



WHITE PAPER

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# FREIGHT ASSESSMENT BLUEPRINT

PRACTICAL GUIDE FOR EVALUATING FREIGHT  
TRANSPORTATION IN SUPPORT OF NATIONAL  
GREEN FREIGHT PROGRAMS

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THE INTERNATIONAL COUNCIL  
ON CLEAN TRANSPORTATION



CLIMATE &  
CLEAN AIR  
COALITION  
TO REDUCE SHORT-LIVED  
CLIMATE POLLUTANTS

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## 1. INTRODUCTION

Freight movement, which comprises the shipping of goods by land, air, and sea, is the backbone of the global economy. Across all modes—truck, rail, marine, and aviation—the freight sector’s growth is expected to outpace that of the passenger car sector in the coming decades (Facanha, Blumberg, & Miller, 2012). There will be an increasing need to mitigate the energy, climate, and health impacts of this growth.

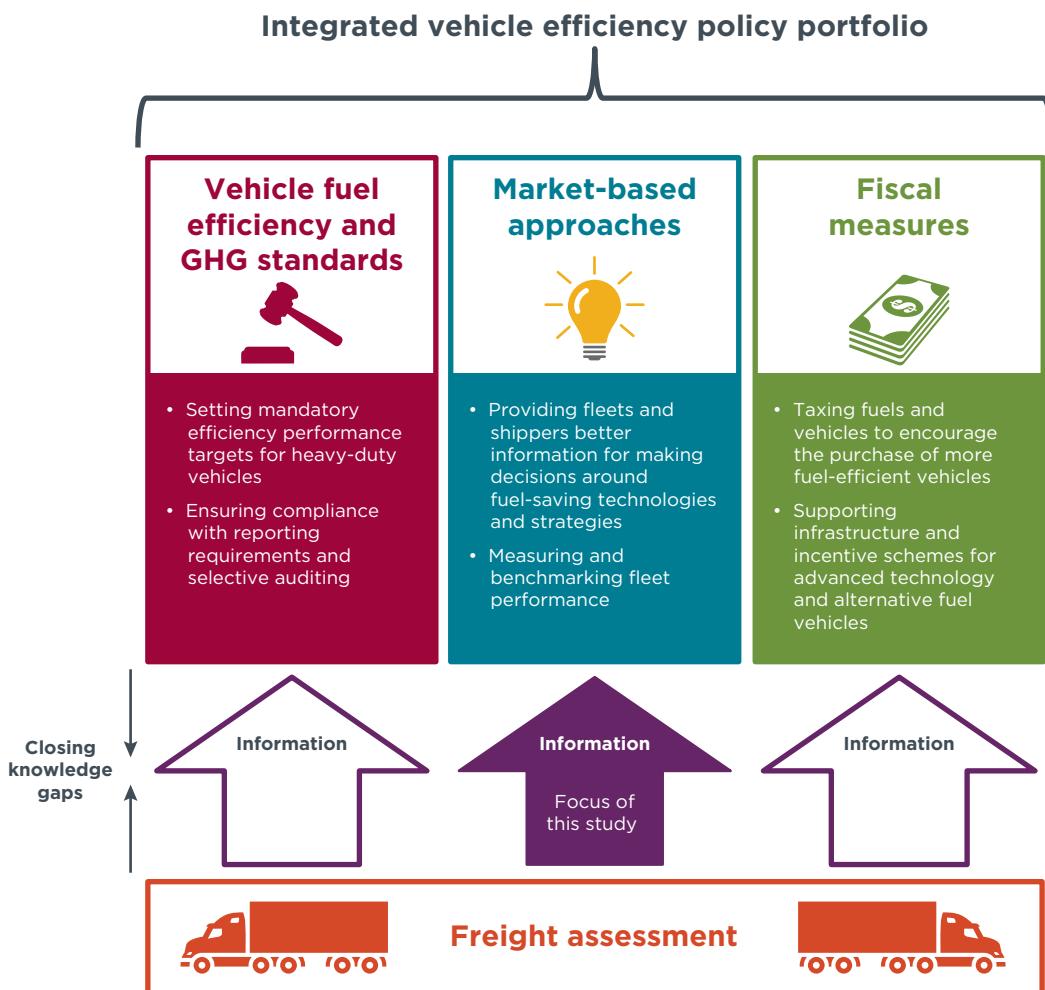
Although there is a pressing need to reduce fuel use and emissions from all freight transport modes, the focus of this guidance document is the on-road freight sector. That is because the trucking industry is responsible for the large majority of fuel use and emissions from the overall freight sector in most countries (The International Council on Clean Transportation [ICCT], 2014).

Because the freight sector’s emissions have increasingly contributed to climate change and diminished local air quality, many nations and regions around the world have developed voluntary “green freight” programs to increase efficiency and reduce fuel use and emissions from trucking fleets and supply chains. In 2004, the U.S. Environmental Protection Agency (EPA) established the SmartWay program, which was the first green freight program in the world (U.S. Environmental Protection Agency, 2016). Since then, roughly a dozen green freight programs have sprung up around the world and are in various stages of maturity (Baker et al., 2015, Sharpe, 2015a). Each program is unique in its functionality and objectives; however, some common features include data collection and benchmarking on fuel consumption and emissions, as well as information sharing on technologies and strategies for boosting efficiency and environmental sustainability.

As more countries and regions explore ways to reduce fuel use and emissions from the trucking sector, there has been increased interest in establishing green freight programs, strengthening existing programs, aligning programs to use globally consistent methodologies to quantify emissions benefits, and incorporating multiple pollutants such as black carbon in addition to carbon dioxide. Ideally, voluntary green freight programs are just one part of a broader portfolio of policy measures aimed at improving the environmental performance of the freight sector. Figure 1 shows the three main areas of policy measures for increasing vehicle efficiency: (a) mandatory fuel efficiency and greenhouse gas (GHG) standards, (b) market-based approaches, and (c) fiscal measures. Green freight programs typically fall into the second category, with a goal of creating better access to financing mechanisms and information about fuel-saving technologies, strategies, and fleet performance so that trucking fleets, shippers, and other stakeholders in the industry can make informed decisions for saving fuel and cutting costs.

This document aims to provide guidance for conducting a freight assessment when the ultimate goal is to develop a green freight program. The key elements of a freight assessment include an analysis of the truck, trailer, and trucking equipment sales market; an in-depth investigation of trucking operations; the chronicling of various stakeholder opinions and expectations regarding technologies and strategies for reducing fuel use and emissions from freight trucks; and, finally, laying the foundation for the development (or strengthening) of a green freight program.

**Why** is a freight assessment important? As depicted in Figure 1, the information presented in a freight assessment can not only inform market-based efforts such as green freight programs, but can also contribute to the development of vehicle fuel-efficiency standards and fiscal programs.



**Figure 1:** Integrated vehicle efficiency policy portfolio

For any region, one of the most critical steps in developing a green freight program is to first gain more in-depth knowledge of the freight industry. To successfully promote the development and deployment of technologies and strategies for improving the efficiency of the on-road freight sector, there must first be an understanding of what areas of the sector are ripe for improvement and what solutions potentially are most appropriate for the local context.

The primary objective of this document is to provide best practices and step-by-step guidance for performing an assessment of the freight sector in any country or region. Although the on-road freight sector can vary greatly depending on location, this guidance document will provide a standard framework by which to perform a freight assessment.

This document is organized as follows:

- » Section 2 presents some best practices and helpful guidelines on **how** to conduct a freight assessment, including (a) understanding public and private data sources; (b) developing successful partnerships; (c) designing an effective in-person, phone, or online survey; (d) analyzing data from a diverse cross-section of stakeholder interviews; and (e) creating a final report and other outreach materials.
- » Section 3 is a step-by-step guide for **what** to include in a freight assessment: (a) roles and trends of trucking, shipping, and rail in the freight sector in your country or region; (b) freight trucks and trailers sales market; (c) operational characteristics of the trucking sector; (d) decision-making around fuel-saving technologies and strategies; and (e) institutional arrangements and green freight program planning.
- » Section 4 provides some first-order approximations of schedule and resource constraints for the freight assessment to assist in planning the execution of the project.

## 2. HOW TO CONDUCT A FREIGHT ASSESSMENT

This section presents various best practices for how to carry out a freight assessment.

### **Do your homework on data sources**

As you begin the freight assessment, a crucial first task is determining (a) what data are needed and (b) how you are going to either acquire or generate these data. This guidance document is designed to support your team in both of these areas.

In your conversations and interviews with a wide variety of stakeholders, your team will certainly be generating a great deal of valuable quantitative and qualitative data as you perform the freight assessment. However, you should first fully explore what relevant data already exists. Data on the freight and trucking sectors can typically be found across a variety of entities in the government, private enterprise, and academic/research spheres.

These data sources can include:

- » Market research companies (e.g., IHS Automotive, Wards Auto)
- » Public records agencies (e.g., Department of Motor Vehicles, tax authorities)
- » Government agencies with regulatory authority over transportation, energy, or environment issues
- » Government statistics agencies or departments (e.g., Bureau of Transportation Statistics [U.S. Department of Transportation: Office of the Assistant Secretary for Research and Technology 2016], Transportation Energy Data Book [Oak Ridge National Laboratory 2015])
- » Academic/research institutions
- » Testing facilities
- » Industry associations and trade groups
- » Fuel-saving technology suppliers
- » Existing green freight program data (e.g., SmartWay carrier performance data [U.S. Environmental Protection Agency, 2016])
- » Stakeholder interviews

Although it may exist, some of this data may be inaccessible, whereas some companies or groups require payment for access to their datasets. As you develop the project plan and budget for the freight assessment project, it is important to determine how much funding is available for data purchases. However, if funding is lacking for data acquisition, there is often relevant data on freight and trucking operations in the public domain. It is certainly worthwhile to invest sufficient time at the beginning of the project to determine what data exists and is accessible before setting out to do stakeholder outreach and interviews.

### **Partnering and getting access to the “right” people.**

Perhaps the most critical elements of performing a freight assessment are (a) deciding with whom to work, and (b) getting access to the people who are best suited to answer questions and/or provide data about the trucking sector in your country or region. To the first point, whether your organization will be carrying out the freight assessment

or using a consultant to perform the majority of the work, it is very important that the person(s) leading the work have as many of the following characteristics as possible:

- » Knowledge of the freight sector in your region
- » Connections within the government, manufacturing, and/or fleet communities
- » Ability to effectively design surveys for conducting in-person and phone interviews and then organize and distill the data collected into summary formats that are easily understandable by non-experts
- » Proficiency with organizing and analyzing large datasets
- » Familiarity with sustainability initiatives and corporate social responsibility

If you opt to work with a consultant, here are some things to keep in mind for fostering a productive relationship and executing a successful project:

- » **Be explicit.** In designing the contract, be as clear as possible about roles, responsibilities, communication intervals, deliverables, and timelines.
- » **Plan for delays.** In the schedule, build in sufficient time for delays, which are likely in a project centered around interviews and interactions with a large number of stakeholders. If possible, be flexible with the order in which tasks are performed to avoid stalling the project.
- » **Envision the final product.** Think strategically about what you want in the final report and any other deliverables for the project. Give the consultant a clear example (or template) of the finished product, and build in sufficient time in the schedule for review and editing of documents.
- » **Build your network.** To leverage the connections made during the project, participate in as many of the stakeholder interactions (e.g., interviews, focus groups) as possible. Also, ask the consultant to provide you with contact lists and other pertinent stakeholder data so that you can use this information in future outreach efforts or projects.

### Designing an effective in-person, telephone, or online survey

Interviews and conversations with a diverse cross-section of stakeholders are a vital component of a freight assessment. Performing a large number of interviews can be resource-intensive; here are some tips to make the best use of everyone's time.

- » **Target the right people.** When developing a list of potential interviewees, questions and topic areas should be well-defined so you can target the person(s) you think will be best suited to answer your questions. It can be useful to email a copy of your questions beforehand so that the potential interviewee is fully prepared or can recommend a colleague who is better able to answer the questions.
- » **Leverage existing contacts.** Successfully recruiting people to participate can be one of the biggest challenges of any survey. This problem is often exacerbated when trying to get access to management or key decision makers with unique knowledge of the area of interest. This is where partnering and leveraging existing relationships can be a real asset to the project. The chance of getting your target interviewee's attention is greatly improved when using an existing colleague rather than a "cold call," which should always be the last resort.

- » **Maximize the interview time.** In many instances, the survey team will want to target managers, directors, or senior-level staff for interviews, and often it can be difficult for these people to volunteer their time due to busy schedules. In your initial outreach, be upfront about exactly how much time you expect the interview to take (e.g., 1 hour). As a best practice, design the interview to last a maximum of 1 hour and rehearse the interview beforehand to get a feel for the flow of the interview questions and timing. Make note of the questions or topic areas that are higher priority in case you are unable to get through all of the material. Also, creating a template for each stakeholder group (e.g., fleets, vehicle manufacturers, suppliers) can be a great way to help ensure that you're covering the same topic areas in each interview, and this will also facilitate the analysis of the interview response.
- » **Stress confidentiality.** Typically, companies are very sensitive about sharing data—especially data that could potential be used by competitors to gain an advantage. In the initial phone call and/or email, explicitly state that all responses will be kept confidential. It might also be useful to specifically mention all of the companies you will be interviewing and how the study team will ensure confidentiality in all of the project materials that are made public.
- » **Make a value proposition to the interviewee.** Ideally, you should make the case to the companies and organizations that you would like to interview that participation will be valuable for them as well. Emphasize that you will share summarized<sup>1</sup> data and findings from the freight assessment with them. Also, it may be advantageous to offer that company or organization an individual briefing after the completion of the freight assessment. Some groups will be fine with simply receiving the final report, but others will find value in a formal teleconference or in-person briefing. Be creative in deciding upon incentives that will motivate different stakeholders.
- » **Use a survey team to maximize interview time.** It can be quite difficult to take detailed notes while conducting an interview and maintain the flow of *natural* question-and-answer conversation. If possible, conduct the interviews using a team of two or more so that one person can ask the questions and engage with the participant, while leaving at least one person to focus on note taking. If this arrangement isn't possible, ask the participant if it would be okay to record the conversation.
- » **Incentivize online surveys.** Online surveys can be an excellent means to reach a large number of people with fewer resources. This method can be especially useful for getting access to difficult-to-reach stakeholders such as owner-operators or small trucking fleets. To maximize participation, it is often very advantageous to partner with an entity that is already well known and trusted by your target participants (e.g., a fleet association). For example, a trucking company representative is much more likely to participate in a survey if the request is coming from their fleet association rather than from a complete stranger. Also, another way to boost participation is to incentivize the successful completion of a survey. For example, offering a voucher for free fuel or credit at an online marketplace (e.g., Amazon) can be a great way to get a larger number of completed surveys. Finally, be conscious of the amount of time the average respondent will take to complete the online survey. Only ask high-priority questions that are easy to understand, and do your best to include only questions that can be answered quickly (i.e., avoid open-ended questions where respondents have to type out long responses). For

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<sup>1</sup> Summarizing data will protect the confidentiality of all participants.

an online survey, a useful rule of thumb is to set a target for a maximum of 10-15 minutes for completion.

### Analyzing data from interviews

It can be challenging to make sense of all of the many stakeholder responses across a range of topic areas. As mentioned in the previous section, using a template for interview questions and responses can help you stay organized and make the analysis go more smoothly. Here are some additional tips:

- » **Look for key takeaways.** Do not try to incorporate the details from every conversation into the final report. Rather, aim to identify the key takeaways—that is, the most important information that is relevant to your audience. Unless you're conducting an extensive online survey, the number of responses collected during the project is not going to be statistically representative of the entire population of that given stakeholder group. As such, focus on identifying key themes or data trends in the responses.
- » **Understand what's behind the numbers.** Quantitative data that you collect or generate as part of the freight assessment is a critical part of the project. Particularly for the data collected from other sources, it is very important to understand how those data were created. It is certainly a best practice to do as much as you can to understand the methods by which the source created or collected the data. Not all data is created equally! In the final report and outreach materials, be upfront with your audience about the quality of the various data and your confidence in the data and the sources.
- » **Value qualitative data.** Treat every interview as an opportunity to get a special “insider” perspective of a given business or industry. Although the questionnaire template is certainly recommended, don't be afraid to stray from the script, especially if the interviewee wants to dive deeper in a certain area or broach new topics. Even when interviewing businesses that may seem very similar, each company and individual will have unique experiences, attitudes, and expectations that may help to put their more quantitative answers into better context. As much as possible, your key takeaways should be a combination of quantitative and qualitative responses.
- » **Pay attention to outliers.** In analyzing interview response data, you may notice some data points that are far outside the range of other responses. These outlier data points can be important pieces of information and should not be discarded unless the survey team is certain that they are the result of a typo or obvious error. Do your best to put the outlier data into context by exploring the story behind the data. It may be necessary to follow up with the interview participant if you need clarification or more information.

### Developing the final report and other outreach materials

The final report and any other outreach materials you develop will likely be a primary means by which the study team communicates the information gleaned during the freight assessment to your network of interested parties. Here are some strategies for helping to maximize the impact of these materials and the project in general:

- » **Envision your audience.** Think about who will be reading the project materials and what you would like them to learn, and tailor your outputs accordingly. For example, you would likely want a report aimed at government officials to look

different than one for trucking fleets. Envisioning the audience is a critical step that should happen during the planning/outlining stage as you develop a set of outreach materials to cover various stakeholder groups.

- » **Develop a suite of outreach materials for varying attention spans.** There will be different appetites for the outputs of the freight assessment. A one-size-fits-all final report will be very useful for some in your audience, but others may prefer something easier to digest. As such, it is best practice to develop a suite of outreach materials of various lengths and formats (e.g., comprehensive final report, briefing slides, short memos, webinar). By disseminating a variety of materials, people are more likely to engage with the information in a way that best fits their interests, needs, and schedule.
- » **Brief project participants.** As a courtesy to the individuals and companies that contributed to the project, the study team should at a minimum circulate all of the relevant project outputs to each participant, but it is also a nice gesture to offer a personal briefing on the project findings. You should also thank the project participants in an acknowledgments section of the final report, but, due to confidentiality concerns, it is best to avoid mentioning the individual participants or companies by name.

### 3. WHAT TO INCLUDE IN A FREIGHT ASSESSMENT

We have broken the freight assessment down into the following five major categories or task areas:

1. Roles and trends of trucking, shipping, and rail in the freight sector
2. Freight trucks and trailers sales market
3. Operational characteristics of the trucking sector
4. Decision making around fuel-saving technologies and strategies
5. Institutional arrangements and green freight program planning

In the remainder of this section, there is a subsection devoted to each of these major task areas. In each of the five subsections, there is a short introduction, followed by a quick-glance table that summarizes the key elements of the task. Following the quick-glance table, we provide a number of examples for your reference in each subsection, including:

- » Useful data and references
- » Sample figures and tables
- » Example interview questions

#### **3.1 ROLES AND TRENDS OF TRUCKING, SHIPPING, AND RAIL**

##### **What are the key things we want to learn?**

- » What is role of the various modes (i.e., trucking, shipping, and rail) in transporting freight?
- » What is the freight tonnage breakdown between trucking, shipping, and rail, and how have these percentages changed over time? What are the modal split projections for the future as well as expectations for growth in tonnage and miles?
- » What factors are influencing the evolution of each mode in terms of its contribution to freight hauling (e.g., geographic features, government influence, economic considerations)?

##### **Data sources**

Primary: Annual freight data in terms of tonnage or economic value is often published by government transport and/or statistics agencies, as goods movement can be a key economic indicator.

Secondary: If you cannot find sufficient quality data for the freight breakdown among trucking, shipping, and rail from government sources, you can pursue this information from industry sources that track such data very closely. Likely best candidates include major shipping companies, third-party logistics providers (3PLs), and their associated industry associations.

## Quick reference guide

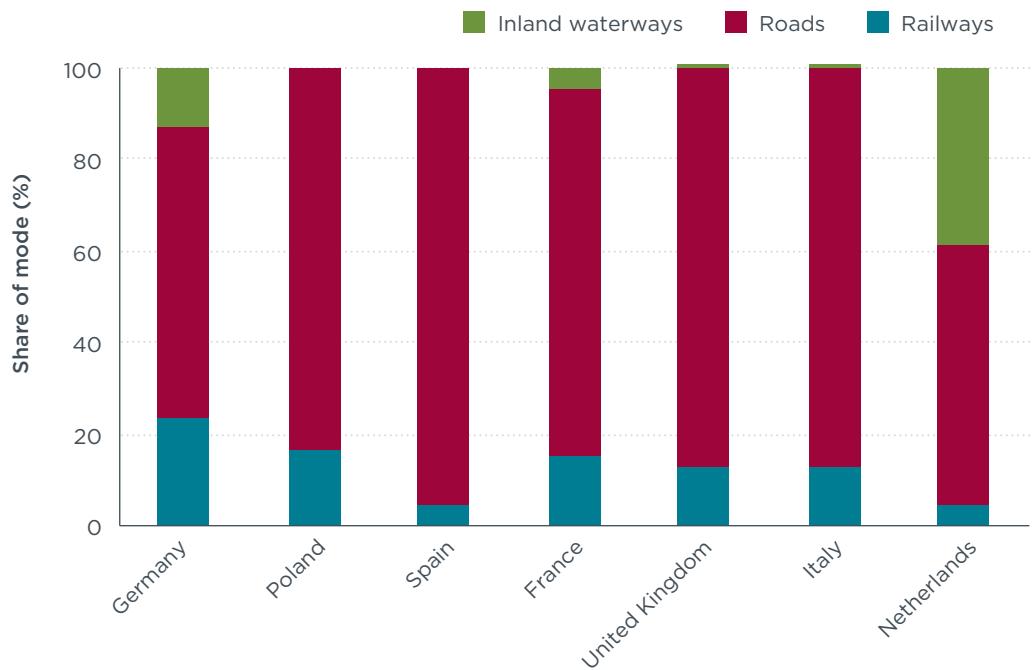
Table 1 summarizes the key aspects of the freight sector modal split analysis.

**Table 1:** Freight sector modal split study framework

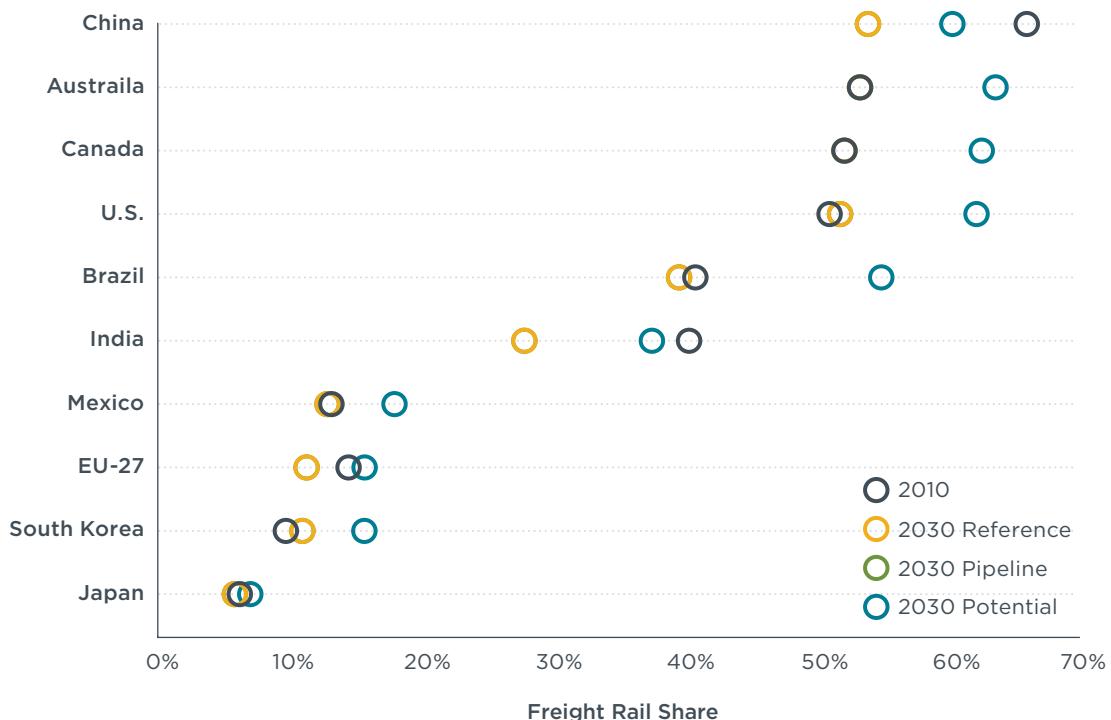
<b>What is this step?</b>	We investigate the roles of the various land and sea freight transport modes.
<b>Why is it important?</b>	To understand the role of trucking in the overall freight system. Key questions to answer include: <ul style="list-style-type: none"> <li>• Is trucking a significant contributor to freight movement in terms of tons and/or economic value of the goods transported?</li> <li>• What is the percentage of goods moved by trucking, shipping, and rail? How have these percentages changed over time, and what are the expectations for the future?</li> </ul>
<b>Key stakeholders to consult</b>	<ul style="list-style-type: none"> <li>• Government agency(ies) responsible for the freight sector</li> <li>• Shipping companies or logistics providers</li> </ul>
<b>How to go about performing this step?</b>	These methods can be complementary: <ul style="list-style-type: none"> <li>• Acquire freight data from government sources online or through direct engagement with government agencies</li> <li>• Interview shipping companies, 3PLs</li> </ul>
<b>Getting creative</b>	Alternative stakeholder groups to approach about trucking, shipping, and rail modal split data can include: <ul style="list-style-type: none"> <li>• Intermodal freight companies</li> <li>• Government taxation agency</li> </ul>
<b>Relevant examples of previously completed projects in this area</b>	<ul style="list-style-type: none"> <li>• Heavy-duty vehicle market in the European Union: <a href="http://www.theicct.org/overview-heavy-duty-vehicle-market-and-co2-emissions-european-union">http://www.theicct.org/overview-heavy-duty-vehicle-market-and-co2-emissions-european-union</a></li> <li>• Data and information about freight activity in countries and regions around the world: <a href="http://www.theicct.org/global-transportation-roadmap-model">http://www.theicct.org/global-transportation-roadmap-model</a></li> </ul>

## Modal split examples

- » Figure 2 illustrates the critical importance of on-road (i.e., truck) goods movement in the European Union. Determining the breakdown of freight moved by each mode is important in assessing the level of benefits available by improving the environmental performance of any of the individual modes, as well as estimating the potential attractiveness of measures to promote mode shift.
- » Figure 3 shows the 2010 baseline and 2030 potential of the share of freight transported by rail in various countries. Generally, goods moved via rail are much less carbon intense in terms of carbon dioxide (CO<sub>2</sub>) emissions per tonne of freight transported over a unit distance (e.g., grams CO<sub>2</sub> per tonne-km, which is the grams of CO<sub>2</sub> emitted for every tonne of freight moved over a kilometer). For freight items where both trucking and rail are viable options, from an environmental standpoint, it is often advantageous to shift as much freight as possible to rail.



**Figure 2:** 2013 Modal split of freight transport in the 7 EU member states with the most freight transport activity (tonne-kilometers) (Muncrief and Sharpe, 2015)



**Figure 3:** Freight rail mode shares by tonnage (Facanha et al., 2012)

## 3.2 FREIGHT TRUCKS AND TRAILERS SALES MARKET

### What are the key things we want to learn?

- » The various types of freight trucks are shown in Figure 4. What types of trucks are most common in your country/region?
- » How big is the market? → What are the year-to-year trends in total sales? How do heavy-duty vehicle (HDV) sales break down in terms of vehicle types and weight?
- » What are the original equipment manufacturer (OEM) market shares for each vehicle segment → How are various manufacturers affected by potential efficiency policies or programs?
- » What is the breakdown of sales by domestic manufacturing versus imports? → How would potential efficiency policies or programs affect domestic industry and the economy?
- » What are the baseline vehicle characteristics for each vehicle segment → What are the top-selling models for each major type of vehicle (e.g. tractor truck, rigid truck, bus)? What are the potential advances and the technology potential for efficiency improvements in each segment?
- » How does the sales market in your country/region compare with other markets?

### Data sources

Primary: Annual sales (or registration) datasets for a particular country or region can often be purchased from market research companies that specialize in the automotive sector. Typically, these datasets from market research firms are much more comprehensive than data you may find from other sources.

Secondary: If data for your country/region are unavailable from a market research company, you can pursue data from government or industry sources. Various government agencies or ministries may have commercial vehicle sales data that you can access. In addition, vehicle manufacturer associations or individual manufacturers likely have sales data for the industry as a whole, but it may be an uphill battle to get such groups to share this data.

## Quick reference guide

Table 2 summarizes the key aspects of the truck and trailer market analysis.

**Table 2:** Freight trucks and trailers sales market study framework

<b>What is this step?</b>	Here, we assess the sales market for new and used tractor trucks and trailers.
<b>Why is it important?</b>	To gain a more comprehensive knowledge of the trucking sector sales market. What types of information shall be gathered? <ul style="list-style-type: none"> <li>• Overall sales totals, trends over time, and projections for the future</li> <li>• Manufacturer market shares by vehicle segment</li> <li>• Domestic manufacturing versus imports</li> <li>• Top-selling models by vehicle segment</li> <li>• Typical vehicle technology characteristics and technology baseline</li> <li>• Key tier 1 suppliers (e.g., engines, transmissions)</li> </ul>
<b>Key stakeholders to consult</b>	<ul style="list-style-type: none"> <li>• Heavy-duty vehicle sales market data vendors</li> <li>• Vehicle and engine OEMs, industry associations</li> <li>• Government agency(ies) responsible for tracking vehicle sales and/or registrations</li> </ul>
<b>How to go about performing this step?</b>	<p>These methods can be complementary:</p> <ul style="list-style-type: none"> <li>• Purchase/acquire dataset for new vehicle sales</li> <li>• Interview OEMs, fleets, and/or government officials that have information about the sales market</li> </ul>
<b>Getting creative</b>	<p>Often, comprehensive datasets on heavy-duty vehicle sales are difficult to find, if they are available at all. Moreover, interviews with OEMs, fleets, and other experts may yield contradictory information. In this case, a creative solution could involve casting a wider net in terms of industry and government. Alternative stakeholder groups to approach about sales data can include:</p> <ul style="list-style-type: none"> <li>• Oil companies</li> <li>• Government taxation agency</li> <li>• State or provincial motor departments, registration authorities</li> </ul>
<b>Relevant examples of previously completed projects in this area</b>	<ul style="list-style-type: none"> <li>• Heavy-duty vehicle market in the European Union: <a href="http://www.theicct.org/overview-heavy-duty-vehicle-market-and-co2-emissions-european-union">http://www.theicct.org/overview-heavy-duty-vehicle-market-and-co2-emissions-european-union</a></li> <li>• Heavy-duty vehicle market in India: <a href="http://www.theicct.org/market-analysis-heavy-duty-vehicles-india">http://www.theicct.org/market-analysis-heavy-duty-vehicles-india</a></li> <li>• Commercial trailer market in the U.S.: <a href="http://www.theicct.org/trailer-technologies-increased-hdv-efficiency">http://www.theicct.org/trailer-technologies-increased-hdv-efficiency</a></li> </ul>

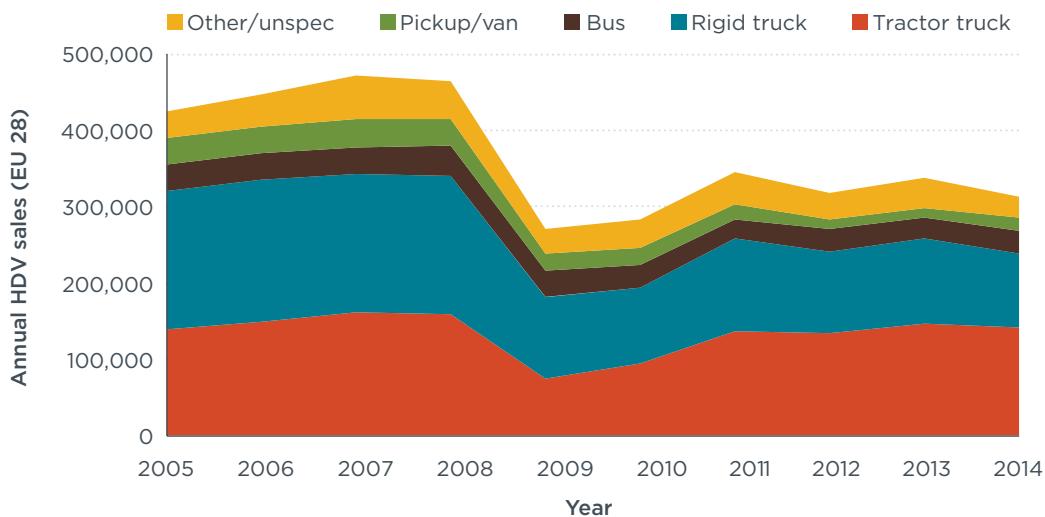
<b>DRY, GENERAL GOODS</b>		<b>REFRIGERATED GOODS</b>	
<ul style="list-style-type: none"> <li>Goods that do not require temperature or humidity control</li> <li>In most regions, this is the most common type of on-road freight transport</li> <li>Tremendous variety in terms of types of goods, drive cycles, and levels of activity (e.g., annual VKT)</li> </ul>		<ul style="list-style-type: none"> <li>Perishable food items or goods such as electronics that require temperature and/or humidity control</li> <li>Trailer or cargo-carrying portion of the truck has refrigeration unit that is typically powered by a small auxiliary diesel engine</li> </ul>	
<b>RIGID</b> 	<b>ARTICULATED</b> 	<b>RIGID</b> 	<b>ARTICULATED</b> 
<b>FLATBED TRANSPORT</b>		<b>LIQUIDS OR BULK GOODS</b>	
<ul style="list-style-type: none"> <li>Rigid or articulated trucks with flatbeds carry a great variety of freight items such as construction materials to irregularly-shaped items that may not easily fit into a box-type trailer or body</li> <li>Trucks likely to have in-city or regional routes</li> </ul>		<ul style="list-style-type: none"> <li>Includes petroleum and gas products, water, sand, gravel, cement, grain, etc.</li> <li>Particularly for rigid trucks, this type of freight transport is generally within regional areas, though some of these trucks have long distance drive cycles</li> </ul>	
<b>RIGID</b> 	<b>ARTICULATED</b> 	<b>RIGID</b> 	<b>ARTICULATED</b> 
<b>REFUSE, RECYCLING</b>		<b>CONTAINER CHASSIS</b>	
<ul style="list-style-type: none"> <li>Includes residential and business waste transport to disposal/recycling facilities</li> <li>Often involves highly transient, stop-and-go driving</li> <li>Typically these trucks are at the larger end of the weight spectrum</li> </ul>		<ul style="list-style-type: none"> <li>Container chassis are the units that are most often used in intermodal transport (i.e., road, rail, and marine)</li> <li>They are virtually always pulled by tractor trucks on the road; don't tend to exist as part of rigid trucks</li> <li>Often found in great numbers at and around ports</li> </ul>	
<b>RIGID</b> 	<b>ARTICULATED</b> 	<b>RIGID</b> 	<b>ARTICULATED</b> 
<b>LIGHT COMMERCIAL</b>		<b>SPECIALTY</b>	
<ul style="list-style-type: none"> <li>Commercial vehicles at the lightest end of the spectrum</li> <li>Used in many different vocations and freight applications</li> <li>Includes vans, pickup trucks</li> <li>Do not typically compete with larger trucks in terms of type and volume of goods moved</li> </ul>		<ul style="list-style-type: none"> <li>Catch-all group for any types of on-road goods movement not included in the previous categories</li> <li>Examples include auto transporters, logging trucks, freight-specific flatbeds, etc.</li> </ul>	
<b>RIGID</b> 	<b>ARTICULATED</b> 	<b>RIGID</b> 	<b>ARTICULATED</b> 

**Figure 4:** Types of freight trucks

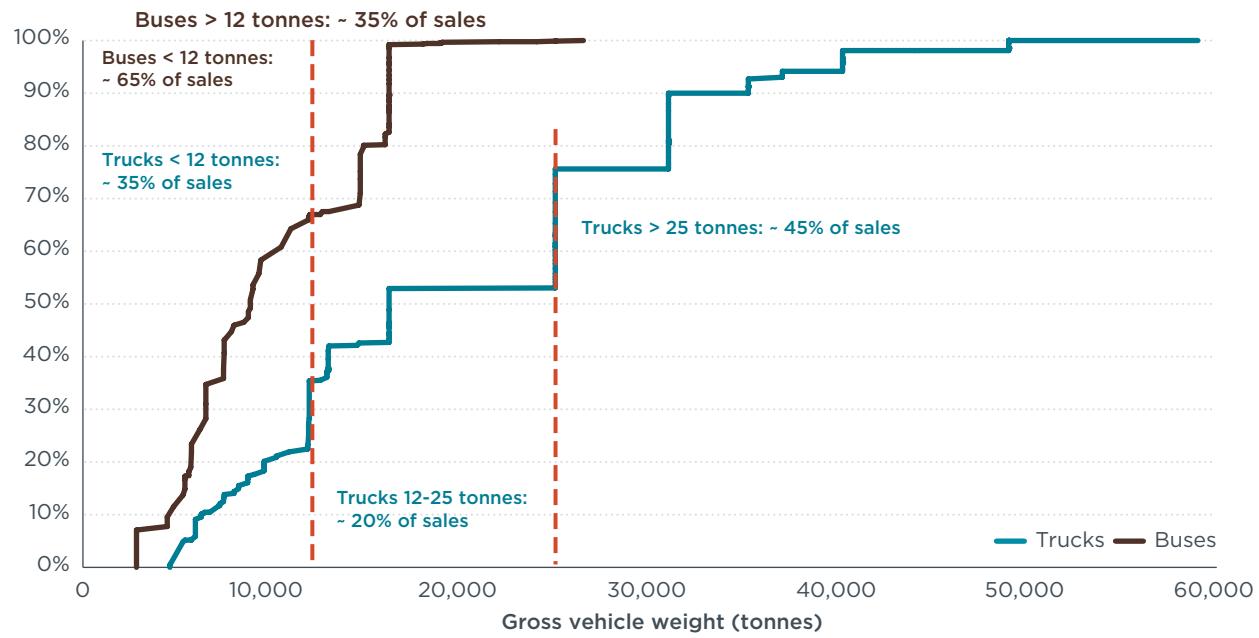
## Freight truck and trailer sales market data and analysis

### *Higher priority data and analysis*

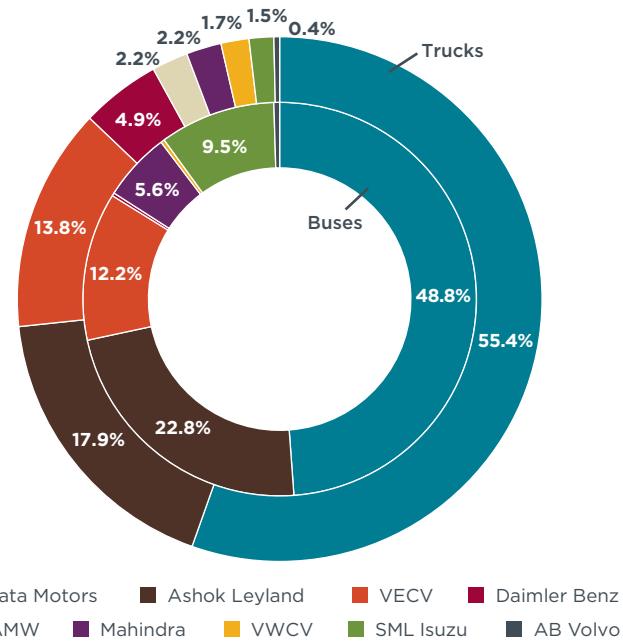
- » HDV sales (or registration) by vehicle type, weight, and manufacturer: these data help you to determine the contribution of the different vehicle types and sizes to overall sales. For example, do freight trucks make a large (or small) percentage of overall sales? What is the breakdown in sales among the types of freight trucks (e.g., tractor-trailers versus rigid trucks such as box trucks, dump trucks, refuse haulers, etc.)? It is also very important to understand the breakdown of manufacturers in the sales market. Who are the market leaders in each segment and, specifically, for various types of freight trucks? How have market shares changed over time? Having a good understanding of the sales market will be very beneficial in the development of a green freight program and potentially other policy measures. This data will help your team determine which vehicle segments and manufacturers have the biggest stake in on-road freight movement.
- » Figure 5 shows the breakdown of sales of commercial vehicles over 3.5 tonnes in the European Union by body type. We can see that freight trucks—that is, rigid trucks and tractor trucks—make up the large majority (roughly 80%) of total commercial vehicle sales.
- » Figure 6 illustrates the cumulative sales of heavy-duty trucks and buses over 3.5 tonnes in India by gross vehicle weight (GVW). The truck curve in particular has a step-like nature, indicating that certain GVW points are popular weight values for vehicle models to be certified (e.g., 25 tonnes).
- » Figure 7 displays the market shares for truck and bus manufacturers in India. We can see that the top 3 manufacturers—Tata, Ashok Leyland, and Volvo Eicher Commercial Vehicles—account for between 80% and 85% of total sales for both trucks and buses.



**Figure 5:** Annual heavy-duty vehicle sales by vehicle type in the European Union (Muncrief and Sharpe, 2015)



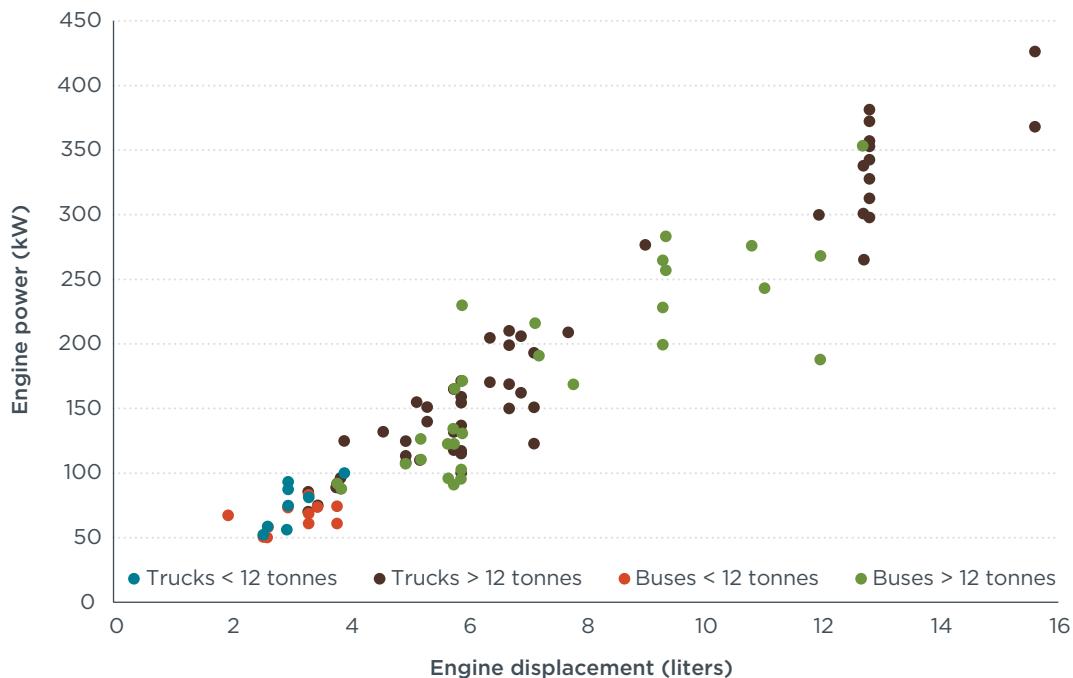
**Figure 6:** Cumulative market shares of truck and buses in India as a function of gross vehicle weight rating (Sharpe, 2015b)<sup>2</sup>



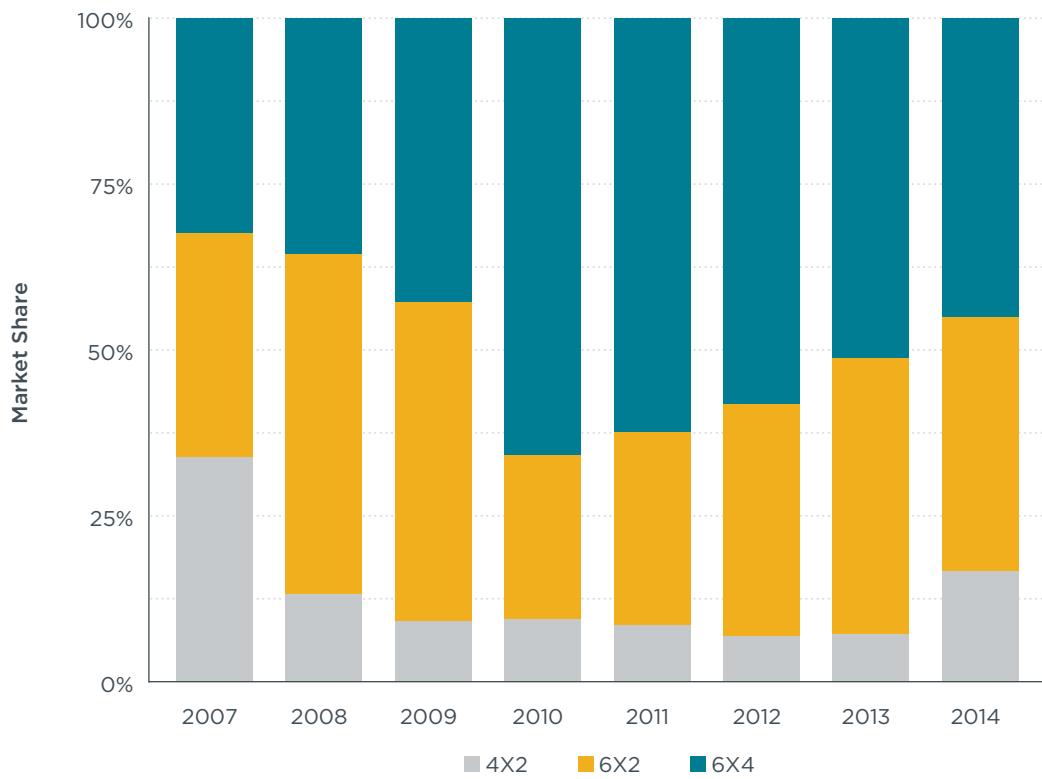
**Figure 7:** Breakdown of manufacturer market shares for trucks and buses in India (Sharpe, 2015b)

<sup>2</sup> In the document, “tonne” means metric tonne—that is, 1,000 kg. A “ton” means 2,000 lb., which is 907.2 kg.

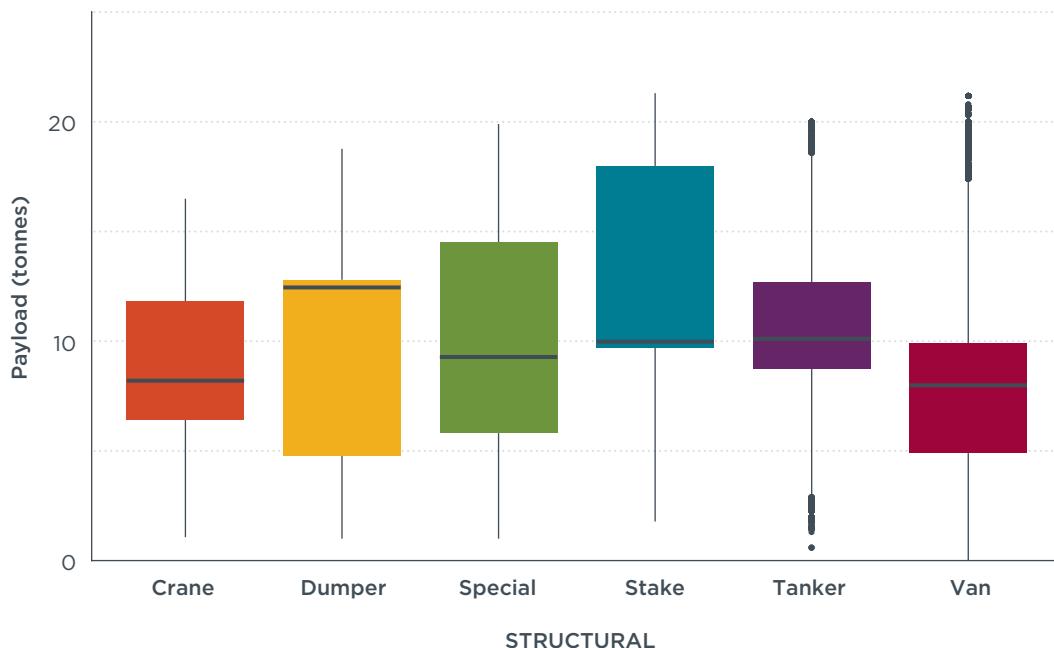
- » Baseline vehicle characteristics: In general, the more information that can be gleaned about new vehicle characteristics, the better. This data can be instrumental in helping to establish what levels of technology are typical on new vehicles and, in particular, freight trucks. The vehicle parameters of most interest include:
  - » Gross vehicle weight (GVW): the maximum rated weight of the vehicle, including payload
  - » Vehicle type: some indications about the configuration and body style (e.g., tractor truck, rigid truck, pickup truck)
  - » Engine characteristics: The most relevant parameters include engine displacement volume (e.g., 9 liters), maximum power rating (e.g., 200 kW), torque rating (e.g., 800 Nm), and emission level (e.g., Euro IV).
  - » Transmission (or gearbox) type: Manual transmission, automated manual transmission, and automatic torque-converter transmission are the most common transmission types.
  - » Figure 8 is a scatter plot of each engine power rating and displacement in the Indian commercial vehicle market. Engine parameters are generally one of the most important vehicle characteristics that impact efficiency and emissions, and figures such as this can help analysts determine which engine sizes are the most common and how the particular country or region compares to other markets.
  - » Figure 9 shows how the market shares of various axle configurations for tractor trucks in China have shifted over time. Axle configuration is commonly shown with two numbers that are separated by an “x” (e.g., 4 x 2, which is expressed as “four by two”). The left-hand value divided by 2 indicates the total number axles on the truck, and the right-hand value divided by 2 gives us the number of powered drive axles. For example, a 6 x 4 axle configuration has three axles ( $6 / 2 = 3$ ) and two drive axles ( $4 / 2 = 2$ ). Decreasing the number of drive axles from two to one can reduce weight and friction in the driveline system, thus improving the overall vehicle efficiency. However, an important drawback of decreasing the number of drive axles can be a reduction in traction in certain situations.
  - » Figure 10 shows the loading capacity of specialized delivery vehicles in China by body type in 2007 and 2014. Over the 8 years, there has been a noticeable increase of loading capacity of all specialized delivery vehicle types, aside from tankers. Because fuel consumption is directly a function of the weight of a vehicle, understanding trends in vehicle GVW is very important when analyzing how fuel efficiency has changed over time.



**Figure 8:** Unique engine size and power points for HDVs in India (Sharpe, 2015b)



**Figure 9:** Historical trend of driveline configuration of tractor trucks in China (Li and Delgado, 2017)



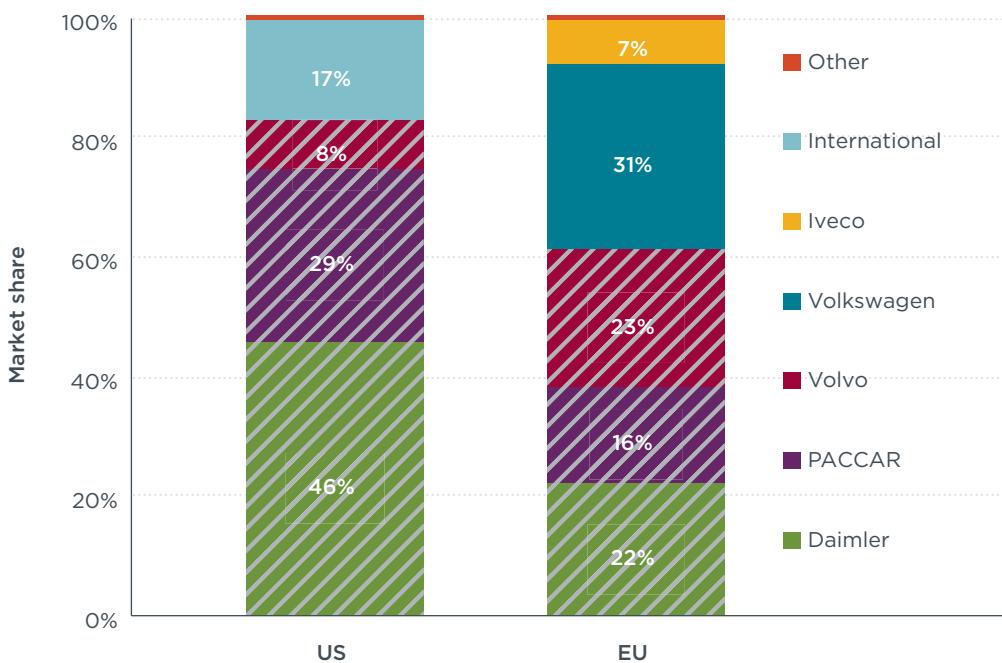
**Figure 10:** Loading capacity by body type of specialized delivery vehicles in China  
(Li and Delgado, 2017)

- » Top-selling models: Datasets that break down sales by individual vehicle model are particularly valuable for determining which vehicle manufacturers and models are most popular in each vehicle segment. Knowing the top-selling models and their market share within each segment can allow the study team to delve deeper into why fleets have a preference for those models (e.g., quality, durability, reliability, fuel efficiency, price). Moreover, having data on the distribution of models sold in each segment provides further insights into what technology levels and vehicle features best represent a baseline profile.
- » Table 3 summarizes the most popular tractor truck brands and models in some of the largest vehicle markets in the European Union. Careful analysis of the characteristics of top-selling vehicles is an excellent way to estimate baseline technology levels in a given market.

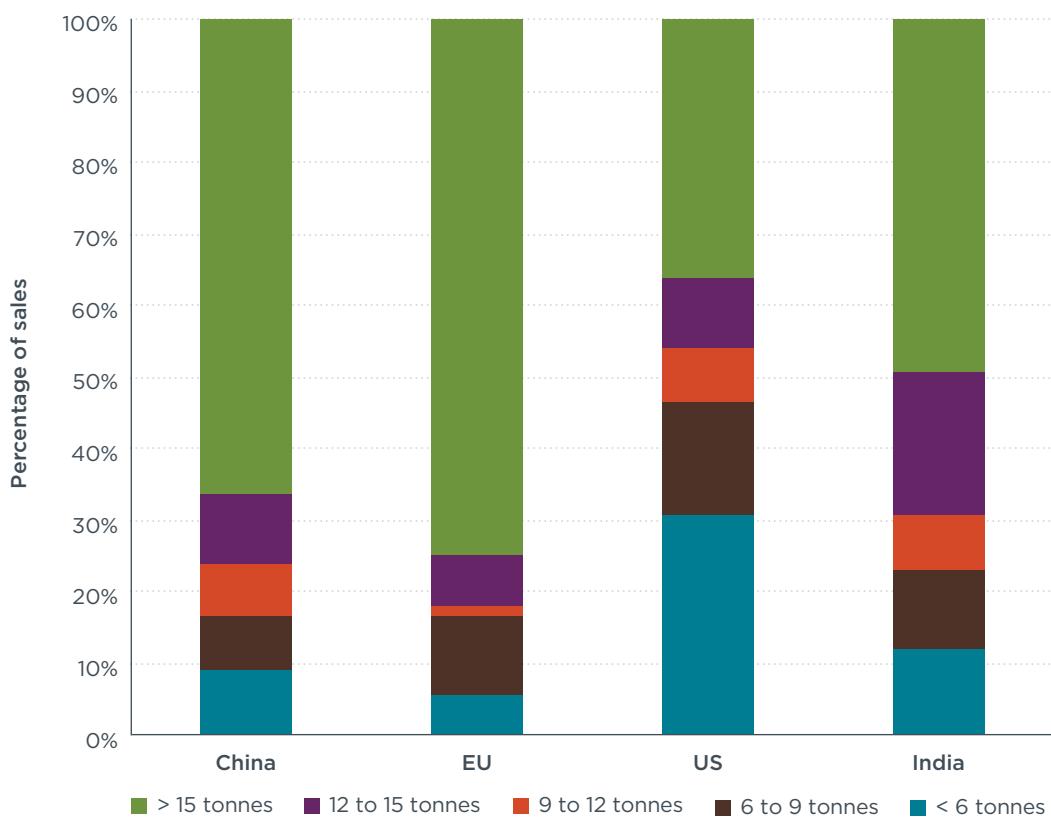
**Table 3:** Top-selling tractor truck brands and models in select EU countries (Muncrief and Sharpe, 2015)

Country	Top-selling make	Top-selling model	% of brand's tractor truck sales
Germany	Mercedes Benz (Daimler)	Actros	98%
United Kingdom	Mercedes Benz (Daimler)	Actros	88%
Spain	Volvo	FH series	96%
Italy	Iveco	Stralis	98%
The Netherlands	DAF (PACCAR)	XF series	71%

- » Comparisons with other markets: An important element of the market analysis is better understanding how sales in your country compare with other countries. Comparisons can be useful in terms of geographical proximity (e.g., the HDV sales market in Brazil vs. other countries in South America) and economic situation and/or projections (e.g., comparing large emerging markets such as China and India). Understanding how HDV sales and vehicle characteristics compare with other markets can yield important insights into what environmental policy measures and programs might be most advantageous to pursue.
- » Figure 11 gives the breakdown of manufacturer market shares for tractor trucks in the United States and European Union. Three of the same manufacturers are the leaders in both markets, although their combined sales represent a larger share of overall sales in the United States. Data summaries such as shown in this figure can help analysts determine how a potential policy measure will affect various manufacturers and suppliers differently.
- » Figure 12 gives the distribution of heavy-duty vehicle sales by GVW groupings in China, the European Union, United States, and India. Access to data sets with sales breakdowns by weight and vehicle type can help in comparisons to other major vehicle markets. Juxtaposing the sales markets of two or more vehicle markets can yield important insights that have important policy implications.



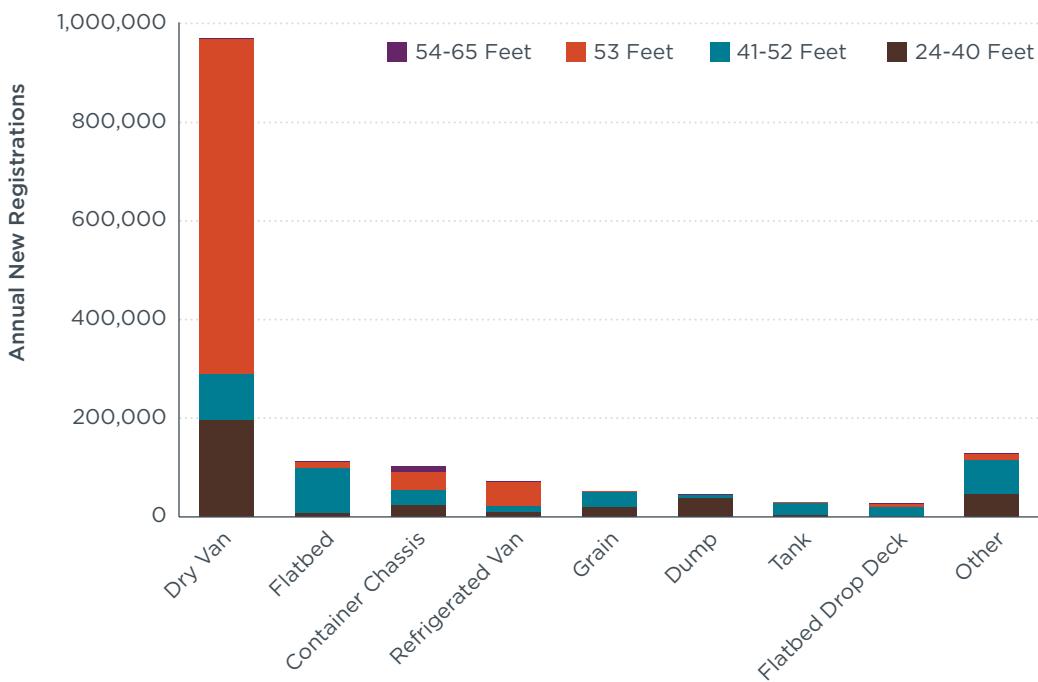
**Figure 11:** 2014 market share of tractor truck manufacturers in the U.S. and EU. Shaded areas are the common manufacturers between the two. (Muncrief and Sharpe, 2015b)



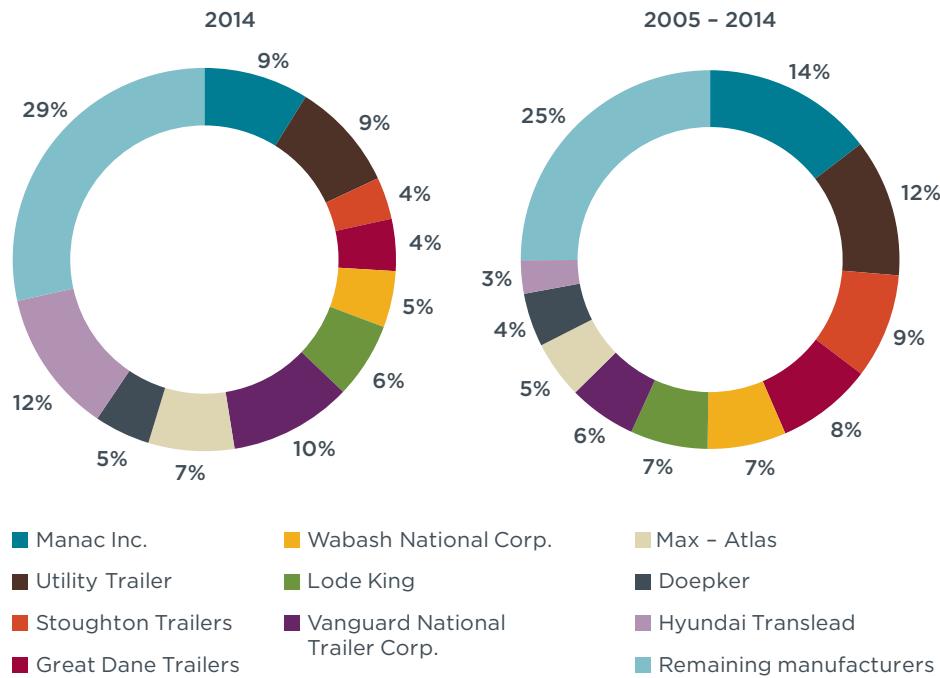
**Figure 12:** Distribution of heavy-duty vehicle sales by weight category in China, the EU, US, and India (Sharpe, 2015b)

### ***Other data and analysis***

- » Commercial trailer sales (or registration) by type, length, and manufacturer: In many countries/regions around the world, on-road goods movement is dominated by articulated tractor-trailers (i.e., the tractor truck can detach from the load-carrying trailer). Trailers are sold as individual pieces of equipment. There are a number of trailer-specific technologies and strategies that can be utilized to increase overall efficiency of the combination vehicle. As such, if trailer sales data exists, it can be valuable in better understanding important parameters such as (a) overall trailer market size and trends, (b) manufacturer market shares, and (c) baseline technology characteristics (e.g., tire and aerodynamic technologies).
- » Figure 13 summarizes commercial trailer sales (new registrations are a reasonable proxy for sales) by type of trailer and by length category. At present, the large majority of research, development, and deployment of aerodynamic technologies are for box-shaped trailers (i.e., dry and refrigerated van trailers). When assessing the potential benefits from advancements in trailer aerodynamics, it is important to quantify the portion of trailers that are box-type trailers.
- » Figure 14 is a breakdown of the market share of various commercial trailer manufacturers in the United States. Typically, the manufacturers that make trailers are completely different companies than those that make trucks, so the trailer market deserves its own unique analysis.

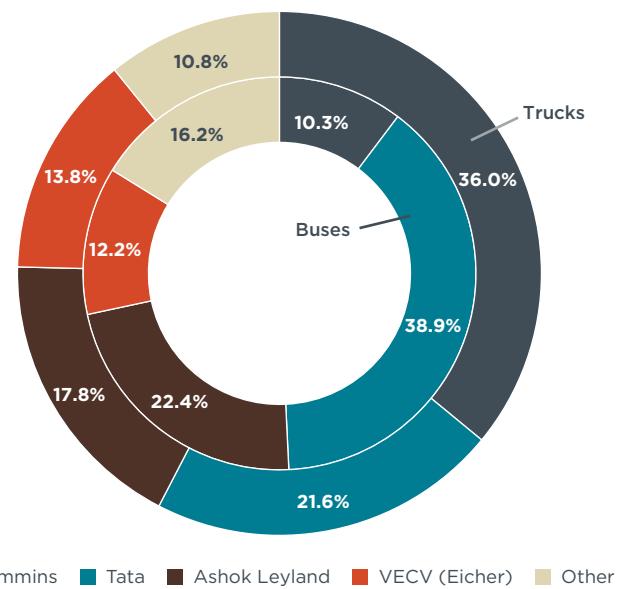


**Figure 13:** Average annual new commercial trailer registrations in the United States, by type and size, 2003 to 2011 (Sharpe, Clark, & Lowell, 2013)



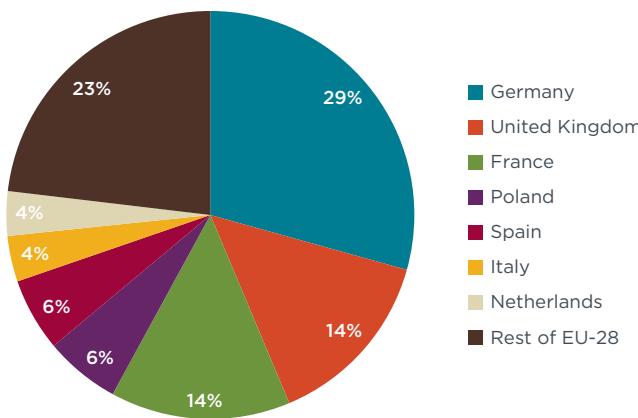
**Figure 14:** Manufacturer market shares for new commercial trailer sales in Canada (Sharpe, 2016)

- » Engine manufacturer market shares: As the power-generating component of the vehicle, the engine is the most important system within the vehicle that directly impacts fuel efficiency and emissions. Therefore, in addition to collecting as much data as possible about technical parameters of commercial vehicle engines, it can be useful to capture the market shares of engine manufacturers. Unlike the passenger vehicle manufacturing process, truck and bus engines are often manufactured by different companies than the overall vehicle. As evidenced in the United States and Canada, there are often situations in which designing engine-specific regulatory provisions is advantageous, and in cases such as those, it is important to understand the market dynamics in the engine manufacturing sector.
- » Figure 15 shows the engine manufacturer market shares for heavy-duty trucks and buses in India. Unlike the passenger vehicle sector, manufacturing of HDVs often involves multiple companies that contribute key systems to the vehicle. For example, in the United States, it is common for the vehicle chassis, engine, and transmission to be made by different companies. Because the engine has such a direct impact on the overall fuel consumption performance of the vehicle, an analysis of the engine manufacturing market can yield important insights when assessing the technology potential and policy design questions for the fleet.

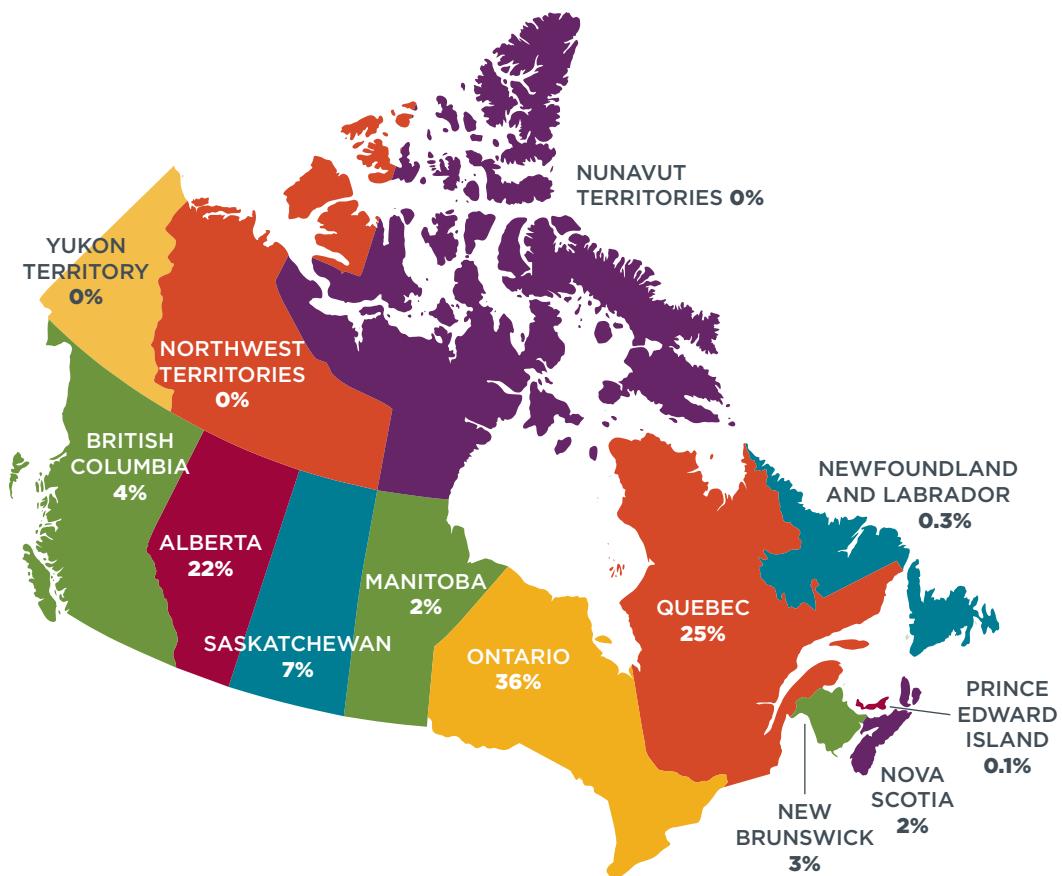


**Figure 15:** Engine manufacturer market shares for trucks and buses in India (Sharpe, 2015b)

- » Sales by sub-region: Within a country/region, there are often autonomous sub-regions such as states or provinces (or even countries in the case of the European Union) that could potentially be affected differently by a new policy measure or program aimed at HDVs. Better understanding how sales differ throughout these sub-regions can provide important insights as you consider potential policy impacts.
- » Figure 16 summarizes HDV sales by country in the European Union. We can see that the top 7 largest markets represent over three-quarters of total sales.
- » Figure 17 shows commercial trailer sales by province in Canada. Combined, Ontario, Quebec, and Alberta account for nearly 85% of the market.



**Figure 16:** 2014 HDV EU sales market share by member state (Muncrief and Sharpe, 2015)



**Figure 17:** Percentage of trailer sales by province in 2014 (Sharpe, 2016)

### 3.3 OPERATIONAL CHARACTERISTICS OF THE TRUCKING SECTOR

#### What are the key things we want to learn?

- » How big is the trucking contribution to freight transport? → What is the contribution of freight trucks to overall HDV fuel consumption and emissions? How has the trucking contribution changed over time?
  - » Data sources: research literature, government transport agency
- » What are typical operating characteristics of the trucking sector? → What are average per-truck annual kilometers or miles traveled? What are representative duty cycles? Is extended idling for cabin comfort (i.e., “hoteling”) prevalent? What are average payloads, and what is the percentage of trucks that are volume-restricted (“cube out”) versus weight-restricted (“weigh out”) versus empty? Do trucking operations tend to follow hub-and-spoke or point-to-point logistics profiles? On average, how do costs break down for trucking fleets (e.g., fuel, driver salary, insurance, maintenance)? How do these various parameters differ by trucking fleet type and size?
  - » Data sources: stakeholder interviews (primary sources—see sample questions below), research literature and government agencies (secondary sources)
- » What are the fuel consumption and emissions trends? → What are the recent trends in fuel consumption and emissions, and how quickly are they growing? How have per-vehicle fuel consumption rates changed over the past 5-10 years, and how are they expected to change in the future?
  - » Aggregate, fleet-wide data sources: industry associations, government transport or statistics agencies, government oil/energy agencies
  - » Individual fleet data sources: stakeholder consultation interviews
- » How are contracts structured in the various formal relationships that exist in the trucking sector? Are there specific provisions around fuel? How are contracts designed for fleets and shippers? Third-party logistics (3PL) suppliers and shippers? Drivers and fleets? Truck and trailer equipment rental companies and fleets?
  - » Data sources: stakeholder interviews

## Quick reference guide

Table 4 summarizes the key aspects of the trucking sector operational characteristics analysis.

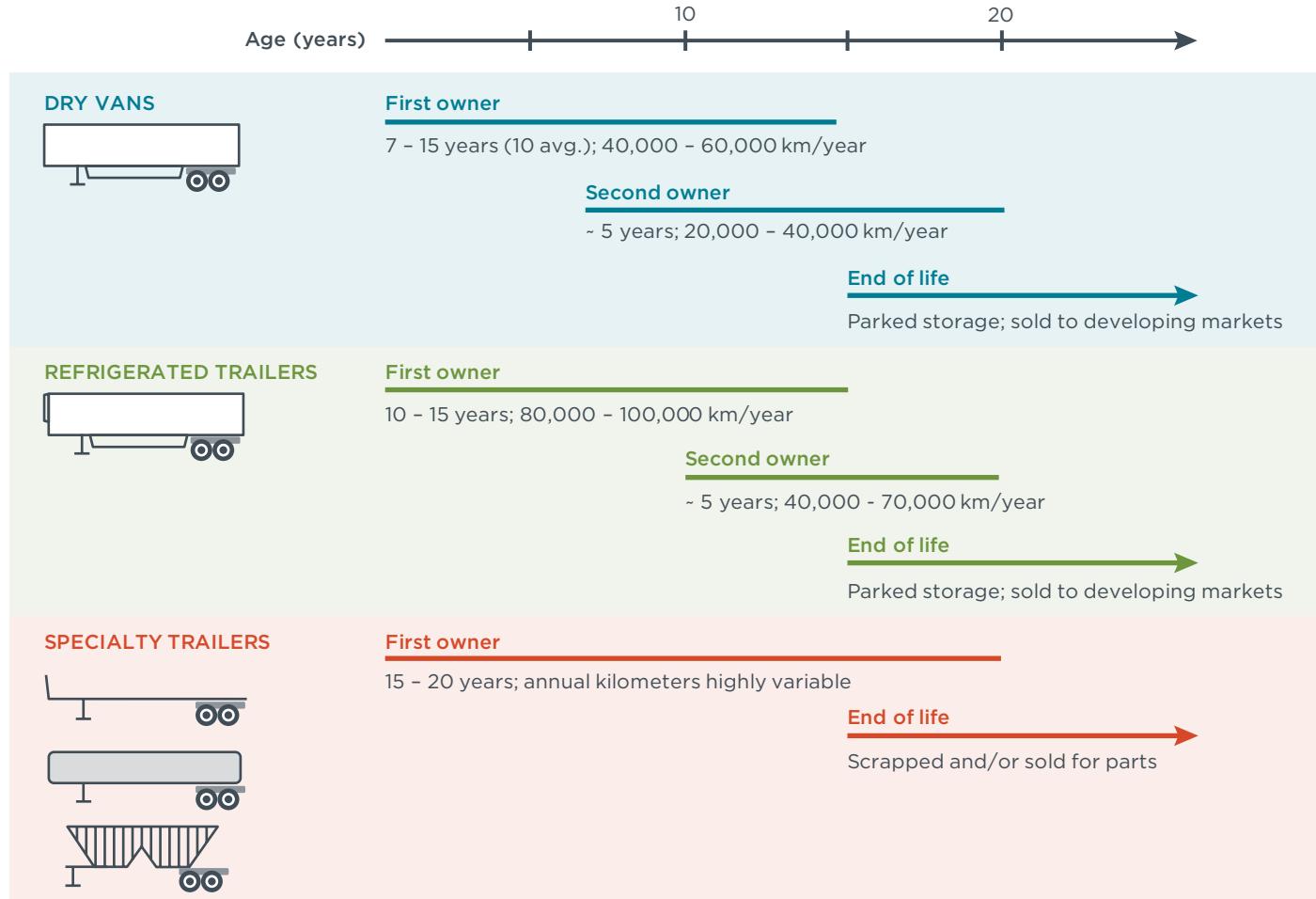
**Table 4:** Operational characteristics of the trucking sector

<b>What is this step?</b>	In this step, we aim to learn as much as possible about how freight trucks operate in this particular market.
<b>Why is it important?</b>	To learn a wide variety of characteristics of the trucking sector. For the following parameters, we aim to collect data about the overall fleet averages as well as how these factors differ based on fleet size and type: <ul style="list-style-type: none"> <li>• Population, historical trends, and projections for the future</li> <li>• Fuel consumption: fuel totals and per-truck efficiency metrics (e.g., mpg)</li> <li>• Average payloads; cube-out vs. weigh-out percentage; empty miles percentage</li> <li>• Activity: per-truck annual averages; typical duty cycles</li> <li>• Idling/hotelng: per-truck average hours</li> <li>• Truck-trailer pairing: drop-n-hook vs. one-way and dead-head</li> <li>• Typical logistics profile: hub-and-spoke vs. point-to-point</li> <li>• Fleet expenses: percentage breakdown of fuel, labor, maintenance, etc.</li> <li>• Relationships to other freight modes</li> <li>• How are freight loads marketed and assigned? Via freight exchange platform, logistics firms, contracts?</li> <li>• What is the proportion of freight carried by various types of fleets (e.g., owner-operators; small, medium, and large fleets)? What are the key differences between private and for-hire fleets (e.g., freight tonnage, truck and trailer characteristics, operating profiles)?</li> </ul>
<b>Key stakeholders to consult</b>	<ul style="list-style-type: none"> <li>• Trucking fleets of various size and type</li> <li>• Owner-operators</li> <li>• Fleet associations</li> <li>• Shippers, third-party logistics companies</li> </ul>
<b>How to go about performing this step?</b>	This task involves speaking to as many trucking fleet practitioners and experts as possible. Here, it is very important to engage with as diverse a cross-section of fleets as possible, since operations are heavily dependent on factors such as fleet size, type, location, and business strategy. When collecting data from fleets and trucking experts, it is important to understand how these data were measured.
<b>Getting creative</b>	Accessing operations experts can be challenging, especially for smaller fleets and owner operators. Consider partnering with industry associations that represent these smaller fleets. In addition, consider electronic means (e.g., email or social media surveys) as way to reach a large number of stakeholders cost-effectively. Incentives (e.g., fuel vouchers) can be an effective manner to boost survey participation.
<b>Relevant examples of previously completed projects in this area</b>	<ul style="list-style-type: none"> <li>• U.S. fleet characteristics (see Chapters 1 and 2): <a href="http://www.nap.edu/catalog/12845.html">http://www.nap.edu/catalog/12845.html</a></li> <li>• EU fleet characteristics (see Chapters 2 and 4): <a href="https://ec.europa.eu/clima/sites/clima/files/transport/vehicles/docs/ec_hdv_ghg_strategy_en.pdf">https://ec.europa.eu/clima/sites/clima/files/transport/vehicles/docs/ec_hdv_ghg_strategy_en.pdf</a></li> </ul>

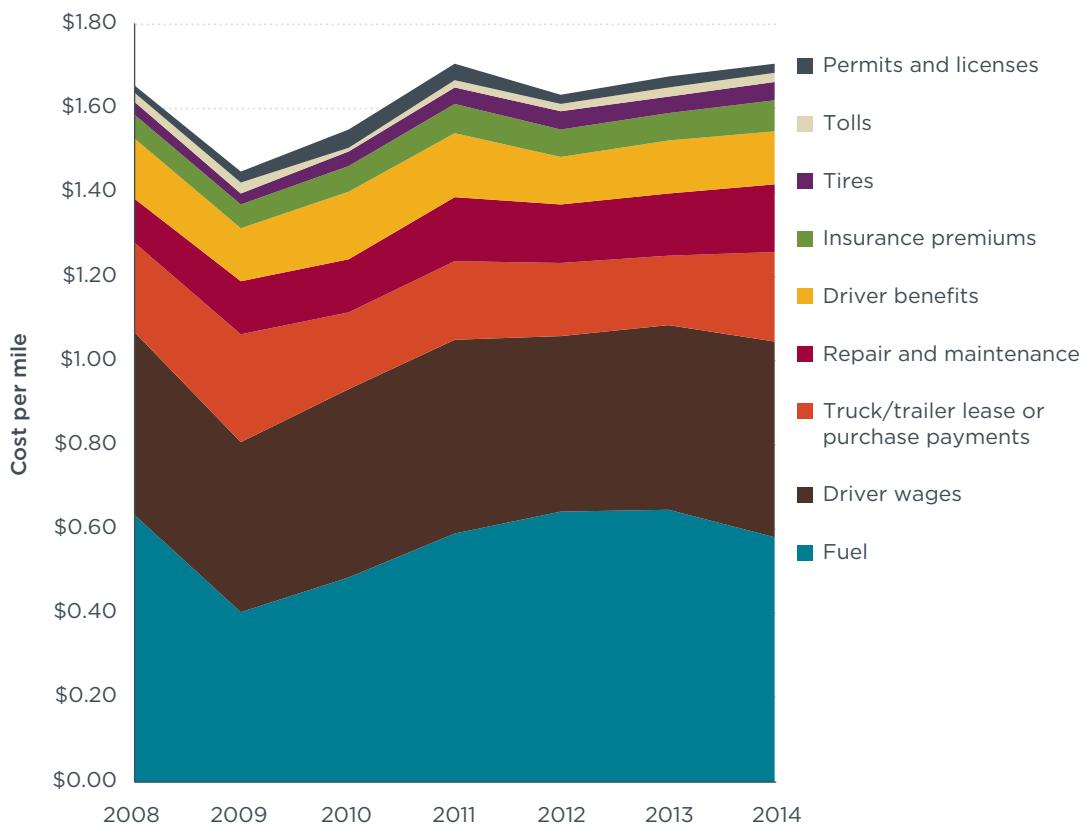
## Example outputs from analysis of operating characteristics of the trucking sector

### *Higher priority data and analysis*

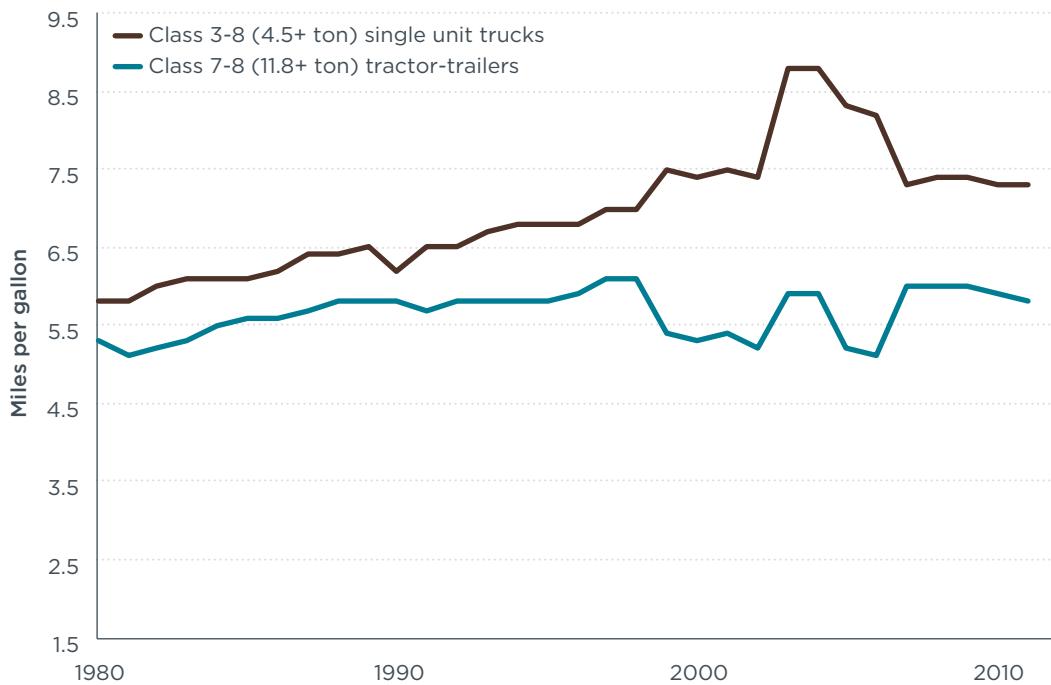
- » Vehicle activity
  - » Figure 18 summarizes various trailer ownership and operations data for Canada. These data were derived from interviews of trucking fleets, OEMs, and key trailer technology suppliers.
- » Operational costs
  - » Figure 19 shows a breakdown of average costs per mile to operate tractor-trailers in the United States. The data were compiled by the American Transportation Research Institute.
- » Fuel consumption and emissions trends
  - » Figure 20 illustrates how average fuel economy of freight trucks in the United States has changed over time.
  - » Figure 21 displays various fuel consumption data points from chassis dynamometer testing of HDVs in China. The red and blue step-shaped lines represent the maximum allowable values for the first and second stage fuel consumption standards, respectively.



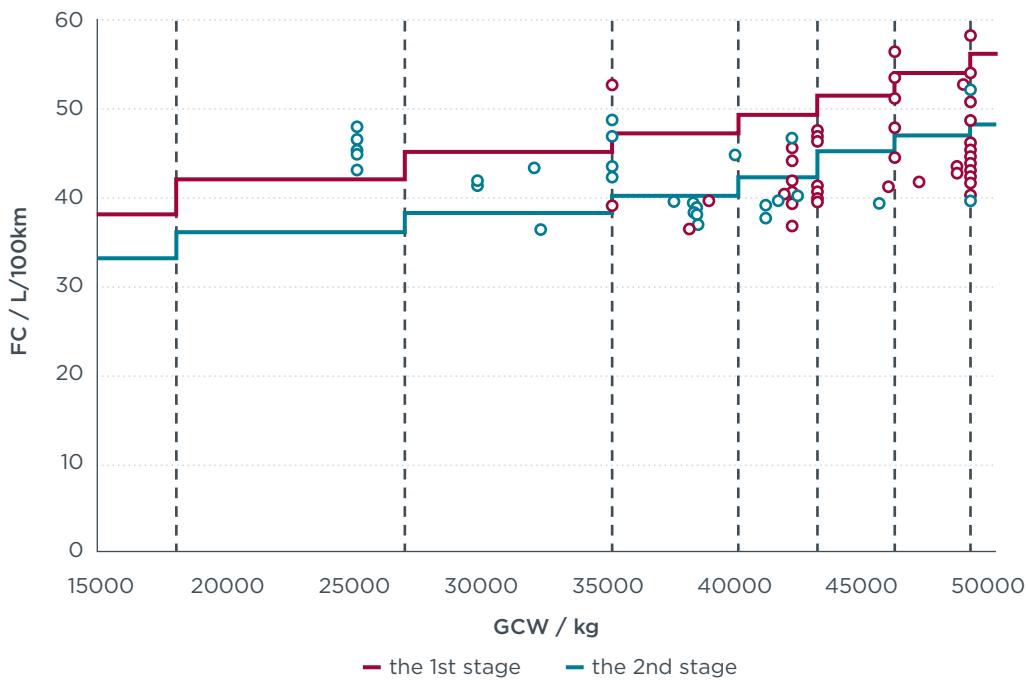
**Figure 18:** Typical Canadian trailer ownership and activity patterns over its useful life (Sharpe, 2016)



**Figure 19:** Average cost per mile for trucking in the United States (Torrey and Murray, 2015)



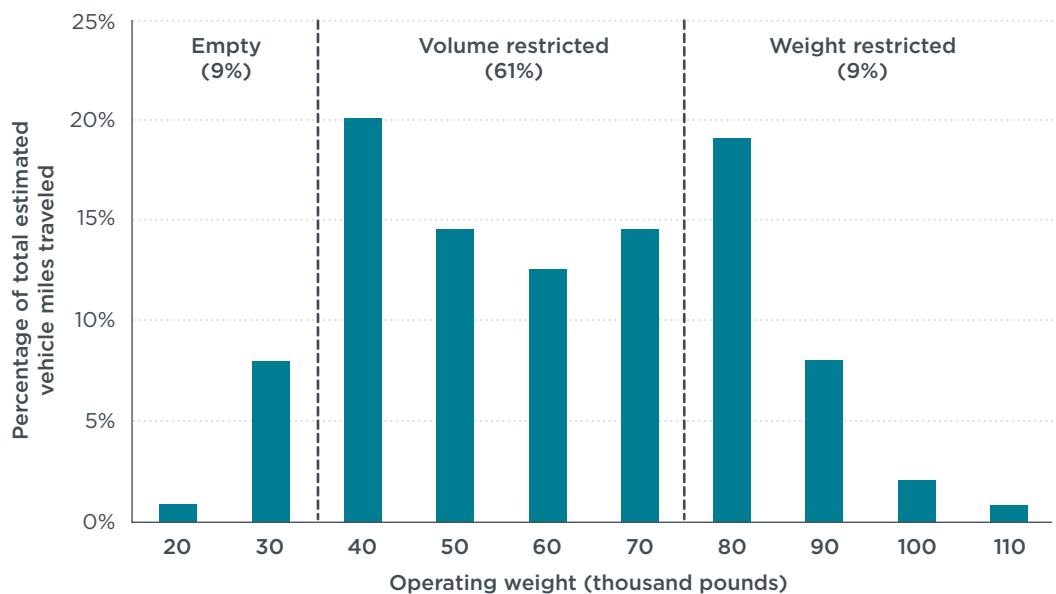
**Figure 20:** Fuel economy of freight trucks in the United States (Davis and Diegel, 2013)



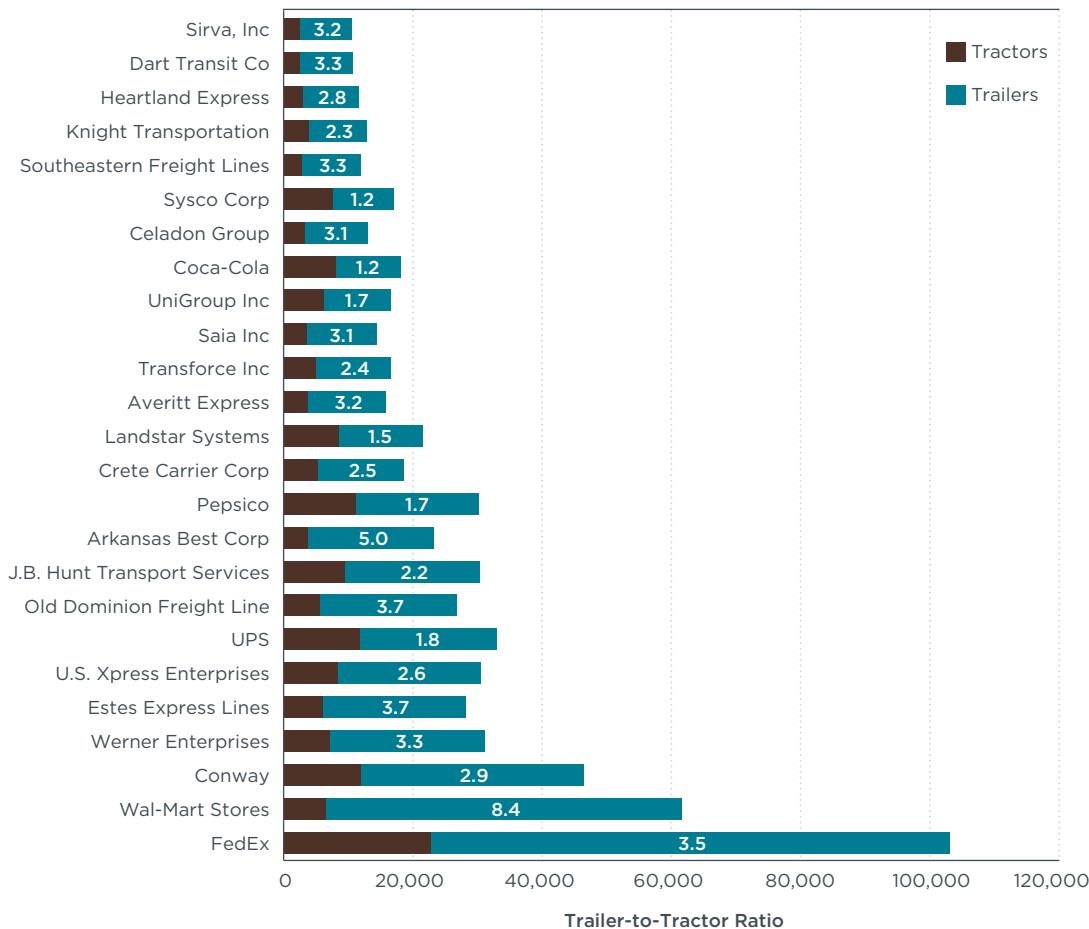
**Figure 21:** Chassis dynamometer test results developed by the China Automotive Technology and Research Center (CATARC) for tractor-trailers (Sharpe and Muncrief, 2015)

#### ***Other data and analysis***

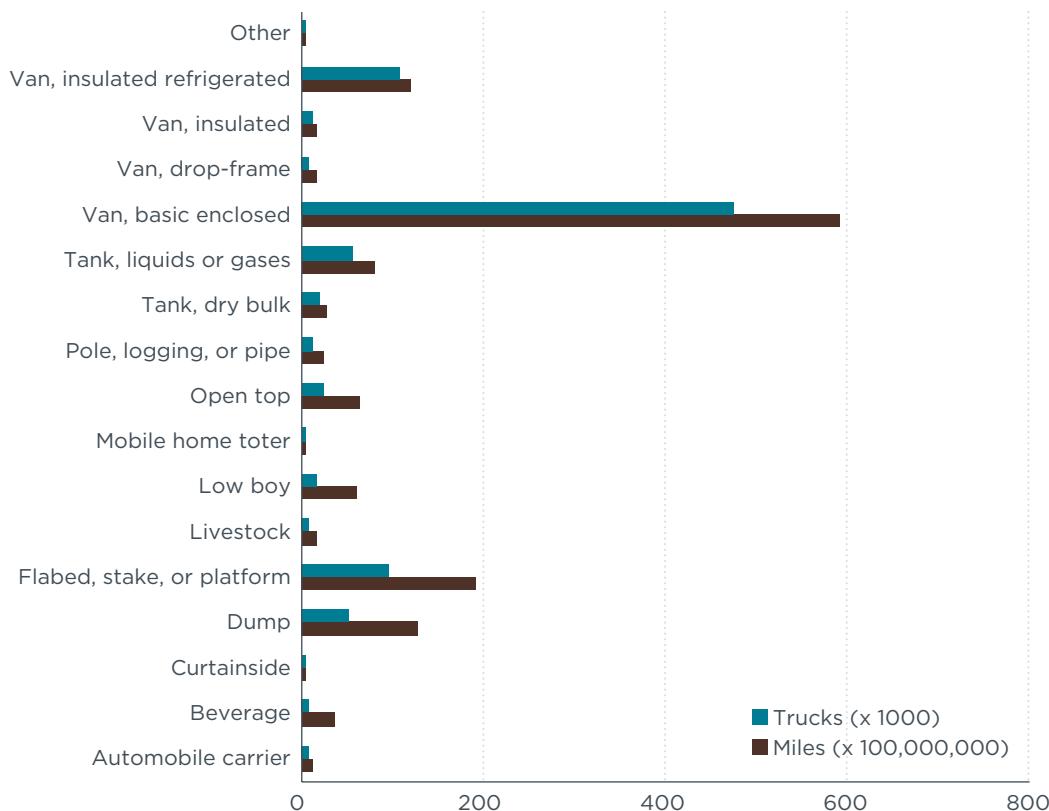
- » Data on vehicle activity and payloads
  - » Figure 22 shows the estimated distribution of operating weights for tractor-trailers in the United States. These data are used to infer what percentage of trucks are empty (or nearly empty), space restricted (i.e., when the amount of payload is limited by the volume of the trailer), and weight restricted (i.e., when the payload may not have filled the volume of the trailer, but the maximum allowable weight of the vehicle has been reached).
- » Breakdown of fleets by type (e.g., for-hire vs. private), size, and truck (and trailer) ownership
  - » Figure 23 shows tractor truck and trailer ownership for the 25 largest trucking fleets in the United States. The numbers on each bar represent the ratio of trailers to tractors.
  - » Figure 24 summarizes estimated truck populations and mileage in the United States by the type of trailer. Box-type trailers (i.e., dry and refrigerated vans) account for the large majority (roughly 80%) of truck population and mileage.



**Figure 22:** U.S. tractor-trailer percentage of miles driven by weight (Lowell and Balon, 2009)



**Figure 23:** 25 largest trucking fleets in the United States by trailer ownership (Sharpe et al., 2013)



**Figure 24:** Truck populations and mileage by trailer type in the United States (U.S. Census Bureau, 2004)

### Sample questions for stakeholder consultations about operational characteristics of the trucking sector

*Note: For each of the questions below, it is important to understand how the fleet collects its data.*

- » What are your typical operating characteristics? Types of goods hauled, loading profiles, annual kilometers, etc.
- » What is your percentage of empty miles?
- » What is your average truck utilization percentage?
- » What types of equipment do you own? Lease? How does vehicle resale value factor in to your asset management process?
- » Do you generally buy new or used equipment? If both, please describe your process for deciding whether to buy new or used.
- » How are your drivers incentivized to save fuel? Is there a driver training program?
- » How are your contracts structured around fuel consumption? What are the incentives or disincentives to increase fuel efficiency?
- » In terms of trucking operations, what are your most important constraints (e.g., fuel costs, driver costs, on-time delivery, safety)?
- » What percentage of your overall budget is devoted to fuel costs? How does this compare with other cost items such as maintenance, vehicle purchase, insurance, etc.?
- » What are the methods that you use to evaluate your fleet's fuel efficiency?

- » How often to do analyze fuel efficiency?
- » How do you measure the fuel-saving effectiveness of a new technology or feature?
- » Do you ever select a particular brand of vehicle because of superior fuel efficiency? If not, what other parameters are more important and why?
- » Do you ever utilize third-party test results in your evaluation process?
- » How do you value manufacturer claims about the fuel efficiency of their products?
- » How do your operating characteristics (e.g., loading, terrain) affect your fuel consumption?
- » What are the maintenance procedures that you have in place?
- » How often are vehicles inspected and serviced?
- » What percentage of your overall budget is devoted to maintenance?
- » Which area of the truck requires the most replacement and/or maintenance?
- » How do you do route planning and management?

### **3.4 DECISION MAKING AROUND FUEL-SAVING TECHNOLOGIES AND STRATEGIES**

#### **What are the key things we want to learn?**

- » What are the key technologies and strategies that have been (and are expected to be) deployed to reduce fuel use and emissions?
- » How does the efficacy of these technologies and strategies change as a function of drive cycle, payload, and other operational characteristics?
- » What have been the most successfully deployed technologies or strategies in this country/region?
- » How are technologies verified (if at all) and by whom?
- » What are the barriers for other technologies and strategies that can potentially be effective in this market?

#### **Data sources**

In this part of the freight assessment, stakeholder interviews with trucking fleets, manufacturers, and truck dealers will be the primary sources of data.

## Quick reference guide

Table 5 summarizes the key aspects of the analysis to better understand how fleets make decisions regarding fuel-saving technologies and strategies.

**Table 5:** Technology applicability and decision-making around fuel-saving and emission reduction strategies

<b>What is this step?</b>	For this task area, we want to learn how and why fleets and manufacturers make decisions about fuel-saving and emission reduction technologies that they buy (fleets) or offer (OEMs).
<b>Why is it important?</b>	To better understand the experiences, attitudes, and expectations of both fleets and manufacturers with regard to the following: <ul style="list-style-type: none"> <li>• Factors of importance during the truck and trailer procurement/specification process</li> <li>• How new (and/or improved) products are marketed</li> <li>• Return on investment assumptions</li> <li>• Fleets: manufacturer claims vs. real-world performance for fuel-saving technologies</li> <li>• Fleets: What are trusted sources of information about technology?</li> <li>• OEMs: near- and long-term product development plans</li> <li>• Technology suppliers: marketing products; relationships with OEMs and fleets</li> <li>• Technology testing and verification</li> </ul>
<b>Key stakeholders to consult</b>	<ul style="list-style-type: none"> <li>• Trucking fleets of various size and type</li> <li>• Owner-operators</li> <li>• Fleet associations</li> <li>• Manufacturers, technology suppliers</li> <li>• Truck dealers</li> </ul>
<b>How to go about performing this step?</b>	As with the previous two steps, cast as wide a net as possible for both fleets and manufacturers in soliciting interview/survey participation. Data collection methods can include in-person or telephone interviews, focus groups, and electronic surveys.
<b>Getting creative</b>	If recruiting fleet and manufacturers to participate proves challenging, try leveraging industry associations or trade groups. Also, as discussed in the previous section, electronic surveys can be an effective way to reach a large number of people with relatively few resources.
<b>Relevant examples of previously completed projects in this area</b>	<ul style="list-style-type: none"> <li>• North America trucking industry survey: <a href="http://www.theicct.org/hdv-technology-market-barriers-north-america">http://www.theicct.org/hdv-technology-market-barriers-north-america</a></li> <li>• EU trucking industry survey: <a href="http://www.theicct.org/market-barriers-increased-efficiency-european-road-freight-sector">http://www.theicct.org/market-barriers-increased-efficiency-european-road-freight-sector</a></li> </ul>

## Finding the best technology areas

Table 6 lists some technologies and technology areas as well as certain operational practices that can be used to save fuel and reduce emissions. This is by no means an exhaustive list for either of the two categories. Looking at the technology areas column, notable omissions include engine and transmission enhancements, as well as alternative fuel options. Technology improvements in the powertrain are generally only available when purchasing a new vehicle, and green freight programs and technology verification campaigns typically focus on after-market technologies.

**Table 6:** Technologies and strategies for reducing truck fuel consumption

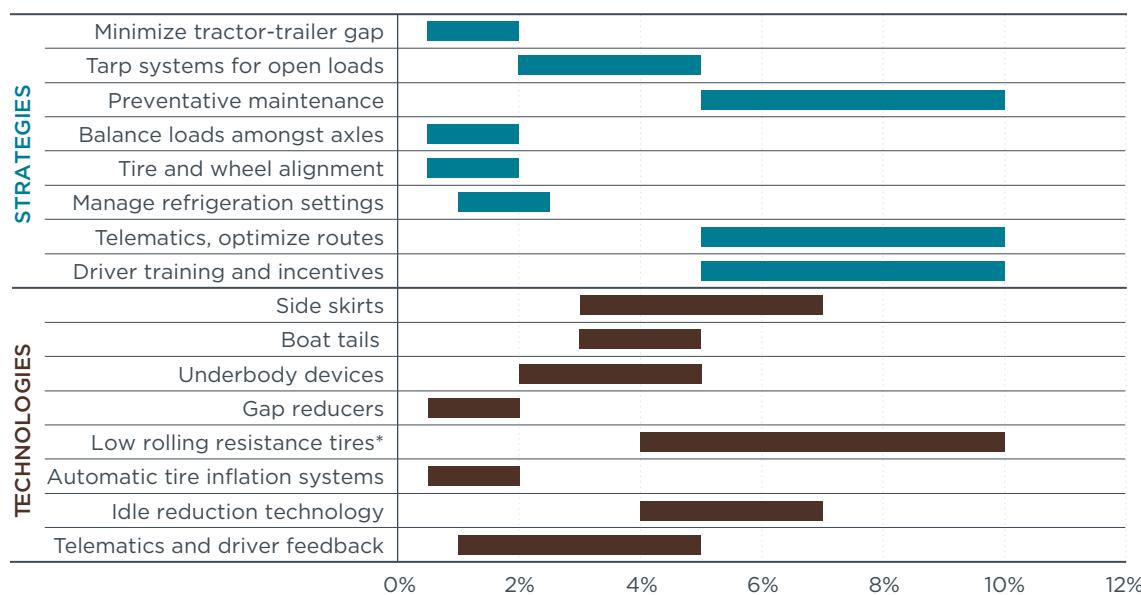
Technology areas	Operational practices
<b>Available in new vehicles and as after-market technologies</b>	<ul style="list-style-type: none"> <li>Driver training</li> <li>Minimize tractor-trailer gap</li> <li>Tarp open loads</li> <li>Maintain robust preventative maintenance schedule</li> <li>Balance payload properly between axles</li> <li>Maintain proper tire and wheel alignment</li> <li>Manage refrigeration settings</li> <li>Optimize routes</li> <li>Train and incentivize drivers</li> <li>Collect data to identify best and worst-performing drivers and vehicles</li> <li>Use transponders and on-board scales to bypass weigh stations</li> </ul>
<b>Typically available in new vehicles only</b>	<ul style="list-style-type: none"> <li>Engine efficiency technologies</li> <li>Transmission technologies</li> <li>Lightweighting via material substitution</li> <li>Improved efficiency accessories</li> <li>Improved efficiency axle configuration (e.g., 6x2 instead of 6x4 layout)</li> <li>Alternative fuel or hybrid drivetrains</li> </ul>

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

Given the difficulty in assigning an exact fuel consumption benefit to a particular technology or strategy, in Figure 23 we show approximate ranges for fuel savings that are based on available literature. The interventions included here are by no means meant to cover all of the available technologies or operational practices that can yield fuel savings. Rather, the items shown in Figure 23 are representative of some of the most common after-market products and operational best practices that are promoted by green freight programs.

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

The percentage fuel savings for individual strategies and technologies in Figure 25 ranges from roughly 1% to 10%. The fuel consumption reduction percentages shown for each intervention are approximations based on various sources (a full list of the references used is given in Table 6) and should only be taken as illustrative of the level of benefits that a trucking fleet might realize. The ranges represent reductions that can be realized when the technologies and strategies are utilized appropriately. For example, aerodynamic technologies typically require a minimum speed to yield fuel savings, and a trucking carrier that exclusively operates at low speeds would likely not achieve the degree of savings shown in the figure. Some technologies and strategies are much more sensitive to drive cycle and operating conditions than others.



**Figure 25.** Approximate fuel consumption reduction ranges for operational strategies and technologies for tractor-trailers

### Sample questions for stakeholder consultations about fuel-saving technologies and strategies

#### *Example of questions geared toward fleets*

- » What are your information sources for new technologies and features?
- » In the past few years, what new fuel-saving technologies or operational practices have you adopted? Please describe your experiences, both good and bad, with deploying new technologies and strategies for saving fuel.

- » How do you make investment decisions on fuel-saving technologies and strategies?
- » How does fuel efficiency compare with other considerations such as cost, durability, warranty, etc.?
- » Do you utilize a payback calculation to estimate how long it will take a technology to pay for itself in terms of fuel savings? If so, what are typical upper bounds that you utilize for the payback time (e.g., two years)?
- » What are the constraints in terms of the overall increase in purchase price that a technology or set of technologies will impose on the vehicle (e.g., 5%)?
- » Are new technologies typically introduced across your entire fleet or are they deployed in selected segments or pilot programs?
- » How have changes in international oil prices in recent years impacted your views on the value of fuel-saving technologies?
- » What are the new technologies and features that you expect to become available in the near-term (3-5 years)?
- » What are the key motivations for investing in these new technologies? Fuel efficiency, performance, reliability, durability, safety, driver comfort, etc.?
- » How do you expect these new technologies to affect your fuel consumption performance, maintenance, and reliability? What do you envision as the most significant obstacles in terms of how new technologies will affect your operations?
- » How much additional capital investment are you willing to spend for upcoming fuel-saving technologies?
- » Are there any technologies that you know of that you'd like to see offered on new vehicles that are currently not available or are too expensive in the market?
- » How long is your planning horizon? Do you have a general sense for the new technologies and improvements that you expect to introduce in the longer term (i.e., 5 years or more)?

***Example of questions geared toward manufacturers and suppliers***

- » What is a typical design cycle for your vehicle models (e.g., 4 years)?
- » How do you decide which technologies or features will end up in the final vehicle design?
- » How much customization is offered to the truck buyers?
- » Is fuel efficiency part of this decision-making process? If so, how does it compare with other design considerations such as cost, durability, warranty, etc.?
- » Do you utilize a payback calculation to estimate how long it will take a technology to pay for itself in terms of fuel savings? If so, what are typical upper bounds that you utilize for the payback time (e.g., 2 years)?
- » What are your customers' expectations in terms of payback time for new technologies or features?
- » What are the constraints in terms of the overall increase in purchase price that a technology or set of technologies will impose on the vehicle (e.g., 5% or X dollars)?
- » Are new technologies typically introduced across your entire vehicle product mix or are they marketed to specific segments or types of fleets?

- » In the past, have you had a particular challenge with the introduction of a given technology or feature?
- » What are the new technologies and features that you expect to introduce in the near-term (3-5 years)? *Note: we are not interested in learning about specific new technologies or products that are considered confidential. Rather, we are interested in learning the general areas where the interventions are planned.*
- » What is the range of overall fuel efficiency improvement that you expect these new technologies to yield?
- » What will these new technologies require in terms of capital investment?
- » Are your research and development efforts in collaboration with any other companies? If so, please describe.
- » How long is your planning horizon? Do you have a general sense for the new technologies and improvements that you expect to introduce in the longer term (i.e., 5 years or more)?
- » Where on the vehicle are you focusing on introducing new technologies or upgrades (e.g., engine, transmission, aerodynamics, tires/wheels, accessories)?
- » What are the key motivations for these new technology deployments: fuel efficiency, safety, reliability, durability, etc.?
- » What do you envision as being the main obstacles in terms of technology integration or how the technology will perform in the real world?

### **Understanding the best technology areas for cost-effective efficiency improvements**

Figures 26 and 27 show the breakdown of energy losses for a typical tractor-trailer operating in the United States and India, respectively. Compared with trucking in other regions around the world, tractor-trailer operations in North America are typified by higher average speeds (particularly during highway driving) and a truck cab design with an elongated nose. The Heavy Heavy-Duty Diesel Truck 65 (HHDDT65) drive cycle represents high-speed highway operation at 65 mph (105 km/hr) but also has elements of transient driving and idling. The payload of 19 tons (17.2 metric tonnes) is the default payload value used for Class 8 tractor-trailers in the U.S. Phase 1 and 2 greenhouse gas regulations for heavy-duty vehicles (U.S. Environmental Protection Agency 2016). For a detailed explanation of the methodology and how these percentages were derived for the U.S. tractor-trailers, see Delgado and Lutsey (Delgado and Lutsey 2015).

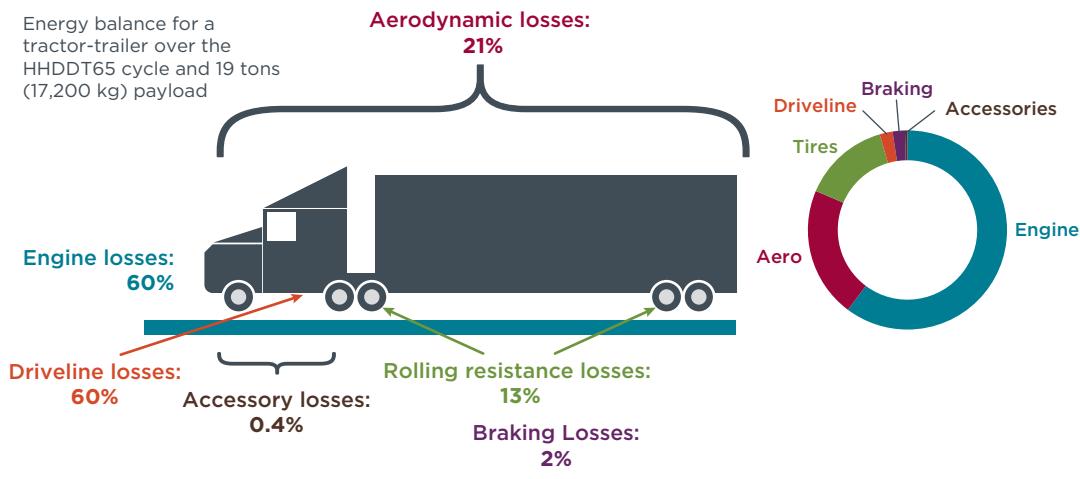
Figure 27 uses an identical methodology as Figure 26, except the vehicle characteristics, drive cycle, and payload are all meant to represent typical conditions for tractor-trailer operations in India. As shown, tractor trucks in India—as in most regions outside of North America—have blunt face ‘cab-over-engine’ designs. Compared with the United States, average speeds in India are much lower, and this is primarily because of poorer road infrastructure, smaller and less powerful engines, and a high degree of overloading. The WHVC-India cycle is derived from the World Harmonized Vehicle Cycle, except the highway cruising speeds are capped around 60 km/hr (37 mph), which is typical of truck travel in India.

Comparing the two figures, the breakdown of energy losses is very different after accounting for engine losses, which are around 60% in both cases. As speeds in the United States are relatively much higher, aerodynamic drag is the dominant non-

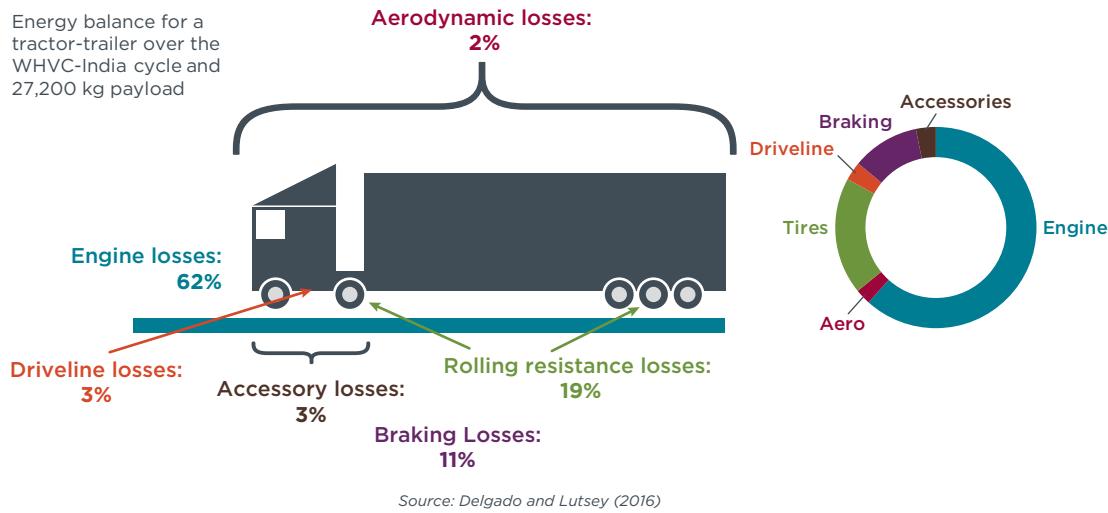
engine energy loss category. This is contrasted with the breakdown for the Indian truck, where tire rolling resistance and braking losses are the largest contributors to energy consumption. Understanding typical vehicle characteristics, driving behavior, and payload profiles are critical first steps in estimating the potential for fuel savings from technological advances. As discussed in Sections 3.1 and 3.2, one of the primary objectives of a freight assessment is to better understand baseline vehicle characteristics and typical vehicle operating speeds and payloads.

Figure 28 shows an approximation of how the relative efficacy of aerodynamic and tire technologies are a function of vehicle speed and payload. The size of the circles represents a rough estimate of the relative contribution to fuel savings for each of the two technology areas in four distinct quadrants: (1) low speed, low payload; (2) low speed, high payload; (3) high speed, low payload; and (4) high speed, high payload. As a simplification, aerodynamic drag force increases as the square of vehicle velocity, whereas tire rolling resistance drag increases linearly with vehicle velocity (Tanguay 2012). As such, aerodynamic drag tends to dominate at higher speeds (e.g., highway cruise), and tire rolling resistance drag is often higher in city, stop-and-go conditions. As payload increases, more force is transferred through the tires and to the ground, and thus, rolling resistance increases. Proportionally, as payload increases, drag due to tires increases as a percentage of overall losses compared with aerodynamics.

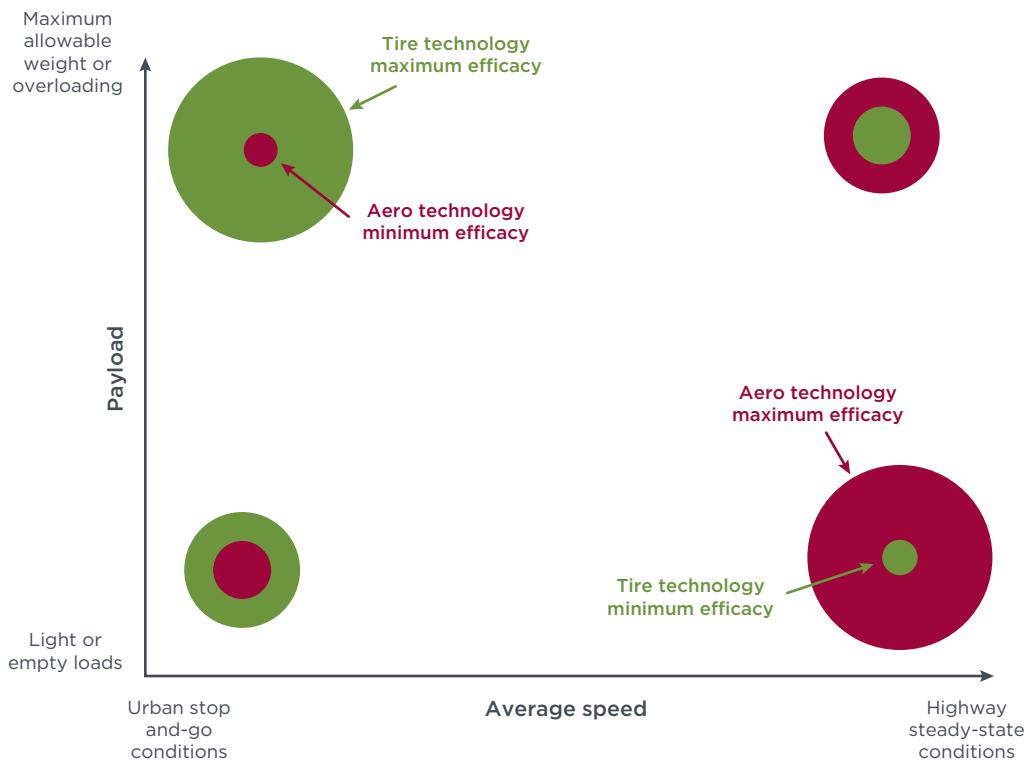
There is a great deal of variety across the heavy-duty vehicle market, and Figure 29 shows that the effectiveness of various technologies and technology packages is very much related to a vehicle's size, configuration, and mission profile. Even though green freight programs typically focus on tractor-trailers—which generally account for the majority of fuel use and emissions from the commercial vehicle sector—there is still a large degree of variety in this segment in terms of vehicle characteristics, duty cycles, and payloads. Understanding the distribution of these various aspects across the trucking industry in a given country or region is a central objective of the freight assessment.



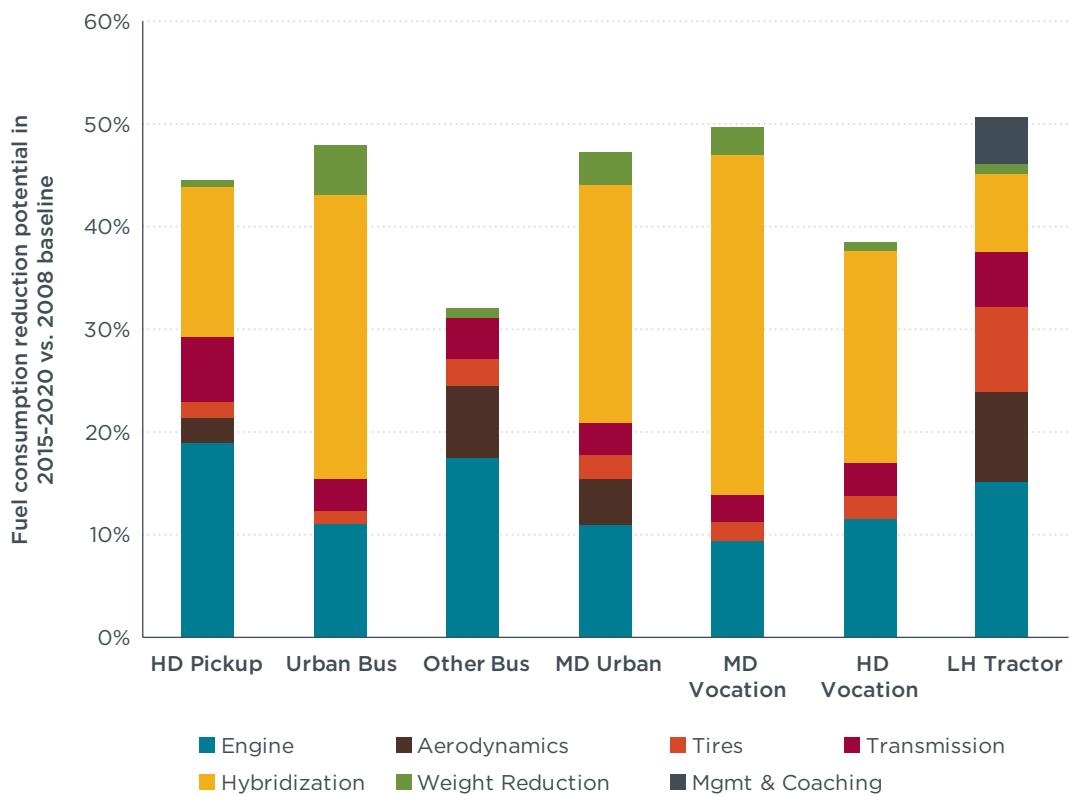
**Figure 26:** Energy balance for a U.S. tractor-trailer over the HHDDT65 cycle and 19 tons (17.2 tonnes) payload



**Figure 27:** Energy balance for an India tractor-trailer over the WHVC-India cycle and 27.2 tonnes payload



**Figure 28:** Relative efficacy of aerodynamic and tire technologies as a result of tractor-trailer average speed and payload



**Figure 29:** Technology potential of various heavy-duty vehicle categories in the 2015-2020 timeframe vs. a model year 2008 baseline (Committee on Assessment of Technologies and Approaches for Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles, 2010)

### 3.5 INSTITUTIONAL FRAMEWORK AND GREEN FREIGHT PROGRAM PLANNING

#### What are the key things we want to learn?

- » What are the federal, provincial, and/or state government agencies responsible for HDV efficiency? → What agencies have what jurisdiction? What policies and programs exist already for improving HDV efficiency?
- » In the private sector, what programs are already in place for measuring and reporting metrics related to efficiency? Are trucking associations and/or other groups already active in this space?
- » What key stakeholders should be involved in the planning and design of a green freight program? → What government agencies or private sector entities are best positioned to develop and administer a green freight program? Have any individuals or groups already expressed interest in such a role?
- » Can the new green freight program leverage an existing related effort or initiative? → Does alignment of programs make sense based on geographical proximity and/or similarities in the trucking fleets? Have there been any pilot programs or technology-specific projects to draw from?

## Quick reference guide

Table 7 summarizes the key aspects of the institutional framework and policy options analysis.

**Table 7:** Institutional framework and policy options

<b>What is this step?</b>	This step entails interacting with government officials and other stakeholders that are involved with developing policies that impact the trucking sector.
<b>Why is it important?</b>	<p>In formulating a plan for developing policies and/ programs to improve the environmental performance of the trucking sector, it is imperative that we understand the current policy landscape. In this step, we aim to answer questions such as:</p> <ul style="list-style-type: none"> <li>• What are the policies affecting the freight and trucking sectors that impact efficiency?</li> <li>• What government agencies are responsible for administering these regulations and programs, and how do these agencies interact?</li> <li>• In the overall government landscape, what agencies wield the most power and influence?</li> <li>• Across the various government agencies of interest, are there staff ‘champions’ for environmental policy? If so, what kinds of support/ resources/access do these champions need to help design and implement policies and programs for improving the efficiency and environmental performance of the trucking sector?</li> </ul>
<b>Key stakeholders to consult</b>	<ul style="list-style-type: none"> <li>• Government agencies charged with developing and implementing environmental policies and/or programs for the trucking sector at both the national and regional levels</li> <li>• Trade associations and/or NGOs that you may be able to partner with</li> </ul>
<b>How to go about performing this step?</b>	As with the engagement with private industry, it is very important to identify and target the most appropriate person(s) that is most likely to have the relevant information. Ideally, the staff member is senior enough to have both a thorough knowledge of the policies and programs under the purview of his/her agency or organization as well as a good understanding of the interplay between the various agencies across government.
<b>Getting creative</b>	For a different perspective on the policy life cycle (concept, rulemaking, implementation, monitoring and enforcement), it may be useful to engage with the regulatory affairs staff at the companies (manufacturers, suppliers) who are most active in regulatory development.

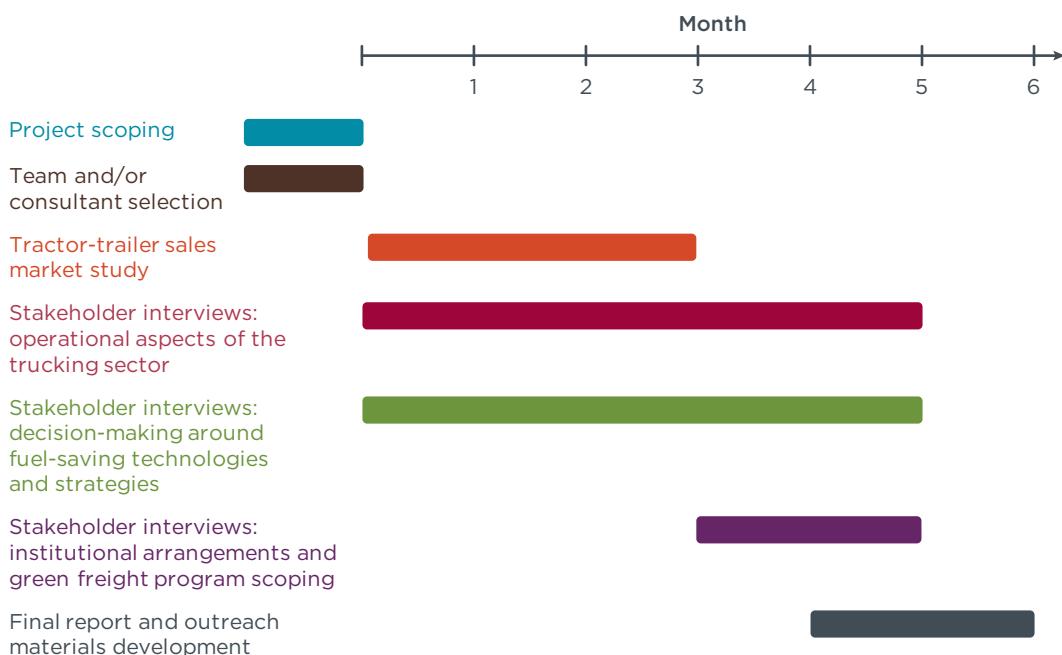
## 4. MAPPING OUT THE PROJECT

Table 8 and Figure 30 provide a very rough guideline for the resources and time commitments imposed by each of the key tasks of the freight assessment. These manpower and timeline estimates are based on previous ICCT projects. As a general rule, the activities that are heavily dependent on stakeholder interviews will require the most time and resources.

Of course, as your team plans the execution of the freight assessment, best practice is to develop detailed resource budgets and timelines for your specific project.

**Table 8:** Estimated level of resources needed for each task of the freight assessment

Task	Level of resources required
Tractor-trailer market study	Low/moderate
Stakeholder interviews: operational aspects of the trucking sector	High
Stakeholder interviews: decision-making around fuel-saving technologies and strategies	High
Stakeholder interviews: institutional arrangements and green freight program scoping	Moderate
Final report and outreach materials development	Moderate



**Figure 30:** Example schedule of freight assessment tasks

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## ACRONYMS

CATARC	China Automotive Technology and Research Center
EPA	U.S. Environmental Protection Agency
EU	European Union
GHG	Greenhouse gas
GVW	Gross vehicle weight
HDV	Heavy-duty vehicle
HHDDT65	Heavy heavy-duty diesel truck 65 miles per hour cycle
ICCT	International Council on Clean Transportation
mpg	miles per gallon
OEM	Original equipment manufacturer
U.S.	United States
VIUS	Vehicle In Use Survey
WHVC	World Harmonized Vehicle Cycle