media accounts maintained by such groups or authorities, providing links to their respective websites.

Appendix I: Literature Review of Case Studies Related to the Impact of Vehicle Emissions on Human Health and the Environment at Land Ports of Entry

1) North American Borders

a) Commercial Vehicles and Rail

Greening North American Transportation Corridors: Challenges and Opportunities. Texas A&M Transportation Institute for the Commission for Environmental Cooperation. Dec. 2010 <www3.cec.org/islandora/en/item/4093-greening-north-american-transportation-corridors>.

This document presents a case study of the Mexico City-Montreal Corridor. It is an assessment of rail and road transportation emissions with a base scenario of 2010 and future projection to 2035. The report mentions that the absence of data is still a problem and requires actions and coordinated policies between Mexico, the US and Canada. Results show that freight movement will continue to cause substantial amounts of CO_2 emissions. Although the report does not particularly mention the truck and rail emissions' impact at the POEs, it does imply a general impact at the Laredo-Nuevo Laredo, Detroit-Windsor, and Port Huron-Sarnia POEs caused by delay and congestion. The report states that there is a positive correlation between freight bottlenecks and freight demand: i.e., as the demand for freight increases, so do the number and length of bottlenecks. The report focuses on five different pollutants: CO_2, CO, NO_x, HC, and PM.

Sustainability and Freight Transportation in North America. Foundation Paper. Texas A&M Transportation Institute for the Commission for Environmental Cooperation. March 2010. <www3.cec.org/islandora/en/item/4094-sustainability-and-freight-transportation-in-north-america>.

The objectives of the foundation paper were to provide a synopsis of the freight transportation system in North America as it relates to greenhouse gas (GHG) emissions; investigate the state of the practice in GHGs measurement/estimation from truck and freight rail modes (as a general approach only, not at land POEs); examine the spectrum of available truck and rail GHG mitigation strategies; review federal, regional, state, and local programs and policies enacted to mitigate GHGs; and develop a group of short- and long-term opportunity areas for action by the North American governments to curb the growth of GHG emissions from truck and rail. This paper describes the lengthy immigration and security procedures as one of the causes of truck congestion, delay, idling, and consequently excess emissions. As a recommendation to reduce congestion and delay, researchers propose a greater use of electronic pre-clearance equipment and an expansion of physical capacity at some border crossings.

The study concludes that a coherent combination of policies consisting of subsidies, regulations, and emissions pricing is the most promising approach for mitigating GHGs from truck and freight rail transportation. Multiple opportunity areas were identified: more rigorous public investment, freight-specific GHG regulation, dynamic cooperation with the private sector, improvement in technology transfer and technical expertise, development of alternative energy sources, and potential emissions and carbon pricing mechanisms.

b) Privately-owned Vehicles, Commercial Vehicles, Buses, Rail, and Airplanes

***Environmental Assessment of NAFTA by the Commission for Environmental Cooperation: An Assessment of the Practice and Results to Date.* International Institute for Sustainable Development. (Aguilar et al. Oct. 2011 <www3.cec.org/islandora/en/item/11047-environmental-assessment-nafta-commission-environmental-cooperation>.**

This CEC report assesses the environment and, subsequently, social and economic effects of NAFTA trade in the NAFTA region. Moreover, this report explores the context of existing NAFTA regulations in the environmental area. The report includes recommendations based on the best practices and the responses to a wide-ranging set of stakeholder interviews. The report also evaluates whether the current and historical practice has delivered, starting by cataloging the existing efforts to date and including small surveys of the main lessons learned on trade and the environment. A very useful section of the report assesses both the strengths and weaknesses of the current approaches. A notable strength in terms of trade and the environmental impact was the organization of symposia and promotion of extensive research efforts for professionals, policy makers, and experts in the area (including emissions caused by freight transportation). However, one of the weaknesses was that too many of the papers suffer from serious methodological and analytical problems and a lack of follow-up on the symposia results. Another overall weakness found was the translation of the research and analysis into policy impact. Finally, the paper concludes with some recommendations for better fulfilling CEC's mandate to consider the environmental effects of NAFTA.

***Greening Transportation at the Border.* Federal Highway Administration. (FHWA Feb. 2011) <http://trid.trb.org/view.aspx?id=1250041>.**

Derived from the trilateral Green Transportation at the Border Workshop hosted by FHWA in San Diego, California, in February 2011, this report and related website explore the implementation of sustainable transportation options that can result in reduced environmental impacts while improving air quality, public health, and wildlife and habitat connectivity. The Green Transportation at the Border initiative intends to promote the adoption of a variety of environmentally sustainable transportation practices along the borders. The report focuses on four border transportation themes: sustainability and livability, green financing and industry, green technology, and performance measures. This report is a reference for agencies involved in border transportation planning, including national, state/provincial, and local governments. This report summarizes the overall findings of the workshop, as well as their recommended possible solutions.

For instance, one of the findings is that emissions and PM from vehicles crossing the borders have significant impacts on air quality and contribute to climate change. Thus, the recommended action for this particular issue was that governmental authorities from Mexico, the US, and Canada should implement targeted programs and technological improvements along their borders. The report also mentions innovative solutions, current technology, and current and proposed strategies at the POEs. The report emphasizes that congestion and delay are the biggest concerns for human and environmental health along the US-Mexico and US-Canada border crossing regions. A list of findings and recommendations related to transportation emissions are summarized in Table 3.

Table 3: Findings and recommendations from FHWA's *Greening Transportation at the Border*

Finding	Recommendation
Negative environmental impacts go beyond the POE into border communities.	Planning should take a complete view of border regions and include livability and sustainability as goals for transportation solutions.
Green finance techniques for border projects have long been underused.	Innovative financing techniques should be tested and employed on green transportation projects at the border.
Emissions and PM from vehicles have an impact on air quality.	The US, Mexico, and Canada should seek program and technology improvements.

Vehicle emissions and other sources of PM have serious public health impacts.	Fund and promote research on current exposures to emissions and PM. Develop and implement new technologies and policies to limit these exposures.
Currently, each country conducts environmental and transportation planning at the border independently of the neighboring country.	Environmental and transportation planning should be done jointly to ensure better environmental and quality of life outcomes.

c) Pedestrians

Because of the importance of cross-border transactions to local, regional, and national economies, the behavioral characteristics of pedestrian cross-border travel have been previously studied. Documents such as the *San Ysidro Pedestrian Crossing Report* (Cruz and Gompper-Graves 2010) and *Toward Understanding the Pedestrian Travel on the Paso Del Norte Bridge* (Sener et al. 2012) demonstrate findings generally for cross-border pedestrian travel times, the behavior of users, and the economic impact of pedestrians along the border between the US and Mexico. However, in terms of air pollution exposure and its related health impacts to border-crossing pedestrians, there is a limited amount of literature. For instance, some of the health and air quality exposure studies along the NAFTA region borders are as follows:

- *Evaluation of Exposures to Diesel Particulate Matter Utilizing Ambient Air Monitoring and Urinary Biomarkers among Pedestrian Commuters Who Cross the US-Mexico Border at San Ysidro, CA* (Galaviz et al. 2013).
- *Ultrafine Particle Levels at an International Port of Entry between the US and Mexico: Exposure Implications for Users, Workers, and Neighbors* (Olvera et al. 2013).

Although these studies contain a closer look at the health impacts on humans (mostly walk-in-line pedestrians crossing a POE), this document assumes that the impacts caused by vehicle emissions and poor air quality will impact POE users that are exposed to pollutants for extended periods of time and stand close to highly concentrated traffic, specifically diesel buses.

d) Community Impacts

In the past 10 years, several studies have been published demonstrating special vulnerability to motor vehicle emanations among those with serious illnesses, including asthma, chronic obstructive pulmonary disease, cardiovascular disease, diabetes, and lung cancer (Wargo et al. 2006).

Specifically for NAFTA POEs, several studies have reported an increased risk of asthma among residents living along the US-Canada border crossing and surrounding areas. For instance, two house-to-house surveys found that households in close proximity to the Peace Bridge Complex POE had asthma prevalence rates that were double those of households located on Buffalo’s East Side (Lwebuga-Mukasa et al. 2004). These observations indicate that increased traffic on Buffalo’s West Side may be associated not only with asthma exacerbations but also with increased prevalence in the community (Oyana et al. 2004). For residents along the US-Mexico border crossing, a research study published in 2014 investigated the potential effect around the San Ysidro POE communities, especially caused by the long northbound traffic delays (Quintana et al. 2014). Researchers sampled at four rooftop locations in 2010: one commercial establishment near the POE, two elementary schools in San Ysidro, and a coastal estuary reference site. The results of these samples indicated consistently higher daytime BC UFP concentrations at the measurement sites near the POE. Additionally, researchers observed higher pollution concentrations during low wind speeds or when wind was blowing from the POE toward San Ysidro.

2) US-Mexico Border

a) Privately-owned Vehicles, Commercial Vehicles, and Buses

***Developing an Emissions Estimation Tool for El Paso Border Crossings*. Texas A&M Transportation Institute, performed in cooperation with the Texas Commission on Environmental Quality and the US Environmental Protection Agency Region 6. DRAFT report. (Farzaneh et al. 2013)**

TTI developed a methodology to specifically estimate the emissions produced at border crossings using EPA's MOVES model in order to develop the emissions rates and construct the tool. EPA developed MOVES to estimate emissions from mobile sources; however, because the national average driving patterns used in MOVES fail to represent the special driving patterns of vehicles crossing the border, researchers developed a methodology to estimate emissions specifically for border crossing conditions. GPS units were used to collect second-by-second vehicle activity data. These data, along with other relevant information obtained from a series of data collection efforts at a sample of El Paso-Juárez border crossing locations, were incorporated into the emissions estimation tool.

Researchers ran MOVES 2010b for 400 different sets of conditions, including:

- two locations—El Paso and Ciudad Juárez
- two seasons—summer and winter
- two fuel types—gasoline and diesel
- three vehicle types—passenger cars, passenger trucks, and combination short-haul trucks
- four time periods—AM peak, midday, PM peak, and overnight
- seven pollutants—THC, CO, NO_x, CO_2, PM_{10}, $PM_{2.5}$, and PM-EC
- 25 analysis years—2010 to 2035
- 31 vehicle ages—0 to 30+ years old

A series of validation runs comparing the outputs of the tool with the results of MOVES indicated that there are discrepancies for NO_x, CO, and THC emissions from light-duty vehicles. The research team is working with EPA staff to determine the cause of these discrepancies. The current version of the tool is not recommended to estimate NO_x, CO, and THC emissions from source types 21 and 31.

The resulting border crossing emissions estimation tool enables users to quickly prepare and execute emissions estimation runs for a variety of conditions and scenarios. While the emissions estimation tool is based on the field data collected in the El Paso-Juárez area, the structure of the estimation process is independent from the data and can be easily updated using local emissions rates and vehicle activity data for other locations.

***United States-Mexico Land Ports of Entry Emissions and Border Wait-Time White Paper and Analysis Template*. Federal Highway Administration. (Cambridge Systematics, Inc. 2013)**

This is perhaps one of the most significant studies to analyze the correlation between congestion and emissions along the US-Mexico border. The report develops an analysis template (guidance) on how to conduct an emissions analysis for US-Mexico land POEs. The document presents two different case studies, or assumptions, at the Ysleta-Zaragoza International Bridge located in eastern El Paso, Texas. Both cases were micro-simulated and analyzed by developing representative emission rates and then combining these rates with the corresponding vehicle activity. The first case study assumes a shift of 1,000 private vehicles into the SENTRI program to reduce the amount of VMT in creeping queues. The second case combines US and Mexican CV inspections to reduce the number of vehicle starts and idle time. The study focuses on two pollutants, NO_x and $PM_{2.5}$, under daily average conditions. The results of this study indicate that even though commercial traffic is much less than private vehicle traffic, CVs account for most of the $PM_{2.5}$ and NO_x emissions. Some of the recommended best practices to minimize delay and congestion at the POEs include:

- Minimize the number of booths and combine inspections.
- Minimize queue VMT and/or minimize delay.
- Park rather than stack vehicles.
- Combine redundant cargo and vehicle inspections (i.e., Mexican-, US-, and state-level vehicle inspections and safety checks).

***US-Mexico Border Region Greenhouse Gas Inventories and Policy.* Prepared for US EPA. (Ross and Associates 2009)**

This report identifies and describes current activities related to measuring and mitigating GHG in the border region, and outlines a framework of strategies for regional collaboration to reduce GHGs (transportation accounts for 28 percent of all GHG emissions in North America). The study focuses on the US-Mexico border region and draws on activities at the national, state, and local levels but examines them in terms of their implications for the border region and what they imply about regional approaches. The research methods of this study are based on discussions with experts in climate policy along the border, and on GHG inventories, actions plans, and other documents.

***Greenhouse Gas Emissions due to Vehicle Delays at the San Diego-Tijuana Border Crossings* (Barzee 2010)**

This research estimates GHG emissions at the three international land POEs in San Diego County, California (located in San Ysidro, Otay Mesa, and Tecate). Emissions were estimated using MOVES 2010 and were based on northbound traffic information. CO_2, N_2O, and carbon tetroxide (CO_4) emissions were quantified and expressed collectively as CO_2e. The results of this research study indicate that the total emissions estimated at the three border crossings were approximately 80,000 metric tons of CO_2e for all three POEs for the base-year model (2009). Of this total, the San Ysidro POE contributed the most GHG emissions (68 percent), Otay Mesa contributed significantly less (30 percent), and Tecate contributed the least (2 percent). Heavy-duty diesel trucks at the Otay Mesa commercial crossing contributed the most on a per-vehicle basis (15.3 kg CO_2e/crossing), and vehicles using the SENTRI lanes contributed the least overall (1.1 kg CO_2e/crossing). Due to the base-year scenario modeled in this research (2009) along with the economic recession and escalated violence in Mexico, the results presented in this research might be considered atypical and are an underestimate of total GHG emissions.

Black Carbon and Polycyclic Aromatic Hydrocarbon Emissions from Vehicles in the United States-Mexico Border Region: Pilot Study. *Journal of Air and Waste Management Association.* (Kelly et al. 2006)

This paper describes the development of a system to measure BC and particle-bound PAH emission factors. Researchers obtained sample data collected along roadsides in four border cities: Calexico, Mexicali, El Paso, and Ciudad Juárez. The experimental study included the implementation of measurement systems along the roadsides. Monitoring vehicle emissions, researchers calculated a fuel-based emission factor capable of measuring BC, CO_2, and PAH. The results indicated that Mexican buses and all medium-duty trucks were more frequently identified as high emitters of BC and PAH than heavy-duty trucks or passenger vehicles. The study also revealed that Mexican trucks and buses had higher average emission factors compared with US trucks and buses, but the differences were not statistically significant. Researchers recommend that one of the next steps of further research include monitoring Mexican buses (transit system and personnel moving from maquiladoras) because of vehicle conditions and their high daily mileage.

b) Privately-owned Vehicles and Commercial Vehicles

***Tier II Air Quality Technical Report for Construction Emissions for State Route 11 and the Otay Mesa East Port of Entry.* California Department of Transportation. (Thompson 2010)**

This project was developed in the San Diego Air Basin. The study analyzes three different build alternatives for connecting State Route 11 and the Otay Mesa POE. The analysis considers the impact in vehicle delay and its possible implications regarding air quality caused by commercial and private vehicles emissions in the area (CO, ozone, nitrous oxide, respirable and fine PM, sulfur dioxide, lead, and toxic air contaminants).

***Mitigating Cross-Border Air Pollution: The Power of a Network.* Center for Technology in Government. (Cresswell et al. 2009)**

The authors of this report examine the challenges and potential benefits of cross-border efforts to mitigate air pollution. Researchers focused on the Joint Advisory Committee for the Improvement of Air Quality in the Ciudad Juárez, Chihuahua/El Paso, Texas/Doña Ana County, and New Mexico Air Basin (JAC). The study explores the best practices in the JAC region and describes the advantages of actions that have been successfully taken in this region regarding the improvement of air quality and other cross-border air issues. The study's main tool is the implementation of interviews of nine current and former JAC members. The authors' conclusions suggest that the JAC's strategies and methods were powerfully shaped by the characteristics of the physical setting and the organizational and political context. Additionally, the authors state that future actions require more efforts than simply getting high-emission vehicles off the road. Instead, both governments should attack difficulties with more expensive and complex strategies such as "high poverty levels in Ciudad Juárez and relative wealth disparities between the United States and Mexico."

***Mariposa Port of Entry Bottleneck Study (Nogales Sonora-Nogales Arizona).* University of Arizona-Atlas and Tecnológico de Monterrey Campus Sonora. Sponsored by the Arizona Department of Transportation. (Golob et al. 2008)**

This report identifies bottleneck areas to and from the Mariposa POE and their impact on cross-border movements. The report also explores and recommends low-cost solutions to increase the efficiency and alleviate congestion of the POE. The research team made use of traffic data collection and analysis to identify the location and possible causes of bottlenecks that restrict the free flow of people and goods into, and away from, the Mariposa POE since this entry point is one of the country's largest POEs for fruits and vegetables.

c) Privately-owned Vehicles, Commercial Vehicles, Buses, Rail, and Airplanes

***Border 2020: US-Mexico Environmental Program.* US Environmental Protection Agency and Secretaría de Medio Ambiente y Recursos Naturales (Mexico). (EPA 2014)**

This document and related website contain the guiding principles to support the mission statement of the Border 2020 binational program. The document and related website point out the five strategic goals that authorities of both countries have agreed to achieve by the year 2020 (in accordance with NAFTA). The Border 2020 program is an eight-year binational effort intended to "protect the environment and public health in the US-Mexico border region, consistent with the principles of sustainable development." Goal number one, and probably the highest priority of this agreement, is to reduce air pollution with the following objectives:

- Promote the reduction of the number of vehicles operating on the border that do not comply with the respective vehicle emissions standards, and reduce vehicle emissions at POEs through anti-idling and other feasible reduction measures.

- Reduce pollutant emissions to approach attainment of respective national ambient air quality standards in San Diego-Tijuana, Imperial County-Mexicali, Nogales Arizona-Nogales Sonora, and Paso Del Norte (El Paso-Juarez-Sunland Park) airsheds.
- By 2018, maintain effective air-quality-monitoring networks and timely access to air quality data.
- By 2015, support completion of climate action plans in each of the six northern Mexican border states.
- Reduce GHG emissions through energy efficiency and alternatives or renewable energy projects.

The program covers the geographic areas of California-Baja California, Arizona-Sonora, New Mexico-Texas-Chihuahua, and Texas-Coahuila-Nuevo León-Tamaulipas. As with the past 2012 program, EPA will promote the overall program implementation while ensuring binational cooperation, coordination, communication, and leveraging of resources from governmental, non-governmental, academic, and private sectors on both sides of the border.

***Developing a Strategy to Reduce Particulate Matter as Part of the "Transporte Limpio" Program.* Border Environmental Cooperation Commission. (TTI 2013)**

This report analyzes CV crossing characteristics in the Laredo/Nuevo Laredo region. The research team gathered truck fleet information from field surveys, truck fleet owners, and local databases, and developed drive-cycle characteristics using GPS devices. The information was used to identify potential technologies to reduce PM emissions. Diesel oxidation catalyst and particle filter technologies were analyzed as potential alternatives to reduce PM emissions at the Laredo/Nuevo Laredo border crossings. A cost/benefit analysis was conducted to produce recommendations. The analysis included an estimation of potential emission reductions based on the fleet and driving-cycle characteristics, equipment, and installation costs. A preliminary implementation plan to retrofit drayage trucks with diesel oxidation catalysts was developed.

***Quantification of Selected Sources for Emission Inventory Improvement in El Paso, Texas.* The University of Texas at El Paso. Prepared for El Paso Metropolitan Planning Organization. (Yang et al. 2012)**

This report provides emission estimates for five locations in El Paso, including light- and heavy-duty vehicles at the El Paso-Juárez international POEs, as well as the El Paso international airport. Among the four international POEs, the study mostly focuses on the Bridge of the Americas since this POE has the highest number of northbound border crossings and the lowest pedestrian activity. Emission factors by hour of the day were developed using EPA's MOVES 2010b. According to the results, the volatile organic compound (VOC) emissions at the El Paso-Juárez POEs represent approximately 2.0 percent of the total VOC emissions in El Paso, Texas. No conclusions or recommendations were stated by the authors of this report.

***Impactos en la Salud de los Cruces Fronterizos En México—Estados Unidos Puertos de Entrada: Deficiencias, Necesidades y Recomendaciones para Acciones.* (EPA-SCERP 2012)**

This report analyzes the potential effects of vehicle emissions on health for residents in communities along the US-Mexico border. The document is a summary of recommendations and findings after a two-day meeting in San Ysidro, California, in May 2012. The report emphasizes the challenges and problems regarding environmental justice, congestion, economy, and social and public health in several communities along the US-Mexico border. In terms of vehicle emissions exposure, the report describes "affected individuals" as any persons crossing the border (using a motor vehicle or walking) and individuals working or performing activities near the POEs or in communities near the border. The research community that participated in this binational meeting agreed on the fact that exposure to emissions from traffic are related to a number of adverse impacts on the health of children, pregnant women, and the elderly—e.g., respiratory problems, cardiovascular effects such as an increased risk of heart attacks, cancer and natal complications.

Some of the deficiencies, needs, and recommendations mentioned in this binational meeting are:

- Shorten border crossing waiting times.
- Improve road and POE infrastructure, as well as design or redesign of the POEs to reduce the economic and health impact.
- Coordinate efforts among the federal, state, and local agencies and planners to reduce the negative impacts of POEs and surrounding areas.
- Analyze existing infrastructure and viable alternatives to reduce air pollution.
- Investigate developing indicators along the border communities.

3) US-Canada Border

a) Privately-owned Vehicles, Commercial Vehicles, and Buses

***Interim Report: Phase 1 of the Air Quality Study of the Impact of the Peace Bridge Plaza on the Surrounding Neighborhood.* (NY DEC 2013)**

As part of a one-year air-monitoring campaign starting in August 2012, the New York State Department of Environmental Conservation (NY DEC) designed a program to assess changes in local air quality resulting from the redesign of the Peace Bridge Plaza and surrounding neighborhoods. The final goal of this study was to perform an analysis of the air quality impact of the relatively new plaza (POE) configuration. Phase one of this study focused on a six-month data collection process. Researchers monitored $PM_{2.5}$ and BC. Researchers concluded that data collected in phase one of this research study correlated very well with the two monitors in the Buffalo and Niagara Falls stations, indicating that there is no significant source of $PM_{2.5}$ impacting the neighborhood around the Peace Bridge that is not also impacting the sites in Niagara Falls and Buffalo. Additionally, researchers observed slightly elevated BC concentrations at the downwind site on weekday afternoons, which were likely due to truck activity at the Peace Bridge Plaza. Researchers used identical models of 1-hour and 24-hour $PM_{2.5}$ instruments as well as BC instruments at each monitored station.

***Green the Border. Climate Action at the Peace Arch Border Crossing.* (British Columbia Ministry of Transportation and Infrastructure 2013)**

The objective of this initiative was to reduce GHG emissions and improve air quality at the Peace Arch Border Crossing. The pilot project included the installation of traffic signals to move waiting traffic in a series of pulses (vehicle-coordinated platoon movements), allowing motorists to turn off their engines while waiting for traffic ahead to clear. Transportation authorities of British Columbia expect that this initiative could reduce emissions at the POE by one-third by 2020 without increasing border wait times. The ultimate goal of this initiative is to reduce GHG emissions by 80 percent compared to the emissions in the base year 2007. Additionally, the British Columbia Ministry of Transportation and Infrastructure's website allows Internet users to keep track of different initiatives, plans, and current actions related to air pollution, such as clean transportation, reduced idling, clean communities and greening the border, among others. Some of these actions might be applicable to other US-Canada border regions and might even be applicable to the US-Mexico region with some changes and adaptations. For instance, stopping motor vehicle engines on a sunny day at more than 90°F would be extremely uncomfortable for motorists who wait inside their vehicles.

Air Toxics Exposure from Vehicle Emissions at a US Border Crossing: Buffalo Peace Bridge Study. **Health Effects Institute. (Spengler et al. 2011)**

Also known as Research Report 158, this report presents the results of measurements of a large number of compounds that are produced by diesel and gasoline vehicles, including VOCs, PAHs, and NPAHs. The researchers' analysis focused on comparing pollutant levels measured at a plaza adjacent to the Peace Bridge (US-Canada border). The research team measured air pollutants, including compounds EPA considers mobile-source air toxics (MSATs). The study was designed to assess differences in upwind and downwind concentrations of MSATs. Results demonstrated that a concentration of motor vehicles resulted in elevated levels of mobile-source-related emissions downwind, to distances of 300 m to 600 m. This study offers a complete dataset to evaluate interrelationships among MSATs and to ascertain the impact of heavy-duty diesel vehicles.

b) Commercial Vehicles

Understanding Pacific Highway Commercial Vehicle Operations to Support Emissions Reduction Programs. **(Goodchild and Klein 2011)**

As part of regional border management solutions, researchers at the University of Washington analyzed CV data collected in 2009 in the Pacific highway crossing between British Columbia, Canada, and Washington to consider solutions to reduce truck idling and subsequently air emissions. The researchers had particular interest in (a) the unique features of border operations that cannot be capture with standard simulation tools at the Blaine POE, (b) the logistical inefficiencies at the border that may increase emissions and travel time, and (c) the impact of e-Manifest filing on inspection times. One of the researchers' main concerns was the large number of empty trucks crossing southbound (to a US destination) on the Pacific highway and the low FAST card program utilization rates. The findings of this study indicate that the logistical impact of the border contributes to unnecessary air emissions, which are a direct result of inefficient operations. The majority of near-border trucking activities occur at trucking facilities, indicating a demand for staging activity created by the border. Another interesting finding reveals that trips that do not, but could transport a backhaul load contribute to emissions. Based on the surveys and data collected, researchers conclude that Canadian carriers carry more goods more efficiently than US carriers, thus producing a smaller share of unnecessary emissions. Regarding environmental logistical efficiency, statistics revealed that trips using the FAST lane are highly inefficient and are responsible for a relatively high proportion of unnecessary emissions.

Preliminary Air Quality Assessment Related to Traffic Congestion at Windsor's Ambassador Bridge. **(Diamond and Parker 2004)**

This report presents a preliminary assessment of the air quality impacts caused mainly by diesel vehicle emissions. This research was performed by monitoring air quality in short-term survey periods along the Huron Church Corridor. The results of this study indicate that:

- There was a minimal increase in PM when traffic experienced no delay in the corridor.
- The Air Quality Index increased by one complete level for $PM_{2.5}$ when truck traffic inspection delay was above average.
- Based on observations and monitoring measurements, researchers concluded that the increase in PM depends on traffic volume, length of delay, and weather.
- A PM increase above ambient conditions was measured up to 300 m (984 feet) from the roadway. Larger PM increased in the vicinity of roads and decreased with distance from roads.
- VOC sampling results indicated no significant concentration (minimal increase).

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