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MARKET ANALYSIS OF HEAVY-DUTY COMMERCIAL TRAILERS IN EUROPE

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TABLE OF CONTENTS

1. INTRODUCTION

Heavy-duty vehicles (HDVs) are currently responsible for about one-fourth of fuel consumption and greenhouse gas (GHG) emissions from the transport sector in the European Union (EU), and this proportion is projected to grow to nearly one-third by 2030 (European Commission, 2016). To combat the growing contribution of HDVs to fuel consumption and climate-warming pollution and to achieve its goal of 60% reduction in carbon dioxide (CO_2) emissions by 2050 relative to 1990 levels (Commission of the European Communities, 2001), the EU will have to implement a robust set of policy measures to accelerate the development and deployment of fuel-saving technologies for commercial vehicles. As its first foray into policy aimed at boosting HDV efficiency, the EU recently introduced a certification procedure for the fuel consumption and CO_2 emissions of HDVs. Starting January 1, 2019, HDVs belonging to one of the four classes with the highest contribution to on-road freight carbon emissions will be certified for their CO_2 emissions and fuel consumption. Six additional HDV classes will be required to be certified for CO_2 emissions and fuel consumption by July 1, 2020 (Rodríguez, 2017). The certification procedure is based on a vehicle simulation tool, VECTO,[1] which uses as inputs the measured performance of the different vehicle components.

Within the HDV sector in the EU, tractor-trailers represent the largest share of CO_2, accounting for roughly 70% of emissions (Delgado, Rodríguez, & Muncrief, 2017). Although tractor-trailers are featured prominently in the CO_2 certification regulation, standard (or default) trailers are used for certifying the performance of tractor truck models in VECTO. Therefore, the impacts of trailer efficiency technologies are not captured in the current certification methodology. Recent studies have identified several cost-effective technologies for reducing the efficiency losses associated with aerodynamic and rolling resistance drag on trailers (Delgado et al., 2017; Meszler et al., 2018; Norris & Escher, 2017). In the latest fuel efficiency and greenhouse regulation for HDVs in the United States, which affects model year 2018 to 2027 vehicles, improvements from trailer technologies represent about 20% of the total efficiency gains from the tractor-trailer segment (ICCT, 2016).

To better take advantage of the full suite of cost-effective technologies for improving tractor-trailer efficiency, a comprehensive assessment of strategies for integrating commercial trailers into HDV CO_2 policies in the EU is warranted. A key part of this assessment is an analysis of the trailer sales market in Europe, which is the focus of this study. The primary objectives of this paper are (1) to analyze the sales market for new commercial trailers in terms of sales by country, manufacturer, and trailer type; and (2) to compare the trailer market in the EU to that in the United States and Canada. The remainder of the paper is organized as follows:

- Section 2 provides an overview of the heavy-duty commercial semi-trailer market in the EU in terms of sales by country, manufacturer, trailer type, curb weight and length, and trailer-to-tractor sales ratios. This section also discusses the similarities and differences between the trailer markets in Europe and North America. Section 2.7 gives some summary statistics for drawbar trailers, which are primarily pulled by smaller rigid trucks.
- Section 3 describes the fuel-saving technologies that are available for trailers and the extent to which these technologies are commercially available and being adopted by trucking fleets in Europe.
- Section 4 provides an overview of the current programs and policies for accelerating the uptake of trailer fuel-saving technologies
- Section 5 summarizes the paper and identifies areas for future work.

1 VECTO stands for Vehicle Energy Consumption Calculation Tool.

2. EUROPE'S TRAILER SALES AND PRODUCTION MARKET

The EU trailer market sales data referenced in this paper includes data for calendar years 2009 through 2016, as well as projections for 2017 to 2021. The datasets were acquired from Clear International Consulting Limited. The first dataset consists of trailer registrations[2] grouped by year, country, and trailer type. The second dataset contains total commercial trailer production by year, manufacturer, and country.

The summary data, figures, and discussion in this section through section 2.5 are limited to semi-trailers, which are pulled by tractor trucks that have a fifth-wheel coupling device.[3] Drawbar trailers are another type of trailer in which a bar (typically 1.5 to 2 m) extends from the front of the trailer to attach to the truck towing connection mechanism. Drawbar trailers are nearly always pulled by smaller rigid trucks, and thus we have separated out these trailers from the analysis of semi-trailers (Hill et al., 2011). Drawbar summary statistics for the EU are provided in section 2.6.

Figure 1 shows the number of trailers sold in the five largest trailer markets in 2016, as well as the approximate proportion of total EU sales represented by each of these markets. Germany is at the forefront with roughly 33,000 trailers sold, or nearly 18% of the total European market (roughly 188,000 units).[4] Germany is followed by the United Kingdom (UK), Poland, France, and Spain, with approximately 25,000, 21,000, 20,000, and 15,000 trailers sold in 2016, respectively. For the remaining countries in the top 10, trailer sales in 2016 ranged from roughly 4,000 (Czech Republic) to 13,000 (Italy).

2 In this analysis, registrations are used as a proxy for sales. This dataset was created by amassing registration data from the various motor vehicle bureaus in each country.

3 The tractor-to-trailer connection mechanism consists of a kingpin (a vertical steel pin, roughly 51 mm or 89 mm, protruding from the bottom of the front of the semi-trailer) and a horseshoe-shaped coupling device called a fifth wheel on the rear of the tractor truck.

4 In this dataset, sales information was unavailable for Greece, Cyprus, and Malta. Assuming that trailer sales follow trends similar to those in the tractor truck market (see section 2.3), combined sales in these four countries are estimated to make up less than 5% of the total EU market.

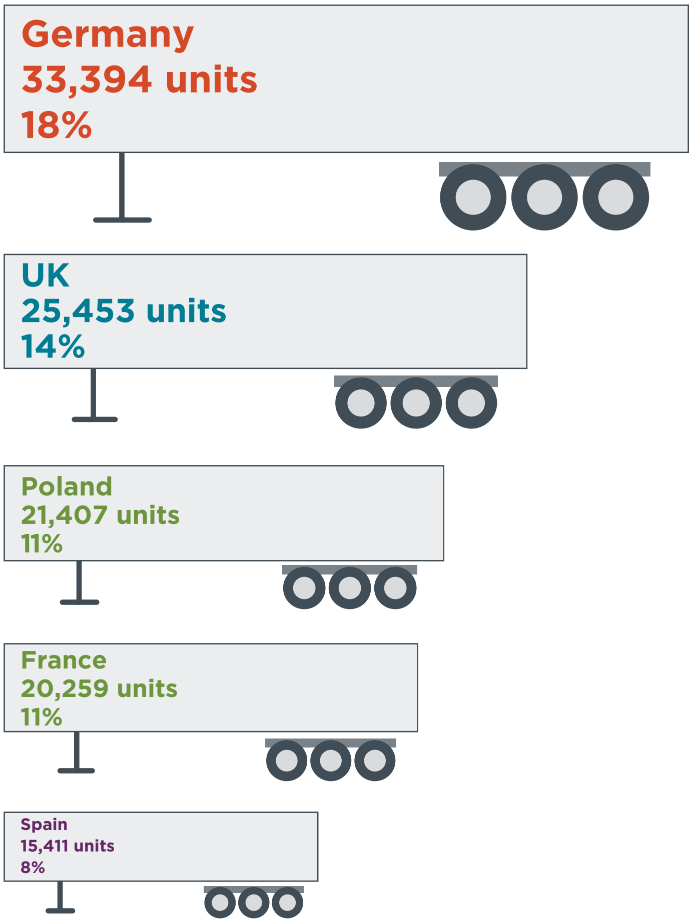


Figure 1. 2016 trailer registrations and proportion of total sales in the European Union: Top five countries.

Figure 2 shows the historical sales trends and forecasts for the EU countries with the nine largest trailer markets and for the rest of the EU combined. Looking out to 2021, the comparative ranks of the countries are projected to remain relatively stable, with France overtaking Poland as the third-largest EU market.

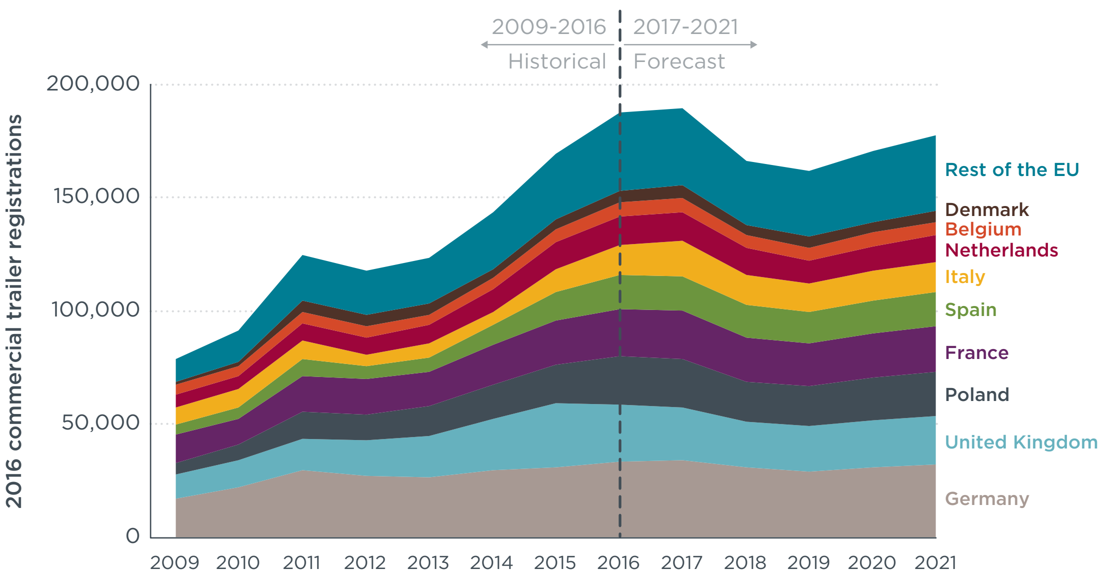


Figure 2. Trailer registrations for the nine largest markets in the European Union and the rest of the EU, 2009–2016 (historical) and 2017–2021 (forecast).

Six countries that are not in the EU are included in the Clear dataset. These countries and their approximate semi-trailer sales in 2016 are summarized below:

- Turkey: 18,300
- Russia: 4,900
- Ukraine: 1,500
- Norway: 1,100
- Belarus: 1,000
- Switzerland: 900

Semi-trailer sales in Turkey are projected to exceed 24,000 units by 2021, which would make it the second-largest market in Europe.

Total trailer production in the EU and North America between 2009 and 2016 is shown in Figure 3. Data for trailer manufacturing in North America was estimated using data from trailer-bodybuilders.com, which has an archive that extends back to 1998 (Informa USA Inc., 2018). Each year's output report includes the trailers produced by the 25 largest manufacturers. Because we only had access to the top 25 sellers, we estimated the contribution from the remaining manufacturers using an IHS Automotive dataset with 2003 to 2011 production data. From the IHS data, on average, the top 25 manufacturers account for 95% of total production in North America. We therefore took the production totals from the top 25 manufacturers and divided those values by 0.95 to derive the estimated totals.

From Figure 3, we see that trailer production in the two regions was nearly identical in 2009 at roughly 80,000 units. Manufacturing in 2009 was depressed as a result of the global economic crash that began in 2008, but both markets rebounded steadily in the ensuing years, with production in Europe and North America increasing by factors of approximately 3 and 4, respectively, relative to 2009 values.

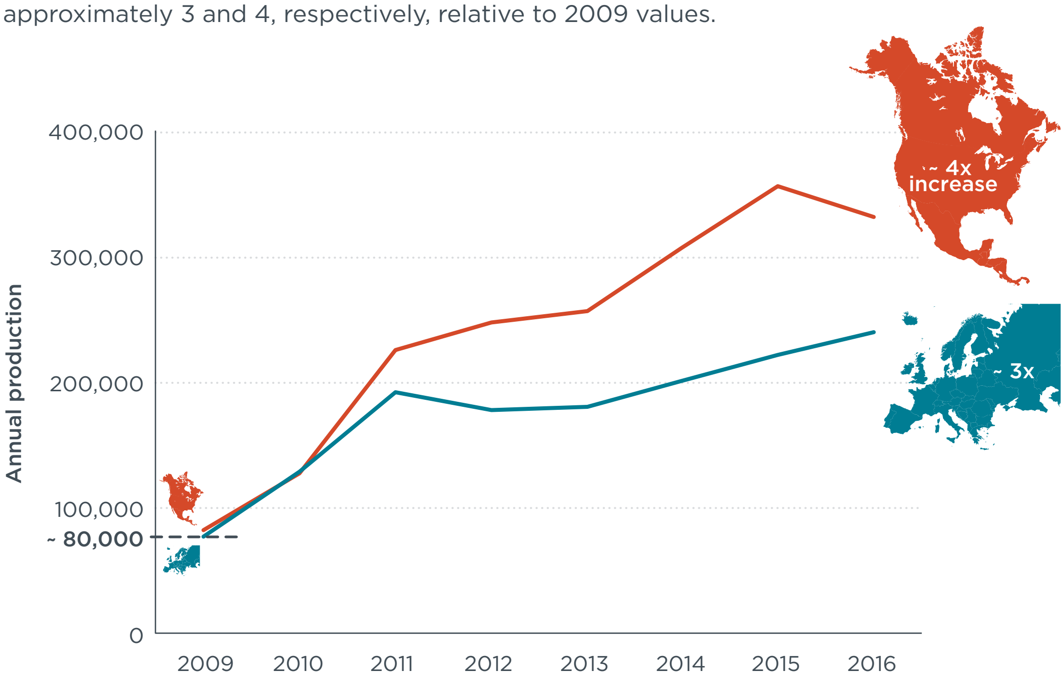


Figure 3. Total commercial trailer production in the European Union and North America.

2.1 MANUFACTURER MARKET SHARES

The numbers of trailers produced in the EU by the top 10 commercial trailer manufacturers between 2009 and 2021 are shown in Figure 4. The manufacturers are ordered in terms of sales ranking in 2016, with the market leader at the bottom and decreasing market shares moving upward. In terms of total trailer sales, Schmitz Cargobull led all manufacturers across the entire time period and had sales of approximately 55,000 trailers in 2016. Schmitz Cargobull's minimum market share was in 2009 at nearly 12% (roughly 7,000 trailers), and then it immediately shot up to a maximum market share of 30% in 2010 (roughly 32,000 trailers), stabilizing at 26% from 2011 onward, with its production increasing from roughly 39,000 trailers in 2011 to 55,000 in 2016. This market share swing of roughly 18 percentage points was the largest change in market share for any company during the study period. Krone is the next largest trailer manufacturer, with sales of about 34,500 units in 2016. Its European market share was close to 6% in 2009, peaked at 18% in 2012, stabilized at 16% from 2014 onward, and is projected to maintain that market share through 2021. Schmitz Cargobull and Krone are the clear market leaders, together accounting for more than 40% of trailer production in the EU. The next three largest sellers—Kögel, Wielton, and SDC—each had sales between 9,000 and 13,000 in 2016, or 4% to 6% of the market. Wielton had the largest percent growth of any top-selling manufacturer, with sales increasing from around 900 in 2009 to more than 12,500 in 2016 as a result of its acquisition of French manufacturer Fruehauf in mid-2015. Rounding out the top 10 are LeciTrailer, Schwarzmüller, Fliegl, Van Hool, and Montracon. These companies each sold between 3,000 and 6,000 trailers in 2016. Beyond these 10 largest companies, there were approximately 90 remaining manufacturers that together produced roughly 67,000 trailers (with sales ranging from about 10 to 3,000 units) in 2016, which translates to 32% of the market.

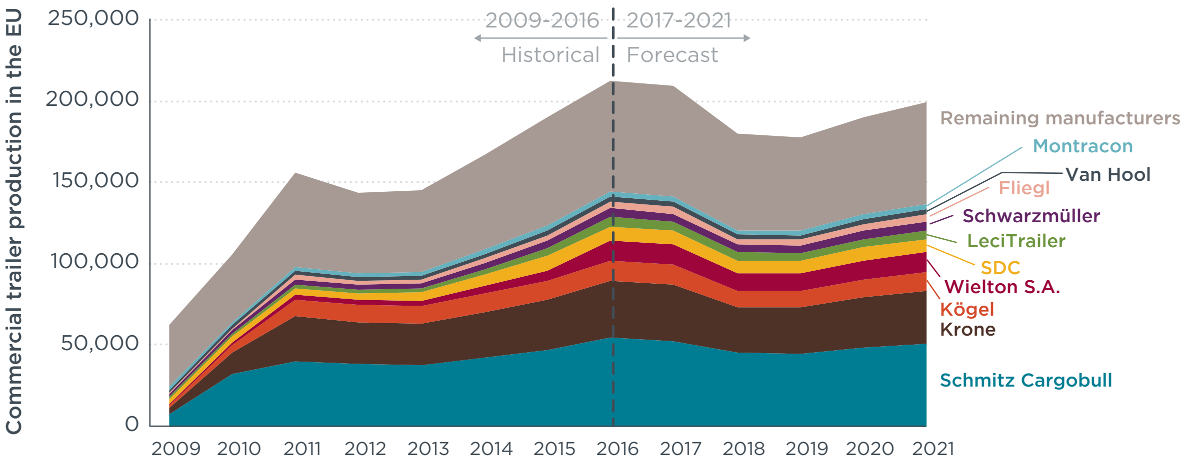


Figure 4. Annual trailer production in the European Union by manufacturer, 2009–2016 (historical) and 2017–2021 (forecast).

In Figure 5, the EU manufacturer production percentages for 2016 are shown in the upper panel; the lower panel shows the percentages for 2009. The figure clearly shows that in the wake of the global economic crisis of 2008 and 2009, the top 10 market-leading manufacturers captured a fairly substantial percentage of sales from the smaller companies. In 2009, the top 10 manufacturers accounted for 39% of production in the EU, and by 2016 this proportion jumped to 68%. Thus, in seven years, the combined market share of the 10 largest companies increased by 75%.

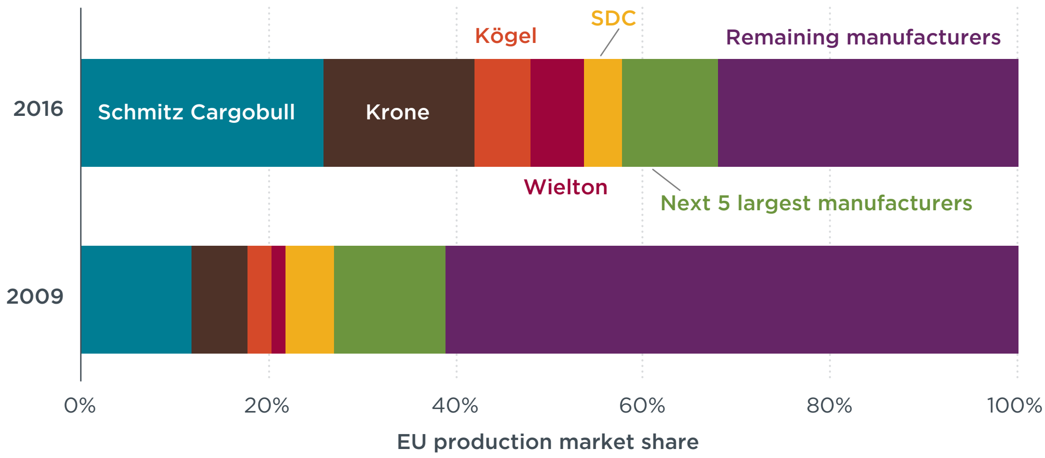


Figure 5. Manufacturer production shares for semi-trailers in 2009 and 2016.

Table 1 shows the average annual production between 2009 and 2016 for the top 10 manufacturers, along with projections for 2017 to 2021. Comparing the time period of 2009–2016 to 2017–2021, although average sales for the entire market are projected to increase by 30% in the 2017–2021 period relative to 2009–2016, total sales in 2021 are projected to be very similar to 2016, indicating that the market has recovered from the economic recession and has stabilized. If we exclude 2009, in which trailer sales were sharply depressed because of the global economic crisis, average sales over the two time periods are much more comparable.

Table 1. Average annual production of the top 10 trailer manufacturers in the European Union, 2009–2016, 2010–2016, and 2017–2021.

Manufacturer	Average annual production (2009–2016)	Average annual production (2010–2016)	Projected average annual production (2017–2021)
Schmitz Cargobull	37,371	41,654	48,454
Krone	23,569	26,420	30,622
Kögel	9,384	10,488	11,235
Wielton S.A.	4,314	4,802	11,481
SDC	5,639	5,984	8,070
LeciTrailer	2,923	3,174	5,265
Schwarzmüller	3,357	3,536	4,940
Fliegl	2,580	2,890	3,813
Van Hool	2,357	2,435	3,023
Montracon	2,685	2,801	3,084

2.1.1 Comparison of manufacturer market shares in Europe and North America

The market shares of the top-selling trailer manufacturers in the EU and North America are shown in Figure 6. Whereas the two biggest companies in the EU, Schmitz Cargobull and Krone, account for combined production that is larger than the combined production of Wabash and Hyundai Translead (42% vs. 30%), the third-, fourth-, and fifth-largest companies have much larger percentage shares in North America. As such, the combined share of the top five manufacturers is larger in the United States (68%) than in the EU (58%).

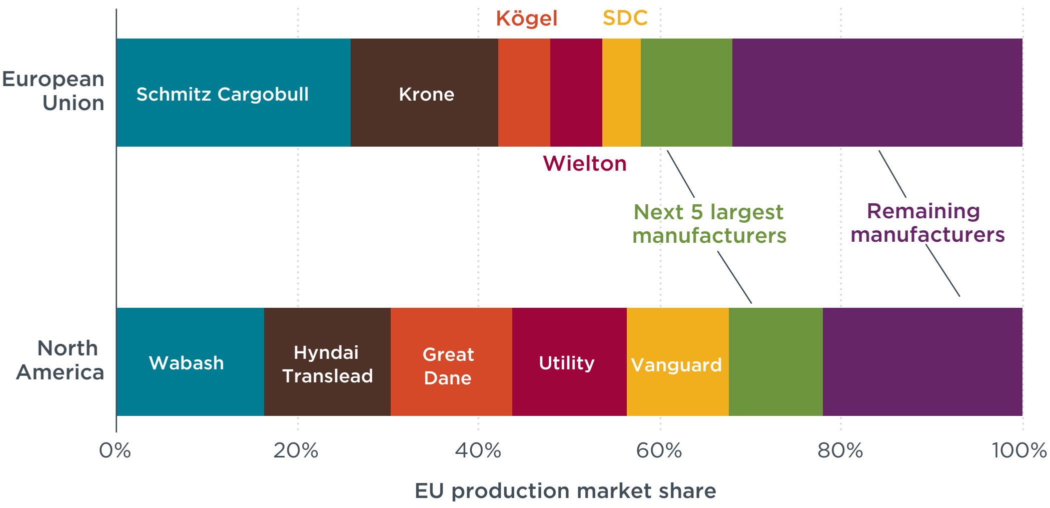


Figure 6. Market shares of the five largest trailer manufacturers in the European Union and North America.

Figure 7 further clarifies the structural differences of the trailer markets in Europe and North America. In the figure, cumulative trailer production is on the *y* axis and the number of manufacturers is on the *x* axis. To develop the cumulative market share curves, we ordered the manufacturers from left to right according to decreasing market share. Thus, the first data point at the far left of the curves represents the market share of the largest company (i.e., Schmitz Cargobull in Europe at 26% and Wabash in North America at 16%). Then, the market share of each subsequent manufacturer is added to the previous cumulative total. The North American dataset only has production values for the top 25 manufacturers.

Starting with the third manufacturer, cumulative market shares in North America pass those in Europe, and by the 10th-highest seller, cumulative sales in North America and Europe are 86% and 76%, respectively; these values jump to 95% and 90%, respectively, by the 25th manufacturer.

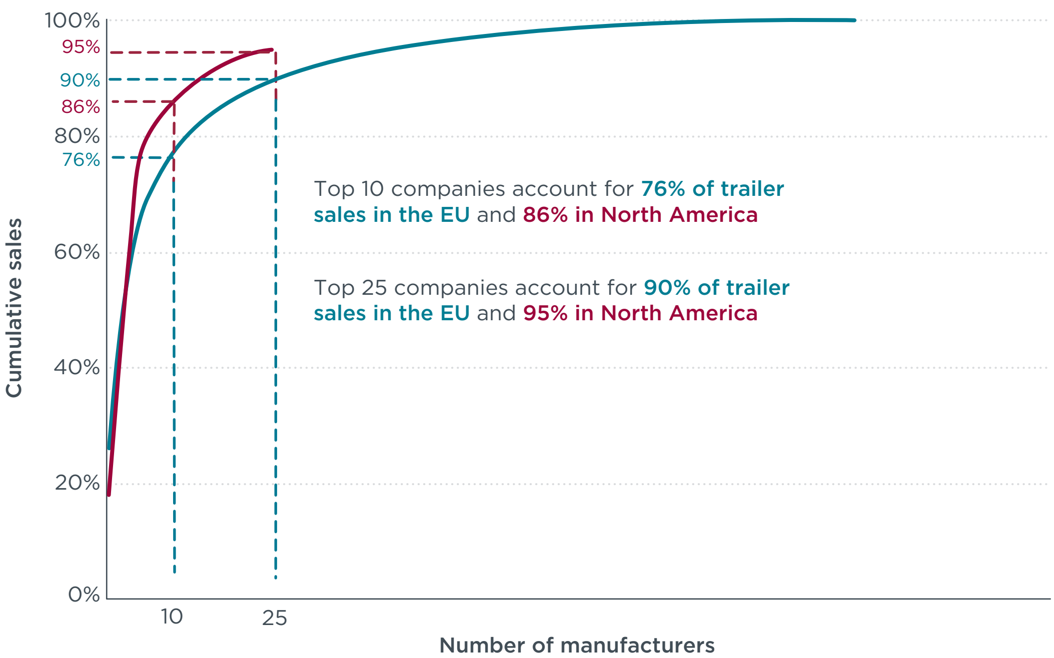


Figure 7. Cumulative market share of semi-trailers by number of manufacturers in Europe and North America.

In both Europe and United States, the situation for tractor truck production is much different, as there are only a handful of manufacturers in each region that dominate the sales market. In Europe, Volkswagen, Volvo, Daimler, PACCAR, and Iveco had 31%, 23%, 22%, 16%, and 7% of the market, respectively, in 2014. These five companies accounted for virtually the entire sales market for tractor trucks in Europe. In the United States, Daimler (46%), PACCAR (29%), Navistar (17%), and Volvo (8%) together make up 99.8% of tractor sales (Muncrief & Sharpe, 2015).

2.2 ANALYSIS OF SALES AND PRODUCTION FOR THE TOP FIVE EU MARKETS

Not surprisingly, the five biggest semi-trailer markets in the EU (see Figure 1) are also the five biggest producers. However, the relative market sizes and production volumes are not entirely tied to each other.

Figure 8 shows the production share originating in the five top EU trailer markets: Germany, the UK, France, Spain, and Poland. Most notably, while Germany's trailer sales market represented 18% of the EU in 2016, its production amounted to 54% of the semi-trailers manufactured in the EU. The production share of each of the other four EU member states is lower than its market share. For example, the UK is responsible for 14% of the registrations but 11% of the production. France and Poland each account for 11% of the sales but only 7% and 5% of the production, respectively. Spain has 8% of the EU semi-trailer market and accounts for 7% of the EU production volume.

Sections 2.2.1 through 2.2.5 present some additional features of these five countries.

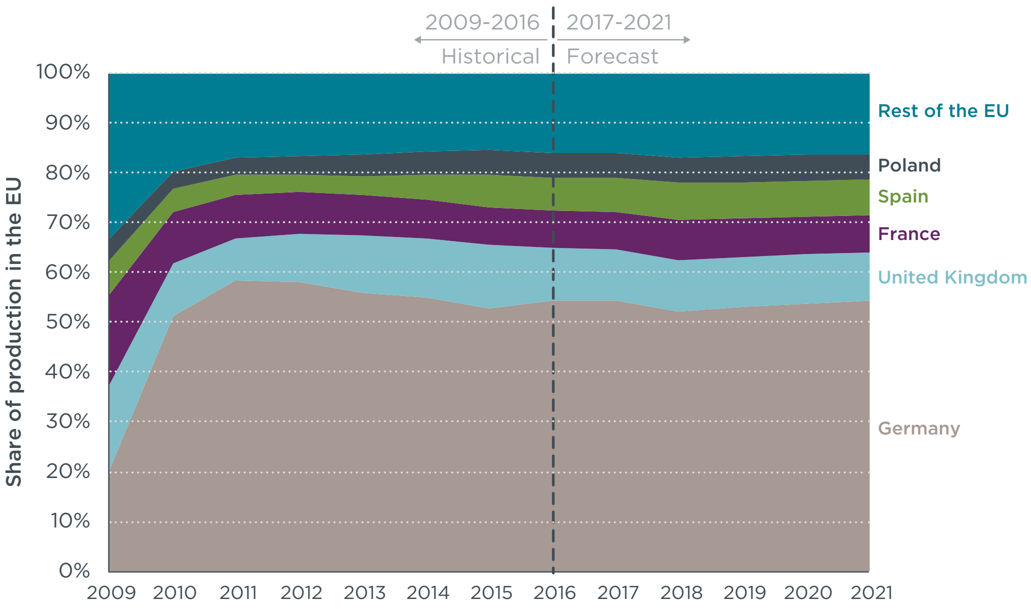
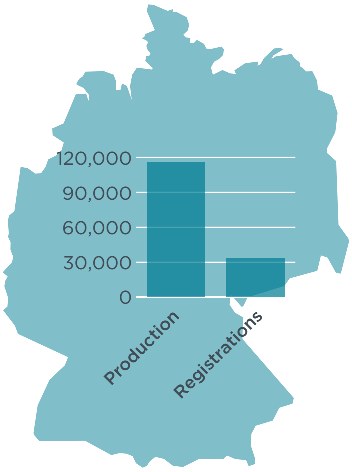


Figure 8. Manufacturing location shares for commercial semi-trailers produced in the European Union, 2009–2016 (historical) and 2017–2021 (forecast).

2.2.1 Germany



Germany (2016)

Production: 115,367 units
Top manufacturer: Schmitz Cargobull (43%)

Registrations: 33,394 units
Top seller: Schmitz Cargobull (34%)

Exports: 85,045 units
Imports: 3,072 units

Germany is by far the largest trailer producer in the EU. The majority of its production is marketed internationally, making it the only net exporter of trailers in the EU. Germany produces more than 3 times its own market demand.

Germany is home to the three largest semi-trailer manufacturers in Europe: Schmitz Cargobull, Krone, and Kögel.

As in the EU, Schmitz Cargobull is also the dominant producer and seller in Germany. Although most of Schmitz Cargobull's production takes place domestically (90%), it also has production facilities in Spain and Lithuania.

2.2.2 United Kingdom

United Kingdom (2016)

Production: 22,585 units
Top manufacturer: SDC (35%)

Registrations: 25,453 units
Top seller: SDC (30%)

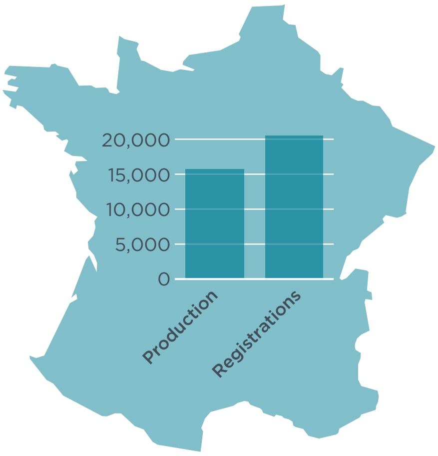
Exports: 1,073 units
Imports: 3,941 units

The market size and production volume in the UK are similar: 22,585 and 25,453 units, respectively. More than 80% of the UK's production is marketed domestically; SDC is its largest producer and seller of semi-trailers, followed by Montracon.

In 2016, SDC was acquired by CIMC, China's largest trailer manufacturer, headquartered in Shenzhen, China.

In the wake of the global financial crisis, Schmitz Cargobull closed its UK plant in 2010, which had been responsible for a volume of around 3,000 semi-trailers. As result, imports have been rising steadily from approximately 1,700 units in 2011 to almost 4,000 units in 2016.

2.2.3 France



France (2016)

Production: 15,575 units
Top manufacturer: Wielton/Fruehauf (33%)

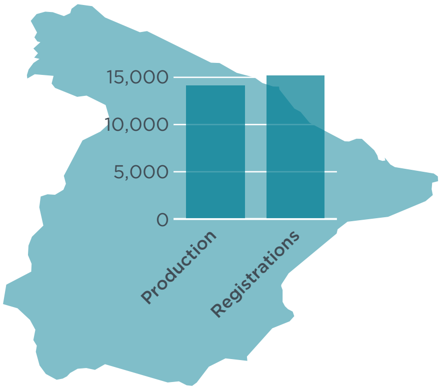
Registrations: 20,259 units
Top seller: Schmitz Cargobull (18%)

Exports: 5,081 units
Imports: 9,765 units

The market demand for semi-trailers surpasses France's production by approximately 5,000 units. French semi-trailer production is dominated by the Polish manufacturer Wielton as a result of its acquisition of Fruehauf in 2015.

Prior to the global financial crisis, Samro was the largest French trailer manufacturer and the fifth largest in Europe. However, the company was declared insolvent in 2009, which ultimately led to a gradual increase in imports; in 2016, imports reached approximately 10,000 units. As a result, the market share of foreign competitors increased in France, with Germany's Schmitz Cargobull taking the leading position in sales.

2.2.4 Spain



Spain (2016)

Production: 14,242 units
Top manufacturer: LeciTrailer (41%)

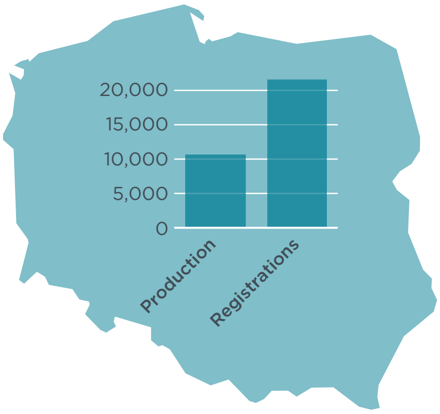
Registrations: 15,411 units
Top seller: LeciTrailer (25%)

Exports: 4,733 units
Imports: 5,902 units

The market size and production volume in Spain are very close to each other at 14,242 and 15,411 units, respectively. LeciTrailer is the leading producer and seller, accounting for 41% of the country's production and 25% of sales. The company accounts for a large share of the country's semi-trailer exports and has a substantial share of the French market.

Schmitz Cargobull has a production facility in Spain and takes second place in production volume and market share.

2.2.5 Poland



Poland (2016)

Production: 10,541 units
Top manufacturer: Wielton (62%)

Registrations: 21,407 units
Top seller: Schmitz Cargobull (22%)

Exports: 5,009 units
Imports: 15,875 units

The Polish semi-trailer market is highly reliant on imports. In 2016, Poland's internal demand, at 21,407 units, was more than double the country's production of 10,541 units.

Polish manufacturer Wielton accounts for more than 60% of the country's production. Wielton increased its EU market share substantially in 2016 thanks to the acquisition of French manufacturer Fruehauf, which continues to be commercialized under the same brand. Furthermore, Wielton announced its intention to reach 10,000 units per year by 2019 under its own brand.

Despite high and growing internal demand, Polish semi-trailers are also exported to Russia, Italy, Lithuania, and other European markets.

2.3 SALES BY SEMI-TRAILER TYPE

Figure 9 provides a breakdown of registrations by trailer type in the EU for 2009 to 2016. The dataset includes seven types of trailer: curtainsiders, refrigerated vans, tippers, dry vans, container chassis, tankers, and "other." Curtainsiders are by far the most popular configuration and in 2016 represented 43% of sales, which is nearly triple the market share of the second most common trailer type, refrigerated vans (15%). In 2016, tippers and dry vans made up 12.5% and 10% of sales, respectively. Container chassis, tankers, and other types of trailers each accounted for less than 10% of the market (8%, 6%, and 6%, respectively). The market shares of each trailer type are projected to remain within one percentage point out to 2021.

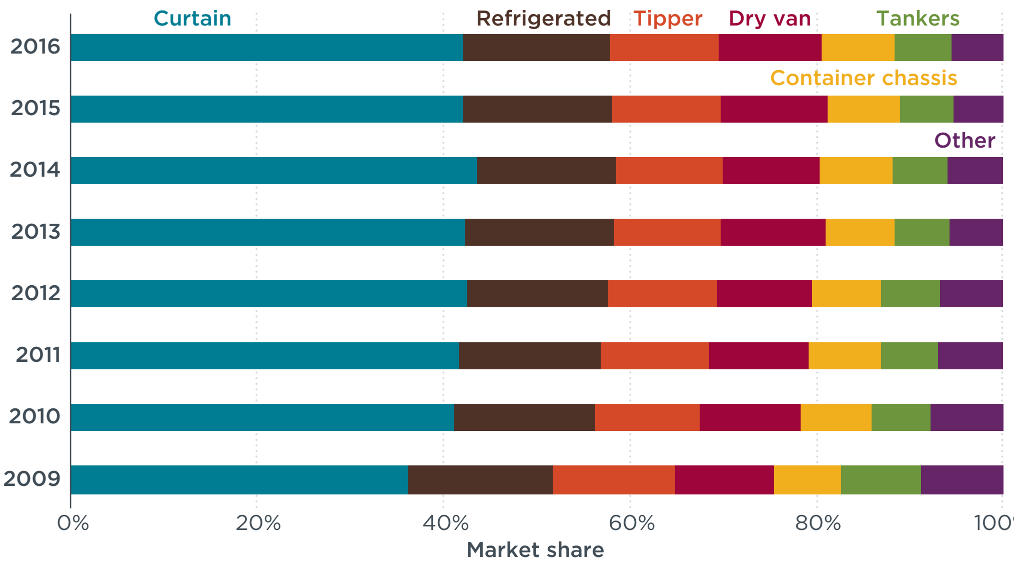


Figure 9. Semi-trailer registrations by type in the European Union, 2009–2016.

Figure 10 shows trailer sales broken down into two broad categories: "box" versus "non-box" trailers. As the name suggests, box-type trailers include rectangular-shaped configurations, including curtainsiders, dry vans, and refrigerated vans. Box-type configurations represented about 69% of registrations in the EU in 2016. Non-box trailers include a great diversity of applications and configurations, including tankers, flatbeds, bulk and grain trailers, auto transporters, container chassis, etc.

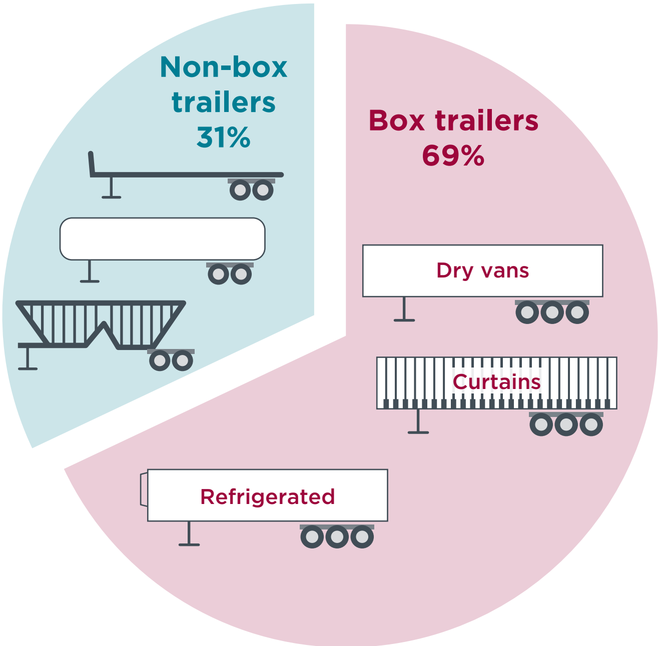


Figure 10. Box and non-box trailer registrations in the European Union in 2016.

2.3.1 Comparison of sales by semi-trailer type in the European Union and the United States

The most recent year for which we have sales data by trailer type for both the EU and the United States is 2011, and a breakdown of the respective markets is shown in Figure 11. What is clearly evident in the figure is the prominence of curtainside trailers in the EU, whereas these types of trailers have a minimal market share in the United States (assuming that some percentage of the "Other" category are curtainside trailers). Another noteworthy feature of the two markets is that the proportions of box versus non-box trailers are nearly identical in the EU and the United States; in each case, box-type trailers account for about two-thirds of the market.

In the non-box segment, the market shares of container chassis are comparable in the two markets (7% in the EU and 6% in the United States). Tankers and bulk transport trailers make up a slightly larger percentage of sales in the United States (10%) as compared to the EU (7%). Tippers and dump trailers are much more prevalent in the EU (13%) than in the United States (2%).

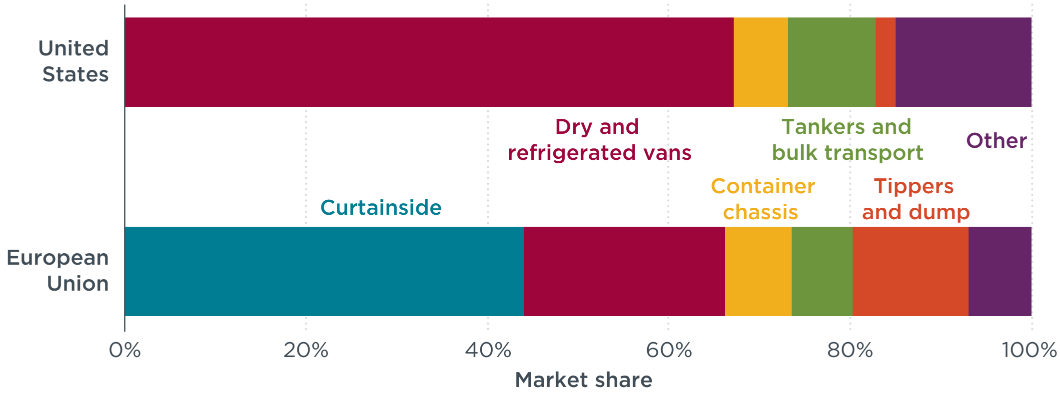


Figure 11. Semi-trailer registrations by type in the European Union and the United States in 2011.

2.4 SALES BY TRAILER CURB WEIGHT IN GERMANY

The European trailer market sales data referenced in this paper does not include any information on curb weight. To explore the historical trends in lightweighting in the EU, we used the German market as a proxy. Specifically, using semi-trailer registration data from the German type-approval authority (KBA, 2016), we analyzed the curb weight of box semi-trailers[5] from 2010 to 2015.

Figure 12 shows the resulting curb weight distribution for new registrations of box semi-trailers in Germany. From 2010 to 2015, the mean curb weight decreased by approximately 70 kg while the median stayed relatively constant. A closer look at the cumulative sales distribution shows that semi-trailers with a curb weight up to 7,500 kg represented 87% of sales in 2010 and 91% in 2015. Lightweight box semi-trailers with a curb weight up to 6,000 kg represented 1% of sales in 2010 and 4% in 2015. The observed trends suggest a slow trend in weight reduction driven by the market uptake of lightweight trailers with a curb weight of less than 6,000 kg.

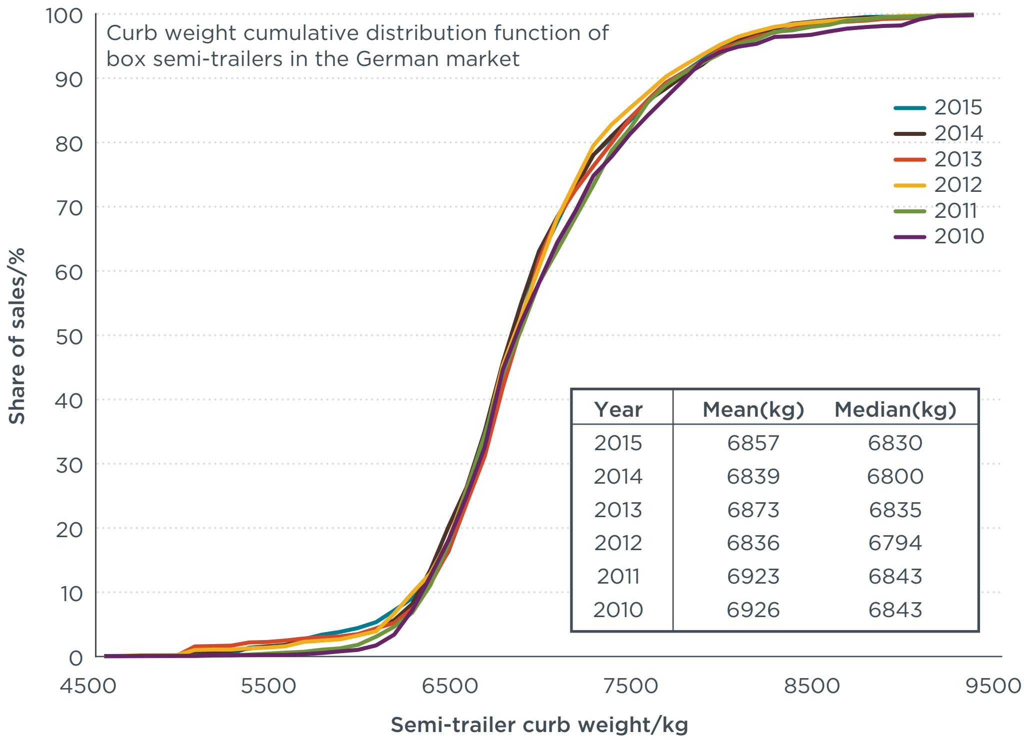


Figure 12. Cumulative market share by curb weight for new box semi-trailer registrations.

5 Box semi-trailers include isolated and refrigerated vans, closed box trailers, and curtainsiders.

The German box semi-trailer market is dominated by the same manufacturers leading the EU market: Schmitz Cargobull, Krone, and Kögel. Together they account for approximately 90% of sales in Germany. Schwarzmüller and Fliegl are two additional manufacturers with measurable market shares at approximately 4% and 2.5%, respectively. Figure 13 illustrates the curb weight distribution for all registrations from 2010 to 2015 produced by these manufacturers. Schmitz Cargobull has the heaviest product portfolio, starting at 5,910 kg and with a curb median weight of 6,926 kg. Krone and Kögel offer products starting at 5,600 and 5,000 kg, respectively. Schwarzmüller is the major German manufacturer with the lightest product portfolio, starting at 5,080 kg and with a curb median weight of 6,350 kg.

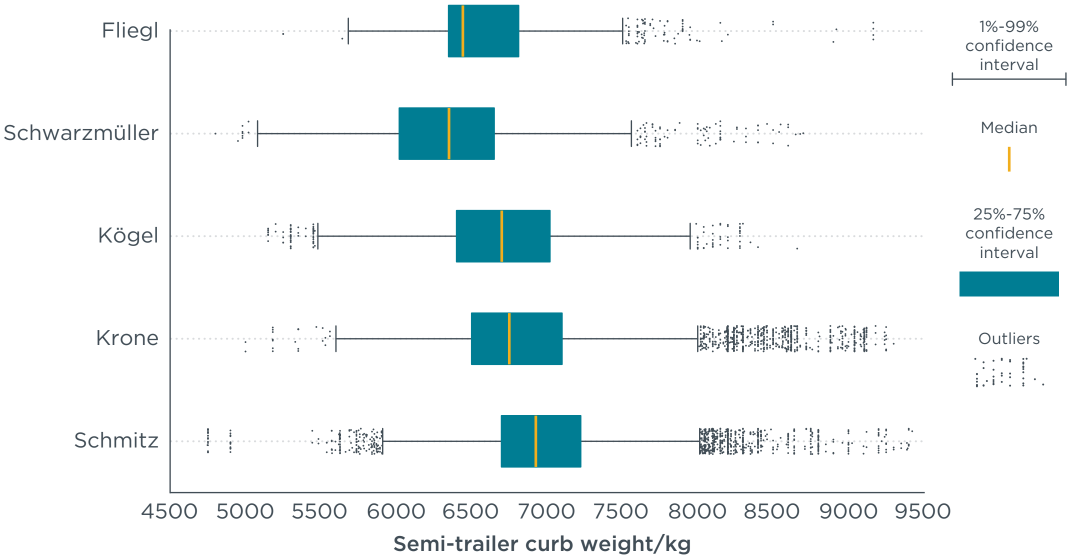


Figure 13. Curb weight distribution for the leading box semi-trailer manufacturers in Germany.

2.5 DIMENSION LIMITS FOR TRACTOR-TRAILERS IN THE EUROPEAN UNION

To ensure the unrestricted cross-border circulation of HDVs, the EU has set maximum dimensions and weights for international traffic. Member states cannot restrict the circulation of vehicles that comply with the limits set within their territories by Directive 96/53/EC (Parliament and Council of the European Union, 1996), which ensures equal access to the road network and fair competition in the transport industry.

Directive 96/53/EC sets a length limit of 16.5 m for tractor-trailers, 18.75 m for road trains (e.g., a rigid truck or tractor-trailer pulling a drawbar trailer), and 12 m for drawbar trailers (including bar). The 12-m length limitation for semi-trailers applies between the kingpin and the rear of the semi-trailer. The maximum distance between the kingpin and any point at the front of the semi-trailer (i.e., one of the front corners) is 2.04 m. Effectively, the regulation sets a length limit of 13.6 m for box semi-trailers.

In the spring of 2013, the European Commission put forward a proposal amending Directive 96/53/EC, which was adopted by the European Parliament in 2015 as Directive (EU) 2015/719 (Parliament and Council of the European Union, 2015). The key technical amendments are the following:

» Vehicles with aerodynamic devices that exceed the length limit by more than 50 cm are to be allowed.[6] This provision can only come into effect after appropriate amendments to the technical requirements for the type approval of aerodynamic devices longer than 50 cm are developed by the EU.

6 Trailer aerodynamic devices and truck designs that increase the vehicle length up to 50 cm do not need to be type-approved and are already permitted by the type-approval Regulation (EU) 1230/2012.

» To facilitate intermodal operations, the amendment legalizes the transportation of 45-ft containers and 45-ft swap bodies by increasing the maximum length of these vehicles by 15 cm.

Directives 96/53/EC and (EU) 2015/719 set the weights and dimension limits allowed in all EU territory. Nevertheless, member states may allow longer vehicles on their roads for national transport, provided that the existing standardized EU modules (i.e., drawbar trailers and semi-trailers) were used. This is the so-called European Modular System (EMS). The EMS provision of directive 96/53/EC was adopted to allow for Sweden and Finland to use longer and heavier vehicle combinations on their roads while allowing foreign operators to participate in those markets on equal conditions of competition. Table 2 shows the length and weight limits for countries that allow longer vehicles than the EU directives (International Transport Forum, 2015). Figure 14 shows the vehicle combinations and dimensions of single modules under the requirements of Directive 96/53/EC and the associated EMS.

Table 2. Permissible maximum dimensions in Nordic countries.

Country	Length (m)	
	Road train	Tractor-trailer
Finland	25.25	16.5
Iceland	22	18.75
Norway	19.5	17.5
Sweden	25.25	24

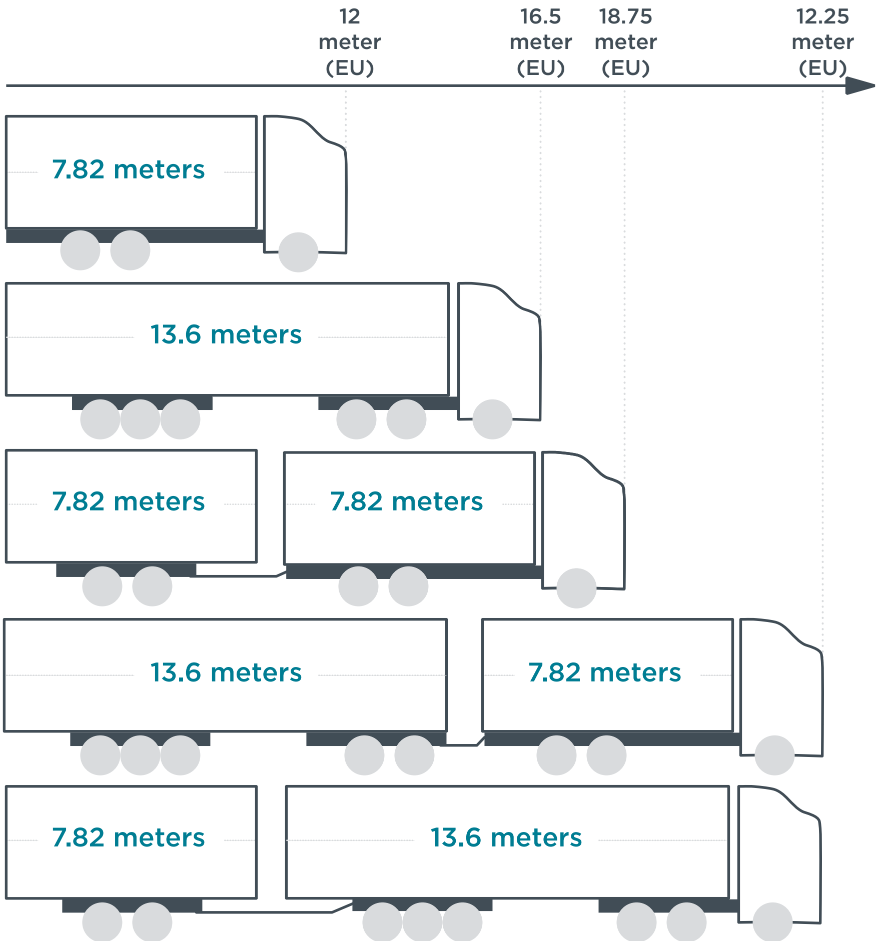


Figure 14. Vehicle combinations and dimensions of single modules under the requirements of Directive 96/53/EC and the associated European Modular System.

2.5.1 Typical tractor-trailer configurations in Europe and North America

When comparing the trucking sectors in Europe and North America, perhaps the most obvious difference between the two markets is in the physical appearance of tractor-trailers. Arguably the most apparent difference is the shape of the front of the trucks. Trucks in Europe (and most markets outside of North America) have a so-called cab-over-engine design, in which the front of the vehicle is relatively flat and in line with the front windshield. In contrast, tractors in North America typically have a longer cab, where the nose of the vehicle extends beyond the front windshield. This divergence of truck designs in the two markets has largely been a result of length restrictions in Europe, as discussed above. Although there are some minor differences across the various countries in Europe, most jurisdictions adhere to a maximum combined tractor-trailer length of 16.5 m (54.1 ft). To maximize cargo-carrying capacity (i.e., maximize trailer volume), the length of the tractor truck has been minimized with the cab-over-engine configuration. Another result of this length restriction is that the gap between the tractor and trailer is typically smaller in Europe.

In the EU, the maximum gross vehicle weight (GVW) of tractor-trailers is limited to 40 tonnes. However, the dimensional limitations of the typical trailer (length 13.6 m, volume 92.5 m^3) result in a volume-constrained cargo and in-use vehicle weight typically much lower than the maximum. In the United States, despite the lower maximum GVW (36.3 tonnes), trailers have a typical length of 16.1 m and volume of 112 m^3. The larger dimensional allowance results in typical payloads that are higher than in the EU, despite lower maximum GVW.

In addition to differences in overall length, another physical difference in tractor-trailers in the two markets is in the axle configuration. It is most common in Europe to have tractors with two axles (referred to as a "four by two" or 4x2) and trailers with three axles. This is reversed in North America, where tractors have three axles (typically 6x4 or 6x2 configurations) and trailers have two axles.

2.6 TRAILER-TO-TRACTOR RATIOS

Estimating the ratio of trailers to tractors is an important element of any analysis looking at the impacts of additional technologies for tractor-trailers. For example, a trucking fleet that has 100 tractors and 200 trailers may be considering a technology package that would impose an increase of X dollars per tractor and Y dollars per trailer. In its return-on-investment calculation, the fleet must express the total per tractor-trailer costs as $X + 2Y$ to account for the fact that there are two trailers for every tractor in the fleet, and thus the average annual vehicle kilometers traveled (VKT) for tractors is twice as large as that for trailers. Therefore, because the value assumed for this ratio has such a critical impact on the economics of trucking operations, it is important that policymakers have a reasonably good assessment of the average trailer-to-tractor in-use and sales ratios so that the costs and benefits estimated in a regulation targeting both tractors and trailers adequately reflect conditions in the real world.

According to data developed by Ricardo-AEA and Meszler et al., the in-use ratio of trailers to tractor trucks in Europe is approximately 1.4-to-1 (Hill et al., 2011; Meszler et al., 2018). This stands in fairly stark contrast to the United States and Canada, where this trailer-to-tractor ratio for equipment on the road is estimated to be around 3-to-1 (Sharpe, 2014). Additional analysis and scrutiny of stock data sources are needed on trucking operations in Europe and North America in order to better understand why in-use trailer-to-tractor ratios are so different between the two markets.

Figure 15 shows the ratio of new trailers to new tractors sold in Europe. Sales data for tractors is available through 2016. Over this time span, the ratio was at a maximum in 2009 at 1.07, and then steadily decreased to a minimum of 0.84 in 2013 before rebounding up to 1.02 in 2014. In 2015 and 2016, this ratio again dropped below 1 (0.94 in 2015 and 0.95 in 2016). One reason why the in-use trailer-to-tractor ratio is higher than the sales ratio is that trailers tend to have longer lives than tractor trucks (Sharpe, 2017a).

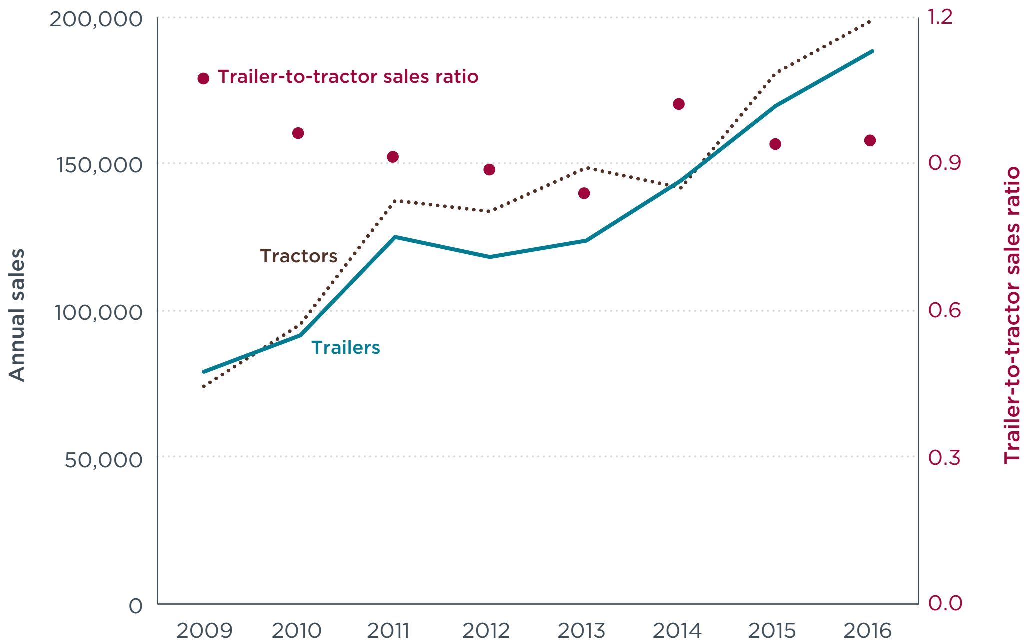


Figure 15. European trailer sales, tractor truck sales, and trailer-to-tractor sales ratio, 2009–2016.

As shown in Figure 16, trailer-to-tractor sales ratios are roughly 60% to 100% higher in North America and range from 1.6 to 2.1. As with the disparity in in-use ratios, more research is needed to better understand why trailer-to-tractor sales ratios are so much lower in Europe.

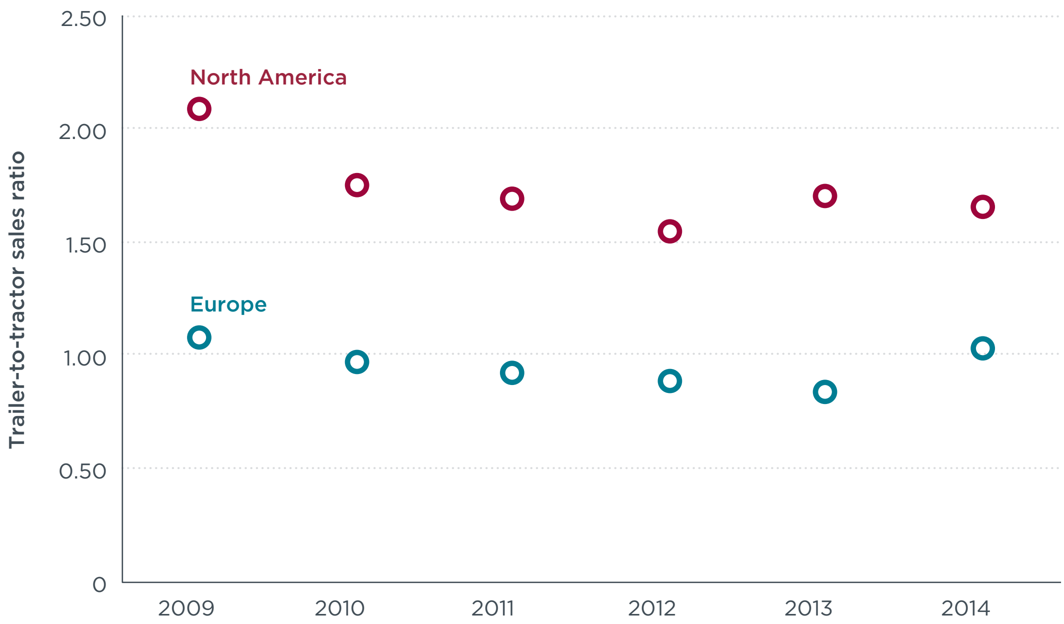


Figure 16. Trailer-to-tractor sales ratios in Europe and North America, 2009–2014.

2.7 DRAWBAR TRAILERS

In addition to semi-trailers, drawbar trailers are the other major category of equipment in the commercial trailer segment. Whereas semi-trailers are exclusively towed by tractor trucks with fifth-wheel couplings, drawbar trailers use a rigid bar that extends from the front of the trailer and connects at the back of the truck.

With approximately 45,000 registrations in 2016, the sales market of drawbar trailers in the on-road commercial freight sector in the EU is roughly one-fourth the size of the semi-trailer market, as shown in Figure 17. The breakdown of registrations by trailer type is summarized on the right side of Figure 17. Relative to the composition of the semi-trailer market, the "Other" category of drawbar trailers is substantial, with 26% of registrations as unspecified in the dataset. Curtainsiders (24%), tippers (22%), and container chassis (19%) together represent the largest portion of drawbar trailers, whereas dry vans, refrigerated vans, and tankers each make up less than 5% of the market. At roughly 30%, the percentage of drawbar box-type trailers (i.e., curtainsiders, dry vans, and refrigerated trailers) is much lower than for semi-trailers (68%).

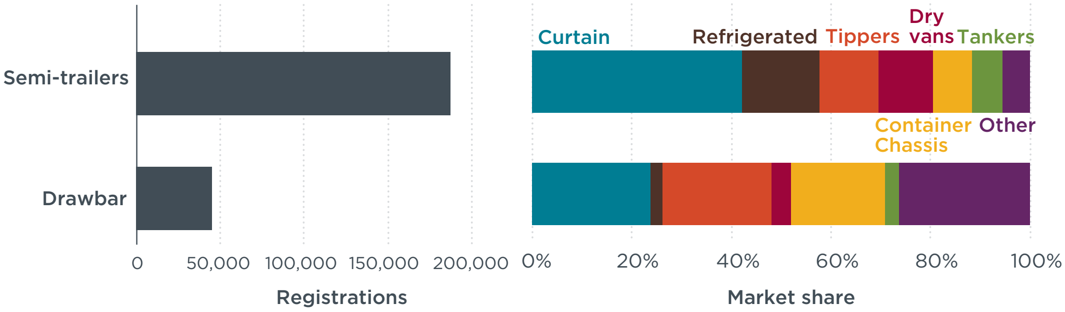


Figure 17. Drawbar trailer registrations and breakdown by type in 2016.

Figure 18 shows historical and projected drawbar trailer registrations by country. As with the semi-trailer market, Germany is the largest market in the EU. However, in the case of drawbar trailers, new registrations are dominated by Germany, which has represented 50% to 60% of the market since 2009 and is projected to remain at roughly 50% out to 2021. Registrations in the five next largest markets in 2016—France, Sweden, Poland, the Czech Republic, and Austria—ranged from about 1,500 to 2,800 units (market shares of 3% to 6%).

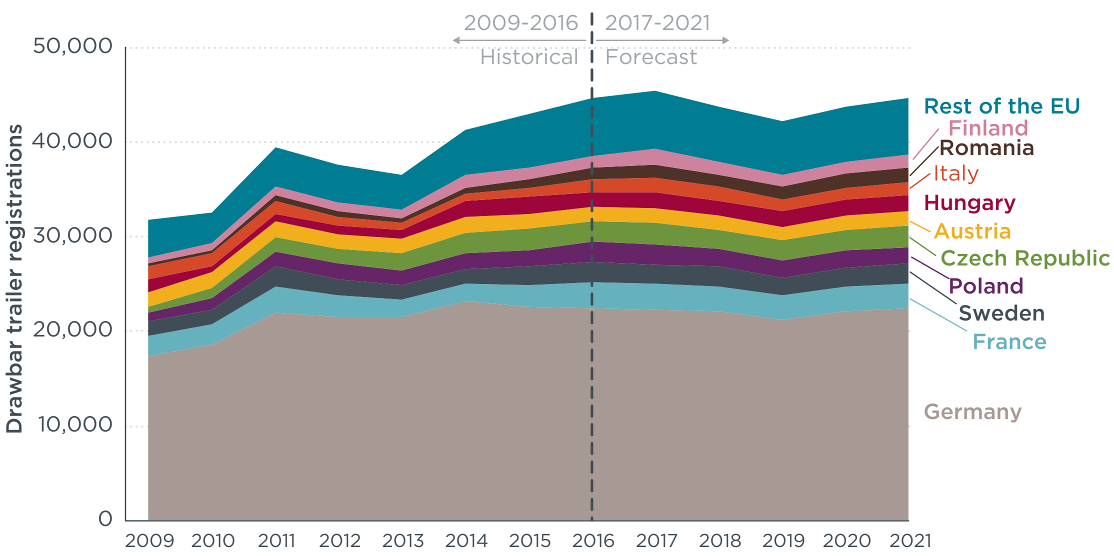


Figure 18. Drawbar trailer registrations for the 10 largest markets in the European Union, 2009–2016 (historical) and 2017–2021 (forecast).

Germany also dominates drawbar trailer production, as shown in Figure 19. With nearly 30,000 units manufactured in 2016, Germany's production was larger than that of the second-largest producer, France, by almost a factor of 7. Germany was also the largest net exporter of drawbar trailers in 2016, with production exceeding registrations by about 7,000 units. France and Poland were also net exporters, although much closer to parity (i.e., production being equal to registrations) than Germany. Sweden and the Czech Republic were net importers, with registration totals exceeding production by factors of 3 and 2, respectively.

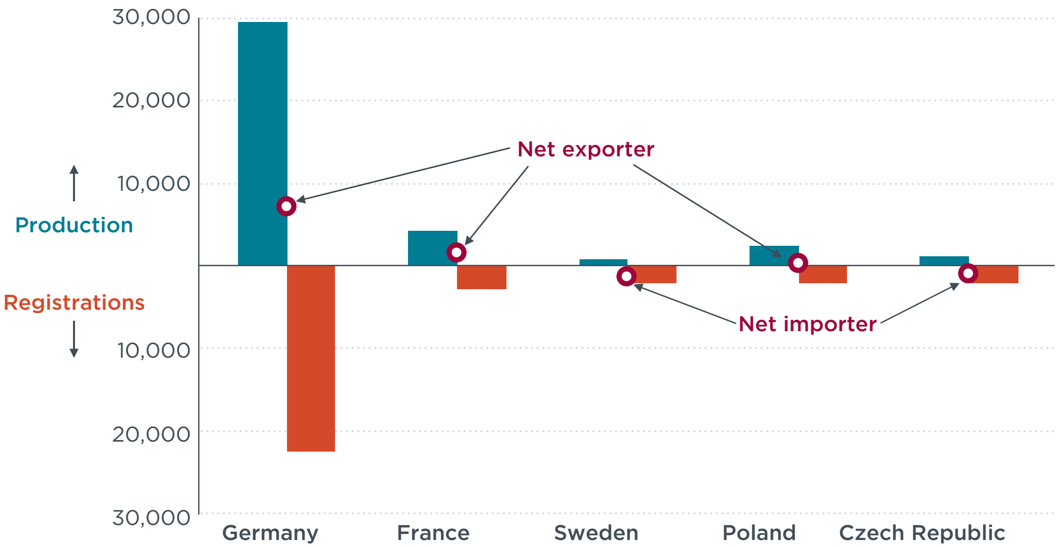


Figure 19. Drawbar trailer production and registrations for the five largest sales markets in the European Union.

Schwarzmüller is the top-selling drawbar manufacturer in the EU, although its market share has decreased from 16% in 2009 to 12% in 2016, as shown in Figure 20. Schwarzmüller was the seventh largest semi-trailer manufacturer in 2016. Between 2009 and 2016, although Krone's production increased from about 1,400 to 1,700 units, it fell from second- to fifth-largest drawbar producer, as Schmitz Cargobull, Fliegl, and Wecon moved into the second, third, and fourth spots, respectively.

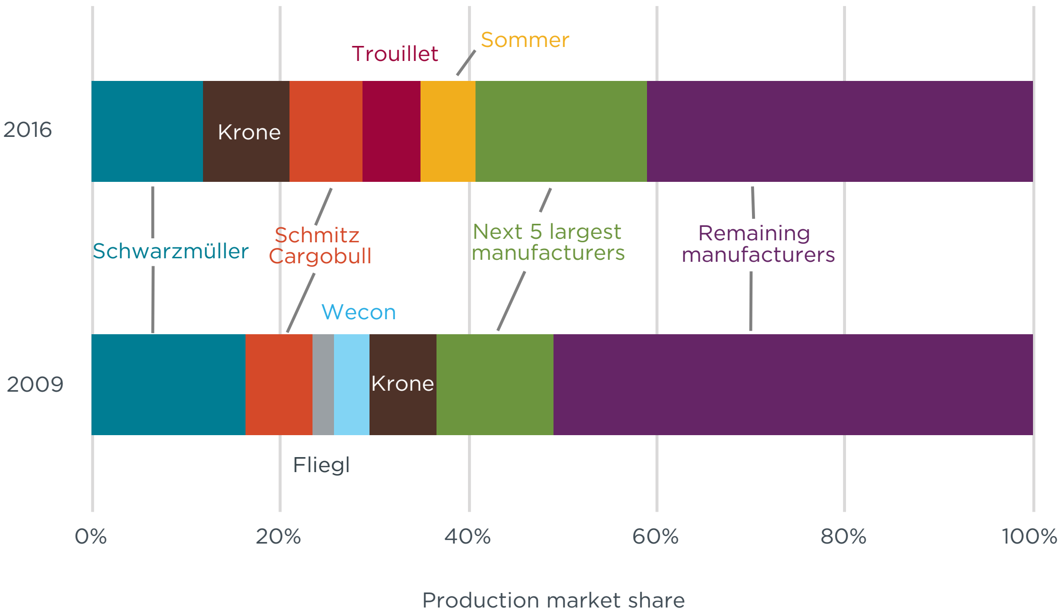


Figure 20. Manufacturer production shares for drawbar trailers in 2009 and 2016.

3. TRAILER FUEL-SAVING TECHNOLOGIES

Figure 21 illustrates the key areas where energy losses occur on a trailer during typical operations, as well as the technologies that can reduce these losses. Fuel consumption reductions due to technology interventions in each of these areas depend on several factors, including average speed, topography, climate conditions, vehicle weight, and driver behavior. Also, in addition to the potential aerodynamic and tire-related improvements shown in the figure, weight reduction using material substitution is a way to reduce the inertia loads associated with the trailer.

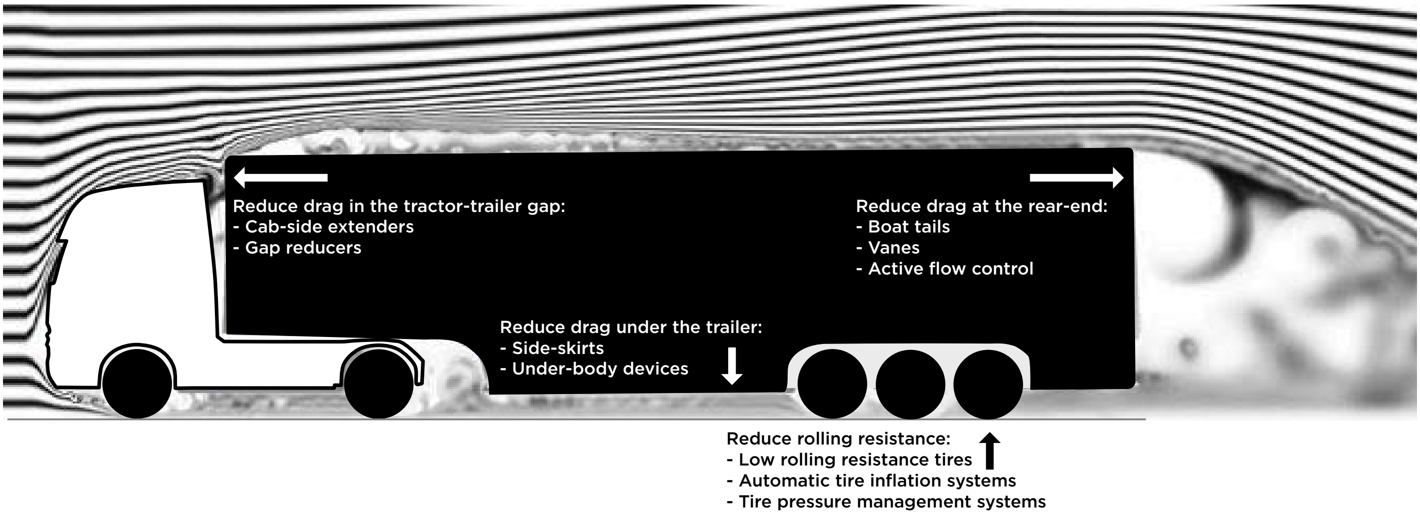


Figure 21. Key energy loss areas on a trailer during typical operations and technologies to reduce these losses.

For trailer aerodynamics, there are many technologies that exist and are in development to target each of the three primary areas where drag occurs: (1) the sides and underbody of the trailer, (2) the rear end of the trailer, and (3) the tractor-trailer gap.[7] Individually, technology innovations devised for each of these three areas typically provide fuel savings of between 1% and 7% for driving at highway speeds (Hill et al., 2011; Lutsey, Langer, & Khan, 2014; Sharpe et al., 2015). In a previous study (Delgado et al., 2017), we estimated the fuel consumption reduction potential for tractor-trailers in the EU from aerodynamic improvements. Relative to a baseline curtainsider with no aerodynamic features, we estimate that in the long term (i.e., out to 2030), trailer technologies can reduce fuel burn by 6.3% and 3.6% over the Long-Haul and Regional Delivery drive cycles, respectively.[8]

To date, side skirts have been the most popular add-on device for improving trailer aerodynamics. They extend below the trailer on each side and typically extend between the rear tires of the tractor and the trailer tires. The side skirts prevent air from entering the upper half of the underbody, reducing the momentum transfer between the fast-moving vehicle and the stationary surrounding air. ICCT research in many major markets has provided information about the adoption rates of several efficiency technologies for tractor-trailers. Specific to trailers, side skirts were sold on roughly half

7 Overall length restrictions for tractor-trailers in the EU have motivated the truck industry to minimize the gap between the tractor and trailer. As such, aerodynamic losses in the tractor-trailer gap have a much lower contribution to total aerodynamic drag as compared to typical tractor-trailers in North America. See section 2.4.

8 As part of the CO_2 certification process for heavy-duty vehicles in the EU, vehicle models are evaluated using a simulation program, VECTO. The Long-Haul and Regional Delivery cycles are used to measure the performance of tractor-trailers in the VECTO model.

of all new box trailers in the United States and Canada (Sharpe et al., 2015; Sharpe & Roeth, 2014). Figure 22 (Rodríguez et al., 2017) draws on adoption rate estimates from the 2014–2015 time frame, and anecdotal evidence from trucking fleets and industry experts suggests that the 40% figure for the United States is now much closer to 50%. Side skirt penetration into the European market has been much slower, with adoption beginning in the mid-2000s and reaching about 10% currently. The higher speed limits and average annual mileage of trucks in North America, coupled with the in-use aerodynamic technology requirements for tractor-trailers operating in California, have resulted in faster technology uptake of side skirts and other aerodynamic technologies in the United States and Canada. Moreover, other barriers impede the increased adoption of trailer aerodynamic devices in Europe, including fleets' limited knowledge of available technologies and their potential fuel savings, lack of available products from a broad range of trailer manufacturers and suppliers, and capital cost constraints. These and several other barriers to technology adoption in the tractor-trailer sector in Europe and other markets are explored in more detail in previous ICCT studies (Aarnink, Faber, & den Boer, 2012; Sharpe, 2017b).

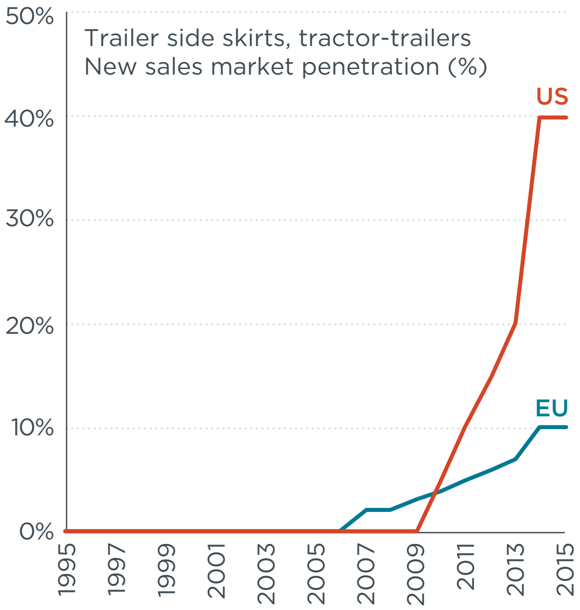


Figure 22. Trailer side skirt penetration in the United States and the EU.

In addition to aerodynamic improvements, lowering the rolling resistance of tires through enhanced design and proper inflation can also reduce the power required to move the tractor-trailer down the road. Tire technologies continue to progress, and there are many trailer tire models that offer low rolling resistance and thus contribute directly to fuel savings. Looking at the specific contribution of trailer tires to overall tractor-trailer rolling resistance drag, improvements can yield fuel savings on the order of 1 to 5% for typical tractor-trailer operations (Hill et al., 2011). In our study looking at the technology potential for commercial trucks in Europe (Delgado et al., 2017), we estimate trailer tire-specific benefits as follows: 4.4% fuel consumption reduction over the Long-Haul cycle and 2.6% over the Regional Delivery cycle.

Finally, in addition to aerodynamic and tire technologies, alternative materials such as composites and aluminum can be used in trailer wheels as well as structural supports in order to decrease the empty weight of the trailer. From a fundamental physics perspective, decreasing the weight of a vehicle reduces the forces needed to accelerate or decelerate the vehicle as well as the forces needed to overcome rolling resistance, which are approximately proportional to the load on the tires. In both tractors and trailers, manufacturers have commercialized and continue to develop products that make use of alternative materials such as aluminum and composites that lower the empty weight of the vehicle. In our assessment of the technology potential of tractor-trailers in Europe (Delgado et al., 2017), we assumed that a baseline curtainside trailer weighs 7,000 kg and that 1,000 kg of weight reduction is possible in the 2030 time frame. This nearly 15% reduction in the empty weight of the trailer results in fuel savings of 1.6% and 2.4% in the Long-Haul and Regional Delivery cycles, respectively.

Looking at the combined impacts of aerodynamic, tire, and weight reduction interventions, our research on the technology potential for trailers in the 2030 time frame is summarized in Table 3. To estimate the total fuel consumption (FC) reduction potential, we use the following formula:

$$\text{Total FC} = 1 - (1 - FC_{aero}) \times (1 - FC_{tires}) \times (1 - FC_{weight\ reduction})$$

where FC_{aero} = fuel consumption reduction from aerodynamic technologies
FC_{tires} = fuel consumption reduction from tire technologies
$FC_{weight\ reduction}$ = fuel consumption reduction from weight reduction

Table 3. Curtainside trailer fuel consumption reduction potential in the 2030 time frame over the Long-Haul and Regional Delivery drive cycles.

Technology area	Percent fuel savings	
	Long-Haul	Regional Delivery
Aerodynamics	6.3	3.6
Tires	4.4	2.6
Weight reduction	1.6	2.4
TOTAL	**12.3**	**8.6**

4. PROGRAMS AND POLICIES FOR ACCELERATING THE UPTAKE OF TRAILER FUEL-SAVING TECHNOLOGIES

In response to the growing negative effects of the trucking sector on climate change and local air quality, many nations and regions around the world have developed programs and policies to improve the environmental performance of heavy-duty tractor-trailer fleets. This section is focused on specific measures that been implemented by governments and the private sector to reduce the fuel use and emissions associated with commercial trailers. We begin by describing voluntary green freight initiatives and the various elements of these programs that have helped to accelerate the uptake of trailer fuel-saving technologies. We then turn our attention to mandatory requirements and describe California's tractor-trailer GHG regulation, and conclude by summarizing the efficiency performance standards for new trailers in the United States and Canada. Table 4 summarizes the key elements of these programs and policies that are motivating increased uptake of technologies for reducing the energy losses associated with trailers.

Table 4. Programs and policies that promote the development and deployment of trailer fuel-saving technologies.

Program or policy	Example(s)	Description	Point of influence / regulation	Key elements and considerations
Green freight programs	• SmartWay Transport Partnership • Green Freight Europe • ECO Stars Fleet Recognition • Lean and Green	These market-based programs are typically public-private partnerships that aim to increase efficiency and reduce fuel use and emissions from trucking fleets and supply chains.	• Carriers • Shippers • OEMs • Suppliers	• Establishing procedures for data collection and benchmarking • Technology verification testing • Disseminating technology and operational best practices
In-use efficiency or technology requirements	California's tractor-trailer greenhouse gas regulation	Starting in 2010, this regulation has required any trucking fleet operating in California to have SmartWay-verified equipment on both tractors and trailers.	Carriers	• Determining baseline technology uptake • Creating allowances and exceptions for special equipment types and fleets • Maintaining list of verified technologies and default fuel savings levels • Special provisions for small fleets • Compliance and enforcement
New trailer performance standards	Regulation for new trailer efficiency in the U.S. (final) and Canada (proposed)	As part of Phase 2 regulation in the U.S. and Canada, trailer manufacturers are required to meet increasingly stringent efficiency targets using combinations of aerodynamic, tire, and weight reduction technologies.	• OEMs • Suppliers	• Determining baseline efficiency levels • Creating regulatory subcategories for various types and sizes of trailers • Test procedures for evaluating individual technologies • Certification protocols • Special provisions for small businesses • Compliance and enforcement

4.1 GREEN FREIGHT PROGRAMS

The overarching purpose of green freight programs is to promote enhanced efficiency and environmental stewardship in the on-road freight sector and often other modes such as marine and rail. Table 5 (adapted from Sharpe, 2015) summarizes various green freight programs around the world and some of their key functions. Common features of green freight programs generally include data collection and benchmarking on fuel consumption and emissions, information sharing on technologies and strategies for boosting efficiency and environmental sustainability, and branding. In addition to these activities, independent testing and verification of efficiency technologies can be a crucial input in the decision-making process for trucking fleets as they consider investments in a myriad of different fuel-saving technologies and operational practices.

Table 5. An overview of green freight programs that focus on the trucking sector.

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

* D = data collection and benchmarking; G = guidance for technologies and operational best practices; TV = technology verification; B = branding

With regard to promoting trailer efficiency technologies, the U.S. SmartWay program has had far-reaching impacts. In particular, the program laid the groundwork for California's tractor-trailer GHG regulation (section 4.2) and the U.S. Environmental Protection Agency's (EPA) and Environment and Climate Change Canada's (ECCC) mandatory requirements for fuel-saving technologies on new trailers (section 4.3). SmartWay was the first green freight program in the world, created by the EPA in 2004. SmartWay is the sole green freight program that explicitly verifies the efficacy of individual trailer technologies. To do this, the EPA has adopted a suite of testing protocols that manufacturers can use to measure the effectiveness of their products. Technologies must meet certain performance thresholds in order for them to be designated as "SmartWay verified." On the SmartWay website, administrators maintain information about how products are verified as well as up-to-date lists of individual manufacturers whose technologies have been verified (U.S. EPA, 2018). Fuel-saving and emission reduction technologies are grouped into four categories: (1) aerodynamics, (2) tire rolling resistance, (3) idle reduction, and (4) criteria pollutant retrofit technologies. For trailers, aerodynamic and tire technologies can be tested and verified.

For trailer aerodynamic technologies, there are four verification levels, which designate fuel consumption reductions relative to a baseline 53-ft (16-m) box-type trailer: 1%, 4%, 5%, and 9% (combination of two or more devices). These technologies can be side skirts, rear end devices (e.g., boat tails), trailer underbody devices, and gap reducers. Aerodynamic device manufacturers can verify the fuel savings of their equipment using track testing, wind tunnel, or computational fluid dynamics.

In addition to aerodynamic devices, SmartWay also maintains a list of verified low-rolling-resistance (LRR) tires. Tire manufacturers must demonstrate that a tire model has a coefficient of rolling resistance at or below 5.1 to 5.6 kg/tonne, depending on the specific testing method used (U.S. EPA, 2011).

The SmartWay program also has two verification levels for the entire trailer: SmartWay and SmartWay Elite. Both levels require SmartWay-verified LRR tires. The SmartWay trailer requires one or more devices verified at the 5% fuel savings level, whereas Elite requires a combination of two or more devices at the 9% level.

4.2 IN-USE EFFICIENCY REQUIREMENTS

The regulatory program that has had arguably the biggest impact on accelerating the deployment of trailer fuel-saving technologies across North America is the California Air Resources Board's (CARB) tractor-trailer GHG regulation, which is based heavily on EPA's SmartWay technology verification program. This regulation, which was first adopted in late 2008 and formally finalized in 2009, is the first and only in-use GHG regulation for tractor-trailers in the world. The regulation began its phase-in in 2010 and will be fully implemented by 2020. It includes mandatory tractor and trailer aerodynamic and tire rolling resistance requirements for any trucking fleet that operates in California; the regulation thus affects roughly 30% of all tractor-trailers in the United States (CARB, 2008).

The regulation affects trucking fleets and owner-operators with box-type trailers 53 ft or longer, including both dry van and refrigerated van trailers. The owners of these types of equipment are responsible for replacing or retrofitting their affected vehicles and trailers with compliant aerodynamic technologies and LRR tires. The requirements for trailers are based on the model year and the type of equipment. As shown in Table 6, there are unique provisions and compliance deadlines based on whether the trailer is a refrigerated or dry van, as well as the trailer's model year. The aerodynamic requirements for trailers are given in terms of a percentage: 4% or 5%. The percentage refers to the SmartWay designation for the verified fuel savings level of a given piece of equipment. In the SmartWay verification scheme, individual aerodynamic devices are certified as providing 1%, 4%, or 5% fuel savings (see section 4.1). For dry van trailers requiring 5% fuel savings, users can combine a 1% certified device with a 4% certified device or opt for a 5% certified device. Operators of refrigerated trailers are only required to install an aerodynamic device that is certified to the 4% level.

There are specific requirements for large fleets, which are defined as any fleet operating 21 or more trailers. Fleets operating 20 or fewer trailers are regulated under the small-fleet provisions, which have less stringent implementation timelines.

Table 6. Trailer requirements in California's tractor-trailer greenhouse gas regulation.

Affected trailers	Requirements	Compliance date
MY 2011 and newer dry vans	LRR tires + 5% fuel-saving aerodynamic technologies	January 1, 2010
MY 2011 and newer refrigerated vans	LRR tires + 4% fuel-saving aerodynamic technologies	January 1, 2010
MY 2010 or older box-type trailers	5% or 4% fuel-saving aerodynamic technologies	January 1, 2013
	LRR tires	January 1, 2017
MY 2003–2004 refrigerated van trailers	LRR tires + 4% fuel-saving aerodynamic technologies	January 1, 2018
MY 2005–2006 refrigerated van trailers	LRR tires + 4% fuel-saving aerodynamic technologies	January 1, 2019
MY 2007–2009 refrigerated van trailers	LRR tires + 4% fuel-saving aerodynamic technologies	January 1, 2020

MY = model year.

4.3 NEW EQUIPMENT PERFORMANCE STANDARDS

The second phase of regulations for controlling fuel consumption and GHGs from HDVs in the United States (finalized in 2016) and Canada (expected to be finalized in summer 2018) includes a new set of regulatory standards to promote the efficiency attributes of trailers that are hauled by Class 7 and 8 tractors. This first-of-its-kind regulatory program for new trailers builds upon California's in-use fleet requirements and the SmartWay program. The standards include requirements for the manufacturers of new trailers, including technologies that lower aerodynamic and rolling resistance drag. As with the regulation for tractor trucks and other HDVs, the numerical fuel use and CO_2 targets for each model year of trailers are based on sales-weighted averaging. As such, trailer manufacturers are able to sell trailer models that undercomply with the standards, provided that they have sufficient sales of overcompliant models so that they meet the targets based on sales weighting of the certified fuel use and CO_2 emissions levels of all of their models.

The standards for box-type trailers use a system of aerodynamic bins numbered I through VII, under which new trailer models are certified. The higher-numbered aerodynamic bins represent greater levels of CO_2 reduction, up to 13% for Aerodynamic Bin VII. The performance standard requires greater deployment of trailers performing at the higher aerodynamic bins over time. Similarly, the standards establish tire rolling resistance Levels 1 and 2, associated with a CO_2 reduction up to 3%. Manufacturers also receive credit for up to a 1.2% CO_2 reduction for automatic tire inflation systems. In addition, the agencies identify 11 common lightweight components that will be credited with approximately 1% CO_2 reduction per 1,000 pounds of weight reduction. For every 3 pounds of trailer weight reduction, 1 pound of additional payload is applied in the certification process to acknowledge the resulting lower CO_2 per ton-mile.

Table 7 summarizes the typical technologies expected to be deployed to meet the required average CO_2 emission reduction levels for model year (MY) 2027 for each of the 10 trailer regulatory subcategories (U.S. EPA, 2016). For box-type trailers, the standards are performance-based, allowing trailer manufacturers to increasingly deploy some combination of aerodynamic devices from 2018 through 2027 to meet the standards. Aerodynamic Bin VI, an advanced aerodynamic drag package that is similar to the SmartWay Elite designation, is expected to become quite common on long box trailers for complying with the MY 2027 standard. The regulation includes discrete steps for MYs 2021, 2024, and 2027. By 2027, new long box trailers are expected to deliver approximately 9% lower CO_2 emissions per ton-mile, whereas other trailer types would deliver 3% to 4% lower CO_2. "Partial aero" trailers are trailers that cannot use combinations of certain aerodynamic technologies and therefore have less stringent targets than the regular box-type trailers. For "non-aero" box trailers that have equipment or features that prevent the installation of any aerodynamic devices, the regulation is a design-based standard (i.e., *not* performance-based) that requires the use of LRR tires and automatic inflation systems. This is also the case for "non-box" trailers such as flatbeds, tankers, grain and bulk transport trailers, and container chassis.

Table 7. Summary of trailer requirements for model year 2027 trailers in the United States.

Trailer type	Typical 2027 technologies to meet performance standards	Standard (g CO_2 / ton-mile)[a]	Percent CO_2 reduction
Reference	• Aerodynamic drag C_dA = 6 to 6.2 m^2 (Bin I) • Tire rolling resistance 6.0 kg/tonne • No automatic tire inflation system	83 to 85 (long) 127 to 130 (short)	0%
Long dry box	• Aerodynamic improvements (Bins V–VII) • LRR tires (Level 2) • Automatic tire inflation system	76	9%
Short dry box	• Aerodynamic improvements (Bins II–IV) • LRR tires (Level 2) • Automatic tire inflation system	119	6%
Long refrigerated box	• Aerodynamic improvements (Bins V–VII) • LRR tires (Level 2) • Automatic tire inflation system	77	9%
Short refrigerated box	• Aerodynamic improvements (Bins II–IV) • LRR tires (Level 2) • Automatic tire inflation system	123	6%
Partial aero long dry box[b]	• Aerodynamic improvements (Bins IV–VI) • LRR tires (Level 2) • Automatic tire inflation system	81	6%
Partial aero short dry box	• Aerodynamic improvements (Bins II–III) • LRR tires (Level 2) • Automatic tire inflation system	124	4%
Partial aero long refrigerated box	• Aerodynamic improvements (Bins IV–VI) • LRR tires (Level 2) • Automatic tire inflation system	82	6%
Partial aero short refrigerated box	• Aerodynamic improvements (Bins II–III) • LRR tires (Level 2) • Automatic tire inflation system	128	4%
Non-aero box trailers[b]	• LRR tires (Level 2) • Automatic tire inflation system		3%–4%
Non-box	• LRR tires (Level 1) • Automatic tire inflation system		3%–4%

[a] Includes assumed 20,000 lb (short van) and 38,000 lb (long van) in payload; equivalent NHTSA fuel consumption standards (in gallons per 1,000 ton-miles) are based on 10,180 g of CO_2 per gallon of diesel; assumes trailers are pulled by a standard tractor.
[b] "Partial aero" trailers are box-type trailers with equipment or features that prevent the installation of certain combinations of aerodynamic technologies. The requirements for partial aero trailers are less stringent than for regular box-type trailers. "Non-aero" box trailers have equipment or features that prevent the installation of any aerodynamic devices. "Non-box" trailers include flatbeds, tankers, container chassis, and any other trailer that does not have a rectangular side profile. Non-aero and non-box trailers are subject to a design-based standard that requires the use of LRR tires and automatic tire inflation systems.

5. SUMMARY AND FUTURE WORK

Semi-trailer sales in the European Union

In 2016, about 188,000 semi-trailers were sold in the EU, which represents roughly a doubling in sales since 2010. Germany is the largest sales market in the EU (18% of total sales in 2016) and is by far the largest manufacturing market (54% of total production in 2016). In terms of sales, Germany is followed by the UK, Poland, France, and Spain, with approximately 14%, 11%, 11%, and 8% of the semi-trailer market in the EU in 2016, respectively.

Schmitz Cargobull is the largest semi-trailer manufacturer and had sales of approximately 55,000 trailers in 2016. Schmitz Cargobull's market share was nearly 12% in 2009, and after an abrupt increase to 30% in 2010, its market share stabilized at 26% from 2011 onward. Krone is the next largest trailer manufacturer, with sales of about 34,500 units in 2016. Schmitz Cargobull and Krone are the clear market leaders and together account for more than 40% of trailer production in the EU. The next three largest sellers—Kögel, Wielton, and SDC—each had sales between 9,000 and 13,000 in 2016, which represents between 4% and 6% of the market.

Curtainsides are by far the most popular configuration and in 2016 represented 43% of sales, which is nearly triple the market share of the second most common trailer type, refrigerated vans (15%). In 2016, tippers and dry vans made up 12.5% and 10% of sales, respectively. Container chassis, tankers, and other types of trailers each accounted for less than 10% of the market (8%, 6%, and 6%, respectively).

Trailer fuel-saving technologies

There are several fuel-saving technologies for trailers that have emerged over the past decade. The most common technologies include aerodynamic devices, such as trailer side skirts, and technologies to reduce rolling resistance, such as improved tire designs and inflation management systems. Recent ICCT research suggests that adoption of trailer efficiency technologies has been more limited in Europe than in the United States and Canada. Some of the reasons for the slower uptake in the European market include slower average highway speeds, a more nascent market for trailer aerodynamic technologies, and lack of any strong policy measures to catalyze technology deployment. However, despite these and other barriers, the ICCT estimates that up to 12% fuel savings are possible by the 2030 time frame with the application of trailer aerodynamic, tire, and weight reduction technologies.

Programs and policies for promoting trailer fuel-saving technologies

Over the past 15 years, several programs and policies have emerged that promote improved efficiency in the on-road freight sector, and for trailers in particular. Voluntary green freight programs are often public-private partnerships and aim to decrease knowledge gaps in the trucking sector by engaging in data collection and benchmarking on tractor-trailer performance and technology efficacy. By providing fleets with third-party technology verification testing data, green freight programs have been a boon to trailer technology adoption, especially in the United States and Canada. The U.S. EPA's SmartWay program has the most extensive repository of trailer-specific verification data on aerodynamic devices and tire rolling resistance.

In the late 2000s, CARB created an in-use regulation for all tractor-trailers operating within the state. CARB's fleet requirements for both tractors and trailers began in 2010 and will be fully phased in by 2020. The regulation heavily leverages the SmartWay program and mandates that fleets use SmartWay-verified trucks as well as aerodynamic technologies and tire models that meet specific SmartWay efficiency thresholds.

The second phase of regulations for commercial trucks and buses in the United States and Canada includes a new set of regulatory standards to promote the efficiency attributes of trailers that are hauled by Class 7 and 8 tractors. This is the first regulatory program for new trailers in the world and builds upon California's in-use fleet requirements and the SmartWay program. The standards include requirements for the manufacturers of new trailers, including technologies that lower aerodynamic and rolling resistance drag.

Future work

As policymakers in the EU deliberate on whether to add trailers into the CO_2 regulatory fold, this study and further analyses by the ICCT and others will be important inputs into the process. The companion piece to this paper explores the process for adding trailers into the CO_2 certification method, and, more broadly, considerations for developing type approval procedures for commercial trailers. In addition, more work is needed to improve the transparency of trailer-related markets in the EU and the specific barriers facing fleets and manufacturers with respect to trailer aerodynamic devices, LRR tires, inflation management systems, and advanced materials for reducing trailer curb weight.

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