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Green freight programs and technology verification

The cornerstone of the global economy is freight movement, which comprises the shipping of goods by land, air, and sea. Across all modes—truck, rail, marine, and aviation—the freight sector's growth is expected to outpace that of the passenger car sector in the coming decades (Fulton, Cazzola et al. 2009, Facanha, Blumberg et al. 2012, ExxonMobil 2013, U.S. Energy Information Administration 2014). There will be an increasing need to mitigate the energy and climate impacts of this growth. Notably, heavy-duty truck movement represents the majority of fuel use and greenhouse gas (GHG) emissions from the commercial vehicle sector in most places around the world (The International Council on Clean Transportation (ICCT) 2014).

In response to the growing negative effects of the trucking sector on climate change and local air quality, many nations and regions around the world have developed programs and policies to improve the environmental performance of heavy-duty truck fleets. To date, Japan, the United States, Canada, and China have enacted mandatory efficiency standards for new heavy-duty vehicles, and many other countries are in various stages of development for their own regulatory measures. In addition, voluntary "green freight" programs have been established in a number of countries and regions with the goal of increasing efficiency and reducing fuel use and emissions from trucking fleets and supply chains.

As discussed in the following section, green freight programs around the world are in various stages of maturity, and each is unique in its functionality and objectives. However, common features generally include data collection and benchmarking on fuel consumption and emissions, as well as information sharing on technologies and strategies for boosting efficiency and environmental sustainability. One key element of some green freight programs is technology testing and verification. This independent vetting of technology can be a crucial input in the decision-making process for trucking fleets as their owners consider investments in a myriad of different fuel-saving technologies and operational practices.

Prepared by Ben Sharpe

The primary objectives of this paper are to explore technology verification in the context of established and emerging green freight programs around the world. This paper begins by summarizing the various green freight programs that have been established or piloted in a number of different countries and regions. This is followed by an overview of some of the programs' key technologies and best practices. The subsequent section discusses the role of technology verification and the increased need for robust, independent testing of the efficacy of technologies and operational practices that can reduce fuel consumption and GHGs. Finally, in the conclusion we recommend future research that can build on this analysis, including assessing the effectiveness of verification programs in influencing fuel-saving technology deployment in various markets.

2. OVERVIEW OF CURRENT AND DEVELOPING GREEN FREIGHT PROGRAMS

While the overarching purpose of green freight programs is to promote enhanced efficiency and environmental stewardship in the on-road freight sector (and often other modes such as marine and rail), there is a great deal of diversity when comparing different programs around the world. This heterogeneity is evidenced by Table 1, which summarizes the key functions and transport modes encompassed by the 12 green freight programs we are highlighting in this study. With this group of programs, this study aims to capture most of the international green freight activities that include a focus on increasing the efficiency of on-road freight movement.

Table 1. An overview of green freight programs that focus on the trucking sector

Program (Administrating agency/entity)	Geographic scope	Program type	Key program elements	Types of member companies
SmartWay (Environmental Protection Agency)	U.S.	Public-private partnership	D, G, TV, B	T, R, L, S, M
SmartWay Canada (Natural Resources Canada)	Canada	Public-private partnership	D, G, B	T, R, L, S, M
Transporte Limpio (Secretary of Environment and Natural Resources)	Mexico	Public-private partnership	D, G	T, S
Green Freight Europe (European Shippers Council; Dutch Shippers Council)	Europe	Industry led	D, G	T, L, S
Objectif CO_2 (Ministry of Ecology; Agency of the Environment and Energy Management)	France	Public-private partnership	D, G	T
Lean and Green (Connekt)	Netherlands	Non-profit led	D, G, B	T, L, S, M
Logistics Carbon Reduction Scheme (Freight Transport Association)	United Kingdom	Industry led	D, G	T, L, S
Freight Best Practice (Department for Transport)	United Kingdom	Public-private partnership	D, G	T
Green Freight Asia	Asia	Non-profit led	D, G, B	T, L, S
Green and Smart Transport Partnership (Korea Energy Management Corporation)	Korea	Industry led	D, G	T, L, S
Green Logistics Partnership (Tokyo Metropolitan Government)	Tokyo region	Public-private partnership	D, G	T
China Green Freight Initiative (China Road Transport Association; Ministry of Transport; Clean Air Asia)	China	Public-private partnership	D, G, B*	T, L, S

"Key program elements" column: D = data collection and benchmarking; G = guidance for technologies and operational best practices; TV = technology verification; B = branding
"Types of member companies" column: T = trucking; R = rail; L = logistics; S = shippers; M = marine

As shown in the "Key program elements" column, green freight programs are generally active in some or all of the following activities:

» **Data collection and benchmarking.** This is arguably the most critical enterprise of any green freight program. Amassing and organizing data on fuel consumption and activity (such as total miles traveled) allows the various stakeholders of the program to assess how truck (or marine or rail) carriers compare in terms of fuel efficiency metrics such as miles per gallon (mpg) or liters per 100 kilometers (l/100 km). Using this information, fleet owners are able to analyze how they compare with similar fleets. Also, shippers and logistics providers that utilize trucking companies are able to select fleets based on performance metrics. In this manner, green freight programs leverage information in order to stimulate heightened awareness and competition for the services of truck fleets and other entities across supply chains. In addition to fuel efficiency, some green freight programs collect and disseminate data on pollutant emissions such as particulate matter (PM) and nitrogen oxides (NO_x).

» **Guidance for technologies and operational best practices.** As with data collection and benchmarking, this function is found to some extent in virtually every green freight program. Program administrators and participating companies generally look to use the data and information collected about efficiency technologies and strategies to share best practices and lessons learned. This is an important service, as fleet operators often lack the information they need to make informed decisions in these areas (Roeth, Kircher et al. 2013).

» **Technology verification.** This refers to the independent testing of technologies using well-established test procedures, such as those of the Society of Automotive Engineers. Employing standardized protocols to assess the fuel savings (or emissions reduction) performance of individual products and making this information public gives fleets, governments, and other stakeholders access to test results that demonstrate that technologies have a minimum level of effectiveness under certain conditions. Often, verification done by green freight programs or other independent entities creates a level playing field in which technology suppliers can showcase their products' merits. By having their products vetted through the technology verification process, manufacturers can highlight third-party results that demonstrate a certain level of performance.

» **Branding.** Within the context of green freight programs, branding is a way for suppliers and fleets to publicize the fact that the technologies that they are selling and utilizing meet a certain level of performance. Green freight program administrators can thereby raise the visibility of the program and give various stakeholders incentives to participate. Branding can take various forms, including public-facing labels on technology devices or complete vehicles that showcase a certain level of performance. Also, manufacturers can advertise that their products have been verified by a certain green freight program or independent testing facility.

As shown in the table, only the U.S. SmartWay program covers all four areas. This was the first green freight program, created by the Environmental Protection Agency (EPA) in 2004. The common two task areas across the remaining 11 programs are data collection/benchmarking and recommendations for technologies and strategies. Aside from SmartWay (both the U.S. and Canada programs, which are similar but separate efforts), only Lean and Green (Netherlands) and Green Freight Asia incorporate branding into their programs.

U.S. SmartWay is the sole green freight program that explicitly verifies the efficacy of individual technologies. To do this, the EPA has adopted a suite of testing protocols, which manufacturers can utilize to measure the effectiveness of their products. Typically, technologies must meet a certain threshold in order for them to be entered onto the "SmartWay Verified Technologies" list. Currently, the EPA verifies four types of technologies: 1) aerodynamic technologies, 2) low rolling resistance tires, 3) idle reduction technologies, and 4) exhaust retrofit technologies. The technology verification efforts of the U.S. SmartWay program and other entities are discussed in more detail in Section 4.

3. OVERVIEW OF FUEL-SAVING TECHNOLOGIES AND OPERATIONAL BEST PRACTICES

This section provides a brief overview of some of the technologies and strategies that are promoted in green freight programs. Table 2 lists some technologies and technology areas as well as certain operational practices that can be used to save fuel and reduce emissions. This is by no means an exhaustive list for either of the two categories. Looking at the technology areas column, notable omissions include engine and transmission enhancements. Technology improvements in the powertrain are generally only available when purchasing a new vehicle, and green freight programs and technology verification campaigns typically focus on after-market technologies. A noteworthy exception is the U.S. SmartWay program, which maintains a list of "SmartWay-designated" tractor truck models that are currently available for purchase as new or used vehicles.

Technologies and operational practices with a "TV" following them in the table generally lend themselves to quantitative verification testing. As described in more detail in the following section, verification testing involves subjecting a device, product, or vehicle configuration to a well-established test procedure that yields performance metrics such as percentage of fuel saved or increase in fuel economy. For the other technologies and strategies, developing standardized test protocols that yield robust results is likely impractical, though in certain instances research studies have been undertaken to quantify the fuel savings of these interventions. For technologies and strategies where it is not possible to derive an exact performance metric through set test protocols, verification takes on a different meaning. In these cases, it might mean determining whether the manufacturer or the user is following a certain set of best practices, or could involve a qualitative comparison (or ranking) amongst technologies or strategies of the same type.

Table 2. Some of the technologies and operational practices promoted by green freight programs

Technology areas	Operational practices
• Truck aerodynamics (TV) • Trailer aerodynamics (TV) • Low rolling resistance tires (TV) • Automatic tire inflation systems (TV) • Idle reduction technology (TV) • Lightweighting (TV) • Vehicle speed limiters (TV) • Low-viscosity oils and lubrication (TV) • Criteria pollutant emission reduction technology (TV) • Telematics and fleet management software • In-cab fuel efficiency coaching software	• Minimize tractor-trailer gap (TV) • Tarp open loads (TV) • Maintain robust preventative maintenance schedule • Balance payload properly between axles • Maintain proper tire and wheel alignment • Manage refrigeration settings • Optimize routes • Train and incentivize drivers • Collect data to identify best and worst-performing drivers and vehicles • Use transponders and on-board scales to bypass weigh stations

4. TECHNOLOGY VERIFICATION

4.1. OVERVIEW

There are various motivations for the independent verification of fuel-saving and emission reduction technologies depending on the point of view of the stakeholders involved, which include technology suppliers, trucking fleets, government agencies, green freight program administrators, and financial services providers.

Technology suppliers. Manufacturers are motivated to sell more of their products and please customers. As with other sectors in the trucking industry, it is often the case that end users are skeptical of performance claims made by technology vendors. A recent study conducted by the ICCT and the North American Council for Freight Efficiency (NACFE) found after surveying numerous fleets and other stakeholders in the trucking industry that many fleets cut the fuel savings claims made by suppliers in half when doing their return on investment calculations to evaluate a technology (Roeth, Kircher et al. 2013). Given this dynamic, independent technology verification serves an important role, as manufacturers can reference the performance results in their sales efforts and also have confidence that other manufacturers face the same test procedure process to have their products verified.

Trucking fleets. Fleets of all sizes—including owner-operators—are faced with scores of technology options for saving fuel and reducing expenses. With so much information and fuel savings claims coming from technology manufacturers, third-party verification of performance often provides welcome data point that fleets can use in their evaluation process. In the aforementioned ICCT/NACFE study, one of the common themes from the survey responses was that to enable good purchasing decisions, fleets must have a clear understanding of the expected payback time for a given investment. Payback calculations require information on not only the capital cost and expected fuel savings of the item purchased, but also additional information such as installation cost, maintenance requirements, and durability details.

Green freight program administrators. As discussed in Section 2, technology verification is a key element of a green freight program, because it bolsters the credibility of the products and strategies being promoted. However, at present only the U.S. SmartWay program explicitly has a verification component as part of its program. Given the critical importance of technology verification, many green freight programs in their earlier stages of development are aiming to develop robust verification efforts over time or look to leverage external verification programs. It is challenging for green freight program administrators to promote the use of certain technologies and strategies without being able to guarantee effectiveness to the end user.

Financial services providers. When investing in fuel-saving technologies, certain fleet operators need financing. Because loan officers at financial institutions are typically not knowledgeable about the merits of individual products, having access to independent technology verification results can give the financiers added confidence that the fleet is going to realize fuel savings and monetary benefits from the investment.

4.2. TECHNOLOGY VERIFICATION ORGANIZATIONS AND TEST PROCEDURES COMMONLY EMPLOYED

As shown in Table 3, only a relatively small number of organizations have explicit technology verification charters for the trucking sector and engage in (or fund) testing campaigns to support this mission. In addition, in certain instances government agencies allow third parties to conduct verification testing. Some of the organizations with expertise in heavy-duty vehicle testing are shown in Table 4. These independent testing facilities must meet certain criteria and follow codified test procedures in order for the sponsoring agency—e.g., the U.S. EPA, the California Air Resources Board (CARB), or the Joint Research Centre of the European Commission—to accept the verification testing results. This subsection provides a brief overview of the government agencies, research organizations, and some of the third-party testing entities as well as the test procedures that they commonly employ to verify technologies. It should be noted that green freight programs are typically focused on technologies and strategies to improve fuel efficiency. Still, there are many opportunities to promote the use of emissions control technology through these programs. Therefore, we focus on technology verification programs for both efficiency and emission control technologies and strategies for freight transport.

Table 3. Government agencies and independent entities engaged in technology verification in the trucking sector

Government agency or organization	Types of test methods	Technology verification areas
U.S. Environmental Protection Agency*	• Closed track • Chassis dynamometer • Wind tunnel	• Aerodynamics • Tire and tire pressure systems • Idle reduction • Criteria pollutant emission reduction devices
California Air Resources Board*	• Engine dynamometer	• Criteria pollutant emission reduction devices
Performance Innovation Transport (FPInnovations)	• Closed track • Chassis dynamometer • Over-the-road	• Aerodynamics and tarp systems • Tire and tire pressure systems • Driveline (e.g., 6x2 axle configuration) • Powertrain, hybrids • Idle reduction • Refrigeration and heating units • Criteria pollutant emission reduction devices
Verification of Emission Reduction Technologies Association (VERT)	• Engine dynamometer	• Criteria pollutant emission reduction devices

* Both the U.S. EPA and the CARB allow third-party laboratories and contractors to perform verification testing. These testing organizations must meet certain criteria and follow well-defined test protocols.

Table 4. Some of the third-party organizations contracted to do technology verification testing in the trucking sector

Organization	Types of test methods	Testing areas
Southwest Research Institute	• Closed track • Chassis dynamometer • Engine dynamometer • Wind tunnel	• Aerodynamics • Tire and tire pressure systems • Idle reduction • Powertrain • Criteria pollutant emission reduction devices
Auto Research Center	• Scale model wind tunnels • Computational fluid dynamics (CFD)	• Aerodynamics
Graz University of Technology (TU Graz) – Institute of Internal Combustion Engines and Thermodynamics	• Closed track • Chassis dynamometer • Engine dynamometer	• Aerodynamics • Tire and tire pressure systems • Powertrain, hybrids • Criteria pollutant emission reduction devices
TÜV NORD Mobilität	• Closed track • Chassis dynamometer • Engine dynamometer	• Aerodynamics • Tire and tire pressure systems • Powertrain, hybrids • Criteria pollutant emission reduction devices
VTT Technical Research Centre of Finland	• Closed track • Chassis dynamometer • Engine dynamometer	• Powertrain, hybrids • Criteria pollutant emission reduction devices
Netherlands Organisation for Applied Scientific Research (TNO)	• Closed track • Chassis dynamometer • Engine dynamometer	• Aerodynamics • Tire and tire pressure systems • Powertrain, hybrids • Criteria pollutant emission reduction devices

* Both the U.S. EPA and the CARB allow third-party laboratories and contractors to perform verification testing. These testing organizations must meet certain criteria and follow well-defined test protocols.

The U.S. EPA is the leading government agency in terms of technology verification for the freight sector. SmartWay has a comprehensive technology program that includes information useful to a wide range of stakeholders. On the SmartWay website (http://epa.gov/smartway/forpartners/technology.htm), administrators maintain information about how products are verified as well as up-to-date lists of individual manufacturers whose technologies have been verified. Fuel-saving and emission reduction technologies are grouped into four categories: 1) aerodynamics, 2) tire rolling resistance, 3) idle reduction, and 4) criteria pollutant retrofit technologies. In addition, the website has detailed descriptions of “SmartWay-designated” tractors and trailers. For tractor trucks, this designation is currently design-based and depends on specific features of the vehicle (e.g., aerodynamic profile, model year of engine, etc.). For trailers, there are five SmartWay configurations that include different combinations of aerodynamic devices for the front, side, or rear of the trailer, along with low rolling resistance tires. According to the EPA, the SmartWay program will soon be expanding to include different types of trailers (e.g., refrigerated), more testing options, and a new “Elite” level (U.S. Environmental Protection Agency (U.S. EPA) 2014).

CARB also has a technology verification program, which since the early 2000s has primarily served to support the various in-use California fleet regulations to reduce PM and NOx emissions. The agency’s verified retrofit technology website evolves as new suppliers verify their products on different engines and vehicles (California Air Resources Board (CARB) 2014).

Verification of Emission Reduction Technologies (VERT) is a nonprofit organization based in Switzerland that is focused on verifying particulate matter (PM) filter systems. They maintain an evolving list of "VERT-certified" filtration systems on their website (Verification of Emission Reduction Technologies (VERT) 2014).

Performance Innovation Technology (PIT) is a unique membership-based venture headquartered outside of Montreal that specializes in the testing and verification of a variety of technologies and strategies for the trucking sector. As shown in Table 3, PIT performs testing in a wide range of technology areas using a combination of closed track, on-road, and chassis dynamometer testing. As detailed in the venture's 2013 report, "Testing and Verification Protocol for Engine and Vehicle After-market Devices," all of PIT's testing is in accordance with the Canadian Environmental Technology Verification (ETV) Program (Performance Innovation Transport (PIT) 2013). The Canadian ETV Program was created by Environment Canada in 1997 and offers independent verification of environmental performance claims for innovative technologies, processes, and products (GLOBE Performance Solutions 2014).

In addition, there are a number of third-party organizations engaged in testing for heavy-duty vehicles. In North America, testing and research organizations such as the Southwest Research Institute (SwRI) and the Automotive Research Center (ARCIndy) are indispensable to the EPA as well as other state and local governments. These organizations provide testing services that support the SmartWay program as well as regulatory development efforts.

Many of the European organizations listed in Table 4 earlier have extensive experience in full-vehicle and engine dynamometer testing for both fuel efficiency and criteria pollutant emissions. First, the Institute of Internal Combustion Engines and Thermodynamics at Graz University of Technology (TU Graz) has done testing for a wide variety of projects related to heavy-duty vehicle efficiency and emissions reduction. TU Graz's testing and collaborative projects extend into work done to support the European Commission's development of certification methods for the CO_2 emissions of heavy-duty vehicles. The Netherlands Organisation for Applied Scientific Research (TNO) and TÜV NORD Mobilität is another important practitioner of heavy-duty vehicle testing in Europe. As with TU Graz, both organizations' experience in this area is substantial, and their testing campaigns have been critical to both the European Commission and the research community. The VTT Technical Research Centre of Finland has expertise in full-vehicle and engine dynamometer testing for both fuel efficiency and criteria pollutant emissions. For commercial vehicles, the organization's portfolio extends to the bus market as well.

To test technologies in a uniform manner, these government agencies and private organizations utilize standardized test procedures. Because there is such a vast catalog of technologies affecting different performance characteristics of the tractor-trailer, there is no single test method or protocol that is sufficient to cover all technology verification needs. Table 5 summarizes some of the most commonly used test procedures for the various technology areas. Generally, there are two or more methods for testing the performance of a particular technology. For example, in assessing the merits of an aerodynamic device, it is possible to test the fuel consumption benefits on a closed track, or the vehicle with the aerodynamic device can be evaluated in real-world traffic conditions. Or, rather than measuring fuel consumption directly, it might be preferable to test the device's impact on the coefficient of aerodynamic drag (C_d). If so, wind tunnel testing or computational fluid dynamics (CFD) software are available as evaluation methods. In all of these cases, the Society of Automotive Engineers (SAE) has developed standardized protocols and guidelines for conducting each of these types of tests.

For the technology areas listed in Table 5, the test methods and example test procedures shown are not an exhaustive list. Rather, this list is meant to highlight some of the more common approaches utilized in technology verification programs.

Table 5. Commonly used test procedures for technology verification in the trucking sector

Technology area	Metric	Test method	Example test procedures
Aerodynamics	Fuel savings	Track test, on-road test	SAE J1321, SAE J1526
	Coefficient of aerodynamic drag (Cd) reduction	Wind tunnel	SAE J1252
		Computational fluid dynamics (CFD)	SAE J2966
Tire rolling resistance	Fuel savings	Track test, On-road test	SAE J1321, SAE J1526
	Coefficient of rolling resistance (Crr) reduction	Laboratory drum test	ISO 28580:2009
Powertrain and driveline	Fuel savings	Track test, on-road test	SAE J1321, SAE J1526
		Chassis dynamometer	SAE J2177
		Engine dynamometer	40 CFR 1065
Criteria pollutant emissions	Emission reductions	Engine dynamometer	40 CFR 1065

4.3. FUEL-SAVING TECHNOLOGIES AND STRATEGIES FOR THE TRUCKING SECTOR

This section provides estimates of the fuel consumption benefits that certain fuel-saving technologies and operational interventions can yield in real-world operations.

With any technology or operational practice, it can be challenging to accurately assess real-world fuel savings; numerous factors continuously increase or decrease fuel efficiency. Some of these factors include: use of poor/inaccurate fuel consumption measurement methods, climate, road speed, infrastructure conditions, traffic conditions, driver behavior, payload, and topology. This uncertainty makes it attractive to verify performance under the more controlled conditions that are often required in standardized test procedures.

Given the difficulty in assigning an exact fuel consumption benefit to a particular technology or strategy, we show approximate ranges for fuel savings in Figure 1 that are based on available literature. As discussed in Section 3, the interventions included here are by no means meant to cover all of the available technologies or operational practices that can yield fuel savings. Rather, the items shown in Figure 1 are representative of some of the most common after-market products and operational best practices that are promoted by green freight programs.

Though many operational measures may be impractical to verify using standardized test protocols, these strategies can certainly provide fuel savings that are on par with, or even surpass, the benefits provided by technologies. In certain instances, operational practices can be more cost-effective than technologies, as evidenced by a recent survey of trucking fleets (Cullen 2012). This is not to say that fleet operators should opt for strategies over technologies (or vice versa). These two types of interventions are complementary, and operators can maximize fuel savings and monetary benefits by adopting a combination of strategies and technologies that best suits their fleet.

The percentage fuel savings for individual strategies and technologies in Figure 1 range from roughly 1% to 10%. The percent fuel consumption reduction values shown for each intervention are approximations based on various sources (a full list of the references used is given in Table 6) and should only be taken as illustrative of the level of benefits that a trucking fleet might realize. The ranges represent when the technologies and strategies are utilized appropriately. For example, typically aerodynamic technologies require a minimum speed to yield fuel savings, and a trucking carrier that exclusively operates at low speeds would likely not achieve the degree of savings shown in the figure. Certain technologies and strategies are much more sensitive to drive cycle and operating conditions than others. Hence, verifying technology (and strategy) performance under well-defined test conditions serves a critical role to give fleets and other stakeholders a certain level of confidence that the intervention can yield fuel savings in the real world as long as the average operating conditions are reasonably similar to the driving conditions of the technology verification test procedure(s).

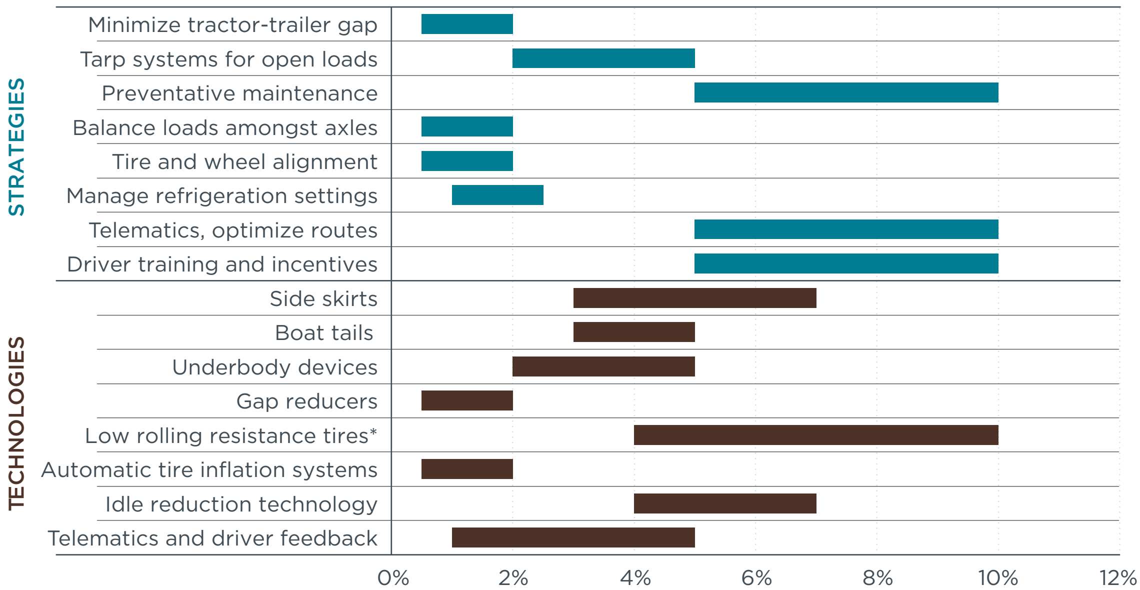

Figure 1. Approximate fuel consumption reduction ranges for operational strategies and technologies for tractor-trailers in typical long-haul operations

* Assumes that low rolling resistance tires are substituted for conventional tires on both the tractor and the trailer.

Table 6. References for fuel saving potential of technologies and operational strategies for trucking fleets

		References
Operational strategies	Minimize tractor-trailer gap	(Muster 2000, Cooper and Leuschen 2005, Leuschen and Cooper 2009)
	Tarp systems for open loads	(Performance Innovation Transport (PIT) 2014)
	Preventative maintenance	(North American Council for Freight Efficiency (NACFE) 2011)
	Balance loads amongst axles	(Wodziak and Fadel 1994, Heavy Duty Trucking 2014)
	Tire and wheel alignment	(Goodyear 2008, Cummins Inc. 2014)
	Manage refrigeration settings	(Carrier Transicold 2013)
	Telematics, optimize routes	(Kromer, Bockholt et al. 2009, National Petroleum Council (NPC) 2012)
	Driver training and incentives	(Kromer, Bockholt et al. 2009, Committee to Assess Fuel Economy Technologies for Medium- and Heavy-Duty Vehicles 2010, Cullen 2012, North American Council for Freight Efficiency (NACFE) 2014)
Technologies	Side skirts	(Committee to Assess Fuel Economy Technologies for Medium- and Heavy-Duty Vehicles 2010, Sharpe and Roeth 2014)
	Boat tails	(Committee to Assess Fuel Economy Technologies for Medium- and Heavy-Duty Vehicles 2010, Sharpe and Roeth 2014)
	Underbody devices	(Committee to Assess Fuel Economy Technologies for Medium- and Heavy-Duty Vehicles 2010, Sharpe and Roeth 2014)
	Gap reducers	(Committee to Assess Fuel Economy Technologies for Medium- and Heavy-Duty Vehicles 2010, Sharpe and Roeth 2014)
	Low rolling resistance tires	(Committee to Assess Fuel Economy Technologies for Medium- and Heavy-Duty Vehicles 2010, Curry, Liberman et al. 2010, Hill, Finnegan et al. 2011, Lutsey, Langer et al. 2014, Sharpe and Roeth 2014)
	Automatic tire inflation systems	(Committee to Assess Fuel Economy Technologies for Medium- and Heavy-Duty Vehicles 2010, Sharpe and Roeth 2014)
	Idle reduction technology	(Committee to Assess Fuel Economy Technologies for Medium- and Heavy-Duty Vehicles 2010, Lutsey, Langer et al. 2014)
	Telematics and driver feedback	(Committee to Assess Fuel Economy Technologies for Medium- and Heavy-Duty Vehicles 2010, Lutsey, Langer et al. 2014)

5. CONCLUSIONS AND FUTURE WORK

This study reviewed and summarized green freight programs around the world and discussed the pivotal role that technology verification plays in promoting the increased deployment of technologies that reduce fuel use and harmful emissions. Technology verification has a vital role to play in green freight programs. The independent testing and verification of technology performance is beneficial to:

- Manufacturers who want to market their technologies
- Fleets that are seeking a credible assessment of the expected benefits of a given technology

» Green freight program administrators and other stakeholders who want some level of assurance that the technologies included in the program provide real, quantifiable benefits to end users.

At present, the following organizations are conducting (and/or funding) verification testing for technologies in the heavy-duty trucking sector:

» U.S. EPA SmartWay Program
» California Air Resources Board
» Performance Innovation Transport
» VTT Technical Research Centre of Finland
» Verification of Emissions Reduction Technologies Association

These organizations use a variety of test methods and standardized test procedures for verifying technologies.

Approximate ranges for the fuel consumption benefits that are provided by individual technologies or operational interventions span from less than 1% to 10% or more. With so many external factors influencing fuel efficiency in the trucking space, these are simply order-of-magnitude estimates for the levels of benefits that a fleet could reasonably expect from each intervention. A literature review as well as conversations with trucking company representatives and industry experts suggest that the fleets most interested in maximizing their fuel savings in a cost-effective manner will invest in a combination of technologies and operational best practices.

Future work for the ICCT will include assessing the viability of an International Technology Verification Center (ITVC). The proposed ITVC is intended to be a resource for truck fleets, technology vendors, governments, and other stakeholders to provide credible, independent validation of the fuel savings and emission reduction benefits associated with various technologies, devices, or operational strategies applicable to on-road heavy-duty trucks. As envisioned, the ITVC would ultimately be able to "verify" the benefits of technologies as well as operational strategies. In addition, the ICCT would ideally want the ITVC verification results to be accepted and used in all of the major vehicle markets world-wide, including the United States, Europe, China, India, and Brazil.

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