Eastern Research Group, Inc.

Global Green Freight Action Plan — Technical Background

Final Report

Prepared for:

U.S. Environmental Protection Agency

Prepared by:

Eastern Research Group, Inc.

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Global Green Freight Action Plan — Technical Background

Final Report

Prepared for:

Buddy Polovick
U.S. Environmental Protection Agency
2000 Traverwood
Ann Arbor, MI 48105

Prepared by:

Rick Baker
Richard Billings
Birgit Caliandro
Mike Sabisch
Alan Stanard
Jim Lindner

Eastern Research Group, Inc.
3508 Far West Blvd., Suite 210
Austin, TX 78731

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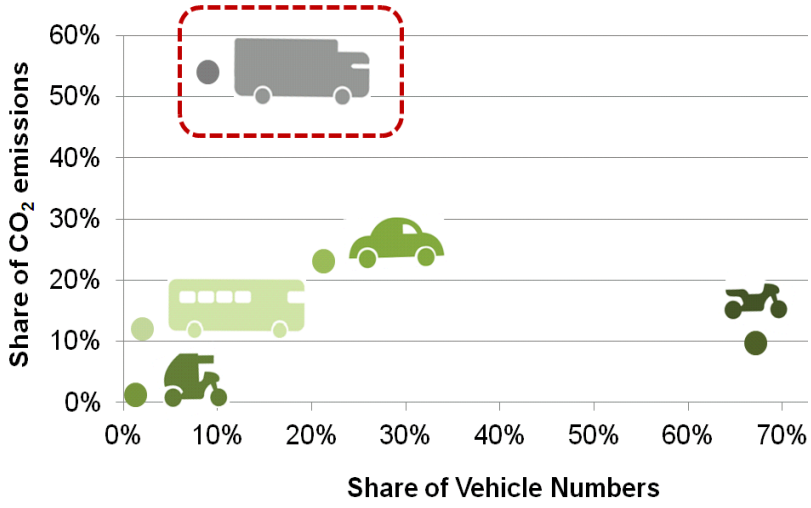
Executive Summary

Global freight, transported predominately by diesel engines, is a major and rapidly increasing source of black carbon and carbon dioxide (CO_2) emissions. Diesel emissions are powerful climate forcers,[1] as well as dangerous air pollutants with multiple impacts on health and ecosystems. Freight transport in particular has relatively high environmental impacts compared to passenger transport in terms of fuel use, black carbon, CO_2 emissions, and other pollutants. For example, as shown in the figure below trucks represent only 9 percent of vehicles on the road in Asia, but contribute 54 percent of transport-related CO_2 emissions. Globally, CO_2 emissions from freight transport are growing more quickly than emissions from passenger vehicles, with heavy-duty vehicles expected to be the largest emitter of CO_2 from all transportation modes by 2035.

Figure ES-1. Asian Transportation CO_2 Emissions by Type of Vehicle



Clean Air Asia (2012)

The Climate and Clean Air Coalition (CCAC) is overseeing a growing international partnership to reduce short-lived climate pollutants. Through its Green Freight Initiative, the CCAC is working to achieve substantial reductions of black carbon and CO_2 emissions from heavy-duty diesel vehicles and engines in the transportation sector. By supporting green freight programs and strategies, governments and the private sector can simultaneously reduce climate impacts and enhance the energy and environmental efficiency of global goods.

Multinational freight shippers, such as manufacturers, retailers, and other cargo owners, are under increasing pressure from shareholders, customers, and insurers to reduce their carbon footprints and mitigate the risks associated with higher fuel prices. Through participation in green freight programs, shippers can help create a demand for greener freight services worldwide, encouraging their multinational freight carriers and logistics providers throughout their supply chains to adopt new efficiency strategies and emission reduction technologies.

[1] Climate forcers include gases and particles that warm the atmosphere by trapping the earth's outgoing radiation.

Central to these efforts, green freight programs seek to provide both shippers and their carriers with reliable and quantifiable information regarding fuel-saving and emission reduction strategies. This information allows program participants to make more informed decisions in order to reduce fuel costs, black carbon, greenhouse gases, and other pollutants in the most cost-effective way. By laying the groundwork for benchmarking, reporting and incentivizing these reductions, green freight programs facilitate the adoption of clean fuel standards, emission control technologies, and fuel efficiency improvements for both in-use and new vehicle fleets.

Many countries, regions, and private sector associations are in various stages of developing and implementing green freight programs. By coordinating and collaborating, government agencies can make their efforts more consistent and more economical. Performance benchmarking, tools, and metrics are all ways to formalize collaboration. The result will be a pathway for protecting public health, reducing short-lived climate forcers, and enhancing energy security and sustainable economic development.

The CCAC is developing a Global Green Freight Action Plan, with input from the private sector and other stakeholders, to provide a roadmap for the advancement and harmonization of green freight programs globally, with the aim of reducing black carbon and CO_2 emissions as well as fuel consumption. The Action Plan will also provide methodologies and tools that will promote the sharing of performance benchmarking data and encourage the adoption of proven technologies and strategies. In addition, the Action Plan will define an information exchange platform structure for the dissemination of best-practices, successful strategies, technology recommendations, and emission estimates.

Several key findings can be drawn from this analysis:

- Truck transport generally dominates all other domestic freight modes, while marine vessels carry the vast majority of international freight.
- The carbon-intensity of freight movement, as measured in g CO_2/tonne-km, varies widely by mode. Therefore, switching from high- to low-carbon-intensity modes can have a substantial impact on overall fuel consumption and emissions where the transport network and infrastructure allows.
- As an alternative to mode switching, a variety of technologies and operational strategies are also available to improve the fuel efficiency and reduce emissions associated with in-use freight trucks, including aerodynamic retrofits, idle reduction, low-rolling-resistance tires, alternative fuels, telematics, and improved logistics, among many others.
- Adopting packages of these strategies can frequently reduce fuel consumption by 10 percent or more, depending upon site- and fleet-specific factors.

Green freight programs can play a role in spurring technological advances in engine, tractor/trailer, and tire design. For example, the use of aerodynamic truck and trailer treatments such as gap reducers can reduce fuel consumption by 5 percent or more. In addition, the pervasiveness of computer- and GPS-based freight tracking systems allows for significant improvements in operational efficiency, such as the reduction of empty back-hauls. Green freight programs can help to bring those innovations to market at scale, which drives down costs.

The type of fuel used for freight movement also has a significant impact on black carbon and CO_2 emissions. Diesel and marine bunker fuel have high energy densities and dominate global freight transport. While switching from diesel to gaseous fuels such as natural gas, or electricity, can dramatically reduce black carbon emissions, these options are frequently limited to niche applications. However, the widespread provision of ultra-low-sulfur diesel (ULSD) fuel enables the introduction of new emission control technologies such as diesel particulate filters. Green freight programs can promote the adoption of these measures by packaging them with fuel-saving strategies such as aerodynamic retrofits or idle reduction technologies. In this way, the resulting fuel savings can help cover the incremental costs associated with black carbon control measures. One objective of the CCAC initiative is for all countries to adopt ULSD standards, as well as the implementation of diesel vehicle emission standards equivalent to advanced (EuroVI) levels.

Green freight programs around the world have developed a variety of approaches to promote the adoption of energy-saving and emission-reducing strategies. The focus of these programs, the types and numbers of partners included, and their data collection, performance benchmarking, and reporting methodologies depend on the transport modes addressed, the pollutants and performance metrics of interest, as well as the geographic regions involved. Many of these programs have consistently demonstrated potential for significant emission reductions in a wide variety of locations and operating conditions. The most successful green freight programs are based on the business case for fuel savings; they incentivize investments in fuel savings technologies and operational strategies, resulting in substantial cost savings to operators. In this way the programs generate a “win-win” outcome, with both financial and environmental benefits.

Although the green freight programs evaluated in this report differ in a number of substantive ways, several common features were found that lead to program success:

- Extensive stakeholder involvement in all aspects of program design, deployment and operation is crucial to long-term success. Although the business-to-business nature of green freight programs presents unique challenges, these can be overcome through strong stakeholder commitment and participation in developing a program vision, quantification methodology, and measurement methods, as well as balancing concerns for transparency with confidentiality and data security.
- Programs should have representatives from across the entire supply chain, including shippers, carriers, and logistics providers, as well as key affiliates such as trade associations to foster mutual trust between partners and program administrators.
- Successful programs integrate both “push” (carrier-driven) and “pull” (shipper-driven) elements to varying degrees, reflecting the strategic and market value of performance measurement and evaluation for carriers, as well as the importance of reliable carbon footprinting and benchmarking for shippers.
- Programs can be successful under a variety of administrative structures, with active leadership coming from industry, government, and/or other research organizations/NGOs. The appropriate structure will depend upon the data needs and preferences of the region,

transport modes, and target participants. ***The key is to provide industry with a trusted, impartial arbiter ensuring that performance data are reliable and secure.***

- Programs should be provided with consistent, reliable funding (commensurate with program goals and commitments) and qualified, trained staff in order to ensure sustained communication with partners, effective data management, reliable program performance assessment, and successful outreach and recruiting.

While green freight programs will continue to have substantial positive impacts domestically and regionally, global harmonization is critical to continued expansion and greater emissions reductions. Until programs are harmonized or aligned across modes with standard metrics, programs will be limited in their ability to reach and fully inform the market, help shippers and carriers improve their efficiency, and foster additional emission reductions.

Although many challenges lie ahead, these goals are attainable, and there has already been significant progress in regional harmonization efforts. As these efforts continue over time, the above challenges will likely be addressed in ways not currently foreseen. The CCAC Partners are currently responding to the Green Freight Call to Action in a variety of creative ways, leveraging both public and private resources to expand the adoption of cost-effective CO_2 and black carbon reduction strategies across all freight sector modes and regions of the globe. Working together, these stakeholders are well-positioned to develop a successful roadmap for the next steps of green freight program expansion and integration.

1.0 Summary of CCAC Green Freight Call to Action and Action Plan

1.1 Background

The Climate and Clean Air Coalition (CCAC) is overseeing a growing international partnership with the primary goal of enhancing global, regional, and national public-private efforts to reduce short-lived climate pollutants. This effort includes a number of programs that cover heavy-duty diesel vehicles and engines, brick production, the municipal and solid waste sector, household cooking and domestic heating, oil and natural gas production, alternative hydrofluorocarbon technologies, and the agriculture sector.

As part of its initiative with heavy-duty diesel vehicles and engines, the CCAC is working to achieve substantial reductions of black carbon and carbon dioxide (CO_2) emissions in the transportation sector through its Green Freight Initiative. The movement of freight throughout the world, especially via heavy-duty diesel engines, is a major and rapidly increasing contributor of these substances to our environment. While important to economic development and global trade, diesel emissions are powerful climate forcers as well as dangerous air pollutants with multiple impacts on health and ecosystems. To address this concern, one objective of the initiative is for all countries to adopt lower-sulfur diesel standards of 50 ppm or lower (with the ultimate target being 10 ppm), as well as the implementation of diesel vehicle emission standards equivalent to EuroVI levels.[2]

The strength of national economies is becoming more dependent on international trade, raising the significance and impact of having an efficient and competitive freight transport sector. The continued growth in the globalization of supply chains means that an energy-efficient and sustainable global freight industry is essential to economic growth and sustainable development across the world. Inefficient freight movement, especially in developing countries, can prove to be a bottleneck to economic growth, while also impacting the environment. Improving the energy and environmental efficiency of goods movement represents an opportunity for both cost savings and emissions reductions.

Freight transport has relatively high environmental impacts when compared to passenger transport in terms of fuel use, black carbon, CO_2 emissions, and other pollutants. In Asia, for example, trucks represent only 9 percent of vehicles on the road, but contribute 54 percent of transport CO_2 emissions. Globally, CO_2 emissions from freight transport are growing at a faster rate than emissions from passenger vehicles. In particular, heavy-duty vehicles are expected to be the largest emitter of CO_2 from all transportation modes by 2035. (In Asia, for example, heavy-duty vehicles will produce more than 2,500 million tons of CO_2 emissions per year by 2035—far more than any other type of on-road transportation, even though those other types outnumber heavy-duty vehicles.[3]) Therefore, improving the energy and environmental efficiency of the freight transport sector is a critical element of reducing global black carbon and CO_2 emissions. By supporting green freight programs and strategies, governments and the private

[2] Climate and Clean Air Coalition (2013). Initiatives. Retrieved from http://www.unep.org/ccac/Portals/50162/HLA/norway/docs/CCAC%20Initiatives%20Factsheet%20-%20EN.pdf.

[3] U.S. Environmental Protection Agency (2012). *Reducing Black Carbon Emissions in South Asia*. Retrieved from http://www2.epa.gov/international-cooperation/opportunities-reduce-black-carbon-emissions-asia.

sector can simultaneously reduce climate impacts and make the global goods movement more sustainable.

Multinational freight shippers, such as manufacturers, retailers, and other cargo owners, can create the demand and drive for greener freight services worldwide by sourcing goods and materials throughout their global supply chain (often in developing economies) and distributing goods from producers to consumers. These firms are under increasing pressure from shareholders, customers, and insurers to reduce their carbon footprint and the risks associated with higher fuel prices. This market pressure can be applied to multinational freight carriers and logistics providers, as well as national and local carriers, to drive new efficiencies and emission reductions from their freight supply chains.

However, in order for market forces to work efficiently, performance benchmarking and freight efficiency data is required for informed decision-making, as shippers can better optimize their carrier and modal choices when they have reliable data about their emissions characteristics. Here government agencies and other stakeholders can assist by providing the market with information about proven successful technologies and other strategies to reduce the emissions intensity of freight, which can help bring these high-potential opportunities to scale.

1.2 Global Green Freight Call to Action

The CCAC "Green Freight Call to Action" endorsed by CCAC Partners at the High Level Assembly in Warsaw, Poland, on November 21, 2013, commits CCAC Partners to collaborate with stakeholders to develop a Global Green Freight Action Plan by December 2014 (see Appendix B). At this meeting, the Partners in the CCAC declared their determination to improve the energy efficiency and environmental performance of freight operations worldwide. The goal of this initiative is to implement the Global Green Freight Action Plan through worldwide public-private partnerships; a cornerstone of this effort will be a common blueprint for countries and regions that aim to establish, or are already implementing, green freight programs.

In a number of countries, including CCAC Partner countries, public-private partnerships through green freight programs have demonstrated the capacity to improve the environmental performance and energy efficiency of freight transportation, as well as enhance the energy security of participating countries while reducing emissions of black carbon and CO_2. Significant efficiency gains and emissions reductions can be achieved by accelerating the adoption of advanced technologies and operational strategies in multimodal goods movement, including through modal shifts, for example from truck to rail. Such measures would also deliver considerable air quality and near term climate protection benefits.

Many countries, regions, and private sector associations are in various stages of developing and implementing green freight programs. By coordinating and collaborating, government agencies can make their efforts more consistent and more economical. Performance benchmarking, tools, and metrics are all ways to formalize collaboration. The result will be a pathway for protecting public health, reducing short-lived climate forcers, and enhancing energy security and sustainable economic development.

Recognizing existing efforts and opportunities, the CCAC Partners are committed to providing a forum to promote cooperation among countries and between international organizations, as well as a platform to engage the private sector that will expand and harmonize green freight programs globally.

In making the Green Freight Call to Action, the CCAC Partners will collaborate with stakeholders to develop and deploy a coordinated Global Green Freight Action Plan that shall be implemented through public-private partnerships worldwide. The Action Plan will provide a common roadmap and program templates that can help to harmonize and coordinate the development of green freight programs, ease implementation, facilitate information sharing, and incorporate a large knowledge base of previous efforts. It will also provide a platform for companies to share best practices, promote innovation, and communicate sustainability improvements on the multimodal transportation of freight.

Toward this end, the primary goal of this Green Freight Call to Action is to support, advance and grow these programs to achieve fuel savings and efficiency gains, cost savings, and black carbon and CO_2 emission reductions. Inherent in achieving this objective will be securing a commitment from CCAC Partners, the private sector and other key stakeholders around the world to work together on developing and implementing the Global Green Freight Action Plan.

1.3 Global Green Freight Action Plan

The CCAC is developing a Global Green Freight Action Plan to provide a blueprint and roadmap for the advancement and harmonization of Green Freight programs globally with the aim of reducing CO_2 and black carbon emissions. To achieve this goal, the CCAC is seeking the participation of industry-leading multinational firms that ship or carry goods through a multi-modal supply chain, CCAC member countries, development banks, and other stakeholders to provide input, insight and guidance on the development of a Global Green Freight Action Plan. It is hoped that freight logistics firms, carriers and retail shippers, manufacturers, and representatives of other key economic sectors will participate in the process. Additionally, government officials from CCAC countries will be engaged to provide political support for this initiative. The Green Freight Steering Group will lead the process with government officials from the U.S. and Canada, the International Council on Clean Transportation, World Bank, Clean Air Asia, and Smart Freight Centre.

The process will consist of a series of roundtable meetings and conference calls that will allow the participants the opportunity to provide leadership, input, insight and guidance on the development and launch of the Green Freight Action Plan. The successful implementation of the Action Plan will accelerate the adoption of advanced technologies and operational strategies in multi-modal goods movement, initially targeting road freight. The Action Plan will outline policies, technologies and strategies to foster accelerated and successful implementation of green freight technologies while achieving reductions in black carbon and CO_2 emissions, the latter of which will inherently improve fuel economy. Additionally, the Action Plan will provide methodologies and tools that will promote the sharing of performance benchmarking data and encourage the adoption of proven technologies and strategies. Lastly, the Action Plan will define an information exchange platform structure for the dissemination of best-practices, successful strategies, technology recommendations and emission estimates that will help shippers optimize

supply chain performance and help carriers and logistics firms identify solutions to reduce black carbon emissions and improve fuel economy by reducing black carbon and CO_2 emissions for their clients.

The CCAC Action Plan will help create political momentum globally for green freight and bring together governments collectively at the global level to engage with private sector companies and the various other initiatives with which they are involved. In addition, the CCAC Action Plan will highlight the need for black carbon reduction initiatives to be included in new and existing green freight programs alongside CO_2 emission goals.

1.4 Technical Background Paper Overview

The purpose of this document is to provide a global overview of freight sector operations; environmental impacts of freight emissions; available in-use technologies and strategies; and program status and initiatives, while highlighting gaps in our knowledge with regard to emissions data, program implementation status or specific regional conditions. Recommendations are provided to address these knowledge gaps wherever possible. The overarching goal is that this work will provide a foundation for the CCAC to move forward in their development of an Action Plan.

The document is organized into the following chapters, which provide specific technical background information to support the development and implementation of the Green Freight Action Plan:

- **Chapter 1** presents background information on the CCAC's goals and initiatives.
- **Chapter 2** provides an overview of the global freight sector, including growth trends by region and mode, health and safety impacts, and fuel and emission standards, all of which impact the opportunities for green freight program development.
- **Chapter 3** provides an overview of existing green freight programs around the world, highlighting commonalities and differences as well as identifying important information gaps. The evaluation attempts to identify which programs and approaches have been particularly successful in fostering freight industry participation and generating fuel savings and emission reductions. Detailed characterization of these programs will help support the goals of the Green Freight Action Plan by identifying common, successful program elements that in turn can provide a framework for developing and harmonizing green freight efforts worldwide.
- **Chapter 4** provides an overview of freight truck, rail, marine, and aircraft fleets, and describes how their characteristics influence the technologies and operational strategies that can be applied to the different types of fleets.
- **Chapters 5 and 6** identify a wide variety of strategies that are available to reduce the fuel consumption and emissions associated with these vehicles and engines. All of the approaches discussed in these chapters can be pursued through collaboration between governments, private industry, and other stakeholders so that resources can be leveraged to their fullest extent, and the goals of the Global Green Freight Call to Action can be realized.

- **Chapter 7** summarizes the findings of the report, identifies elements common to green freight program success, and discusses the prospects for harmonization across programs in the future.

2.0 Global Goods Movement and Associated Impacts

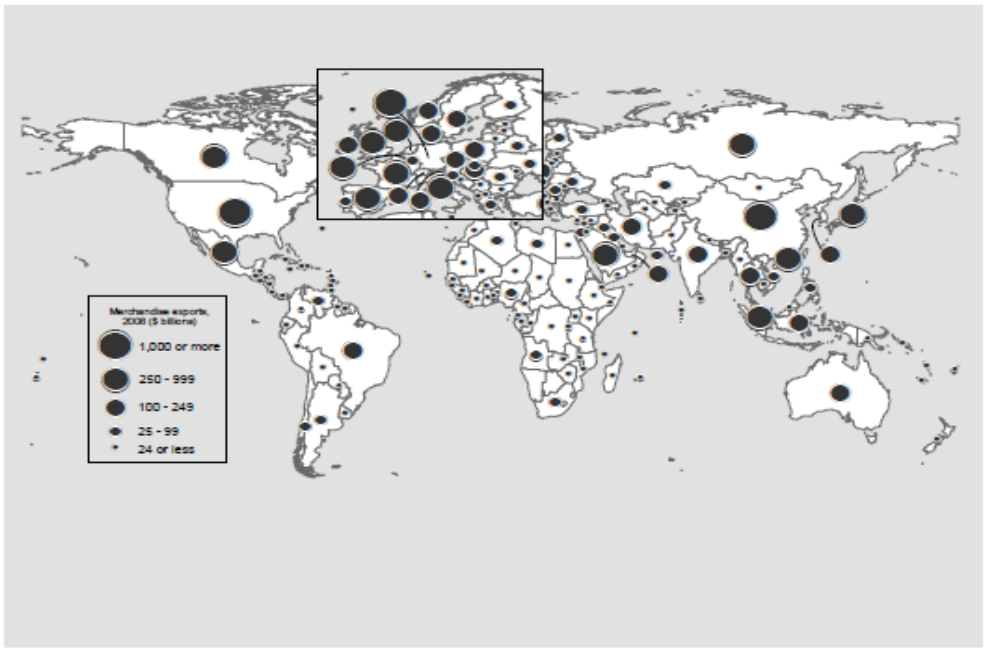
2.1 Overview of Green Freight Opportunities in the Global Freight Sector

Opportunities for green freight initiatives exist throughout the world in developed and developing economies; however, any given opportunity will be uniquely shaped by many factors including a country's current level of exports, economy, and existing infrastructure and transportation systems. This initial discussion focuses on those three factors—though other characteristics, such as population, political stability, and geography, also play key roles in development and implementation of a green freight program).

The information in this chapter highlights some of the characteristics and trends in today's global freight sector. In general, freight data are more readily available for countries with well-developed and rapidly developing freight sectors. Accordingly, the following tends to highlight information from such regions as North America, the EU, Russia, China, and Brazil.

In 2008, 51 percent of global exports by value were from 10 countries, with 26 percent alone coming from the United States, Germany, and China. The top 25 exporting countries accounted for 76 percent of all exports; of these 25, none were on the African continent and only Brazil was in South America. Figure 2-1 illustrates this in more detail and also provides additional context to help appreciate where the bulk of trade is occurring, as well as which countries or regions play dominant roles. The importance of North America, Europe, Pacific Rim nations, and India is clearly highlighted in the figure. Additionally, it can be seen that Middle Eastern countries such as Saudi Arabia, Iran, and the United Arab Emirates also have considerable export activity—chiefly due to their crude oil exports.

Figure 2-1. Value of World Goods Exports by Country: 2008



SOURCES: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, based on data from various sources. **United States**—U.S. Department of Commerce, U.S. Census Bureau, Foreign Trade Division, available at www.census.gov/foreign-trade/www as of May 12, 2009. **World**—International Monetary Fund, Direction of Trade Statistics. Available at www.imfstatistics.org/dot/ as of Sept. 14, 2009.

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Similar trends can be seen in gross domestic product (GDP): the United States, Japan, China, Germany, and France, the world's top five economies, accounted for 50 percent of global GDP ($30.1 trillion out of $60.9 trillion). Again, no African countries ranked in the top 25 in terms of GDP, and Brazil (#10) is the only South American country. Table 2-1 provides a complete list of the top 25 economies in 2008 as well as their ranking in 1995 and 2000, which allows one to see how a country's position has fluctuated over this 13-year period. China and Russia have moved up in position, although China has made a slow and consistent move while Russia actually moved down from 1995 to 2000 but then jumped 11 places in the next eight years. In addition, the other "BRIC" nations,[4] India and Brazil, have stayed relatively static in comparison, which again emphasizes the uniqueness across countries that are often grouped together.

[4] Brazil, Russia, Indonesia, and China.

Table 2-1. World's Leading Economies by GDP

Rank in 1995	Rank in 2000	Rank in 2008	Country	Billions of current U.S. $ 1995	2000	2008	Share of global GDP (percent) 1995	2000	2008
			World	29,633	31,972	60,863	100.0	100.0	100.0
1	1	1	United States	7,398	9,817	14,265	25.0	30.7	23.4
2	2	2	Japan	5,278	4,669	4,924	17.8	14.6	8.1
8	6	3	China	728	1,198	4,402	2.5	3.7	7.2
3	3	4	Germany	2,525	1,906	3,668	8.5	6.0	6.0
4	5	5	France	1,572	1,333	2,866	5.3	4.2	4.7
5	4	6	United Kingdom	1,157	1,481	2,674	3.9	4.6	4.4
6	7	7	Italy	1,127	1,101	2,314	3.8	3.4	3.8
17	19	8	Russia	313	260	1,677	1.1	0.8	2.8
9	11	9	Spain	597	582	1,612	2.0	1.8	2.6
7	9	10	Brazil	770	644	1,573	2.6	2.0	2.6
10	8	11	Canada	591	725	1,511	2.0	2.3	2.5
14	13	12	India	354	462	1,210	1.2	1.4	2.0
16	10	13	Mexico	314	629	1,088	1.1	2.0	1.8
13	14	14	Australia	371	390	1,011	1.3	1.2	1.7
11	12	15	South Korea	539	534	947	1.8	1.7	1.6
12	15	16	The Netherlands	419	386	869	1.4	1.2	1.4
23	18	17	Turkey	228	266	729	0.8	0.8	1.2
31	25	18	Poland	139	171	526	0.5	0.5	0.9
24	28	19	Indonesia	223	166	512	0.8	0.5	0.8
18	22	20	Belgium	276	233	506	0.9	0.7	0.8
15	20	21	Switzerland	316	250	493	1.1	0.8	0.8
21	21	22	Sweden	254	246	485	0.9	0.8	0.8
30	24	23	Saudi Arabia	142	189	482	0.5	0.6	0.8
28	27	24	Norway	149	169	456	0.5	0.5	0.7
22	23	25	Austria	239	192	415	0.8	0.6	0.7

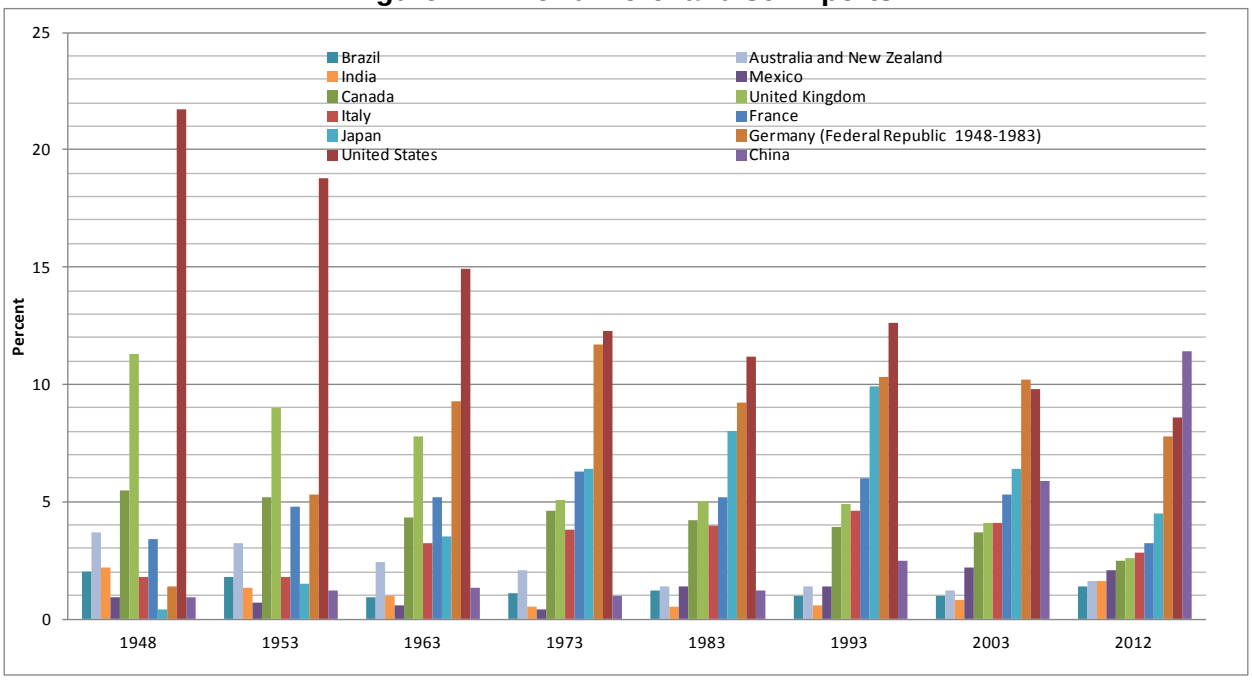
SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, based on data from International Monetary Fund, World Economic Outlook Database, April 2009, available at www.imf.org as of Sept. 14, 2009.

U.S. Department of Transportation

The World Trade Organization's 2013 report provides some additional insight into the historical flow of merchandise between countries.[5] The figure below illustrates the percentage of world merchandise exports for 12 economies. The figure is structured so that the economies' share of world exports are ordered from smallest to largest in 2012. This allows one to more clearly see how the share of world trade has shifted over the course of time. The graph clearly illustrates globalization and the shift of export growth toward Asian economies over the last 50 to 60 years.

[5] World Trade Organization (2013). *International Trade Statistics 2013*. Retrieved from http://www.wto.org/english/res_e/statis_e/its2013_e/its13_toc_e.htm.

Figure 2-2. World Merchandise Exports



A nation's existing infrastructure and transportation system is also an important factor to consider for any program designed to improve freight operations by increasing efficiency and reducing environmental impacts. Table 2-2 lists the top 25 countries ranked by total roadway mileages. The table also includes data on railways, waterways, pipelines, and airports. It can be seen that these are the same countries with the top 25 GDP rankings, although very few have the same position in both tables. The relatively large area of the United States coupled with a lower population density and higher urban population leads to relatively more freight activity, as goods must be moved longer distances from where they are manufactured or imported to consumers. Consequently, as can be seen in the table below, the United States has the world's most extensive freight network in terms of kilometers of paved roads, railways, waterways, pipelines, and airports. In some categories this difference is dramatic— for example, the United States has 5,146 airports and the country with the next highest number is Indonesia, with 669. Although airports themselves are not strongly correlated to the movement of freight, they are correlated with the movement of people, and the ability of executives or sales personnel to easily visit each other, clients, and potential customers may be an important precursor to the actual movement of goods and freight.

Table 2-2. Extent of Physical Transportation Systems in the World's Top Economies: 2008

Ranked by total roadways	Roadways		Railways (km)	Waterways (km)	Pipelines (km)	Airports (number)
	Total (km)	Paved roads (km)				
United States	6,465,799	4,209,835	226,427	41,009	793,285	5,146
India	3,316,452	1,517,077	63,327	14,500	22,773	251
China	1,930,544	1,575,571	77,834	110,000	58,082	413
Brazil	1,751,868	96,353	28,857	50,000	19,289	734
Japan	1,196,999	949,101	23,506	1,770	4,082	144
Canada	1,042,300	415,600	46,688	636	98,544	514
France	951,500	951,500	29,213	8,501	22,804	295
Russia	933,000	754,984	87,157	102,000	246,855	596
Australia	812,972	341,448	37,855	2,000	30,604	462
Spain	681,224	681,224	15,288	1,000	11,743	154
Germany	644,480	644,480	41,896	7,467	31,586	331
Italy	487,700	487,700	19,729	2,400	18,785	101
Turkey	426,951	177,500	8,697	1,200	11,191	103
Sweden	425,300	139,300	11,633	2,052	786	249
Poland	423,997	295,356	22,314	3,997	15,792	126
United Kingdom	398,366	398,366	16,454	3,200	12,759	312
Indonesia	391,009	216,714	8,529	21,579	13,752	669
Mexico	356,945	178,473	17,516	2,900	40,016	243
Saudi Arabia	221,372	47,529	1,392	U	8,662	215
Belgium	152,256	119,079	3,233	2,043	2,023	42
Netherlands	135,470	113,018	2,811	6,215	4,897	27
Austria	107,262	107,262	6,399	358	3,541	55
South Korea	103,029	80,642	3,381	1,608	2,250	113
Norway	92,946	72,033	4,114	1,577	95	98
Switzerland	71,298	71,298	4,888	65	1,763	66

KEY: U = Data are unavailable.

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, based on data from Central Intelligence Agency, *Fact Book 2009*, available www.cia.gov as of Sept. 20, 2009.

U.S. Department of Transportation

Table 2-1 provided historical GDP data that allow the overall economic growth of a nation to be assessed for the past 13 years. However, growth can also be measured in terms of road traffic, as shown in the tables and figures below for the emerging market economies of Brazil, China, and Russia.[6] These data illustrate the following:

- Road freight sector growth
  - Data were not available for Brazil.
  - China's road freight traffic grew from 784 million tonne-kilometers in 2004 to more than five billion in 2011 (a 554 percent increase).

[6] BRICS (2012). *BRICS Joint Statistical Publication 2012*. Retrieved from http://mospi.nic.in/mospi_new/upload/bricks_2012_24aug12/htm/.

- Russia's growth over the same time frame was much more modest, from 182 million to 223 million tonne-kilometers (a 23 percent increase).

- Rail freight sector growth
  - Brazil increased from 170 to 278 million tonne-kilometers from 2002 to 2010 (a 61 percent increase).
  - China increased from 1.9 to 2.9 billion tonne-kilometers from 2004 to 2011 (a 53 percent increase).
  - Russia increased from 1.8 to 2.1 billion tonne-kilometers from 2004 to 2011 (a 17 percent increase).
- Air freight sector growth
  - Brazil increased from 6.8 to 8.5 million tonne-kilometers from 2002 to 2008 (a 25 percent increase).
  - China increased from 7.2 to 17.2 million tonne-kilometers from 2004 to 2011 (a 139 percent increase).
  - Russia increased from 3 billion to 4.9 billion tonne-kilometers from 2004 to 2011 (a 63 percent increase).

Based on growth rates and relative economy sizes, it is clear from these data that these countries provide opportunities within multiple modes of transportation for green freight initiatives to be explored.

Table 2-3. Road Freight Sector Growth

Road (million tons-km)	2004	2005	2006	2007	2008	2009	2010	2011
China	784,090	869,320	975,425	1,135,469	3,286,819	3,718,882	4,338,967	5,133,316
		10.87%	12.21%	16.41%	189.47%	13.15%	16.67%	18.31%
Russia	182,141	193,597	198,766	205,849	216,276	180,136	199,341	222,823
		6.29%	2.67%	3.56%	5.07%	-16.71%	10.66%	11.78%

Figure 2-3. Road Freight Sector Growth

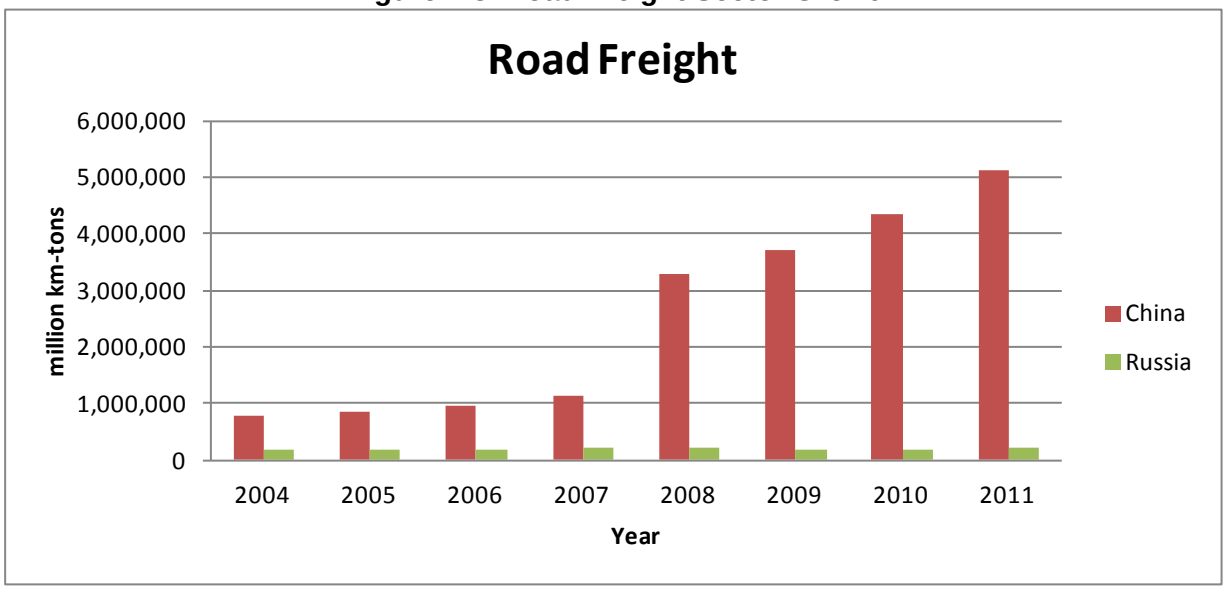


Table 2-4. Rail Freight Sector Growth

Rail (million tons-km)	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Brazil	170,178	182,644	205,711	221,633	238,054	257,118	266,967	245,316	277,922	
		7.33%	12.63%	7.74%	7.41%	8.01%	3.83%	-8.11%	13.29%	
China			1,928,880	2,072,600	2,195,441	2,379,700	2,510,628	2,523,917	2,764,413	2,946,579
				7.45%	5.93%	8.39%	5.50%	0.53%	9.53%	6.59%
Russia			1,801,601	1,858,093	1,950,830	2,090,337	2,116,240	1,865,305	2,011,308	2,127,212
				3.14%	4.99%	7.15%	1.24%	-11.86%	7.83%	5.76%

Figure 2-4. Rail Freight Sector Growth

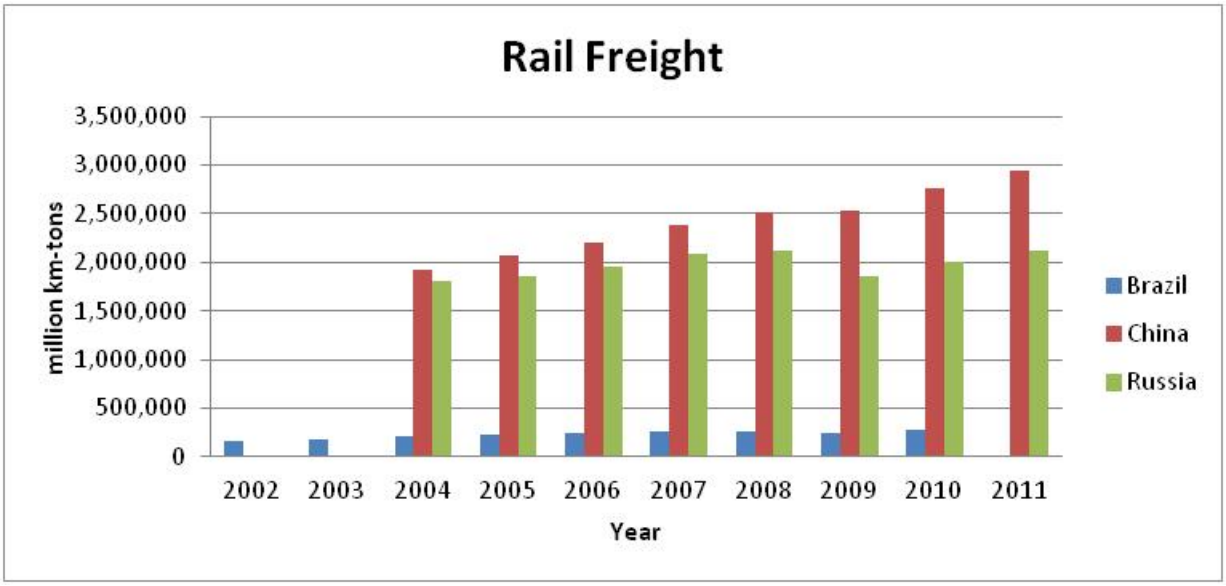


Table 2-5. Air Freight Sector Growth

Air (million tons-km)	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Brazil	6,796	6,677	7,343	8,185	7,725	7,604	8,535			
		-1.75%	9.97%	11.47%	-5.62%	-1.57%	12.24%			
China			7,180	7,890	9,428	11,639	11,960	12,623	17,890	17,166
				9.89%	19.49%	23.45%	2.76%	5.54%	41.73%	-4.05%
Russia			3,003	2,830	2,927	3,424	3,692	3,558	4,715	4,950
				-5.74%	3.43%	16.98%	7.80%	-3.63%	32.54%	4.98%

Figure 2-5. Air Freight Sector Growth

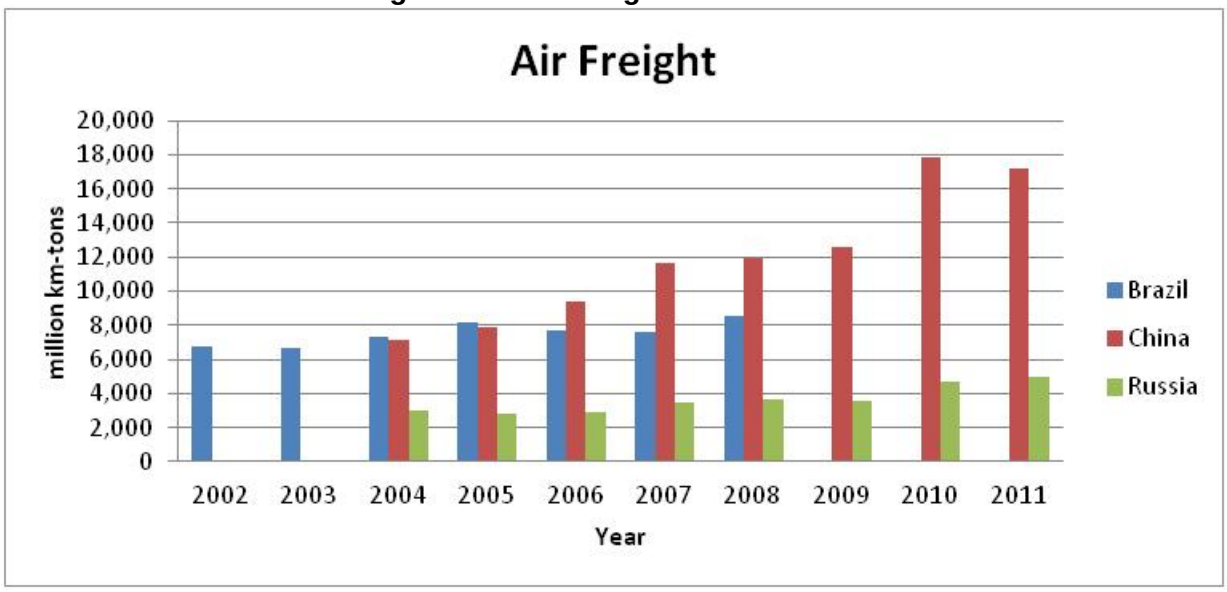
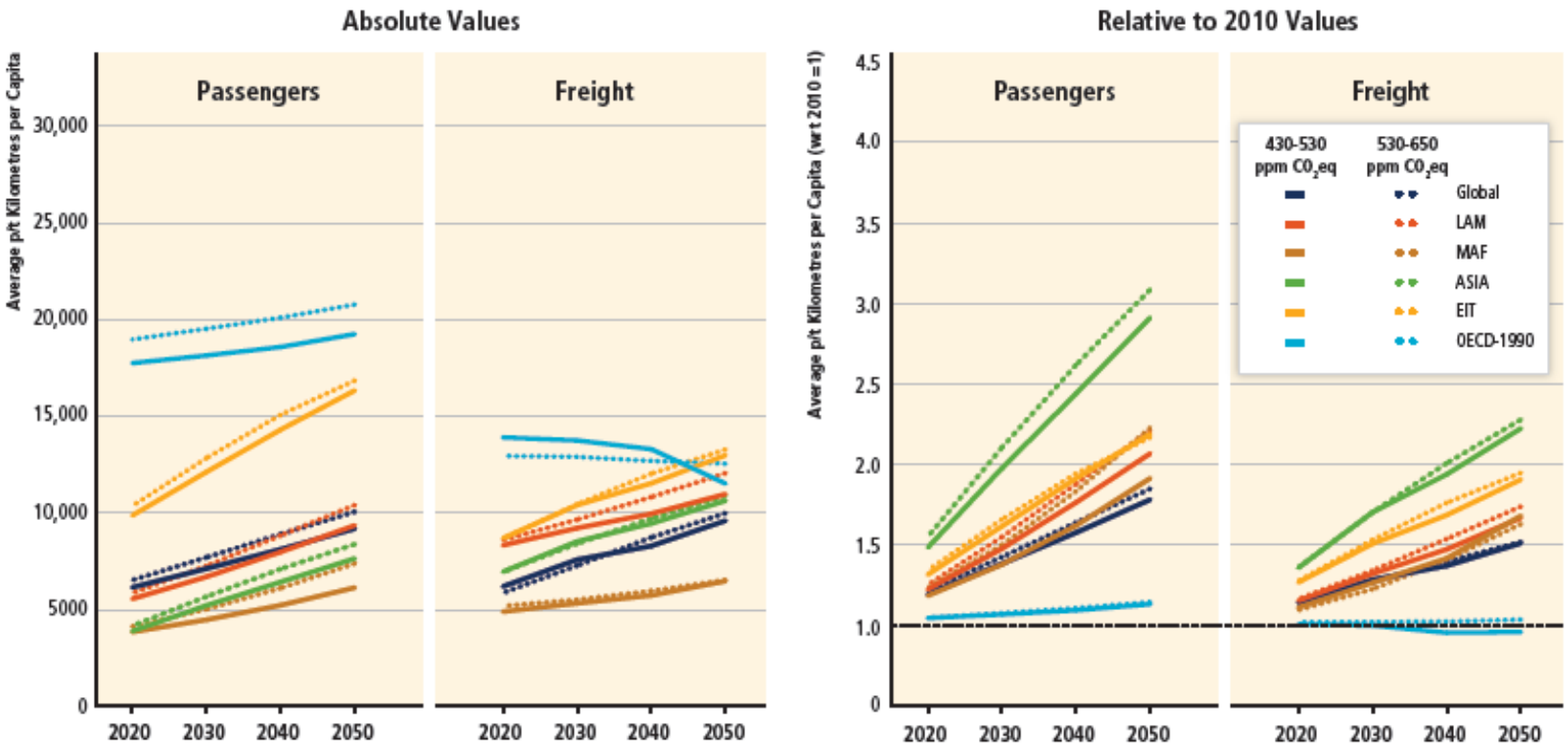


Figure 2-6 presents projected future growth in global freight by major region, as well as passenger transportation from 2020 through 2050, showing a general continuation of current trends. The figure, expressed in terms of tonne-km per capita per year for freight, also clearly indicates that the intensity of freight activity per person is strongly trending upward in all but the OECD countries.

Figure 2-6. Projected Global Passenger and Freight Growth by Region, 2020–2050 (Tonne-km per Capita per Year)[7]



LAM: Latin America and the Caribbean
MAF: Middle East and North Africa
EIT: economies in transition
OECD 1990: countries in the Organisation for Economic Co-operation and Development in 1990

[7] The IPCC analysis provides "high" and "low" intensity scenario projections for each region, as indicated by the solid and dashed lines, respectively. Source: Sims R., R. Schaeffer, F. Creutzig, X. Cruz-Núñez, M. D'Agosto, D. Dimitriu, M.J. Figueroa Meza, L. Fulton, S. Kobayashi, O. Lah, A. McKinnon, P. Newman, M. Ouyang, J.J. Schauer, D. Sperling, and G. Tiwari (2014). Transport. Figure 8.10 in Intergovernmental Panel on Climate Change. *Climate Change 2014: Mitigation of Climate Change.*

2.2 Health, Logistics, Technology, and Economic Impacts

There are many important reasons for establishing a green freight program. The freight industry has far-reaching and complex environmental, social, and economic impacts that accrue at the local level but have global consequences as well. While it provides a critical service to the world's growing population, it also accounts for a significant portion of total black carbon and GHG emissions and other pollutants from the transport sector. In certain regions of the world, the freight sector's contribution of GHG emissions can be inordinately high. For example, in India, only 5 percent of vehicles are trucks, yet they consume 46 percent of transport fuel and generate 63 percent of CO_2 and 59 percent of particulate matter emissions (which includes black carbon).[8]

Black Carbon Emissions

Black carbon is emitted directly into the atmosphere as a part of $PM_{2.5}$ emissions and it is the most strongly light-absorbing component of particulate matter. There is not a set fraction of $PM_{2.5}$ that is black carbon in a given sample; however, an EPA study[10] estimated that in 2005 the United States emitted 5.5 million tons of $PM_{2.5}$ and of that 12 percent was black carbon. Black carbon is a component of PM that comes from the incomplete combustion of fossil fuels, biofuels, and biomass. Older, less efficient engines and higher-sulfur diesel fuels are significant sources of black carbon. It is very effective at absorbing light and also reduces the reflectivity of snow and ice, which contributes to increased temperatures and accelerated snowmelt. Black carbon is of particular concern due to its very high global warming potential—by some estimate 680 times higher than CO_2's on a mass basis.[11]

As globalization and urbanization continues, developing economies grow, and standards of living continue to rise, fuel consumption and emissions associated with freight movement will rise as well. By the year 2050, medium- and heavy-duty freight trucks worldwide are projected to consume 1,240 billion liters of fuel, a 138 percent increase over 2000 levels.[9]

2.2.1 Health

Oxides of nitrogen and particulate matter, including black carbon, are key diesel pollutants that are produced by the diesel engines that are the workhorses of the freight industry. Those emissions contribute to serious public health problems, including premature mortality, and contribute to the creation of ground-level ozone. These pollutants aggravate respiratory and cardiovascular diseases, which can result in increased hospital admissions, emergency room visits, and school absences; lost work days; and restricted activity days. Additionally, since 2002, EPA has classified exposure to diesel exhaust as likely to be carcinogenic to humans.[12]

Children, the elderly, and people with existing health conditions are disproportionately affected by emissions generated by the freight industry because their cardiovascular, respiratory, and immune systems are more vulnerable to pollutants. In addition, freight yards, ports, borders, and

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[8] Clean Air Initiative for Asian Cities (n.d.). The rise of green freight in Asia. Retrieved from http://cleanairinitiative.org/portal/sites/default/files/Rise_of_Green_Freight_in_Asia_-_CAI-Asia_-_Sep_2012.pdf.

[9] Ibid.

[10] U.S. Environmental Protection Agency (2012). Basic information. http://www.epa.gov/blackcarbon/basic.html.

[11] Hill, B. (2009). *The Carbon Dioxide Equivalent Benefits of Reducing Black Carbon Emissions from U.S. Class 8 Trucks Using Particular Filters: A Preliminary Analysis.* Retrieved from http://www.catf.us/resources/publications/files/CATF-BC-DPF-Climate.pdf.

[12] U.S. Environmental Protection Agency (2002). *Health Assessment Document for Diesel Engine Exhaust.* Retrieved from http://www.epa.gov/ttn/atw/dieselfinal.pdf.

other areas of concentrated truck/rail activity are often located near lower-income neighborhoods, with their emissions disproportionately impacting these communities.

Given these realities, green freight programs can provide considerable benefits to public health as economies grow and nations become more heavily populated and there is an increasing reliance on diesel fuel to move freight and drive commerce.

2.2.2 Traffic Congestion

The freight industry demands space on roads for moving its products by truck. Freight movement can exacerbate already congested roadways, particularly in urban areas, increasing the costs associated with lost productivity. For example, recent estimates put the daily cost of traffic congestion at $55 million per day in the Philippines.[13] More efficient freight operations, such as reducing empty-miles, can both help reduce congestion and minimize freight-related infrastructure needs and pollution. Furthermore, as urban populations and vehicle ownership grow (estimates suggest that globally people living in cities will nearly double, to 6.3 billion, by 2050 and at the same time vehicle ownership will also increase, particularly in developing countries[14]), freight efficiency will become imperative to minimizing congestion and transportation-related air pollution.

2.2.3 Safety

All on-road traffic poses safety risks, including accidents resulting in injuries and loss of life. As overall traffic volumes increase, so do such accidents. Large, heavy-duty trucks can be responsible for a significant and increasing proportion of overall accidents and fatalities. For example, Figure 2-7 shows truck-related fatalities in Brazil from 2000 to 2009, with the majority of deaths occurring outside the truck (pedestrians or in automobiles). During this time, the fatality incidence rate associated with truck accidents increased substantially faster than the increase in total fatalities.[15,16,17] To the extent that Green Freight programs improve routing, reduce kilometers travelled, and reduce truck speeds, overall roadway safety should also improve.

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[13] Remo, M.V. (2013). Traffic costs P2.4B daily. *Philippine Daily Inquirer*. Retrieved from http://business.inquirer.net/130649/traffic-costs-p2-4b-daily. (P2.4 billion at 0.023 U.S. dollars per Philippine peso.)
[14] Shell Foundation (2012). *Scaling Solutions for Sustainable Mobility*.
[15] Federal Highway Administration (n.d.). Table VM-1. In *Highway Statistics 2010*. Retrieved from https://www.fhwa.dot.gov/policyinformation/statistics/2010/.
[16] Ibid.
[17] National Highway Traffic Safety Administration: FARS and GES data.

Figure 2-7. Fatalities in Truck and All Crashes

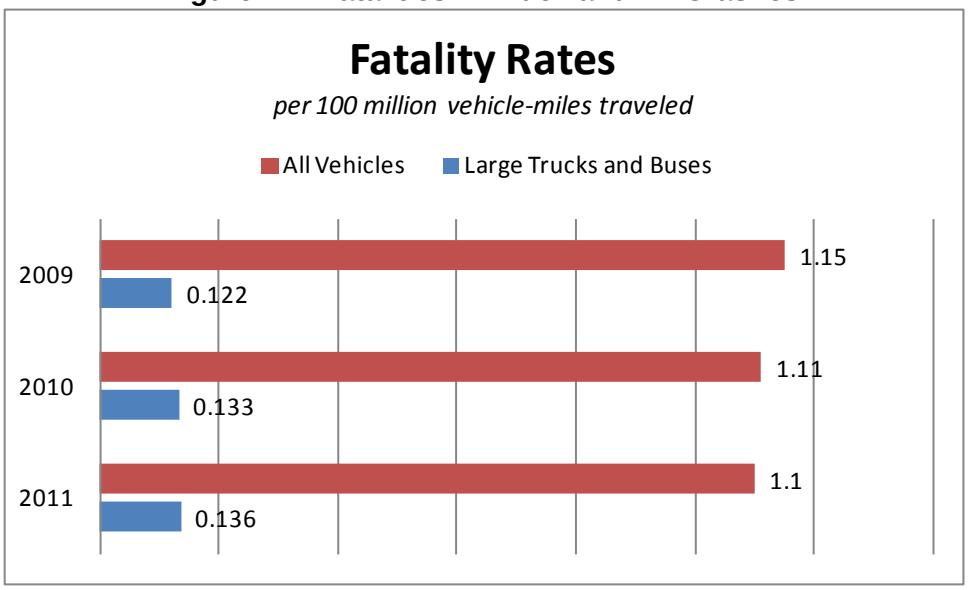
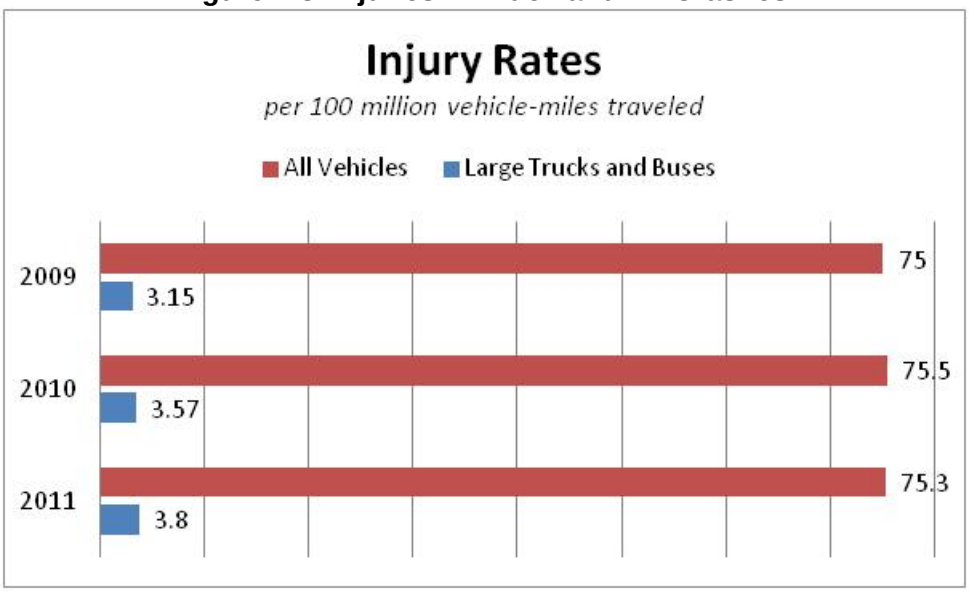


Figure 2-8. Injuries in Truck and All Crashes



2.2.4 Technology Advancement

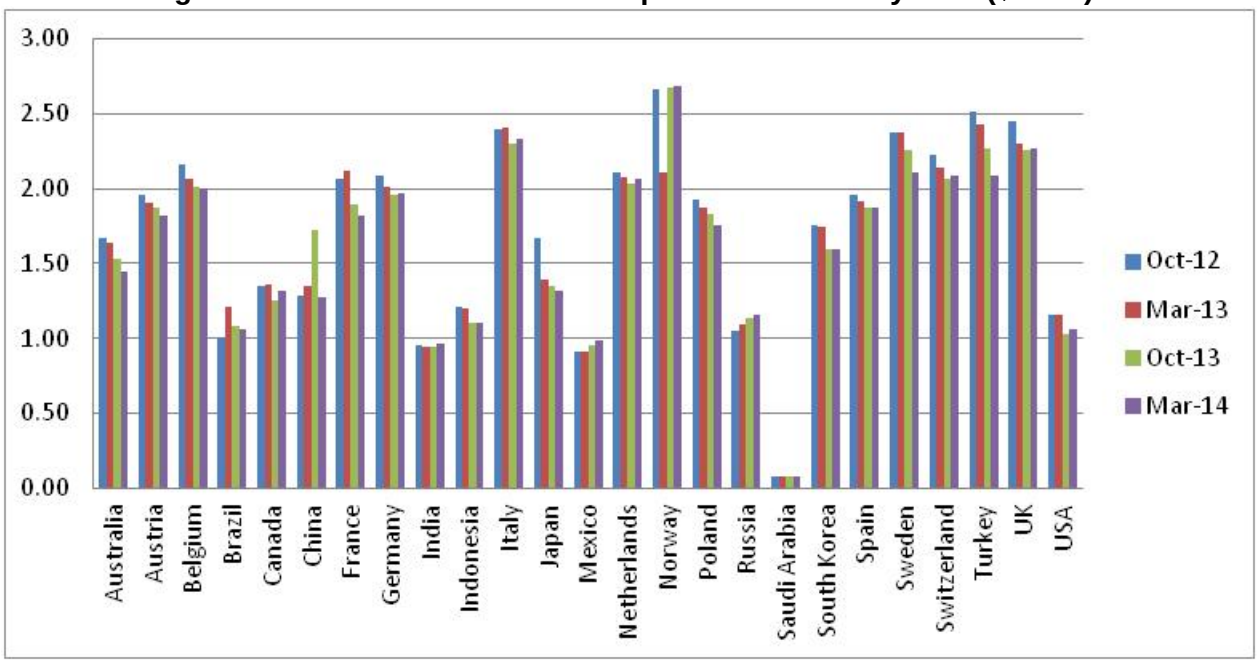
Green freight programs can play a role in spurring technological advances in engine, tractor/trailer, and tire design, as well as cleaner fuel standards. Programs can also help to bring those innovations to market at scale, which drives down costs. For example, EPA's SmartWay Transport Partnership program has promoted the use of aerodynamic truck and trailer treatments such as gap reducers, which have become increasingly common on tractor-trailer rigs in the United States and can reduce fuel consumption by 5 percent or more. In addition, the pervasiveness of computer- and GPS-based freight tracking systems allows for significant improvements in operational efficiency, such as the reduction of empty back-hauls. As truck fleets in other countries continue to take advantage of new efficiency technologies and logistics

strategies, their adoption will become easier and less costly elsewhere. Freight carriers and shippers that do not adopt these measures soon are likely to operate at a disadvantage relative to their competition.

2.2.5 Fuel Costs

Fuel prices have a significant impact on freight carrier profitability and competitiveness. They also affect the cost of delivering products to shippers and, ultimately, to consumers. In the United States, along with labor, fuel costs represent the highest portion of operating costs for truck freight transportation.[18] In some countries that rely on fuel imports, fuel costs may be responsible for up to two-thirds of total freight costs.[19] So a green freight program that delivers improved freight operating efficiency and reduced fuel consumption will have a direct economic benefit to freight carriers, shippers, and the public. The figure below illustrates diesel fuel costs for the top 25 economies as measured by GDP in 2008 from October 2012 to March 2014. These are the same countries listed in Table 2-1 above.[20]

Figure 2-9. Diesel Fuel Costs for Top 25 Economies by GDP ($/Liter)



2.2.6 Other Economic Impacts

Freight efficiency has the potential to keep local capital local and frees up financial resources for alternative uses. Additionally, a green freight program can foster new local business

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[18] American Transportation Research Institute (2010). *An Analysis of the Operational Costs of Trucking*. Retrieved from http://www.atri-online.org/research/results/ATRITRBOpCosts.pdf.

[19] U.N. Centre for Regional Development (2011). *Best Practices in Green Freight for an Environmentally Sustainable Road Freight Sector in Asia*. p. 9. Retrieved from http://cleanairinitiative.org/portal/sites/default/files/BGP-EST5A_Green_Freight_Best_Practices_-_CAI-Asia_Dec2011.pdf.

[20] Data obtained from http://www.globalpetrolprices.com/diesel_prices/ (accessed January 28, 2014).

opportunities. This could occur through the improvement of roadways, ports, and/or airports, which certainly provide local job opportunities. In addition to this economic activity spurred by infrastructure development, additional jobs associated with installing and maintaining clean diesel technologies can be created and sustained from the demand driven by a green freight program.

2.3 Emission Standards and Policy

Emission levels and potential reductions associated with freight carriers are significantly influenced by vehicle/engine sizes, fuel types, and the age distribution of the fleet. In general, large, older diesel engines will have higher PM and NO_x emissions than newer and/or smaller diesels. On the other hand, engines relying on gasoline or gaseous fuels (e.g., CNG, LNG, or LPG) will have lower PM and NO_x emissions, although they are likely to be less fuel-efficient than comparable diesel engines. Emerging markets often have a greater proportion of smaller, lighter trucks such as urban delivery vehicles compared to heavier, long-haul tractor-trailer rigs (partly due to the higher capital cost of heavier trucks), but because many of these trucks are obtained through the used vehicle market they are often relatively older and higher-polluting.

In order to lower emissions many advanced emission control technologies first require the widespread availability of clean fuel such as ultra-low sulfur diesel fuel (typically less than 50 ppm sulfur, although precise definitions vary by region). Sulfur levels below 50 ppm are important because emission control systems are poisoned and rendered ineffective when exposed to higher levels of fuel sulfur.

Once clean fuel is available in a region, the emission concerns that are inherent with a legacy fleet can be addressed using retrofit technologies. The availability and prevalence of emissions control technologies and fuel efficiency retrofits vary depending on the relative cost and quality of fuel, as well as the freight industry's stage of market development. Mature markets are more interested in fuel efficiency retrofits and often have higher investment in efficiency and pollution control technologies. In emerging markets experiencing significant growth, there is often less concern with emission control technologies that may actually increase fuel consumption, and for that reason PM and NO_x retrofits may have low adoption rates in the absence of other market incentives, such as packaging fuel saving technologies with emissions reduction technologies. For example, diesel particulate filters can reduce fuel economy by 2 to 4 percent.[21] If adopted alone, these technologies do not offer cost savings; however, if vehicle PM and NO_x controls can be bundled with integrated fuel efficiency improvement strategies, fleet managers can effectively offset these costs through greater overall fuel savings.

Because of the slow turnover of the heavy-diesel truck fleet, it can take decades to see the full benefit of adopting emission standards for new vehicle engines. Figure 2-10[22] clearly demonstrates this feature of the heavy truck fleet, showing the fraction of NO_x, PM_{10}, and total mileage attributable to pre-2010 model year long-haul diesel trucks in the United States. Over the period shown (2010–2020), the mileage fraction associated with these older trucks drops

[21] Cambridge Systematics (2010). *NCHRP 25-25 (Task 59): Evaluate the Interactions Between Transportation-Related Particulate Matter, Ozone, Air Toxics, Climate Change, and Other Air Pollutant Control Strategies*.
[22] Source: MOVES 2010b.

dramatically (from roughly 90 to 20 percent). However, due to their much higher emission rates, these older vehicles are still responsible for the majority of emissions in 2020 (~50 percent of NO_x and ~85 percent of PM). This disproportionate relationship between truck age and the fraction of emissions highlights the need for programs to address the emissions associated with the in-use ("legacy") fleet through green freight programs and other strategies. A similar figure is provided for the Hong Kong medium and heavy-duty fleet.

Figure 2-10. Emissions Fraction Attributable to Pre-2010 Trucks (United States)

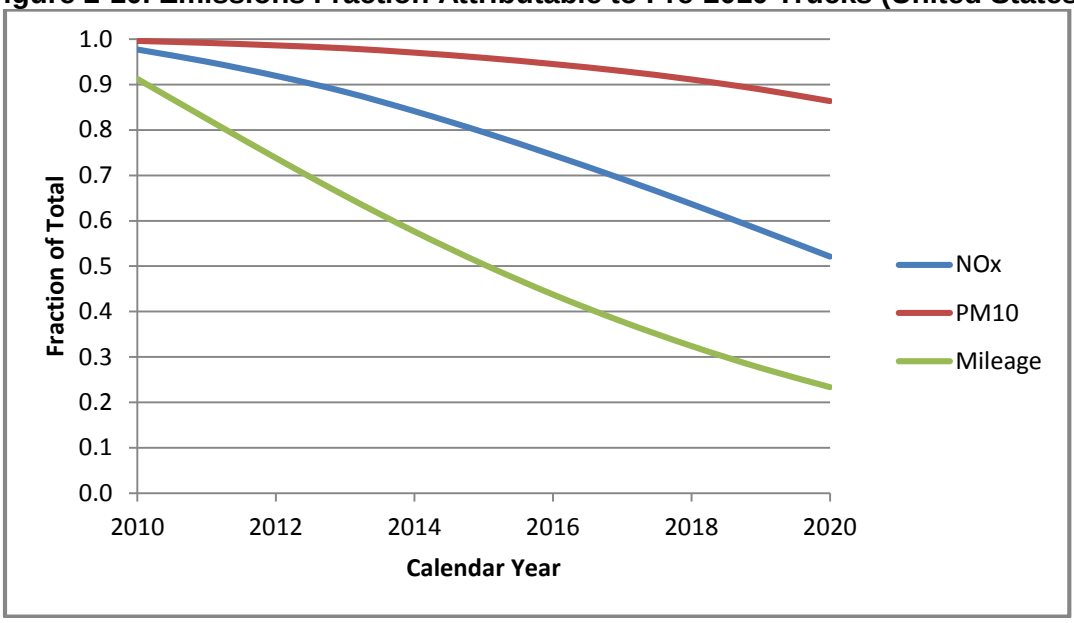
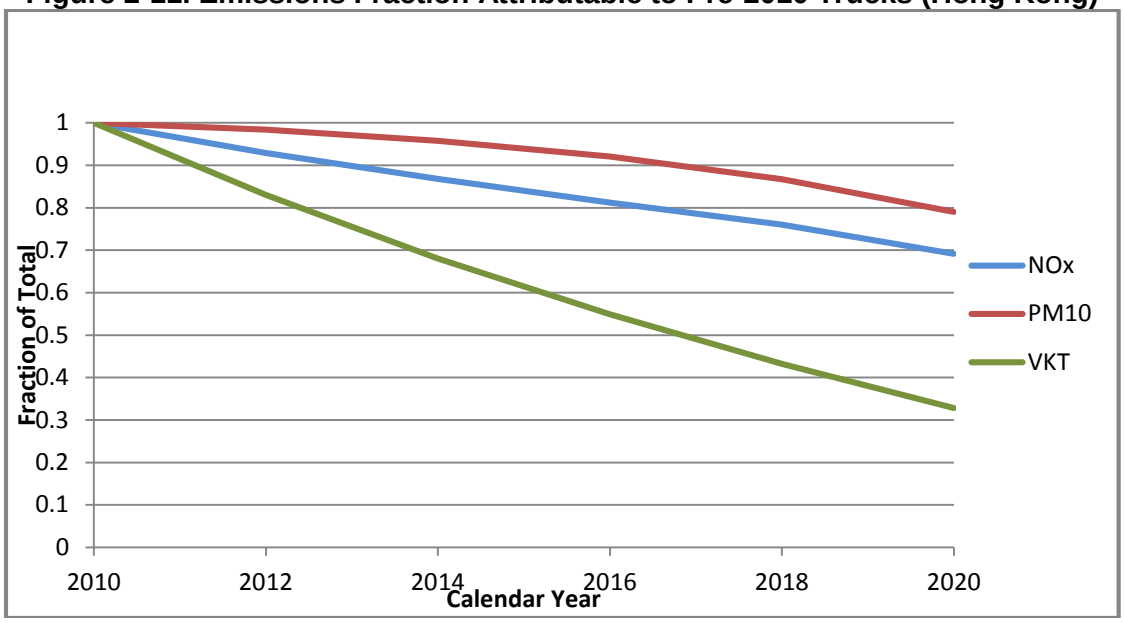


Figure 2-11. Emissions Fraction Attributable to Pre-2010 Trucks (Hong Kong)



Generally, emission standards are more stringent in mature markets than emerging markets. The United States, Japan, and Western Europe lead the way in limiting commercial vehicle emissions. In 2001, in the United States, EPA signed emission standards for heavy-duty highway

engines model year 2007 and later for PM (0.01 g/bhp-hr), NO_x (0.20 g/bhp-hr), and NMHC (0.14 g/bhp-hr). However, standards are not limited to mature markets: environmental demands in emerging markets are rising in China, India, and Russia, particularly in large metropolitan areas. Combining information on vehicle age distributions with the phase-in of emissions and fuel economy standards will help identify which portions of the carrier fleet are particularly high-emitting and/or have relatively poor fuel economy.

Table 2-6 summarizes the historical emission standards for heavy on-road diesel engines in both the United States and the EU, clearly demonstrating the progressive tightening of NO_x and PM limits over time. Table 2-7 illustrates emission standards in various other countries.[23]

Table 2-6. United States and EU Heavy-Duty Emission Standards

Heavy-Duty Diesel Truck Emission Standards, EPA and EU Engine Dynamometer Testing over Transient Cycles				
EPA, Converted to g/kWh				
Year	**HC**	**CO**	**NO_x**	**PM**
1994	1.74	20.79	6.71	0.13
1998	1.74	20.79	5.36	0.13
2004	**NMHC**	**CO**	**NMHC + NO_x**	**PM**
Option 1	n/a	20.79	3.22	0.13
Option 2	0.67	20.79	3.35	0.13
2007+	**NMHC1**	**CO**	**NO_x**	**PM**
	0.19	20.79	0.27	0.013
EU, g/kWh				
Date, Stage	**NMHC**	**CO**	**NO_x**	**PM**
2000, Euro III	0.78	5.45	5	0.1
2005, Euro IV	0.55	4	3.5	0.02
2008, Euro V	0.55	4	2	0.02
2013, Euro VI	0.164	4	0.4	0.01
Notes				
[a] Sales-weighted phase-in from 2007 (50%) to 2010 (100%).				
[b] Most engines from 2007 to 2009 meet family emissions limit of ~1.6–2 g/kWh NO_x.				
[c] Note that additional steady-state standards also applied to Euro III–Euro V.				

[23] http://www.dieselnet.com

Table 2-7. Emission Standards in Other Countries (g/kWh)

EU		Euro I	Euro II	Euro III	Euro IV	Euro V	Euro VI
	NOx	8.00	7.00	5	3.50	2.00	0.4
	PM	0.36	0.15	0.1	0.02	0.02	0.01

		1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Australia	NOx				EU III					Euro IV			Euro V						
	PM																		
Brazil	NOx		Euro II						Euro III			Euro IV			Euro V				
	PM																		
China	NOx		Euro I			Euro II			EU III					Euro IV		Euro V			
	PM																		
India	NOx		Euro I					Euro II					Euro III						
	PM																		
Japan	NOx	4.5	4.5	4.5	4.5	3.38	3.38	2.0	2.0	2.0	2.0	0.7	0.7	0.7	Euro VI				
	PM	0.25	0.25	0.25	0.25	0.18	0.18	0.027	0.03	0.027	0.027	0.01	0.01	0.01					
Russia	NOx	Euro I							Euro II		EU III					Euro IV			Euro V
	PM																		
South Korea	NOx	6.0	6.0	6.0	6.0	Euro III			Euro IV			Euro V					Euro VI		
	PM	0.25	0.25	0.25	0.15														
Turkey	NOx			Euro I						Euro IV				Euro V				Euro VI	
	PM																		

As noted above, to meet tighter emission standards, advanced control technologies typically require ultra-low-sulfur diesel fuel (e.g., less than 50 ppm sulfur). Many areas, including the United States, Western Europe, and Japan, have transitioned to such fuels. In 2006, the United States implemented a diesel sulfur standard of 15 ppm. While emerging market countries have begun to reduce the sulfur content in their fuels, they have not yet reached ultra-low levels: China and India have both set maximum sulfur levels for diesel at 350 ppm, and China has set further targets for the coming years (50 ppm by 2014, 10 ppm by 2017).[24] Green freight programs can generate market demand for the adoption of the aggressive fuel quality standards needed to enable the use of advanced emission control technologies, as discussed above. Table 2-8 provides a snapshot of sulfur levels in diesel fuel for nine countries over 15 years. Figure 2-12 shows fuel sulfur trends from 2005 through 2014, indicating how countries have made significant progress in implementing low-sulfur diesel standards.

Table 2-8. Diesel Sulfur Levels in Various Countries[25]

On-Road Diesel Sulfur Levels (ppm)

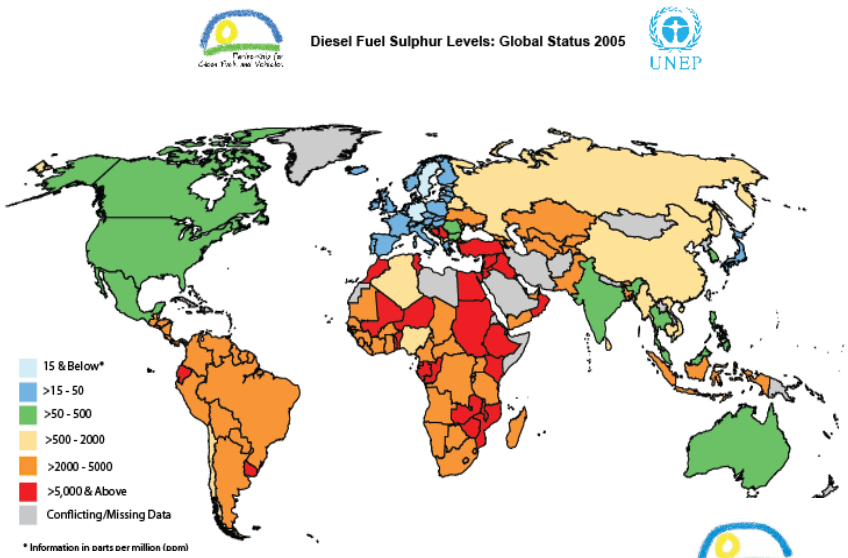
Country	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Brazil*	3500	2000				1800-500 transition				500						
China*	2000						350				50			10		
EU-27	50				10											
India*	500					350										
Japan	50		10													
Russia	500								350		50	10				
Thailand	150							50								
USA	500	15														
South Africa	3000	500 (50 in some markets)											10			

TransportPolicy.net

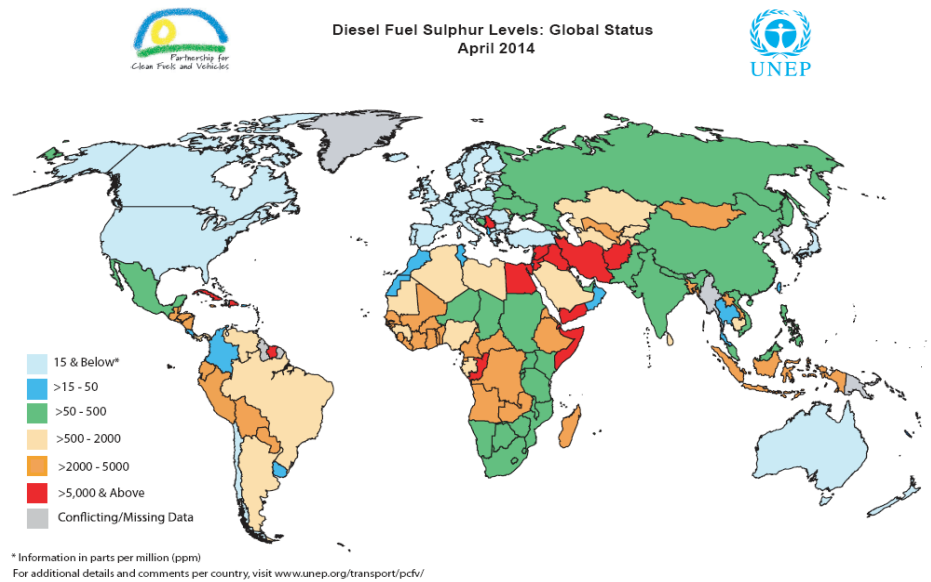
[24] TransportPolicy.net (2014). China: Fuels: Diesel and gasoline. Retrieved from http://transportpolicy.net/index.php?title=China:_Fuels:_Diesel_and_Gasoline.

[25] TransportPolicy.net (2014). Global comparison: Fuels. Retrieved from http://transportpolicy.net/index.php?title=Global_Comparison:_Fuels.

Figure 2-12. Global Fuel Sulfur Level Trends



Diesel Sulphur 2005 and 2014



- 13 countries at 50 ppm & below
- At least 5 more by end 2014
- More countries have lowered sulphur levels
- More cities at 50 ppm

UNEP

Green freight programs can play a significant role in promoting the adoption of tighter emission standards and implementation of low-sulfur diesel fuel. All of the opportunities outlined in this chapter can be pursued through collaborative efforts between governments, private industry, and other stakeholders so that all resources can be leveraged to the fullest advantage and the goals of the Global Green Freight Call to Action will be realized.

3.0 Current and Developing Green Freight Programs

Green freight programs around the world have developed a variety of approaches to promote the adoption of energy-saving and emission-reducing strategies such as those described in the preceding chapters. The focus of these programs, the types and numbers of partners included, and their data collection, performance benchmarking, and reporting methodologies depend on the transport modes addressed, the pollutants and performance metrics of interest, as well as the geographic regions involved.

While these programs vary in many ways, many of them share elements including:

- Standardized data collection and performance benchmarking processes that are organized by a neutral party who can ensure protection of sensitive data as well as data consistency, integrity, and verification.
- Streamlined and consistent methods for fuel, CO_2, and/or other emissions measurement and reporting.
- Active participation of the private sector in developing internally consistent green freight policies and programs.
- Active collaboration among stakeholders (shippers, carriers, and logistics service providers) to share best practices and jointly scale up green freight efforts.
- Consistent branding, outreach, and marketing initiatives to core stakeholder groups, high-profile recognition events, and if possible, leverage financial support.

Central to these efforts, green freight programs seek to provide reliable and quantifiable information regarding fuel-saving and emission reduction strategies. These programs aim to accelerate the adoption of operational strategies and technologies in goods movement. This information allows program participants to make more informed decisions in order to reduce fuel costs, greenhouse gases, black carbon, and other pollutants in the most cost-effective way. By laying the groundwork for measuring and incentivizing these reductions, green freight programs facilitate the adoption of clean fuel standards, emission control technologies, and fuel efficiency improvements for both in-use and new vehicle fleets.

Some programs, such as the SmartWay Transport Partnership in the U.S. and Canada, as well as other national initiatives in China, Australia, Mexico, France, and Korea, are based on public-private partnerships. These publicly funded programs rely on the close cooperation of government agencies as well as private sector stakeholders such as freight carriers, shippers, and logistics companies. Other initiatives, such as Green Freight Europe and Green Freight Asia, are led by the private sector and do not use public funding. Although the public-private partnerships and privately led initiatives may share many goals and quantification methodologies, their different funding sources and organizations can lead to important differences in how the programs are implemented and managed.

This chapter provides an overview of the status of existing green freight programs around the world, highlighting commonalities and differences as well as identifying important information gaps. The evaluation also attempts to identify which programs and approaches have been

particularly successful in fostering freight industry participation and generating fuel savings and emission reductions. Detailed characterization of these programs will help support the goals of the CCAC's Global Green Freight Action Plan by identifying common, successful program elements that in turn can provide a framework for developing and harmonizing green freight efforts worldwide.

Green freight programs were identified for inclusion in this background paper through a combination of Web searches and contacts with experts in the field. Mr. Buddy Polovick (of the U.S. EPA's SmartWay program) and Ms. Sophie Punte (of the Smart Freight Centre) in particular provided a number of contacts with various green freight programs for information requests.

To identify programs for detailed evaluation, we adopted the following criteria:

- The initiative must be a voluntary truck/rail/marine freight program, targeting carriers, shippers, and/or logistics companies.
- The program must be ongoing or under active development (i.e., beyond the "paper study" stage).
- The program must involve both benefit quantification methods and calculation tools (planned or existing).

The above selection criteria excluded a wide variety of general grant programs, such as EPA's National Clean Diesel Campaign, as well as programs not specific to freight movement (e.g., the Carbon Disclosure Project). While such programs can be complementary to global green freight initiatives, they generally do not provide enough specific information to facilitate full-scale green freight program development and harmonization.

Voluntary Partnership Programs

A voluntary partnership program is a structured relationship between a government agency and multiple private sector entities to address a public policy problem. Such problems can include air pollution resulting from economic activity, energy security, or other issues not fully addressed by private sector markets. Voluntary partnership programs are becoming a popular policy tool around the globe. They are deployed in lieu of, or as a complement to, regulatory programs to achieve environmental goals. They can be effective tools because they can spark action without legislation, regulations, or civil penalties.

In a voluntary program, participants, or partners, commit to benchmarking, monitoring, and sharing information as well as taking specific verifiable actions beyond "business as usual." In exchange, the government agency commits to help remove market and other barriers, providing a reliable source of performance data and technical support, furnishing public recognition, and supplying other market incentives. Typically, participation in a voluntary program is codified in either a memorandum of understanding or a partnership agreement. Both documents are legally binding agreements that either party can terminate at any time, if the terms are violated, without fear of fines or other penalties.

Voluntary partnership programs can be used to provide grants or subsidies for equipment retrofits, engine rebuilds/early retirement (scrappage), and alternative/clean fuel adoption to reduce emissions. Examples of such programs include EPA's National Clean Diesel Program and the California Air Resources Board's Carl Moyer Program. Voluntary green freight programs such as SmartWay can be successful in collecting standardized, reliable activity and fuel consumption data from freight carriers and making them available to their customers (shippers).

Successful participants in partnership programs will often find themselves "ahead of the curve" in terms of meeting vehicle, fuel, and operational efficiency targets if and when regulatory standards are adopted. Conversely, the data and knowledge obtained during the course of a well-run partnership program, such as voluntarily submitted data on partner actions, facilities, and resources, can also be used to inform successful regulatory programs and more effective environmental policies down the line.

3.1 Detailed Program Summaries

The subsections below describe eight green freight programs in detail. The information available on these programs varied significantly from program to program; this information came from standard Web and literature searches, and (when certain important information could not be gathered from those sources) from program contacts obtained from EPA and the Smart Freight Centre.

Each summary begins with an overview of the program and its primary objectives, followed by a table containing general information, data on partner participation levels, an overview of key program components, any benefit estimates, and miscellaneous additional information. The overviews conclude with a short assessment of program strengths with respect to breadth, depth, precision, comparability, and verifiability.[26]

3.1.1 SmartWay Transport Partnership[27,28,29,30]

The SmartWay Transport Partnership was officially launched by the U.S. EPA in 2004. EPA and Natural Resources Canada (NRCan) worked to expand the program to Canada by establishing joint administration of the SmartWay program under a letter of agreement dated July 2012. Under this agreement EPA and NRCan have fully harmonized their data collection, emission calculation, and database functionality for data sharing to create one seamless program, with the same partner recognition and logo qualification requirements in each country.[31] Accordingly, SmartWay now covers all U.S. and Canadian domestic truck, rail, intermodal, and barge freight transport. The integration process between these two agencies has been successful and may serve as a template guiding future program harmonization efforts. As SmartWay develops reciprocal agreements with other countries developing compatible programs, the emission data from those countries could potentially be included in a global SmartWay database.

SmartWay is the most extensive, mature green freight program in operation today. With over 3,100 shippers and carriers, the program covers roughly 30 percent of total freight miles travelled in the United States, and its overall design has influenced other green freight programs as discussed below. The SmartWay Tools and accompanying support database were designed to form the basis of a global freight transportation carbon analysis system. Specific performance data provided by Carrier Partners are processed to generate carrier-specific performance metrics (e.g., grams per mile and grams per ton-mile for EPA, grams per kilometer and grams per tonne-

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[26] Program summary information was reviewed by program representatives, but not independently verified by ERG.
[27] U.S. Environmental Protection Agency (2014). SmartWay. Retrieved from http://www.epa.gov/smartway/.
[28] Natural Resources Canada (2014). SmartWay. Retrieved from http://www.nrcan.gc.ca/energy/efficiency/transportation/commercial-vehicles/smartway/7615.
[29] Personal communications: Buddy Polovick, U.S. EPA, January–June 2014.
[30] Personal communications: Jennifer Tuthill, Natural Resources Canada, January–June 2014.
[31] Small but important differences between the programs include different Partnership Agreements reflecting the differing legal frameworks and privacy issues in each country; the use of metric system reporting units and optional French language text in the NRCan Tools; and assorted differences in information provided to Partners through program Web pages.

kilometer for NRCan), which are in turn used by shipper and logistics partners to help improve their own emission footprints.

Along with BSR's Clean Cargo Working Group, the SmartWay Transport Partnership is the longest continually operating green freight program. Its durability and overall success are attributable to a number of factors, most notably the broad and deep leadership and commitment from its Partners. The 15 Charter Partners, including national and international carriers, shippers, and trade organizations, provided EPA with key institutional knowledge of the freight industry and helped legitimize the program from its inception. Over the last decade, SmartWay has developed a particularly effective public-private partnership model, with a very broad range of Partners across multiple modes as well as a wide variety of affiliates. SmartWay's Shipper Partners include some of the largest corporations in the world, and in key economic sectors such as retail, manufacturing, consumer products and food and beverage; accordingly, these Partners exert great influence on carrier participation and overall program visibility.

SmartWay also has an effective incentive and rewards system in place. Most importantly, Shipper and Logistics Partners' use of the publicly available carrier performance rankings is a highly effective means of incentivizing carrier participation in the program, as well as promoting continual improvement. In addition, the program has well-known, recognizable logos, clear logo qualification criteria, and an Excellence Awards program. Logos are available for Partner participation,[32] as well as for the use of verified tractor and trailer technologies. SmartWay has made access and retrieval of Partner logos and program registration documents very easy through the use of company-specific, secure "Partner Portals." In the future it will be possible to provide partners with company- and fleet-specific performance and benchmarking "business intelligence" reports through the portal, giving program participants the ability to compare their efficiency levels with other similar participants. For example, truckload dry van Partners could compare their performance to the full distribution of other truckload dry van Partners. Alternatively, shippers could compare their chosen carriers' performance with that of shippers of identical or similar commodities/freight modes. Summary "Performance Report Cards" tailored for each partner are also under development.

Another key to SmartWay's continued growth and success is the provision of broad implementation support, including development and maintenance of outreach and education materials, fuel savings and payback estimates for technology investments and operational changes, online driver training, and a variety of other partner services. Adequate, consistent funding over multiple years has been crucial to delivering high-quality, value-added services to program participants. Both EPA and NRCan currently provide for full-time partner account manager (PAM) support, as well as contractor support for tool and database development and maintenance. PAMs are assigned specific Partners and establish long-term working relationships with their Partner contacts, facilitating effective communication and promoting loyalty to the program over time.

[32] Partner logos are available for any participant submitting a complete, approvable tool on time each year.

Program Element	U.S. EPA	NRCan
General Information/Program Organization		
Program administrator/ contact agency/ consortium funding source	Cheryl Bynum EPA Office of Transportation and Air Quality Transportation and Climate Division SmartWay and Supply Chain Programs Center 734-214-4844; bynum.cheryl@epa.gov	Cara Scales Chief, SmartWay Program Natural Resources Canada 613-793-0276; cara.scales@NRCan-RNCan.gc.ca
Program goals	Reduce transportation-related emissions by creating incentives to improve freight supply chain energy and environmental efficiency.	Reduce energy use in the Canadian freight transportation sector. Increase the accessibility of the SmartWay program to Canadian firms by offering it in French and English and in metric units.
Description	SmartWay covers freight transport throughout the United States and Canada, and currently includes truck, rail, multi-modal, and barge transportation modes. Shippers and logistics companies are also included. Future modes will include oceangoing marine and air cargo.	
Start year	Charter Partners joined in 2002; official launch 2004.	Official launch September 2012, with the introduction of the Canadian version of the SmartWay Truck Tool. Other modes were phased in between 2012-2015.
Pollutants quantified and performance metrics used	Pollutants: CO_2, NO_x, PM_{10}, $PM_{2.5}$. Performance metrics (English units for EPA, metric for NRCan): g/mile, g/ton-mile, g/1,000 cubic foot-miles, g/utilized 1,000 cubic foot-miles.	
Annual funding range	Varies due to budgetary allowance. Budget includes contractor support and all programmatic costs including PAMS, but does not include federal employee salaries/benefits.	Varies due to budgetary allowance. During the period of the Canadian launch and implementation (2011, 2012, 2013), the program received approximately $3M (Canadian dollars) for contractor support and program costs including federal employee salaries/benefits.
State of development	Fully developed “2.0” stage. Investigating methods for including larger numbers of small (owner-operator) fleets.	
Partners		
Number of partners (as of June 15, 2014)	**Total: 2,884** • Truck: 2,114 • Rail: 20 • Multi-modal : 18 • Logistics: 481 • Shipper: 248 • Barge: 3	

Program Element	U.S. EPA	NRCan
Other key stakeholders/ affiliates	226 affiliates as of June 15, 2014. The following types of organizations can become SmartWay affiliates: • SmartWay nonprofit affiliates are trade and professional associations, non-governmental organizations, academic institutions, and governmental agencies that educate their constituents about the SmartWay program. • SmartWay truck/trailer dealerships promote and sell tractors and trailers that have been SmartWay-designated by the U.S. EPA, and/or promote and sell SmartWay-verified add-on technologies. • SmartWay leasing companies promote and lease SmartWay-designated vehicles, tractors, or trailers to dealerships and/or multiple franchises. • SmartWay truck stops/travel plazas educate customers about ways to reduce long duration idling.	
Program Components		
Data collection / evaluation process	Annual fuel consumption and mileage reported by carriers; shippers and logistics companies report carrier-specific mileage and tonnage, which is matched with carrier-specific g/mile and/or g/ton-mile (g/km and or g/tonne-km in Canada) performance factors to calculate emission footprint. The NRCan truck tool also collects information on the specific fuel-saving and emission control strategies currently employed by partners' fleets, although this is not used for calculation.	
Quantification methodologies	CO_2 benefit based on fuel consumption estimates combined with fuel factors by fuel type; NO_x and PM benefits based on reported mileage combined with MOVES[33] g/mile (or g/km) emission factor by truck class, fuel type, and engine model year. Separate emissions calculated for truck refrigeration units using NONROAD model emission factors. Annual emission reductions calculated at the partner level based on the incremental change in calculated gram per ton-mile (or km) emissions multiplied by the current year's total ton-miles.	
Data collection tools	Excel forms using VBA programming. Tools downloaded through program Web pages.	
Branding and marketing strategies	Logos available for Partners in good standing, trucks and trailers meeting program specifications. Annual Excellence Awards based on performance relative to peers and supplemental qualitative application for some categories. Outreach includes targeted advertising and recruiting to key sectors such as retail, food and beverage, and consumer products.	
Technology program details	Administered by the U.S. EPA, SmartWay's Technology program develops test protocols, reviews strategies, and verifies the performance of vehicles, technologies, and equipment that have the potential to reduce greenhouse gases and other air pollutants from freight transport. The program establishes credible performance criteria and reviews test data to ensure that vehicles, equipment, and technologies will help fleets improve their efficiency and reduce emissions. For SmartWay Verified Technologies, EPA has evaluated the fuel-saving benefits of various devices through grants, cooperative agreements, emissions and fuel economy testing, demonstration projects, and technical literature review. As a result, EPA has determined the following types of technologies provide fuel-saving and/or emission-reducing benefits when used properly in their designed applications: aerodynamic technologies, idle reduction technologies, low-rolling-resistance tires, and retrofit technologies. Within each of these categories, EPA has verified specific products.	
Financial assistance mechanisms	Previously sponsored a loan program; currently directs interested parties to alternative grant opportunities such as DERA funding.	N/A

[33] EPA's Motor Vehicle Emissions Simulator model (MOVES2010b)—see http://www.epa.gov/otaq/models/moves/.

Program Element	U.S. EPA	NRCan
Partner account managers	Eight for EPA; four for NRCan. Responsible for welcoming new partners into the program, informing partners about tool submittal deadlines; answering questions and troubleshooting tool completions; uploading and reviewing/validating tools; and working with Partners to document unusually extreme data entries, correct entry errors or other issues with tools, and upload approved tools.	
Data management system	Oracle database with a ColdFusion interface; EPA and NRCan databases linked so PAMs and program administrators from one program can view the other program's data.	
Data quality assurance measures	Best practices guidance document on compiling data for tool submittal: http://www.epa.gov/smartway/forpartners/documents/dataquality/420b13005.pdf. NRCan has developed a verification checklist and guidance for its partner account managers to use in the tool validation process.	
Measurement/Impact		
Estimated aggregate benefits (annual pollutant reduction, fuel savings, etc.)	51.6 MMTCE reduced since 2004 (combined program benefit).	NRCan's SmartWay Transport Partnership is evaluated upon: • Increased fuel efficiency in the freight trucking sector based on year-over-year submissions of participants. • Energy saved annually by March 2016 (as measured by comparing fuel efficiency of participants with that of non-participants).
Further Information		
Further information	Considering addition of black carbon to pollutants list. Will develop oceangoing vessel and air cargo tools next. EPA and NRCan signed a letter of agreement in June 2012 to allow NRCan to administer EPA's SmartWay program in Canada. NRCan produces a benchmarking report and an energy efficiency toolkit for all of its partners to encourage and provide opportunities for them to decrease their fuel use.	

SmartWay's internationally recognized verification and designation programs have driven innovation in the market by providing carriers with a reliable assessment of fuel efficiency technology options. Financing support through SmartWay and other mechanisms has also facilitated technology adoption in the market. The collection of performance data through these testing programs was also critical to the development of the EPA Heavy-Duty Vehicle GHG standards rule, which will further drive efficiency improvements across the on-road freight fleet in the future.

SmartWay has also developed a slate of user-friendly, effective tools for quantifying emissions performance. The SmartWay tools have great breadth, depth, precision, comparability, and verifiability, as discussed below. The tools are discussed in the context of specific criteria used by industry experts to evaluate carbon footprinting methodologies used by freight programs.[34]

Breadth: The program currently covers truck, rail, intermodal, and barge freight transport, and includes tools for quantifying freight vehicle emissions from carriers as well as shipper and logistics companies. The SmartWay Truck Tool also explicitly accounts for emissions associated with trailer refrigeration units. The program plans on expanding in breadth to include oceangoing marine and air freight modes in the future. The Shipper Tool also allows shippers to calculate the impact associated with operational changes such as packaging improvements or modal shifts upon emissions and performance levels, although validation and verification procedures for the inputs and calculations are not well-established.

Depth: The SmartWay Tools calculate carbon (CO_2), NO_x, and PM inventories and efficiencies for fleets based on mileage and weight metrics. All emissions are direct combustion (tank to wheels[35]), and do not account for upstream or other lifecycle emissions. Other pollutants of concern such as methane, N_2O, and black carbon are not calculated at this time, although the tools could be modified to report these as needed.

Precision: The SmartWay Tools develop relatively precise emissions and emission performance metrics at the carrier-specific level. CO_2 emissions are based solely on fuel factors (in g/gallon or g/liter), and are calculated based on fleet-specific fuel consumption estimates. NO_x and PM emissions are based on mileage-based emission factors developed using EPA's MOVES model.[36] The Truck Tool considers the following factors when estimating fleet-average emission rates:

- Fuel type (diesel/biodiesel blend, gasoline/ethanol blend,[37] CNG, LNG, LPG, electric, hybrid)
- Vehicle weight class distribution (8,501 to > 60,000 pounds gross vehicle weight)

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[34] Craig, A.J., E.E. Blanco, and C.G. Caplice (2013). *Carbon Footprint of Supply Chains: A Scoping Study*. Retrieved from http://www.trb.org/Main/Blurbs/169329.aspx.

[35] "Tank-to-wheels" emissions result from combustion of fuel in the vehicle's engine, as opposed to other measures such as "well-to-wheels" which include emissions associated with fuel extraction, refining, and distribution, as well as combustion.

[36] Refrigeration unit NO_x and PM emissions are developed using fuel consumption estimates and outputs from EPA's NONROAD model.

[37] Biofuel consumption is tracked separately within SmartWay, which can facilitate the introduction of life-cycle emission calculations in the future if desired.

- Engine age distribution
- Road type distribution (percent urban vs. rural)
- Average speed distribution (< 25 mph, 25–50 mph, > 50 mph—urban only)
- Idle hours (short vs. long duration)

Total NO_x and PM emissions are calculated by multiplying the g/mi factors by total miles (including empty miles). The Truck Tool also provides substantial precision with respect to performance metrics, combining calculated emissions with mileage and ton-mileage totals to obtain g/mile and g/ton-mile values (or g/km and g/tonne-km for NRCan tools). These values are grouped by operation and body type, including truckload dry van, less than truckload, drayage, and other categories. Carriers are then grouped into five performance ranking bins for each operation/body type category. For example, the top-performing truckload dry van carriers may range between 1,300 and 1,700 g CO_2/mile, with each of these assigned the midpoint value of 1,500 g/mile for reference by shippers and logistics companies. Individual performance bins must have a minimum number of partners (e.g., five or more) to help protect the identity of individual carrier companies. This "binning" approach represents a compromise between fully carrier-specific performance reporting (as desired by many decision-makers at shipping companies) and confidentiality, i.e., partial transparency (desired by the carriers themselves).

Similar approaches are used to calculate emissions for rail, intermodal, and barge carriers, although performance metrics are not broken out at the same level of detail as truck carriers for reporting to shipper companies. (Logistics company performance is also calculated for use by shippers and other logistics companies, but their performance metrics are calculated based on the weighted average performance of their selected carriers, rather than the mix of specific vehicle characteristics and activity levels like the other carrier types.) Intermodal carriers are reported using a single, separate grouping, as are barge carriers, while rail carrier performance is reported as a single industry average at this time. Given an adequate number of partners, the performance bins used for reporting may be refined further in the future (e.g., breaking out logistics companies by size grouping).

The performance level for non-SmartWay carriers is set relative to the lowest-performing SmartWay carriers. In this way shippers are incentivized to use SmartWay carrier partners whenever possible.

Comparability: The SmartWay emission and performance metric calculation methodology has remained the same for truck carriers and shippers since 2010, with additional tools added for rail, multi-modal, logistics, and barge companies in subsequent years. The SmartWay Tools provide a consistent means of estimating emission footprints and performance levels for individual fleets and companies over time using the "Year-to-Year" comparison report, as well as through various database reports. The Carrier Performance Rankings provide sortable performance metric listings for all carriers in the program, for current as well as archived reporting years. SmartWay also strives to develop consistent mileage, payload, and volume reporting to facilitate comparison of performance metrics across modes. For example, the Rail Tool provides performance outputs in terms of both railcar and truck-equivalent miles in order to allow consistent comparison across both modes.

Verifiability: Since the SmartWay program relies on self-reported fleet characterization and activity data, the potential exists for inaccurate or biased reporting. SmartWay has developed a number of validation routines and reports to help identify inaccurate data inputs by either the Partner or at the administering agency before approval of the submitted data. The SmartWay Tools employ a variety of validation checks for external consistency, comparing inputs for mileage, fuel consumption, average payload, idle hours, and a range of other parameters against industry averages and distributions. The year-to-year report functions also allow partners to evaluate inputs for temporal consistency (compared to the previous year).

Although regular third party audits of data inputs are not required, the standard Partnership Agreements allow for audits if requested. SmartWay has also developed a guidance document summarizing best practices for data collection and quality assurance for all partners (see http://www.epa.gov/smartway/forpartners/documents/dataquality/420b13005.pdf). To verify the integrity of SmartWay Partner data submissions, EPA also invites a sample of SmartWay partners from a cross-section of freight industries to participate in data verification interviews.

SmartWay also conducts a number of specific activities every year to ensure the integrity of the program data reported. These range from comprehensive reviews and cross-checking SmartWay Partner data before acceptance to the use of a Partner Excel-based reporting system. This reporting system has rigorous internal data quality assurance controls, including reasonableness checks and annual data comparison reports. One unique feature of these checks is the "cross-reference" validation, wherein the mileage attributed to specific carriers by shipper and logistics companies is compared with the total distance reported by the carriers themselves. Using this function SmartWay has identified and corrected numerous reporting errors from shippers and logistics companies reporting carrier mileage levels that were orders of magnitude higher than reported by carriers (typically data entry errors or problems associated with allocating less than truckload shipments).

Finally, SmartWay is particularly well-positioned for harmonization with other green freight programs. Notably it has served as a template for other programs such as Green Freight Europe and Green Freight Asia, and has successfully integrated with another country (Canada). In addition, the program is designed to be fully "trans-modal" (i.e., it can eventually cover all modes of freight). More effective quantification and verification of logistic/operational strategies would further facilitate harmonization with other programs.

U.S.-Canada Program Integration

U.S. and Canadian freight transportation occurs in the context of an integrated North American marketplace. American shippers (Walmart, Chrysler, Safeway, and many others) have been preferentially contracting with truck carrier companies that are SmartWay Partners. Before 2012, Canadian firms needed to register for the SmartWay Transport Partnership through the U.S. EPA in order to compete for the business of American companies (only about 10 percent of the existing 3,000 U.S. SmartWay Partner companies are Canadian). However, EPA's SmartWay tools are only available in English and use American measurement units (U.S. gallons, short tons), which puts an extra burden and makes the program inaccessible to Canadian firms who work in metric and/or in French. Additionally, there was a significant missed opportunity: companies that do business solely or primarily within Canada were not benefitting from the opportunity to participate in a similar network. For these reasons, NRCan and EPA signed a letter of agreement in 2012 that focuses specifically on joint delivery of the SmartWay Transport Partnership for five years (to 2017).

3.1.2 Green Freight Europe[38,39]

With over 180 participating companies, the Green Freight Europe (GFE) program provides a standardized system for reporting activity, calculating emissions and efficiency performance metrics, and industry-average benchmarking for road freight carriers, shippers, and logistics operations in Europe. The program also provides a platform for sharing industry best practices and technological innovations among its participants. Under development since 2009 and officially launched in 2012, the program design was largely inspired by the SmartWay program and incorporates many similar features, such as the use of carrier-specific performance metrics by shippers in calculating carbon footprints for their supply chains. GFE actively seeks cooperation with related programs to promote harmonized carbon accounting for the global freight sector.

Although similar to SmartWay, GFE is designed to address the specific needs of Europe, such as differing truck classifications. The program is also organized in a different fashion from SmartWay, relying solely on private organizations and member fees for funding. Annual fees vary depending upon company size, with sponsors and knowledge partners (e.g., academic research institutions) contributing funds and/or in kind contributions. The program is managed on behalf of its members by a neutral secretariat including the Dutch Shippers' Council (EVO) and the European Shippers' Council, and is guided by a steering group with several specialized working groups.

The key elements of the GFE program are summarized below.

- Carriers provide GFE with primary data (e.g., fuel, kilometers, fleet profile), enabling the calculation of their carbon emission performance.
- Carriers receive a score and a benchmark against similar operations.
- Carriers commit to improving the fuel efficiency of their fleet over time.
- Shippers provide GFE with operations data (e.g., shipments, carriers used), enabling the calculation of the carbon emission performance of transportation operations contracted with GFE carriers.
- Shippers commit to improving their carbon emission performance over time.

The GFE program is still under active development; the following summary describes intended program design features as of this writing.

[38] Green Freight Europe (2014). Green Freight Europe. Retrieved from http://www.greenfreighteurope.eu/.
[39] Personal communications: Peter van der Sterre, Managing Director, Green Freight Europe, December 2013–May 2014.

Program Element	Green Freight Europe
General Information/Program Organization	
Program administrator/ contact agency/ consortium funding source	Peter van der Steere Managing Director pvandersteere@greenfreightеurope.eu Daniel Jaestch Contact for D-A-C-H djaetsch@greenfreigheurope.eu, +31 65 51 52 702 Andrew Traill Contact for UK-IRE atraill@greenfreighteurope.eu, +44 77 56 03 9379 http://www.greenfreighteurope.eu/ Facilitated by neutral secretariat (European Shippers' Council and Dutch Shippers' Council), on behalf of GFE members. Funded primarily by annual membership fees.
Program goals	Ultimate goal: Reduce carbon emissions from road freight sector in Europe • Establish a standardized way of monitoring and report of carbon emissions, compliant to the upcoming CEN standard on transportation and the GHGP. • Reduce efforts, costs, inconsistency in monitoring and reporting. • Increase comparison, data quality, awareness. • Collect primary data.
Description	The program covers road freight only; may be expanded to rail, barge (inland navigation), marine, and air. The program drives reductions of carbon emissions by: • Establishing a platform for monitoring and reporting of carbon emissions, to assist in the procurement of transportation services and based on existing standards. Promoting collaboration between carriers and shippers in driving improvement actions and monitoring progress. Establishing a certification system to reward shippers and carriers who fully participate in the program. A platform to share best practices, promote innovations, and communicate sustainability improvements on European road freight. Regional or national networks are established together with national shippers or transport councils or other stakeholders acting as local agents. The current focus is on specific countries: United Kingdom/Ireland, Germany, Austria, Czechoslovakia, BNL, France, Spain, Portugal, and Poland.
Start year	March 2012

Program Element	Green Freight Europe
Pollutants quantified and performance metrics used	CO_2e, including CO_2,weighted by DEFRA GWPs. Performance metrics reported in g/tonne-km for truckload and LTL (refrigerated and ambient), and bulk. g/package metric for mail/parcel carriers. May add PM and NO_x in future.
Annual funding range	Annual participant fees range from free to €6,000 depending on company size.
State of development	Initiation phase
Partners	
Number of partners	150 members as of September 2013
Other key stakeholders/ affiliates	Advisory body (to be established) will include public agencies, academic/research institutions, industry associations, and NGOs. Associated members in "Carrier Shop" include manufacturers, technology vendors, and financial institutions.
Program Components	
Data collection / evaluation process	Quantitative data: vehicle and fuel type, fuel consumption, distance, and tonnage for owned/private fleets; shipment/load info, carriers used for contracted fleets (GFE and non-GFE carriers). Qualitative data: use of eco-driving training or other best practices.
Quantification methodologies	Emissions CO_2e based on fuel consumption; calculations broken out by owned, subcontracted GFE, and subcontracted non-GFE fleets. Also broken out by service type (truckload and LTL—refrigerated and ambient—and bulk). Qualitative gold/silver/bronze (public) ranking.
Data collection tools	CO_2 Monitoring and Reporting Tool (operated by a third party, the Energy Savings Trust): company fills out a spreadsheet with annual figures for road transport, submits results via XML files to central database through secure Web server. Partner-specific emissions, performance, and benchmarking reports also available through Web.
Branding and marketing strategies	Logo qualification and use rules under development

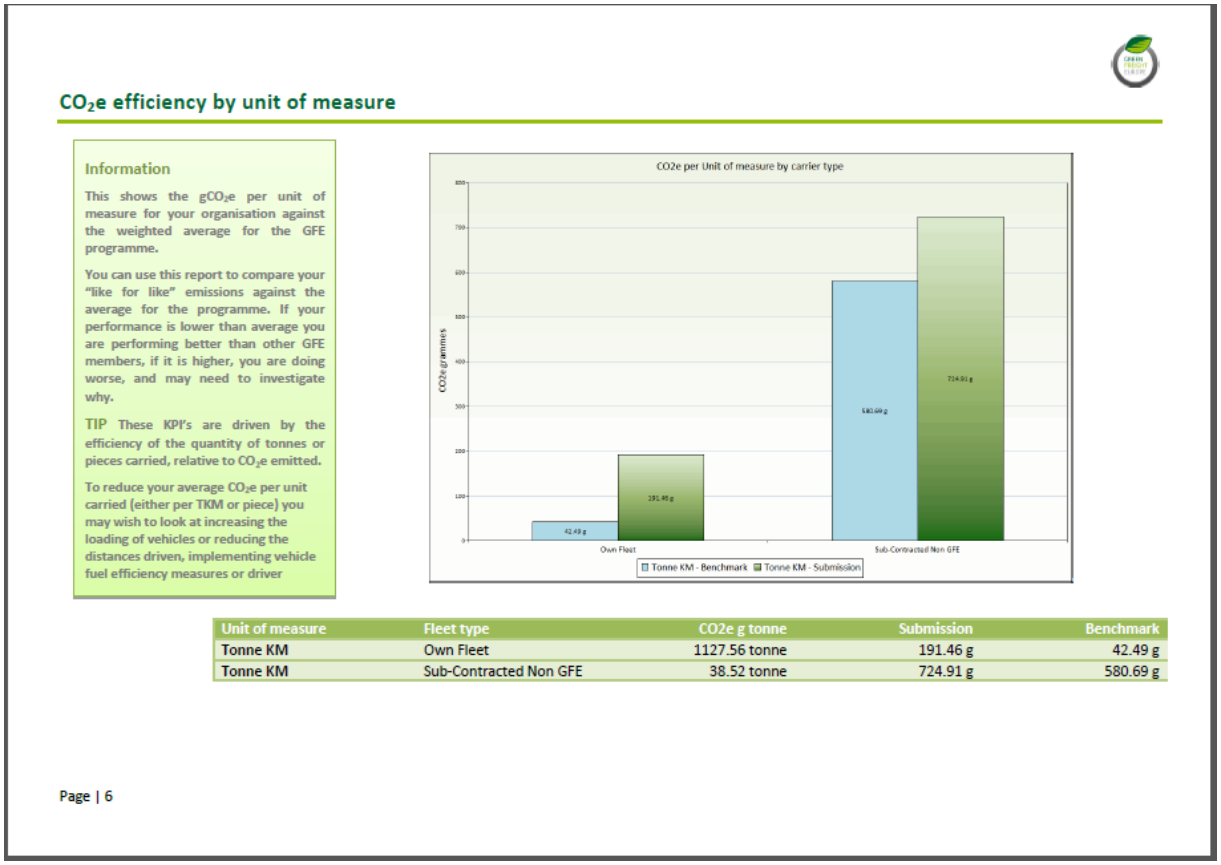
Technology program details	**Verified technologies (work to begin in 2014)**
	• GFE will identify and endorse proven technologies and practices and share them among members.
	• GFE will publish registers of verified technologies that will enable its fleet operators to reduce their CO_2 emissions.
	  o Using U.S. EPA SmartWay as a basis—aerodynamics, anti-idling, low-rolling-resistance tires, truck manufacturers, retrofit technologies, fuel management systems, telematics, alternative fuel conversions.
	  o Using European programs (e.g., Swiss FEON–VERT program) as a basis.
	• Set standards for the technologies that GFE members indicate a need for assurance with respect to performance.
	• A scientific advisory board to support this process and verify the independent research.

Program Element	Green Freight Europe
Financial/other assistance mechanisms	**Carrier shop** Verified technologies will be offered to GFE members at a discount, including: • Technologies • Financing products (loans and grants) • Insurance • Services (consultancy) and training This working group makes an in-depth inventory of requirements of carriers through a round table and or survey. The first aim of the carrier shop is to offer products to carriers that they need at a discount.
Partner account managers	EST provides program support, having worked out the methodology and developed the platform guided by GFE members. EST supports companies in the data submitting process and produces the reports.
Data management system	Centrally operated Quickbase database, exported to a secure server that makes calculations and reports to be downloaded by the members. Managed by an independent and neutral third party (EST).
Data quality assurance measures	All data undergo quality assurance evaluation by EST.
Measurement/Impact	
Estimated aggregate benefits (annual pollutant reduction, fuel savings, etc.)	Not currently available

Program Element	Green Freight Europe
Further Information	
Further information	A multimodal working group has been established. It focuses on mapping different initiatives (sea, rail, barge, air) and developing a strategy for alignment or development of own platforms. A platform for best practice sharing will be developed this year including the option to get in contact with other members (forum or chat in combination with social media). Signed a memorandum of understanding with the Lean and Green Program to: • Exchange knowledge and best practices on sustainable logistics. • Create and support a common framework and definition for logistics for measuring and combining CO_2 emissions, network performance, and carrier performance, allowing for absolute comparison in peer groups, using primary operational data, based on EN 16258. The framework includes a practical interpretation (and application) of the EN 16258 rules and describes how companies should deal with existing gaps in the standard. • Create a joined proposition (and preferably a joined membership) with a clear individual branding of both programs throughout the European network. Lean and Green will have a clear focus on front-running companies and being the incubator for best practices on improving environmental performances throughout freight transport. Green Freight Europe will focus on monitoring and reporting and knowledge dissemination (best practice sharing) to European companies. • Explore further collaboration and integration of both programs, respecting their separate identities. • Explore the potential of one overarching European organization on sustainable logistics including Lean and Green, Green Freight Europe, and other initiatives.

Like the SmartWay program, GFE members include some of the world's largest carriers, logistics companies, and shippers, capable of helping to drive the technology market and leveraging program participation from smaller companies. (In fact, many global companies are participants in two or more of the green freight programs discussed in this chapter.) In addition, the fact that partners join GFE voluntarily and contribute annual fees for its operation clearly demonstrates a strong commitment to the success of the program. The program appears to be expanding rapidly, growing from roughly 100 partners in 2012 to a target of 250 by the end of 2013.

Again, like SmartWay, GFE has a designed very effective incentive and reward structure. It handles data sharing in a more proprietary fashion than SmartWay does, with carriers sharing their performance information through direct agreement with their shippers rather than through public listings. By promoting data sharing agreements between shippers and carriers, the program fosters direct, transparent communication about baseline fleet performance as well as specific strategies that both parties can adopt to improve their performance. The calculated emissions, performance, and benchmarking reports in particular provide great added value for partners. An example report indicating efficiency per tonne-km is provided below.



CO_2e efficiency by unit of measure

Information

This shows the gCO_2e per unit of measure for your organisation against the weighted average for the GFE programme.

You can use this report to compare your "like for like" emissions against the average for the programme. If your performance is lower than average you are performing better than other GFE members, if it is higher, you are doing worse, and may need to investigate why.

TIP These KPI's are driven by the efficiency of the quantity of tonnes or pieces carried, relative to CO_2e emitted.

To reduce your average CO_2e per unit carried (either per TKM or piece) you may wish to look at increasing the loading of vehicles or reducing the distances driven, implementing vehicle fuel efficiency measures or driver

Unit of measure	Fleet type	CO2e g tonne	Submission	Benchmark
Tonne KM	Own Fleet	1127.56 tonne	191.46 g	42.49 g
Tonne KM	Sub-Contracted Non GFE	38.52 tonne	724.91 g	580.69 g

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Green Freight Europe

The "Carrier Shop" component of the program has the potential to provide significant support for GFE participants through identification of verified technologies, discounts and financing options for technology purchases, insurance arrangements, and consulting and training services.

The quantification procedure used in the GFE Carbon Monitoring and Reporting Tool provides accurate, precise emissions and performance estimates for use by its partners, as described below.

Breadth: The GFE program currently covers ground truck freight transport, although rail, marine, and air transport may be included in the future. A single tool covers activity for owned truck fleets, activity subcontracted to GFE carriers, and activity contracted to non-GFE carriers.

Depth: The GFE platform uses a centralized database to calculate CO_2e as well as tonne-km and per-package efficiency metrics based on participant inputs. The platform treats all emissions as direct combustion (tank to wheels), and does not account for upstream or other lifecycle emissions. CO_2e estimates include CO_2, CH_4, and N_2O, aggregated using DEFRA's GHG conversion factors. Other pollutants of concern such as NO_x and PM are not calculated at this time, although the platform may report these in the future.

Precision: Unlike the binned SmartWay performance data, which fall within a range for any given carrier, the GFE efficiency metrics represent exact values. The GFE calculation methodology itself allows users to choose between three different levels of precision: carrier-specific (primary) data, averages by vehicle type, and industry averages. The precision associated with specific inputs can vary as well. For example, vehicle type can be input at a general level (e.g., HGV truck) or at a specific level (diesel rigid HGV with a gross vehicle weight between 7.5 and 17 tonnes). Tonne-km efficiency metrics are calculated for truckload, less-than-truckload, and bulk carrier service types, while per-package metrics are estimated for mail and parcel carriers. Load levels and types can also be provided to improve the precision associated with tonne-km calculations. The vehicles' emission standards (Euro levels) can also be provided. Carriers are encouraged to provide the most detailed, primary activity data possible for their operations, as more precise data inputs will receive a higher relative weighting in the performance scoring calculation.[40] Final scoring assignments are qualitative, including gold, silver, and bronze.

Comparability: GFE provides standardized calculation methods and tools for establishing consistent performance comparisons across all participating companies. The performance database created provides Europe-wide CO_2 benchmarks for the road transport freight sector.

Verifiability: Although GFE performance data are not made available to the public, participants can allow access to others within the GFE program. Nevertheless, all data undergo monitoring and compliance evaluation. In addition, all participants declare that their data submittal is accurate to the best of their knowledge, and agree to submit supporting documentation and/or allow a third party audit if requested, similar to the terms of the SmartWay Partnership Agreements.

The GFE program is designed to be "trans-modal," and may incorporate rail, marine, and air modes. GFE is also actively working with the Lean and Green Program (see Section 3.1.7) to develop and integrate quantification of logistic and operational strategies in the carbon

[40] Details regarding the weighting calculation to be determined.

monitoring and reporting framework. As such it is particularly well-positioned to facilitate harmonization with other programs in the future.

3.1.3 Objectif CO_2 (France)[41,42]

Objectif CO_2 is a green freight initiative to reduce CO_2 emissions from road carriers and shippers in France. The program was developed in 2008 by the Ministry of Ecology and the ADEME, which is a public agency for the Environment and Energy Management. Participating companies may join for free, and develop a personalized action plan to reduce CO_2 emissions over three years. The first step in the action plan is develop the baseline CO_2 emissions for the company's fleet based on the current fuel consumption, number of vehicles, and annual distance traveled. Then the companies identify specific actions to implement based on a guideline document provided by Objectif CO_2. Action areas involve changes to the vehicle, fuel consumption, driver behavior, and operational/logistic measures. The companies must choose at least one action to implement in each of these areas. They then estimate the potential CO_2 emissions reductions to be realized by these actions. All of the data are entered into a centrally located Web tool at www.objectifco2.fr. The participants then report annually during the next three years using the same Web tool.

Almost 1,000 truck carriers companies have joined the Objectif CO_2 program to date, which includes 113,000 vehicles (about 23 percent of the French fleet) and over 125,000 drivers. The projected potential emission reductions include over 760,000 tons of CO_2 reduced per year and 260 million liters of fuel saved.

The following table highlights important aspects of the Objectif CO_2 program.

[41] Objectif CO_2 (2014). Objectif CO_2: Les Transporteurs s'Engagent. Retrieved from http://www.objectifco2.fr/.
[42] Personal communications: Gérald Lalevée, Department of Transport and Mobility, ADEME, January–March 2014.

Program Element	France Objectif CO_2
General Information/Program Organization	
Program administrator/ contact agency/ consortium funding source	Gérald Lalevée Department of Transport and Mobility ADEME gerald.lalevee@ademe.fr The program is run and financed jointly by ADEME (the French public Environment and Energy Management Agency) and the French Ministry of Ecology, Sustainable Development, and Energy.
Program goals	Objectif CO_2 is a voluntary program to reduce CO_2 emissions and fuel consumption of the road freight transport operators (road carriers operating for third parties and shippers with their own-account fleets).
Description	The program is free to join for transport companies based in France. A company must sign a charter with ADEME and the regional representative of the Ministry of Ecology to commit itself for three years to develop and implement its personalized action plan and achieve its target for reducing fuel consumption (and thus CO_2 emissions). The company's objective is to improve their CO_2 efficiency using a specific action plan based on a range of solutions organized around the vehicles, fuel, drivers, and operational and logistic measures. At least one measure must be implemented from each of these four areas. Performance targets are established for both CO_2/km and CO_2/t-km.
Start year	December 2008
Pollutants quantified and performance metrics used	Well-to-wheel CO_2 emissions are quantified with efficiency indicators expressed in g CO_2 /km and g CO_2/t-km by vehicle category (4 categories by gross vehicle weight) and activity type. Metrics also available for based on number of packages if appropriate. A study is being conducted to evaluate the feasibility of including additional pollutants (PM and NO_x).
Annual funding range	Around €800,000 since 2008
State of development or program maturity	Fully implemented, under periodic evaluation/improvement
Partners	
Number of partners (as of January 27, 2014)	955 truck carriers
Other key stakeholders/ affiliates	The four French carrier trade organizations are extensively involved in the program and are represented on the national steering committee. They represent all carrier sizes and all types of activities. The program has partnerships with the main professional training organizations, vehicle manufacturers, and solution providers.

Program Element	France Objectif CO_2
Program Components	
Data collection / evaluation process	Each company uses the online Web tool to: • Perform self-assessment and review prerequisites for participation. • Enter operational data (types and numbers of vehicles, fuel consumption, tonnage, distances, number of drivers) to establish a baseline. • Evaluate and identify potential action plan elements with the help of "action forms" giving details for implementing 54 different actions organized around the vehicle, driver, fuel, and logistical organization. • Specify the action plan, using a Web tool to estimate fuel savings, payback, and emissions benefits, and to establish CO_2 efficiency indicator targets (g CO_2 /km and g CO_2/t-km). • Monitor and report annual progress. Depending on the company's situation and the actions selected, other information may also be collected including: • The number of refrigeration units • The number of eco-driving-trained drivers • The proportion of subcontracted activity • The use of non-road modes (rail, maritime, inland marine, and air) The database is used to evaluate the program as a whole.
Quantification methodologies	Annual company fuel consumption is combined with emission factors to calculate CO_2 emissions on a well-to-wheel basis. These factors are consistent with Article L 1431-3 of the French transport code on CO_2 regulations for transport activities. The full guide is downloadable at http://www.developpement-durable.gouv.fr/IMG/pdf/Information_CO_2_ENG_Web-2.pdf. Fuel types include diesel, biodiesel, gasoline, LNG, hybrid, and electricity. CO_2 emissions are combined with distance traveled and tonnage hauled (or number of packages) to develop performance metrics. The Web tool enables companies to benchmark different indicators allowing for comparison across vehicles, drivers, vehicle types, and activity types. Vehicle types include rigid small trucks (3.6–12 tonnes GVW), rigid large trucks (>12 tonnes), and semi-trailer trucks.
Data collection tools	The online Web tool is hosted at www.objectifco2.fr. The tool enables the company to define its action plan and its global CO_2 emission reduction target. It enables the company to calculate the potential fuel and CO_2 emission savings and simulate the time to return on investment according to the actions chosen. The tool must be used throughout the company's three-year period of commitment to the program. In this way, monitoring is made possible using the defined environmental efficiency indicators and the various actions selected by the company.

Program Element	France Objectif CO_2
Branding and marketing strategies	Today, companies that are partners (having signed the charter) can use the program logo on their vehicles, websites, and invoices during their three-year commitment. Every six months, a newsletter is released showing carrier feedback. Carrier trade associations and transport professional press write frequent articles about the program. One of the top priorities for 2014 is to develop a labeling system in order to bring better visibility to the engaged carriers in the program. This label will indicate which carriers achieve a high CO_2 performance level.
Technology program details	The action forms are designed to be a decision-making resource and a reference for program partners. The forms are intended to inform, in an independent and unbiased manner, transport operators on all solutions that are available on the market, and which will have a positive impact on fuel consumption and CO_2 abatement issues. Action forms are organized around four elements: • Vehicle—options relating to the vehicle and trailer (accessories, engine options, tires, etc.). • Fuel—actions involving alternative fuels and advanced power train technologies (biofuels, hybrid and electric vehicles, etc.). • Driver—opportunities to enhance driver's behavior (Eco-Drive, good practice for the temperature-controlled transport sector). • Organization of transport flows—actions involving the optimization of the loading process, the utilization of other alternative modes of transport, and raising the awareness of customers and road transport subcontractors.
Financial assistance mechanisms	Financial assistance may be available from ADEME for companies that use consultants to assist them in assessing options for their action plans as well as for implementing and monitoring the plans. Energy Savings Certificates (ESCs) encourage the introduction of energy-efficient technologies. Carriers can use ESCs to generate an alternate source of funding. Under this system the government requires all entities selling energy, called "obligated parties" (e.g., electricity, gas, heat, cooling, fuel providers) to achieve a specific level of energy savings. ESCs can be used as credits by the obligated parties to meet their fuel use reduction targets. ESCs are generated, under certain conditions, to any energy user that achieves a verifiable energy savings. Energy sellers can satisfy their obligations by holding certificates of same value, by generating certificates obtained through further actions taken by the operators themselves, or by buying from other operators who have generated ESCs. Processing and validating ESC certificates is now the responsibility of the Pôle National des Certificats d'Economies d'Energie (PNCEE) created in October 2011. To simplify the ESC registration process, a standard operation form has been created in order to identify the eligibility conditions and the quantification of energy savings for current operations. Among the transport forms, some correspond to the Objectif CO_2 program. Transport operators become involved in the ESC program through Eco-Drive training, the use of energy-saving lubricants, optimized tractor or the use of rail-road Intermodal transport unit.
Partner account managers	The program is monitored and overseen by the Ministry of Ecology and ADEME. At the national level, two people are responsible for program strategy development, marketing, development of tools, and managing relations between the Ministry of Ecology and the carrier trade organizations. Each of the 26 regions of France has at least one person who can be directly in contact with companies interested in becoming program partners. These staff are responsible for informing companies about the tools; answering questions and troubleshooting tool completions; and validating data, action plans, and company targets. At the regional level, there are about 10 full-time staff equivalents.

Program Element	France Objectif CO_2
Data management system	MySQL database and Linux CentOS operating system
Data quality assurance measures	The regional committees verify and validate the accuracy of each company submittal. The Web tool's user manual is available for use by partners. Regional committees use market data references and their experience to validate company data and their commitments. The future labeling system will improve data quality through independent and certified verifications.
Measurement/Impact	
Estimated aggregate benefits (annual pollutant reduction, fuel savings, etc.)	The program involves more than: • 113,000 vehicles (23 percent of the French fleet) • 125,000 drivers With the potential of : • 760,000 tonnes of CO_2 avoided per year • 260 million liters of fuel saved • 9.3 percent efficiency improvement, on average, over the three years of commitment In April 2014, public statistics and operational data on the program will be available.
Further Information	
Further information	Similar freight transport programs are under evaluation for shippers and local fleets.

The Objectif CO_2 program has benefited from the strong leadership of the French carrier trade organizations that were involved with the development of the program from the outset. These partners are represented in the national steering committee that establishes the program's overall strategy and components. In addition, each region of France has a regional steering committee composed of local representatives of the national partners. These regional committees verify and validate the accuracy of each company engagement.

The design of the Objectif CO_2 program promotes very strong partner commitment at all stages of the process. First, the online decision tool and action sheets help participants identify the most feasible, cost-effective improvement strategies *before* committing to specific performance targets. In addition, the action plan and signed charter agreement are highly visible statements of each partner's commitment to performing specific steps in order to meet their performance targets. The annual reporting updates help partners monitor their progress and adjust their strategies if needed, making it easier to keep their commitments. Finally, participants commit to the program for a minimum of three years.

The Objectif CO_2 program has an excellent implementation support system. In addition to the easy-to-use Web-based data entry platform, the program offers user-friendly action forms containing detailed assessments of 54 potential technological and operational improvement strategies. Each form clearly explains the basic principles of the measure, applicable vehicle types, any relevant regulatory issues, technical feasibility, estimated efficiency improvement and fuel savings, availability of Energy Savings Certificates, cost and payback period, opportunities and constraints for implementation, and monitoring guidance.

The precision of the monitoring and reporting system is particularly valuable to partners' improvement efforts, allowing for detailed evaluation of fuel and cost savings for each action adopted. Progress can also be evaluated down to the vehicle and driver level given adequate monitoring processes. Finally, implementation is also facilitated by the potential availability of financial assistance for consulting services to help develop and monitor action plans. The extensive resources supporting implementation also tend to drive innovation in the marketplace, promoting the accelerated adoption of a wide variety of vehicle, fuel, behavioral, and operational improvement strategies. The transparency of the publicly available action plans will also allow program administrators to assess the penetration of these technologies into the marketplace over time.

The quantification procedure used in the Objectif CO_2 program provides accurate, precise emissions and performance estimates for use by its partners, as described below.

Breadth: The program covers ground truck freight transport as well as associated logistics and operational functions. Benefits can be estimated for modal shifts, although modal averages are used for non-road modes rather than fleet-specific factors. A single tool is used for third-party carriers and private fleets.

Depth: The program calculates well-to-wheel CO_2 emissions.[43] Other pollutants of concern, such as NO_x and PM, are not calculated at this time.

Precision: g/km, g/tonne-km and g/other delivery unit (e.g., g/package or g/palette) efficiency metrics are calculated based on participant inputs (e.g., vehicle types, fuel consumption, mileage, weight moved). Four vehicle types are differentiated: light commercial vehicles, small and large rigid trucks, and semi-trailers. The tool also distinguishes between refrigerated and non-refrigerated trucks. Fuel consumption is multiplied by the fuel-specific emission factor in order to estimate CO_2 emissions. Emission factors are well-to-wheel.

Comparability: The Web tool provides standardized calculation methods for establishing consistent performance comparisons across all participating companies. A carrier engaged in the program will be able to compare its performance level with the levels of average carriers in the same activity category using the Web tool and its personal access code. This function will be offered soon and will be developed at the same time as the labeling system.

Verifiability: All data undergo monitoring and compliance evaluation. The regional committees verify and validate the accuracy of each company submittal. Companies can use the Web tool's user manual to help ensure accuracy. Regional committees use market data references and their experiences to validate companies' data and their commitments. The future labeling system will improve data quality using independent and certified verifications.

3.1.4 Green Freight Asia[44,45,46]

Green Freight Asia (GFA) is a nonprofit organization funded and led by its member companies. Its key objective is to help lower fuel consumption across Asia-Pacific-sourced road freight movements, reduce CO_2e emissions and air pollution from these movements, and lower shipping costs across the entire supply chain. Emissions estimates and performance metrics will be based on tank-to-wheels CO_2e, although PM and NO_x evaluation may be added in the future. Although GFA does not intend to develop its own CO_2e calculation and accounting methodology, it is committed to contribute to global alignment of these methodologies.

The GFA program is currently funded by membership fees. Its membership is composed mostly of carriers and shippers. GFA's primary goals include:

- Educating all Asia-Pacific-based stakeholders (governments, manufacturers, logistics companies, and consumers) about sustainable supply chain practices.

[43] Well-to-wheel emissions include emissions associated with fuel extraction, refining, distribution, and combustion within the vehicle.
[44] Green Freight Asia (2013). Welcome to Green Freight Asia. Retrieved from http://greenfreightasia.org/.
[45] Personal communications: Robert Earley, Program Manager, Clean Air Asia, December 2013–April 2014.
[46] Personal communications: Stephan Schablinski, Green Freight Asia, December 2013–April 2014.

- Creating a business-to-business green freight label certification and renewal process indicating a company's degree of commitment to, and actual adoption of, sustainable supply chain practices.
- Aligning with other green freight programs and national initiatives to harmonize, avoid overlaps, and collaborate with other regional and global environmental NGOs.

The GFA program is currently in the design phase. Available program details are summarized in the table below.

Program Element	Green Freight Asia (GFA)
General Information/Program Organization	
Program administrator/ contact agency/ consortium funding source	Stephan Schablinski stephan.schablinski@greenfreightasia.org, M: +65 97723713 Green Freight Asia is incorporated as a not-for-profit organization in Singapore. GFA is currently funded through membership fees. The first five subscribers provided startup funding for the first financial year. These founding members are DHL, HP, IKEA, Lenovo, and UPS.
Program goals	GFA's key objectives are to help lower fuel consumption for freight movement in the Asia-Pacific region, reduce CO_2e emissions from these movements, and lower shipping costs across the entire supply chain. GFA hopes to educate all Asia-Pacific-based stakeholders (governments, manufacturers, logistics companies, and consumers) about sustainable supply chain practices and create a business-to-business green freight label certification and renewal process that indicates a company's degree of commitment to, and actual adoption of, sustainable supply chain practices.
Description	GFA is a nonprofit organization funded through member fees dedicated to reducing fuel consumption, greenhouse gas emissions, and operating costs in the Asia-Pacific region. The initial focus is on road freight. The GFA program is composed mostly of carriers and shippers at this time. Currently in the design phase, it intends to incorporate many of the features of the U.S. EPA SmartWay program, including collecting and scoring performance data from carriers, providing these data to shippers for evaluation, and creating a green freight labeling and certification process.
Start year	2012 as a consortium known as the Green Freight Asia Network. Emerged from the informal network in 2013 as Green Freight Asia. Full rollout planned for 2015.
Pollutants quantified and performance metrics used	CO_2e. Specific metrics to be developed.
Annual funding range	N/A
State of development or program maturity (pilot/demonstration, initiation, expansion)	Design phase. Rollout of GFA labeling scheme planned for second half of 2014.
Partners	
Number of partners	25 partners total. Member companies include DHL, HP, IKEA, Lenovo, UPS, Heineken, Infineon, P&G, ANTS, Logistics Chengdu.
Other key stakeholders/ affiliates	Clean Air Asia Smart Freight Center Green Transformation Lab

Program Element	Green Freight Asia (GFA)
Program Components	
Data collection / evaluation process	Design in progress. Draft elements include: 1. Collect primary data (e.g., fleet composition, fuel consumption, freight volumes) and other information about the adoption of green technologies and sustainable supply chain practices from carriers. Shippers to provide information about the composition of their carrier base as well as their adoption of sustainable supply chain practices and level of commitment. 2. Evaluate data for CO_2e and fuel efficiency and the commitment of companies to adopting green supply chain practices. 3. Assign a GFA label stage and record score in database.
Quantification methodologies—performance benchmarking, scoring, rating, and/or ranking	Design in progress. Draft elements include: 1. GFA label to be made available to carriers and shippers. 2. Shippers will be entitled to use the GFA label if they meet certain criteria (e.g. award a certain amount of freight transport business to green-freight-label-certified logistics companies). 3. Carriers will also be entitled to receive the GFA label if they meet specific criteria (e.g., disclosure of fleet statistics, degree of adoption of CO_2e/fuel-reducing technologies and practices such as driver training and fuel-efficient technologies).
Data collection tools (types: online/Excel forms/other)	Design in progress. Likely design to be similar to SmartWay and Green Freight Europe: 1. Data collection via collection spreadsheet or online 2. Data processing and analytics in IT application/database
Branding and marketing strategies	The Green Freight Asia brand represents the adoption of cleaner and more efficient road freight transportation practices that reduce greenhouse gases and improve air quality. The Green Freight Asia brand is represented by the **Green Freight Asia logo.** The **Green Freight Asia label** identifies companies and organizations that are committed to adopting sustainable freight practices and supporting the implementation of green freight programs and initiatives throughout Asia, with a vision to increase the fuel efficiency of freight, improve air quality, and minimize CO_2e emissions while reducing other transportation-related emissions. Details can be found in the GFA logo and GFA label use guidelines.
Technology program details (verification offered, certification, labeling)	Uncertain—design in progress
Financial assistance mechanisms	Uncertain—design in progress
Partner account managers (number, responsibilities—e.g., how do they administer partnership process)	Uncertain—design in progress

Program Element	Green Freight Asia (GFA)
Data management system (relational database, other)	Uncertain—design in progress
Data quality assurance measures	At design stage—external auditing /verification planned
Measurement/Impact	
Estimated aggregate benefits (annual pollutant reduction, fuel savings, etc.)	Uncertain—design in progress Qualitative program benefits include: • **Develop strong, single voice**—an independent industry group that will help address, educate, and inform all stakeholders. • **Provide information pipeline**—on changing metrics and measurement standards. • **Create a fair and level playing field**—buyers and sellers working toward a common goal. • **Be a catalyst for change**—through reduced consumption and emissions. • **Create recognition**—for each company's sustainability leadership. • **Connect** environmentally conscious buyers and sellers. • **Certify** green freight carriers and shippers so they can inform and grow their customer base. • **Provide support and guidance** on how to lower fuel costs and reduce CO_2e. • **Provide incentives** to greening supply chains. • **Help** companies navigate regulations, identify partners, and avoid pitfalls.
Further Information	
Other program details	Green Freight Asia also organizes workshops, conferences, etc., to share best practices among all GFA members. GFA holds conferences twice a year.

At this early stage, GFA is focused on establishing brand recognition among manufacturers and shippers, and on demonstrating the efficacy of efficiency improvement technologies and strategies under day-to-day operating conditions. Gathering actual fuel consumption data and pledges to meet specific improvement targets will follow in later stages of program development.

3.1.5 China Green Freight Initiative[47,48]

The China Green Freight Initiative (CGFI) is multi-stakeholder program, launched in April 2012, which operates under the supervision of a steering group made up of representatives from Chinese government ministries. Currently funded by the nonprofit Energy Foundation, the program is managed and implemented by the China Road Transport Association (CRTA), the Research Institute of Highway, and Clean Air Asia.

China's freight industry is growing rapidly along with its overall economic growth. The average annual growth of freight volume in China from 2008 to 2012 was about 14 percent per year. However, the adoption of green freight practices in the transport industry in China is still in its very early stages. The CGFI was formed to address the need for a national program to improve the fuel efficiency and reduce the emissions from the rapidly growing road freight industry in China.

Two pilot programs in China led the way for the formation of the CGFI. The first was funded by the World Bank and implemented by Clean Air Asia. It was carried out in Guangzhou in 2008–2010 and targeted improving fuel economy and reducing CO_2 emissions from trucks. As a part of this pilot, technology was tested on 14 trucks in three truck fleets; a driver training course and truck sector surveys were also conducted. This pilot showed that improvements in technology and driving can help reduce emissions from diesel trucks, and it caused interest from the provincial government in a broader program.

The second pilot, called the GEF Guangdong Green Freight Demonstration Project, is being carried out in Guangdong Province. It is funded by the Global Environment Facility and implemented by the World Bank. This pilot began in September 2011 and is scheduled to be completed in May 2015. As a part of this pilot, green truck technology demonstrations will be conducted for at least 1,200 trucks and training for more than 1,200 drivers. In addition, the pilot project will focus on green freight logistics demonstrations (market studies for different methodologies such as drop-and-hook), capacity building (supporting green freight policy research, as well as training for government officials and other key people in the industry), and project implementation support. The main goal of this project is to reduce the road freight emissions in the Guangdong Province by 10 percent.

The CGFI is now in the initial design and development phase (Phase 1 of 3). During the first year of the program, the focus was on setting up the organizational structure of the CGFI. The organization includes a steering committee composed of the Ministry of Transport, the Ministry

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[47] Clean Freight and Logistics (2011). Green Freight China Program. Retrieved from http://www.greenfreightandlogistics.org/programs/green-freight-china-program-2/.

[48] Personal communications: Robert Earley, Program Manager, Clean Air Asia, January–April 2014.

of Environmental Protection, the National Development and Reform Commission, the Ministry of Public Security, and the Ministry of Industry and Information Technology. There is also an expert group that provides technical guidance and input.

After development of the organization, the CGFI's intent is to focus on including "avoid" (avoid empty weight trips, change logistics to reduce the number of trips), "shift" (shift to other forms of transport for goods), and "improve" (improve truck technology, fuel improvements, and improvements to driver behavior) strategies used in many green freight programs. Specifically, the CGFI intends to focus on green management strategies through logistics and planning, the use of green truck technologies, and implementing training to promote green driving. They will accomplish this in the road freight industry by developing emissions standards and fuel consumption limits, carrying out pilot projects and demonstrations, providing training, and developing consistent, recognized branding.

Program Element	China Green Freight Initiative (CGFI)
GENERAL INFORMATION / PROGRAM ORGANIZATION	
Program administrator/ contact agency/ consortium funding source	Mr. Peter Zhang China Road Transport Association zhangguanghe@crta.org.cn Managed and implemented by the China Road Transport Association (CRTA), the Research Institute of Highway, and Clean Air Asia.
Program goals	This initiative will support the relevant government agencies and freight carriers in China in their goal to achieve sustainable development within the freight industry through implementation of green management, green technology, and green driving. Specific goals include: • Green freight management—to promote efficient management of fleets that reduces travel distances and empty miles through the development of a green carrier standard. Priority strategies currently promoted under CGFI are drop-and-hook methods and the application of information technology for logistics improvement. • Green technologies—to promote the adoption of green technologies for freight trucks through the development of green truck standards and issuance of a catalogue of green technologies and energy saving products. • Green driving—to promote eco-driving through the development of an eco-driving standard.
Description	The initial focus of the CGFI is road freight given the rapid growth of ground freight usage in recent years and the neglect of the management of energy savings and emissions reduction in the freight sector. Potential partners submit detailed information on each vehicle in their fleet as well as organizational and management details. Program administrators rank submissions by Green Leaf level (1 to 5) based on the degree to which green vehicle, fuel, and operational strategies are adopted. Detailed performance monitoring and reporting procedures are specified to ensure emission reductions.
Start year	April 2012
Pollutants quantified and performance metrics used	No pollutant quantification. Program focuses on verifying technologies (for emission and fuel consumption standards) and operational procedures (such as drop-and-hook logistics strategies).
Annual funding range	Funding from the Energy Foundation—2012 and 2013 levels at $200,000 U.S. per year. Funding levels expected to decline in 2014.
State of development or program maturity (pilot/demonstration, initiation, expansion)	Currently implementing Phase 1 of program focusing on development and testing of green freight carrier standards and green freight vehicle standards.
Partners	
Number of partners	Uncertain—design in progress
Other key stakeholders/ affiliates	Research Institute of Highways of the Ministry of Transport Clean Air Asia U.S. EPA SmartWay program

Program Element	China Green Freight Initiative (CGFI)
Program Components	
Data collection / evaluation process	Green freight carrier standard and green freight vehicle standard have been developed. 20 pilot carriers tested the practicability of the two draft standards and submitted the self-assessment of their performance level (designated Leaf 1, 2, 3, 4, or 5) based on the draft standards.
Quantification methodologies—performance benchmarking, scoring, rating, and/or ranking	CO_2 may eventually be calculated based on reported fuel consumption. Fuel types referenced include diesel, natural gas, and electricity. Performance metrics such as g/km and g/t-km not discussed at this time. Vehicle-specific inputs in the application include weight and average payload, engine emission and fuel efficiency standards, use of GPS, and description of other fuel efficiency and emission reduction technologies/strategies. Draft evaluation and assessment benchmarks and relative weighting factors developed for Green Leaf Level scoring for carriers. Evaluation categories include operational strategies, vehicle benchmarks, technological requirements, and driving practice requirements.
Data collection tools (types; online/Excel forms/other)	None at this time
Branding and marketing strategies	The CRTA will be responsible for certification and labeling of green carriers and green vehicles, and the evaluation and assessment process will be completed by CGFI's expert group.
Technology program details (verification offered, certification, labeling)	CGFI is waiting to see the result of the Guangdong Green Freight Demonstration Project. The Research Institute of Highways will develop the catalogue of verified green technologies and energy savings products in the 2014–2015 timeframe. Verification/certification process uncertain—design in progress.
Financial assistance mechanisms	None at this time. Government financial incentives for green carriers and green vehicles could be offered in the future.
Partner account managers (number, responsibilities—e.g., how do they administer partnership process)	In development
Data management system (relational database, other)	In development
Data quality assurance measures	In development

Program Element	China Green Freight Initiative (CGFI)
Measurement/Impact	
Estimated aggregate benefits (annual pollutant reduction, fuel savings, etc.)	In development—estimates will require specific verified technologies with quantified benefits.
Further Information	
Other program details	N/A

The CGFI has the potential to encourage active fleet participation for CRTA member truck fleets. Specific incentives and participation rates will be determined after establishment of the green carrier and green vehicle standards, branding, and logo qualification requirements. The program also has the potential to drive innovation across several areas of the market, encouraging a wide variety of technology and operational changes in order to obtain high Green Leaf ratings. Credit may be given for adoption of the following strategies:

- Organization and vehicle dispatching
- Drop-and-hook freight
- Use of advanced logistics services
- Purchase of vehicles meeting the latest national fuel efficiency standards
- Positioning and navigation equipment
- Use of assorted fuel efficiency technologies (e.g., low-viscosity lubricants, lightweighting)
- Use of alternative fuels (e.g., natural gas, hybrids, electric)

Breadth: The initial phase of the CGFI program will focus on ground truck freight transport, although other mode of transport including waterborne, air, and rail transport may be included in the future. Partner types include truck carriers as well as logistics providers, and possibly shippers. Trucks included in the program are limited in a variety of ways including requirements to meet specified national efficiency and emission standards as well as minimum payload utilization ratios.

Depth: CO_2 may eventually be calculated based on reported fuel consumption. Fuel types referenced include diesel, natural gas, and electricity. Other pollutants such as NO_x and PM, and other performance metrics such as g/km and g/t-km, are not under discussion at this time.

Precision: Partners may be required to submit a large amount of vehicle-specific information with their applications and monitoring reports. This could allow future performance metrics to be broken out in a variety of ways:

- By truck class (N1, N2, and N3—weight categories)
- By vehicle type (e.g., box trucks, tankers, flatbeds, containers)
- By fuel type (diesel, natural gas, hybrid, electric)
- By efficiency technology/technologies adopted (e.g., low-rolling-resistance tires, idle reduction equipment)
- Presence of GPS

Data collection under the green freight carrier standard may also provide extensive opportunities for quantifying the benefits associated with a variety of logistic and management strategies (e.g., drop-and-hook adoption).

Comparability: The voluntary green vehicle and green carrier certification processes being standardized under CGFI could provide a reliable basis for comparing truck carrier and logistics company performance. The Green Leaf certification levels will be introduced in phases. During the 2012–2014 period, Level 1 corresponds to a "passing" basic level of performance, while Level 3 certification indicates outstanding performance. Criteria will be reassessed for the 2015–2016 period, with the best performers assigned a Level 5 rating. The final scoring criteria will include clear quantitative assessments for the different evaluation categories (vehicle and other technologies, management strategies, and driver training/performance requirements).

Verification: Data collection procedures for the CGFI have not yet been established, and specific calculations and data processes have yet to be determined. For this reason a definitive assessment regarding performance quantification and verification cannot be made at this time.

3.1.6 Transporte Limpio (Mexico)[49,50]

The Transporte Limpio initiative in Mexico is a nation-wide, free, voluntary program created in 2010 by the SEMARNAT (Secretary of Environmental and Natural Resources) and the SCT (Secretary of Communications and Transport) to make freight and passenger transport more efficient, lower costs, and reduce emissions. The program has three types of participants: truck carriers, shippers, and technology vendors. Goals are achieved through strategies and technologies that reduce fuel consumption. Some of the measures promoted by Transporte Limpio include training operators in technical-economic driving (eco-driving), improving the aerodynamics of trailer truck and trailers, energy diagnostics, reduction of empty kilometers traveled, single-wide and low-rolling-resistance tires, automatic tire inflation systems, usage of lightweight materials, advanced lubricants, alternative fuels such as natural gas, retrofit emissions control devices, intermodal operations, and use of hybrid vehicles.

Transporte Limpio uses a version of the FLEET model similar to that used during the first phase of the SmartWay program (through 2009). The model has been adapted to score and rank Mexico's participants once they have completed a questionnaire characterizing their fleets. Truck carriers and shippers use the same methodology for data collection, but their evaluation scores are differentiated. The data are collected using Excel-based tools for the questionnaire and the FLEET model. The pollutants quantified for the participants of Transporte Limpio are CO_2, PM, and NO_x. Participation in the program allows the carrier to estimate the environmental impact generated by its fleet, reduce emissions through the use of recommended strategies and technologies, reduce operating costs, become preferred carriers, and improve its public image by being recognized as a company committed to the environment. About 150 companies with more than 18,000 trucks have participated in the program between December 2008 (when it started as a pilot) and 2013.

The following table highlights the key aspects of the Transporte Limpio program.

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[49] Reyna-Bensusan, N. (2013). Mexico's strategies to reduce black carbon from heavy duty diesel vehicles.
[50] Personal communications: Rodrigo Perrusquia Máximo, Chief, Departamento de Gestión Ambiental del Sector Transporte, SEMARNAT, January–May 2014.

Program Element	Mexico Transporte Limpio
General Information/Program Organization	
Program administrator / contact—agency/funding source	Judith Trujillo Machado Subdirectora del Sector Transporte Dirección General de Gestión de la Calidad del Aire y RETC SEMARNAT judith.trujillo@semarnat.gob.mx +55 56243717 SEMARNAT (Secretary of Environment and Natural Resources) SCT (Secretary of Communications and Transportation)
Program goals	Transporte Limpio is a nationwide, voluntary, free program, created to make the freight and passenger transport more efficient, lower costs, and reduce emissions.
Description	Transporte Limpio has three types of partners: truck carriers, shippers, and technology suppliers. Goals are achieved through the implementation of strategies and technologies that reduce fuel consumption. Partners complete questionnaires regarding their fleets and specify select improvement strategies. The strategies selected are used to calculate an overall performance score. When joining the program partners commit to the following: • Complete the questionnaire provided by the SEMARNAT within first 30 days of joining the program. • Within the first six months after joining the program, develop an action plan with strategies to improve the environmental performance in a course of three years. • Update the questionnaire annually and send to SEMARNAT.
Start year	2010
Pollutants quantified and performance metrics used	CO_2, PM, and NO_x
Annual funding range	< 3.0 million pesos
State of development or program maturity	Pilot phase complete; program has been implemented and is in an expansion mode.

Program Element	Mexico Transporte Limpio
Partners	
Number of partners	As of December 2013: • Total: 148 • Carriers: 122 • Shippers: 12 • Vendors and/or promoters of technology: 14 • Number of trailer trucks for which performance has been evaluated in 2013: 18,722 • Companies with an action plan: 37
Other key stakeholders/ affiliates	Not available
Program Components	
Data collection / evaluation process	Data inputs differentiate straight and combination trucks, fuel type (diesel, gasoline, CNG, LPG, LNG, biodiesel, ethanol), and short- and long-haul operation. Average and total miles, gallons, payload, and idle hours also collected by truck/tool/operation type. Truck counts provided by truck weight class and engine model year for NO_x and PM calculation.
Quantification methodologies	Once the company fills out and sends in the questionnaire with the annual operation of its fleet, SEMARNAT performs an evaluation running the FLEET model (the first-generation U.S. EPA SmartWay model, adapted to account for differing emission standards in Mexico), which generates a score according to the reduction of emissions of each company. Control strategies are entered into the tool. Controls include training operators in technical-economic driving (eco-driving), idle reduction, aerodynamic improvements, tire technologies, weight reduction, improved lubricants, engine upgrades, speed management systems, and intermodal shifts. Finally PM and NO_x control retrofits are input (e.g., diesel particulate filters). The carrier tool calculates baseline fleet emissions and performance metrics (g/km, g/tonne-km), as well as the emissions savings associated with the current control strategies used. Benefits associated with control strategies may be assessed individually for financial and planning evaluations. Benefits associated with action plan measures are calculated in the same way. The emission savings are combined in a weighted formula to calculate an overall performance score. This composite carrier fleet score is then used by shippers in determining their carriers' overall performance. Shipper tool calculates footprints just based on modal averages, not carrier performance.
Data collection tools	Two Excel tools are used—one for the fleet characterization questionnaire and the FLEET model.
Branding and marketing strategies	Logo developed Facebook page: Transporte Limpio Web page: in construction
Technology program details	No verification or labeling at this time
Financial assistance mechanisms	Not available

Program Element	Mexico Transporte Limpio
Partner account managers	None provided
Data management system	Uncertain
Data quality assurance measures	Uncertain
Measurement/Impact	
Estimated aggregate benefits (annual pollutant reduction, fuel savings, etc.)	The 150 companies (with more than 18,000 vehicles) participating in 2012 obtained an average fuel savings of 15 percent. 2,587,921 tons of CO_2 reduced cumulatively from 2008 to 2012.
Further Information	
Further information	As part of the activities in 2013, Transporte Limpio, with the support of Mercedes-Benz, carried out eight driver training courses in eco-driving for van type vehicles and four training courses for teachers from the CECATIs and companies located in the northern region with the support of the Border Environment Cooperation Commission through the Clean Air Institute and with resources from SEMARNAT. The new strategies and guiding principles of the Transporte Limpio program going forward include the creation of a national training network for technical-economic driving, a certification design, updating of the transport emissions assessment tool, and identifying synergies with other entities related to the Sector. Also in 2013, Transporte Limpio conducted three workshops for the “Elaboration of Energetic Diagnosis for Freight Companies.” The objective was to raise awareness among freight managers regarding the importance of the efficient use of fuel and its relationship to competitiveness. The attendees were trained in energy diagnosis for their company. This allows the carrier to do a simple self-diagnosis of energy use and identify fuel saving and emission reduction opportunities.

The Transporte Limpio program requires strong commitment, with carrier's partners developing and submitting a three year Action Plan for their fleets, along with annual updates to monitor their progress.

The program provides effective implementation support through funding from the Mexican government and partnership with companies such as Mercedes Benz as well as guidance from the U.S. EPA SmartWay program. The program's FLEET model also gives partners a powerful evaluation and planning tool for developing their action plans, allowing carriers to assess the likely costs and benefits of a wide range of specific control options.

Although the FLEET model does not allow shippers to calculate quantitative emission footprints, the program's scoring system does give shippers and carriers a clear incentive to improve their performance. The FLEET model also provides a clear, consistent methodology for quantifying program benefits in terms of mass emission reductions. The link between technology and operational strategy adoption and emission reductions is made particularly transparent through the FLEET tool's benefit assessment capability. In addition, the requirement for the development of three-year action plans based on the adoption of proven technologies and strategies drives innovation in the market place over a sustained period.

The FLEET tool developed by the SmartWay program and modified for use in Mexico provides a proven methodology for quantifying fuel savings and emissions benefits in an accurate, consistent fashion.

Breadth: At this time, the program is restricted to truck carriers and shippers.

Depth: The program quantifies tank to wheels carrier emission reductions for CO_2, NO_x, and PM, as well as performance metrics for carriers based on mileage and weight metrics.

Precision: The FLEET tool calculates precise emissions and emission performance metrics at the carrier-specific level for trucks. CO_2 emissions are based solely on fuel factors (in g/liter), adjusted to account for the specific energy content of Mexican fuels, and are calculated based on fleet-specific fuel consumption estimates. NO_x and PM emissions are based on mileage-based emission factors developed using the FLEET model. The Truck Tool considers the following factors when estimating fleet-average emission rates:

- Fuel type (diesel/biodiesel blend, gasoline, ethanol blend, CNG, LNG, LPG, electric, and hybrid)
- Vehicle weight class distribution (based on gross vehicle weight)
- Engine age distribution
- Idle hours (short vs. long duration)

The tool calculates total NO_x and PM emissions by multiplying the g/km factors by total kilometers. The FLEET Tool also provides substantial precision with respect to performance metrics, combining calculated emissions with km and tonne-km totals to obtain g/km and g/tonne-km values. Shipper performance ratings are qualitative, based on weighted average rankings of their carriers.

Comparability: The Transporte Limpio calculation tools provide a consistent means of estimating performance levels for individual fleets and companies. The weighted average composite index factors for carriers also provide shippers with a consistent process for ranking the overall emissions performance of their carrier options.

At this time the Transporte Limpio program does not provide emission footprinting capability for shippers and as such is not harmonized directly with other programs such as SmartWay and Green Freight Europe. However, the program uses many of the fundamental data collection elements used by these other programs (carrier fuel consumption, distance and weight data). In addition, having adopted the FLEET model system previously employed by the U.S. EPA, the program is well situated to use the lessons SmartWay learned in converting from its "1.0" system to its "2.0" system.

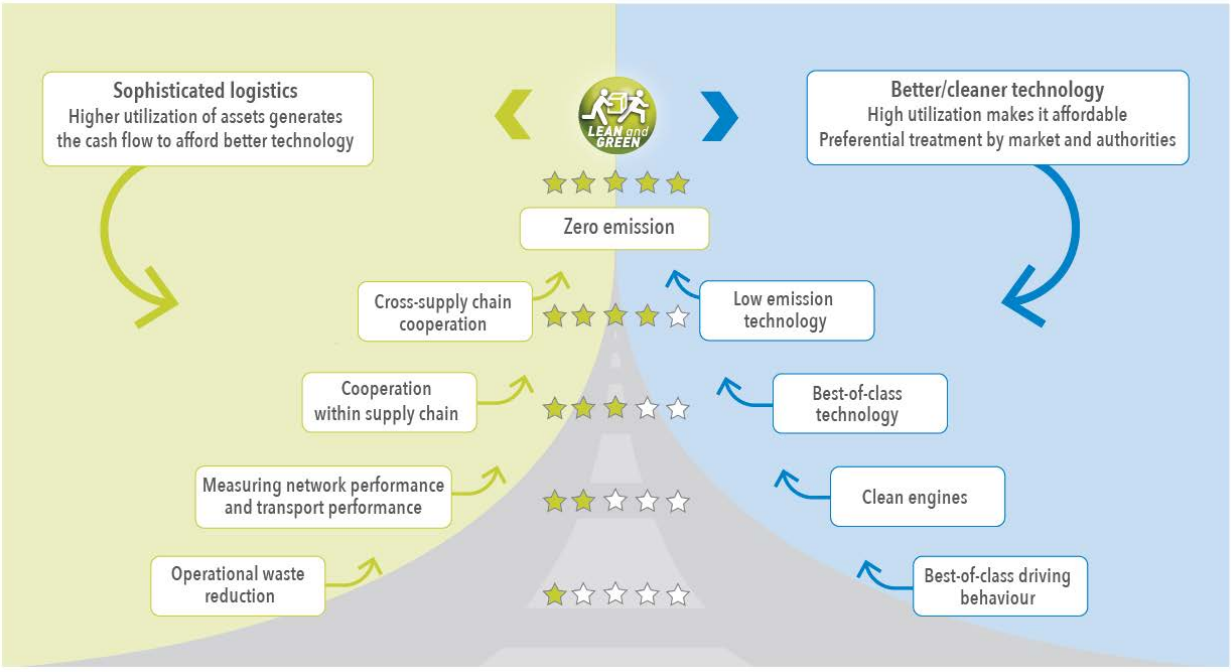
Verifiability: Data quality and verification measures for the Transporte Limpio program have not been identified at this time.

3.1.7 Lean and Green (Netherlands)[51,52]

Lean and Green is a European private, member-funded network of more than 300 companies, municipalities, and institutions in a program administered by Connekt, a Dutch nonprofit organization. The program is currently supported by five licensee organizations in Belgium, the Netherlands, Luxemburg, Germany, and Italy, to be expanded in the near future to Austria and Switzerland. The program began in 2007. In the Netherlands alone it has over 250 partners including truck carriers, shippers, logistic service providers, and municipalities. The 115 companies who have reported their emissions savings have realized a 22 percent reduction of CO_2 emissions.

The Lean and Green network has multiple components, of which Lean and Green Logistics is the oldest. Recently Lean and Green added personal mobility (focusing on sustainability improvements), and "Lean and Green solutions" components. Lean and Green Logistics is a community-driven program of companies that strive for continuous improvement. This process of continual improvement is depicted below, with the ultimate goal being "zero emissions."

[51] Connekt (2014). Lean and Green. Retrieved from http://lean-green.nl/en-gb/.
[52] Personal communications: Lia Hsu, Project Manager, Connekt/ITS Netherlands, March–April 2014.



LEAN AND GREEN PERSPECTIVE

Connekt

The Lean and Green community members:

- Acknowledge the efforts and the improvements made by members of the community.
- Innovate by sharing best practices, developing new means of cooperation, and testing new technologies.
- Improve their performance data to strengthen evidence-based decision-making and track their progress.

The Lean and Green community encourages its members to communicate with their peers to exchange experiences. Together they discuss how their complex international supply chains can be improved. Improvement targets have been categorized by the community in five levels (one to five stars), of which the first two levels have been fully defined. The remaining levels have been conceptually characterized but will be defined rigorously in the future.

Award and first star: The Lean and Green Award and first star assists members in focusing their initial improvement efforts, in helping organizations gain experience in identifying and reducing waste, and in measuring the relative effects of their adopted strategies. The recipient must develop an action plan to reduce its CO_2 emission by 20 percent within five years, relative to its reference measurement. Strategies include a combination of improving driver performance, increasing utilization rate, and improving trip coordination, among others.

Companies eligible for the Lean and Green Award are subject to four specific requirements:

- A CO_2 baseline measurement, presented in both absolute and relative emissions (e.g. CO_2 per tonne-km).
- The CO_2 reduction target is fixed and represents at least 20 percent in five years compared to the baseline measurement.
- There is an approved plan of action, meeting the prescribed format, which describes how the reduction objective is to be achieved.
- The results are monitored through twice-annual reporting.

The scope of the action plan can range from local (e.g., a specific well-defined division or smaller company in a specific country) to European (multinational companies). Local action plans are supported by local licensees, multinational action plans by the combined Lean and Green Logistics support network.

To monitor progress, members report their CPIs (critical performance indicators), which are numerical indicators expressing the results of their measures. These measures and reports are audited by an independent third party, TNO (the Netherlands Organization for Applied Scientific Research). If the member is in compliance with the criteria, the Lean and Green Award is granted and the Lean and Green Logo may be displayed on trucks and external publications. If the targets of the action plan are met, subject to external audit and verification, the member is award the first star, which also may be displayed on trucks and external publications.

Award of second star: The second star (first awarded in May 2014) challenges the members to improve through cooperation in the logistics value chain(s). In addition to the criteria set for the first star, recipients of the second star must meet qualitative criteria on innovation and cooperation, and demonstrate that they can measure and calculate two Key Performance Indicators (KPIs) with acceptable accuracy, given the defined methodology. The KPIs are the Network Performance Indicator, or NPI (CO_2 per unit) and the Transport Performance Indicator, or TPI (CO_2 per unit.km, CO_2 per move for terminals or cross docks, and CO_2 per unit-day for storage).

The two KPIs focus on communication between parts of the supply chain, analyzing supply chains in total or by component, and on comparing and benchmarking. The KPIs also encourage using a common acceptable methodology to gather data and to calculate these indicators with acceptable accuracy.

The performance quantification methodology is derived from the European standard EN 16258, as well as COFRET implementation guides, and has been tested by Lean and Green members. The methodology and the scope of the second star include all modes of transport (sea/river/air/rail/road), warehousing, storage, and terminal/docking activities.

The third star is reserved for absolute peer-to-peer benchmarking in specific subsectors, where members can demonstrate that they meet and surpass absolute levels of NPI and/or TPI. The fourth and fifth stars are designed to be stepping stones on the path to Zero Emission Logistics, as some of the members already have this goal set in their strategy.

The program hosts a specific development program (Lean and Green Barge) at the request of the Dutch Ministry of Transport to accelerate the development of Lean and Green in the large Dutch barge sector. The goal of the program is to develop cooperation between shippers to obtain a high enough freight volume and shipment frequency to be able to use barges, and to develop accurate data on CO_2 barge emissions in order to calculate and track the use of barges in their action plans. Currently the data quality for transport by barges (and rail) is much lower than for transport by road or air. The initial program has succeeded in attracting of over 75 shippers, building a database of over 400,000 TEU of transport movements, and establishing more than 10 lanes. The data accuracy model is being tested and will be made available to members in 2014.

The following table highlights the key aspects of the Lean and Green program.

Program Element	Lean and Green Logistics
General Information/Program Organization	
Program administrator—agency/funding source	Lia Hsu Program Manager hsu@connekt.nl Operated by Connekt and (currently) five licensees in Europe. Funded by member fees. (For example, in the Netherlands, the initial fee is €2,000; annual renewal is €600 to €1,800.)
Program Goals	Lean and Green Logistics encourages businesses, municipalities, and institutions to continuously improve their logistics processes. Its vision is that improving the sustainability and reducing the footprint of their members' logistics processes is aligned with improving their competitiveness, increasing value, and reducing waste. Each member can make progress at its own level and learn from its peers. There are five levels (one star to five stars), with the highest level aiming at Zero Emission Logistics.
Description	Lean and Green Logistics encourages businesses (freight forwarders, logistics service providers, shippers, and carriers) and government bodies (municipalities) to continuously improve their sustainability by taking measures that are Lean (add value, reduce waste) and Green (reduce environmental impact, consumption of nonrenewable resources). The common goal is continuous improvement by accepting challenges, cooperating in the logistics chain, and learning from peers. The entry-level challenge (award and first star) confirms the program target. The participant then develops an action plan with the goal of reducing its CO_2 emissions by at least 20 percent in five years. (Inclusion of PM emission reductions is under development and is being piloted in Germany.) Companies eligible for the Lean and Green Award are subject to four criteria including CO_2 baseline development, specifying an emission reduction target, development of an action plan to meet the target, and periodic monitoring and reporting of progress. Strategies specified in the action plan must be applicable to at least five customers, and contact information for these customers must be submitted for verification purposes. The scope of the action plan can range from local to European, and can include every step in a supply chain. To monitor progress, partners report their CPIs (critical performance indicators), which are numerical indicators expressing the results of their measures. These measures and reports are audited by an independent third party, such as TNO in the Netherlands and TUV in Germany. If the partner is in compliance with the criteria and the action plan is accepted, the Lean and Green Award is granted and the Lean and Green logo may be displayed on trucks/barges, etc., and used in external publications. When the target of the action plan is met, the member receives the first star, which may be displayed on vehicles and used in external publications. The second star challenges the members to improve through cooperation in the logistics value chain(s). In addition to the criteria set for the first star, they have to meet qualitative criteria on innovation and cooperation, and demonstrate that they can measure and calculate two Key Performance Indicators with a minimal acceptable accuracy. The KPIs are the NPI (CO_2 per unit) and the TPI (CO_2 per unit.km, CO_2 per move, or CO_2 per unit-day). The methodology and the scope of the second star include all modes of transport (sea/river/air/rail/road), warehousing, storage, and terminal/docking activities. The scope of the second star is Europe (not localized). The third star is reserved for absolute peer-to-peer benchmarking, where members can demonstrate they meet and surpass absolute levels of NPI and/or TPI. The fourth and fifth stars are designed to lead to Zero Emission Logistics.

Program Element	Lean and Green Logistics
Start year	2007
Pollutants quantified and performance metrics used	CO_2: CO_2 per unit, CO_2 per unit.km, CO_2 per move, CO_2 per unit-day Euro norms for other emissions
Annual funding range	€175,000–€725,000
State of development or program maturity	Mature, implemented at the multinational level
Partners	
Number of partners	Partners in the Netherlands: • Truck carriers: 102 • Shippers: 73 • Logistic service providers: 99 • Municipalities: 16 As of May 2013, 31 members had attained the Lean and Green Star designation.
Other key stakeholders/ affiliates	Partners in Germany (GS1 Germany), Belgium (Flanders Institute for Logistics and Logistics in Wallonia), Luxembourg (Ministry of Transport), Italy (Freight Leaders Council).

Program Element	Lean and Green Logistics
PROGRAM COMPONENTS	
Data collection / evaluation process	Action plan (award, first star). The submitted action plan contains the key elements for emissions and performance quantifications. The action plans include: 1 Introduction. 2. Description of the company—a qualitative and quantitative description of the organization. 3. The scope—that portion of the logistic activities to which the target applies. Non-logistic activities are not taken into account. 4. The CO_2 savings target—the planned CO_2 reduction in five years, versus the base year (not earlier than 2007). At least 20 percent. Expressed as relative CO_2 emissions performance (CO_2 per unit). 5. The CO_2 baseline measurement—the absolute and relative CO_2 emissions in the base year, based on volume data, distance, fuel consumption, etc., expressed in either CO_2 per unit, CO_2 per unit.km, and/or total CO_2. 6. The saving measures—the total set of activities that will lead to the planned CO_2 savings. 7. The critical performance indicators (CPIs)—the numerical indicators that measure the results. 8. Monitoring/anchoring—a description of the way in which the target(s) and results are monitored. 9. External publication—a description of the way in which the target, the efforts, and the results are communicated to the public. 10. Dashboard—a schematic summary of the baseline measurement, measures, and CPIs over the course of time. The submitted documents for the second star consist of additional information including: 1. Measurement of **KPIs** (NPI, TPI) in compliance with uniform calculation methodology (based on EN 16258). 2. Minimum levels of **data accuracy** for KPI calculation. 3. For **carriers,** documentation of compliance with a minimum target on **Euronorm** (average 4.5). 4. Demonstration of two measures on **cooperation** and **innovation** to reduce CO_2. 5. Demonstration of one measure on **sustainable logistics (beyond CO_2).** 6. For **shippers,** demonstration of how carriers are encouraged to become more sustainable. A second (or third/fourth/fifth) star is valid for one year and must be renewed every year through document submission.
Quantification methodologies	Partner strategies or "solutions" specified in the action plan focus on logistic improvements such as use of vehicle tracking, ITS and advanced dispatching/communication systems, implementation of driver training programs, and adoption of clean fuels such as LNG and gas-to-liquids (GTL). Mass emission reductions and performance metrics are calculated with the baseline evaluation as well as with the action plan and monitoring reports. Calculation methods for pollutants other than CO_2 will be established in the future. The methodology for CO_2 reduction calculation and allocation is derived from the European standard EN 16258 and COFRET implementation guides. A data accuracy model is used to assess the quality of the results based on the primary data sources and the selected methodology. A minimum accuracy level is needed to be acceptable.

Program Element	Lean and Green Logistics
Data collection tools	Performance monitoring data for the award and first star can be submitted via online portal or through the GFE database (under development). Submitted data are confidential. Action plans are also submitted digitally. (Data for the second star are submitted by mail.) A wide variety of Excel-based support tools are also offered, including: • An Emissions Scan tool to calculate the impact of logistics strategies, including mode shifts on CO_2, NO_x, PM, and SO_2 emissions. • A Green Order tool that estimates the CO_2 impacts associated with specific product orders. • A Green Tender tool to provide guidance on choosing sustainable logistics services, including details regarding Euro emission standards, environmentally friendly fuels, and empty kilometers travelled. • An Environmental Barometer that provides a global environmental impact and cost overview for shippers and carriers, including a CO_2 per product estimate. • A Quick Scan that serves as a screening tool for carriers and shippers, using inputs regarding kilometers travelled, tonnage hauled, and engine power to assess the CO_2 emission impact associated with various operation activities. • A Bike Messenger Calculator that identifies package delivery types where bike delivery can be competitive with van delivery. • Standardized emission factors, developed in cooperation with other agencies and government bodies for the Netherlands.
Branding and marketing strategies	Recognizable logos are available for both the Lean and Green Award and the Lean and Green first star, as well as the European second star. The criteria for qualifying for the logos are clear and well-documented.
Technology program details	Not applicable
Financial assistance mechanisms	No subsidies are available
Partner account managers	Not provided
Data management system	Not provided
Data quality assurance measures	Audits of action plan and second star submittals are carried out by an independent auditor, such as TNO or TUV. Audits of progress results are performed by an independent auditor, selected by the member from a list of accepted auditors.
Measurement/Impact	
Estimated aggregate benefits (annual pollutant reduction, fuel savings, etc.)	The 115 companies that have reported their savings have realized a 22 percent reduction in CO_2 emissions.

Program Element	Lean and Green Logistics
Further Information	
Further information	Lean and Green Logistics has developed a logistic emission calculation handbook that provides a standardized methodology for calculating emissions associated with logistic activities, consistent with the Greenhouse Gas Protocol. Lean and Green Logistics has also developed a uniform calculation and allocation methodology for NPI and TPI calculations for all parts of the logistic chain, and a data accuracy model. The new Lean and Green Barge program promotes cooperation between shippers to obtain a high enough freight volume and frequency to be able to use barges (Lean) and to develop accurate data on CO_2 emissions by barges to be able to calculate and track the use of barges in action plans for stars one and two. The program has succeeded in attracting of over 75 shippers, building a database of over 400,000 TEU of transport movements, and getting more than 10 lanes active. The data accuracy model is being tested in practice and will be made available to members in 2014. Lean and Green signed a memorandum of understanding with Green Freight Europe to: • Exchange knowledge and best practices on sustainable logistics. • Create and support a common framework and definition for logistics for measuring and combining CO_2 emissions, network performance, and carrier performance, allowing for absolute comparison in peer groups, using primary operational data, based on EN 16258. The framework includes a practical interpretation (and application) of the EN 16258 rules and describes how companies should deal with existing gaps in the standard. • Create a joined proposition (and preferably a joined membership) with a clear individual branding of both programs throughout the European network. Lean and Green will have a clear focus on front-running companies and being the incubator for best practices on improving environmental performances throughout freight transport. Green Freight Europe will focus on monitoring and reporting and knowledge dissemination (best practice sharing) to European companies. • Explore further collaboration and integration of both programs, respecting the own identities, will be worked out. • Explore the potential of one overarching European organization on sustainable logistics including Lean and Green, Green Freight Europe, and other initiatives.

Entry-level participants in the Lean and Green Program demonstrate notable commitment to the program as evidenced by their adoption of a specific five-year action plan, including twice-yearly monitoring reports audited by a third party. The program also has an effective reward and incentive system, using clearly defined logos indicating different performance levels: the Lean and Green first star designation for members that have met their targets, the second star level for advanced members, and the three- to five-star levels moving toward zero emissions. The Lean and Green program also features particularly strong implementation support, offering partners assistance, advice, and information on best practices.

Breadth: Lean and Green Logistics characterizes emissions and performance metrics for truck carriers, logistics companies, and shippers. The recently implemented Lean and Green Barge effort expands the program to inland barge carriers. Participants include private businesses as well as municipalities and institutions seeking to improve their freight logistics performance.

Depth: The Lean and Green Program currently quantifies CO_2 emissions and performance. Performance metrics include CO_2 per unit, CO_2 per unit.km, CO_2 per move, and CO_2 per unit-day.

Precision: Quantitative emissions reduction calculations are based on primary operational data like fuel consumption data, distances driven, and units transported. The calculated emission factors used are established in cooperation with other agencies and applicable government bodies (e.g., the European standard EN 16258).

Comparability: The program offers a variety of assessment tools (e.g., Quick Screen, Emissions Scan), designed to help the wide variety of users assess the costs and environmental impacts for a variety of measures in a consistent fashion. In addition, in November 2013, Lean and Green signed a memorandum of understanding with Green Freight Europe. The memorandum indicates that the parties "agree to create a common framework and definition for measuring and combining CO_2 emissions, network- and carrier performance." This will allow the two groups to compare and harmonize results among their partners.

Verifiability: The data calculation and processing system allows for the accurate determination of CO_2 reductions on a twice-annual basis. In addition, the requirement for independent third-party audits of CPIs and monitoring submittals makes the program benefit estimates highly verifiable.

3.1.8 Clean Cargo Working Group[53,54]

The Clean Cargo Working Group (CCWG) is focused on improving environmental performance in marine container transport using standardized tools for measurement, evaluation, and reporting. The CCWG was established in 2003 by BSR (Business for Social Responsibility) and founding industry members. CCWG is composed of a member-elected

[53] BSR (2014). Clean Cargo Working Group. Retrieved from http://www.bsr.org/en/our-work/working-groups/clean-cargo.

[54] Personal communications: Angie Farrag-Thibault, Associate Director, BSR Transportation and Logistics Practice, January–May 2014.

steering committee and several working teams. BSR serves as the neutral secretariat, data manager, and expert facilitator. Data from more than 20 of the world's leading ocean carriers are reported to CCWG, representing more approximately 85 percent of global ocean trade (based on TEU capacity represented by CCWG carrier members in February 2014, as measured by Alphaliner).

The CCWG provides tools to its members for measuring, evaluating, and reporting ocean carrier performance for CO_2, NO_x, and SO_2 emissions as well as environmental management system and waste, water, and chemical practice implementation. Every year Clean Cargo carriers report on vessel-specific data to BSR via a standard template. CO_2 emissions factors (in g CO_2/TEU-km) are calculated for CCWG's performance metrics system. CCWG carriers report data for each vessel including capacity (in TEU), distance sailed, and fuel type through the annual CCWG Performance Metrics data collection process. The aggregated data are provided to all members, and shipping customers are given individualized carrier scorecards.

This reporting and dialogue enables shipping customers to calculate the environmental impacts of transporting goods around the world and benchmark carriers' performance. Having this information helps shipping customers make informed buying decisions in their supply chains, and approximately 95 percent of CCWG shippers use CCWG tools or data in procurement practices. CCWG also consistently engages in dialogue with other initiatives and experts working on these issues in the global transport industry to align approaches that can improve information sharing and performance for shipping customers and cargo carriers across the full transport supply chain.

In order to continually increase data transparency, as well as the availability of quality metrics, CCWG annually publishes aggregated trade-lane emissions factors. CCWG's annual emissions factor publication indicates that average CO_2 emissions per TEU-km for global ocean container transportation have declined by more than 7 percent from 2011 to 2012 and by 16 percent since 2009. While changes in carrier representation or global trade conditions likely explain a portion of these reductions, the continued performance improvement is also attributed to carrier fleet efficiency and data quality, both of which have direct benefits for shipping customers.

The following table highlights the aspects of the CCWG program.

Program Element	Clean Cargo Working Group
General Information/Program Organization	
Program administrator—agency/funding source	Angie Farrag-Thibault CCWG Project Director Associate Director, BSR Transport and Logistics Practice afarrag-thibault@bsr.org +45 2120 5015 Nate Springer CCWG Project Manager nspringer@bsr.org +1 415-984-3309 CCWG is a working group of BSR (www.bsr.org/cleancargo), funded by member dues.
Program goals	The overarching objective is to achieve environmental performance improvement in marine container transport through measurement, evaluation, reporting, and sharing of best practices. Project outputs include: • Practical, standardized tools for measuring and reporting the environmental impacts of cargo transported by sea that allows companies to make informed business decisions. • Direct dialogue and best practice sharing between shippers, transportation providers, and other relevant stakeholders in the pursuit of continuous environmental improvement. The vision is for CCWG tools and methodology to become the industry standard where applicable.
Description	CCWG is a business-to-business collaboration between leading shippers and global ocean carriers and logistics providers. CCWG is dedicated to environmental performance improvement through measurement, evaluation, and reporting in maritime transportation management. Container carriers have been reporting their CO_2 performance to their customers in a credible and comparable format, based on the CCWG CO_2 methodology—the only existing and broadly recognized industry standard for maritime container shipping—for the past eight years. Modes: maritime cargo containers Geography: global Membership: carriers, shippers, and freight forwarders
Start year	2003

Program Element	Clean Cargo Working Group

Pollutants quantified and performance metrics used	• CO_2, SO_x, NO_x:
	  o CO_2—gCO_2/TEU-km
	  o SO_x—g SO_x/TEU-km, average sulfur content of fuel (percent)
	  o NO_x—percent below IMO curve
	• EMS—percent of fleet certified with EMS equivalent to ISO 14001
	• Waste/water/chemicals—score (18 indicators)
	• Transparency—score (10 indicators)

Annual funding range	$250,000–$1 million (U.S. dollars).
State of development or program maturity	Mature
Partners	
Number of partners	2014 membership: • Carriers: 23 • Shippers: 11 • Freight forwarders: 6 Approximately 85 percent of the global ocean container fleet by volume is represented by carriers in the CCWG. Shippers include IKEA, Wal-Mart, Nike, Heineken, Kohl's, Ralph Lauren, Nordstrom, Electrolux, and others.
Other key stakeholders/ affiliates	Feeders and other ocean cargo modes
Program Components	
Data collection / evaluation process	CCWG collects quantitative and qualitative data from its members to score and rank them. Every year Clean Cargo carriers report on vessel-specific environmental performance data to BSR via a standard template. The aggregated data are provided to shipping customers via individualized annual carrier scorecards. All data collection is done with an online system.

Program Element	Clean Cargo Working Group
Quantification methodologies	CO_2 emissions factors (in g CO_2/TEU-km) are calculated for the purposes of CCWG's performance metrics system. CCWG carriers report on the following data for each vessel through the annual CCWG Performance Metrics data collection process: • Nominal capacity (in TEU) • Number of reefer plugs (used to calculate separate CO_2 emission factors for reefer containers) • Distance sailed • Fuel consumed (heavy fuel oil and marine diesel/marine gas oil reported separately) • Time frame of data The calculation methodology for dry containers uses this information to calculate vessel CO_2 emissions data based on International Maritime Organization (IMO) guidance for emissions and carbon contents of fuels (Ref. T5/1.08 MEPC/Circ.471). A general description of this calculation for dry and reefer containers is as follows: CO_2 emissions = (actual fuel consumption × CO_2 conversion factor) ÷ (nominal capacity × actual distance sailed) Vessel metrics and benefits aggregated and reported publicly at a trade-lane-specific level, based on g CO_2/TEU-km (broken out by dry and reefer containers)
Data collection tools	Standardized measurement and reporting tools are online-based and include: • The Environmental Performance Survey (EPS), which covers a series of qualitative questions on carriers' environmental focus areas. • The Environmental Performance Metrics (EMS), which enables container shipping customers to benchmark carriers' performance on a broad range of environmental impacts (e.g., CO_2, SO_x, and NO_x; chemical use; and waste) of the carriers' operated fleets (including charter vessels). The EMS is updated every year with the latest performance data for each CCWG carrier. • The Intermodal Carbon Calculator, a CO_2 emissions calculation Excel tool that covers the whole transportation supply chain. This tool requires users to enter actual or estimated distance for each mode and calculates emissions using the latest publicly available modal average emissions factors from sources such as DEFRA and the U.S. EPA. Updated versions are issued annually, and training decks are available. • The Verification Protocol, which enables carriers to have their CO_2 and SO_x performance data verified independently based on a standardized framework.
Branding and marketing strategies	Website: http://www.bsr.org/en/our-work/working-groups/clean-cargo CCWG and partners publish five to seven blogs, reports, and press releases each year. Members speak at various conferences, and CCWG holds one or two webinars throughout the year. Clean Cargo has a logo, available upon request.
Technology program details	CCWG collects best practices in CO_2, NO_x, and SO_x emissions management and reductions from carriers that it shares with members. These include lists of technological measures and management practices that carriers use across their fleets or for pilot testing.

Program Element	Clean Cargo Working Group
Financial assistance mechanisms	N/A
Partner account managers	Four, who manage day-to-day administration of CCWG. This includes annual data collection, planning and logistics for two member meetings per year, Steering Committee and other working committees, and some recruitment, marketing, and member support activities.
Data management system	The system is online and spreadsheet-based, and all spreadsheets and data are protected.
Data quality assurance measures	Nine out of 23 carriers were verified by third parties against standard methodology in 2013. External audits are conducted to verify the data and calculations. In order to continually increase data transparency, as well as the availability of quality metrics, CCWG annually publishes aggregated trade-lane emissions factors, available at www.bsr.org/cleancargo.
Measurement/Impact	
Estimated aggregate benefits (annual pollutant reduction, fuel savings, etc.)	CCWG's 2013 publication indicates that average CO_2 emissions per TEU-km for global ocean transportation routes have declined by more than 7 percent from 2011 to 2012 and by 16 percent since 2009. While changes in carrier representation or global trade conditions likely explain a portion of these results, the continued performance improvement is also attributed to carrier fleet efficiency and data quality, both of which have direct benefits for shipping customers. 2012–2014 program indicators and benefits include: • Data were collected on ~3,000 container vessels, accounting for 1.74 trillion TEU-km traveled. • 21 of 25 trade lanes demonstrated annual CO_2 reduction in 2013.
Further Information	
Further information	Through in-person meetings, webinars, case studies, and other means of interaction, Clean Cargo promotes the sharing of best practices between shipping customers, freight forwarders, and ocean transport providers. Recently, Clean Cargo published a report titled *How Clean Cargo Shippers Use, Integrate, and Benefit from Ocean Transport Emissions Data*. See http://www.bsr.org/en/our-insights/report-view/clean-cargo-shippers-transport-emissions. From CCWG: "Our membership continues to grow, and we have expanded our scope both geographically and across industries. Throughout 2012 and 2013, we made significant strides in our core activity of environmental performance data measurement, reporting, and verification. Looking forward, we are improving the reporting systems to allow for more flexibility in supplier performance analysis and industry performance benchmarking, as well as tools for members to integrate the data within operations and business partner relationships."

The CCWG program exhibits extremely strong leadership, as evidenced by the participation of the majority of the world's leading cargo lines. BSR also provides an effective, impartial third party for coordinating the collection, calculation, performance scoring, and auditing of partner data.

Shipper partners demonstrate strong commitment to the program, assuring that they will integrate the carrier scorecard data and other analysis tools into their freight service procurement systems. Shippers also commit to train staff and to share how they use CCWG data with their carriers.

By providing carrier-specific scorecards to shippers and freight forwarders, the CCWG provides an effective incentive for communication between carriers and shippers and for continual carrier improvement. Partner companies share best practices, and shipping customers can directly engage with their transportation providers to build appropriate environmental expectations into supplier relationships. Shipping customers use CCWG as a resource to keep abreast of the latest developments in methodology alignment across the transport supply chain, enabling them to use resources more effectively.

Carrier-specific performance information at the company and trade-line level provides customers with a highly transparent performance assessment, often verified by an independent third-party audit. While individual scorecard information is confidential, CCWG publishes aggregated average performance metrics by trade lane each year.

The program provides strong implementation support with a suite of calculation and assessment tools for its partners, along with four staff assigned to assist with data submittal, recruitment, and other program-related activities. BSR also recently surveyed shipper partners to obtain feedback on how program data are being used and the value CCWG brings to their companies.

The CCGW program uses its standardized calculation tools and methods to develop clear, reliable program benefit estimates over time. According to CCWG, it is a "credible and comparable format, based on the CCWG CO_2 methodology—the only existing and broadly recognized industry standard for maritime container shipping—for the past eight years." The CCWG tools generate accurate CO_2 emissions factors and associated metrics using actual fuel consumption and distance traveled. Precision for emissions calculations will improve further when recently collected average utilization factor data are made publicly available.[55] Performance for NO_x is assessed relative to IMO curves, but is limited to engines built/converted after 1999. Details on emissions and performance quantification are discussed below.

Breadth: The program focuses primarily on oceangoing container vessel emissions, including trade-lane and port movements, for propulsion and auxiliary engines. A separate tool is offered to characterize intermodal CO_2 emissions at a modal-average level of detail.

Depth: Program tools estimate CO_2, NO_x and SO_2 emissions. CO_2 emissions are based on total fuel consumption and fuel carbon content, consistent with IMO standards, rather than lifecycle

[55] Currently, emissions factor estimates are based on the rated capacity of the vessels, assuming 100 percent utilization of cargo space.

factors. SO_2 emissions are derived from fuel sulfur content, and NO_x emissions are based on IMO curves.

Precision: Emissions estimates are very specific, developed at the carrier/trade-lane level. Twenty-five distinct trade lanes are characterized and emissions performance for CO_2 and SO_2 are presented for each (in g/TEU-km). Emissions performance (in g CO_2/TEU-km) is also differentiated across dry and reefer containers. Emissions performance for NO_x is presented for each carrier in terms of a relative score rather than an activity-based metric, although specific information regarding the percentage reduction below standard benchmarks is provided as well.

Comparability: The CCWG protocol is generally recognized as providing the industry standard emissions factors for use in carbon footprinting for oceangoing container vessel activities. Calculation methods are aligned with IMO procedures and the GHG Reporting Protocol, and allow for consistent scoring across carriers.

Verifiability: CCWG's encouraged use of third-party audits of carrier data as well as transparent sharing of trade-lane-specific performance information promotes high-quality, reliable emissions and efficiency estimates.

Finally, the CCWG protocol is particularly well-positioned for harmonization with other green freight programs at a global scale. It has established itself as *the* primary, trusted source for emissions factors used in carbon footprinting for container vessels. Its CO_2 estimation methodology is consistent with WRI's distance-based methodology for supply chain emissions characterization, as well as IMO's Energy Efficiency Operational Index guideline. Its members are also likely to be supportive of harmonization, with the recent shipper survey finding that some member companies have a strong desire to use CCWG tools and procedures to characterize emissions and benchmarks for all freight modes for global supply chain assessments. Finally, CCWG is actively engaged with other industry initiatives to coordinate calculation methodologies and tools across the entire shipping industry and intermodal supply chain.

3.2 Other Programs

The following programs usefully illustrate different aspects of green freight program development, but do not meet the selection requirements (presented above) for full programmatic evaluation for various reasons. Abbreviated summaries are provided for these programs below.

3.2.1 EcoTransIT® World Initiative[56,57]

EcoTransIT World Initiative (ETWI) is an independent industry-driven platform for carriers, logistics service providers, and shippers dedicated to maintaining and developing a globally recognized tool and methodology for carbon footprinting and environmental impact assessments in the transport sector. ETWI was established in 1998 by five European railway companies, specifically to help quantify the environmental impact of freight movement by various modes.

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[56] EcoTransIT (2014). EcoTransIT World. Retrieved from http://www.ecotransit.org/.

[57] Personal communication: Andrea Dorothea Schoen, Senior Manager, Carbon Controlling and Consulting, March 2014.

The Institute for Energy and Environmental Research (IFEU) from Heidelberg, the Öko-Institut from Berlin, and the Rail Management Consultants GmbH (RMCon/IVE mbH) from Hanover developed the EcoTransit Tool to quantify emissions.

ETWI provides an open platform dedicated to work on globally harmonized methods of assessing carbon footprints and environmental impacts in transportation. ETWI aims to:

- Increase transparency on the environmental impact of the freight transport.
- Promote the integration of environmental criteria in supply chain management.
- Encourage demand for environmentally friendly logistics services.
- Help transport providers meet their stakeholders' demands in a broadly accepted manner.
- Ensure continuous improvement of the existing EcoTransIT World (ETW) calculator tool[58] to best comply with customer needs and to be in line with international standardization requirements.
- Ensure that the tool maintains the state-of-the-art assessment of environmental impacts covering every transport mode, every leg of global transport chains, and every geographical region in compliance with existing and upcoming standards ensuring that the ETW and its methodology will meet the requirements of its users including confidentiality and security of data.

The ETW calculator quantifies the environmental impact of freight transportation in terms of direct energy consumption (fuel use) and emissions during the transport of products. It also calculates the indirect energy consumption and emissions related to production, transportation, and the distribution of energy required for operating vehicles. Calculations are performed for CO_{2e}, CO_2, SO_2, NO_x, NMHC, PM, as well as total energy consumption (on a well-to-wheel, well-to-tank, and tank-to-wheels basis). The tool compares the energy consumption and emissions of freight transported by rail, road, ship, and aircraft. It also takes into account the intermodal transport services and the different technical standards of the vehicles. In addition, the tool allows the user to select from an array of influencing factors to customize it for each company's individual conditions.

The tool calculates environmental impacts of any transport chain across the world. This is possible due to an intelligent input methodology, large amounts of GIS data, and an elaborate basis of computation. Data and methodology are scientifically founded and transparent for all users. The input parameters and the process of analysis illustrate the tool's precision:

- For each mode of transport, a GIS details the routes taken by goods.
- The computations integrate any trans-shipments at frontier crossings, or those occurring in piggybacking.

[58] The ETW calculator tool is hosted by IVE mbH.

- The volumetric weight of the transported cargo allows a precise assessment of the size of the trains.
- The type of loading locations (rail station, harbor, airport, roadway platform) enables accurate modeling to reflect local circumstances.

Responding to the needs of companies on a European scale, the conditions of each country such as energy combinations and topology are included in the calculations. Accordingly, EcoTransIT can be used for routes traversing Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Hungary, Italy, Luxembourg, the Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, and the United Kingdom.

ETW is unique as it is global (including all transport modes, all geographies), complete (calculating all GHGs and other pollutants), and flexible (users can calculate with real measured values or provide default values). The result of each calculation is presented in the form of diagrams and compares the energy consumption and emissions of different environmental pollutants, differentiating between selected modes of transports. This allows the user to select the routes and transportation mode with the lowest environmental impact.

The state-of-the-art emission calculator tool is available as a free-of-charge Internet version or a specifically customized version. Results are used for reporting and benchmarking purposes. All key parameters—load factor, vehicle type, emission class, empty trip factor, speed reduction, etc.—are transparent in the extended mode of the online version and can be adjusted to the user's actual business and transport structure. The overall methodology report is free, available, and published at http://www.ecotransit.org/basis.en.html.

3.2.2 Green Logistics Partnership (Tokyo)[59]

The Green Logistics Partnership (GLP) is a logistics benchmarking program for truck carriers operating in the Tokyo area. The GLP is led by the Tokyo Metropolitan Government Bureau of the Environment, and has been developed in close cooperation with the Tokyo Trucking Association. The program continues long-standing teaming efforts between government and industry to reduce freight truck emissions, dating back to the adoption of local in-use PM standards and retrofit requirements in the early 2000s.

The program commenced with two years of data collection on in-use freight trucks between 2010 and 2012 to establish CO_2 performance baselines. Data collected included monthly fuel consumption and distance traveled at the vehicle-specific level, although payload data were not collected. Fuel economy distributions were developed and differentiated based on vehicle weight range (six weight classes), age, and operation types (nine categories including dry vans, reefers, dump trucks, and containers)—39 categories in total. (A rough characterization of drive cycle can also be inferred based on the area of registration.) A total of 34,000 vehicle months were collected over this period, resulting in an extraordinarily robust data set for establishing relative carrier performance.

[59] Personal communication: Dan Rutherford, International Council on Clean Transportation, January–April 2014.

Under the second phase of program implementation (April 2012–March 2013), km/liter performance distributions were finalized for the various operation type/weight class combinations (fitted to normal bell curves) for 115 participating companies. Performance ratings of one, two, or three stars were then assigned to each vehicle evaluated based on the relative placement on the curves. Freight companies were then assigned overall ratings based on simple averages across their entire truck fleets. After the initial assessment, seven companies earned three-star ratings, 43 earned two stars, and 65 earned one star. Company ratings are publicly posted on the Bureau of the Environment's website.

The third phase of program implementation (currently underway) involves integration with the nonprofit Green Purchasing Network, or GPN (http://www.gpn.jp) broad umbrella organization and currently has 2,749 members including businesses, governments and NGOs. The GLP is also in discussion with other local government agencies in other areas of Japan, evaluating opportunities for program expansion.

3.2.3 Freight Best Practice (Wales)[60]

Freight Best Practice promotes operational efficiency within freight operations in Wales. The program was first developed and deployed in England in the mid-1990s, and focuses on fuel-saving measures, developing skills, equipment and systems improvements, performance management, and multi-modal transport. The primary goal of Freight Best Practice is to help freight operators reduce fuel consumption, lower operating costs, increase profit margins, and lower CO_2 emissions. Freight Best Practice has assembled a free information framework directed toward all carriers in the industry. While some information is geared toward drivers, the majority is aimed at transport managers and includes a series of guides to aid in benchmarking carrier performance across a range of sectors (e.g., food, next-day parcel delivery, and pallet networks). The program also provides information on best-in-class performers. The publications are accompanied by a software tool (the Fleet Performance Management Tool, or FPMT) to assist in benchmarking the fleet. The FPMT is a PC-based tool, complete with user manuals that allow operators to track fleet performance week by week for 22 Key Performance Indicators (KPIs) for each industry sector included.

3.2.4 EcoStation (Australia)[61,62]

EcoStation was a joint initiative between the Victorian Environment Protection Authority (EPA Victoria) and the Australian federal government. The program was outsourced to the Victorian Transport Association (VTA), who represented the interests of over 800 members throughout Australia, composed of approximately 2.9 million trucks ranging from light commercial to heavy articulated vehicles. The partnership was established through a sustainability covenant: a voluntary agreement between the parties to explore creative ways to reduce environmental impacts and increase resource efficiency. EPA Victoria elected to end its funding of the program

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[60] Freight Best Practice (2014). Freight Brest Practice. Retrieved from http://www.freightbestpractice.org.uk/.
[61] EcoStation (2014). Ecostation: Saving fuel, money and the environment. Retrieved from http://www.ecostation.com.au/.
[62] Personal communication: Rob Perkins, Project Director, Victorian Transport Association, March 2014.

approximately two years ago, causing a suspension of activities until new funding sources can be established.

EcoStation served as a comprehensive resource center for the freight industry to assist individual companies in maximizing their transport efficiencies and minimizing their environmental impact, and was based largely on the SmartWay Transport program. By becoming members of EcoStation, companies agreed to measure, reduce, and report their emissions to EcoStation. EcoStation provided the necessary tools (e.g., driver training and fleet assessment) and technical guidance to assist its members in quantifying and developing strategies to improve fuel use and reduce emissions. EcoStation's initiatives focused on reducing freight emissions across the entire supply chain and included driver training and education, alternative drivetrains and fuel types, improved tires and aerodynamics, improved auditing systems that allowed operators to test scenarios for changes to the fleet, changes to traffic infrastructure and road management, supply chain improvements, and bringing the industry together to share their knowledge on emissions reduction.

The pilot program for EcoStation was launched in September 2009 and involved 27 foundation partners. The program developed the key tools and services required to implement and quantify fuel efficiency measures suitable for the Victorian freight industry, including the Excel-based EcoStation Fleet Assessment Tool. The tool's baseline module calculates fuel efficiency and the GHG emissions of the given fleet, and the scenario module predicts changes in fuel efficiency and emissions based on specific interventions selected by the user. The interventions include fuel efficiency actions, changes to driving behavior and freight practices, alternative fuels, and alternative drivetrains. The pilot program also tested the EcoStation freight partnership process and options for a cost-effective and efficient service, and identified and selected key environmental performance and recognition indicators that are relevant to both freight customers and operators.

3.2.5 Green and Smart Transport Partnership (Korea)[63,64,65]

The Korea Energy Management Corporation (KEMCO) is the implementing agency for the Green and Smart Transport Partnership. The Partnership currently has 24 participating companies. KEMCO's goal is to enhance energy security and mitigate climate change by reducing national energy consumption and GHG emissions. The goals of its partners are to reduce fuel consumption, improve sustainable development, and better understand their freight practices.

The Green and Smart Transport Partnership is a voluntary program open to any company, and relies on a cooperative agreement between KEMCO and program partners. Upon joining the Green and Smart Transport Partnership, a partner analyzes its current status by assessing and

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[63] Korea Energy Management Corporation (2013). Green & Smart Transport Partnership. Retrieved from http://cleanairinitiative.org/portal/sites/default/files/presentations/PM-2-korea_2_-_GreenSmart_Partnership_CGFI.pdf

[64] Personal communication: Kyung Wan, Manager, Transportation Energy Team, Korea Energy Management Corporation, January 2014.

[65] Personal communication: Seong Woo Park, Korea Energy Management Corporation, June 27, 2013.

tracking fuel consumption and GHG emissions and assesses its freight operations. The program provides tools to help partners make these assessments. Once the initial baseline analysis is complete, the program helps partners identify improvement opportunities for fuel efficiency and system logistics, as well as support for technology improvements and potential financing sources for implementing the suggesting measures.

Once the improvement measures are implemented, each partner continues to measure and report its fuel consumption and emissions estimates, as well as the method of verification it used for these estimates. Information collected through the Partnership will be shared with other companies, developing a network for data sharing, best technology identification, and establishing best practices. Participation in the program allows partners to fully understand their freight operations and carbon footprints. Measures implemented through participation in the program include idle reduction, modal shifts, vehicle replacements, fuel switching, and aerodynamic modifications, among others.

KEMCO developed two baseline and monitoring methodologies for its partners to earn carbon credits. Some fuel-efficient equipment qualifies for loans offered by KEMCO (i.e., eco-drive systems and idle reduction systems). Partners that achieve outstanding performance win a prize from the government and are recognized at conferences sharing best practices among the partners. Green and Smart Transport continues to collaborate with other international programs such as U.S. SmartWay, the Green Freight Asia Network, the China Green Freight Initiative, and Green Freight Europe.

3.2.6 ECOSTARS Europe[66]

ECOSTARS Europe provides guidance and advice to operators of vehicle fleets in an effort to achieve more efficient and cleaner freight and passenger transport vehicle movements. ECOSTARS rates the environmental and energy savings performance of vehicles and operation practices for its recognition programs. ECOSTARS offers tailored support for its members, customizing suggestions for efficiency improvements. ECOSTARS standards are developed by a Europe-wide reference group. The goals of ECOSTARS Europe are:

- To increase the energy efficiency of freight distribution by giving recognition and publicity to transport operators using sustainable practices in their procurement and management processes.
- To encourage the faster introduction of vehicles using clean fuel technologies.
- To encourage the development of energy-efficient driving schemes and operational management practices.
- To promote the auditing and certification of freight operators using a Europe-wide approach to sustainable practices in freight operations.

[66] ECOSTARS (2014). ECOSTARS fleet recognition scheme. Retrieved from http://www.ecostars-europe.eu/en/.

3.2.7 Partnership on Sustainable Low Carbon Transport (SLoCaT)[67]

SLoCaT is a broad effort targeting sustainable transport as a whole, rather than focusing solely on freight movement. The Partnership was formed by the UN in 2009. It is a voluntary non-governmental partnership currently representing over 80 organizations including UN and bilateral development organizations, NGOs and foundations, academia, and the private sector. SLoCaT promotes the adoption of global sustainable transport policies. The partnership focuses on land transport in developing countries and includes freight and passenger transport. The initial focus of the program will be on Asia, Latin America, and Africa.

The primary goal of the partnership is to provide access to global support for reducing the growth of GHG emissions from land transport activities in developing countries by encouraging sustainable, low-carbon transport. The four primary goals of SLoCaT are:

- The integration of sustainable, low carbon transport in climate negotiations, as well as national and local climate policies and programs.
- The integration of climate considerations in regional, national, and local transport policies.
- The adoption of mainstream sustainable, low-carbon transport operations by international development organizations.
- Contributing to sustainable development, especially providing access to goods and services for lower-income groups.

3.3 Other Resources

3.3.1 Smart Freight Centre[68,69,70]

The Smart Freight Centre (SFC) promotes a global freight sector that is more environmentally sustainable and competitive by reducing emissions and improving fuel efficiency. SFC is a nonprofit organization registered in Amsterdam, the Netherlands. It was established in response to the growth in the global freight sector and to help overcome logistics/operational costs and reduce environmental impacts. SFC is collaborating with global shippers, logistics providers, freight forwarders, carriers, SmartWay, Green Freight Europe, Green Freight Asia, and other key initiatives to develop a recognized, strategic, global framework for action regarding sustainable growth and environmental responsibility. As a nonprofit organization with secure funding, SFC is uniquely positioned to serve as an independent bridge between industry, government, and other organizations establishing a global network across all stakeholder groups. Industry and other stakeholders will benefit from SFC efforts to harmonize emissions footprint methodologies, develop initiatives for regions/modes where there are gaps, and mobilize

[67] SLoCaT (2014). Partnership on Sustainable Low Carbon Transport. Retrieved from http://www.slocat.net/.
[68] Smart Freight Centre (2014). Smart Freight Centre. Retrieved from http://www.smartfreightcentre.org/.
[69] Personal communications: Sophie Punte, Executive Director, Smart Freight Centre, January–February 2014.
[70] Personal communications: Alan Lewis, Stakeholder Engagement Adviser, Smart Freight Centre, March–April 2014.

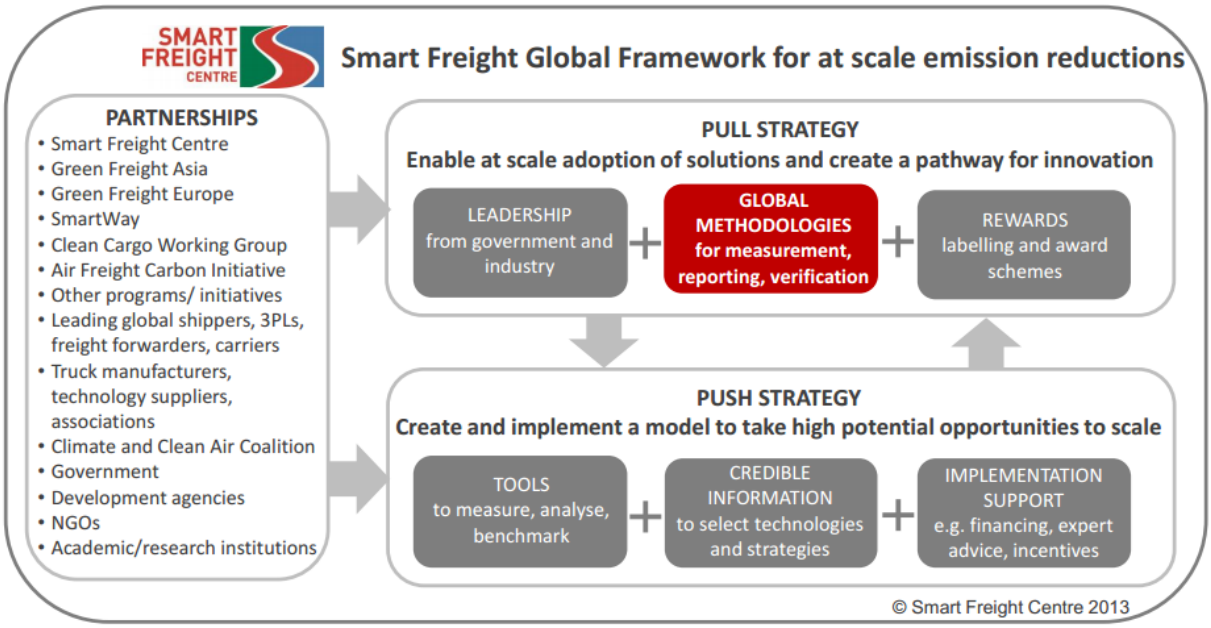
resources to priority areas. SFC is assembling an advisory group with representatives from key partners and stakeholder groups.

SFC's specific objectives include:

- Lead the development and deployment of a global framework for action.
- Lead the Global Logistics Emissions Council to align freight emissions methodologies and integrate these into initiatives globally (a "pull" strategy).
- Remove barriers to the uptake of high-potential measures across the freight sector (a "push" strategy).
- Strategically support industry-led initiatives (e.g., GFE and GFA), incubate new initiatives, and align with other stakeholders and initiatives.

SFC's generalized framework for action is presented in the figure below, which shows complementary "push" and "pull" strategies for implementation.

Figure 3-1. Global Framework for Action (Putting Methodologies into Context)



Smart Freight Centre

SFC has developed the following key approaches and preliminary timetable for taking green freight technologies and strategies to a global scale:

- Start with tires and telematics (rapid potential impact, supported by key players).
- Start with Asia (can be integrated into GFA's labeling program).
- 2014—with a group of first movers, select specific technologies, create the model, and agree on an implementation plan.
- 2015–2017—demonstrate and implement the model with the first movers.

- 2018 and beyond—implement the model across Asia and spread to other regions.

SFC is also collaborating with GFE to provide strategic support (e.g., regarding methodologies and labeling, financing mechanisms, technology scale-up, and links with other initiatives). SFC and GFE are meeting with leading GFE shipper members to present the business case for the program and obtain their commitment to include CO_2 from freight transport in their carrier and modal selection process.

Global Logistics Emissions Council

Hosted by the SFC, the Global Logistics Emissions Council (GLEC) is an industry-led/-backed initiative of leading shippers and companies involved in freight movement. The GLEC was established in 2013 to align industry and government green freight initiatives in order to achieve harmonized methodologies across the global multi-modal supply chain. Current members include a variety of industry and government initiatives such as GFA, GFE, SmartWay (via Edgar Blanco, MIT), CCWG, IATA/Air Cargo Carbon Footprint, EcoTransIT, Lean and Green, and NTM. Company members include DB Schenker, DHL, Kuehne-Nagel, Maersk, and TNT.

The GLEC's objectives include:

- A common industry vision statement regarding methodologies and broader green freight strategies.
- Globally harmonized methodologies (i.e., a Global Framework for Freight Emissions Methodologies) for measurement and reporting of emissions from freight movement applicable to all modes, nodes (warehousing, transfer points, etc.), and global regions within the transport supply chain.
- Alignment of industry-led/-backed initiatives across modes and global regions.
- Active engagement and communication with the entire global freight sector and other key stakeholders (e.g., government, scientific/research institutes, NGOs, development agencies), which includes positioning the work of the GLEC within a wider portfolio of programs aimed at increasing freight sector efficiency.

The focus of the GLEC at this time is the development of a Global Framework for Freight Emissions Methodologies that achieves widespread acceptance, followed by application to scale. The development of an industry vision statement helps place globally harmonized methodologies into the broader green freight context. Harmonization of methodologies can be expanded to other areas over time (e.g., labeling schemes, support to carriers). The Global Framework builds on existing methodologies and the outputs from the EU-funded COFRET project (see Section 3.3.3).

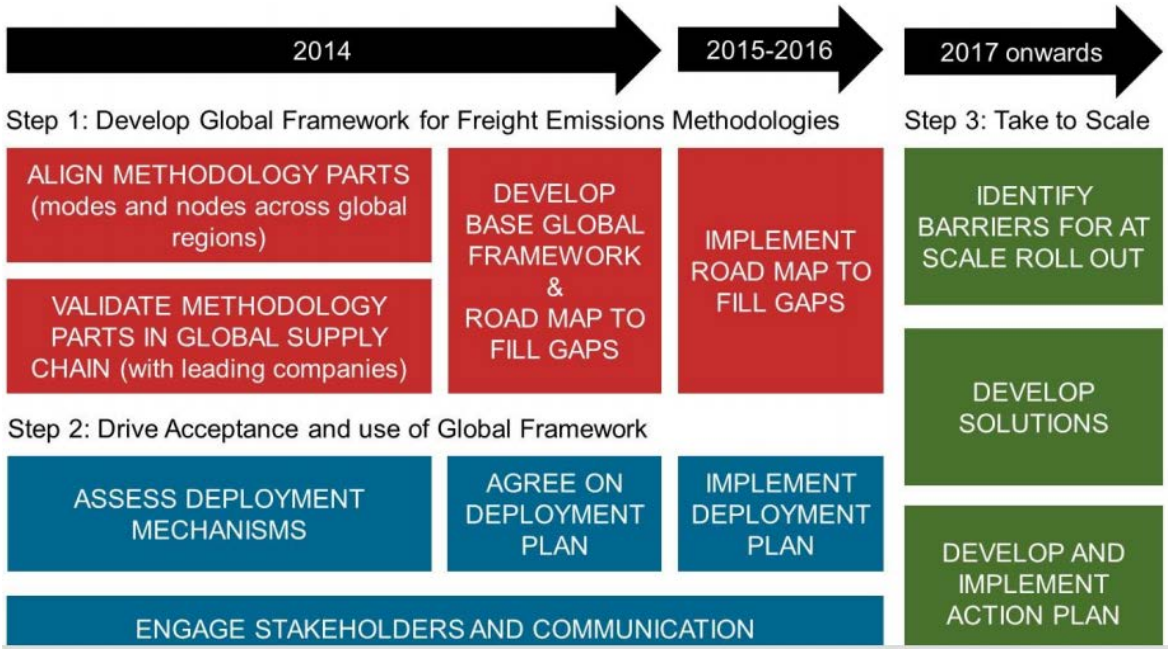
The planned timetable for the GLEC initiatives is as follows:

- Develop the Global Framework for Freight Emissions Methodologies for measurement and reporting of emissions across modes, nodes, and global regions (2014–2016).

- Drive the acceptance and use of the Global Framework by industry, government, and other players (e.g., through integration into tools; regional/national programs and labeling schemes; policies; possible standardization through GHG Protocol, ISO, or other) (2014–2016).
- Take the application of the Global Framework to scale across the global freight supply chain to generate and communicate credible emissions data to customers, consumers, and investors (2016 and beyond).
- Facilitate shipper and carrier incorporation of emissions into their decision-making on carrier selection, reporting (e.g., Carbon Disclosure Project), and selection and implementation of improvement measures.

The overall GLEC approach is summarized in the figure below.

Figure 3-2. GLEC Approach



Smart Freight Centre

The GLEC governance consists of the GLEC council itself, action groups, a secretariat hosted by the SFC, and participation of industry and other stakeholder groups. The action groups include:

- The Multi-Modal Action Group, tasked with developing a set of principles where alignment within and between modes is needed and feasible, and with pulling together the Global Framework and roadmap based on input from Modal Action Groups and the Validation Action Group.
- Modal Action Groups, which cover different modes (air, road/rail, inland waterways, maritime, and transshipment centers). Tasks include aligning the methodology/ies within the mode, identifying gaps and priorities, and developing a strategy to address gaps.

- The Supply Chain Application Group, which represents companies and operations across all modes, and covers developed and developing countries/regions. Its tasks are to apply and validate the Global Framework to a real case supply chain and provide feedback to the Multi-Modal and Modal Action Groups on what works, what does not work, and gaps and proposed solutions.

Shippers and companies involved with freight movement and industry associations can participate in three ways:

- As active participants in the GFEC and/or the action groups. New members must sign a commitment letter and undergo a briefing with the SFC to ensure that their participation will facilitate the process.
- Through consultation, where the leads of each action group make direct contact with companies to obtain ideas and input for the methodology, and send them draft outputs for review.
- As observers, especially for companies that do not have time but want to be kept informed about GFEC activities through regular updates.

The GLEC will consult and engage other stakeholders throughout the process, including standardization bodies, government, academic and research institutes, non-governmental organizations (NGOs), development banks, and development agencies. This engagement will ensure the Global Framework is credible and usable to all stakeholders.

3.3.2 European Standard EN 16258, "Methodology for Calculation and Declaration of Energy Consumption and GHG Emissions of Transport Services (Freight and Passengers)"

European Committee for Standardization (CEN) members are bound to comply with EN 16258, approved on November 8, 2012. CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, and the United Kingdom. The emission quantification protocols for the GFE and Lean and Green programs are based on and consistent with this standard.

The following description is from the introduction to the standard.

> This standard sets out the methodology and requirements for calculating and reporting energy consumption and greenhouse gas (GHG) emissions in transport services. This first edition of the standard is primarily focused on energy consumption and GHG emissions associated with vehicles (used on land, water and in the air) during the operational phase of the lifecycle. However, when calculating the energy consumption and emissions associated with vehicles, account is also taken of the energy consumption and emissions associated with energy processes for fuels and/or electricity used by vehicles (including for example production and distribution of transport fuels). This ensures the standard takes a

"well-to-wheel" approach when undertaking calculations, and when making declarations to transport service users.

The philosophy, contents, and structure adopted in this standard seek to make it widely applicable across the transport sector (encompassing all modes impartially) and accessible to a very diverse user group. Within this sector, it is recognized that transport operations vary hugely, from multi-national organizations operating multiple transport modes to deliver transport services across the globe, through to a small local operator delivering a simple service to one user. In addition, the potential user group for this standard is similarly diverse, and the monitoring of transport energy and emissions within organizations can be at different levels of maturity and sophistication. Consequently, this first edition of the standard balances the desire for absolute precision and scientific rigor with a degree of pragmatism in order to achieve ease of use, accessibility and encourage widespread use.

Use of this standard will provide a common approach and frameworks for the calculation and declaration of energy consumption and emissions for transport services irrespective of the level of complexity (e.g. a simple transport service can provide one customer with a single journey, whereas a complex system can involve several legs, multiple vehicle types, different transport modes and several companies within the transport supply chain). The standard ensures declarations have greater consistency and transparency, and that the energy and emissions are fully allocated to a vehicle's load (passengers and/or cargo).

It is anticipated that future editions of the standard will have broader quantification boundaries, to include additional aspects such as, transport terminals, trans-shipment activities, and other phases of the lifecycle. Users of the standard that would now like to use broader quantification boundaries, without waiting for a new edition of the standard are advised to communicate such results separately from the ones calculated according to this standard, and to give a transparent description of the methodology applied.

3.3.3 COFRET[71,72]

Begun in 2011 and funded by the European Commission, COFRET is a collaborative effort of consultants, universities, and other research institutions to provide industry, shippers, receivers, and logistics providers with information to reduce the uncertainty in calculating the carbon footprint for freight transport. Other greenhouse gases including methane and N_2O are also addressed. COFRET has reviewed the strengths and weaknesses of existing methodologies and tools for all modes and regions, as well as methodologies and tools under development, for stakeholders to estimate their carbon footprint. COFRET is also assessing existing tools' consistency with EN 16258 (see above), and attempting to address gaps/shortcomings in the EN standard itself for possible inclusion in future editions of the standard. While new tools and methods are not being developed, the research findings are collected and distributed through an information clearinghouse on the COFRET website.

COFRET's analysis takes the entire supply chain into consideration, and focuses on the need for industry to harmonize its approach and methodologies for estimating CO_2 emissions. Without

[71] COFRET (2014). Carbon Footprint of Freight Transport. Retrieved from http://www.cofret-project.eu/.
[72] Personal communication: Alan Lewis, Stakeholder Engagement Adviser, Smart Freight Centre, April 2014.

this alignment, it is impossible to compare across different modes and routings, direct comparisons cannot be made between providers, there can be no comparisons over time, calculation of impacts for supply chains with multiple layers is difficult, and comparisons across supply chains cannot be assessed.

The following COFRET deliverables have been approved by the European Commission and are available for download:

- COFRET Deliverable 2.1, "Existing Methods and Tools for Calculation of Carbon Footprint of Transport and Logistics."
- COFRET Deliverable 2.2, "User Needs, Practices and Experiences in the Context of Carbon Footprint Calculations in Supply Chain Configurations."
- COFRET Deliverable 2.3, "Future Technologies and Innovations Relating to Freight Transport Which Are Relevant for Carbon Footprint Calculation."
- COFRET Deliverable 2.4, "Methodologies for Emission Calculations—Best Practices, Implications and Future Needs."

A report evaluating the effectiveness of EN 16258 and its applicability to the current freight industry is also near publication, as is a comparison of the EN standard with other ISO and GHG calculation protocols.

COFRET activities are scheduled to continue through May of 2014, although a six month extension may be granted. The COFRET website/information clearinghouse will be maintained after completion of other research activities.

3.3.4 Geospatial Intermodal Freight Transportation (GIFT) Model[73]

The GIFT model was developed by the University of Delaware in collaboration with the Rochester Institute of Technology to help policy makers understand the environmental, economic, and energy impacts of various intermodal freight transportation modes. GIFT uses transportation modes (highway, railway, waterway) connected by intermodal terminals (ports, rail yards, truck terminals). Routes along the network are characterized not only by temporal and distance attributes, but also by cost, energy, and emissions attributes (including emissions of CO_2, PM, SO_2, VOCs, and NO_x). Decision-makers can use the model to explore tradeoffs among alternative route selection across different modal combinations, and to identify optimal routes for objectives that feature energy and environmental parameters (e.g., minimize CO_2 emissions).

[73] Winebrake, J.J., J.J. Corbett, A. Falzarano, J.S. Hawker, K. Korfmacher, S. Ketha, and S. Zilora (2008). Assessing energy, environmental, and economic tradeoffs in intermodal freight transportation. *Journal of the Air Waste Management Association* 58(8): 1004–1013. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/18720650.

3.3.5 Network for Transport and Environment (NTM)[74]

The NTM is a nonprofit organization founded in 1993. The NTM has worked to establish a common methodology for calculating emissions, natural resource consumption, and other effects of freight and passenger transport. The methodology was developed so that shippers can evaluate the environmental impact of their freight movement. The NTM provides a standard calculation method linking to relevant environmental data, and offers a suite of tools for supplier evaluation.

3.3.6 South Australian Freight Council (SAFC)[75]

The SAFC was formed in 2002 with the merger of the South Australian Freight Council for Sea Cargo and the South Australian Air Freight Export Council. The SAFC was expanded in 2003 with the merger of the South Australian Land Freight Export Council into the association. These mergers allowed the combined council to offer truly multi-modal industry representation to government, and to work on projects that enhance the effectiveness and competitiveness of all sectors along the full logistics supply chain.

The SAFC has approximately 100 member organizations representing over 10,000 individual companies. It focuses on identifying key freight logistics issues for South Australia, and developing solutions. Its membership is composed of all industry sectors along the supply chain (road, rail, sea, air, and storage, and the interaction between these modes), ranging from buyers to users of freight to freight service providers and government. The SAFC's primary goals are:

- To promote the welfare and development of the freight and logistics industry in South Australia, including the movement of goods to urban, intrastate, interstate, and overseas markets across all modes of transport.
- To facilitate improved efficiency and integration of freight transport improvements throughout the freight logistics chain.
- To focus on "common interest" issues and identify solutions for the benefit of the Association and South Australia.
- To identify constraints on competitive freight transport, generate innovative solutions, and make recommendations to government and industry on their implementation.
- To provide a forum for the exchange of views within industry and between industry and government on matters affecting the efficiency of freight logistics.
- To offer practical "strategic" advice to government.

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[74] NTM (2014). General methods and data; detailed methods and data. Retrieved from http://www.ntmcalc.org/index.html.

[75] SAFC (2014). About SAFC. Retrieved from http://www.safreightcouncil.com.au/aboutus.asp.

3.4 Freight Supply Chain Carbon Accounting and Reporting

The emergence and growth of the green freight programs described above—and of many others around the world—coincides with a growing customer demand for supply chain carbon accounting and reporting. In addition to complying with regulations targeting PM, NO_x, and fuel economy, more and more the global freight industry is being asked to define its contribution to customer carbon footprints and climate risk. Reporting CO_2 emissions ("carbon reporting") is becoming commonplace for various industry sectors around the globe, often driven by customer interest in product and service sustainability. Overall, indirect emissions, of which transportation is a major contributor, can represent as much as 86 percent of a company's total emissions.[76] As a result, corporate customers, shareholders, lenders, and insurers are increasingly demanding greener freight options to complement their overall corporate social responsibility (CSR) initiatives. CSR initiatives often include carbon reporting goals through nonprofit organizations like the Carbon Disclosure Project, which provides a platform for organizations to report their carbon performance. These organizations assist corporations seeking to understand the sources of their greenhouse gas emissions and decrease emissions through both operations and supply chain management, including a freight transportation component.

GHG Protocol Emissions Scope

When businesses and organizations report their greenhouse gas emissions for the Greenhouse Gas Reporting Protocol, they account for both their *direct emissions* (Scope 1 emissions) and *indirect emissions* (Scope 2 and 3 emissions). Scope 1 emissions are direct emissions from company-owned or company-controlled sources. Scope 2 emissions are indirect emissions from the generation of purchased energy, and Scope 3 emissions are all indirect emissions that occur in the company's value chain. When an organization hires a freight transport company to move its products, those transport emissions contribute to that organization's Scope 3 emissions.

To fulfill the reporting requirements of their sustainability initiatives, freight customers need to quantify the environmental impact of their freight. The 2012 CDP Supply Chain Report indicates that 39 percent of reporting supply chain member companies will begin deselecting suppliers that do not adopt good carbon-management practices. So, as awareness of climate change issues continues to increase worldwide among investors and consumers, reducing supply chain carbon emissions through efficient freight choices is becoming an economic imperative.[77] To this end, the accurate and verifiable carbon footprint quantification provided by green freight programs can provide a strong complement to larger carbon accounting goals.

Many of today's multinational firms and global suppliers are also interested in green freight programs in particular, especially if they build in standardized carbon reporting requirements. Multinational firms like Wal-Mart and IKEA that have global operations need to coordinate freight logistics in multiple countries to get products delivered from factory to customer in the most fuel efficient manner possible. Not only are they seeking to reduce costs, but they are

[76] Mathews, H S., C.T. Hendrickson, and C.L. Weber (2008). The importance of carbon footprint estimation boundaries. *Environmental Science and Technology* 42: 5839–5842. Cited in Carbon Disclosure Project (2012). *CDP Supply Chain Report 2012: A New Era: Supplier Management in the Low-Carbon Economy.* Retrieved from https://www.cdp.net/CDPResults/CDP-Supply-Chain-Report-2012.pdf.

[77] Carbon Disclosure Project (2012). *CDP Supply Chain Report 2012: A New Era: Supplier Management in the Low-Carbon Economy.* Retrieved from https://www.cdp.net/CDPResults/CDP-Supply-Chain-Report-2012.pdf.

driving the demand for tools to accurately measure and reduce their carbon footprint throughout their entire supply and delivery chains worldwide.

Customers, clients, and shareholders are increasingly demanding transparency, accountability, and disclosure. Supply chain sustainability efforts create real business value through new products and services, premium pricing opportunities, and enhanced corporate reputations. Because carbon is a leading indicator of operational efficiency, addressing carbon reduces operating costs, improves a company's ability to compete globally, and reduces climate and supply chain risk. For example, the Carbon Disclosure Project findings from 2013 reported that 90 percent of members report business risks from climate change and 73 percent of members report cost savings from emission reduction activities.

Making carbon footprint information publicly available, as the Carbon Disclosure Project, the Global Reporting Initiative, and a number of green freight programs do, can inspire a general movement toward sustainable operations. However, market-based green freight programs have the potential to do more by strongly incentivizing continual carbon performance improvements among their participants.

Additionally, many corporations are responding to internal and external pressures to adopt CSR goals and initiatives. Driven by a recognition of corporations' influence on such global issues as human rights, labor practices, climate change, economic development and poverty, more and more stakeholders (e.g., shareholders, employees, customers, nonprofit and advocacy organizations, local communities) are holding corporations accountable for their actions, meeting best practices, and submitting to third-party inspections and oversight. Participating in a green freight program responds to many CSR concerns and can be a centerpiece in a corporation's efforts to become a more responsible corporate citizen.

4.0 Freight Vehicles and Operation Practices

4.1 Trucking (Vehicles and Operational Practices)

This chapter provides an overview of diesel truck characteristics and describes how these characteristics influence the technologies and operational strategies that can be applied to the different types of truck fleets. As reduction of black carbon is a primary focus of the Green Freight Action Plan, this discussion is limited to trucks that are diesel-fueled.

4.1.1 Truck Classification

Diesel truck fleets can be classified in a number of ways, and classification of trucks varies among countries and regions. In the United States, diesel trucks are classified by vehicle weight group, as described later in this chapter. In Canada, classifications vary among provinces, based on a number of factors such as size, weight, economic activity, and physical environment; several Canadian provinces use the U.S. Federal Highway Administration's (FHWA's) weight classification system, also described below.[78] Licensing in the European Union is based on gross vehicle and trailer weight ratings. The U.S. and EU truck classification schemes, and associated emission standards, are commonly adopted by other countries. Restrictions are also applied based on vehicle and trailer length, as well as allowable payloads, which can be more variable from country to country. Therefore, regional plans for targeting certain fleets need to consider local truck classification standards and dimensional specifications. The most common methods used to classify freight trucks are summarized below, along with general information on technologies and operational strategies applicable to the various truck types and applications.

In the United States, commercial truck classification is based the vehicle's gross vehicle weight rating (GVWR), with trucks falling into one of eight weight classes. The FHWA uses the same GVWR splits, but assigns weight classification more broadly in one of three categories: light duty, medium duty, and heavy duty. The FHWA further classifies vehicles based on whether they carry passengers or commodities, and non-passenger vehicles are further subdivided into groups according to the number of axles and number of units, including both power and trailer units.[79] The EPA weight class categories used for emission standard certification and modeling are very similar to U.S. FHWA weight classes. The various weight classifications used in the United States are shown in Figure 4-1.

[78] http://ops.fhwa.dot.gov/Freight/sw/index.htm
[79] http://www.fhwa.dot.gov/policy/ohpi/vehclass.htm

Figure 4-1. Weight Classifications Used in the United States

Gross Vehicle Weight Rating (lbs)	Federal Highway Administration		US Census Bureau
	Vehicle Class	GVWR Catagory	VIUS Classes
<6,000	Class 1: <6,000 lbs	Light Duty <10,000 lbs	Light Duty <10,000 lbs
10,000	Class 2: 6,001–10,000lbs		
14,000	Class 3: 10,001–14,000 lbs	Medium Duty 10,001–26,000 lbs	Medium Duty 10,001–19,500 lbs
16,000	Class 4: 14,001–16,000 lbs		
19,500	Class 5: 16,001–19,500 lbs		
26,000	Class 6: 19,501–26,000 lbs		Light Heavy Duty: 19,001–26,000 lbs
33,000	Class 7: 26,001–33,000 lbs	Heavy Duty >26,001 lbs	Heavy Duty >26,001 lbs
>33,000	Class 8: >33,001 lbs		

Gross Vehicle Weight Rating (lbs)	EPA Emissions Classification			
	Heavy Duty Vehicle and Engines			Light Duty Vehicles
	H.D. Trucks	H.D. Engines	General Trucks	Passenger Vehicles
<6,000 6,000	Light Duty Truck 1 & 2 <6,000 lbs	Light Light Duty Trucks <6,000 lbs	Light Duty Trucks < 8500 lbs	Light Duty Vehicle < 8500 lbs
8,500	Light Duty Truck 3 & 4 6,001–8,500 lbs	Heavy Light Duty Trucks 6,001-8,500 lbs		
10,000	Heavy Duty Vehicle 2b 8,501–10,000 lbs	Light Heavy Duty Engines 8,501 lbs–19,500 lbs	Heavy Duty Vehicle Heavy Duty Engine >8,500 lbs	Medium Duty Passenger Vehicle 8,501–10,000 lbs
14,000	Heavy Duty Vehicle 3 10,001–14,000 lbs			
16,000	Heavy Duty Vehicle 4 14,001–16,000 lbs			
19,500	Heavy Duty Vehicle 5 16,001–19,500 lbs			
26,000	Heavy Duty Vehicle 6 19,501–26,000 lbs	Medium Heavy Duty Engines 19,501–33,000 lbs		
33,000	Heavy Duty Vehicle 7 26,001–33,000 lbs			
60,000	Heavy Duty Vehicle 8a 33,001–60,000 lbs	Heavy Heavy Duty Engines Urban Bus >33,001		
>60,000	Heavy Duty Vehicle 8b >60,001			

U.S. Department of Energy

In Europe, a similar system is used to classify vehicles based on weight. Self-propelled vehicles with at least four wheels used specifically for carrying goods fall into Category N, with the following subcategories:

- N1—vehicles for carrying goods with a maximum mass less than or equal to 3.5 tonnes.
- N2—vehicles for carrying goods with a maximum mass greater than 3.5 tonnes but less than 12 tonnes.
- N3—vehicles for carrying goods with a maximum mass greater than 12 tonnes.

(Emission standards for European vehicles, as well as those for other countries, are listed in Chapter 2, Table 2-6 and Table 2-7.)

4.1.2 Global Freight Truck Market

Roadways serve as the predominant mode of freight transportation in most regions of the world. As such, roadway tonne-km hauled estimates provide a good indicator of the overall size of a country's total freight transportation market. Table 4-1 provides an indication of the intensity of road freight transportation for 66 selected countries, ranked in terms of absolute tonne-km hauled per year in 2009.[80] The table shows China clearly outdistancing all other countries on the list. In addition, China, India, and the United States are responsible for almost two thirds of the tonne-km hauled for the selected countries.

Table 4-2 presents the change in tonne-km hauled over the 2000-2009 period for many of these same countries. This table shows that in addition to China, road freight volumes have increased dramatically over the previous decade in many Central Asian and Eastern European nations, while many North American and Western European nations have experienced relatively low or even negative growth rates.

The next table, Table 4-3, provides an approximate snapshot of the world's heavy-duty fleet population in 2010 and its projected size in 2030. In some areas, such as the Middle East, India, and South Korea, the heavy-duty fleet is expected to more than double in this 20-year period. However, all areas are expected to see an increase in the fleet size (except Japan, where a 6 percent decline is projected).

[80] http://data.worldbank.org/indicator/IS.ROD.GOOD.MT.K6

Table 4-1. Annual Roadway Tonne-km Hauled, Selected Countries, 2009

Country	2009
China	3,718,882
United States	1,929,201
India	1,005,200
Germany	415,600
Japan	334,667
Spain	286,167
France	276,000
Mexico	211,600
Poland	191,484
Australia	183,437
Russian Federation	180,135
Turkey	176,455
Italy	167,627
Pakistan	145,303
South Asia	145,303
United Kingdom	125,177
Canada	118,903
Netherlands	72,675
Kazakhstan	66,254
Colombia	65,688
Czech Republic	44,955
Belgium	43,591
Hungary	35,373
Portugal	35,356
Sweden	35,000
Romania	34,265
Ukraine	33,193
Vietnam	31,587
Greece	28,585
Slovak Republic	27,484
Finland	25,200
Uzbekistan	23,200
Lithuania	17,757

Country	2009
Switzerland	16,734
New Zealand	16,509
Austria	16,276
Norway	16,109
Slovenia	14,762
Bulgaria	13,871
Belarus	13,512
Ireland	12,071
Azerbaijan	10,634
Denmark	10,003
Croatia	9,429
Luxembourg	8,400
Latvia	8,115
Afghanistan	6,575
Estonia	6,290
Albania	4,400
Macedonia, FYR	4,035
Moldova	2,674
Cuba	2,315
Bosnia and Herzegovina	1,712
Algeria	1,512
Kyrgyz Republic	1,256
Mongolia	1,161
Cyprus	944
Iceland	810
Morocco	800
Georgia	611
Serbia	418
Liechtenstein	300
Lao PDR	296
Armenia	182
Montenegro	179
Myanmar	4

Table 4-2. Growth in Roadway Tonne-km Hauled, 2000–2009

Country	% Increase
Uzbekistan	1,833%
Russian Federation	673%
China	507%
Bosnia and Herzegovina	471%
Macedonia, FYR	420%
Armenia	355%
Bulgaria	236%
Azerbaijan	203%
Slovenia	181%
Belarus	169%
Moldova	167%
Hungary	165%
Poland	155%
Colombia	142%
Romania	140%
Lithuania	129%
Spain	115%
Albania	100%
Myanmar	100%
Slovak Republic	92%
Latvia	69%
Croatia	62%
Netherlands	59%

Country	% Increase
Greece	56%
Australia	38%
Belgium	34%
Norway	29%
Georgia	29%
Portugal	28%
Germany	20%
Czech Republic	15%
Cuba	14%
United States	11%
Mexico	9%
Sweden	8%
Japan	7%
Kyrgyz Republic	5%
France	4%
Serbia	-1%
Ireland	-2%
Austria	-5%
Finland	-8%
Denmark	-9%
Italy	-9%
United Kingdom	-17%
Mongolia	-22%

Table 4-3. World Heavy-Duty Fleet Estimates (Millions of Vehicles)[81]

Country	2010	2030 Projected	% Increase
Canada	3	4	33%
U.S.	12	15	25%
Mexico	3	5	67%
Brazil	2	3	50%
Latin America (excluding Brazil)	8	14	75%
EU-27	35	41	17%
Non-EU	6	8	33%
Africa	10	15	50%
Middle East	7	17	143%
India	5	19	280%
Australia	3	4	33%
China	17	32	88%
Russia	6	7	17%
Japan	17	16	-6%
South Korea	5	11	120%

[81] International Council on Clean Transportation. 2013. *European Vehicle Market Statistics: Pocketbook 2013.* Retrieved from http://eupocketbook.theicct.org/.

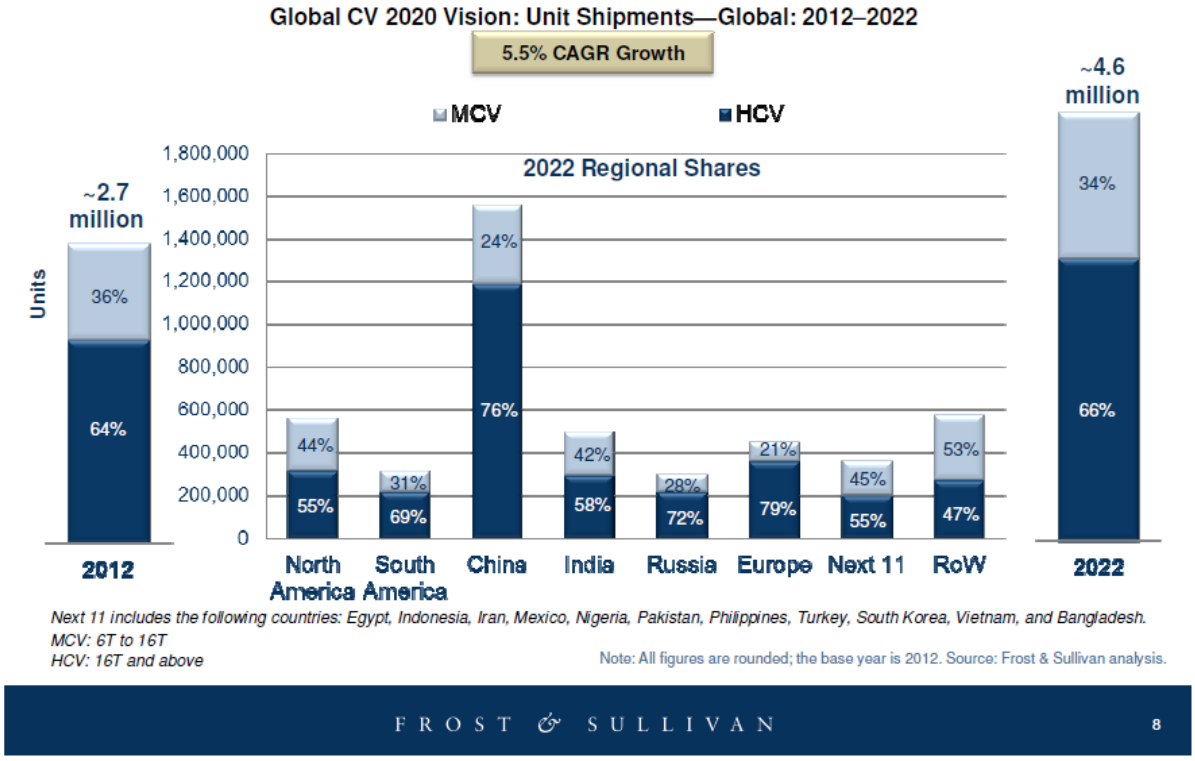
Country	2010	2030 Projected	% Increase
Total	139	211	52%

Frost and Sullivan has conducted a more detailed evaluation of the global growth prospects for the medium and heavy commercial vehicle (MCV and HCV) fleet through 2022. The figures below provide a snapshot of their most recent analyses and highlight growth trends for specific regions and countries, as well as advanced technologies in the MCV and HCV fleets.

Figure 4-2 below provides vehicle unit estimates for MCV and HCV fleets from 2012 through 2022 for various regions. In terms of the absolute number of freight trucks added to the global fleet, Chinese growth far outpaces any other region in this analysis.

Figure 4-2. Global Medium and Heavy Truck Market Forecast

Despite short-term global headwinds, stabilizing BRIC markets and rising Next 11 and African markets to elevate global MCV and HCV sales to 4.7 million by 2022



BRIC: Brazil, Russia, India, and China
CAGR: compound annual growth rate
CV: commercial vehicle
HCV: heavy commercial vehicle
MCV: medium commercial vehicle
RoW: rest of world

Figure 4-3 provides country-specific estimates for Africa. Unlike the regions presented in the previous figure, Africa is expected to see fleet growth focusing on medium rather than heavy-duty trucks. Note that these countries are often difficult to obtain data for, so this information

may be of particular interest to stakeholders considering the viability of Green Freight initiatives on the African continent.

Figure 4-3. African Medium and Heavy Truck Market Forecast

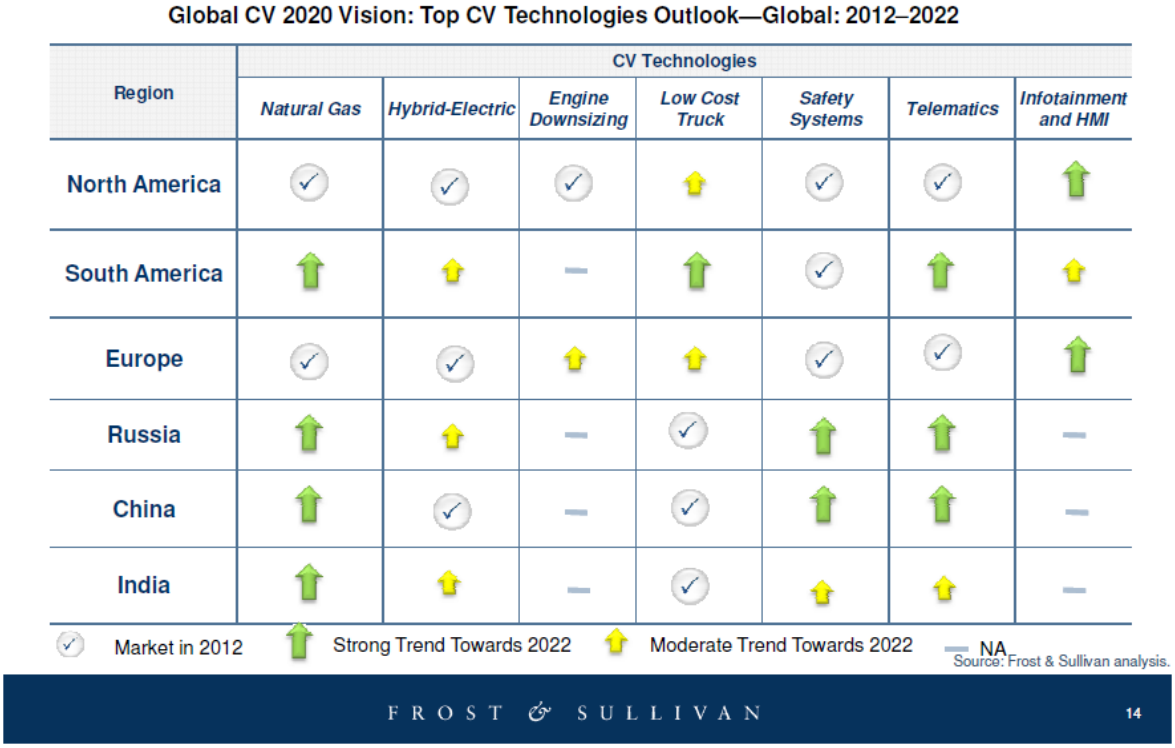
South African, Algeria, and Nigeria to lead African truck market; low-cost product line, CKD assembly, and after-sales support are key entry strategies for OEMs

CKD: completely knocked down
OEM: original equipment manufacturer
CV: commercial vehicle
HCV: heavy commercial vehicle
MCV: medium commercial vehicle

Figure 4-4 highlights anticipated technology adaptations for the global commercial trucking fleet, by major region. It provides a matrix of popular commercial vehicle technologies along with projections for their expected implementation. The developing markets represented (South America, Russia, China, and India) offer the greatest opportunity for substantial technology uptake, with significant developments expected in natural gas and telematics in particular.

Figure 4-4. Top Commercial Vehicle Technologies—Global Outlook

OEMs to increasingly focus on advanced powertrain, safety, telematics, and cabin systems for diversified leadership across segments and geographies



CV: commercial vehicle
NA: not applicable
OEM: original equipment manufacturer

Highlights from the Frost & Sullivan analysis[82] include:

- Global MVC truck sales are expected to increase by 70 percent between 2012 and 2022.
- BRIC, "Next 11," Africa, and rest-of-world countries are expected to account for 75 percent of truck sales growth volume during this period, providing prime opportunities for penetration of new technologies and emission controls in developing markets.
- Sales of alternative technology OEM vehicles (CNG/LNG and hybrid electric trucks) will reach half a million by 2022.
- Global natural gas penetration is projected to reach 8.5 percent by 2022.

4.1.3 In-Use Operating Characteristics

Average fuel economy and carbon efficiency values for freight trucks operating in selected countries are provided in Table 4-4 below. The fuel economy values are highly dependent upon

[82] For more information on the global truck industry outlook from Frost & Sullivan, contact Jeannette Garcia, Corporate Communications, at jeannette.garcia@frost.com or 210-477-8427.

local operating conditions such as topography and traffic congestion. On the other hand, the carbon performance metric, expressed in grams of CO_2 per tonne-kilometer, can provide a more useful efficiency comparison as it is tied to actual freight delivered rather than distance travelled. For example, higher allowable payloads in China result in relatively more efficient grams of CO_2 per tonne-kilometer values than might be expected based on the Chinese fleet's fuel economy value alone.

Table 4-4. Average Fuel Economy and Carbon Performance for Selected Countries[83]

Country	Fuel Economy (l/100 km)	Carbon Performance (g CO_2/Tonne-km)	Average Payload (Tonnes)
EU	32	32	26
U.S.	33	41	21
Japan	23	43	14
China	47	36	34

The following provides a more in-depth profile of heavy-duty diesel truck operating characteristics used for freight transport in the United States and Canada, supplemented by data sources from other regions where available. Much of the efficiency and performance data presented below came from the SmartWay program, illustrating the ability of green freight programs to collect and evaluate high-quality operational data across the freight sector.

Typically, heavy trucks fall into the equivalent of U.S. FHWA weight classes 6 through 8. Class 6 trucks commonly include school buses, beverage trucks, bucket trucks, package delivery trucks, and others, with payloads typically falling between 2 and 5 tons.[84] Class 7 trucks may include moving vans, dump trucks, city buses, tankers, tractor-trailers, and others, with payloads typically falling between 4 and 8 tons.[85] Class 8 trucks are generally over-the-road trucks used for freight transport, with class 8A trucks typically being used for local or regional transport and Class 8B trucks generally used for long-haul transport. Class 8 trucks in EPA's SmartWay program typically have fuel economies ranging from about 5 to 8 miles per gallon.[86] Generally, because of their size and power requirements, class 6, 7, and 8 trucks are powered by compression ignition (diesel-fueled) engines.

Examples of class 6, 7, and 8 trucks are shown in Figure 4-5, Figure 4-6, and Figure 4-7.

[83] Personal communication: Manfred Schuckert, Business Environment and Corporate Regulatory Strategy, Daimler AG, May 30, 2013.
[84] http://www.epa.gov/smartway/tips/tips-12.htm (chart 2)
[85] http://www.epa.gov/smartway/tips/tips-12.htm (chart 3)
[86] http://www.epa.gov/smartway/tips/tips-17.htm (charts 1 and 2)

Figure 4-5. Class 6 Single-Unit Truck

Mr. Choppers/Wikimedia Commons; CC BY-SA 3.0

Figure 4-6. Class 7 Dump Truck

Ky MacPherson/Wikimedia Commons; CC BY-SA 3.0

Figure 4-7. Class 8 Combination Cab-Over Tractor-Trailer

111 Emergency/Wikimedia Commons; CC BY 2.0

Combination tractor trailers typically can benefit from the addition of aerodynamic retrofits, such as skirts and fairings. However, advances in retrofits for single-unit trucks have lagged behind those for combination trucks, likely a result of the lower speeds, lower annual mileage, and typical stop/go service which is more common for single-unit trucks.[87] SmartWay verifies some low-rolling-resistance tires when used on combination trucks (class 8 line-haul tractor trailers).[88] Idle reduction strategies can be applied to either single-unit trucks or combination trucks, depending on the type of operation, but specific idle reduction technologies are typically best suited to specific types of truck operation. For example, truck stops with sleeper cab climate control or tractor electrification pertain primarily to over-the-road combination truck operation, while automatic engine shutdown/startup systems might best apply to single-unit trucks used for local delivery service or combination trucks used for local operations, such as drayage operations.

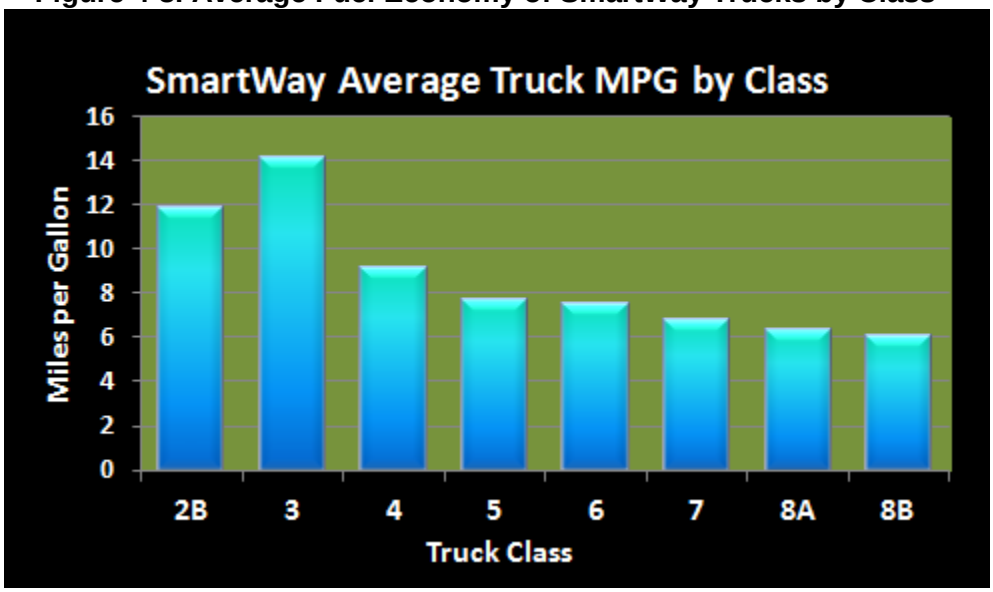
[87] U.S. Environmental Protection Agency (2002). *Industry Options for Improving Ground Freight Fuel Efficiency*. p. 35.

[88] http://www.epa.gov/smartway/forpartners/documents/verified/420f12024.pdf

Driveline efficiency improvements and exhaust after-treatment retrofits can be applied to either single-unit trucks or combination tractor trailers, depending on the engine's year, control technology, and fuel used, as described in Section 4.2.

Figure 4-8 shows the average fuel economy of class 2B through class 8B trucks in EPA's SmartWay program, and Figure 4-9 shows the average fuel economy of SmartWay trucks by operational category. As expected, miles per gallon values generally decrease with increasing truck weight.

Figure 4-8. Average Fuel Economy of SmartWay Trucks by Class[89]



[89] http://www.epa.gov/smartway/tips/tips-17.htm (chart 3)

Figure 4-9. Average Fuel Economy of SmartWay Trucks by Operational Category[90]

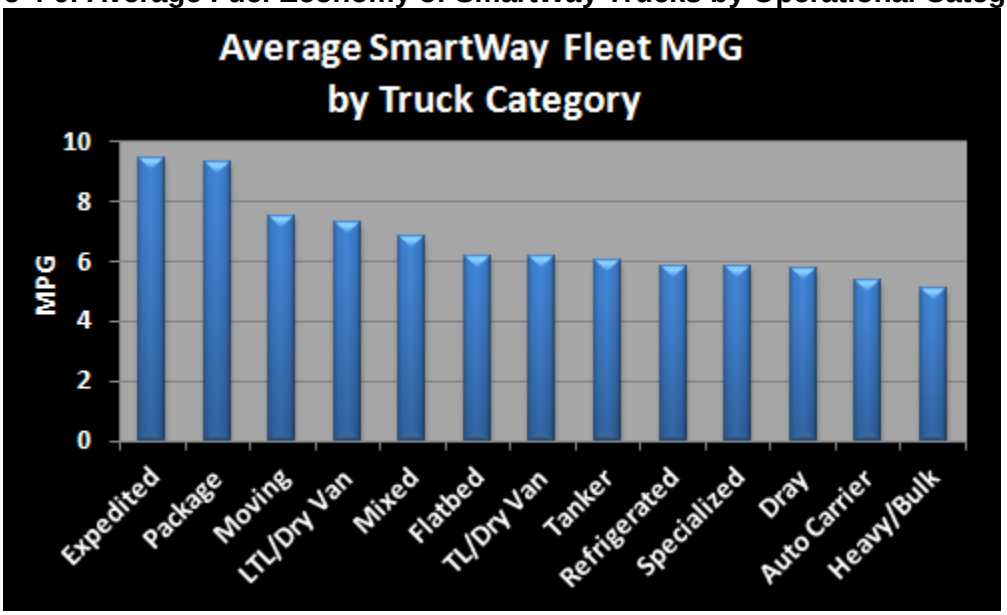
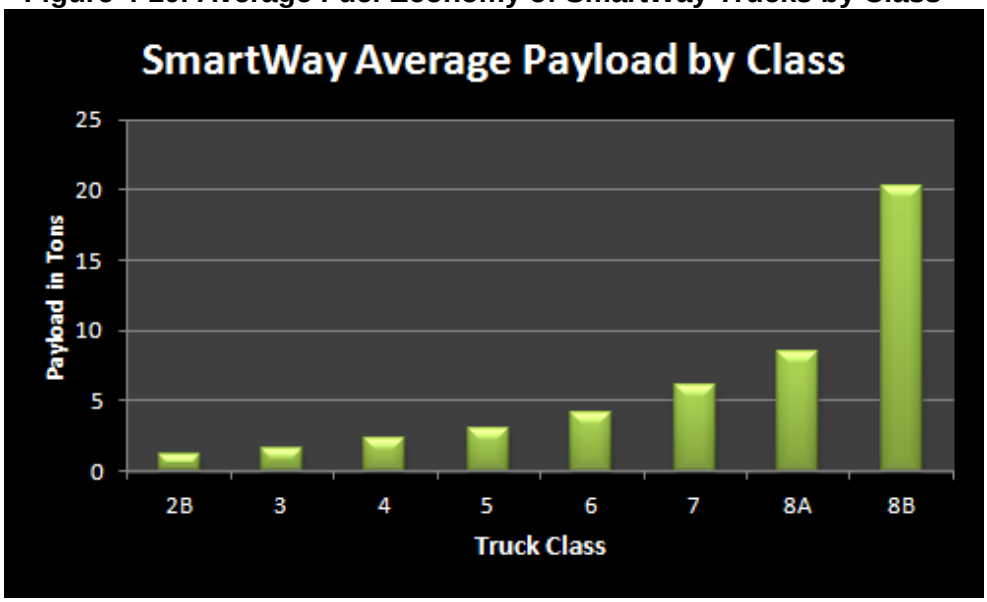


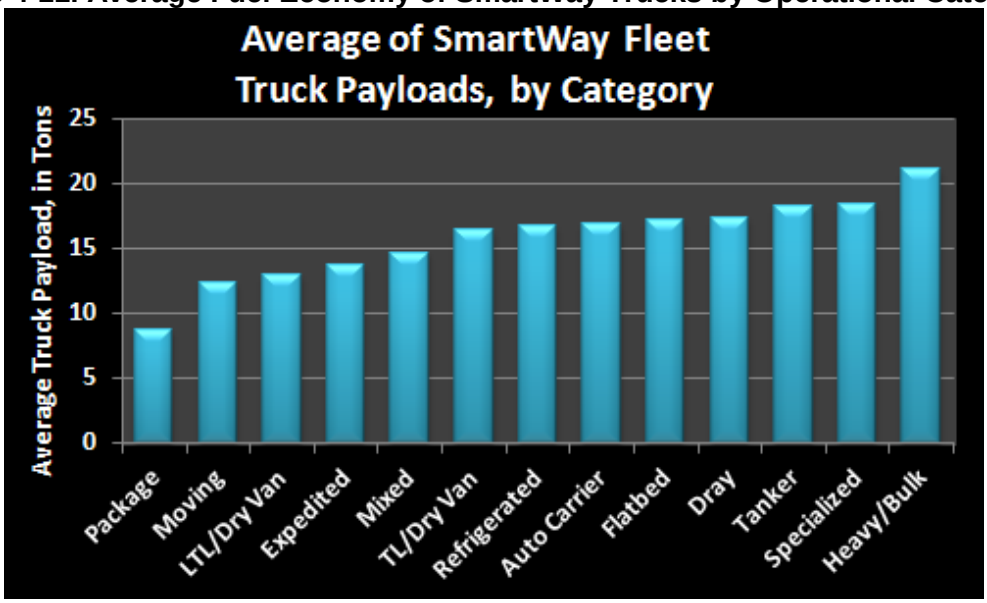
Figure 4-10 shows the average payloads (excluding vehicle weight and empty backhaul) of class 2B through class 8B trucks in the EPA's SmartWay program, and Figure 4-11 shows the average payload (again, excluding vehicle weight and empty backhauls) of SmartWay trucks by operational category.

Figure 4-10. Average Fuel Economy of SmartWay Trucks by Class[91]



[90] http://www.epa.gov/smartway/tips/tips5-b.htm
[91] http://www.epa.gov/smartway/tips/tips3-a.htm

Figure 4-11. Average Fuel Economy of SmartWay Trucks by Operational Category[92]



A report from the European Automobile Manufacturers' Association[93] provides average payload data from 2009 for 21 EU countries, with values ranging from approximately 18 tonnes in Sweden down to 10 tonnes in the United Kingdom. The average payload values for the other three top EU countries in terms of light commercial vehicle registration were 16 tonnes for Spain, 13.8 tonnes for Germany, and 13.5 tonnes for France. However, average payloads can be much higher in developing countries—as shown in Table 4-4 above, typical payloads in China are more than 10 tons higher than in the United States, for example.

The amount of empty backhauls for a given fleet can have a significant impact on fuel consumption and overall system efficiency. To the extent that empty backhauls can be minimized, efficiency will improve. However, certain commodities do not lend themselves readily to easy backhauls—for example, tanker and livestock fleets usually deliver their cargo to locations that do not provide easy access to a return load. For these reasons, empty backhaul fractions should be assessed based on freight commodity and/or associated truck body and service type.

Figure 4-12 shows the average percent of empty miles traveled for SmartWay trucks by operational category. The overall averages of SmartWay fleet empty vs. non-empty miles are 16.4 and 83.6 percent, respectively.[94] Empty miles traveled estimates vary dramatically across operational categories, as expected.

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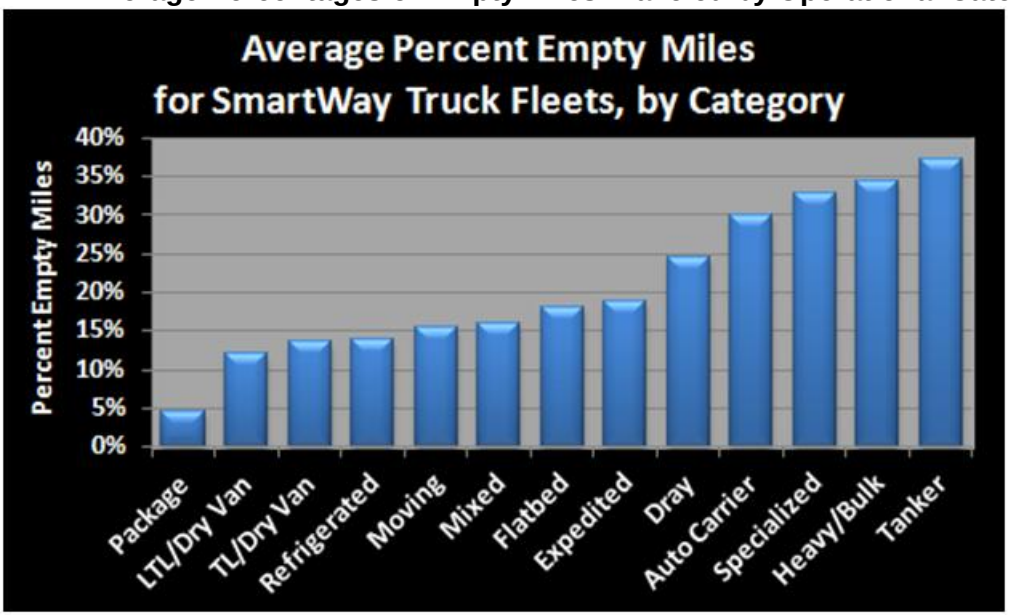
[92] http://www.epa.gov/smartway/tips/tips-12.htm (chart 1)

[93] McKinnon, A. (2010). *European Freight Statistics: Limitations, Misinterpretations and Aspirations*. Retrieved from http://www.acea.be/uploads/publications/SAG_15_European_Freight_Transport_Statistics.pdf.

[94] http://www.epa.gov/smartway/tips/tips10-b.htm

Figure 4-12. Average Percentages of Empty Miles Traveled by Operational Category[95]



The Instituto de Energia e Medio Ambiente has developed similar estimates of empty backhaul rates by truck service category, as shown below. Although the service categories do not match precisely between the SmartWay and Brazilian data, similar percentages and ranges are evident across categories:

Table 4-5. Empty Backhaul Rates by Truck Service Category, Brazil, 2013

Bulk hauler	22%
Reefer	23%
Auto carrier	32%
Chemical tanker	39%
Dry van	26%
Beverage	22%
Livestock	48%
LTL	19%
Miscellaneous cargo	19%

The ACEA report cited above also provides empty backhaul estimates for 23 EU nations, with fleet average values ranging from approximately 38 percent for Ireland down to 13 percent for Latvia. The values for the four top EU countries in light commercial vehicle registration are 27 percent for Spain, 25.5 percent for France, 22 percent for the United Kingdom, and 20 percent for Germany.

4.1.4 Truck Configurations

The configuration of tractors and trailers can impact the technology options available to truck fleets. For example, verified aerodynamic retrofits may only be available for certain trailer length

[95] http://www.epa.gov/smartway/tips/tips10-c.htm

and heights. Accordingly, unit configurations must be assessed carefully before specific technologies and operational strategies are chosen.

Trucks may be classified as single-unit trucks or combination trucks. Single-unit trucks are one-piece vehicles without a separate trailer; examples include vans, service utility trucks, flatbed trucks, refrigeration vans or garbage and dump trucks.[96] Figure 4-5 and Figure 4-6 show examples of single-unit trucks.

Combination trucks consist of a towing engine, known as a tractor, and a semi-trailer. Semi-trailers are mounted on the "fifth wheel," just forward of the tractor's rear axle, in order to distribute a portion of the trailer's load to the tractor. In addition to the tractor, combinations include an enclosed trailer, flatbed or lowboy trailer, refrigeration trailer, tanker, vehicle transporter, or other specialty trailer. The tractor may be a single day cab or a sleeper cab for over-the-road travel.

In the United States, two-axle tractors are permitted to pull two semi-trailers on national network highways. In addition, some states allow use of "longer combination vehicles," or LCVs, such as the following:[97]

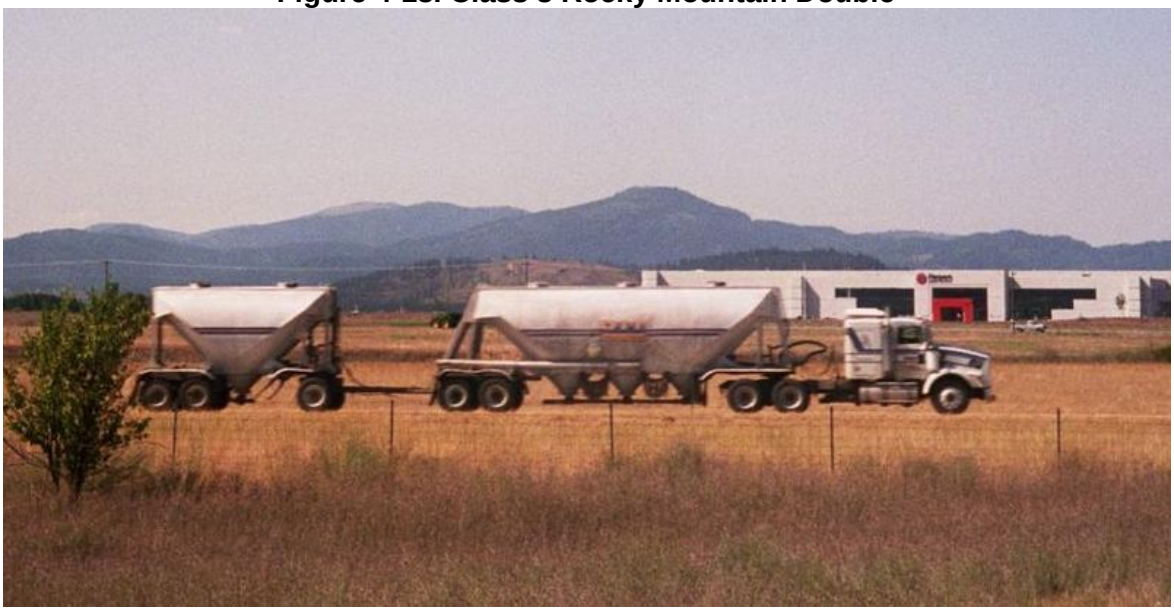
- Triples—three 28.5-foot (8.7-meter) trailers.
- Turnpike doubles—two 48-foot (14.6-meter) trailers.
- Rocky Mountain doubles—one 40-to-53-foot (12.2-to-16.2-meter) trailer and one 28.5-foot (8.7-meter) trailer.

Figure 4-13 provides an example of a Rocky Mountain double tractor-trailer combination.

[96] U.S. Environmental Protection Agency (2002). *Industry Options for Improving Ground Freight Fuel Efficiency*. p. 17.

[97] http://en.wikipedia.org/wiki/Semi-trailer_truck

Figure 4-13. Class 8 Rocky Mountain Double



Alex1011/Wikimedia Commons; CC BY-SA 3.0

Allowable trailer length and the number and size of LCVs varies from country to country, depending upon safety regulations and infrastructure constraints (e.g., road and bridge specifications). For example, Australia allows for triples as well as quads in certain areas. In Canada, LCVs include turnpike and Rocky Mountain doubles, as well as triples, depending upon location, while Mexico permits operation of double trailers. Length restrictions a single tractor-trailer unit vary substantially as well. For example, certain EU countries including Sweden and Germany overall length can reach 25.25 meters, substantially more than the 19.2 meter limit in the United States.[98]

Tractor configuration will also impact the efficiency technologies available to fleets. With "conventional" cabs, such as that shown in Figure 4-13, the engine is forward of the cab, over the front axle. The hood is rotated on hinges located near the lower front bumper to access the drivetrain. Although most U.S. tractors have conventional cabs, many tractors in Europe and Asia are "cab over engine" units, such as that shown in Figure 4-7. Cab-overs offer a shorter tractor length, which improves maneuverability and allows for a longer trailer, and the flat front (lack of a hood) improves the driver's view of the road, but generally the ride is rougher and noisier because the cab is directly over the engine and the wheelbase is shorter. To service the engine or transmission in a cab-over, the entire cab is rotated on front hinges to expose the drivetrain.

By design, the maneuverability but much smaller cargo capacity of single-unit trucks makes them better suited for local and short-haul service.[99] Combination trucks, on the other hand, have

[98] Wikipedia editors. 2014. Road train. Retrieved from http://en.wikipedia.org/wiki/Road_train.

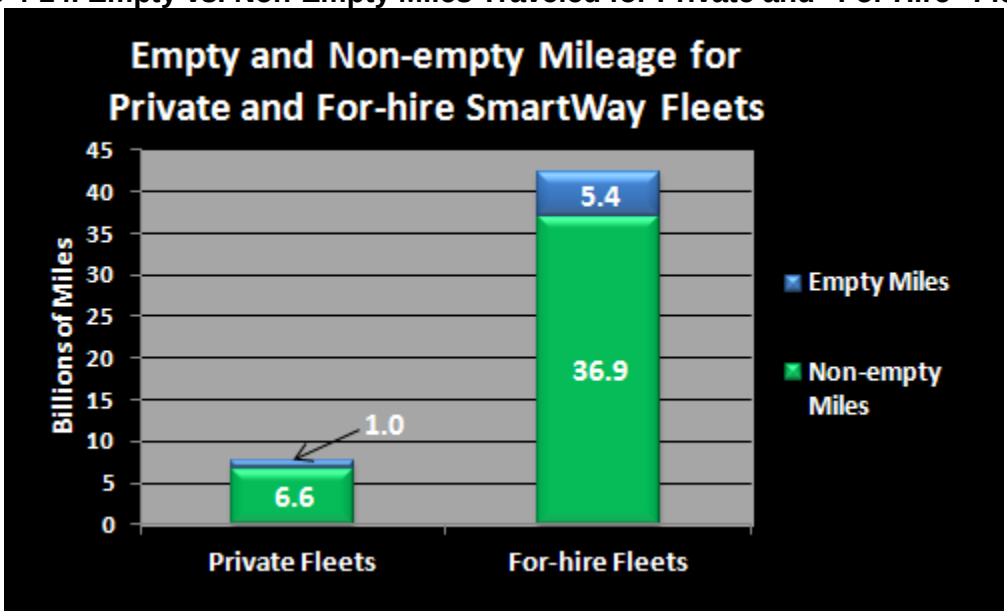
[99] U.S. Environmental Protection Agency (2002). *Industry Options for Improving Ground Freight Fuel Efficiency*. p. 20.

more cargo capacity but less maneuverability, which generally makes them better suited for long-haul and over-the-road (OTR) service.

4.1.5 Fleet Ownership/Contracting

The nature of a trucking fleet's business can directly affect responsiveness to incentives, access to financing, and other factors influencing their willingness to participate in green freight programs. The freight trucking industry can generally be sub-divided into private and public (for-hire) carriers. Private carriers maintain a truck fleet that provides freight transport services necessary to maintain their business, while public carries offer "for hire" or "for fee" freight transport services. Public carriers may be categorized either as "truckload" or "less than truckload" (LTL) carriers. Truckload carriers typically contract the entire trailer load to a single customer, while a LTL carrier mixes freight from several customers within a trailer.[100] Other types of "for hire" trucking includes parcel delivery trucks or specialty services such as trucks for delivery of appliances, movement of household goods or rental trucks. For-hire trucks may be company-owned (fleet trucks) or privately-owned (owner-operator trucks that are owned and operated by an individual). Self-reported fuel economies by participants in the EPA's SmartWay program indicate nearly identical fuel economies for private (6.2 mpg) vs. "for hire" (6.1 mpg) SmartWay fleet trucks.[101] Also, Figure 4-14 shows self-reported empty vs. non-empty miles for private vs. "for-hire" trucks in the SmartWay fleet. As shown in this chart, the percentage of empty miles traveled is roughly equivalent for both industry subdivisions (private empty percentage is 13.2 percent and "for hire" empty percentage is 12.8 percent).

Figure 4-14. Empty vs. Non-Empty Miles Traveled for Private and "For Hire" Fleets[102]

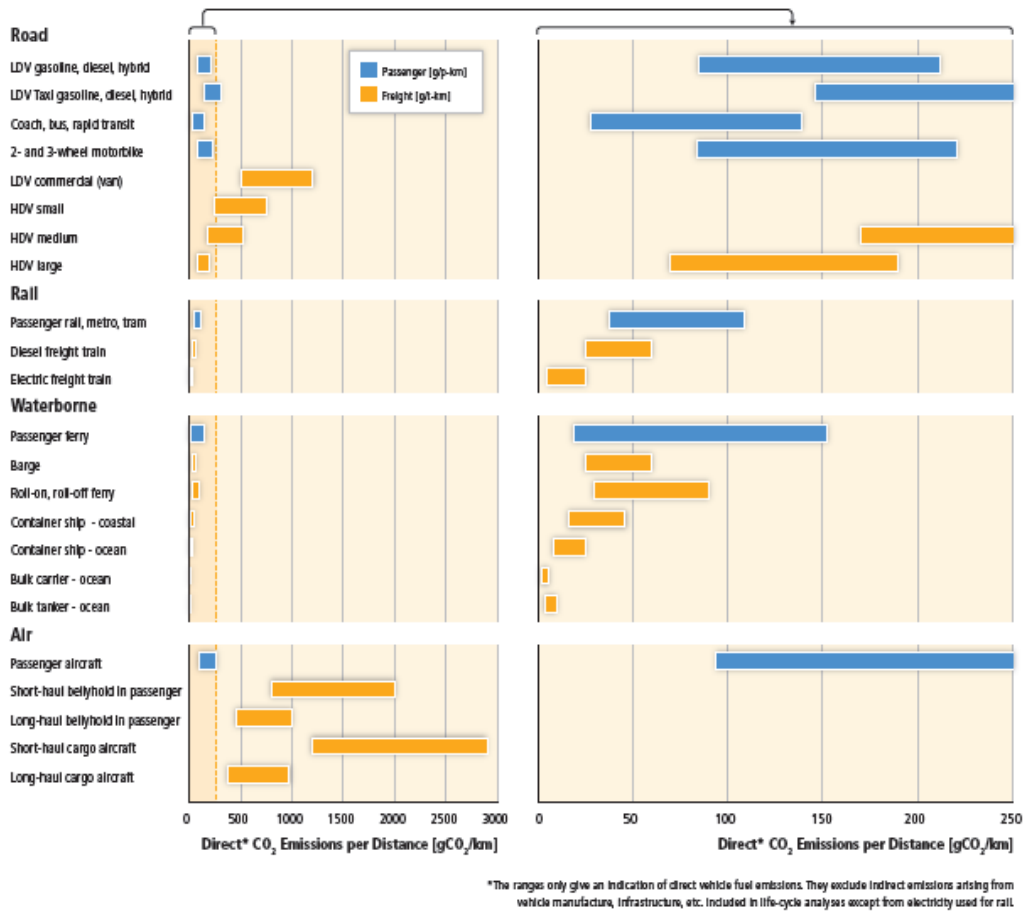


[100] http://en.wikipedia.org/wiki/Truckload_shipping
[101] http://www.epa.gov/smartway/tips/tips7-a.htm
[102] http://www.epa.gov/smartway/tips/tips7-c.htm

4.2 Intermodal Options

In the last four decades, global intermodal freight traffic has increased by an order of magnitude, playing a critical role in facilitating economic globalization by providing a cost-effective method of moving freight from one location to another. Intermodal transfers can be highly efficient, minimizing fuel consumption and thereby reducing emission of other combustion-related pollutants such as CO_2, PM, and black carbon. Carbon intensity, expressed in terms of grams of CO_2 per kilometer or per tonne-kilometer, varies widely across the different transport modes, as shown in Figure 4-15 below. For freight movement options, the figure clearly shows that CO_2 emission rates are generally highest for short-haul aircraft, followed by lighter trucks, then heavy over-the-road trucks, rail and barge transports, and finally ocean-going vessels. The highest-intensity estimates are more than two orders of magnitude greater than for bulk ocean transport, the lowest-intensity mode.

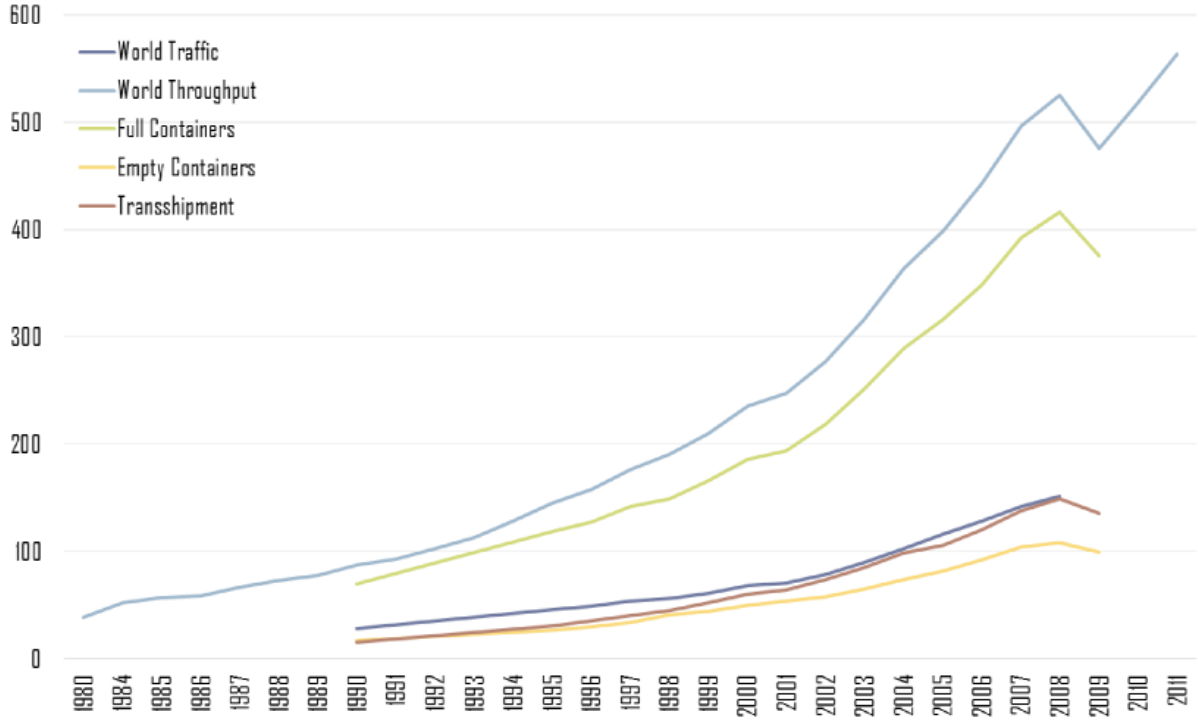
Figure 4-15. Direct CO_2 Emissions Intensity by Transport Mode (CO_2 per km and per Tonne-km)[103]



[103] Source: Sims R., R. Schaeffer, F. Creutzig, X. Cruz-Núñez, M. D'Agosto, D. Dimitriu, M.J. Figueroa Meza, L. Fulton, S. Kobayashi, O. Lah, A. McKinnon, P. Newman, M. Ouyang, J.J. Schauer, D. Sperling, and G. Tiwari

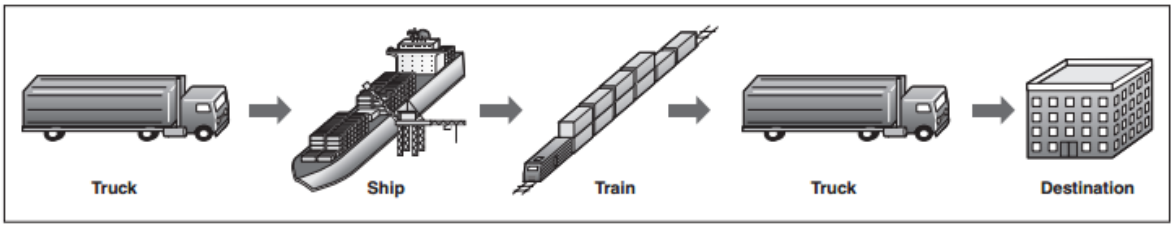
Intermodal systems shift cargo from origination to destination using the most appropriate and fuel-efficient mode of transportation. Marine vessels are generally preferred, as they represent one of the most fuel-efficient modes available, but they can only serve ports along navigable waterways and shipping routes. From the port, cargo can be moved efficiently by rail to the destination city and by truck to the final destination.

Figure 4-16. World Container Traffic and Throughput, 1980–2011 (Millions of TEU)



Jean-Paul Rodrigue; data adapted from Drewry Shipping Consultants

Figure 4-17. Example of Intermodal Transportation for Freight

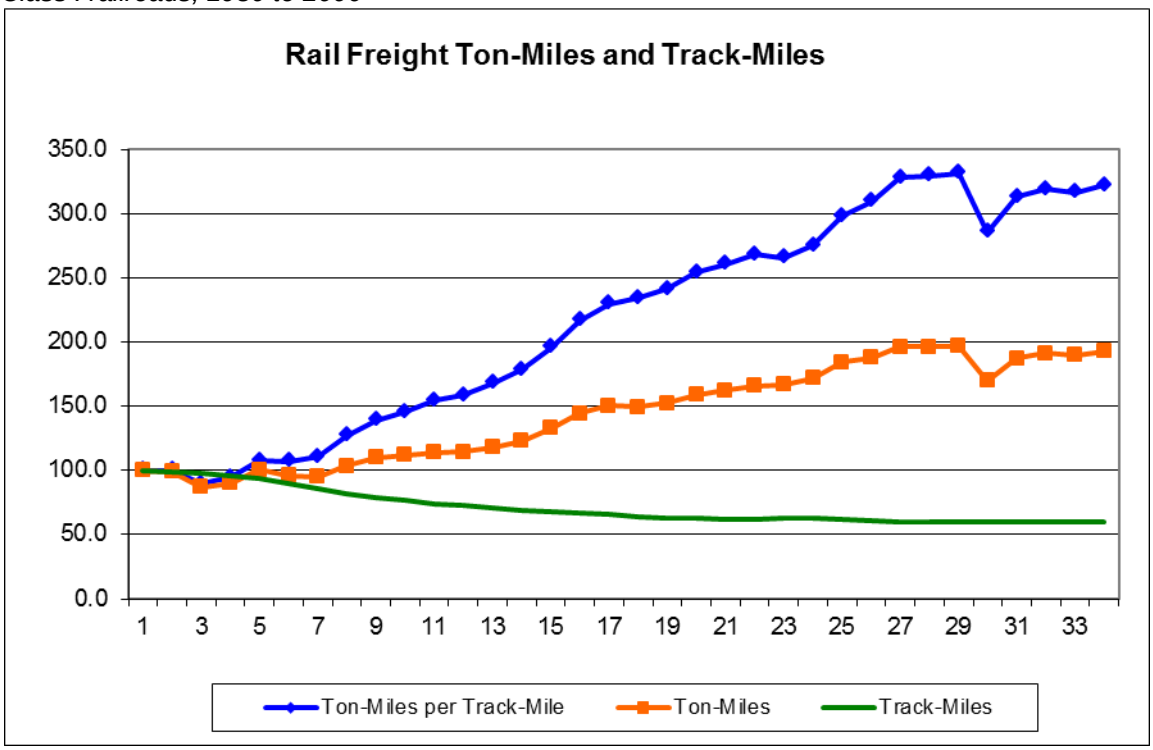


Government Accountability Office

(2014). Transport. Figure 8.6 in Intergovernmental Panel on Climate Change. *Climate Change 2014: Mitigation of Climate Change.*

Figure 4-18. Rail Freight Ton-Miles and Track Miles

Class I railroads, 1980 to 2006



American Association of Railroads

Intermodal transfers are facilitated by the use of standardized containers that can be efficiently transferred from ship to rail at the port and from rail to truck at the rail yard using specially designed cargo handling equipment.

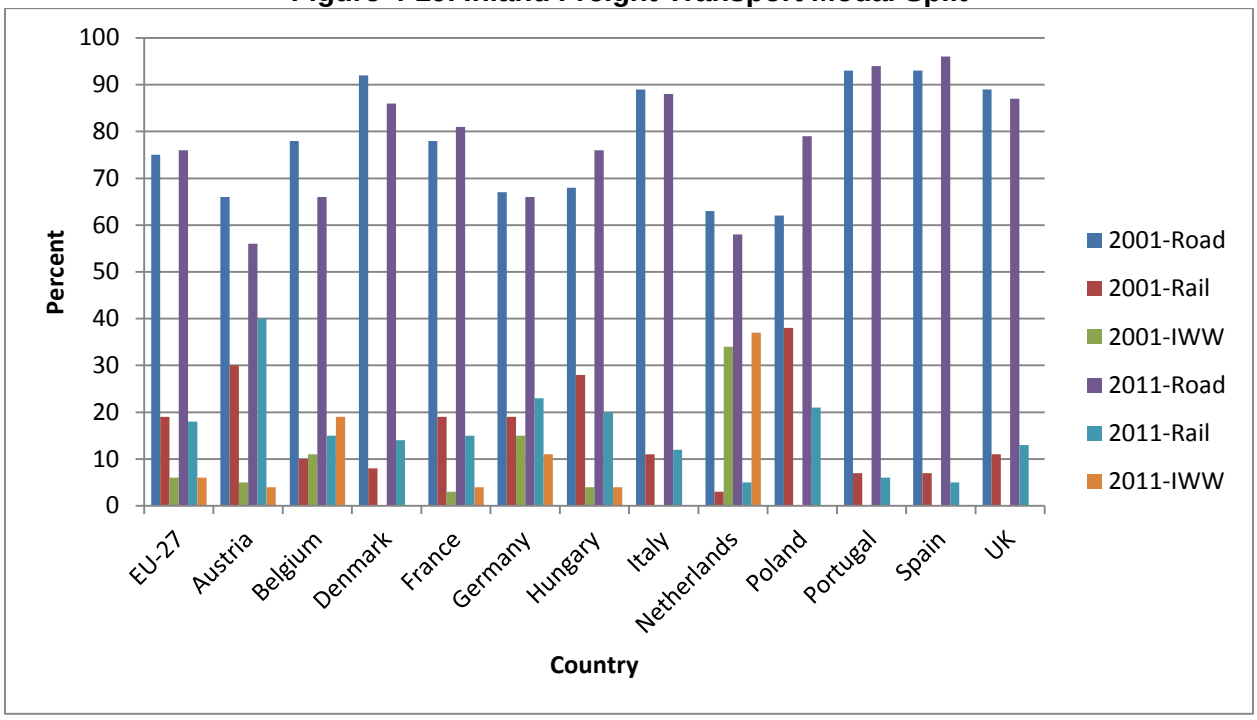
Green freight action plans that include development or improvement of intermodal systems need to consider a range of issues: possible changes in land use; coordination between logistics, trucking, ship operators, airlines, and railroad companies; customs clearance; available warehouse storage; infrastructure improvements to harbors, rail yards, and ports; channel dredging; cargo traffic monitoring systems; and dockside rail linkage/drayage operations. Emissions associated with drayage trucks and idling of highway vehicles, vessels, and trains should also be assessed.

The potential for intermodal shifts in a given region depends heavily on the level of rail infrastructure development, as well as access to inland waterways and the density and characteristics of the road network itself. For instance, even within the EU the relative split across these modes can vary significantly. Figure 4-19[104] illustrates the modal transportation splits between roads, rail, and inland waterways for the EU and selected European countries in 2001 and 2011. This figure illustrates that despite the availability of developed rail and inland waterway systems, road transport has dominated the movement of freight throughout this 10-

[104] Eurostat (2013). *Energy, Transport and Environment Indicators.* Retrieved from http://epp.eurostat.ec.europa.eu/portal/page/portal/product_details/publication?p_product_code=KS-DK-13-001.

year period. At no time during this period did the fraction of freight moved via road fall below 50 percent, with the minimum being approximately 55 percent for Austria in 2011. All other countries except the Netherlands had road freight values greater than 60 percent for both 2001 and 2011, with five (Denmark, Italy, Portugal, Spain, and the UK) greater than 80 percent for both years. The EU's road freight fraction as a whole was between 70 and 75 percent for both years. Regions with less well-developed rail and waterway systems generally will have even higher road freight fractions.

Figure 4-19. Inland Freight Transport Modal Split



4.3 Rail Freight Options

Growth in the rail freight sector is strongly correlated with growth in intermodal traffic, as container shipments become an increasingly large component of total rail shipments. For example, in the United States movement of containers accounts for 20 to 30 percent of railroad revenues, larger than any other commodity group. (Until recently, coal has usually been the most significant commodity group.)

Table 4-6 presents rail freight transportation intensity for 75 countries, ranked in terms of tonne-km hauled per year in 2010.[105] As with road freight transportation, the United States and China have the highest levels of rail freight transportation. In this case the Russian Federation ranks third on the list, and these three countries are responsible for a full 75 percent of the total tonne-km hauled for the countries on the list.

[105] http://data.worldbank.org/indicator/IS.RRS.GOOD.MT.K6

Table 4-6. Annual Rail Tonne-km Hauled, Selected Countries, 2010

Country Name	2010
United States	2,468,738
China	2,451,185
Russian Federation	2,011,308
India	600,548
Canada	322,741
Brazil	267,700
Ukraine	218,091
Kazakhstan	213,174
South Africa	113,342
Germany	105,794
Australia	64,172
Belarus	46,224
Poland	34,266
Austria	23,104
France	22,840
Uzbekistan	22,282
Japan	20,432
Iran, Islamic Republic	20,247
Latvia	17,164
Czech Republic	13,592
Lithuania	13,431
Italy	12,037
Argentina	12,025
Turkmenistan	11,992
Turkey	11,030
Mongolia	10,287
Finland	9,760
Korea, Republic	9,452
Romania	9,134
Switzerland	8,725
Azerbaijan	8,250
Spain	7,844
Slovak Republic	7,669
Mauritania	7,566
Estonia	6,261
Georgia	6,228
Pakistan	6,187
Morocco	5,572

Country Name	2010
Belgium	5,439
Chile	4,032
Vietnam	3,901
Serbia	3,868
Egypt, Arab Republic	3,840
Slovenia	3,283
Thailand	3,161
Bulgaria	3,061
Croatia	2,618
Syrian Arab Republic	2,370
Gabon	2,238
Tunisia	2,073
Portugal	1,932
Saudi Arabia	1,748
Malaysia	1,384
Algeria	1,281
Bosnia and Herzegovina	1,227
Israel	1,062
Hungary	1,000
Cameroon	978
Moldova	927
Peru	900
Tajikistan	808
Swaziland	776
Kyrgyz Republic	738
Bangladesh	710
Mozambique	695
Botswana	674
Greece	538
Macedonia, FYR	497
Jordan	353
Armenia	346
Congo, Democratic Republic	193
Luxembourg	189
Iraq	121
Ireland	92
Albania	46

While the scale of existing rail freight activity is instructive, ideally it is more important to determine overall rail system utilization in order to identify potentials for mode shifts. While system capacities were not identified explicitly for most countries, growth in rail freight activity can help identify target areas for potential mode shifts. To this end, Table 4-7 presents the change in tonne-kilometers hauled over the 2000–2010 period for many of the countries shown in Table 4-6. This table indicates that several countries have dramatically increased their rail freight movement over the last decade, most of them in Asia and Eastern Europe. During the same period a number of Western and Central European nations, as well as certain countries in Southeast Asia and Africa, experienced negative growth rates.

Table 4-7. Growth in Rail Tonne-km Hauled, 2000–2010

Country Name	% Increase
Bosnia and Herzegovina	473%
Mongolia	140%
Saudi Arabia	113%
Vietnam	105%
Serbia	102%
India	97%
Australia	88%
China	84%
Brazil	74%
Kazakhstan	71%
Greece	65%
Pakistan	65%
Albania	64%
Georgia	59%
Malaysia	53%
Lithuania	51%
Syrian Arab Republic	50%
Belarus	47%
Russian Federation	46%
Croatia	46%
Uzbekistan	44%
Azerbaijan	43%
Iran, Islamic Republic	43%
Austria	42%
Gabon	39%
Germany	31%
Latvia	29%
Chile	29%
Slovenia	26%
Ukraine	26%
Morocco	22%
United States	15%

Country Name	% Increase
Turkey	13%
South Africa	6%
Peru	3%
Armenia	-2%
Finland	-3%
Egypt, Arab Republic	-4%
Macedonia, FYR	-6%
Thailand	-7%
Cameroon	-7%
Japan	-8%
Bangladesh	-9%
Tunisia	-9%
Israel	-9%
Portugal	-11%
Korea, Republic	-13%
Switzerland	-18%
Estonia	-20%
Czech Republic	-21%
Slovak Republic	-32%
Spain	-35%
Algeria	-35%
Belgium	-38%
Poland	-38%
Jordan	-39%
Tajikistan	-39%
Bulgaria	-45%
Congo, Democratic Republic	-47%
Italy	-47%
Romania	-49%
France	-59%
Ireland	-81%
Hungary	-87%

Technologies that reduce fuel consumption and emissions vary according to the type of rail operation. For example, line-haul locomotives carry goods over long distances, so technologies that optimize constant engine operations would be useful; yard locomotives, meanwhile, work in a smaller geographic area where engines tend to operate in a "stop-and-go" mode as they move cars around the yard over shorter distances. Yard locomotives tend to have a smaller impact on fuel consumption and air quality—they are typically associated with approximately 10 percent of annual rail fuel usage—but they can have a significant impact on local air quality, as their operations are limited to specific areas, often in urban communities.

A large number of options can be considered in a green freight action plan to improve railroad fuel usage and reduced emissions. These options (discussed in detail in Chapter 6) include:

- Infrastructure improvements that would allow for double stacking of containers or electrification of rail lines.
- Use of low-sulfur diesel fuels or alternative fuels, such as biodiesel, synthetic fuels, and natural gas.
- Optimization systems that monitor train movements and improve load with optimal engine operations.
- Friction reduction options such as wheel-to-rail lubrications, improved train aerodynamics, and use of lightweight cars.
- Add-on locomotive controls such as oxidation catalysts, PM filters, and exhaust gas recirculation.[106]
- Idle reduction and application of auxiliary power units that allow for the main propulsion engine to be shut down while in the rail yard.
- Engine improvements such as turbocharging, turbocompounding, intercooling, and common rail fuel distribution.
- Use of gensets and hybrid locomotives.

4.4 Marine Cargo Options

More than 90 percent of global trade is carried by sea; this includes movement of raw materials to processing and manufacturing facilities and shipments of final products to markets. Marine cargo shipments tend to be the most energy-efficient ways to move freight (in terms of fuel consumption and emissions per tonne-kilometer).

Table 4-8, on the next page, shows total marine container freight movements for 123 countries in 2010, expressed in terms of 20-foot equivalent units (TEUs). In this case China far outpaces the rest of the world, responsible for almost one quarter of all container shipments.[107]

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[106] http://www.alphaliner.com/liner2/research_files/newsletters/2011/no19/Alphaliner%20Newsletter%20no%2019%20-%202011.pdf

[107] http://data.worldbank.org/indicator/IS.SHP.GOOD.TU

Table 4-8. Annual Marine Container Shipments in TEUs, Selected Countries, 2010

Country Name	2010
China	130,290,443
United States	42,337,513
Singapore	29,178,500
Hong Kong SAR, China	23,699,242
Korea, Republic	18,542,804
Malaysia	18,267,475
Japan	18,098,346
South Asia	17,323,023
United Arab Emirates	15,176,524
Germany	14,821,767
Spain	12,613,016
Netherlands	11,345,167
Belgium	10,984,824
Italy	9,787,403
India	9,752,908
United Kingdom	8,590,282
Indonesia	8,482,636
Brazil	8,138,608
Egypt, Arab Republic	6,709,053
Australia	6,668,075
Thailand	6,648,532
Panama	6,003,298
Vietnam	5,983,583
Turkey	5,574,018
France	5,346,800
Saudi Arabia	5,313,141
Philippines	4,947,039
Canada	4,829,806
Sri Lanka	4,000,000
Oman	3,893,198
South Africa	3,806,427
Mexico	3,693,956
Russian Federation	3,199,980
Chile	3,171,959
Iran, Islamic Republic	2,592,522
New Zealand	2,463,278
Malta	2,450,665
Colombia	2,443,786
Israel	2,281,552
Pakistan	2,149,000
Morocco	2,058,430
Argentina	2,021,676
Jamaica	1,891,770
Portugal	1,622,247
Peru	1,534,056
Puerto Rico	1,525,532
Sweden	1,390,504

Country Name	2010
Dominican Republic	1,382,680
Bangladesh	1,356,099
Finland	1,247,521
Venezuela, RB	1,226,508
Ecuador	1,221,849
Greece	1,165,185
Bahamas, The	1,125,000
Poland	1,045,232
Costa Rica	1,013,483
Guatemala	1,012,360
Kuwait	991,545
Lebanon	949,155
Ireland	790,067
Denmark	709,147
Kenya	696,000
Uruguay	671,952
Yemen, Republic	669,021
Ukraine	659,541
Syrian Arab Republic	649,005
Ghana	647,052
Honduras	619,867
Jordan	619,000
Cote d'Ivoire	607,730
Djibouti	600,000
Trinidad and Tobago	573,217
Romania	556,694
Slovenia	476,731
Tunisia	466,398
Sudan	439,100
Tanzania	429,285
Austria	350,461
Cyprus	349,357
Senegal	349,231
Qatar	346,000
Congo, Republic	338,916
Mauritius	332,662
Norway	330,873
Benin	316,744
Papua New Guinea	295,286
Lithuania	294,954
Bahrain	289,956
Cameroon	285,070
Algeria	279,785
Latvia	256,713
Namibia	256,319
Mozambique	254,701
Cuba	228,346

Country Name	2010
Georgia	226,115
Cambodia	224,206
Iceland	192,778
Myanmar	190,046
Libya	184,585
Guam	183,214
Gabon	153,657
Estonia	151,969
El Salvador	145,774
Bulgaria	142,611
Madagascar	141,093
Croatia	137,048
Aruba	130,000
Nigeria	101,007
Brunei Darussalam	99,355
Switzerland	99,048

Country Name	2010
New Caledonia	90,574
Albania	86,875
Barbados	80,424
French Polynesia	68,889
Nicaragua	68,545
Mauritania	65,705
Maldives	65,016
St. Lucia	52,479
Cayman Islands	40,281
Belize	31,919
Antigua and Barbuda	24,615
St. Vincent and the Grenadines	18,852
Paraguay	8,179
World	**542,034,853**

The next table presents the growth in marine container traffic between 2000 and 2010 for a subset of the above countries. Unlike the road and rail modes, the vast majority of these countries have experienced extremely high growth rates in marine container shipments over the 10-year period, with over half seeing at least a doubling in shipments during this time, and the Russian Federation seeing an increase of almost an order of magnitude.

Table 4-9. Growth in Marine Container Shipments, 2000–2010

Country Name	% Increase
Russian Federation	912%
Croatia	868%
Morocco	526%
Vietnam	403%
Egypt, Arab Republic	313%
India	298%
Malaysia	293%
South Asia	273%
Saudi Arabia	254%
Turkey	250%
Brazil	237%
Oman	235%
Peru	233%
China	218%
Colombia	209%
United Arab Emirates	200%
Bangladesh	197%
Ecuador	195%
Mexico	181%
Yemen, Republic	170%
Panama	153%

Country Name	% Increase
Chile	153%
Jamaica	147%
Dominican Republic	144%
Portugal	142%
World	**141%**
Sri Lanka	131%
New Zealand	131%
Malta	126%
Indonesia	123%
Spain	118%
Belgium	117%
Thailand	109%
South Africa	106%
Korea, Republic	105%
Guatemala	104%
Trinidad and Tobago	103%
Germany	93%
Australia	88%
France	83%
Venezuela, RB	82%
Netherlands	77%

Country Name	% Increase
Costa Rica	77%
Argentina	77%
Singapore	71%
Canada	65%
Philippines	63%
Honduras	58%
Sweden	57%
United States	50%
Italy	41%

Country Name	% Increase
Cote d'Ivoire	40%
Japan	38%
Finland	34%
United Kingdom	33%
Denmark	25%
Ireland	10%
Algeria	5%
Greece	-16%
Puerto Rico	-22%

Opportunities for marine freight movement for a given area depend not only on the presence and size of regional port facilities, but also on the quality of the infrastructure itself. The following table presents ratings for the quality of port infrastructure around the world, based on annual surveys of over 13,000 business executives. Port facility ratings range from 1 to 7, with 7 representing the most advanced, efficient facilities. Respondents from land-locked countries rated their access to port facilities, again from 1 to 7 with 7 representing highly accessible ports.[108] Further analysis of the data indicates that heavily indebted countries with low GDP levels have notably lower port infrastructure quality scores than high-income countries (approximately 3.5 vs. 5.2 on average in 2013).

[108] http://data.worldbank.org/indicator/IQ.WEF.PORT.XQ

Table 4-10. Port Infrastructure Quality Index, 2013

Country Name	2013
Netherlands	6.8
Singapore	6.8
Hong Kong SAR, China	6.6
United Arab Emirates	6.4
Finland	6.4
Panama	6.4
Belgium	6.3
Iceland	6.0
Bahrain	5.8
Germany	5.8
Spain	5.8
Malta	5.8
Sweden	5.8
Denmark	5.7
United Kingdom	5.7
United States	5.7
Barbados	5.6
Estonia	5.6
Canada	5.5
Korea, Republic	5.5
Norway	5.5
New Zealand	5.5
Oman	5.5
France	5.4
Luxembourg	5.4
Malaysia	5.4
Namibia	5.3
Puerto Rico	5.3
Chile	5.2
Ireland	5.2
Japan	5.2
Portugal	5.2
Qatar	5.2
Jamaica	5.1
Lithuania	5.1
Latvia	5.1
Saudi Arabia	5.1
Slovenia	5.1
Australia	5.0
Switzerland	5.0
Morocco	5.0
Mauritius	4.9
Suriname	4.9
Seychelles	4.9
Cyprus	4.8
Senegal	4.8
Austria	4.7

Country Name	2013
Brunei Darussalam	4.7
Uruguay	4.7
South Africa	4.7
Caribbean small states	4.6
Dominican Republic	4.6
Gambia, The	4.6
Azerbaijan	4.5
China	4.5
Cote d'Ivoire	4.5
Greece	4.5
Jordan	4.5
Pakistan	4.5
Thailand	4.5
Czech Republic	4.4
Mexico	4.4
Croatia	4.3
Italy	4.3
Lebanon	4.3
Swaziland	4.3
Turkey	4.3
Ecuador	4.2
Georgia	4.2
Ghana	4.2
India	4.2
Sri Lanka	4.2
El Salvador	4.2
Egypt, Arab Republic	4.1
Guatemala	4.1
Iran, Islamic Republic	4.1
Kenya	4.1
Kuwait	4.1
Trinidad and Tobago	4.1
Zimbabwe	4.1
Cambodia	4.0
Mali	4.0
Tunisia	4.0
Bulgaria	3.9
Honduras	3.9
Hungary	3.9
Indonesia	3.9
Montenegro	3.9
Russian Federation	3.9
Cabo Verde	3.8
Israel	3.8
Macedonia, FYR	3.8
Argentina	3.7
Benin	3.7

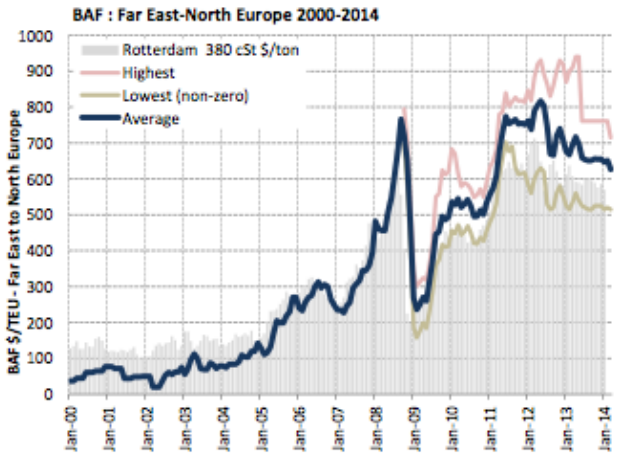
Country Name	2013
Cameroon	3.7
Peru	3.7
Poland	3.7
Slovak Republic	3.7
Ukraine	3.7
Vietnam	3.7
Botswana	3.6
Rwanda	3.6
Sierra Leone	3.6
Albania	3.5
Burkina Faso	3.5
Bangladesh	3.5
Colombia	3.5
Madagascar	3.5
Mozambique	3.5
Nicaragua	3.5
Zambia	3.5
Guyana	3.4
Liberia	3.4
Nigeria	3.4
Philippines	3.4
Paraguay	3.4
Uganda	3.4
Malawi	3.3
Guinea	3.2
Tanzania	3.2
Ethiopia	3.1

Country Name	2013
Armenia	3.0
Libya	3.0
Romania	3.0
Angola	2.9
Costa Rica	2.9
Lesotho	2.9
Mauritania	2.9
Yemen, Republic	2.9
Burundi	2.8
Brazil	2.7
Algeria	2.7
Gabon	2.7
Kazakhstan	2.7
Nepal	2.7
Lao PDR	2.6
Moldova	2.6
Myanmar	2.6
Mongolia	2.6
Serbia	2.6
Bolivia	2.5
Chad	2.5
Venezuela, RB	2.5
Haiti	2.4
Timor-Leste	2.4
Bhutan	2.2
Bosnia and Herzegovina	1.8
Kyrgyz Republic	1.3

The marine transportation mode is also most sensitive to fuel cost, which represents 60 to 80 percent of total expenditures. As marine bunker fuel prices have been generally increasing (see Figure 4-20), it is important that green freight action plans include options that allow for improved fuel efficiency along with anticipated emission reductions. These options include:

- Replacement of older engines with newer, more fuel-efficient engines that have common rail fuel distribution, turbo chargers or turbo compounding, or diesel/electric engine configurations.
- Use of improved propeller designs.

Figure 4-20. Rising Marine Bunker Fuel Prices



- Application of hull friction reduction technologies such as high-tech antifouling coatings and bubble lubrication.
- Use of low-sulfur fuels and alternative fuels such as biofuels and natural gas.
- Encouraging solar cell and wind-powered options.

Alphaliner

- Route and engine optimization systems.
- Operational changes such as cold ironing in port and slow-speed shipping while underway.
- Application of add-on control devices.

4.5 Air Freight Options

Despite recent economic downturns in the global market, air cargo traffic has grown consistently throughout the years (Figure 4-20) and is expected to continue to grow in the future (Figure 4-21)—including express traffic, which is anticipated to average 5.3 percent annual growth (measured in revenue ton kilometers, or RTKs). This will increase world air cargo traffic from 202.4 billion RTKs in 2011 to more than 558.3 billion RTKs in 2031.[109]

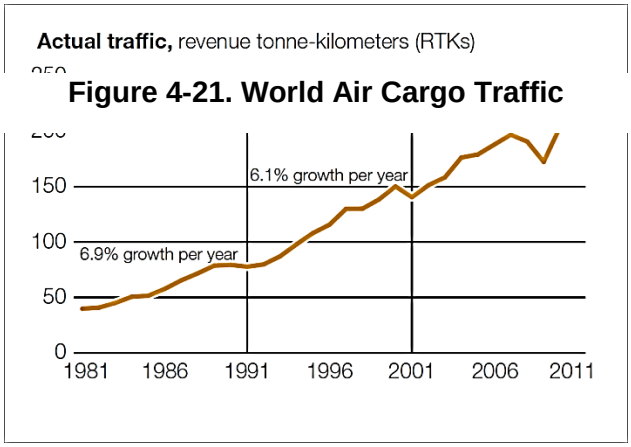


Figure 4-21. World Air Cargo Traffic

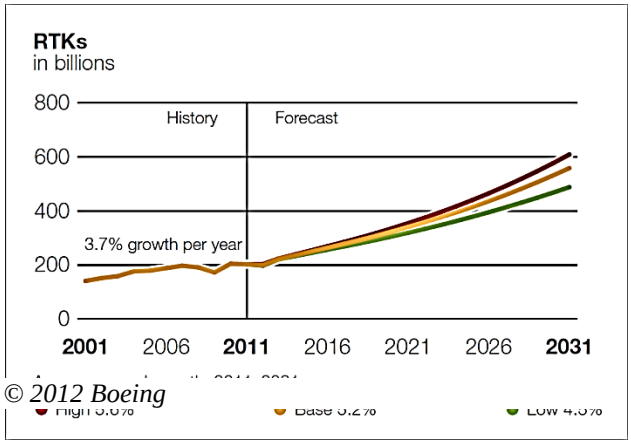


Figure 4-22. World Air Cargo Traffic: 20-Year Forecast

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Asia is expected to lead the world air cargo industry in average annual growth rates, with domestic China and intra-Asia markets expanding 8.0 and 6.9 percent per year, respectively.

Freight aircraft companies include those that are directly involved in cargo movement (such as DHL, UPS, and Federal Express), but also large air carriers that move both cargo and passengers during a flight. Many of the technologies presented in this study would be applicable for both. Because aircraft use large amounts of fuel to move cargo, the profitability of aviation activities is highly dependent on fuel costs, which have increased over the years; Figure 4-23 indicates that current Gulf Coast kerosene/jet fuel prices are about six times higher than during the 1990–

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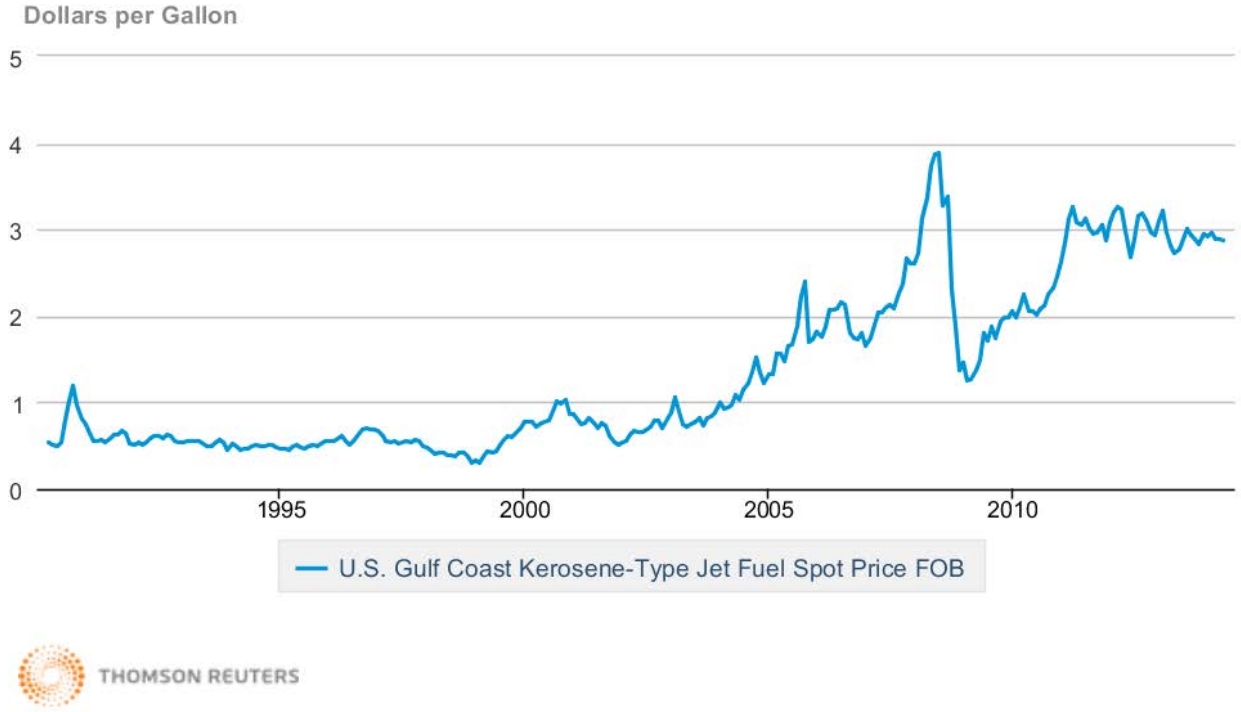
[109] Boeing (2013). *Boeing World Cargo Forecast 2012–2013*. Retrieved from http://www.boeing.com/assets/pdf/commercial/cargo/wacf.pdf.

2002 period.[110] Therefore, the aviation industry would be very receptive to components of a green freight action plan that improve fuel consumption while reducing emissions. These options could include:

- Encouraging use of new fuel-efficient engines, including high-bypass geared jet and the open rotor engines.
- Use of electric wheels to reduce main engine operations during taxi modes.
- Use of alternative fuels such as biofuels and synthetic fuels.
- Airframe improvements such as wing lengthening, laminar flow wings, multilayer wings, winglets, and low-friction surface coatings.
- Introduction of alternative aircraft such as cargo airships.
- Operational changes such as the FAA's NextGen system to reduce trip distances, reduce delay times, and ensure that aircraft are operating at the optimal elevation.

Figure 4-23. Jet Fuel Prices, 1990–2014



Energy Information Administration

[110] U.S. Energy Information Administration (2014). U.S. Gulf Coast kerosene-type jet fuel spot price FOB. http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=EER_EPJK_PF4_RGC_DPG&f=M.

5.0 Review of Current Truck Technologies and Operating Strategies

A wide variety of strategies are available to reduce the fuel consumption and emissions associated with freight movement. The feasibility and cost-effectiveness of these options vary greatly from region to region depending upon the characteristics of the industry fleet, available fueling options, predominant freight modes, and the level of transportation infrastructure development, among other factors. For this reason the adoption of these strategies should be prioritized and tailored to the unique characteristics of each region's freight industry. For example, the following illustrates some of the strategies most appropriate for consideration in a few selected regions.

Country	Freight System Characteristics	Target Control Strategies
United States/Canada	High speed, long haul	Aerodynamic improvements, extended idle reduction
China	Large fraction of empty backhauls	Initial logistics improvements (e.g., drop-and-hook)
India	Infrastructure constraints	Road network investments, mode shifts
EU	Lower speeds, dense roadway network	Advanced tires/lubricants, hybridization

In order to help identify the appropriate mix of strategies for a given region, this chapter presents various technologies, concepts, fuels, and actions that can be taken to reduce GHG emissions from the on-road portion of freight operations. These include options that can be retrofitted to existing trucks and trailers; technologies a buyer can specify or choose when purchasing new trucks and trailers; and logistical concepts, programs, and strategies, all of which can reduce fuel consumption, decrease GHG emissions, or reduce pollutant emissions from on-road freight operations.

To create this chapter, the authors reviewed a variety of publications, technical journal articles, white papers, books, and various forms of informational marketing materials. Books and publications from government agencies were the preferred source for many of the concepts in this chapter, as well as their calculated benefit potential. This chapter also refers to sponsored publications written by independent research organizations, which were considered valuable even if not given the same level of priority. For some newer devices, promotional material listing features was useful to describe how the devices worked as well as their intended use; this was the least rigorous in terms of reference quality, but in some cases it was the only available literature. If a GHG or fuel consumption benefit presented in this chapter was taken from promotional material, that fact is stated explicitly alongside the presented data.

For on-road trucking operations using conventional fuel, GHG emission levels are very closely tied to fuel consumption, and reductions in either are cited equivalently in much of this chapter. For on-road freight hauling, there are two key definitions of fuel efficiency, vehicle miles per gallon and freight ton-miles per gallon. The first is defined similarly to passenger car fuel economy: the total distance traveled by a truck divided by the fuel used over that distance. For freight operations, it can also be beneficial to define freight-specific fuel economy. This is calculated by the tons of freight moved, multiplied by the miles traveled, divided by the fuel consumed, i.e. freight-ton miles per gallon. Using this metric is beneficial as it accounts for the

amount of freight being transported in each trip. For example, loading a truck completely full instead of half-full will reduce its vehicle fuel economy, but will raise the freight-specific fuel economy as the percentage fuel consumption penalty for the added weight is much lower than the doubling of the goods transported. Generally speaking, discussing vehicle fuel economy is appropriate for technologies that improve vehicle fuel consumption, while freight-specific fuel economy is a more appropriate metric for operational and routing strategies.

5.1 Factors Influencing Truck Fuel Consumption and Emissions

5.1.1 Fuel Consumption

The factors that influence freight vehicle fuel economy can be divided into two groups, those intrinsic to the vehicle's design and those that are related to its environment or operating conditions. This section discusses how a truck's design characteristics and operating conditions affect fuel economy.

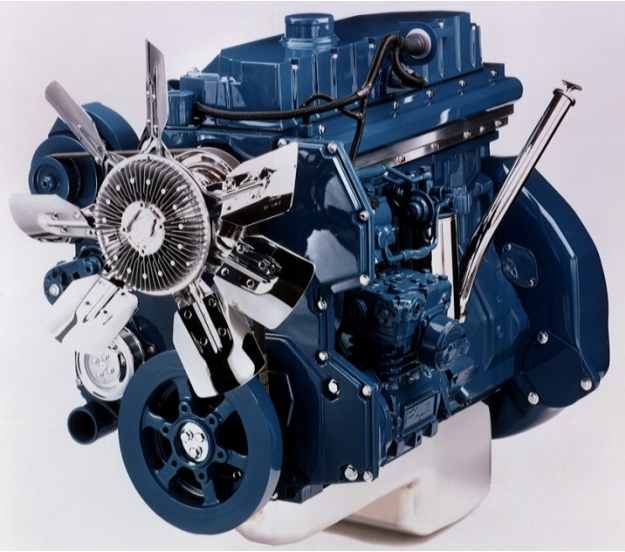
A vehicle moving along a level road must expend tractive power in order to overcome the frictional forces acting upon it. These frictional energy losses include aerodynamic drag, rolling resistance, and the friction associated with the rotating components within the engine and powertrain. In addition to the tractive power, a vehicle must meet various accessory load demands such as air conditioning and air compressors. The sum of these various energy sinks constitutes the total power required by the vehicle at any moment of operation.

The aerodynamic drag acting on a vehicle represents the energy lost when moving the vehicle through the air. The power required to overcome this drag is proportional to the cube of the vehicle speed, and also depends upon the vehicle's shape and the frontal area that is projected toward the direction of motion. Drag can also be increased by the turbulence created by sharp corners and edges, as well as appendages such as rearview mirrors. Drag is usually higher for cab-over trucks as compared to front-engine, or conventional trucks.

In this context, "rolling resistance" primarily refers to tire rolling resistance, but also includes friction in the wheel bearings and other driveline components that rotate when the wheels are rotating. During rotation, tires are deformed by the weight of the vehicle on the road surface. The deformation and subsequent rebounding of the tire consumes energy that is dissipated as heat and sound. This energy is proportional the amount of weight on the tire, as well as other construction and material characteristics. Tire deformation also causes a small amount of slip and frictional loss against the roadway surface, and less firm roadway surfaces such dirt or gravel can also cause energy loss due to deformation or shifting of the roadway surface. Tire pressure affects rolling resistance when operating on paved roadways, as a tire with low pressure deforms more when rolling than a properly inflated tire. Drivetrain losses also can contribute to rolling resistance, as the bearings and lubricants necessary for the operation of driveshafts and axles consume energy due to frictional and hydraulic losses while the vehicle is in motion.

Vehicle accessory loads represent another power demand that must be met in addition to the tractive power demand required to propel the vehicle. Heavy-duty vehicles such as those used in freight movement will typically be equipped with the following components that contribute an accessory load:

- **Air conditioning compressor.** This compressor drives the air conditioning cycle used to cool or dehumidify (in the case of defroster use) the vehicle cab.
- **Onboard air compressor.** This device pressurizes a reserve of compressed air in order to operate trailer brakes, the truck's parking brake, and any other pneumatically driven systems.
- **Alternator.** This device generates the electrical power to charge batteries and operate any electrical loads such as lighting, air conditioning fans, and electrical devices.



AVL Powertrain, NREL 02266

- **Cooling fan.** The cooling fan draws air through the engine's radiator in order to enhance natural air flow. This fan can be driven mechanically or electrically, but either method requires energy to be provided by the main engine.
- **Fluid pumps.** The cooling water pump and oil pump are usually integral to the engine. These devices require the use of fuel energy in the engine that does not result in crankshaft power output, however.

The above energy demands must all be met by the vehicle's power unit, which for most heavy-duty vehicles is a diesel engine. The vehicle's engine and transmission must convert fuel energy into mechanical power to meet the tractive and accessory power demands specified above. The efficiency of the energy conversion, known as brake-specific fuel consumption or BSFC (expressed in quantity of fuel per horsepower-hour of engine work), varies with engine type, engine speed, and load. For a typical diesel engine, the most efficient operating condition in terms of BSFC is relatively high load and low to moderate engine speed. Each particular engine design will have its own BSFC map, which consists of the BSFC value at each point on the map of engine speed vs. torque output. Some of the engine characteristics that help determine BSFC are:

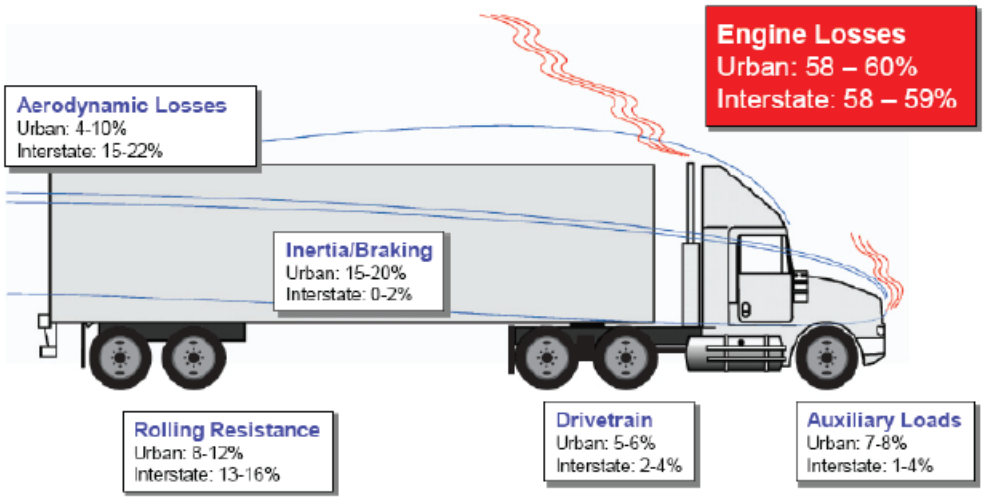
- **Internal friction.** Friction in the engine's bearings, rings, and valve train, along with the viscous drag of rotating parts moving through lube oil, consume some of the power produced by the engine.
- **Engine displacement.** Larger-displacement engines generally have more friction than smaller engines. For a diesel engine, this manifests itself most in terms of the fuel consumption at idle, as at higher speeds and loads the increased output of the engine offsets the increased friction.
- **Engine temperature.** When cold, engines consume more fuel to do the same work than they do when warmed to operating temperature. This is because of reduced combustion efficiency

due to higher heat loss to the cool internal engine surfaces, as well as greater viscosity of the engine oil increasing the parasitic drag on the crankshaft.

- **Waste heat.** Even when fully warmed up, most of the fuel energy that goes into an engine is lost as heat due to inherent inefficiency in the engine's thermodynamic cycle. Designs that reduce heat loss result in higher BSFC.
- **Accessory loads.** Some of the accessory loads described above are internal to the engine and result in fuel energy consumption that does not reach the crankshaft as torque output. The engine's oil pump is an example of an internal accessory as it is typically driven off the camshaft or crankshaft within the engine.[111]

Diesel engines operate using compression-ignition, in which the heat caused by the compression of the air within the cylinder ignites the injected fuel. Diesel engines generally operate unthrottled (with the exception of some modern engines which use throttles for emissions control purposes), which means that the quantity of fuel injected in each stroke determines the engine's torque output, and that the fuel generally burns in an environment containing excess oxygen. Diesel engines operate more efficiently than gasoline engine for two key reasons: their higher compression ratio results in greater thermal efficiency, and unthrottled operation eliminates the energy loss caused by drawing intake air past the throttle's restriction as in a gasoline engine. Figure 5-1 illustrates the various sources of energy losses on a typical truck operating at highway speeds.

Figure 5-1. Typical Energy Demands of Various Losses of a Tractor Trailer Operating at Highway Speeds[112]



John Woodrooffe

[111] Houston Advanced Research Council (2010). *Identification and Assessment of Light Duty Retrofit Vehicle Technologies to Reduce Emissions.*

[112] National Research Council (2010). *Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.*

Tractive power requirements and engine efficiency govern the fuel economy potential for a particular vehicle. The fuel economy that a vehicle achieves while in use, however, also depends on how the vehicle is actually operated. Various modes of operation can result in different fuel consumption rates over a period of time. This variation depends on the following factors:

- **Idling.** Time spent idling is time that the engine is achieving 0 mpg. Driving conditions that include long or frequent periods of idle will result in lower fuel economy.
- **Braking.** Any time that the brakes are used in a conventional vehicle, kinetic energy in the vehicle is lost to heat. This kinetic energy was converted from fuel energy by the engine, so its loss represents energy that can no longer be used to propel the vehicle.
- **Speed.** The power required to overcome the aerodynamic drag force caused by the truck moving through air increases with the cube of the speed of the vehicle. As a vehicle moves faster at highway speeds, the aerodynamic drag becomes the dominant source of energy loss.
- **Terrain.** Driving over inclines often results in more frequent braking and greater opportunities for energy loss.
- **Vehicle weight/payload.** The fuel required to accelerate a vehicle is proportional to the vehicle weight, as is the rolling resistance. Also, increased weight requires more fuel energy to climb over hilly terrain. In the case of freight transport, however, the fuel consumed per payload ton-miles traveled is reduced by loading the vehicle as heavily as possible.
- **Routing.** For a given fuel economy in terms of miles per gallon, fewer miles driven will reduce total fuel consumed. Changing routing or frequency of trips can make it possible to reduce fuel consumption and still deliver needed freight to its destination.
- **Number of cold starts.** As described above, engines do not run as efficiently below their design operating temperature. Frequent short trips with longer periods of engine-off time in between, allowing engines to cool, will result in lower fuel economy because the engine spends more of its operating time in this temperature range.
- **Road surface.** Rougher roads will generally increase rolling resistance. Many international locations require freight trucks to travel over unpaved roads, and these can further increase the energy requirements of rolling tires.

5.1.2 PM and NO_x Emissions

In addition to carbon dioxide, NO_x and PM are the other two key pollutants in diesel exhaust that are considered problematic. NO_x is formed during combustion as a result of the oxidation of nitrogen molecules at elevated temperature. In a diesel engine, NO_x is produced not only at the flame front during ignition, but also within the burned gases in the cylinder as the cylinder pressure (and temperature) continues to rise as remaining fuel burns. In general, higher cylinder temperatures and longer residence times at elevated temperature result in greater levels of NO_x formation. A key challenge regarding NO_x formation is that engines generally operate at higher efficiency levels when higher in-cylinder temperatures and pressures are reached. This is one of

the reasons that there is frequently a tradeoff between fuel efficiency and NO_x formation in engine design.[113]

PM and associated BC are formed in diesel engines primarily due to incomplete combustion of the injected fuel. After injection, a portion of fuel is exposed to enough heat in the cylinder to burn or oxidize, but may not be exposed to enough local oxygen in order to allow complete combustion. This process can also be known as pyrolysis, and produces a less flammable but still organic substance. These secondary substances continue to oxidize in the cylinder and leave behind soot. This process is common in older engines, in which fuel droplets would not completely atomize before combustion, and, as such, would involve oxidation of some of the fuel in the absence of adequate amounts of oxygen. Engine oil that seeps into the cylinder can also provide less flammable organic molecules that can initiate soot formation. After the initial formation of soot particles, which are primarily carbonaceous, other organic materials and byproducts of combustion will continue to condense upon some of the soot particles (while other soot particles may dissociate and react to form CO_2). As the remaining particles expand in the combustion stroke of the cylinder and flow into the exhaust stream, they continue to grow and coagulate, providing a surface for the nucleation of various substances in the exhaust stream and nearby atmosphere.[114]

As described above, diesel particulate is not a homogenous substance. It generally consists of inorganic carbon (or black carbon) coated or interspersed with hydrocarbons or other soluble organic compounds. Not only is particulate matter a respiratory health hazard, the black carbon component is considered a short-term climate forcer, meaning it exhibits global warming potential but does not generally remain in the atmosphere for very long as compared to carbon dioxide.[115] The two mechanisms for warming are airborne PM absorbing sunlight and PM settling on snow or ice, where it will not only absorb sunlight but also block solar reflectivity, further increasing the warming effect.[116]

Fuel characteristics can affect the rate at which some pollutants are formed in exhaust. The fuel's sulfur concentration is one of the most significant properties for determining emission rates. The sulfur in fuel can act as a nucleation site for the formation of PM. Also, modern exhaust after-treatment systems are less effective or can be destroyed when an engine is run with anything but very low levels of sulfur. Exhaust aftertreatment systems reduce tailpipe emissions by converting pollutant molecules into less harmful compounds. For example, a NO_x adsorber catalyst stores NO and NO_2 and then converts these molecules into N_2 and H_2O. Diesel particulate filters (DPFs) trap PM and then convert the particles primarily into CO_2. Both types of devices are less effective if there is anything beyond trace levels of sulfur in the fuel. Generally, fuel sulfur levels are specified by governmental regulation, not the choices of individual operators. In order for advanced aftertreatment systems to function, the political system of the area must make available or require fuel with very low sulfur levels.

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[113] Heywood, J.B. (1988). *Internal Combustion Engine Fundamentals.*
[114] Ibid.
[115] U.S. Environmental Protection Agency (2012). *Reducing Black Carbon Emissions in South Asia—Low Cost Opportunities.*
[116] Diesel Technology Forum (2009). *Climate Change, Black Carbon and Clean Diesel*.

Exhaust aftertreatment systems deteriorate with age and usage, and their effectiveness generally decreases after their initial stabilization when new. In addition to poisoning from sulfur in fuel, improper maintenance can cause aftertreatment systems to deteriorate more quickly. Because they do not always specifically benefit or impact a vehicle's operation or performance, these systems are not always maintained or replaced when they lose effectiveness. In addition to aftertreatment deterioration, pollutant emission rates generally increase as an engine ages as well, especially in terms of PM. As diesel engines age, they tend to operate with reduced fuel pressure, worn fuel injectors, and lower compression ratios. These characteristics tend to result in conditions that increase the rate of formation of PM and reduce combustion efficiency, although NO_x emissions may actually decrease slightly with age.

5.1.3 Recent Trends in Heavy-Duty Diesel Fuel Economy

For the United States and EU, trucks improved in efficiency during the nineties and into the mid-2000s. Beginning around the 2004–2005 timeframe, EPA and EU emissions regulations required significant decreases in NO_x emissions from heavy-duty diesel engines. The aftertreatment and engine designs required to meet these standards inevitably resulted in reduction of the efficiency of these engines to a small degree. As the standards continued to tighten through the 2010 time frame, engine efficiency did not improve due to increases in aftertreatment requirements. Emissions standard changes moving into the future are likely to be less radical than those enacted in the mid- to late 2000s, and it is probable that technology improvements implemented in new trucks will again drive improvements in efficiency as time progresses. This improvement is more likely also because of new heavy-duty fuel efficiency standards being implemented by a number of countries around the world.[117,118]

In the United States, light-duty vehicles have been subject to fuel economy standards since 1975. By the 2000s, many nations had enacted light-duty vehicle fuel economy standards including the EU, Japan, China, South Korea, Canada, and Australia.[119] Heavy-duty vehicles have not received this level of regulatory attention until much more recently. Japan was the first nation to establish a heavy-duty fuel economy requirement, in 2005, though the rulemaking had a long lead time and does not come into effect until 2015. The United States created the second heavy-duty fuel economy requirement. The EPA rulemaking is somewhat more expansive than the Japanese plan. It involves computer simulation, but the model also includes aerodynamics, weight reduction, tire efficiency, and other fuel-saving characteristics. Engine efficiency is verified separately using engine dynamometer results, and the engine dynamometer results are also used in the model. Canadian standards will align with the U.S. program when they come into effect.

China has also developed heavy-duty fuel economy standards. Initially, the Ministry of Industry and Information Technology conducted numerous dynamometer tests of new vehicles in order to establish baseline fuel economy for vehicles with modern technology. This became a minimum-level standard for new vehicles, and is being implemented now with full phase-in required by July 2015. The fuel consumption regulations are based on gross vehicle weight. The Chinese

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[117] National Research Council (2010). *Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.*
[118] International Transport Forum (2011). *Moving Freight with Better Trucks.*
[119] Resources for the Future (2010). *Automobile Fuel Economy Standards—Impacts, Efficiency, and Alternatives.*

program is different than the others mentioned because they use chassis dynamometers for almost all measurements, with options for using modeling in special cases.[120]

To summarize, heavy-duty fuel economy regulations are relatively new, and in place only in some nations. There are significant differences in the various programs, as the "best practice" approach has not yet become apparent. Smaller nations may align themselves with one approach or another to maximize benefit based on similarities with their own fleet of heavy-duty vehicles, or based on the types and country of origin of most new heavy-duty vehicles purchased.

5.2 Technologies for the In-Use Fleet

This section presents various technologies and concepts that can be retrofitted or implemented on fleets of trucks that are already in-use. Retrofit approaches allow for faster technology penetration rates than waiting for new vehicles to replace in-use vehicles through attrition. All of the technologies here are currently available and past the proof of concept phase. Many of the fuel-saving concepts reduce fuel consumption enough that the cost of purchase and installation can be paid back within a few months or years due to the reduction in fuel costs. The costs and benefits of the following technologies are presented in Section 5.2.7.

5.2.1 Aerodynamic Retrofits

One of the most readily available groups of devices available for trucks that travel primarily at high speeds on highways are aerodynamic retrofits. The devices are generally either attached to the tractor or trailer and reduce the level of drag acting on the vehicle. They require an initial capital expenditure but will usually save enough fuel to have a payback period after which the net cost of the device becomes negative. They are only effective on vehicles that typically travel fast enough that their drag reduction benefits outweigh the increased weight of the devices. Trucks in the United States and Canada typically travel faster than the trucks in most other countries, so aerodynamic retrofits will be more effective in the United States.[121] For example, most trucks in the EU are limited to 80 kph (50 mph).[122]

A key consideration for comparing tractor devices to trailer devices is the relative numbers of each. In the United States, there are about three times as many registered box trailers as there are semi trucks. This reduces the true cost-effectiveness of upgrades to trailers as compared to trucks because, on average, each trailer spends much less time in operation than each truck.[123] However, research has shown that trailer modifications can result in greater fuel savings potential than can

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[120] International Council on Clean Transportation (2011). Evolution of heavy-duty vehicle GHG and fuel economy standards. Presentation to Asilomar Conference: Rethinking Energy and Climate Strategies for Transportation.

[121] International Council on Clean Transportation (2011). *European Union Greenhouse Gas Reduction Potential for Heavy-Duty Vehicles.* TIAX reference no. D5625.

[122] European Union Road Safety (2012). Speed limits. Retrieved December 2012 from http://ec.europa.eu/transport/road_safety/specialist/knowledge/speed/speed_limits/current_speed_limit_policies.htm.

[123] Northeast States Center for a Clean Air Future, International Council on Clean Transportation, Southwest Research Institute, and TIAX (2009. *Reducing Heavy-Duty Long Haul Combination Truck Fuel Consumption and CO_2 Emissions.*

changes to modern trucks.[124] Both trucks and trailers can be fitted with devices to reduce the aerodynamic drag caused by the gap between them. This gap causes turbulence and increased drag as air gets entrained and disturbed by the sharp edges of the truck and trailer in this area. This effect is magnified in crosswind conditions, which generally cause combination trucks to have much higher amounts of drag than in calm conditions. The trailer gap should be minimized for drag, but the tradeoff is that space is necessary to prevent contact between truck and trailer during articulation as the vehicle goes over bumps, up and down grades, and around turns.[125] In order to reduce drag caused by the truck/trailer gap, modifications can be made to either the truck, the trailer, or to both.

5.2.1.1 Tractor Treatments

For tractors, there are a few key areas that contribute greatly to drag. Open wheels and rotating tires create large amounts of turbulence, as do exposed fuel tanks, side mirrors, and air filters. At the front of the truck, sharp edges at the hood and fenders can increase drag as well. As air passes around the rear of the tractor, drag is created in the truck/trailer gap as described above. The following devices can reduce the drag caused by these areas.

- **Chassis skirts.** These panels can be fitted in the area between the front and rear tires of the tractor. They can cover an exposed fuel tank or other frame boxes such as battery storage boxes. They reduce the turbulence caused by these appendages as well as turbulence caused by the rotating drive and steering wheels.
- **Wheel covers.** Generally, wheels have an offset so that they have a concave recession in the center. Covering these with smooth wheel covers can reduce drag and turbulence. Consideration should be given to cooling of the brakes: if the truck operates in an area where continuous brake operation is required (such as mountainous regions), smooth wheel covers may not allow adequate brake cooling.
- **Roof deflectors and fairings.** These devices manage the air flow over the top of the truck as it passes over the tractor/trailer gap. If a truck has a roof height that is appreciably shorter than the height of the trailers that it usually tows, aerodynamic drag can be reduced by the addition of a roof deflector or a completely faired roof similar to that found in modern sleeper cabs. These devices allow the airflow to smoothly transition up to the height and width of the trailer and not flow directly into the bluff face of the front of the trailer.

- **Vortex generators.** These devices attach to the rear of the truck's cab just in front of the trailer gap. They create a row of vortices whose axis is parallel with the length of the truck. These vortices have greater energy than the airflow would otherwise have, and so do not change

[124] Hakansson, C., and M. Lenngren (2010). *CFD Analysis of Aerodynamic Trailer Devices for Drag Reduction of Heavy Duty Trucks.* Master's thesis, Chalmers University.
[125] Ibid.

direction as easily as they pass around the sharp rear edge of the truck's cab. As a result, the row of vortices presents a type of "fluidic curtain" that reduces the drag caused by cross-flow and turbulence in the trailer gap area.

5.2.1.2 Trailer Treatments

The trailer has four key areas that contribute to the total aerodynamic drag:

- The trailer gap.
- The underbody.
- The wheel trucks (or bogie).
- The flat back surface for a box trailer.

The underbody usually has appendages that can cause turbulence such as the spare tire carrier, jack legs, and (for trailers with integrated refrigerators or generators) a diesel fuel tank. The rear wheels and axle bogie also cause drag because these bluff mechanical parts are exposed to the airflow, and the exposed rotating wheels cause a large amount of turbulence. Finally, the flat rear of a box trailer causes a large amount of turbulence and wake drag. For ease of loading and unloading, and to maximize internal volume, box trailers usually have flat, squared-off rear surfaces. As air flows around the rear corners of the trailer, turbulence is created and a low-pressure zone is created behind the trailer that exerts a drag force on the vehicle. The following trailer treatments can be used to reduce these aerodynamic drag effects.

- **Trailer nose cone.** A round or bulbous cover can be added to the upper part of the front surface of a box trailer. This device can smooth the flow around the front of the trailer and reduce pressure drag caused by the front face of the trailer. It can also reduce the drag caused by the trailer gap area even if the tractor has a full round air deflector, as its can further eliminate turbulence in this region beyond the level possible with only the tractor fairing.
- **Trailer vortex stabilizer.** This device is a flat vertical panel surface mounted to the center of the front of the trailer. It serves to block cross-flow through the trailer gap. It is especially effective at reducing drag in crosswind conditions, but also can reduce oscillation effects of cross flow through this area even in low-wind conditions.
- **Side skirt.** Side skirts extend downward from the trailer body on each side to cover the area between the jack legs and the trailer wheels. They reduce turbulence and cross-flow in the underbody area, reduce pressure drag on the trailer bogie, and also smooth the flow over the rear wheels. They are susceptible to damage from road debris and also high-centering if cresting sharp gradients. Some of these devices are intentionally created to be flexible in order to reduce damage from these conditions. Side skirts are fairly common on EU trailers, but less so for the rest of the world.[126]

[126] International Council on Clean Transportation (2013). *Trailer Technologies for Increased Heavy-Duty Vehicle Efficiency.*

- **Bogie cover/fairing.** Undercarriage covers consist of fairings around the trailer bogie area. These fairings can smooth airflow around the axles, springs, suspension, and support framework. They would be made less effective by the presence of side skirts on the trailer.
- **Trailer wheel covers.** As with the tractor wheels, smooth covers on trailer wheels can reduce turbulence around rotating wheels and tires as compared to typical concave wheel designs. This drag reduction would be greatest for vehicles equipped with side skirts, because the airflow would be smooth before flowing over the wheels.
- **Vortex generators.** Vortex generators can also be used at the rear of the trailer. Instead of smoothing the flow between the truck and trailer, as they do when installed behind the cab, they reduce the turbulence created by the sharp rear edge of the trailer and smooth the trailer's wake.
- **UnderTray systems.** These systems are retrofit underneath trailers that reduce turbulence and drag at the rear wheels. Different configurations are available with claimed fuel savings ranging from 5 to 10 percent. Trailer clearance is reduced to some extent by these systems.[127]
- **Boat tail/trailer end fairing.** These devices can also smooth the transition of the sharp edge of the rear of a box trailer. The fairings reduce the sharp angled flow at the rear of the trailer and thus reduce pressure drag. A key disadvantage to these retrofits is their effect on opening the trailer doors for loading and unloading. The most important factor in the success of these designs is whether they minimize logistical problems with accessing the rear of the trailer. Because these devices protrude from the rear of the trailer, another limitation is legislation regarding the maximum length of the trailer. The devices will only be useful if they do not require a reduction of the useable volume inside the trailer.
- **Aerodynamic mudflaps.** There are vented mudflaps available that can reduce the drag caused by the flat face of typical mudflaps. These flaps are vented or slatted and reduce drag and are even claimed to reduce the spray caused by water droplets impacting standard flaps.

The effects and benefits of the above devices are not necessarily additive. Some of the different devices address the same sources of drag, and as such only one or the other would be required to achieve most of the fuel savings possible in that area. Conversely, the effectiveness of some technologies may require the presence of others. For example, smooth trailer wheel covers would very likely not reduce drag by any consequential amount without trailer side skirts mounted to smooth the airflow moving toward the wheels. Figure 5-2 depicts a trailer equipped with both side skirts and a rear boat tail.

[127] SmartTruck (2009). SmartTruck systems portfolio. Retrieved from http://smarttrucksystems.com/undertray.php.

Figure 5-2. A Trailer Equipped with Side Skirts, Gap Fairings, and a Rear Boat Tail

5.2.2 Rolling Resistance

Several retrofit options are available to reduce the part of the rolling resistance caused by the tires. Tires must be replaced periodically throughout the life of the vehicle, so shifting to low-resistance options at the time of necessary replacement can reduce capital costs for some tire models. The following is a list of retrofit options that help reduce tire rolling resistance.

- **Low-rolling-resistance tires.** In general, improvements in tire technology have continually reduced truck tire rolling resistance over the last few decades.[128] However, some tires are at the leading edge of these reductions. The SmartWay program certifies some specific models of tire as low-rolling-resistance. For a given level of technological development, there is often a tradeoff between rolling resistance and traction. However, as technology levels improve, rolling resistance has generally decreased over time without a loss in traction.
- **Single-wide tires.** Heavy-duty tractor-trailer trucks operate with dual wheels on each side of the drive axles, and most box trailers have dual wheels on each side of their axles. Each pair can be replaced with single wide-base tires (or super singles) that are nearly as wide as the pair of dual wheels and tires. Replacement requires the purchase of a new wheel to fit the single tires' dimension. These tires reduce rolling resistance as compared to duals. This is thought to be because they have fewer sidewall/tread interfaces, which is an area where significant energy is lost during deformation caused by rolling. Another advantage of this type of tire, especially as compared to trucks and trailers with dual steel wheels, is a weight reduction by substituting a single aluminum wheel. This weight reduction can improve efficiency or allow a truck to haul more cargo for a given gross weight. Outside of replacement wheel cost, the other disadvantage of these tires is reduced ability to run in case of a blowout. A single-tire blowout on a truck with dual wheels will often still allow the truck to "limp" to a service station, but a blowout of a super single will usually require a service technician to travel to the truck in order to replace or repair the tire.[129] While these tires are becoming more prevalent and available in the United States, they may not be available

[128] National Research Council (2010). *Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.*

[129] International Council on Clean Transportation (2013). *Trailer Technologies for Increased Heavy-Duty Vehicle Efficiency.*

enough in other nations to allow for prompt enough repair or replacement in the event of a blowout to justify their use.

- **Low-rolling-resistance retreads.** In addition to low-resistance technologies for new tires, low-resistance retreads are also available. These retreads are available for dual and single-wide tires. While retreads have higher rolling resistance than comparable new tires, some retread products have lower rolling resistance than others.[130] The EPA SmartWay program has verified a number of retread products in addition to the verified new low-rolling-resistance tires.[131]
- **Tire and wheel alignment.** Tire slip angle, which defines an angle between a tire's rotational path and its actual direction of travel, can contribute to rolling resistance. Though this effect is usually small, an operator can eliminate the loss in efficiency caused by this effect by ensuring that an in-use truck and trailer's wheels are in proper alignment.[132]
- **Tire pressure monitoring and automatic tire inflation.** Low tire pressure increases the amount of deformation experienced by a rotating tire, and in turn increases rolling resistance. While many fleets encourage drivers to check tire pressure often, this may not occur for all trucks. Electronic tire pressure monitoring systems (TPMS) allow for passive monitoring of tire pressures. These devices usually have sensors mounted at the tire valves at the time the tire is mounted. The sensors transmit a pressure signal to the head unit, which reports all pressures together and can sound an alarm if one or more tires fall below a set level. The next level of tire pressure management is automatic tire inflation (ATI) systems. These systems contain pressure monitoring systems similar to TPMS, but also tap into the truck's onboard compressed air system. The controller unit can manually or automatically command independent solenoid values to bring up the pressure in a low tire.[133]

5.2.3 Driveline Efficiency Improvements

For the in-use fleet, the most prevalent way to increase driveline efficiency is the substitution of low-friction or low-viscosity lubricants. Fluid lubricants resist the rotation of driveshafts, pumps, and gears due to viscous and shear effects. These cause an energy loss that must be met with power from the engine. These viscous effects can be reduced by specifying low-viscosity or energy-saving engine and transmission fluids. These fluids are designed to still meet the lubrication requirements of the engines, transmissions, and rear differentials while reducing the energy loss from viscous drag. Often, the highest-efficiency lubricants tend to be synthetics, but there are some conventional lubricants available that can increase fuel economy.[134] Higher-efficiency wheel bearing greases are also available, though their benefits may be small enough to be negligible.

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[130] National Research Council (2010). *Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.*

[131] U.S. Environmental Protection Agency (2014). SmartWay technology: About the SmartWay Technology Program. Retrieved from http://epa.gov/smartway/forpartners/technology.htm.

[132] National Research Council (2010). *Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.*

[133] Ibid.

[134] U.S. Environmental Protection Agency (2002). *Industry Options for Improving Ground Freight Fuel Efficiency.*

5.2.4 Idle Reduction

Heavy-duty vehicles often idle for extended periods of time for various reasons. During extended idle, the engine is consuming fuel, pollutant emissions are being produced, but no freight is being moved. Different technologies exist to meet the various needs that cause operators to idle for extended periods while reducing the fuel consumption and emissions effects of the process. The most common reason for extended idling of heavy-duty trucks is to keep climate control systems operating while long-haul drivers are resting in sleeper cabs. This power demand is often called the "hotel load." The following options can help reduce idling:

- **Auxiliary power units.** These are small IC engines that can meet required hotel loads more efficiently than a truck's main engine. They usually power a generator as well as producing useable heat. Because their working parts are much smaller, they operate with far less internal friction than main engines and they can meet the relatively small hotel load requirements while burning less fuel. The key drawbacks to these devices are their initial cost and added weight.[135]
- **Direct-fired diesel heaters.** These devices can provide warmth to the sleeper cab relatively quietly and efficiently. They burn fuel from the truck's main tanks, and this fuel is converted into heat in the cab.[136] They have relatively few drawbacks, except that they are limited in use to cold and winter conditions.
- **Automatic engine shutdown and startup.** These devices electronically control automatic engine startup and shutdown to meet a cab temperature demand or battery charging requirements. They can cycle the engine in either air-conditioning or heating mode in order to keep the sleeper cab within a set temperature range.[137]
- **Battery-powered air conditioning.** These can either use separate batteries or the truck's main battery bank to supply the demands of various hotel loads. Systems exist that can provide eight hours of heating or cooling under moderate conditions. Severe heating or cooling requirements will reduce the length of time for which these devices can meet hotel loads. The key drawbacks to these systems are cost and the weight of increased battery capacity.[138]
- **Thermal storage systems.** These systems use a thermal sink, either water or another working fluid, to store energy taken from the engine when it is running. This stored energy is then drawn into the sleeper cab after the engine is shut down in order to maintain cab temperatures for an overnight rest period. While the engine is running, the thermal storage is either heated by the engine's coolant, or cooled using a refrigeration compressor driven from

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[135] U.S. Environmental Protection Agency (2002). *Industry Options for Improving Ground Freight Fuel Efficiency.*
[136] Ibid.
[137] Ibid.
[138] National Research Council (2010). *Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.*

the truck's electrical system. The drawbacks of this type of system are installation cost and the weight of the thermal sink that must be mounted to the truck.[139]

- **Truck stop electrification.** This is not a vehicle retrofit, but it is a non-OEM concept that does not require the same period of time for benefits to be realized as required by new vehicle rates of market penetration. There are two main types of truck stop electrification.[140]

U.S. Department of Energy

  - *Dual system (shore power/electricity only).* In these types of truck stops, electrical supply is run to stations throughout the overnight parking areas. The operator can plug the truck into these stations and use electricity to run onboard heating or cooling or to power other accessories. The drawbacks to these systems are the cost and weight of onboard AC-powered heating and air conditioning systems. They are referred to as dual systems because they require hardware both at the truck stop and within each truck.[141]
  - *Single system (onsite climate controls and electric).* Some truck stops have stations set up in their parking lots for conditioned air as well as electricity. In these locations, ducting is run to each parking space that can provide hot or cool air as well as electrical outlets for the operation of accessories. They are called single systems because equipment only needs to be installed at the truck stop, not in the trucks. These systems eliminate the need for idling as well as the need to carry the weight of any onboard devices for sleeper comfort. Their key disadvantage is that use is subject to the discretionary pricing of the truck stop operator for these services. They will almost always be priced lower than the cost of extended idling, however. Also, if these types of truck stops are not available all along a route, an operator may need to still carry the weight of other installed systems, partially reducing the benefits that are achievable with these systems.[142]

5.2.5 Exhaust Aftertreatment

Exhaust aftertreatment devices are not designed to reduce fuel consumption or CO_2 production, but rather to reduce regulated pollutant emissions. Because they have no ability to reduce operational costs as do many of the technologies described above, private companies are unlikely to adopt them without some additional incentive.

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[139] Webasto (2014). Bunk cooling systems. Retrieved from http://www.webasto.com/us/markets-products/truck/bunk-cooling-systems/.

[140] National Research Council (2010). *Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.*

[141] Millard-Ball, A. (2009). *Truck Stop Electrification and Carbon Offsets.*

[142] Ibid.

- **Diesel oxidation catalyst (DOC).** These aftertreatment devices facilitate a reaction between PM, HC, and CO in the exhaust to produce CO_2 and water. DOCs are entirely passive systems that can be retrofitted on vehicles widely varying in age, and because of this, they are the most widely-implemented diesel aftertreatment retrofit in the world.[143] The DOC is typically a flow through device, in which the exhaust flows uninterrupted through a substrate designed to have maximum surface area for the reactants to come in contact with the catalyst material. DOCs are tolerant of a wide range of fuel quality and have a fairly low exhaust temperature requirement of around 150º C. These devices became popular in the 1990s in the United States when fuel sulfur was around 500 ppm. They are effective at these sulfur levels and become even more effective at lower levels. DOCs generally reduce the soluble organic fraction of PM by reacting that portion with other exhaust constituents. They are not typically considered to react the elemental or black carbon portion of PM. DOC systems in retrofit are generally known for their high reliability and minimal maintenance requirements.

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- **Diesel particulate filter (DPF).** DPF devices are now standard on OEM trucks in the United States and EU. For new trucks, most OEM DPFs are of the wall-flow type. This type of filter is made up of many porous axial tubes, with alternating tubes capped at either the entrance or the exit. With this design, exhaust flow enters the open tubes, travels through the porous walls of each tube, and exits through the tubes that are open at the outlet. The wall between tubes provides the surface to collect PM. The other type of DPF is the flow-through type. In these filters, a catalyzed metal mesh grid makes up the filter surface. The filter contains metal fins, tubes, and channels that are designed to cause large amounts of turbulence and changes in flow direction to force particles to adhere to the metal mesh inside. Flow-through filters do not have as high a filtration efficiency as wall-flow filters. They are more appropriate for retrofits on older engines that have much higher levels of engine-out PM emissions. One consideration for wall-flow filters is that, at extended intervals, they must be

[143] Manufacturers of Emission Controls Association (2009). *Retrofitting Emission Controls for Diesel-Powered Vehicles.*

cleaned of ash that can slowly build up in their pores. This ash does not burn off during the regeneration cycle, so every few years the DPF must be removed for this service.[144]

For those DPFs that can be regenerated, there are two main types of approaches to regeneration, active and passive. With both of these methods the carbonaceous PM compounds trapped on the filter react with the compounds in the incoming exhaust to create CO_2 and other gaseous byproducts.

- In the case of active regeneration, a control device measures the pressure difference across the DPF; when it hits a threshold, the regeneration process begins. During regeneration, the control unit either increases the temperature of the incoming exhaust or creates an oxidizing environment with an auxiliary fuel injector placed in the exhaust stream. This causes the truck to incur a small fuel consumption penalty during regeneration as this fuel energy is not used to move the vehicle.
- Passive regeneration systems do not require a controller or monitoring of the DPF pressure drop. Instead, they are regenerated any time the engine is operating at high loads with high exhaust temperatures. Application of passive retrofit DPF devices is limited to engines that spend adequate time at high loads. If the engine operates continuously with low exhaust temperatures for an extended period, the DPF could clog. A clogged DPF needs to be removed and cleaned or replaced. This will result in downtime for the truck and may or may not be covered under the truck's warranty.

- **Closed crankcase ventilation.** Older engines typically had crankcases that were vented directly to the atmosphere. During the combustion cycle, a small amount of the byproducts of combustion inevitably slip past the engine's piston rings (a process called blowby) and into the crankcase. Because of the rapid motion of the crankshaft and oil within the crankcase, there are usually suspended droplets of oil in this space. This suspended oil may react with PM and other exhaust compounds to increase PM mass, and then can be expelled from the crankcase due to blowby pressure. If the crankcase is open to the atmosphere, these emissions (which contain pollutants as untreated exhaust) must be considered with the tailpipe emissions to make up the total pollutant emissions from the truck. For a truck equipped with aftertreatment, the crankcase gases escape without the benefit of the reductions to the rest of the exhaust within the aftertreatment devices.

  Closed crankcase systems are not specifically an aftertreatment concept, but do provide an emissions reduction effect. They involve hardware to redirect blowby gasses back into the intake stream of the engine. They are usually equipped with liquid filters that capture droplets of oil and return them to the oil sump of the engines. Any captured PM is removed by the oil filter and eliminated during the next oil change. The filters allow the gaseous portion of the crankcase flow to return to the intake of the engine, where they pass back through the combustion process again.[145]

- **Selective catalytic reduction (SCR).** SCR systems are designed to create a chemically reducing environment in the exhaust to eliminate NO_x. Instead of using fuel to create the

[144] Manufacturers of Emission Controls Association (2009). *Retrofitting Emission Controls for Diesel-Powered Vehicles.*
[145] Ibid.

reducing environment, as in the case of the actively regenerated DPF, SCR systems inject an ammonia-type liquid into the exhaust upstream of a catalyst substrate. OEM-type SCR systems use urea as the working fluid, a molecule of which contains two NH_2 groups instead of the NH_3 atoms in ammonia. The similar atomic structures allow urea to support similar reactions to ammonia, but at a much lower level of toxicity. The urea reacts with the NO_x in the exhaust stream to produce molecular nitrogen and water.[146]

Vehicles equipped with SCR must carry a tank of the urea, which is typically mixed with water and marketed as diesel exhaust fluid (DEF). Generally, the service requirements of SCR systems require the DEF tank to be replenished at approximately the same service interval as the engine oil change. SCR systems are not very susceptible to fuel sulfur poisoning and do not necessarily require ultra-low-sulfur fuel, but they are more effective when used with lower levels of fuel sulfur. In OEM installations, the engine's ECU commands a certain DEF injection rate based on either an expected NO_x formation rate at any given engine operating condition or based on a NO_x sensor in the exhaust. This type of control is considered closed-loop SCR control, and allows for very high NO_x reduction efficiency levels. For retrofits, this level of control is not always possible or affordable. If no NO_x sensor is present, the SCR controller must operate in open loop and the effectiveness of the NO_x reduction is decreased because the DEF injection rate is not precisely matched to the engine's NO_x formation rate. DEF costs approximately $3.00 U.S. per gallon, and trucks consume DEF at a rate of about 3 percent of the amount of fuel consumed. Most U.S. and European spec trucks are programmed to be unable to be restarted, or be able only to run in limp-home mode, if their DEF tanks become fully depleted.[147]

- **Lean NO_x catalyst (LNC)** or **lean NO_x trap (LNT).** These systems are both designed to reduce the NO_x in the exhaust stream, usually by using fuel injected into the exhaust to react with the NO_x in the presence of a catalyst. As a result, both types of system usually require a small penalty to fuel economy in order to achieve NO_x reduction levels high enough to justify their installation costs.
    - In the LNC, the catalyst reduces a portion of exhaust NO_x continuously. This is usually done with a small amount of fuel continuously or periodically injected upstream. However, these devices can also operate without exhaust fuel injection, though their effectiveness will be greatly reduced in that configuration.[148]
    - In the LNT, also known as a NO_x adsorber catalyst, NO_x molecules entering in the exhaust stream are stored temporarily on catalyzed surfaces as they flow through the unit. An LNT system is designed to have an interior framework with maximum catalyzed surface area for storage of NO_x molecules. In retrofit systems, these stored molecules are periodically reduced directly off the surfaces by briefly injecting fuel into the exhaust stream. In OEM applications, the reducing environment in the exhaust can often be created through engine calibration without necessarily requiring an exhaust fuel injector,

[146] Manufacturers of Emission Controls Association (2009). *Retrofitting Emission Controls for Diesel-Powered Vehicles.*
[147] Johnson, C. (2012). *What Truck Stop Operators Need to Know About Diesel Exhaust Fluid (DEF).*
[148] Manufacturers of Emission Controls Association (2009). *Retrofitting Emission Controls for Diesel-Powered Vehicles.*

but in either case a fuel consumption penalty will result. LNT systems can have an effectiveness of up to or over 90 percent.[149]

- It is possible to combine the above technologies in various ways. In general, closed crankcase ventilation operates independently and can be used with (or without) any of the other systems. For the others, aftertreatment concepts generally involve the combination of one PM filtering device and one NO_x-reducing device. Common aftertreatment combinations are.
  - LNC/LNT + (DPF or DOC)
  - DOC + SCR
  - SCR + DPF
  - DOC + DPF
- **Fuel sulfur and aftertreatment systems.** Many of the devices listed in this section require low levels of fuel sulfur to function and to avoid damage. Mandating fuel sulfur concentration levels requires regulatory action and is not typically a choice made by end users. In general, the more effective the aftertreatment, the less fuel sulfur it can tolerate. The DOC and SCR retrofits can tolerate a moderate amount of sulfur (up to approximately 500 ppm), but the other devices generally require fuel sulfur levels in the range of 10 to 30 ppm. As a result, the first step in any retrofit program is to make sure that the desired aftertreatment types can function on the type of fuel that is usually supplied in the area of interest.

5.2.6 Fuel Strategies

Diesel vehicle operators have a small number of fuel-related options for reducing the emissions of trucking operations:

- **Biodiesel blends.** Operators can fuel in-use trucks with biodiesel blends. Blends with conventional diesel of up to 20 percent biodiesel (B20) are compatible with most existing engines and infrastructure. Higher-percentage blends may be used with minor changes to fittings and other vehicle components, as well as other fuel delivery and storage systems, depending on specific designs. Operators of newer vehicles under warranty should verify that the biodiesel use does not void the warranty, as some manufacturers do have biodiesel exclusions. Research into sourcing biodiesel from algae continues, and this holds promise as the source of biodiesel with the lowest requirement for energy input during production of the fuel.

  There is considerable uncertainty over the life-cycle GHG benefits of biodiesel when indirect land use change and other indirect effects are included. The estimated GHG impacts of B20 produced from soy range from a 13 percent reduction to a 10 percent increase in GHG emissions compared to conventional diesel. If the biodiesel is sourced from a truly renewable feedstock, its use will have a net GHG benefit. Operating a diesel engine with biodiesel typically results in lower PM emissions as well. Data regarding its effect on NO_x emissions shows some disagreement, with some sources suggesting a slight increase and some showing

[149] Ibid.

a decrease or equivocal impacts. HC and CO, while typically already very low in diesel combustion, are also lower from engines operating on biodiesel. The energy content of biodiesel is lower than that of conventional diesel fuel, so operators will experience slightly increased fuel consumption. Depending on the method used for production of the fuel, GHG reductions are still possible in spite of increased consumption because the fuel is renewable.[150,151]

- **Cetane-enhancing additives.** These additives can affect the way fuel is burned within a diesel engine. The cetane number refers to a fuel's propensity to ignite; and higher cetane is desirable for cold starting and driveability, especially in older engines. In locations that have a relatively low-cetane fuel supply, benefits can come from the use of additives that increase cetane. These additives can reduce NO_x and PM formation, primarily in older engines. Cetane improvers generally do not have an appreciable benefit when used with higher-cetane base fuels, such as those with a cetane over approximately 50–55. While there is some anecdotal information in the literature suggesting possible fuel economy improvement with the use of cetane improvers in low-cetane fuel, there is little independent data to support this and the effect seems to be dependent upon specific engine designs.[152,153]
- **Natural gas conversion.**[154] Natural gas retrofit systems are available for a variety of heavy truck makes and models, and can often be installed by local vendors. Natural gas use practically eliminates PM emissions, a great benefit compared to older diesel engines. NO_x emissions may also be reduced, although carbon emission impacts are likely equivocal relative to diesel.[155] Compressed natural gas (CNG) and liquefied natural gas (LNG) conversions are generally lower in cost than purchasing new vehicles from OEMs, but the conversion systems themselves can be less reliable and durable than OEM vehicles if not performed properly. CNG tanks store gaseous fuel at high pressures (e.g., commonly at 3,600 psi), although vehicle range may be very limited compared to diesel due to the much lower energy density. For this reason CNG conversions are typically applied to local delivery fleets with relatively low daily mileage and a central refueling location. CNG conversions also require multiple, bulky storage tanks, which add weight and limit available cargo space. LNG systems are more expensive than CNG but offer longer range, and can be adopted for long-haul applications. Depending upon the local availability and cost of CNG and LNG, substantial fuel cost savings may be realized through this option.

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[150] National Renewable Energy Laboratory (2013). *Clean Cities Guide to Alternative Fuel and Advanced Medium- and Heavy-Duty Vehicles.* Publication no. DOE/GO-102013-3624.

[151] U.S. Environmental Protection Agency (2002). *A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions.* EPA-420-P-02-001.

[152] U.S. Environmental Protection Agency (2003). *The Effect of Cetane Number Increase Due to Additives on NO_x Emissions from Heavy-Duty Highway Engines.* EPA-420-R-03-002.

[153] Chevron Global Marketing (2007). *Diesel Fuels Technical Review.*

[154] http://www.afdc.energy.gov/vehicles/natural_gas_emissions.html

[155] Improperly maintained CNG/LNG equipment can leak large amounts of methane, resulting in a much greater GHG impact than equivalent diesel vehicles.

5.2.7 Costs, Benefits, and Degree of Utilization for Retrofittable Strategies

The technologies and concepts discussed in Chapter 5 require a capital cost for the hardware purchase, and some involve ongoing maintenance costs that can usually be estimated on a per-mile-traveled basis. Many of the fuel-saving concepts reduce operating costs in such a way that there is a payback period after which cost reductions exceed the installation cost. The exhaust aftertreatment concepts generally have a small fuel consumption penalty associated with their use, so they will not have a payback period unless the trucks operate in an area where legislative initiatives provide compensation through grants or other means for emissions reductions. One example of this situation was the Ecopass area in Milan, Italy. This program operated from 2008 to 2011 and involved a use tax on polluting vehicles entering the city center. Diesel vehicles equipped with DPFs were allowed to access this area at no cost.

Estimates of the cost and benefits of the various on-road fuel-saving retrofit devices are presented in Table 5-1. The benefits in terms of fuel consumption are presented in terms of the percent reduction in fuel consumed for a typical on-highway freight truck. The table divides the costs of the devices into capital/one-time costs and operating/continuous costs, presenting the latter in terms of per mile or per year. Finally, the table lists any co-benefits or potential negative side effects that can affect a truck's operations.

Table 5-1. Costs and Benefits of the On-Road Retrofit Technologies for On-Highway Freight Trucks

Device	Benefit (% Reduction in Fuel Consumed)	Capital Cost ($ U.S.)	Operating Cost ($ U.S.)	Co-benefit or Side Effect
Tractor roof and side fairings	1–2%[a] 2–10%[b] 3–5%[c]	1,250[a,d] 300–1,800[b]	—	
Vortex generators on truck and trailer	Up to 2–3%[b,e]	$220[b]	—	Can increase the stability (or perceived stability) of the truck and trailer.
Tractor side skirt	3-4%[b] 3-4% [c]	1,500–2,000[b]	—	
Trailer side skirt	5.6–7%[b,e]	700–1,000[f]	50–400/year if damaged[g]	Susceptible to damage on severe terrain or over steep railroad crossings.
Trailer nose cone	2–3.8%[b,h]	800–1,260[b]	—	
Trailer boat tail/rear fairing	2–4%[a] 2.8–4.8%[b,h] 4–6%[c]	1,000–1,600[f]	—	Can cause a loading delay depending on how quickly it can be moved out of the way of the trailer doors.
Low-rolling-resistance tires	5%[a] 1–2%[c] 3% or more[i]	455[a,d] 240[c] 300–500[j]	—	Can also reduce NO_x emission rate by 3%.[i]

Device	Benefit (% Reduction in Fuel Consumed)	Capital Cost ($ U.S.)	Operating Cost ($ U.S.)	Co-benefit or Side Effect
Single-wide tires	9–12%[a] 2.6%[k] 5%[k] Up to 10%[b] 4–6% (trailer)[c] 5–10%[j]	450[a,d] 900 (trailer) [c] 1,700[j]	—	Weight reduction can benefit cargo capacity. Can also reduce limp-home ability of truck in case of a blowout.
Low-friction driveline lubes	1.5–3%[k]	—	Up to 0.004 per mile[b]	
Automatic tire inflation system	Variable	700–1,000[f]	—	

Notes

[a] International Council on Clean Transportation (2011). *European Union Greenhouse Gas Reduction Potential for Heavy-Duty Vehicles.* TIAX reference no. D5625.

[b] National Research Council (2010). *Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.*

[c] International Council on Clean Transportation (2013). *Trailer Technologies for Increased Heavy-Duty Vehicle Efficiency.*

[d] Converted euros to U.S. dollars using 1.3 dollars per euro (as of the December 2011 publication date).

[e] Values taken from manufacturer-supplied data, not independent test data.

[f] Sharpe, B., and M. Roeth (2014). *Costs and Adoption Rates of Fuel-Saving Technologies for Trailers in the North American On-Road Freight Sector*. Retrieved from http://www.theicct.org/sites/default/files/publications/ICCT_trailer-tech-costs_20140218.pdf.

[g] Lowe, M., G. Ayee, and G. Gereffi (2009). Chapter 9: Hybrid drivetrains for medium- and heavy-duty trucks. In *Manufacturing Climate Solutions: Carbon-Reducing Technologies and U.S. Jobs.* Retrieved from http://www.cggc.duke.edu/environment/climatesolutions/greeneconomy_Ch9_HybridDrivetrainsforTrucks.pdf.

[h] ERG converted values from percent fuel economy improvement to percent fuel consumption reduction.

[i] U.S. Environmental Protection Agency (2014). SmartWay technology: About the SmartWay Technology Program. Retrieved from http://epa.gov/smartway/forpartners/technology.htm.

[j] International Energy Agency (2012). *Technology Roadmap—Fuel Economy of Road Vehicles.*

[k] Federal Railroad Administration (2009). *Comparative Evaluation of Rail and Truck Fuel Efficiency on Competitive Corridors.*

Not all of the benefits presented in the table are additive. For example, if a truck has well-faired sides and roofline, the addition of a trailer nose cone may not produce as great a benefit. It is important that each operator select from the best technologies that are most conducive to benefits for the type of operation that is most often encountered. Also, as mentioned in the table, two of the benefit estimates are drawn from manufacturer data and do not necessarily reflect independent testing results. Finally, some of the benefit percentage estimates were taken from literature that gave values in terms of percentage increases in fuel economy. ERG converted these values to percent reduction in fuel consumption so that all values would be presented on the same basis.

The various strategies that address extended idle reduction are presented in Table 5-2. The reduction in fuel consumed for a typical long-haul truck are given, as well as the costs involved for each. Most onboard strategies are given as capital costs, but the truck stop electrification concepts have both capital costs and per-use costs.

Table 5-2. Costs and Benefits of the Extended-Idle Reduction Strategies

Device	Benefit (% Reduction in Fuel Consumed)	Costs ($ U.S.)	Co-benefit or Side Effect
APU	8.1%[a] 4–8%[b] 5–6%[c]	5,000–12,000[b]	Increased weight, noise, and maintenance, but flexible and can be used anywhere. Does require yearly maintenance.
Diesel heat	4.3%[a] 1–3%[b]	1,000–3,000[b]	Can only provide heat.
Engine start/stop control	5.6%[a] 2–3%[b]	0 (OEM)[b] 1,325–3,750 (retrofit)[b]	Engine starting and stopping can interrupt driver rest.
Battery AC	Variable[d]	1,600–6,900[b]	Batteries add weight to vehicle and the cooling systems may not be able to keep cab cool on hotter days.
Thermal storage	7–8%[e]	2,700[f]	Very efficient when used for heat, as it uses heat that would otherwise be wasted. Does require some extra fuel consumption for cooling, however.
Dual TSE	7–8%[e]	Capital cost for operator: 125–2,500 Approximately 0.50 per hour[b] to $1 per hour[g] 1,700[f] For truckstop: 4,500–$8,500 per space[g]	There are a limited number of available parking spaces based on the number of equipped truck stops. Weight and investment of systems are not beneficial if the truck must spend some rest periods at non-TSE locations. Operators become subject to pricing variation of TSE company.
Single TSE	7–8%[e]	Minimal capital costs: 1.85–2.18 per hour,[b] up to 2.45–2.89 per hour[g] For truckstop: 10,000–$20,000 per space[g]	There are a limited number of available parking spaces based on the number of equipped truck stops. Weight and investment of systems are not beneficial if the truck must spend some rest periods at non-TSE locations. Operators become subject to pricing variation of TSE company. Systems can also provide ancillary benefits such as TV or Internet connectivity.

Notes

[a] Federal Railroad Administration (2009). *Comparative Evaluation of Rail and Truck Fuel Efficiency on Competitive Corridors.*

[b] National Research Council (2010). *Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.*

[c] International Council on Clean Transportation (2013). *Trailer Technologies for Increased Heavy-Duty Vehicle Efficiency*.

[d] Available literature values do not take fuel burned for increased alternator charging load into consideration, and so are not appropriate from an engineering perspective.

[e] These estimates are based on the estimate of total fuel burn during idling for an average long-haul truck. The devices can reduce fuel consumption up to this total amount. See Northeast States Center for a Clean Air Future, International Council on Clean Transportation, Southwest Research Institute, and TIAX (2009). *Reducing Heavy-Duty Long Haul Combination Truck Fuel Consumption and CO_2 Emissions*.

[f] Argonne National Laboratory (2000). *Analysis of Technology Options to Reduce the Fuel Consumption of Idling Trucks Center.* Publication no. ANL/ESD-43.

[g] Millard-Ball, A. (2009). *Truck Stop Electrification and Carbon Offsets.*

Section 5.3.6 also described various pollutant-reducing aftertreatment systems that can be retrofitted to in-use vehicles. These systems are summarized in Table 5-3 with the pollutant reduction levels and the installation costs. The installation costs also include the approximate length of time for an experienced shop to install the devices. The table also includes the approximate level of fuel economy penalty that can be expected due to the operation of the systems.

Table 5-3. Costs and Emission Reduction Levels of Various Retrofit Aftertreatment Devices

After-treatment Type	Percent Reduction in Pollutant Emissions				Cost (U.S. $)	Fuel Economy Penalty[a]
	NO_x	PM	HC	CO		
DOC	—	20–40%[b] 25–50%[c]	40–70%[b] 50–90%[c]	40–60%[b]	600–4,000 + 2 hours[b] 500–2,000[c]	—
DPF (wall-flow)	—	85–95%[b] >85%[c]	85–95%[b] 50–95%[c]	50–90%[b]	8,000–50,000 + 7 hours[b] 7,000–30,000[c]	1%
DPF (partial/ flow-through)	—	Up to 60%[b] 30–60%[c]	40–75%[b] 50–95%[c]	10–60%[b]	4,000–6,000 + 7 hours[b] 5,000–7,000[c]	< 1%
CCV[d]	—	Variable 5–10%[c]	—	—	450–700[c]	—
SCR[d]	Up to 75%[b] 80%[c]	20–30%[c]	80%[c]	—	10,000–20,000[b] 16,000–20,000[c]	< 1%
LNC[d]	5–40%[b] 5–30%[c]	—	—	—	6,500–10,000[b] 15,000–20,000[c]	3%
Biodiesel use[e]	-2%[f]	10.1%[f]	21.1%[f]	11%[f]		1–2%[g]

Notes

[a] Jackson, M., R. Schubert, and E. Kassoy (2005). *Comparative Costs of 2010 Heavy-Duty Diesel and Natural Gas Technologies.* TIAX reference no. D0286.

[b] U.N. Centre for Regional Development (2011). *Best Practices in Green Freight for an Environmentally Sustainable Road Freight Sector in Asia.* Retrieved from http://cleanairinitiative.org/portal/sites/default/files/BGP-EST5A_Green_Freight_Best_Practices_-_CAI-Asia_Dec2011.pdf.

[c] Manufacturers of Emission Controls Association (2009). *Retrofitting Emission Controls for Diesel-Powered Vehicles.*

[d] Can combine with DOC or DPF to reduce emissions from all four pollutants.

[e] Trucks with aftertreatment systems will have lower benefits and penalties from biodiesel use.

[f] U.S. Environmental Protection Agency (2002). *A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions.* EPA-420-P-02-001.

[g] Biodiesel use typically results in a well-to-wheels GHG emission reduction in spite of the increased fuel consumption rate.

5.3 Technologies for the OEM Fleet

This section presents various technologies and options that can be specified or chosen in the purchase of a new heavy-duty diesel truck. The technologies presented here are generally available, and any increased demand is likely to decrease cost of production as volume increases. Some of the devices and concepts in this section can reduce fuel consumption enough that the

additional cost of the option can be paid back within some period of time due to the reduction in fuel costs.

Many of the retrofit technologies described in Section 5.2 can also be used with new trucks. This section primarily focuses on additional technologies that could not be practically or cost-effectively added to in-use vehicles.

5.3.1 Engine Efficiency/Thermal Management

Engine manufacturers continuously seek to improve their engines' thermal efficiency—the amount of fuel energy that actually creates torque output and is not lost as waste heat, either to the engine's coolant or as thermal energy in the exhaust stream. Turbocharging allows an engine to recoup some of the energy that would otherwise be wasted in the exhaust, and has been used in production diesel truck engines since the 1950s. Much more recent designs improve the efficiency of exhaust energy recovery even more, and some of these concepts are described below.

- **Dual-stage turbocharging.** Engines using this technology have two different turbochargers mounted in series. Generally, the two have different but complementary characteristics. For example, one turbocharger may be large to efficiently convert high exhaust flow rates to higher pressure in the intake, and the other may be relatively small in order to respond quickly to changes in exhaust flow rate. By having two different turbochargers, the engine can operate more efficiently over a wider range of operating conditions. Additionally, two-stage turbochargers can drive a higher overall intake pressure than can a single turbocharger, which allows for engine downsizing while maintaining the same power output level.
- **Variable geometry turbocharging (VGT).** Another way to allow the turbocharger to work more efficiently over a wide range of speeds and loads is to employ variable geometry. A turbocharger is a device with an exhaust flow-driven turbine (located in the upstream part of the exhaust) that is directly connected to and drives a compressor in the engine's intake stream. Typical turbochargers employ fixed geometry, so the designed ratio of flow through the intake and exhaust turbines is fixed. This means that the system design must be a compromise intended to work over all engine speeds and loads. As a result, the system is not as efficient as it could be, especially at operational extremes. Variable geometry systems allow the design flow/pressure ratios to vary as necessary to maintain more efficient engine operation (i.e., the device can supply a larger amount of air at low loads while still not over-pressurizing or choking the airflow at higher speeds and loads). VGT systems generally work by altering the geometry at the point where the exhaust flow meets the turbine blades. VGTs can vary the angle of stator blades in the exhaust housing, increasing or decreasing the angle and speed of the exhaust flow against the turbine. They can also expand or restrict the size of the aperture in which the exhaust enters the turbine housing. By decreasing the size of this opening, the flow speed increases for a constant flow rate, increasing the energy transferred to the turbine blades.[156]

[156] Mowitz, D. (2013). Variable geometry turbocharger. *Successful Farming* (summer): 24–26.

- **Turbocompounding.** This is a similar concept to turbocharging as it is intended to recoup some of the energy that would otherwise be lost in the exhaust stream. As with a turbocharger, a turbine is mounted in the exhaust stream. Instead of driving a compressor in the intake, however, the torque from this shaft either powers an electric generator or is connected to the engine's crankshaft via a geared drive in order to supplement the cylinder torque on the crankshaft. These devices can be used in addition to a turbocharger, and in this case are generally mounted downstream of the turbocharger.[157,158]
    - *Mechanical turbocompound*. In a mechanical turbocompound system, the exhaust turbine is geared to provide additional torque to the engine's driveshaft. These systems are generally connected via a fluid coupling that reduces the forces caused by oscillations in the crankshaft. The gear ratio between the turbine speed and the engine speed needs to be so great in order to operate efficiently that combustion oscillations could damage the turbine or housing without the fluid coupling in place.
    - *Electrical Turbocompound*. These systems use the rotational energy in the exhaust turbine to drive an electric generator instead. The electric generator can be used to control the load on the turbine irrespective of the crankshaft rotational speed. Because of this, electrical turbocompounding can be more efficient than mechanical systems. However, the rest of the vehicle must be able to use the greater amount of electrical energy. Electric hybrid drive systems can use this power, as can trucks with greater electrical demands (such as those with multiple electrified accessories like power steering, coolant, and oil pumps).
- **Variable valve actuation.** This technology initially gained popularity in light-duty gasoline engines in the 1990s, but is now being adopted in some heavy-duty diesel engines. This design allows the intake and/or exhaust valve timing to be varied throughout a range depending on engine operating condition. Just like a conventional turbocharger, conventional valve timing represents a single compromise value that must work over the entire range of engine operating conditions. When the engine computer can vary this value, air can flow through the engine more efficiently over the entire range of speeds and loads. The efficiency benefit of variable valve timing is more limited for diesel engines than for gasoline, but the system becomes more effective when used to assist either turbocompounding, exhaust gas recirculation, or other advanced exhaust flow managing systems, as it can be used to alter the energy in the exhaust under some operating conditions. One example of this alteration would be to change the exhaust valve timing so that the exhaust valves open earlier to allow higher temperatures and/or pressures in the exhaust stream under some conditions, helping to increase EGR flow or turbocompounding effectiveness.[159]

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[157] Northeast States Center for a Clean Air Future, International Council on Clean Transportation, Southwest Research Institute, and TIAX (2009. *Reducing Heavy-Duty Long Haul Combination Truck Fuel Consumption and CO_2 Emissions.*

[158] National Research Council (2010). *Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.*

[159] Northeast States Center for a Clean Air Future, International Council on Clean Transportation, Southwest Research Institute, and TIAX (2009. *Reducing Heavy-Duty Long Haul Combination Truck Fuel Consumption and CO_2 Emissions.*

5.3.2 Mass Reduction

The reduction of vehicle mass reduces the road loads on the vehicle. A vehicle with lower mass requires less fuel energy to accelerate to highway speed, consumes less fuel when climbing hills, and also has lower rolling resistance. In a freight vehicle, reducing truck mass can also allow that weight to be replaced with greater payload capacity. If this is the case, the substitution does not improve the fuel economy of the vehicle, but it still does improve fuel economy in terms of the freight movement in freight-ton miles per gallon. Many trucks operate empty, partially loaded, or completely loaded by volume but not weight, and in all of these cases, mass reduction can improve vehicle fuel economy.

Vehicle mass reduction can vary greatly in cost-effectiveness. There are advanced materials that are extremely light but extremely expensive, and replacement materials must be carefully selected and extensively tested to ensure they satisfy the many demand requirements of the material being replaced. Carbon fiber and other advanced materials fall into this category. For heavy-duty trucking, weight reduction in the near term is likely limited to replacing components made from low-alloy steel with those made either from high-strength steel or aluminum. Depending on duty cycle and initial weight, a class 8 combination truck can improve fuel consumption anywhere from 0.5 percent to 1.5 percent with a reduction of 1,000 pounds.[160]

As mentioned in Section 5.2.2, operators can select wide-base tires to substitute for dual wheels and tires at the ends of each axle. In addition to reducing rolling resistance, specifying single aluminum wheels reduces weight as compared to dual steel wheels. Weight reduction at the wheels is even more beneficial than weight reduction of other components because the mass of the wheels requires energy to accelerate rotationally as well as linearly along a road's surface. Specifying wide-base tires at the time of purchase makes them more cost-effective than if purchased to replace wheels as a retrofit. Even if wide-base tires are not specified, the use of aluminum wheels can reduce fuel consumption as compared to steel wheels.

Several manufacturers are using lighter-weight materials in construction of their trucks. Cab and sleeper units built using more aluminum in the structure are gaining market share. Some modern engines use lightweight and strong compacted graphite iron (CGI) for engine blocks and turbocharger housings. Suspension components such as leaf springs can be replaced with composite materials. Some driveline components can be made of composites or aluminum. When purchasing a new truck, buyers who are aware of the various areas in which weight reduction can take place will be better able to choose the lightest truck possible. As more buyers demand weight reductions, manufacturers will place a greater priority on this concept.

New trailers can also benefit from substitution with lighter components. Modern trailers use less wood, steel, or iron than older trailers. Notably, aluminum can be used in place of other heavier materials to reduce trailer weight. The floor crossmembers and roof supports are both types of components that, when replaced with aluminum, can save a few hundred pounds. Specifying a

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[160] National Research Council (2010). *Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.*

lighter trailer at the time of purchase will result in fuel savings and greater productivity for routes that are loaded to the maximum allowable GVW.

5.3.3 Driveline Efficiency

New truck buyers have the opportunity to specify fuel saving options in the driveline of their trucks as well. Certain types of transmissions and drive axle configurations can save fuel over conventional systems. Depending on the anticipated duty cycle of the truck, purchasing hybrid options may result in fuel consumption reductions as well.

- **Reducing driveline losses.** Class 8 long-haul trucks are generally equipped with manual transmissions. While these transmissions are fairly efficient, their operation requires a drive interruption during each shift, in which the engine is running and consuming fuel but no torque is going to the wheels. Some trucks, primarily those used for short hauls, use automatic transmissions with a fluid coupling to allow shifts to take place. While they do not have a torque interruption during shifting, the fluid coupling does consume energy and they typically are less efficient than manual transmissions. Recently, automated manual transmissions (AMTs) have become available, combining the benefits of both previous types of units. They are mechanically similar to manuals and do not have a fluid coupling, but the control computer performs the shifts very quickly so there can be less torque interruption than with a conventional manual. They can be set to choose the most efficient gear at any given time and offer fuel economy benefits over either other type of transmission.

  Typical class 8 trucks that have dual axles have conventionally had both axles powered. The differential of the first axle has an output shaft that continues back to drive the second axle. This is considered a 6×4 configuration, meaning the truck has six total wheels (or wheel pairs), four of which are driven. For trucks that do not typically operate in low-traction environments, 6×2 configurations can reduce fuel consumption. In this configuration, only the forward of the rear axle pair is driven. This saves the frictional losses in the front differential's output shaft bearing and the differential gears and bearings in the rear axle. While it has a lower initial cost than the 6×4, the penalty is a loss of traction in some terrain situations in which the forward drive axle has less traction than the rear, resulting in wheel slip. The 6×2 configuration is fairly common in European trucks but relatively uncommon in trucks sourced from the United States.[161]

- **Hybrid drive systems.** Hybrid systems have been developed in order to recoup energy that would otherwise be lost as heat in the braking system when slowing down. Hybrid systems for heavy-duty trucks operate either electrically or hydraulically. They allow the energy of a vehicle to be stored as the vehicle slows down (termed regenerative braking), and then released to assist the drive engine in getting the vehicle moving again. In general, a hybrid system will have the most benefit on trucks that have frequent stops and starts in their duty cycles. Hybridization can also benefit fuel economy by allowing the specification of a downsized engine. Because peak power demands can be reduced by the addition of the hybrid system, the engine can be smaller, with reduced frictional losses, and still maintain the

[161] National Research Council (2010). *Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.*

same level of driveability. Finally, some hybrid systems are designed to allow an engine to continuously operate under its most efficient operating conditions more often. This allows the engine to produce usable output energy more efficiently than in a conventional vehicle. A hybrid system generally adds significant weight to a vehicle, but this weight is usually more than offset by the increased energy efficiency that comes with regenerative braking, especially over driving cycles with frequent starts and stops.[162]

Hybrid systems can have varying levels of energy storage. The greatest efficiency gains come when the total energy storage is well matched to the duty cycle demands and typical weight of a given truck. Too much energy storage generally results in reduced effectiveness due to the added weight and cost of the system. Too little energy storage will not allow the full benefits of the system to overcome the increased cost and complexity of the various hybrid components.

- *Electric hybrids.* Electric hybrids use batteries to store the energy of the hybrid system. Generally, these vehicles have an electric motor that can also act as a generator. An electronic motor controller optimizes the level of torque output or power generation that takes place on a second-by-second basis. Electric hybrid systems can offer a wide range of capacities and functions. The minimal level of hybridization is the integrated starter and alternator. In this system, the hybrid generator performs the functions of the alternator and starter. When the vehicle comes to a stop, the system automatically shuts the engine down to prevent idling and save fuel. When the vehicle is ready to accelerate, the integrated system acts as a heavy-duty starter that starts the engine, allowing it to immediately accelerate the vehicle. This is known as a mild hybrid system. The amount of hybridization and electrification can increase all the way up to the plug-in hybrid electric vehicle (PHEV) in which the electrical storage capacity and motor power are so great that the truck can be plugged in while parked and then operate for the first few miles on electricity alone.

  Driveline hybridization can be used for parallel benefits in various heavy-duty applications. As mentioned in Section 5.3.1, electric turbocompounding systems can create a source of a large amount of electrical energy. Electric hybrid systems can be used store and use this electrical energy. Electric accessories such as power steering, engine cooling pumps, and electric air compressors, which are traditionally driven directly off the engine accessory belt, can also provide an efficient use of this energy. For long-haul heavy-duty trucks, larger amounts of electric energy storage can be used to meet or help meet hotel loads such as heating or air conditioning.[163,164]

- *Hydraulic hybrids.* These systems use hydraulic fluid to transfer energy stored by the hybrid system. These devices use tanks in which the hydraulic fluid compresses a gas in order to store energy, known as an accumulator. A hydraulic pump/drive performs a similar function to the motor/generator in an electric hybrid. The driveline is connected to

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[162] Ibid.

[163] National Research Council (2010). *Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.*

[164] Lowe, M., G. Ayee, and G. Gereffi (2009). Chapter 9: Hybrid drivetrains for medium- and heavy-duty trucks. In *Manufacturing Climate Solutions: Carbon-Reducing Technologies and U.S. Jobs.* Retrieved from http://www.cggc.duke.edu/environment/climatesolutions/greeneconomy_Ch9_HybridDrivetrainsforTrucks.pdf.

the pump/drive so that it can either pump fluid into the accumulator during regenerative braking, or provide torque output when stored gas pressure drives the fluid back out of the accumulator and through the hydraulic pump/drive.

Hydraulic hybrids are generally most effective in extreme stop and go conditions. This is because they have high power density but limited energy storage capability; they can provide a large amount of power for a brief period. As such, their benefits are maximized in situations in which there is frequent use of regenerative braking. This is typically encountered in relatively low speed routes and duty cycles.

Heavy-duty trucks frequently have to meet vocational demands. Long haul hotel loads could be considered one type of vocational demand, while other types of trucks have hydraulic or electrical loads that must be met. Generally, even though hydraulic hybrids could provide stored energy for vocational loads, electric hybrids are better suited to meet these demands because of their greater energy density; they can drive vocational loads for longer amounts of time in spite of the energy losses associated with charging and discharging the battery system.[165,166]

5.3.4 Alternative Fuels/Advanced Power Sources

At the time of purchase, new truck buyers can specify powertrains that operate using other fuels besides gasoline and diesel. The most widely available alternative-fuel powertrains for use in heavy-duty trucking use gaseous fuels that are typically derived from natural gas. They can also be derived in limited quantities from other sources, such as landfill waste gas streams. Most natural gas engines operate similarly to gasoline engines by using spark ignition, but some use dual-fuel setups in which a small amount of diesel fuel is injected into the engine in order to ignite the gaseous fuel.

- **Natural gas.** Natural gas can be stored on board vehicles in either liquefied or gaseous form.
  - Liquefied natural gas (LNG) has greater energy storage density and is therefore better suited to longer-haul operations requiring longer range. LNG must be cooled cryogenically in order to be stored in liquid form. Vehicle fuel tanks must be resistant to thermal extremes and well insulated. This adds cost and weight to the vehicles fuel system. Also, as LNG heats up during onboard storage over extended periods of time, various compounds within the gas can evaporate, reducing the quality of the fuel. An LNG fuel tank is pictured in Figure 5-3 below.
  - Compressed natural gas (CNG) has lower energy density but poses fewer logistical difficulties to store on board, as it is still in gaseous form and does not require any thermal extremes during storage or transport. It is, however, stored at relatively high pressures—up to around 3,600 psi.[167] Both types of natural gas engines typically offer a

[165] National Research Council (2010). *Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.*

[166] Lowe, M., G. Ayee, and G. Gereffi (2009). Chapter 9: Hybrid drivetrains for medium- and heavy-duty trucks. In *Manufacturing Climate Solutions: Carbon-Reducing Technologies and U.S. Jobs.* Retrieved from http://www.cggc.duke.edu/environment/climatesolutions/greeneconomy_Ch9_HybridDrivetrainsforTrucks.pdf.

[167] National Renewable Energy Laboratory (2013). Clean Cities Guide to Alternative Fuel and Advanced Medium- and Heavy-Duty Vehicles. Publication no. DOE/GO-102013-3624.

GHG benefit over gasoline engines but, due to lower thermal efficiency, they do not offer a GHG reduction over diesel engines. If a leak develops in the fuel systems of these trucks, the fugitive methane can result in increased GHG emissions, however. This fuel does burn more cleanly and emit lower levels of NO_x and dramatically lower PM than diesel in conventional engines, however.

Figure 5-3. LNG Tank on a Heavy-Duty Truck

Battelle, NREL 11613

- **Liquefied petroleum gas (LPG).** LPG is a byproduct of natural gas refining and is almost pure propane. Because propane condenses at a higher temperature than natural gas, it is typically carried around 150 psi as a mixture of liquid and gas, making it logistically easier to store onboard a vehicle with more cost-effective tankage. Because of its higher purity and level of refinement, LPG generally costs more than natural gas. It burns more cleanly than diesel and, because of its molecular structure, emits lower levels of GHG than diesel fuel. Because it is a refining byproduct, its supply is more limited than conventional fuel types and it is not likely to become a large part of the transportation fuel supply.[168,169]
- **Dimethyl ether (DME).** This gaseous fuel can be produced from natural gas or biomass feedstocks. It can be burned in a similar fashion to diesel fuel but it burns more cleanly. While the basic engine architecture is similar for DME engines and diesel engines, DME is

[168] National Renewable Energy Laboratory (2013). Clean Cities Guide to Alternative Fuel and Advanced Medium- and Heavy-Duty Vehicles. Publication no. DOE/GO-102013-3624.
[169] U.S. Department of Transportation (2009). *Transportation's Impact on Climate Change and Solutions.*

not a direct drop-in fuel and engines of this type will need to be specific to this fuel. It has a similar GHG emission rate in exhaust, but is nearly carbon-neutral if produced from biomass. In terms of onboard storage, it is relatively similar to LPG in that it liquefies at low pressure and does not have logistical problems regarding storage. There is minimal infrastructure change required for this fuel, and its time-to-market depends on consumer interest and demand.

5.3.5 Alternative Refrigerant Systems

Vehicle air conditioning systems operate using various refrigerants as their working fluid. These refrigerants must have favorable heat transfer as well as boiling temperatures and pressures in order to function in air conditioning systems. When these systems leak, the refrigerant evaporates into the atmosphere. The most common refrigerant in new vehicles is HFC-134a. This refrigerant does not cause ozone depletion, unlike its predecessor R-12, but does have a GHG effect. Many auto companies are phasing in HFC-1234yf. It has a much lower GHG effect than HFC-134a. It is more expensive, however, and total supply is limited due to few manufacturers. Some European manufacturers are also considering the use of CO_2 (known as R-744) as a refrigerant. It is not as efficient a refrigerant as the others, but it is relatively safe, inexpensive, and has the lowest GHG effect of all practical refrigerant options. Consumer demand may drive these refrigerants to wider market share sooner, but it is unlikely than any new vehicle buyers will choose a vehicle based on its supplied air conditioning refrigerant.[170]

5.3.6 Costs, Benefits, and Degree of Utilization for Non-Retrofittable Strategies

The costs and percentage of fuel consumption reduction for each of the OEM technologies are presented in Table 5-4. The table also includes the co-benefits or negative side effects of each. The costs presented in the table represent estimates of the marginal cost of heavy-duty vehicles equipped with each option. Note that the fuel savings for each concept are not additive: for example, both types of turbocompounding could not be used on a single engine with each operating at maximum effectiveness. Also, the advantages of an automated manual transmission would not be as great with a full hybrid electric or hydraulic powertrain, and they may not be appropriate for use together at all, depending on the specific design.

Table 5-4. Costs and Fuel Consumption Reductions for the OEM Technologies

Technology	Fuel Consumption Reduction	Capital Cost (U.S. $)	Co-benefits/Side Effects
Mechanical turbocompound	2.5–4%[a] 2.5–5%[b]	2,650–5,300[c]	—
Electrical turbocompound	3–10%[a]	6,500–13,100[c]	To gain benefits, this needs to be used with accessory electrification or electric hybridization.
Variable valve actuation	1%[a]	300–600[c]	—

[170] U.S. Department of Transportation (2009). *Transportation's Impact on Climate Change and Solutions.*

Technology	Fuel Consumption Reduction	Capital Cost (U.S. $)	Co-benefits/Side Effects
Mass reduction	1.25%[a] 2–5%[d]	13,500[a] 2,000–5,000[d]	Values given are the benefits and costs for varying levels of OEM weight reduction.
Automated manual Transmission	3–8%[a] 4–8%[b] 4–6%[d]	4,000–5,700[a] 4,500–6,000[d]	Can increase productivity and reduce driver fatigue as compared to traditional manual.
6×2 axle layout	1%[a] 1%[b]	-300 (i.e., savings)[e]	May require hardware that can lift the undriven axle to prevent losing traction; this would add to cost. Concept is appropriate for trucks that are used almost exclusively on paved surfaces.
Mild electric hybrid	2.9–14.2%[a] 5–22%[d]	4,500[d]	—
Full electric hybrid	5.6–41.7%[a] 20–50%[f] 4–30%[d]	23,000–35,000[c] 30,000–33,000[d]	The electrical storage can be used to support hotel loads and reduce extended idling in addition to motive power.
Hydraulic hybrid	25–70%[a] 50%[f] 12–25%[d]	13,000[d]	Greater fuel savings are available only over cycles with large numbers of starts and stops (e.g., urban delivery)

Notes

[a] National Research Council (2010). *Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.*

[b] International Council on Clean Transportation (2013). *Trailer Technologies for Increased Heavy-Duty Vehicle Efficiency.*

[c] Northeast States Center for a Clean Air Future, International Council on Clean Transportation, Southwest Research Institute, and TIAX (2009. *Reducing Heavy-Duty Long Haul Combination Truck Fuel Consumption and CO_2 Emissions.*

[d] International Energy Agency (2012). *Technology Roadmap—Fuel Economy of Road Vehicles.*

[e] Carbon War Room (2012). *Road Transport: Unlocking Fuel-Saving Technologies in Trucking and Fleets.*

[f] Lowe, M., G. Ayee, and G. Gereffi (2009). Chapter 9: Hybrid drivetrains for medium- and heavy-duty trucks. In *Manufacturing Climate Solutions: Carbon-Reducing Technologies and U.S. Jobs.* Retrieved from http://www.cggc.duke.edu/environment/climatesolutions/greeneconomy_Ch9_HybridDrivetrainsforTrucks.pdf.

5.4 Operational Strategies

This section presents strategies to minimize total trips, reduce empty return trips, and keep truck and engine operation as efficient as possible. Where applicable, technologies that can be used to implement or enhance these strategies are also presented along with the options. Some information is provided regarding barriers to adoption of strategies, but information on the potential extent of adoption is highly site- and company-specific and is generally not included in this report.

5.4.1 Route Optimization

In this section, we consider three tiers of route optimization, including steps an individual shipping company could take, stakeholder programs which could be developed, and regional planning efforts that could be undertaken in order to optimize shipping efficiency.

5.4.1.1 Individual Shipping Company Activities to Improve Route Optimization

Route optimization can be as simple as "static routing," in which the best route is selected based on current conditions, or "dynamic routing," in which routes are modified based on real-time data such as:[171]

- Fuel availability and cost.
- Weather conditions.
- Last-minute customer requests.
- Construction and traffic congestion (using real-time traffic reports).
- Changes in availability of vehicles and operators.

For local shipments with few stops, static route optimization using basic maps or Internet mapping software may be sufficient. However, for larger delivery areas, over-the-road shipments, or shipments with multiple stops, dynamic routing using route optimization software is usually advantageous. Dynamic route optimization software is generally part of an overall transportation management system suite that also includes loading and network optimization modules. Since this software uses real-time information about conditions that can affect shipping costs, delays, and objectives, use of this software to update routes in real-time can result in lower shipping costs, reduction in shipping delays, reduction of product returns and redeliveries, and a higher level of customer satisfaction. Like other strategies to optimize transportation operations, these increases in transportation efficiency and reductions in transportation costs equate to reduced fuel usage and reduced greenhouse gas and black carbon emissions.

5.4.1.2 Stakeholder Programs to Improve Route Optimization

The UN's *Best Practices in Asia* describes several techniques for route optimization, including the following:[172]

- **Backloading.** Backloading involves finding loads that need to be moved between similar areas, such as two points within the delivery area of a returning vehicle.[173] This type of route optimization simply attempts to minimize reduced or empty loads. It is similar to what the UN best practices report calls the "milk run" concept, which includes collection and distribution. This idea is derived from historical milk delivery route planning, in which the delivery truck is filled with empty bottles after milk delivery but prior to return to the dairy plant, so the truck is full on both legs of the route. The milk run concept is used to maximize loads and minimize trucks and travel distances, especially travel of empty trucks. This reduction in empty backhauls can offer a significant improvement of overall transport

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[171] U.S. Environmental Protection Agency (2013). *Route Optimization for Shippers*. EPA-420-F-13-030. p. 1.

[172] U.N. Centre for Regional Development (2011). *Best Practices in Green Freight for an Environmentally Sustainable Road Freight Sector in Asia.* p. 28. Retrieved from http://cleanairinitiative.org/portal/sites/default/files/BGP-EST5A_Green_Freight_Best_Practices_-_CAI-Asia_Dec2011.pdf.

[173] http://www.freightbestpractice.org.uk/default.aspx?appid=3511&pid=7778

efficiency in countries such as China, which is known to have very high empty backhaul rates. As described in Section 4.1.3, empty miles traveled varies among operational categories, so strategies to reduce empty miles traveled might be most effective by targeting certain operational categories with higher percentages of empty miles traveled.

- **Freight exchange.** A freight exchange is an online service for freight haulers and haulage companies, logistics providers, and freight forwarders.[174] This service offers haulers and companies offering cargo loads for shipment a common Internet site at which they can search for cargo or freight to be shipped or for transporters with available space on a desired route. Although not a centrally controlled logistics operation, this type of service allows communication among transporters, forwarders, cargo companies, and logistics companies by providing a sort of matchmaking tool.
- **Freight company consortiums.** Consortiums among smaller freight companies allow them to compete more efficiently against larger carriers. This type of consortium allows small operators to improve backloading and improve fleet utilization, thereby creating greater opportunities to compete against large operators. The key features of these types of consortiums are integrated fleet management, information sharing, facilities sharing, and profit sharing.[175]
- **Freight consolidation centers.** At freight consolidation centers (also referred to as "freight centers," "transshipment centers," "public logistics centers," "city distribution centers," or "urban platforms"), goods from different suppliers with the same origin and destination are combined into single shipments, thereby improving efficiency and reducing vehicles on the road. However, it has been reported that a large number of freight center projects have failed due to poor design, high cost, location, and non-participation by key stakeholders, so it is important to have proper discussions with the stakeholders before establishing a consolidation center.[176] A well-managed outreach effort targeted at key shippers and suppliers can also help increase the opportunity for success of a freight consolidation center.

5.4.1.3 Regional Planning Efforts to Improve Route Optimization

From a city planning perspective, route optimization can also be obtained through population distribution control measures and development of attractive mass transit options. For example, a U.N. African transportation report described an April 2005 declaration adopted by African ministers that included (among other things) a target of reducing the proportion of rural population living beyond 2 kilometers of an all-season mode of transport by half, in order to improve access to inputs and markets, as well as generate employment opportunities.[177] This same report also described the implementation of a "Bus Rapid Transit" program to stimulate a

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[174] http://en.wikipedia.org/wiki/Freight_exchange

[175] http://www.freightbestpractice.org.uk/profit-through-partnership

[176] U.N. Centre for Regional Development (2011). *Best Practices in Green Freight for an Environmentally Sustainable Road Freight Sector in Asia*. p. 31. Retrieved from http://cleanairinitiative.org/portal/sites/default/files/BGP-EST5A_Green_Freight_Best_Practices_-_CAI-Asia_Dec2011.pdf.

[177] U.N. Economic and Social Council (2009). *Africa Review Report on Transport—A Summary*. E/ECA/CFSSD/6/6. p. 4.

mass transit system using exclusive right-of-way lanes similar to the metro systems in well-known developed countries, except using bus technology instead of rail.

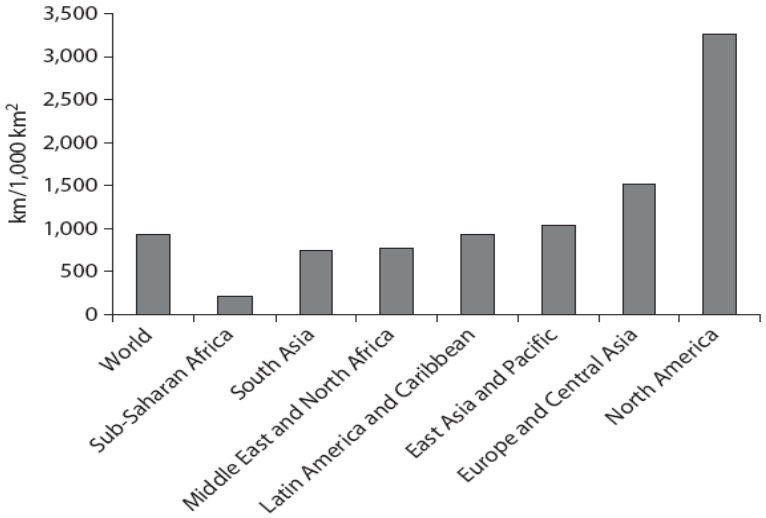
Road traffic optimization strategies—such as location and control of traffic signals and other traffic control devices; minimization of traffic obstructions such as pedestrians, non-motorized vehicles, vendors, or lane encroachment as vehicles turn and navigate into parking areas; increasing roadway capacities with additional (and possibly dedicated) lanes; and developing overpasses, orbital links, and other forms of intersection bypass—can all contribute to increased route optimization, particularly in urban regions. Regional planning strategies intended to decongest roadways (i.e., toll ways, increased mass transit options and attractiveness, and increases in parking fees and other impediments to personal transport) can all serve to open up roadways to increase trucking efficiency. However, any efforts to reduce roadway traffic congestion will also increase the attractiveness of private transport on that roadway, possibly resulting in a move back toward the original level of congestion (i.e., nature abhors a vacuum).

In regions such as Africa, road use efficiency suffers as the road freight industry is heavily cartelized and controlled, which will act as a barrier to successful implementation of regional planning efforts to improve freight transport efficiency. This can inhibit regional changes intended to improve efficiency.

For less developed countries, a fundamental component of network optimization involves ensuring that an adequate network of paved roads is in place. For example, in Africa, a plan for a 59,000-kilometer African comprehensive continental road system was developed in the 1970s, but due to lack of financial commitments from national governments, this comprehensive network has not materialized. Overall, Sub-Saharan Africa has only 204 kilometers of roads per 1,000 square kilometers of land area, with only one-quarter paved; the world average is 944 kilometers per 1,000 square kilometers, with over half paved, as shown in Figure 5-4. Figure 5-5 provides additional context for world road densities among other developing areas. Together, these two figures show that the spatial density ratio (roadway length/regional area) of Sub-Saharan Africa (0.204) is much lower than the world average of 0.944; India has a spatial density ratio of 0.79, while Russia has a very low spatial density ratio of 0.038. The spatial density of Sub-Saharan Africa's roads is less than 30 percent that of South Asia, where half of the roads are paved, and only 6 percent that of North America, where two-thirds are paved.[178] Costs for completion of a network such as this can be high, and can act as a barrier to implementation, in particular for developing countries with limited national income.

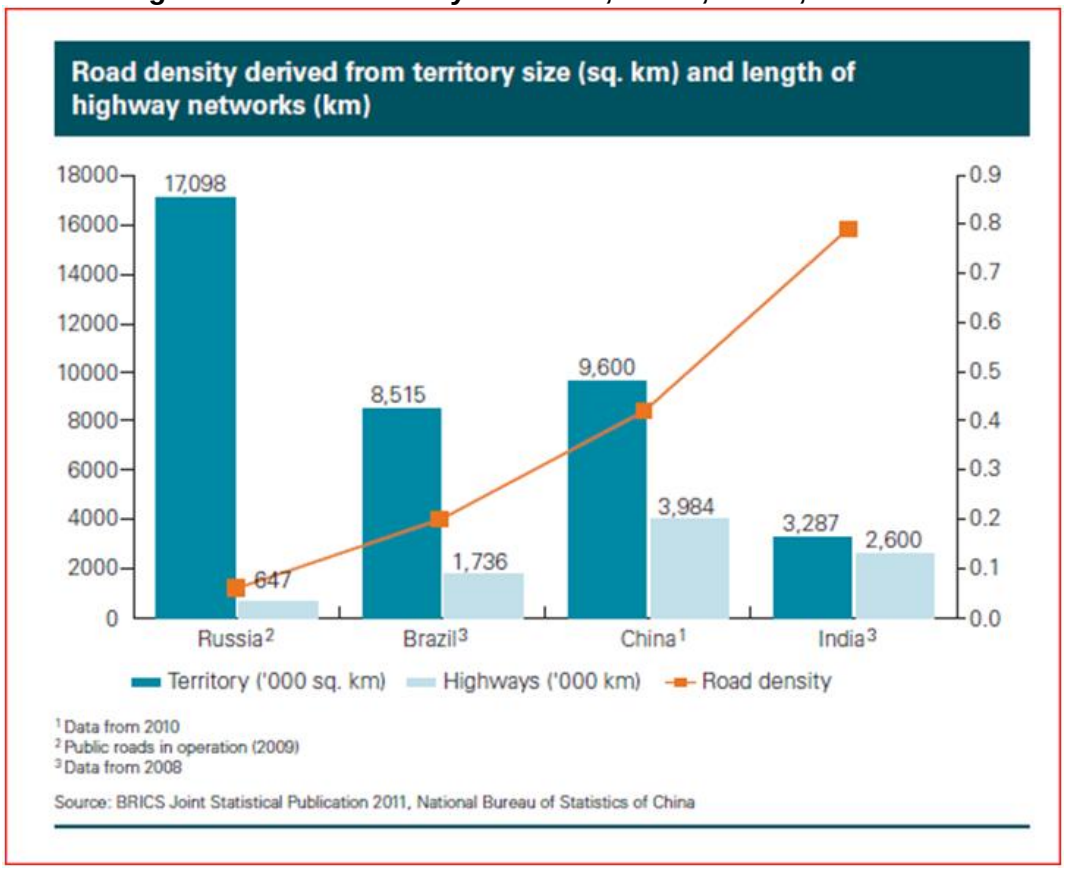
[178] World Bank (2011). *Africa's Transport Infrastructure—Mainstreaming Maintenance and Management.* p. 22

Figure 5-4. Spatial Densities of Road Networks in World Regions



World Bank

Figure 5-5. Road Density in Russia, Brazil, China, and India



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Another factor to consider in a country's roadway network optimization is roadway density, with consideration of spatial (geographic) density, industry density, and population density (in terms of vehicle traffic volume or per-capita).[179] When developing regional roadway plans, the regional densities of various roadway types (primary, secondary, tertiary) should be evaluated in light of international standards in an effort to maximize the positive impact of roadway network upgrades. Certainly, per capita income and a nation's GDP will influence a nation's roadway network optimization, as limited financial resources will act as an impediment to improvements for developing nations. While funding for roadway development and maintenance can be problematic, a restructuring of revenue sources to reflect traffic patterns, and development of new revenue sources could help increase available funding for roadway network improvements. For example, cities could charge private cars for parking and tax new urban developments that impose a burden on existing transport networks.[180]

Geographic conditions (climate and terrain) will also influence the feasibility of network optimization. Wet regions, or regions with mountainous terrain, will carry higher road construction and maintenance costs than regions with flat terrain or arid climates, and these higher costs will also impede roadway network development.

Changes in regional legislation that allow increased truck size and weight limits will allow truck operators to carry more goods per truck, using heavier or longer trucks than currently allowed. This basic improvement in productivity per truck could translate to fewer trucks on the road, reduced fuel consumption, and reduced greenhouse gas emissions.[181] However, such changes would result in additional wear on each region's transportation infrastructure, which would somewhat reduce the gains in emissions and cost benefits. Safety issues would also need to be considered when evaluating legislative changes of this nature.

5.4.2 Network Optimization

Although all shipping networks are developed with efficiency in mind, a number of factors must be considered in order to fully optimize a network and changes in customer bases, carriers, inventories and distribution center locations, among other factors, can reduce a network's efficiency over time. Various network models, such as a single-site model, a multi-site model, or a hybrid model, can be used to best meet the needs of a transportation company.[182] The process of determining which model (or combination of models) to use, along with tuning the model's parameters, is complex and must balance factors such as the types, sizes, and volume of products, customer base specifics, transportation costs and times, inbound transport requirements (including customer returns), inventory required for the type of network, and facility costs for the type of network. In addition, in some scenarios it may be advantageous for shippers to arrange a collaborative agreement to share network capacity in order to reduce costs while maintaining a high level of shipping service. This sharing is usually handled by an independent third-party logistics firm to ensure that proprietary data are kept confidential and routes are offered

[179] World Bank (2011). *Africa's Transport Infrastructure—Mainstreaming Maintenance and Management.* p. 20.
[180] Ibid., p. 230.
[181] U.S. Department of Transportation (2009). *Transportation's Impact on Climate Change and Solutions*. p. 4-40.
[182] U.S. Environmental Protection Agency (2013). *Network Optimization for Shippers*. EPA-420-F-13-027. p. 1.

impartially.[183] A shipper that continually evaluates its shipping network may choose to purchase shipping network design and optimization software, while it might be more cost-effective for other shippers to rent software or temporarily hire a consultant with access to modeling software.

5.4.3 Facility Optimization

One fairly fundamental concept intended to increase the efficiency of the flow of goods to and through a port is to ensure an adequate network of transportation corridors between each port and major distribution centers. In Africa, container traffic is constrained by administrative blocks, and corridor development programs as well as competition between corridors could serve to increase the flow of goods.[184] Road and rail systems should be developed to support container transport, and efforts to minimize container stripping and stuffing at or near the port could ease restrictions on port flow. Certainly, an integrated port management system must be in place to maximize port throughput while minimizing shipping distances traveled and engine operation time.

The UN's *Best Practices in Asia* describes "drop-and-hook,"[185] a strategy intended to "eliminate empty miles and optimize performance." This simply refers to dropping a trailer at the destination and immediately hooking to a new (already loaded) trailer, thereby reducing or eliminating empty return runs and extended idling at destinations while trailers are unloaded. However, this requires a dedicated trailer pool, and trailer pool management integrated with specialized route management.

Two major indicators of landside container terminal performance are truck cycle time and the average dwell time of containers in the terminal. Truck cycle time is the truck's total time at the port, including time in queues to enter and leave. Due to an ever-increasing growth of container traffic, the rough international benchmark of one hour truck cycle time is becoming increasingly rare.[186] Many strategies, such as pre-booking, terminal organization and IT management strategies, modernizing gate systems and also container movement, transfer and storage systems, and reducing or moving non-critical activities (such as container stripping and stuffing activities) offsite to alleviate congestion can all serve to reduce engine operation time and increase road, rail and waterway port transport efficiency. The port's management structure as well as a lack of the necessary capital required to implement the technological, management and operational changes such as those listed above can serve as impediments to improvement.

With respect to delivery of cargo, improvements in delivery efficiency can be obtained through regional plans which include urban consolidation centers.[187] These centers are freight facilities where deliveries (retail, office, or residential) can be consolidated for subsequent delivery in an efficient manner (rather than delivery by the transport truck). Although these centers can reduce

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[183] U.S. Environmental Protection Agency (2013). *Network Optimization for Shippers*. EPA-420-F-13-027. p. 2.
[184] World Bank (2011). *Africa's Transport Infrastructure—Mainstreaming Maintenance and Management.* p. 184.
[185] U.N. Centre for Regional Development (2011). *Best Practices in Green Freight for an Environmentally Sustainable Road Freight Sector in Asia*. p. 28. Retrieved from http://cleanairinitiative.org/portal/sites/default/files/BGP-EST5A_Green_Freight_Best_Practices_-_CAI-Asia_Dec2011.pdf.
[186] World Bank (2011). *Africa's Transport Infrastructure—Mainstreaming Maintenance and Management*. p. 215.
[187] U.S. Department of Transportation (2009). *Transportation's Impact on Climate Change and Solutions*. p. 4-44.

the number of large trucks operating on urban streets, they are not ideal for loads that are perishable or time-sensitive.

Although a country's ratio of imports to exports will have a large effect on the number of containers brought into and shipped from ports, efforts undertaken to reduce the imbalance of flows can minimize the number of empty containers shipped. A high trade imbalance will serve as an impediment to reducing the shipment of empty containers. Research and efforts should be undertaken, when necessary, to balance containerized imports and exports. Although economic interests can be an impediment, balancing imports and exports among ports could help reduce the flow of empty containers, as well as ensuring an open market is maintained for transport operators.

5.4.4 Packaging Reduction

In this context, the term "packages" refers to either delivery parcels (such as boxes) or product containers (such as pallets or cases). The objectives of packaging reduction strategies are to increase the amount of product delivered per shipment, reduce the total amount of shipping miles traveled (and hence reduce shipping costs, emissions and fuel used), and reduce packaging waste. In general, packaging reduction can involve switching to different and/or reusable materials, reconfiguring products to decrease empty space in shipping packages, or eliminating unnecessary materials to reduce weight.[188] Some specific options for packaging reduction include:[189]

- Using bulk deliveries (such as tanker deliveries or use of Intermediate Bulk Containers) instead of packaging for fluids.
- Using lighter materials to reduce packaging weight.
- Using reusable packaging such as metal instead of wood or cardboard.
- Redesigning packaging and even the products to fit more items into one package.
- Ensuring that the maximum number of packages, pallets or cases fit into trucks or railcars (a process typically referred to as "cubing out").
- Using renewable filler material instead of petroleum-based, shock-absorbing materials like "peanuts." For example, organic materials such as bamboo and mushrooms can be mechanically broken down and formed into shapes that hold delicate equipment during shipping.
- Optimizing the width of tape adhesives or using slotted tabs in packaging.
- Using spot gluing instead of full-length gluing on boxes.
- Eliminating unnecessary tertiary packaging and layers such as bags within bags.
- Reducing the thickness of packaging walls.

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[188] U.S. Environmental Protection Agency (2013). *Packaging Reduction for Shippers.* EPA-420-F-13-029. p. 1.
[189] Ibid., pp. 1-2.

- Increasing rigidity by using stronger, but lighter, materials or changing shapes.
- Eliminating paper labels by printing directly onto packaging.
- Shipping items only when necessary. Some products like software, media, and documentation can be transmitted electronically or placed on websites for customer downloading. Ask customers to "opt in" for additional items, such as cables or power cords, which they may not need.

5.4.5 Load Optimization

Load optimization is a strategy which can be used by shippers to not only reduce carbon emissions but also to reduce shipping costs and increase operational efficiency. Load optimization is the process of loading pallets, containers, or trailers to hold the maximum amount of product while conforming to local regulations and company policies regarding overall weights, load distributions, and product placements. While the concept is simple, the process can become complex due to multiple factors, including:[190]

- Location within the trailer or container based on where it will be delivered.
- Balance and load distribution.
- Product placement requirements such as box sizes, weights, fragility, or product placement restrictions (such as for some food shipments).
- Local regulations and company requirements such as those governing total allowable weight.

Due to the dynamic complexities of load optimization, load optimization software as part of an overall transportation management software (TMS) system is likely the best solution. This software will determine optimum loading strategies based on a transportation company's specific situation. The four primary types of load optimization are:[191]

- **Mode optimization**—choosing a package delivery company or a truckload (TL) carrier who is willing to make multiple stops may be more efficient than using a less-than-truckload (LTL) carrier. Analysis of individual loads is necessary in order to determine the most effective carrier option.
- **Pool-point optimization**—pooling inbound loads from multiple suppliers in a distant area improves process efficiency, and TMS load optimization software can be used to perform this analysis.
- **Consolidated optimization**—load optimization software can help decide how to combine shipments to lower carrier miles based on delivery times, distances, closeness of customers, and recipient expectations.

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[190] U.S. Environmental Protection Agency (2013). *Load Optimization for Shippers.* EPA-420-F-13-031. p. 1.
[191] Ibid.

- **Multi-stop truckload optimization**—load optimization software can be used to determine how to load a multi-stop delivery truck to maximize loading and unloading efficiency.

Based on review of anecdotal evidence, it is possible that a reduction in truck utilization (percent of available capacity used) has resulted from the high growth in the number of small shipments and also just-in-time (JIT) systems that rely on frequent shipments that do not necessarily optimize truck capacity.[192] Since JIT system operations prioritize inventory minimization and delivery times, JIT management and small shipment deliveries can act as barriers to load optimization.

5.4.6 Intermodal Strategies

Intermodal transport refers to transportation using more than one mode (i.e., road to rail), without handling the cargo during transport.[193] Various intermodal freight options that can be used in freight transport include rail, truck, inland barge, cargo ship and air transport. Intermodal shipping is growing, especially for distances over 500 miles, for shipments that are heavy, or where delivery times are more flexible. Intermodal container volume set a new record in 2011 for the United States, with 12.4 million moves in North America, beating former record year of 2007 by 3.7 percent, according to the Intermodal Association of North America (IANA).[194] Road to rail intermodal transport is commonly facilitated by transporting a combination trailer on a flatcar (TOF) or by transfer of containers to flatcar, as shown in Figure 5-6 and Figure 5-7.

Figure 5-6. Trailer on Flatcar Intermodal Transport

Peter Van den Bossche; CC BY-SA 2.0

[192] ICF International and Federal Railroad Administration (2009). *Comparative Evaluation of Rail and Truck Fuel Efficiency on Competitive Corridors*. Publication no. 13.4841.21. pp. 46–47.
[193] http://en.wikipedia.org/wiki/Intermodal_freight_transport
[194] Berman, J. (2014). Intermodal volumes finish Q4 and 2013 strong, reports IANA. *Logistics Management.* Retrieved from http://www.logisticsmgmt.com/article/intermodal_volumes_finish_q4_and_2013_strong_reports_iana.

Figure 5-7. Container on Flatcar Intermodal Transport

Sean Lamb/Wikimedia Commons; CC BY-SA 2.0

The use of intermodal shipping services can increase transportation efficiency and reduce shipping emissions, fuel usage, and costs. Each mode of transport has costs and benefits in terms of fuel used, shipping costs, transport times, schedule delays and flexibility, delivery capabilities, types of cargo (weight/size), and freight security. Many logistics services and software providers offer planning tools that can help identify what works best for different shipping scenarios. Also, intermodal brokers can help determine if a combination of transportation modes is cost-effective and appropriate for shipments based on distance, delivery time, and contents.[195] An analysis of various intermodal shipment options can help reveal the best intermodal shipment combination to maximize efficiency within the specific constraints of a shipment.

As previously discussed, development of primary roadway networks that can accommodate reasonable volumes of containerized traffic can minimize engine operation times and roadway distances traveled required for the transport of goods. In addition, alternatives to on-road transport may also be used in order to maximize the efficiency of goods transport to and from a port. Mode shifts using alternative forms of transport may include rail or ship, including travel on inland waterways, when available.[196]

To play a role in transshipment, ports should have deep water and good container-handling performance, and be unencumbered by excessive bureaucracy.[197] Having a suitable network of transshipment-capable ports at strategic commerce locations can maximize the efficiency of intermodal transport and port operations.

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[195] U.S. Environmental Protection Agency (2013). *Intermodal for Shippers.* EPA-420-F-13-028. p. 2

[196] World Bank (2011). *Africa's Transport Infrastructure—Mainstreaming Maintenance and Management.* pp. 184–186.

[197] Ibid., p. 188.

5.4.7 Adaptive Cruise Control and Speed Reduction

Adaptive cruise control systems for trucks are designed to allow a greater amount of vehicle speed variation in order to minimize fuel consumption, especially over hilly terrain. In addition, since aerodynamic drag and tire rolling resistance increase with speed, the amount of fuel used and thus truck emissions can be reduced through a limit on overall truck speed. For vehicles with a GVW of 60,000 pounds, the fuel economy at 55, 65, and 75 mph were 9.5, 8.0, and 6.8 miles per gallon respectively. For those same speeds, the fuel economies were 9.0, 7.5, and 6.5 for a 70,000 GVW vehicle and 8.5, 7.1, and 6.2 for an 80,000 GVW vehicle.[198]

In addition to fuel savings, a reduction in maximum truck speed can also result in a reduction of truck maintenance costs and increased safety. However, some of these savings may be offset by potentially greater over-the-road transportation costs and driver dissatisfaction. Both of these can serve as a barrier to adoption by shipping companies, but they may be offset through stakeholder outreach programs and driver incentives.

One possible strategy for reducing maximum truck speeds is to set speed governors or reduce maximum speed settings on electronically controlled trucks. This is typically more effective for long-haul trucks than local delivery trucks, as local delivery trucks rarely reach maximum speeds. In addition, maximum truck speed can be monitored and controlled through the use of GPS/cellular-based fleet monitoring systems. With such systems, speed, location, load, engine information, and other parameters are continually monitored and broadcast back to a central office (such as a dispatch office) via a cellular uplink connection. Any violation of corporate driving policies can be automatically flagged in summary reports for management.

5.4.8 Driver Performance and Incentive Programs

In addition to electronically monitoring truck speeds as discussed in the prior section, driver training and incentive programs can be implemented in order to reduce fuel use and emissions. Driver training can also focus on topics such as up-shifting and down-shifting strategies to optimize efficiency, coasting, effective use of cruise control, idle reduction, and limiting the use of accessories. For large companies, in-house training programs can be offered, while smaller companies may opt to send their drivers to offsite training. In addition, online training programs, such as the SmartDriver E-learning portal, jointly developed by EPA and NRCan, can also be used to provide in-depth training on fuel-efficient driving techniques. Additional information regarding this program can be accessed at http://fleetsmartlearning.nrcan.gc.ca/Saba/Web/Main.

After a training program is offered, an incentive program (such as bonus or vacation packages) can help encourage drivers to implement these driving strategies. Fuel economy, possibly enhanced by GPS-based fleet management reports, may likely be the best metric for monitoring driver performance and serve as the basis for awarding driver incentive programs.

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[198] ICF Consulting (2002). *Industry Options for Improving Ground Freight Fuel Efficiency*. p. 54.

5.4.9 Cost, Benefits, and Degree of Utilization for Operational Strategies

Costs and benefits for the operational strategies discussed in this section are highly dependent on factors such as the way each option is implemented, details of the shipping company, products shipped, frequency and volume of shipments, current shipping routes, modes and network, and a number of other factors. Some general information regarding costs and benefits on some of the different strategies presented in the preceding subsections are provided in Table 5-5. No information is provided regarding the degree of utilization in the United States or other countries for the various strategies.

Table 5-5. Costs and Benefits of Various Shipping Optimization Strategies[199]

Operational Strategy	Costs	Benefits
Route optimization	Costs can be as low as several hundred dollars for simple GPS-based routing systems to several thousand dollars (as a module in an overall TMS software suite).	Benefits are generally incremental, and cumulative benefit varies based on existing routes, shipping volumes, and other factors.
Network optimization software	$10,000–$250,000, depending on company size, whether a cost calculator or optimizer is used, number of software licenses, etc. $250,000 is for purchase of a TMS software suite.	Generally, benefits are incremental improvements which accrue to larger savings due to daily network usage.
Network optimization consultant	Varies on time required, complexity of network and distribution, etc.	
Packaging reduction	One-time labor costs to research materials and redesign packaging and costs to retool or replace production equipment can range from several hundred dollars to tens of thousands of dollars.	Incremental improvements from longer life cycle on reusable packaging equipment and lower shipping costs from fewer and lighter loads.
Load optimization	Load optimization software costs vary, depending on the shipper's volume and frequency of shipments, whether the software is stand-alone or part of a TMS software package, and whether the software is licensed and hosted onsite or remotely.	Substantial benefits, with return on investment typically less than one year, depending on current shipping volume and practices.
Intermodal shipping	Costs for use of an intermodal broker vary. Also, each mode of transport has costs and benefits in terms of fuel used, shipping costs, transport times, schedule delays and flexibility, delivery capabilities, types of cargo (weight/size), and freight security.	Intermodal shipments are typically secure, as cargo remains in locked containers and stored in secure yards. Intermodal can overcome obstacles, such as weather delays, that can at times impede single-mode transport.

[199] http://www.epa.gov/smartway

Operational Strategy	Costs	Benefits
Other strategies (facility optimization, speed reduction, adaptive cruise control, driver programs, other)	Costs and benefits for other strategies can vary widely based on specifics of each individual scenario.	

6.0 Intermodal—Rail, Marine, and Air

6.1 Intermodal Strategies

Intermodal transport refers to transportation using more than one mode (e.g., road to rail), without handling the cargo during transport.[200] Various intermodal freight options that can be used in freight transport include rail, truck, inland barge, cargo ship and air transport. Intermodal shipping is growing, especially for distances over 500 miles, for shipments that are heavy, or where delivery times are more flexible. Intermodal container volume set a new record in 2011 with 12.4 million moves, beating former record year 2007 by 3.7 percent, according to the Intermodal Association of North America (IANA).[201]

> If 10 percent of long-haul U.S. highway freight were shifted to rail:
>
> Annual fuel consumption would decrease by **12 billion gallons**, and
>
> Annual greenhouse emissions would decrease by **12 million tons.**

The use of intermodal shipping services can increase transportation efficiency and reduce shipping emissions, fuel usage, and costs. Each mode of transport has costs and benefits in terms of fuel used, shipping costs, transport times, schedule delays and flexibility, delivery capabilities, types of cargo (weight/size), freight security, and impacts on traffic congestion.

Hannes Grobe; CC BY 3.0

When viewed separately each mode of freight transportation has strengths and weaknesses, but when combined they can provide a flexible and efficient mode of shipping. For example, marine shipments tend to be the most efficient method of freight transportation, able to handle large amounts of tonnage in a single vessel, but they are the slowest mode and can only deliver to ports with proper cargo handling equipment. Railways provide the next-best fuel efficiency; they are faster than marine vessels, and use less space than highway systems, but can only carry cargo between ports and rail yards. Aircraft can carry high-value freight long distances very quickly, but they use the most fuel relative to ton-miles traveled and can only carry cargo from airport to airport. Trucks have the next-highest fuel per ton-mile value, but have the greatest flexibility in providing door-to-door service.

[200] http://en.wikipedia.org/wiki/Intermodal_freight_transport
[201] U.S. Environmental Protection Agency (2013). *Intermodal for Shippers*. EPA-420-F-13-028. p. 1

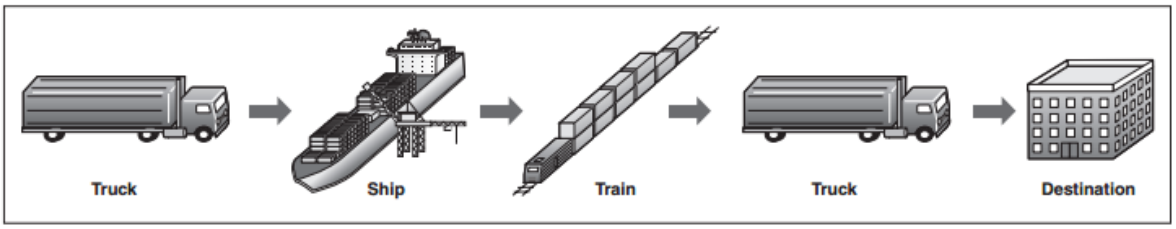
Table 6-1. Fuel Consumption for Freight Transportation, 2010[202,203,204,205]

Transportation Mode	Fuel Consumption	
	BTU per Short-Ton-Mile	kJ per Tonne-Kilometer
Domestic waterborne	217	160
Class 1 railroads	289	209
Heavy trucks	3,357	2,426
Air freight (approximate)	9,600	6,900

Wikimedia Foundation; CC BY-SA 3.0

Many intermodal transfers rely on marine vessels to carry cargo from an origination port to a destination port. If the final location is within 500 to 750 kilometers of the destination port, highway trucks can then be used for the delivery.[206] If the distance is longer, then the cargo can be transferred to a rail line to get to the destination city and then by truck to make the final delivery (shown in the figure below). Examples of successful intermodal components of action plans can be found in the Welsh government's Multi-modal Freight Best Practice Navigator.[207] Note that intermodal transfers can occur within the marine component, with cargo from large deep water vessels being transferred to barges that operate along inland waterways.

Figure 6-1. Example of Intermodal Transportation for Freight



Government Accountability Office

Obviously the shipping time can be shortened if the cargo can be sent via aircraft to the destination city and delivered by truck to the final destination. Intermodal systems have even been developed that use ships to bring high-value/low-time-sensitivity cargo to a country, and once the cargo arrives in port, it is delivered quickly to the final destination using aircraft. This approach reduces the price of aviation delivered products as the system only uses domestic flights, but provides faster service than traditional ship/rail/truck transfers.

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[202] Davis, S.C., S.W. Diegel, and R.G. Boundy (2011). Transportation Energy Data Book: Edition 30. ORNL-6986. Table 2.12. Retrieved from http://cta.ornl.gov/data/index.shtml.

[203] U.S. Environmental Protection Agency (n.d.). Where you live. Retrieved from http://yosemite.epa.gov/gw/heatisland.nsf/webpages/HIRI_Initiatives.html?OpenDocument.

[204] U.S. Energy Information Administration (1995). *Measuring Energy Efficiency in the United States' Economy: A Beginning.* Chapter 5. Retrieved from http://www.eia.doe.gov/emeu/efficiency/ee_ch5.htm.

[205] Oak Ridge National Laboratory (2013). *Transportation Energy Data Book.* Table 2.15. Retrieved from http://cta.ornl.gov/data/chapter2.shtml.

[206] Rodrigue, J.-P., and B. Slack (2013). *The Geography of Transport Systems.* Chapter 3. Retrieved from http://people.hofstra.edu/geotrans/eng/ch3en/conc3en/ch3c6en.html.

[207] http://www.freightbestpractice.org.uk/categories/3589_586_amlfodd--multi-modal-.aspx

The introduction of containerized freight that uses interlocking containers with a standard size and shape (i.e., 20-foot equivalents, or TEUs) is the critical element needed to allow for efficient intermodal shipments, as these allow cargo to be quickly and efficiently transferred from ship to rail to truck. Aircraft transfers require use of special lightweight containers that match the cargo storage space of cargo aircraft (seen in the photo to the right).

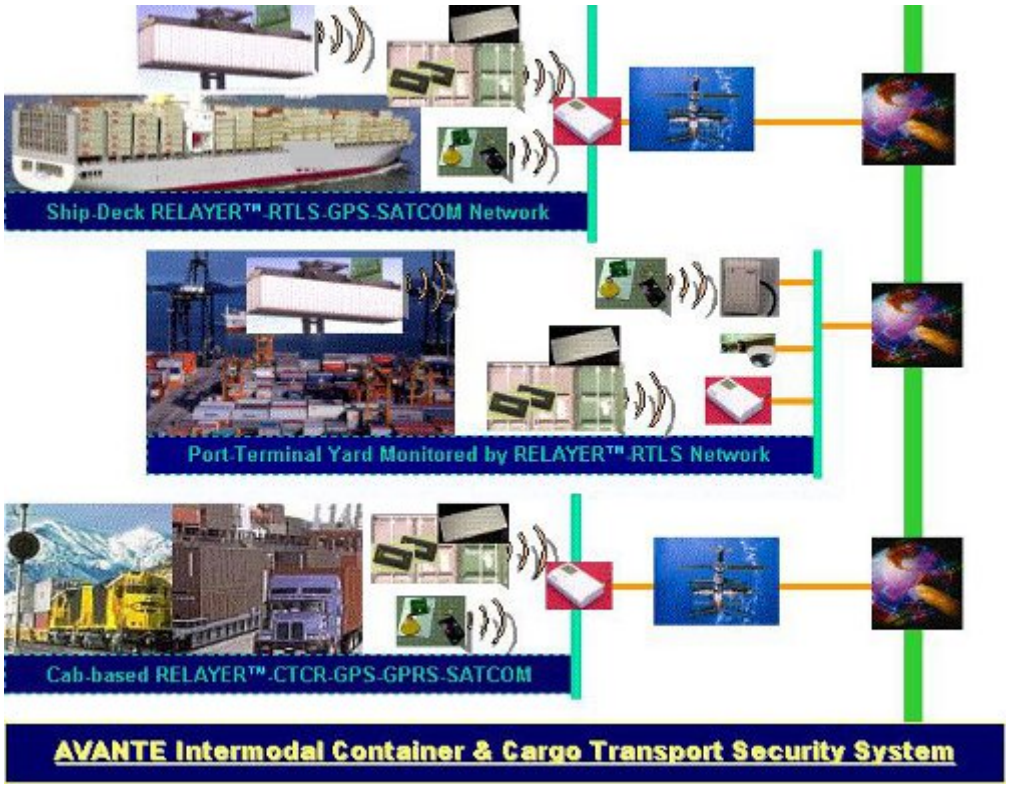
UPS

Use of intermodal systems requires specialized cargo handling equipment designed specifically for moving these standardized containers, such as gantry cranes that are used in ports and rail yards. These extremely large cranes are portable and can be moved into position next to a ship or train, and are able to extend 200 meters over the vessel and systematically lift the containers off a ship and onto railcars if the port has a rail link integrated into the docks. If there is no rail link, than the containers need to be moved by drayage truck to a terminal location where the containers can be put onto a rail car or be made available for a highway truck pickup. The rail link is preferred for several important reasons. For example, a single container ship can hold up to 14,000 TEUs, and gantry cranes can move 40–60 TEUs per hour. Therefore, a large ship can be unloaded and reloaded in about two days, but would require over 5,000 truckloads to move the same cargo over a 48-hour period, which would generate a significant amount of local traffic congestion. Alternatively, a train can carry the same amount as 300 trucks, and because trains do not operate on the highway systems, their movements do not necessarily impact local traffic.

Many logistics services and software providers offer planning tools that can help identify what works best for different shipping scenarios. Also, intermodal brokers can help determine if a combination of transportation modes is cost-effective and appropriate for shipments based on distance, delivery time, and contents.[208] An analysis of various intermodal shipment options can help reveal the best intermodal shipment combination to maximize efficiency within the specific constraints of a shipment. A second issue with regard to using trucks to offload container ships is that drayage trucks tend to be older high-emitting vehicles. It is estimated that California contains 100,000 drayage trucks. If drayage is the only option to move cargo from ship to warehouse or rail hub, fuel-efficient and low-emitting drayage options are available, including replacement of older trucks with newer ones, retrofitting trucks with add on control devices, use of electric or hybrid trucks, and CNG-powered trucks.

[208] U.S. Environmental Protection Agency (2013). *Intermodal for Shippers*. p. 2.

Figure 6-2. AVANTE Electronic Cargo Tracking System



Avante International Technology

When considering intermodal transfer points such as ports, rail yards, and airports, it is important to evaluate how cargo-handling equipment is powered. Often application of natural gas or electric-powered equipment can reduce emissions from cargo handling engines. Where diesels cannot be replaced, use of biofuels should be considered as well as idle reduction options. For large marine vessels, idling emissions can be eliminated through cold ironing (connecting the ship's power system to the local electric grid). But these systems require significant investment for both vessels and ports: a vessel needs to add an onboard connection linked to its electrical control panel and a port needs to provide shoreside power line, a frequency/transformer converter, and access to the electrical grid. There are also issues related to standardization of cold ironing practices; vessels' voltage requirements can vary from 100 to 11,000 volts. If cold ironing is not possible, port and railway yards can collect and treat emissions from large ships and line-haul locomotives through advance control systems that fit over the engine exhaust, treat the emissions using sodium hydroxide to remove SO_2, and cloud chamber scrubbers to further reduce SO_2 and PM, and then selective catalytic reduction to remove VOCs and NO_x.

Intermodal systems can be complicated, as cargo routing involves coordination of different combinations of truck, ship, rail, and aviation modes. Geographic information systems (GIS) in conjunction with geopositioning systems (GPS) have been developed to map cargo flow, ensuring that the freight movement system is optimized and able to quickly address unanticipated disruption such as train derailment, weather-related events, or shutdowns due to bridge repair. Optimizing systems allow cargo to be shifted to alternative routes or modes, reducing the disruption.

Table 6-2. Summary of Emissions—Grams per Ton-Mile—2009

Emissions (Grams/Ton-Mile)					
	HC (VOC for Truck)	**CO**	**NO_x**	**PM**	**CO_2**
Inland towing	0.014	0.043	0.274	0.008	16
Railroad	0.018	0.056	0.354	0.010	21
Truck	0.100	0.370	1.450	0.060	171
Note [a] CO_2 emissions for railroads were calculated on a system-wide basis.					

Texas Transportation Institute

As noted earlier, intermodal systems optimize freight transfers by shifting cargo to the most fuel-efficient modes of transportation; these also tend to be less-polluting modes based on ton-miles traveled, as shown in the table above.

If the development or enhancement of intermodal systems is included in the green freight action plan, it will be necessary to consider a range of issues: changes in land use; required coordination between logistics, trucking, ship operators, airlines, and railroad companies; custom clearance; available warehouse storage; infrastructure improvements to harbors, rail yards and ports; channel dredging; cargo traffic monitoring systems; as well as dockside rail linkage/drayage operations.

6.2 Rail Cargo Strategies

Doug Wertman

Rail is one of the more efficient methods of freight transport, with fewer emissions than other modes of transportation on a tonne-kilometer basis, as noted in the intermodal section. Green freight action plans that include enhancements to rail infrastructure offer benefits to countries with a broad range of sizes and financial backing. For example, the use of double-stacking containers improves the capacity of trains, allowing a single train to carry the equivalent volume of up to 280 trucks[209] while using less fuel and producing fewer emissions than the equivalent number of trucks. In order to double stack cars, bridges and tunnels may need to be modified to accommodate the higher trains, while rail yards need appropriate crane support to shift the containers.

Other infrastructure changes include those that facilitate the use of alternative fuels, such as upgrading the electric grid and adding transformers and electrically charged rails or catenary

[209] Stehly, M. (2008). Train resistance and railroad emissions and efficiency presentation.

lines, installing pipelines for natural gas transport or storage tanks for biodiesel or synthetic fuels. These alternative fuels displace petroleum usage and also offer some emission benefits.

Biodiesel fuels have been field-tested in the form of 10 to 20 percent vegetable oils blended with diesel fuel. Blended biodiesel fuels require no retrofitting of existing engines, and therefore no investment cost related to the locomotives. However, it should be noted that biofuels have less energy content than traditional diesel.

For countries such as South Africa with large coal reserves but little oil, coal-to-liquid synthetic fuels offer several benefits. The liquefaction processing technology includes steps that remove sulfur, ash, mercury, and other pollutants as well. The sulfur and hydrogen resulting from the processing can be sold as byproducts. The synthetic gasoline and diesel produced are high-grade and clean, capable of meeting even future "clean diesel" requirements in countries with strong environmental standards.

Another alternative fuel option includes natural gas. Primarily composed of methane (70 to 90 percent) and extracted from gas wells or as a byproduct of oil production, natural gas can be used for transportation applications in two forms, as compressed natural gas (CNG) and liquefied natural gas (LNG). CNG is compressed to between 3,000 and 3,600 pounds per square inch (psi). To liquefy, natural gas must be cooled to -260 degrees Fahrenheit. The liquefaction process used for LNG removes most, though not all, impurities, such as water, solids, and heavy hydrocarbons, that when combusted may increase emissions. CNG and LNG are inherently clean-burning fuels, with drastically lower PM levels.[210] Long-term options for railways include use of CNG for switching activities and LNG for switching and long-haul operations due to its higher energy density and increased vehicle range.[211] Even with LNG, range is substantially less than with comparable diesel units, often being reduced by 40 to 50 percent.[212] Gaseous fuels such as CNG and LNG either require spark-ignition or can be co-fired with diesel fuel. Therefore, adopting either of these fuels would require a rail line to either modify its locomotives or purchase new ones. Also, either of these fuels requires extensive infrastructure enhancements, which may include the development of natural gas fields, extension of natural gas pipelines, and construction of refueling stations.

Urawa; CC BY 2.0

Electrification of rails supplies electrical energy to trains so they operate without onboard combustion sources. Emissions from electrification of rail lines depend upon the mix of electricity generating units that provide energy to the local grid. Most of the cost associated with electrification of rail lines

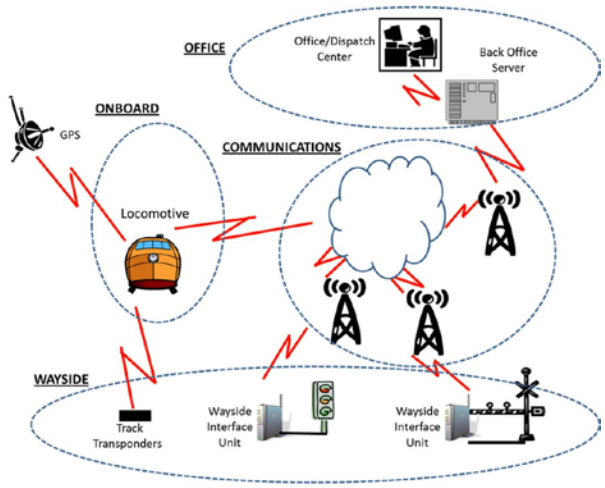
[210] BNSF Railway Company, Union Pacific Railroad Company, The Association of American Railroads, and California Environmental Associates (2007). *An Evaluation of Natural Gas-Fueled Locomotives.*

[211] http://www.nrel.gov/docs/fy00osti/27678.pdf

[212] http://www.railwayage.com/index.php/mechanical/locomotives/cn-testing-lng-fueled-main-line-locomotive.html?channel=35

relates to construction of infrastructure such as transformers, substations, third rails, or overhead power lines.

Advantages of electrification include lower costs of building, running, and maintaining locomotives and less rail upkeep due to reduced wear from lower-weight rolling stock. However, if the routes are not completely electrified, companies may find the need to continue using diesel locomotives as well, making the option expensive and inconvenient. Also, most overhead electrification designs do not allow sufficient clearance for double-stack cars.[213]



Federal Railroad Administration

Driving optimization systems are also currently being developed and enhanced that use satellite position data, engine operating data, and other information on track geometry and load to provide the optimal speed and power setting to move freight quickly, while reducing fuel consumption and emissions. For example, the European Train Control System (ETCS) is a signaling, control, and train protection system designed to replace the many incompatible safety systems currently used by European railways, especially on high-speed lines. ETCS requires standard trackside equipment and a standard controller within the train cab. In its final form, all lineside information is passed to the driver electronically, removing the need for lineside signals which, at high speed, could be almost impossible to see or assimilate. [214]

Locomotives expend energy to address wheel-to-rail friction and to overcome aerodynamic drag. Several options are available to reduce these energy expenditures, from the basic and inexpensive to more technologically advanced and costly. For example, improved lubrication decreases wheel-to-rail resistance. Lubrication systems reduce wheel and rail wear as well as fuel consumption. The cost of retrofitting wheel/rail lubrication systems to the current fleet of freight locomotives includes investment cost and fixed costs for additional lubricant and system upkeep. Simple systems for low-tonnage railroads allow operators to control the application of lubricants with roller nozzles spraying directly onto the wheels of the locomotive or the rails. The U.S. DOE estimates from field studies and manufacturer data that wheel-to-rail lubrication systems can reduce fuel consumption and GHG emissions between 4 and 10 percent.

Freight trains also use energy to overcome air friction.[215] This is due to the aerodynamically unfavorable shape of freight trains, space between cars not being shielded, and lack of covers for

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[213] Center for Clean Air Policy and Center for Neighborhood Technology (2006). *High Speed Rail and Greenhouse Gas Emissions in U.S.*

[214] Argonne National Laboratory Center for Transportation Research (2002). *Railroad and Locomotive Technology Roadmap*.

[215] Union Pacific (2013). Union Pacific unveils new aerodynamic technology for double-stack intermodal trains. Retrieved from http://www.uprr.com/newsinfo/releases/environment/2013/0903_arrowedge.shtml.

empty cars.[216] When cars are empty, air drag associated with moving uncovered cars is maximized because of poor aerodynamics. For example, a locomotive pulling open, empty cars consumes the same or more energy than when pulling full freight cars with a better aerodynamic profile. In many cases simple approaches, such as covering empty hopper cars, decreasing the gaps between railcars, and using simple fairings or foils to direct the air flow over empty cars, are effective with minimal costs relative to the overall cost of rolling stock. Another cost-effective approach involves loading freight on cars closest to the locomotive, with empty cars grouped together at the back of the train or removed completely, when possible. Improving the load configuration for intermodal trains can reduce fuel consumption by as much as 27 percent.[217]

Decreasing weight also reduces friction and improves efficiency. Aluminum rail cars are two-thirds the weight of comparable steel cars. Use of such lightweight materials allows for the construction of cars with more carrying capacity. These cars have become increasingly common for use in carrying coal, and are becoming available for other uses as well. Aluminum cars also require less repair and maintenance than traditional rail cars. The cost differential of investing in aluminum cars over traditional cars can be repaid in only a few years by the increased carrying capacity and decreased fixed costs. Light-weight, high-capacity railcars have been introduced by Canadian Pacific Railway, demonstrating a reduction of energy use by 10 percent for coal shipments and by 5 percent for grain.[218]

In addition to infrastructure improvements, use of alternative fuels, and friction reduction options, there are several pollution control systems available to reduce emissions. Many can be added to existing locomotives without the need to invest in new stock. Using low-sulfur diesel fuels results in direct reductions in PM emissions, and can enable the adoption of additional exhaust controls (for example, oxidation catalysts for NO_x reduction). Additionally, new technologies are becoming available, such as exhaust gas recirculation, diesel oxidation catalysts, and diesel particulate filters. Union Pacific is currently testing these newer technologies through 2014.[219]

As noted in Section 5.2.5, lean NO_x technologies reduce NO_x emissions and, when used in combination with a diesel particular filter (DPF), can also reduce particulate emissions.

Though more costly than many of the previously mentioned approaches for improving efficiency and reducing emissions, locomotive improvements provide excellent, long-term results. Most of the improvements can be applied to existing locomotives as a retrofit during routine maintenance. Among the most cost-effective improvements are technologies such as APUs or anti-idling strategies to minimize locomotive engine usage when the locomotive is not actively

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[216] Argonne National Laboratory Center for Transportation Research (2002). *Railroad and Locomotive Technology Roadmap*.

[217] Lai, Y.-C., C.P.L. Barkan, and Ö. (2008). Optimizing the aerodynamic efficiency of intermodal freight trains. *Transportation Research Part E: Logistics and Transportation Review* 44(5): 820–834.

[218] Skillingberg, M., and J. Green (2007). Aluminum applications in the rail industry. *Light Metal Age.*

[219] Union Pacific (2012). Union Pacific Railroad investing $20 million to test emissions-reducing locomotive technology in California. Retrieved from http://www.uprr.com/newsinfo/releases/capital_investment/2012/0813_loco-tech.shtml.

engaged in hauling freight. Typical line-haul locomotives spend approximately 16 percent of their time idling, because the engine is needed for heating/cooling. Anti-idling strategies use smaller, more efficient engines for supplemental power at times of idling, allowing the larger propulsion engines to shut down.[220]

Honeywell

Available improvements to locomotive diesel engine design includes use of advanced turbocharging which enhances energy efficiency over a wider range of operating conditions; application of turbocompounding using heat from the exhaust to increase power and reduce fuel consumption and emissions; and the use of intercooling systems that increase the density of the intake air, which in turn increases the amount of air and fuel entering the cylinder, allowing for better combustion. Common rail injection systems allow for greater control of fuel injection rates across all engine speeds by storing fuel at high pressures along a common rail connected to each cylinder. By controlling the point in the engine cycle when the fuel is injected into the cylinder and the duration of the injection, the engines perform better and with greater combustion efficiency. Additionally, the high-pressure injection creates a fine atomization of the fuel, yielding more efficient combustion.

Genesee & Wyoming Inc.

Genset yard or short-haul locomotives use multiple smaller (generally 700 horsepower) diesel engines rather than the more common single 2,000 horsepower diesel engine. These smaller diesel engines are newer and comply with more stringent emission standards than the current engines.[221] Gensets' improved efficiency results from the use of electronic controls that regulate engine performance to optimize fuel consumption and reduce emissions. For example, these engines reduce fuel consumption by 35 to 50 percent and provide an 80 percent reduction in NO_x and PM emissions. Electronic engine controls reduce wheel slippage, which enhances traction.[222]

Similarly, hybrid locomotives also operate using small, highly efficient diesel engines that power banks of long-life, recyclable batteries which run electric motors and turn the wheels. The small diesel engines operate only when the batteries need to be recharged. Hybrid locomotives improve

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[220] U.S. Environmental Protection Agency (2008). *Regulatory Impact Analysis: Control of Emissions of Air Pollution from Locomotive Engines and Marine Compression Ignition Engines Less Than 30 Liters per Cylinder.*
[221] http://www.gwrr.com/about_us/community_and_environment/gwi_green/genset_locomotives
[222] U.S. Department of Transportation (2010). *Transportation's Role in Reducing U.S. Greenhouse Gas Emissions*.

efficiency because diesel engines have an optimal operating load, outside of which, fuel consumption and emissions increase. By operating hybrid engines only at a constant optimal load when the batteries require charging or greater power allows the locomotive to avoid operating in less efficient load conditions.

U.S. Army Corps of Engineers

Estimates of GHG reductions as well as the cost-effectiveness of the various strategies are based on a comprehensive review of the existing literature on the impacts of individual strategies. Table 6-3 summarizes the results of this analysis. Note that where possible operational differences for yard and long-haul locomotives were accounted.

Table 6-3. Table Summary of Rail Freight Technology Options

Technology	Fuel Reduction (%)	Incremental Capital Cost ($ Thousand)	Annual Fuel Savings (Thousand Gallons per Year)	Annual Fuel Cost Savings ($ Thousands)	Payback Period (Years)	Annual GHG Emissions Reduction (Tons per Year)
Common rail diesel system	10	16 to 32	17.9	65.69	< 1 year	54.9
Genset yard locomotives	35 to 50	400	17.5 to 25.0	64.2 to 91.75	4 to 6	53.7 to 76.7
Hybrid line-haul locomotives	10	115	17.9	65.7	2	54.9
Light-weight cars	5 to 10	1,000 to 3,500	8.95 to 17.9	32.85 to 65.7	30 to 53	27.5 to 54.9
Wheel/rail lubrication	4 to 6	40	7.16 to 10.74	26.3 to 39.4	1 to 2	22.0 to 33.0

All options are evaluated based on incremental cost of the technology relative to a locomotive without the technology—except for wheel/rail lubrication, as it can be applied as an add on technology. Yard locomotives were differentiated from long-haul operations; for example, yard locomotives were assumed to use 50,000 annual gallons per year and line-haul locomotives were assumed to use 179,000 gallons per year. Rail fuel cost was assumed to be $3.57 per gallon.

6.3 Marine Cargo Strategies

Roberto Venturini

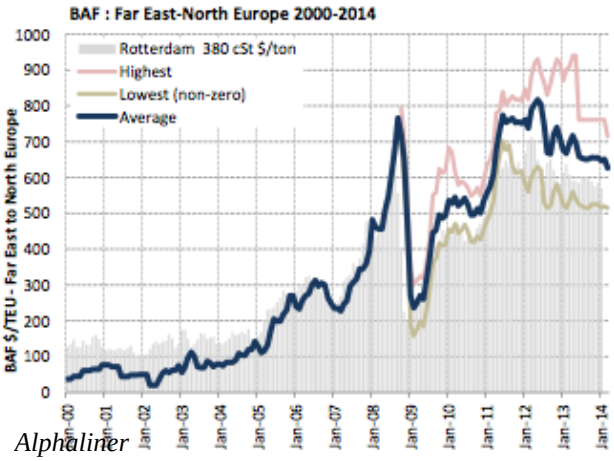
Marine vessels have played and will continue to play a critical role in integrating the global economy. The International Maritime Organization (IMO) anticipates that the 8 billion tonnes of cargo that ships currently carry annually will grow to 23 billion in 2060, increasing the global carbon foot print of marine vessels by 300 percent under business-as-usual operation.

More than 90 percent of global trade is carried by sea, of which developing countries account for the largest share of global seaborne trade (60 percent of all goods loaded and 56 percent of all goods unloaded). Developing countries account for the dominant share of ship construction and ownership, with China and Korea alone accounting for 72 percent of world ship capacity (in terms of dead weight tonnage, or DWT). There are currently 104,304 commercial marine vessels operating greater than 100 gross weight tonnage. The global fleet used 370 million tonnes of fuel and emitted 870 million tonnes of CO_2 or 2.7 percent of global CO_2 emissions in 2009. With this noted, marine shipments represent some of the most efficient methods to move cargo based on ton-miles (as noted in the intermodal section). The IMO suggests that efficiency can be further improved and emissions reduced by 25 to 75 percent using existing reduction strategies summarized below.[223]

Most of the current commercial marine vessels use compression ignition engines (diesel) for propulsion and auxiliary applications. These engines vary in size from relatively small engines used for auxiliary power to run winches, cranes, pumps, and generators; to engines similar in size and power rating to those found on locomotives, used to power domestic vessels, tugs, and towboats; to very large engines used by commercial marine vessels involved in international freight movements on the open seas. Over the last century, since these diesel engines were first developed, they have evolved and continue to evolve, able to burn a wide range of distillate and residual fuels of varying quality.

As fuel cost typically represents 60 to 80 percent of shipping expenses (depending on length of trade route) and fuel prices continue

Figure 6-3. Rising Marine Bunker Fuel Prices

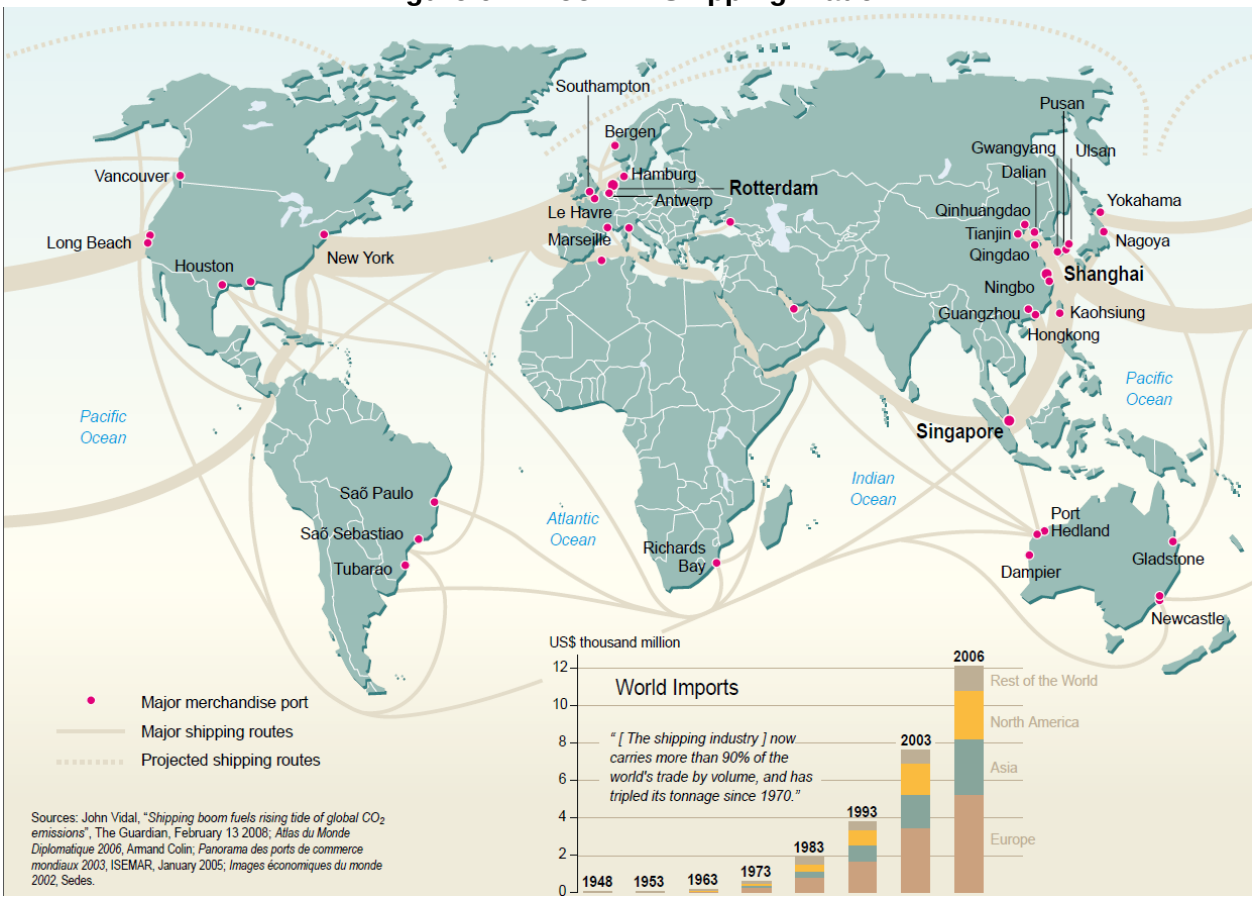


Alphaliner

[223] International Maritime Organization/Maritime Knowledge Centre (2011). *International Shipping Facts and Figures—Information Resources on Trade, Safety, Security and Environment.*

to increase from decade to decade,[224] fuel costs are a significant driving force to reduce usage through improvements in energy efficiency, use of alternative fuels, or changes in vessel operation (e.g., slow steaming).

Figure 6-4. Boom in Shipping Trade



Emmanuelle Bournay, UNEP/GRID-Arendal

Vessels tend to last for 30 to 40 years; therefore, engine technologies associated with older vessels do not represent advances in engine design such as improved fuel distribution through use of common rail fuel system that provides fuel to the cylinders at consistent and high pressure, improving combustion efficiencies. Older engines also do not have turbochargers or turbocompounding (which improve fuel efficiency by increasing the density of air into cylinders, which also enhances combustion). More advanced diesel/electric engine configurations also enhance fuel efficiency for tugs and roll-on/roll-off

Xtrememachineuk/Wikimedia Commons

[224] OECD Council Working Party on Shipbuilding (2013). *Encouraging Construction and Operation for "Green Ships."*

ferries that operate over a wide range of loads. Green freight action plans that encourage replacement of older engines with newer, more fuel-efficient, less-polluting engines need to balance the replacement cost with the associated fuel savings. To help identify seagoing ships that perform better in reducing air emissions, the World Port Climate initiative has developed the Environmental Ship Index (ESI) and the Clean Shipping Network has developed the Clean Shipping Index (CSI). The ESI evaluates the amount of nitrogen oxide (NO_x) and sulfur oxide (SO_x) that is released by a ship and includes a reporting scheme on the greenhouse gas emission of the ship. The ESI is a good indication of the environmental performance of oceangoing vessels and will assist in identifying cleaner ships in a general way.[225] For the CSI, ships and carriers are evaluated based on levels of emission of carbon dioxide (CO_2), nitrogen oxides (NO_x), sulfur oxides (SO_x), and particulate matter (PM). CSI also includes use of chemicals, how carriers take care of their wastes on board, and how they treat different discharges to water, such as sewage and ballast water.[226]

There are a variety of other fuel efficiency methods that use variable pitch propellers to match a vessel's operating load to the diesel engines optimal design efficiency (which is typically 80 percent of the maximum continuous rating). Counter-rotating propellers can also be used to recover rotational energy from the main propulsion propellers: as the recovery propellers rotate, they provide force to a generator which then provides electricity to the vessel. Enclosing propellers or applying small winglets to them improves propeller performance by reducing drag at the propeller tips.[227] Green freight action plans that encourage use of new propeller technologies are often attractive as they can be incorporated into normal maintenance activities and do not require costly replacement of engine or hull components.

More advanced technologies are being assessed that reduce hull friction through application of high-tech bottom coatings, such as glass flake coatings (which are proving to be a durable technology to reduce hull fouling). Also promising is bubble lubrication, in which air is forced out of the bottom of a ship, lubricating the hull. Green freight action plans that encourage hull friction reductions can see engine efficiency improvements of approximately 5 to 40 percent,[228] if not higher.[229]

As noted earlier, fuel pricing is a critical component of marine industries. Use of low-emitting alternative fuels is possible as long as they are cost-competitive with current fuels, require minimal changes to engines and existing fuel distribution infrastructure, and can withstand extreme environmental conditions. Ultra-low-sulfur fuels will be required for emission control areas in Europe and North America, but there is a concern that as demand for these fuels increase, the cost will increase. Given the importance of fuel pricing, green freight action plans

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[225] http://esi.wpci.nl/Public/Home
[226] http://www.cleanshippingindex.com/
[227] U.S. DOT (2010). *Transportation's Role in Reducing U.S. Greenhouse Gas Emissions*. Retrieved from http://ntl.bts.gov/lib/32000/32700/32779/DOT_Climate_Change_Report_-_April_2010_-_Volume_1_and_2.pdf.
[228] http://shippingefficiency.org
[229] Mike Garside (2013). Measuring the fuel efficiency of hull coatings. Retrieved from http://www.maritime-executive.com/article/Guest-Editorial-Measuring-the-Fuel-Efficiency-of-Hull-Coatings-2013-07-16/.

that require use of ultra-low-sulfur fuel need to link noncompliance fines with the price differential between high sulfur and compliant fuels.

Eidesvik

Natural gas has low emissions and is readily available in many developing and developed countries. This makes it attractive as a replacement fuel for diesel, but its energy content is considerably less than that of existing marine fuels, and consequently a larger volume of fuel is required to make the same journey. Given the issues of energy density, natural gas fuels are probably most suitable for harbor vessels and short sea shipping. Biofuels are potentially effective options, but there is a concern with fuel availability and possible long term maintenance issues. Solar cells and wind power (sails/rotors) are included as their applications can be used to address a vessel's energy demand, by providing electricity for non-propulsion activities such as navigation, lighting, and communication (solar cells) or by taking advantage of prevailing winds (as seen in the example to the left).[230] Both of these options are appropriate for large vessels with large surface areas for mounting solar cells or vessels traveling long distances in international waters.

© *Skysails*

In addition to fuel efficiency improvement and use of alternative fuels, there are operational changes that green freight action plans can encourage to further reduce fuel consumption and emission of pollutants. These include optimization systems that match load with the engine's most efficient operating speed; route optimization systems that provide the most direct route to a destination, avoiding storm systems and allowing for changes in port destination based on port terminal traffic; idle reduction systems (cold ironing); and expansion of reduced speed zones. A 10 percent reduction in vessel speed will reduce fuel usage by 20 percent.[231] Note that operating at too slow a speed for long periods can damage the engine, though engine manufactures such as Wärtsilä have kits to

[230] U.S. DOT (2010). *Transportation's Role in Reducing U.S. Greenhouse Gas Emissions*. Retrieved from http://ntl.bts.gov/lib/32000/32700/32779/DOT_Climate_Change_Report_-_April_2010_-_Volume_1_and_2.pdf.

[231] Santa Barbara County APCD (n.d.) Vessel speed reduction initiative fact sheet. Retrieved from http://www.edcnet.org/learn/current_cases/save_the_whales/vsr_factsheet.pdf.

retrofit older engines for slower operations.[232] Newer engines are being designed to address the issue of engine maintenance at slower speed such that kits will no longer be needed.[233]

Marine vessel emissions can also be reduced through the add-on application of closed crankcase ventilation, diesel particulate filters, selective catalytic reduction, diesel oxidation catalysts, and lean NO_x catalysts. Note that using most of these control devices requires that engines use low-sulfur fuels, as sulfur compounds can poison the catalysts, rendering them useless. As well, green freight action plans that encourage use of these add-on controls must be coupled with appropriate fuel standards.

Estimates of these strategies' GHG reductions and cost-effectiveness are based on a comprehensive review of the existing literature on the impacts of individual strategies. The following table summarizes the results of this analysis. Note that where possible operational differences for harbor and long-haul vessels were differentiated.

[232] http://www.wartsila.com/en/engine-services-2-stroke/slow-steaming-upgrade-kit

[233] Mersk (2011). Slow steaming: The full story. Retrieved from http://www.maersk.com/Innovation/WorkingWithInnovation/Documents/Slow%20Steaming%20-%20the%20full%20story.pdf.

Table 6-4. Table Summary of Marine Freight Technology Options

Technology	Fuel Reduction (%)	Incremental Capital Cost ($ Thousand)	Annual Fuel Savings (Thousand Gallons per Year)	Annual Fuel Cost Savings ($ Thousands)	Payback Period (Years)	Annual GHG Emissions Reduction (Tons per Year)
Enhanced ship design	2 to 7	500–2,000	56.24–196.84	158.6–555.1	3–4	649–2,272
Bubble lubrication	10 to 15	75–750	281.2–421.8	793–1,189	< 1	3,245–4,868
Diesel electric configuration	15 to 20	300–3,000	562.4	1,586	< 1–2	6,490
Hybrid engines	35	600	492.1	1,388	< 1	5,807
Counter rotating propellers	10 to 15	Not available	370.6	1,045–1,568	Missing capital cost	4,374–6,560
Propeller nozzles	5	Not available	185	522.6	Missing capital cost	2,187
Propeller winglets	4	Not available	148	418.1	Missing capital cost	1,749
Wind power	5 to 30	510–1560	140.6–843.6	396.5–2,379	< 1–2	1,623–9,735
Solar power	5 to 7	1,400	140.6	396.5–555.1	2–4	1,622–2,272

All options are evaluated based on incremental cost of the technology relative to a vessel without the technology—except for bubble lubrication, wind power, solar power, and advanced propeller technologies, as these can be applied as add on technologies. For this analysis, efforts were made to account for the different types of vessels that would be candidates for these technologies; for example, hybrid engines were considered appropriate for harbor vessels that have an annual fuel usage of 1,406,000 gallons in contrast to medium and large long-haul vessels that have an annual fuel usage of 2,812,000 and 3,706,415 gallons, respectively, and would be candidates for enhanced ship design, advance propellers, bubble lubrication, diesel electric configuration, wind, and solar power options. ERG used the IMO annual GHG emission estimates from the April 2009 GHG study. Marine fuel costs were assumed to be $2.056 per gallon.

6.4 Air Freight Strategies

Worldwide, there are approximately 2,500 aircraft involved in freight shipments. These aircraft are either associated with the cargo division of large air carriers such as Delta Cargo, China Airlines Cargo, Emirates SkyCargo, or approximately 1,650 aircraft[234] provide dedicated cargo services such as UPS, Federal Express, DHL, Eva Cargo, and Etihad. These large corporations have modern international fleets equipped with engines that comply with existing International Civil Aviation Organization (ICAO) engine standards. As with the other transportation modes, fuel usage represents a significant fraction of their expenditures (20 to 30 percent),[235] so green freight action plans associated with air cargo should encourage application of technologies that reduce fuel consumption and better utilization of the aircraft fleet (e.g., facilitate quick turnaround times in shifting cargo at airports).

Commercial aircraft used for air freight range in size from medium-sized regional aircraft such as the Beech 1900,[236] equipped with twin turboprops (jet engines that turn propellers), to large 747 Boeings and massive Airbus Beluga aircraft (shown below), equipped with turbo fan jet engines.

Duch.seb/Wikimedia Commons; CC BY-SA 3.0

Because aircraft use relatively large volumes of fuel, engines that are more fuel-efficient provide companies with a competitive advantage over competitors with older fleets equipped with less fuel-efficient engines. Over the last 40 years, aviation fuel efficiency has improved by 70 percent.[237] ICAO anticipates that an additional 20 percent improvement in fuel efficiency is possible by 2024.[238]

General Electric (GE) has been promoting a new line of engines that employs new designs and materials, such as ceramic matrix composite turbine blades, that reduce fuel consumption by 10 to 15 percent which equates to a cost saving of over a million dollars per year per aircraft.[239]

Pratt & Whitney (P&W) has developed a high-bypass geared jet engine (PW1000 G) which will be installed in the Bombardier C-Series aircraft in 2015, and is being considered for aircraft such as Boeing's 747-SP and Airbus' A340-600. This geared jet engine allows the engine fan to

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[234] Airbus (2013). *Global Market Forecast: Future Journeys: 2013–2032.*
[235] World Bank (2009). *Air Freight: A Market Study with Implications for Landlocked Countries.* Section 4.
[236] https://www.evernote.com/shard/s2/sh/a9549bec-fd15-48fc-9bdc-4b96d28cd316/e672917a1c97e90b343aa761d2085452
[237] Intergovernmental Panel on Climate Change (1999). *Special Report: Aviation and the Global Atmosphere.*
[238] International Civil Aviation Organization (2013). *2013 Environmental Report.*
[239] http://www.geaviation.com/

operate at a slower, more optimal speed while the low-pressure compressor and turbine operate at their optimized higher speed. This engine is anticipated to reduce fuel consumption by 20 percent and noise by 75 percent.[240]

Several companies such as GE, Rolls Royce, and P&W are working on an open rotor engine where propeller blades are geared to the turbine and mounted outside the casing. Such designs can be lighter and provide higher fuel efficiency (25 to 30 percent improvement), but they tend to be noisier than similar turbo fans of equivalent power rating.[241]

Note that there is a significant secondary benefit to improving jet engine efficiency. As less fuel is needed, the total weight of the aircraft (that includes the weight of the fuel) is reduced, which further reduces fuel consumption and emissions.

An aircraft's main engines use fuel and emit pollutants while taxiing in and out of a terminal gate; this can be particularly problematic for high-volume airports, where delays are regularly encountered. Boeing and several other companies have developed an electric wheel[242] that is powered by the aircraft's auxiliary power unit (APU), which is a much smaller, more fuel-efficient way to maneuver around the runways than operating the main jet engines at their least-efficient loads. Single-engine taxi has also been used to reduce aircraft taxi emissions. Consideration of electric wheel or single-engine taxiing in a green freight action plan will reduce aircraft fuel consumption and improve local air quality.

WheelTug

In addition to engine improvements, alternative aviation fuels—specifically biofuels and synthetic fuels—can be considered. There have been several successful test flights using biofuel since 2011, when it was approved for use in aviation operations.[243] Depending upon the source of the biofuel, GHG emissions can be reduced by up to 85 percent. But there are still unresolved issues concerning the storage life of the fuel and its performance at higher altitudes, where lower temperatures cause it to gel. The military has been investigating the use of synthetic aviation fuels derived from coal, natural gas, or biomass, using the Fischer-Tropsch process. Synthetic aviation fuels tend to emit fewer pollutants than conventional jet fuels due to their high purity and lack of contaminants. Because they have a higher energy content relative to the carbon content of the fuel, they emit less CO_2. Depending on the feed stock for the synthetic fuel, lifecycle assessment of GHG emissions indicate that coal to liquid fuels have a 147 percent higher carbon footprint than traditional petroleum-based fuels.

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[240] http://www.purepowerengine.com/
[241] Warwick, G. (2007). Open debate on open rotors. *Flight Global*. Retrieved from http://www.flightglobal.com/blogs/graham-warwick/2007/06/open-debate-on-open-rotors/.
[242] http://www.wheeltug.gi/
[243] http://en.wikipedia.org/wiki/Aviation_biofuel

Green freight action plans that encourage use of these fuels need to account for infrastructure changes required for fuel storage and distribution.[244]

FlugKerl2/Wikimedia Commons; CC BY-SA 3.0

In addition to the aircraft engine and fuel options, improvements to the airframe are possible that reduce friction and enhance lift, thereby improving the overall efficiency of the aircraft. These improvements include wing lengthening, laminar flow wings, multilayer wings, winglets (shown to the left), and low-friction surface coatings.[245]

Alternative aircraft types such as blimp-like cargo ships are currently being developed that reduce fuel consumption, emissions, and freight costs.[246] These aircraft are ideal for applications where roads are relatively scarce and cargo is a shape and size that is not suitable for flatbed trucks.

Lastly, green freight action plans may want to consider operational changes such as the U.S. FAA's NextGen system, which is anticipated to save 1.6 billion gallons of fuel and reduce CO_2 emissions by 16 million metric tons between 2013 and 2020.[247] These benefits will be achieved by reducing time delays, ensuring that aircraft operate at their optimal elevation and fly directly to their destination airport, and making in-flight adjustments to avoid storms that could affect the flight. Most of these operational enhancements are derived from better use of satellite navigation.

Aeroscraft

Estimates of GHG reductions, as well as cost-effectiveness of these various strategies, are based on a comprehensive review of the existing literature on the impacts of individual strategies. The following table summarizes the results of this analysis.

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[244] Stratton, R.W. (2010). *Life Cycle Assessment of GHG Emissions and Non-CO_2 Combustion Effects from Alternative Jet Fuels.* Retrieved from http://dspace.mit.edu/handle/1721.1/59694#files-area.

[245] U.S. DOT (2010). *Transportation's Role in Reducing U.S. Greenhouse Gas Emissions*. Retrieved from http://ntl.bts.gov/lib/32000/32700/32779/DOT_Climate_Change_Report_-_April_2010_-_Volume_1_and_2.pdf.

[246] RT.com (2013). Super-Zeppelin: Revolutionary airship may become cargo-carrying champion. Retrieved from http://rt.com/news/aeroscraft-revolutionary-airship-cargo-187/.

[247] FAA (2013). NextGen Implementation Plan. Retrieved from http://www.faa.gov/nextgen/implementation/media/NextGen_Implementation_Plan_2013.pdf.

Table 6-5. Table Summary of Air Freight Technology Options

Technology	Fuel Reduction (%)	Incremental Capital Cost ($ Thousand)	Annual Fuel Savings (Thousand Gallons per Year)	Annual Fuel Cost Savings ($ Thousands)	Payback Period (Years)	Annual GHG Emissions Reduction (Tons per Year)
Engine improvement	10–15	65,000	290–435	965.7–1,449	> 40 years	3,059–4,589
Geared-jet	10–15	19,000	290–435	965.7–1,449	13–20	3,059–4,589
Rotor	10–30	12,000	290–870	965.7–2,897	4–13	3,059–9,178
Wing tip device	2–10	500–1,000	49.3–290	164–965.7	1–3	520–3,059

All options are evaluated based on incremental cost of the technology relative to an aircraft without the technology—except for wing tip devices, as these can be applied as add-on technologies. Annual fuel usage was assumed to be 2,900.000 gallons per aircraft. Aviation jet fuel cost was assumed to be $3.33 per gallon.

7.0 Conclusions and Prospects for Harmonization

7.1 Summary

The CCAC's Global Green Freight Action Plan will provide guidance for the advancement and harmonization of green freight programs around the world, with the aim of reducing CO_2 and black carbon emissions. The successful implementation of the Action Alan will accelerate the adoption of advanced fuel efficiency and emission control technologies and operational strategies in multi-modal goods movement. This document provides an overview of global freight operations; the environmental impacts of freight emissions; available in-use technologies and strategies; and green freight program status and initiatives, while highlighting gaps in our knowledge with regard to emissions data, program implementation status or specific regional conditions. The goal of this document is to provide a foundation for the CCAC to move forward in the development of the Action Plan.

A number of general observations can be made from the preceding analysis. First, heavy on-road trucks were responsible for over 50 percent of total global freight-related energy use in 2009. On-road domestic goods transport generally dominates other modes, although 80 percent of *internationally* traded goods were carried by marine vessels in 2011.[248] In addition, the carbon-intensity of freight movement, as measured in g CO_2/tonne-km, varies widely by mode, as summarized in Table 7-1 below.

Table 7-1. Carbon-Intensity of Freight Travel by Mode, g CO_2/Tonne-km[249]

Aircraft, short-haul	~1,200–2,800
Aircraft, long-haul	~220–1,000
On-road diesel trucks, light commercial truck/van	~500–1,200
On-road diesel trucks, Class 3–6	~250–750
On-road diesel trucks, Class 7–8	~75–180
Diesel rail	~25–60
Waterborne barge	~25–60
Container ships	~15–45
Ocean-going bulk carriers/tankers	~10

As evidenced by the table above, switching from high- to low-carbon-intensity modes can have a substantial impact on overall fuel consumption and emissions in those areas where the transport network and infrastructure allows. As an alternative to mode switching, a variety of technologies and operational strategies are also available to improve the fuel efficiency and reduce emissions associated with in-use freight trucks, including aerodynamic retrofits, idle reduction, low-rolling-resistance tires, alternative fuels, telematics, and improved logistics, among many others. Adopting packages of these strategies can frequently reduce fuel consumption by 10 percent or more, depending upon site- and fleet-specific factors.

[248] Intergovernmental Panel on Climate Change (2013). *Climate Change 2014: Mitigation of Climate Change.* Draft final report. Chapter 8, p. 11.
[249] Ibid., Figure 8.6.

The type of fuel used for freight movement also has a significant impact on climate change. Diesel and marine bunker fuel have high energy densities and dominate global freight transport. Combustion of these fuels also generates substantial emissions of black carbon, a powerful short-lived climate forcer. While switching to gaseous fuels such as natural gas, or electricity, can dramatically reduce black carbon emissions relative to diesel, fuel delivery systems and vehicle conversion costs frequently limit these options to niche applications (e.g., to centrally fueled urban delivery fleets). However, the widespread provision of ultra-low-sulfur diesel (ULSD) fuel enables the introduction of new emission control technologies coupled with more stringent emission standards for new vehicles. ULSD fuel also allows vehicle owners to retrofit their in-use fleet with highly effective PM emission control devices such as diesel particulate filters. Green freight programs can promote the adoption of these measures by packaging them with fuel-saving strategies such as aerodynamic retrofits or idle reduction technologies. In this way, the resulting fuel savings can help cover the incremental costs associated with black carbon control measures.

Freight markets vary widely around the world in terms of volume and types of goods transported, operational efficiency, available modes, fleet condition/age, etc. The mix of these factors in turn impacts the preferred strategies for each region. Chapters 5 and 6 identify a variety of potentially cost-effective technology and operational strategies for fleets of differing operating categories, conditions, and modes.

As discussed in Chapter 3, there are a number of green freight programs in operation around the world tailored for a variety of regions, stakeholders, and transport modes. These programs have consistently demonstrated potential for significant emission reductions in a wide variety of locations and operating conditions. The most successful green freight programs are based on the business case for fuel savings; they incentivize investments in fuel savings technologies and operational strategies, such as those described in this report, resulting in substantial cost savings to operators. In this way these programs generate a “win-win” outcome, with both financial and environmental benefits. For example, the figures below clearly demonstrate how fuel cost savings and CO_2 reductions for the SmartWay program go hand in hand.

Figure 7-1. Truck CO_2 Emissions Reductions, U.S. EPA SmartWay Program, 2004–2013

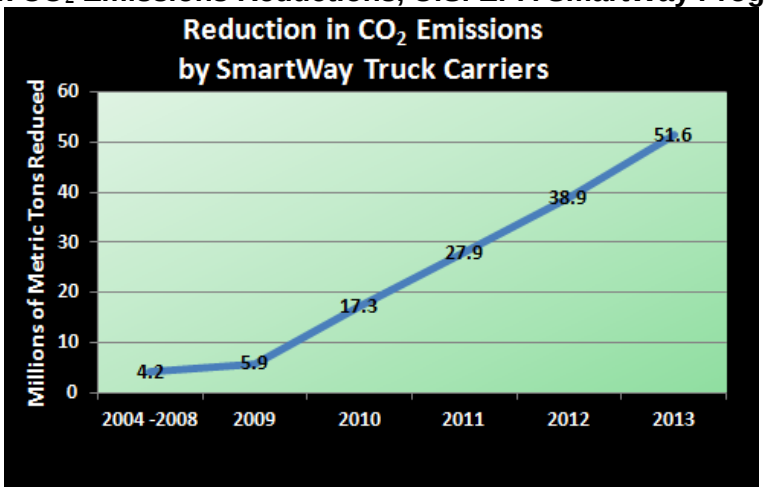
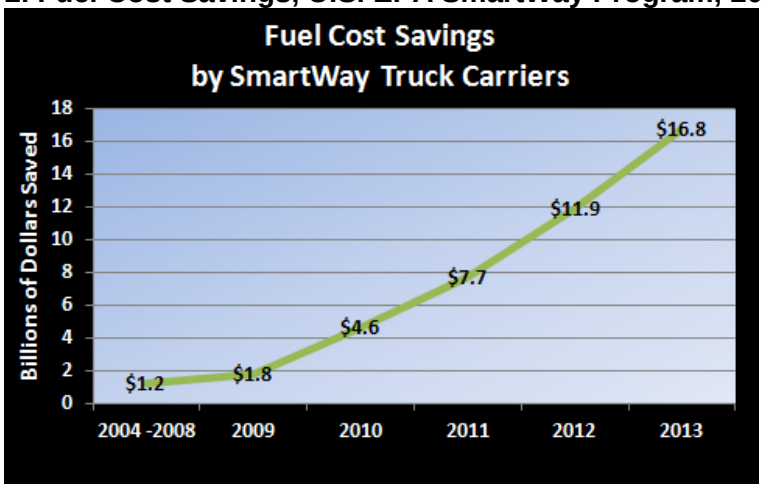


Figure 7-2. Fuel Cost Savings, U.S. EPA SmartWay Program, 2004–2013



7.2 Lessons Learned, Findings, and Recommendations

Draft sections of this technical background report were also provided to representatives of the green freight programs described in Sections 3.1 ("Detailed Program Summaries") and 3.2 ("Other Programs"). In addition to asking for input regarding the technical content of the report, ERG requested follow-up interviews with program representatives. Interview questions sought to obtain opinions on the perceived strengths and weaknesses of the respective programs, lessons learned, and recommendations for future expansion and potential harmonization with other programs, among other topics. (A complete list of interview questions is provided in Appendix A.)[250]

These program representatives made the following recommendations.

7.2.1 Program Design

- Develop a clear roadmap for program scope, modes, schedule for expansion, etc., and ensure senior management sign-off and ongoing support.
- Identify staff resource needs and funding requirements early in program design.
- Clearly define staff roles explicitly for client support and retention.
- Obtain active input and support from high-profile industry leaders during program development and launch. This greatly aids in establishing credibility from the outset. Continuous industry and other stakeholder support is crucial to success.
- Ensure frequent communication and data sharing through the distribution of customized benchmarking reports, webinars regarding tool use and data analysis, technology evaluation

[250] Interviews were conducted via conference call in April 2014, with representatives from the following programs: SmartWay (both U.S. EPA and Natural Resources Canada), Green Freight Asia, Clean Cargo Working Group, and Smart Freight Centre/Global Logistics Emissions Council.

summaries and toolkits, and driver training outreach to provide significant added value to partners, and help with recruitment and retention efforts.[251]

- Establish legal guidelines and policies regarding privacy and data security during the program development phase, before implementing a database and data exchange procedures.
- To measure program success, develop a program benefit estimation methodology that is simple to implement. Ensure that all the data required for the benefit assessment will be collected during standard tool completion and submittal.
- Define program data needs based to support stakeholder goals and program evaluation requirements. Data needs can vary with program objectives. For example, programs oriented toward logistics providers may focus more on activity-based information rather than the adoption of specific technologies.
- Balance tool simplicity (i.e., user-friendly and secure) vs. providing detailed data for performance evaluations, metrics, and trend analysis.[252]
- Identify opportunities for third-party data validation.

7.2.2 Implementation

- Have partner support materials ready for distribution at program launch (e.g., promo/website/tools).
- Establish frequent, personal communication between partner account managers (PAMs) and partners to promote trust in, and commitment to, the program. Clear and frequent communication with stakeholders is particularly crucial during the first years of the program.
- Leverage existing relationships with stakeholders in order to build momentum for the program at the outset, especially relationships with large, influential shippers.[253] Also encourage initiatives to recruit highly visible, international partners in order to garner attention for the program. Greater visibility increases the chance to sustain public support and maintain funding resources.
- Provide program support staff with background documentation on freight industry operation and terminology before beginning engagement with stakeholders.

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[251] For example, NRCan successfully leveraged past relationships established through its successful FleetSmart Driver Training program to identify recruits for the initial SmartWay Program launch.

[252] Presentation of emissions performance can be complicated by the wide variety of metrics, ranking categories, and transport modes, as well as stakeholder needs. The U.S. EPA developed the current "SmartWay 2.0" performance evaluation and reporting system in order to meet shipper demands to quantify carbon footprints more accurately and precisely. Nevertheless, the EPA representative acknowledged the difficulty in presenting performance reports at an executive level while maintaining useful detail for developing action plans. EPA is investigating alternative approaches to improving the usefulness and understandability of carrier performance data (e.g., the "partner report card" currently under development).

[253] As a counter-example, it was noted that the China Green Freight Initiative may have relative difficulty incentivizing carrier cooperation—since only shippers are included in the program, CGFI must rely on governments to require carrier action.

- Be aware of region- or mode-specific sensitivities (e.g., try to incentivize each mode to provide company-specific operations data).
- Develop a partner retention strategy based on a strong value proposition (e.g., providing toolkits, driver training, fleet manager training).

7.2.3 Program Maintenance and Growth

Green freight programs need to grow over time in order to maintain stakeholder support. Program representatives identified various obstacles to growth for their programs:

- The value proposition for green freight programs are frequently influenced by conditions in the broader economy. "Environmental benefits" generally diminish in importance to companies during difficult economic times. Alternatively, the business case for investing in fuel savings strategies becomes more difficult when fuel prices fall.
- Time and resource requirements for joining a program can be onerous for small carriers such as owner-operators which may not have the staff, data or computer skills and equipment to conduct sophisticated data input and analysis. This limits the appeal of the program for this significant portion of the freight sector.
- Budget constraints can place significant limitations on outreach activities including travel to meetings and symposia, and advertising.[254]

Program representatives suggested a variety of ways to maintain program support and encourage growth.

- For programs in the early phase of development, consider creating a simplified "excellence mark" to summarize overall performance level (e.g., similar to the Lean and Green star designations).
- Make tools simpler and easier to use for small carriers to encourage participation.
- Consider placing tools online and pre-populating them with some data from the previous year (e.g., contact information, fleet names) to ease subsequent years' data submissions.
- Tools could link directly to each partner's historical data to assist with trend evaluations.
- Verify the quality of the data submitted by program partners to ensure reliable program performance evaluations.
- Apply a consistent calculation methodology over the years, ensuring reliability and comparability of the performance data.[255]

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[254] As a business-to-business effort green freight programs are inherently limited in their outreach efforts, having little or no direct public relations target.

[255] Similarly, introducing major programmatic changes (e.g., moving from SmartWay 1.0 to 2.0) can be very disruptive to partners and cause confusion. Significant up-front planning is required to minimize program disruption, along with frequent communication with partners regarding any upcoming changes.

- Conduct continual research into program impacts in order to publicize benefits at the fleet, corporate, modal, and industry levels.
- Encourage dialogue directly between shippers and their carriers regarding best practices and performance goals in order to facilitate the adoption of technical and operational efficiency improvements.
- Foster a collaborative relationship with the freight industry. For example, the data collected through the SmartWay technology verification process have been instrumental in the development of subsequent regulatory efforts such as the heavy-duty vehicle fuel economy rules recently adopted in the United States. In this way the voluntary nature of the program helps counter the adversarial relationship often found in regulatory development efforts.
- Hold regular forums to obtain partner feedback regarding potential changes to data collection and reporting procedures. For example, the CCWG program currently lacks data regarding capacity utilization. The CCWG is working with partners to develop a revised data collection methodology to consistently collect reported capacity data considering the range of different utilization reporting procedures used by marine carriers.
- Consider using social media platforms such as Twitter and Facebook to notify stakeholders about program developments for a highly cost-effective means of enhancing outreach strategies.
- Protect business-sensitive operation information through annual contract agreement renewals with program partners.
- Establish a long-term task authorization contract mechanism with a single contractor to facilitate the consistent execution of program support functions such as tool development and database maintenance over multiple years.

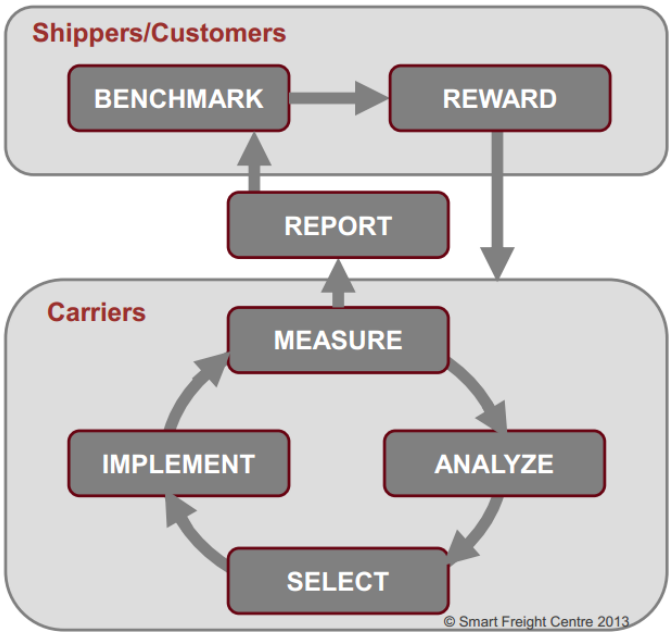
7.3 Program Advancement, Expansion and Harmonization

7.3.1 Common Indicators for Success

Although the green freight programs evaluated in Chapter 3 differ in a number of substantive ways, several common features lead to program success:

- Extensive stakeholder involvement in all aspects of program design, deployment and operation is crucial to long-term success. Although the business-to-business nature of green freight programs presents unique challenges, these can be overcome through strong stakeholder commitment and participation in developing a program vision, quantification methodology, and measurement methods, as well as balancing concerns for transparency with confidentiality and data security.
- Broad programs should have representatives from across the entire supply chain, including shippers, carriers, and logistics providers, as well as key affiliates such as trade associations to help foster a sense of mutual trust between partners and program administrators.
- Successful programs integrate both “push” (carrier-driven) and “pull” (shipper-driven) elements to varying degrees, reflecting the strategic and market value of performance measurement and evaluation for carriers, as well as the importance of reliable carbon

footprinting and benchmarking for shippers. The integrated, dynamic nature of these drivers is summarized in the following diagram.



Smart Freight Centre

- Programs can be successful under a variety of administrative structures, with active leadership coming from industry, government, and/or other research organizations/NGOs. The appropriate structure will depend upon the data needs and preferences of the region, transport modes, and target participants. ***The key is to provide industry with a trusted, impartial arbiter ensuring that performance data are reliable and secure.***
- Programs should be provided with consistent, reliable funding (commensurate with program goals and commitments) and qualified, trained staff in order to ensure sustained communication with partners, effective data management, reliable program performance assessments, and successful outreach and recruiting efforts.

7.3.2 Prospects for Harmonization

Long-term program harmonization appears to be essential to ensure the success of green freight goals at the global level, and in ways that foster reductions in energy use and emissions. While green freight programs will continue to have substantial positive impacts domestically and regionally, global harmonization is critical to continued expansion and greater emissions reductions. Until programs are harmonized or aligned across modes and with standard metrics, programs will be limited in their ability to reach and fully inform the market, help shippers and carriers improve their efficiency, and foster additional emission reductions.

The green freight programs identified in this study focus on a variety of different goals and strategies, posing potential challenges to future integration. Programs exist along continua across a number of different “dimensions”:

- Predominantly shipper- vs. carrier-driven.
- Government vs. industry administered.
- Large vs. small partner focus.
- Target mode (truck, multi-modal, marine, logistics, etc.).

The representatives frequently emphasized that successful green freight programs can fall anywhere along the above continua, depending upon the opportunities and constraints of the regional freight market, carrier fleets, and regulatory environment.

However, green freight programs at differing stages of development may present challenges for harmonization. For example, the GFCI is currently focusing on technology demonstrations and education rather than actual data collection. On the other hand, collaboration and coordination across programs at an early stage also provides an opportunity to align future data collection and measurement methods with a broader harmonized network.

Other potentially challenging differences across existing programs are described below.

7.3.2.1 Institutional/Administrative Challenges

- **Regulatory requirements and constraints on the local freight industry.** Opportunities for implementing technology and operational strategies will vary by region and mode due to region-specific constraints. In addition, certain modes may be more reluctant than others when it comes to providing company-specific performance data, for a variety of reasons.
- **Legal frameworks and policies regarding partner privacy and data security.** Even the highest-quality performance data will be of limited value in a broader global network if distribution of information is restricted or even forbidden due to differing legal, regulatory, and industry policies. Data reporting methodologies that promote transparency and accountability will help minimize these concerns.
- **Levels of available funding and resources.** Programs face numerous challenges maintaining adequate funding levels. At any given time certain programs may be well-funded and staffed, while others struggle to find adequate resources. For example, government-led programs are subject to potentially frequent changes in legislative budgeting priorities. In addition, governments in developing countries face particularly significant budget constraints and may be less inclined to focus resources on voluntary programs. Privately funded programs, or those funded by participant fees face similar challenges raising funds in difficult markets.
- **Language barriers.** For example, informational materials and trademarked branding/logos must be translated and reviewed by technical and legal staff before dissemination.
- **Overlapping functions and skill sets among program staff.** Some programs target the same modes and even the same companies. Up-front coordination may be needed to limit redundancy in skill sets and “competition” for specific partners and possibly even for funding

7.3.2.2 Data Collection/Management Challenges

- **Data reporting requirements, quantification methodologies, and reporting metrics.** Truly uniform, harmonized programs must have integrated these elements in order to provide consistent, useful performance data. For example, even though CCWG and SmartWay both collect highly reliable data from their partners, it would be necessary to establish equivalencies between CCWG's volumetric performance measures and SmartWay's mileage and tonne-mileage measures.
- **Access to reliable activity performance data.** Many developing countries do not have extensive logistical data collection systems in place, making collection of accurate activity data more challenging. Nevertheless, as programs grow their measurement methodologies can also evolve to take advantage of newly available data sources.
- **Data management systems.** Differences in platforms (e.g., reporting formats, databases) potentially constrain data sharing potential across programs. Establishing simple terms of agreement between agencies can greatly facilitate information exchange.[256]
- **Data quality.** As noted above, differences in data quality limit the reliability of supply chain assessments depending upon location and mode. Such differences could be addressed by establishing common data quality rating criteria. Alternatively, encouraging third-party data validation, as the CCWG program does, will go a long way toward ensuring the credibility of program data. Nevertheless, programs with less robust data quality and verification procedures should not be discouraged from participating.[257]

7.3.3 Considerations for Developing Countries

Programs in developing countries can present particular challenges for harmonization:

- **A lack of familiarity with technology and operational efficiency options.** In this case there is a role for pilot programs and platforms for sharing best practices, such as through the GFA network. Establishing early research and demonstration projects requires careful assessment of what is achievable in terms of funding, technologies, local regulatory requirements, and general region priorities. For example, given the extremely high empty backhaul rate in China, investments in infrastructure and logistics systems may prove to be the "lowest-hanging fruit" for their programs.
- **A greater preponderance of small operators,** which entails a number of other challenges. For instance, carriers in these regions frequently operate on extremely small margins, increasing their effective discount rate and limiting their ability and willingness to invest in efficiency improvements. In turn, such companies typically have less access to financing. These operators are even less likely to invest/participate in a green freight program when

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[256] Integration of the U.S. and Canadian programs has been very successful, with data now shared seamlessly between the programs. A strong relationship has also been developed between EPA and NRCan, fostered by frequent exchange of presentations and support documentation. Up-front coordination between program management and technical staff was deemed to be critical to the successful merging of the programs.

[257] It was also noted that data quality differences are somewhat less of a concern between countries (at least for road freight) as carriers operating in the same region are often subject to the same data quality constraints.

relative fuel costs are flat or falling. In addition, they are particularly vulnerable to economic downturns and decreased demand for freight services, making long-term commitment to and participation in voluntary programs less likely.

- **Even less access to funding and qualified staffing resources** than in developed countries.
- **Inconsistent regulatory and burdensome bureaucratic requirements** placed on potential partners in the freight industry by a variety of agencies. On the other hand, fleets in developing countries often have the oldest, dirtiest equipment and thus offer the greatest potential for efficiency gains and emission reductions.

Although many challenges lie ahead, these goals are attainable. For example, there has already been significant movement in regional harmonization efforts. In addition to the CCAC initiative, these efforts include SmartWay's expansion to Canada, coordination efforts between GFE, Lean and Green, and the Smart Freight Centre, and the development of the GFA country networks. The CCWG is also seeking a strategic alignment with the Clean Shippers Index, and is coordinating planning efforts with GFE, GFA, and many others.

As harmonization efforts progress over time, the above challenges will likely be addressed in ways not currently foreseen. The CCAC Partners are currently responding to the Green Freight Call to Action in a variety of creative ways, leveraging both public and private resources to expand the adoption of cost-effective CO_2 and black carbon reduction strategies across all freight sector modes and regions of the globe. Working together, these stakeholders are well-positioned to develop a successful roadmap for the next steps of green freight program expansion and integration.

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8.5 Other Links and Resources

8.5.1 Websites of Green Freight Organizations

- Official SmartWay homepage: http://epa.gov/smartway
- SmartWay Canada: http://smartway.nrcan.gc.ca
- Transporte Limpio (Mexico): http://www.transportelimpio.gob.mx (under construction)
- EcoStation (Australia): http://www.ecostation.com.au
- GreenFreight Europe: http://www.greenfreighteurope.eu
- Green Distribution Partnership (Japan): www.greenpartnership.jp
- Green Freight Asia Network: http://greenfreightasia.org/
- Green and Smart Transport Partnership (Korea): http://cleanairinitiative.org/portal/sites/default/files/presentations/PM-2-korea_2_-_GreenSmart_Partnership_CGFI.pdf
- Clean Cargo Working Group: http://www.bsr.org/en/our-work/working-groups/clean-cargo

8.5.2 Websites of Relevant Associations and Stakeholder Groups

- Clean Air Asia: http://www.greenfreightandlogistics.org
- ATA Trucks Deliver a Cleaner Tomorrow: http://trucking.org/cleaner_tomorrow.aspx
- EPA National Clean Diesel Campaign: http://epa.gov/diesel
- EPA Clean Diesel Collaboratives: http://epa.gov/cleandiesel/collaboratives.htm
- International Council on Clean Transportation: http://theicct.org
- American Council for an Energy Efficient Economy: http://www.aceee.org/sector/transportation
- DieselNet: http://www.dieselnet.com/
- Consignment Carbon: http://www.consignmentcarbon.org/index.php
- Climate and Clean Air Coalition Heavy Duty Diesel Vehicles and Engines Initiative: http://www.unep.org/ccac/Initiatives/HeavyDutyDieselVehiclesandEngines/tabid/130319/language/en-US/Default.aspx
- Green Freight Asia: http://greenfreightasia.org
- Partnership on Sustainable Low Carbon Transport: http://www.slocat.net/

8.5.3 Other Resources

- NRCan and SmartWay's SmartDriver E-learning: http://fleetsmartlearning.nrcan.gc.ca/Saba/Web/Main

- EPA Heavy-Duty Regulations and Standards: http://www.epa.gov/otaq/climate/regs-heavy-duty.htm
- NHTSA Fuel Economy website: http://www.nhtsa.gov/fuel-economy
- CARB Heavy-Duty Greenhouse Gas Regulation: http://www.arb.ca.gov/cc/hdghg/hdghg.htm
- Greenhouse Gas Equivalencies Calculator: http://epa.gov/cleanenergy/energy-resources/calculator.html
- Detailed EPA emissions standards document: http://epa.gov/oms/highway-diesel/regs/diesel-engine-standards.htm
- SmartWay Verified Technologies list: http://www.epa.gov/cleandiesel/verification/verif-list.htm
- National Clean Diesel Verified Technologies list: http://www.epa.gov/cleandiesel/verification/verif-list.htm
- California Air Resources Board Verified Technologies list: http://www.arb.ca.gov/diesel/verdev/vt/cvt.htm
- National Academy of Sciences technology overview: http://www.nap.edu/catalog.php?record_id=12845

8.5.4 Region-Specific Articles and Other Resources

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- DHL (2014). Green solutions for air, ocean and road freight. Retrieved from http://www.dhl.com/en/about_us/green_solutions/air_ocean_road_freight.html.

Appendix A
Interview Questions for Green Freight Program Representatives

1) What elements of your program are the most successful and worthy of highlighting in the Technical Background Document?

2) What lessons or best practices have you learned over the course of your program's development? i.e., What could have been done differently to improve the effectiveness and extent of your program?

3) What recommendations do you have regarding best practices for green freight program design, development and implementation? (Break down by: 1) program design and features, 2) program implementation (e.g., stakeholders and partner engagement), 3) Administration and management, and 4) program growth and expansion)

4) What data do you most need in order to improve program performance? What constraints limit your access to this data?

5) What limits the growth of your program? What are the greatest challenges that you foresee? (e.g., institutional, regulatory, funding, market factors, information, other factors?)

6) What types of resources would be most valuable in overcoming these obstacles, helping you to sustain and grow your program? (Financial, staff training, educational outreach, other)

7) What international resources are you, or do you plan to, take advantage of? (information from other programs, Green Freight Charter, COFRET, other)

8) Do you see opportunities with coordinating or collaborating between your program and others at the global level? If so, what do you envision as the goal?

9) The CCAC GF initiative hopes to encourage the integration and harmonization of national and regional green freight programs over time, creating a global standard for freight carrier performance assessments and benchmarking. What opportunities or advantages do you see with cooperating and harmonizing with other programs? Do you anticipate institutional limitations or other constraints?

Appendix B
CCAC Stakeholder Proposal, Executive Brief, and Call to Action

STAKEHOLDER CONSULTATION PROPOSAL
Developing a Global Green Freight Action Plan

Background

- The Climate and Clean Air Coalition (CCAC) is developing a ***Global Green Freight Action Plan*** to provide a blueprint and roadmap for the advancement and harmonization of Green Freight programs globally with the aim of reducing carbon dioxide (CO_2) and black carbon (BC) emissions. *Please see the Executive Brief and Call To Action, attached for more information.*

What is being proposed?

- The CCAC is seeking the participation of industry-leading multinational firms who ship or carry goods through a multimodal supply chain, CCAC member countries, development banks, civil society and other stakeholders to provide input, insight and guidance on the development of a Global Green Freight Action Plan.

Who will participate?

- Freight logistics firms, carriers and shippers in retail, manufacturing and other key economic sectors are invited to designate a transportation, logistics or environmental leader from within the organization to participate in a near term stakeholder process.
- Government officials from CCAC member countries are invited to lend expertise and resources to participate in this process, in addition to providing political support and engagement on a global scale.
- The Green Freight Steering Group leads the process with government officials from the U.S. and Canada, the International Council for Clean Transportation, World Bank, Clean Air Asia, and Smart Freight Centre.

What is the process and when and where is participation needed?

- A series of roundtable meetings, conference calls and discussions will form a consultative process through which firms and CCAC member countries will be invited to provide leadership, input, insight and guidance on the needs, challenges and opportunities to develop and launch a Global Green Freight Action Plan. The consultative process will commence spring 2014 and conclude with the launch of the Action Plan by December 2014. Companies, countries and other stakeholders will be asked to:

1) <u>Assist with the development</u> of the Global Green Freight Action Plan: May – August 2014

- Provide input, insight and information for the development of the Action Plan with emphasis on needs of countries, industry and marketplace, best practices, lessons learned from existing Green Freight programs, gaps and global needs.
- Roles and commitments of the various stakeholders and participants will be defined in the Action Plan, with emphasis on how each will contribute to the successful implementation of the Plan.

2) <u>Champion and endorse</u> the Global Green Freight Action Plan: May – December 2014

- **Stakeholders may be invited to join the United Nations Secretary General Climate Summit Sept 23rd** in New York to announce their commitment and progress on developing the Action Plan.

- As industry leaders, companies will be encouraged to lead the way for their peers, including promoting and educating others through forums, meetings, and other outreach, as well as commitments to participate in the implementation of Green Freight programs in the countries in which they operate.
- Governmental engagement at the Ministerial level will support the piloting of Green Freight programs in three CCAC member countries, with the participation of CCAC and other stakeholders.

3) Implement the Global Green Freight Action Plan: December 2014 and onward

- All stakeholders will be invited to participate at a launch press event in late 2014 or early 2015 to share global efforts and announce finalization and launch of the Action Plan.
- Stakeholders will commit to use the Action Plan as a template or roadmap for their firms and their industry, to move forward and support ongoing development and implementation.
- Governments, civil society, development banks and other stakeholders will also participate and have clear roles in implementing the Plan.

What are the benefits of participating?

- Industry leaders committed to shaping the marketplace and public policy landscape have the opportunity to provide input to policy makers at a global level, and drive the advancement of Green Freight initiatives globally.
- Stakeholders will gain opportunities to assert their corporate citizenship and create visibility for their leadership with policy makers in countries where they have operations.
- Firms can help guide the evolution of global efforts in ways that enhance their competitiveness, generate cost savings, and develop markets.
- Countries can build capacity to develop their own Green Freight initiatives based on established efforts.
- Civil society, development banks and other stakeholders can help advance their sustainability and development agendas.

What are the goals and outcomes?

Once fully implemented, the Action Plan will help ensure that complementary multimodal Green Freight programs will have been implemented at the national or regional level in many of the world's largest economies with the aim to reduce CO_2 and BC from goods movement. Multinational shippers and carriers of freight will be able to optimize multimodal freight supply chain energy and environmental efficiency across the network of these programs. A global network of Green Freight programs will provide for programs and supporting engagement which will ideally have some or all of these common features:

- Voluntary public-private partnerships, that support and complement efforts to reduce emissions, based on market mechanisms, information sharing and training;
- Supply chain freight transportation carbon quantification, through the use of harmonized reporting and benchmarking methods and tools, that will allow for mode and carrier optimization and ongoing efficiency improvement;
- Quantifiable fuel and cost savings which subsequently produce health and climate benefits through the reduction of CO_2 and BC;
- Technology verification programs, which can quantify the fuel and cost savings of technologies and strategies, and accelerate their adoption in the marketplace;
- Financing and incentive programs which facilitate retrofits of emission reducing technologies on in-use vehicles and/or fleet turnover;
- Promotion and sharing of operational strategies which further reduce emissions and costs; and

- Freight performance reporting, disclosure and data sharing, freight supply chain assessment, mode and carrier optimization, across mode, regions and programs (via global information sharing platform).

For More Information Please Contact:

Environment Canada	U.S. Environmental Protection Agency
Sonja Henneman	Buddy Polovick
+ 1-819-953-9483	+1-734-214-4928
sonja.henneman@ec.gc.ca	polovick.buddy@epa.gov

EXECUTIVE BRIEF

8.6 Introduction

Green freight and logistics organizations are beginning to lead global discussions on the reduction of greenhouse gasses such as carbon dioxide (CO_2), climate forcing agents such as black carbon (BC), (a component of fine particulate matter), and other conventional air pollutants. From global initiatives by the private sector to unifying methodologies for calculating emissions of freight services, to regional and national programs aimed at finding appropriate implementation measures for local circumstances, the drivers for and the approaches to green freight and logistics are multiplying.

This document outlines the role of the Climate and Clean Air Coalition in helping to ensure that these programs and methodologies are coming together at a global level to result in a harmonized, compatible approach to measuring and reducing the emissions of CO_2 and BC from the freight sector.

What is the Climate and Clean Air Coalition?

The Climate and Clean Air Coalition (CCAC) to Reduce Short-Lived Climate Pollutants (SLCPs) is a growing voluntary international coalition of State and non-State Partners who have pledged to enhance global, regional, and national public and private efforts to reduce SLCPs with an initial focus on methane, black carbon (soot) and many hydrofluorocarbons (HFCs). The CCAC is the first global effort to treat SLCPs as an urgent and collective action.

SLCPs are chemical agents that have a relatively short-life time in the atmosphere – a few days to a few decades – and a warming influence on climate. Some SLCPs are also dangerous air pollutants and can have detrimental impacts on human health, agriculture and ecosystems.

The CCAC carries out its core functions by:

- raising awareness of SLCPs and their impacts;
- enhancing existing and developing new national actions to reduce SLCPs;
- encouraging existing and new regional actions, and promoting opportunities for greater international coordination;
- reinforcing and tracking existing efforts to reduce SLCPs and developing and improving inventories;
- identifying barriers to action and seeking to surmount them;
- promoting best practices or available technologies and showcasing efforts to address SLCPs;
- improving understanding of and reviewing scientific progress on SLCPs, their impacts and the benefits of mitigation, and disseminating knowledge; and
- mobilizing targeted support for those developing countries that require resources to develop their capacity and to implement actions consistent with national strategies to support sustainable development.

Since its launch, the CCAC has made substantial progress with over 80 State and non-State Partners providing political and technical support and resources to reduce SLCPs through ten focal areas or "initiatives". One of the first initiatives to be approved by the Coalition was the initiative *Reducing Black Carbon Emissions from Heavy Duty Diesel Vehicles and Engines*.

Additional information on the CCAC can be found at:
http://www.unep.org/ccac/Home/tabid/101612/Default.aspx

8.7 The CCAC Heavy Duty Diesel Vehicles and Engines Initiative: Green Freight

The strength of the CCAC comes from its broad-based partnership of over 80 governments, intergovernmental organizations and international non-government organizations working together under a voluntary international framework to support concrete actions to reduce short-lived climate pollutants from key source sectors. In determining the Coalitions' activities, Partners take into account the catalytic effect of the activity to complement, scale-up, accelerate, and leverage existing efforts beyond the Coalition.

The objective of the Heavy Duty Diesel Vehicles and Engines initiative (HDDI) under the CCAC is to virtually eliminate fine particles, including black carbon emissions from new and existing heavy duty diesel vehicles and engines. Black carbon is a potent, near term climate pollutant of which diesel engines are a major source.

In order to make the largest impact, CCAC Partners have agreed that the HDDI will focus on four main elements:

- Country and regional work to support the establishment of more stringent emission standards with interested nations and parties;
- Development of a global strategy to reduce sulfur in diesel fuel;
- Efforts to clean up existing fleets, especially in cities and ports; and
- A green freight initiative to enhance existing global, regional and national public and private green freight efforts.

Recognizing the need for coordination and collaboration at a global level, and the ability of the CCAC to catalyze action by leveraging high–level government and non-government support for the continued development of green freight programs, CCAC Partners adopted a Green Freight Call to Action at the High Level Assembly in Warsaw Poland in November 2013 (attached).

In making the Green Freight Call to Action, CCAC Partners committed to providing a forum to foster cooperation among countries, and with international organizations and a platform from which to engage the private sector and other stakeholders in the development and deployment of a Global Green Freight Action Plan that can be implemented through public-private partnerships worldwide. The Green Freight Action Plan is to be finalized by December 2014.

The Action Plan will clearly define roles, responsibilities and opportunities for governments, private sector, civil society and other stakeholders. While the CCAC will support the development and launch of the Global Green Freight Action Plan, it is intended that this plan will act as a catalyst for stakeholder engagement and cooperation over the coming years. The development of the Green Freight Action Plan is led by Canada, the United States, the International Council for Clean Transportation (ICCT), World Bank, Clean Air Asia and Smart Freight Centre.

8.8 About Green Freight

"Green Freight" within the context of the CCAC Green Freight Initiative

For the purposes of the CCAC Green Freight Initiative, the term "Green Freight" is defined as activities that could reduce the energy use and emissions footprint of the in-use freight fleet with a combination of

market-driven voluntary actions undertaken by private sector stakeholders (carriers, shippers, and logistics providers), in partnership with governmental or administrative authorities. This may include the adoption of uniform systems to measure the carbon footprint of a supply chain, and/or the adoption of various after-market technologies (such as low rolling resistance tires, aerodynamics, telematics devices, etc.) and strategies (such as modal shifts, for example from truck to rail) that increase vehicle fuel-efficiency, drawing on the experience of programs such as the SmartWay Transport Partnership in the U.S. and Canada.

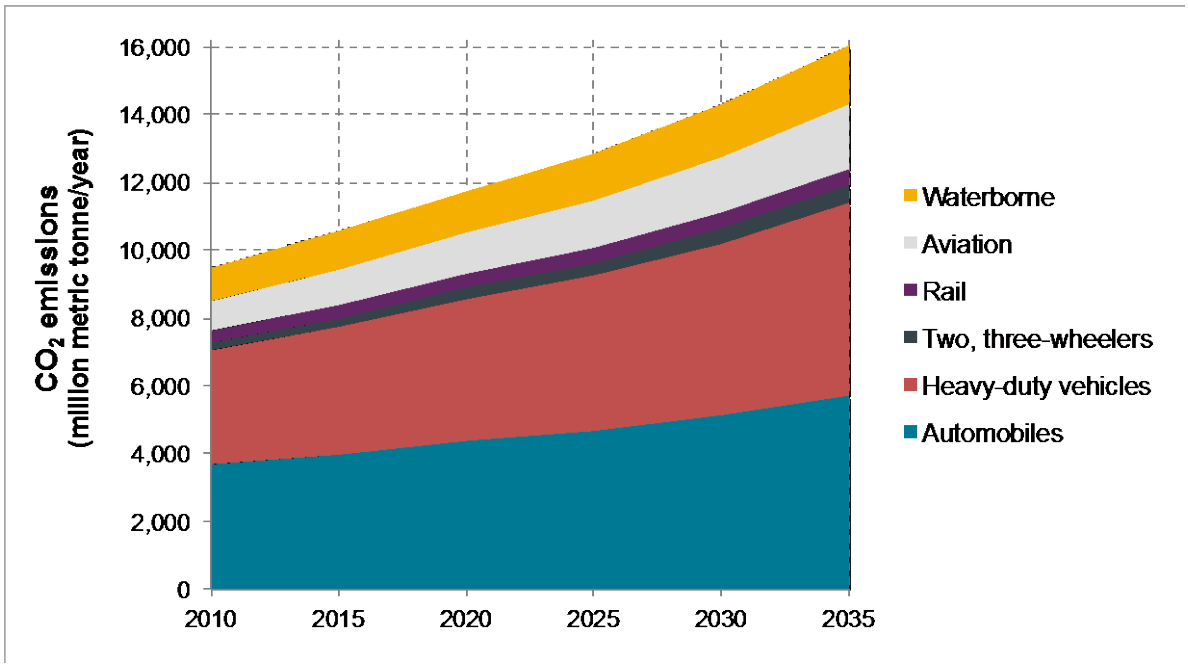
Why is the CCAC promoting the development of Green Freight programs globally?

1. An Efficient Global Freight Sector Is Essential to Sustainable Economic Growth

The strength of national, regional and global economies is becoming more dependent on growing international trade, raising the significance and impact of having an efficient and competitive freight transport sector. The continued growth in the globalization of supply chains means that an energy efficient and sustainable global freight industry is essential to economic growth and sustainable development across the world.

2. Goods Movement Has Significant Environmental Impacts

Globally, CO_2 emissions from freight transport are growing at a faster rate than passenger vehicles. In particular, heavy duty vehicles, the workhorse of the freight sector, are expected to be the largest emitters of CO_2 from all transportation modes by 2035 if left unaddressed. Therefore, improving the energy and environmental efficiency of the freight transport sector is a critical element of reducing global black carbon and CO_2 emissions.



Heavy duty vehicles will be the largest emitter of CO_2 emissions by 2035
International Council for Clean Transportation (2013). Global Transportation Energy and Climate Roadmap

3. Powerful Market Forces Can Be Leveraged to Drive Demand for Green Freight

Multinational freight shippers are under increasing pressure from shareholders, customers, and insurers to reduce their carbon footprint and the risks associated with higher fuel prices. These market forces can

be applied by global freight shippers to freight carriers and logistics providers, to drive freight performance benchmarking and reporting as well as new efficiencies and emission reductions from their freight supply chains. However, industry requires accurate and reliable performance benchmarking and freight efficiency data in order to inform decision-making and optimize freight efficiency. Providing the market with information about proven successful technologies and operational strategies to reduce the emissions intensity of freight, can help bring these high-potential opportunities to scale.

How do green freight programs contribute to black carbon reductions?

Green freight programs reduce CO_2 and BC emissions by improving the fuel efficiency of vehicle and freight operations, which reduces fuel use and fuel expenditures, thus resulting in environmental, health, and economic benefits simultaneously. In addition, green freight programs can provide the framework needed to accelerate the adoption and penetration of cleaner fuels, particulate filters and other measures to reduce particulate matter (i.e., black carbon) and other emissions from in-use vehicles.

What is the status of green freight programs around the world?

Green freight programs have been established in a number of countries and regions, including in many CCAC Partner countries, and through public-private partnerships around the world. In North America, the U.S. Environmental Protection Agency's (EPA) SmartWay Transport Partnership is the most-widely adopted *national* program targeting the fuel efficiency of freight transport. SmartWay is a public-private partnership launched in 2004 by the U.S. EPA, and its success has led to the Government of Canada adopting the program in 2012. In addition to the SmartWay Transport Partnership, other national green freight programs exist in various countries such as Mexico, China, France, Korea, Japan and Australia.

As these countries demonstrate success, other countries such as India, Thailand, Vietnam, Laos, Indonesia and others around the world have begun to initiate policy discussions within their governments and industries to move towards greener freight and logistics. Efforts of development banks such as the Asian Development Bank, development agencies such as GIZ, non-government organizations such as Clean Air Asia, and intergovernmental organizations such as the United Nations Commission on Regional Development (UNCRD) in Asia, are beginning to scale up green freight national programs on a regional basis across Asia.

Furthermore, regional initiatives such as Green Freight Europe and Green Freight Asia have recently been established by the private sector. Green Freight Europe was launched in 2012 as an independent voluntary program for improving environmental performance of road freight transport in Europe involving more than 100 multinational carriers, shippers and logistics service providers. Similarly, Green Freight Asia, formally incorporated in October 2013, is a consortium of private sector companies that builds on the success of Green Freight Europe and is working to expand their network of member countries and partners. Both differ from SmartWay, in that they are administered by a consortium of private companies and are not funded by a public agency.

These programs have demonstrated improved energy and environmental efficiency of freight transportation, emissions reductions and cost savings which enhance energy security, improve public health and support economic development. In addition, green freight programs have fostered the accelerated adoption of advanced technologies and strategies in multimodal goods movement, including through modal shifts, for example from truck to rail.

Other organizations and initiatives complement these global programs with supporting engagement. The Clean Cargo Working Group was established for maritime freight and the International Air Transport

Association (IATA) initiated the Air Cargo Carbon Footprint initiative for the airline industry. The Smart Freight Centre plays a critical role in the CCAC process by bringing together these industry-led initiatives and leading companies through the Global Logistics Emissions Council to create global harmonized methodologies. This important work supplements and strengthens the CCAC process by providing the longer term facilitation of the harmonization process which the Action Plan will include.

8.9 The CCAC Global Green Freight Initiative:

What are the goals of the Green Freight Action Plan?

The goals of the Green Freight Action Plan are to:

- Provide a vision and framework that allows all relevant stakeholders to understand what is needed to enhance freight sector energy and environmental efficiency and significantly reduce CO_2 and BC emissions from freight movement;
- Provide a common roadmap and blueprint that will catalyze the coordinated and ongoing development of green freight programs between regions and countries, ease implementation, and incorporate a large knowledge base of previous efforts;
- Ensure long term success by establishing roles and responsibilities for key actors to implement and support the Action Plan after its launch, as well as clear benefits and opportunities leveraged by participating in these efforts; and
- Provide a platform for companies and other stakeholder to share best practices and freight efficiency data, promote innovation, and communicate sustainability improvements on freight.

What work has been accomplished so far under the Green Freight Initiative?

To support the Global Green Freight Action Plan, the Green Freight Steering Group has developed the following documents:

- A SmartWay Transport Partnership Implementation Guide and Workbook to help build capacity for other countries to design, build and implement their own green freight programs.
- A Technical Background Report to assess the available and proven fuel efficiency technologies for all transport modes, as well as detailed summaries and analyses of the established green freight programs globally.

The Steering Group is also in the process of identifying three countries with which to engage over the next several months to build or enhance existing green freight programs.

8.10 Development of the Green Freight Action Plan: Barriers and Challenges

As part of the development of the Green Freight Action Plan, the CCAC Green Freight Steering Group has identified some of the perceived barriers that limit the growth and expansion of green freight, from both the private and public perspective, in order to understand what role and actions the CCAC could play in advancing green freight. The barriers and potential actions by the CCAC, and subsequent stakeholder engagement listed below, are for discussion with stakeholders from all sectors:

Barrier 1: Multimodal performance benchmarking tools are not available globally for multinational companies to reliably and consistently measure, calculate, report and optimize their emissions and fuel use. Without these tools, it is difficult for companies to compare and benchmark their global, regional or national CO_2 and BC emissions, across mode and/or

between countries, nor to fully assess the efficiency of their freight operations internally, nor compare with their industry peers.

Potential actions to overcome barrier:

- CCAC and participating partners will provide initial training and support to advance the adoption of the tools to measure and calculate freight transport emissions for national/regional green freight programs.
- CCAC will initiate work with three countries to help build and demonstrate freight transportation calculation and reporting tools.
- CCAC will provide initial support to interested governments via training and capacity building, e.g., sharing best practices and lessons learned to facilitate the calculation and reporting of freight emissions through policies and national green freight programs.
- The Global Green Freight Action Plan will be designed to facilitate ongoing longer term collaboration and facilitation through organizations such as the Smart Freight Centre.

Barrier 2: The lack of harmonization between the different existing freight emissions reporting systems is creating an added burden for companies that have global freight operations and is limiting the efficiency and efficacy of their reporting.

Potential actions to overcome barrier:

- The Global Green Freight Action Plan will showcase research on the different existing freight emissions and reporting systems.
- CCAC will support initial discussions between national, regional, global and private reporting systems on opportunities for harmonization of reporting methodologies.
- CCAC will seek to leverage Ministerial level support and other global policy making influence to advance the collective public and private sector goals of harmonizing green freight programs, tools and methods.
- CCAC will work with new enterprises such as the Smart Freight Centre, and its work with the Global Logistics Emissions Council as well as within existing global dialogues committed to carry on this harmonization work.

Barrier 3: CO_2 and not black carbon, has been the focus of currently existing green freight reporting systems. Without including black carbon in the tools, it is difficult for the private sector to measure and manage their black carbon emissions.

Potential actions to overcome barrier:

- The Global Green Freight Action Plan could showcase a review of existing tools and assess the viability of incorporating black carbon into these tools.

Barrier 4: Credible information is essential for carriers and shippers to gain the confidence that the available fuel savings technologies and strategies are technically, practically and financially feasible.

Potential actions to overcome barrier:

- CCAC will facilitate initial discussions with governments to incorporate technology verification and certification into their national green freight programs and to seek harmonization with other countries where applicable.

- The Global Green Freight Action Plan will establish roles for governments and industry-led initiatives to support the piloting of technologies and strategies and sharing the results of these pilots with carriers and shippers across a trusted platform.

Barrier 5: Other than cost savings from fuel efficiency gains, and compliance where regulatory pressures exist, additional incentives may be needed for multinational firms to invest in green freight programs, technologies and strategies to reduce CO_2 and BC.

Potential actions to overcome barriers:

- The Global Green Freight Action Plan will seek the input, insight and engagement of firms to better understand the needs and challenges they face, and thus work to advance globally harmonized green freight policies and programs which make sense for industry.
- CCAC will create greater visibility at the global, regional and national level for firms who elect to support and advance global green freight efforts.
- CCAC will enhance education and recognition efforts for industry leaders who support green freight efforts, including global forums and recognition events.
- The Global Green Freight Action Plan will be designed to facilitate ongoing longer term collaboration.

Outstanding Questions for Discussion:

- Are there other barriers that limit the growth of green freight?
- Are there other suggestions on actions that are required to overcome the identified barriers?
- What roles do freight stakeholders envision as the most appropriate for their organizations?
- How can governments and civil society best help business and industry advance freight efficiency goals?
- What opportunities or incentives can be developed to advance green freight and grow support? How can the CCAC best ensure that the Global Green Freight Action Plan will continue to be implemented and supported by governments, industry and civil society after its launch?

HLA/NOV2013/3
Adopted for support by the High Level Assembly, 21 November 2013, Warsaw

CLIMATE AND CLEAN AIR COALITION TO REDUCE SHORT-LIVED CLIMATE POLLUTANTS

Green Freight Call to Action

The movement of freight is a major and rapidly increasing contributor of black carbon and carbon dioxide (CO_2) emissions. Black carbon is a powerful climate forcer and a dangerous air pollutant with multiple impacts on health and ecosystems.

The Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants (CCAC) is a growing voluntary international partnership, bringing together over 70 State and non-State Partners pledged to enhancing global, regional, and national public and private efforts to reduce SLCPs with an initial focus on black carbon, methane and hydrofluorocarbons (HFCs). As part of its initiative on Reducing Black Carbon Emissions from Heavy Duty Diesel Vehicles and Engines, the CCAC is working to achieve substantial reductions of fine particulate matter and black carbon emissions from the transportation sector.

As Partners in the CCAC, we declare our determination to improve the energy efficiency and environmental performance of freight operations worldwide.

In a number of countries, including CCAC Partner countries, public-private partnerships through "green freight" programs have demonstrated the capacity to improve the environmental performance and energy efficiency of freight transportation, as well as enhance the energy security of participating countries while reducing emissions of black carbon and CO_2. Significant efficiency gains and emissions reductions can be achieved by accelerating the adoption of advanced technologies and strategies in multimodal goods movement, including through modal shifts, for example from truck to rail. Such measures would also deliver considerable clean air and near term climate protection benefits.

Many countries and private sector associations are in various stages of developing and implementing green freight programs. Greater consistency between programs through performance benchmarking, tools, metrics, and methods will facilitate the improvement of the environmental performance of the international movement of goods in an economically efficient way. The result will be a pathway for protecting public health, reducing near term climate change, and enhancing energy security and sustainable economic development.

Recognizing existing efforts, we, the CCAC Partners, will provide a forum to foster cooperation among countries and with international organizations, and a platform from which to engage with the private sector to expand and harmonize green freight programs.

In making this Green Freight Call to Action, we, the CCAC Partners, will collaborate with stakeholders to develop and deploy a coordinated Global Green Freight Action Plan that can be implemented through public-private partnerships worldwide. The Action Plan will provide a common roadmap that can help to harmonize and coordinate the development of green freight programs, ease implementation, and incorporate a large knowledge base of previous efforts. It

will also provide a platform for companies to share best practices, promote innovation, and communicate sustainability improvements on road freight.

We recognize that participation from the private sector is critical for the success of this initiative and invite multinational shippers and cargo owners, their freight transportation carriers, and third party logistics companies as well as other global stakeholders to join the effort and engage with the CCAC in the development and launch of a Global Green Freight Action Plan by December 2014. We will take stock of progress at our next High Level Assembly.