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Overview of the heavy-duty vehicle market and CO_2 emissions in the European Union

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Summary

Heavy-duty vehicles (HDVs) represent only 4% of the on-road fleet in the European Union, but are responsible for 30% of on-road CO_2 emissions. Countries around the world are implementing standards to regulate CO_2 emissions from HDVs. The EU's current strategy is focused on addressing market forces and developing a new framework to certify and report on HDV CO_2 emissions. This report is meant to inform that strategy by presenting current data on freight movement and HDV sales and statistics in the EU.

The approach used in this study is to first gather the latest data on freight movement in the EU, HDV sales trends, and HDV fuel consumption. Key data sources utilized in this study are Eurostat, IHS Automotive, and Lastauto Omnibus magazine. The resulting analysis is focused on key trends over the past decade, noting the effects of the economic downturn and recovery. This paper begins by putting HDVs in context, both in terms of comparisons with light-duty vehicles and comparisons with other modes of freight transport. It then presents trends in real-world fuel consumption for HDVs. The bulk of the paper reports on the HDV market in the EU, focusing on the tractor truck[1] and rigid truck segments. Finally, the report presents some differences and similarities between the EU and US HDV markets.

Freight movement and HDVs are inextricably linked in the EU, with HDVs responsible for moving 75% of the freight tonne-kilometers. The member states that move the most freight are Germany, Poland, Spain, France, the United Kingdom, Italy, and the Netherlands. These seven countries are responsible for nearly 75% of the EU's freight movement, and therefore they account for approximately 75% of the EU's CO_2 emissions from freight transport.

This study's analysis shows evidence that the efficiency of tractor-trailers in the EU has remained relatively constant since the early 2000s. In addition, the key HDV types in the EU are tractor-trailers and rigid trucks, responsible for the bulk of HDV sales and fuel consumption in the sector. Assessing sales trends over the past ten years illustrates that the trend in the EU is towards heavier vehicles and larger engines, more similar to those being sold in the US. Five truck manufacturers, namely Volkswagen, Volvo, Daimler, PACCAR, and Iveco, dominate the EU market. Three of these manufacturers (Volvo, Daimler, and PACCAR) are also major manufacturers in the US market.

The findings indicate that the share of CO_2 emissions from HDVs is growing in the EU. The best available data shows that real-world efficiency of HDVs has been relatively flat in the EU for more than a decade. However, introducing CO_2 standards could change that trajectory, as it is starting to do in the US market (see Figure ES1). Noting the many similarities between the EU and US HDV markets, it is likely that many technologies US manufacturers are starting to adopt (such as improved aerodynamics for trailers, automatic tire inflation, and improved engine efficiency) could likewise be applied in the EU. Next steps resulting from this work are to study, at a more detailed level, the baseline, CO_2 reduction potential and cost effectiveness from available and emerging HDV efficiency technologies.

1 On the road, tractor trucks are almost always paired with trailers, which are the goods-carrying portion of the combination vehicle. For clarity, the term "tractor truck" is used in the discussion of sales figures, as tractors and trailers are made by different manufacturers and are sold separately. The EU trailer market was not included in the sales analysis.

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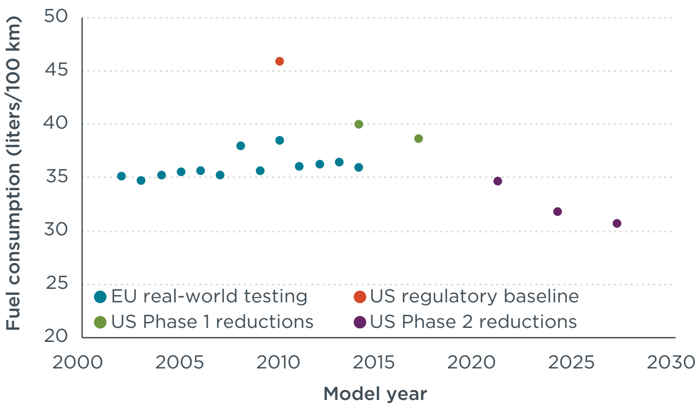

Figure ES1. Comparison of tractor-trailer fuel consumption trends for US and EU

1. Introduction

In 2006, the European Commission began investigating potential policy options to mitigate CO_2 from Europe's heavy-duty vehicle (HDV) segment. Starting in 2009, the Commission launched an effort to develop a type approval protocol to certify the CO_2 emissions from new HDVs. The certification test procedure is based on a combination of component testing and simulation modeling. The procedure is scheduled to be finalized by the end of 2016, and legislation to codify the monitoring and reporting of CO_2 values from HDVs is scheduled to be finalized in 2018.

The objective of this paper is to analyze key aspects and trends in the EU's current HDV market in order to form a basis for more detailed discussions and analyses of future potential CO_2 policy. This paper reviews available data from the literature, as well as from new vehicle sales and registration data, to identify and discuss key market and fuel consumption trends within the EU HDV fleet. This paper also presents select comparisons between the EU and US HDV fleets.

The paper is organized as follows: Section 2 gives an overview of freight transport in the EU with a focus on CO_2 emissions from road freight. Section 3 gives an overview of the HDV market in the EU, including a discussion of key segments, vehicle specifications and manufacturers. Section 4 discusses various differences and similarities between the HDV market in the US and EU. Finally, Section 5 discusses conclusions and regulatory recommendations.

2. Heavy-duty vehicle trends and CO_2 emissions in the European Union

The HDV fleet in the European Union (EU, inclusive of all 28 member states) is a significant contributor to the total CO_2 footprint of the region's transportation sector.

HDVs, which are nominally defined as vehicles weighing more than 3.5 metric tonnes[2], are mainly used for commercial purposes, primarily in the moving of freight. Globally, transportation as a whole is estimated to be responsible for nearly one-quarter of the total anthropogenic CO_2 emissions, and HDVs currently contribute around one-third of these emissions, or roughly 7% of global anthropogenic CO_2 (Facanha, Miller et al. 2014). In addition, freight demand is predicted to grow substantially in upcoming decades (European Commission 2015).

Figure 1 illustrates the predicted growing share of CO_2 emissions from the HDV segment in the EU over the upcoming decades. Over time, the per-vehicle efficiency improvements in the light-duty vehicle (LDV) sector, which have been driven in large part by mandatory efficiency performance standards, will mean that sector contributes a relatively smaller proportion of emissions—and, in turn, that the projected contribution of HDVs to on-road CO_2 emissions will grow from the current one-third to roughly 40% by 2020 and 45% by 2030 (Facanha, Miller et al. 2014).

Figure 2 provides the percent breakdown of freight movement in the EU in terms of tonne-kilometers. Trucks—which fall under the "Roads" category—represent three-quarters of the tonnage of goods transported, followed by rail at 18% and inland shipping at 7% (European Commission 2015).

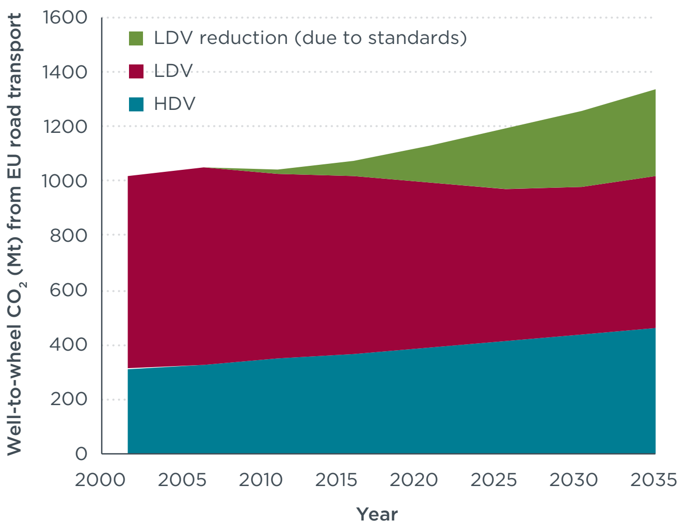

Figure 1. Road transport CO_2 emissions in the EU between 2000 and 2035

2 In this paper, *tonne and metric tonne* are used interchangeably and both refer to 1,000 kilograms.

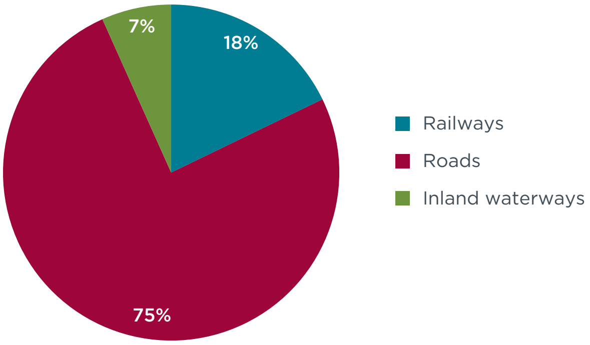

Figure 2. Modal split of freight transport in the EU in 2013 (tonne-kilometers)

EU FREIGHT TRANSPORT OVERVIEW

Currently, the EU has the third largest CO_2 footprint from HDVs of all major markets, behind China and the US (Façanha, Miller, and Shao, 2014). This is due, in part, to the fact that three-quarters of freight is moved by road in the EU, as shown in **Figure 2**. The distribution of goods movement among trucks, ships, and rail varies from member state to member state, as illustrated in **Figure 3** (European Commission 2015). For example, the Netherlands moves nearly 40% of its freight by inland waterways, whereas in Spain on-road commercial vehicles account for more than 95% of all goods movement.

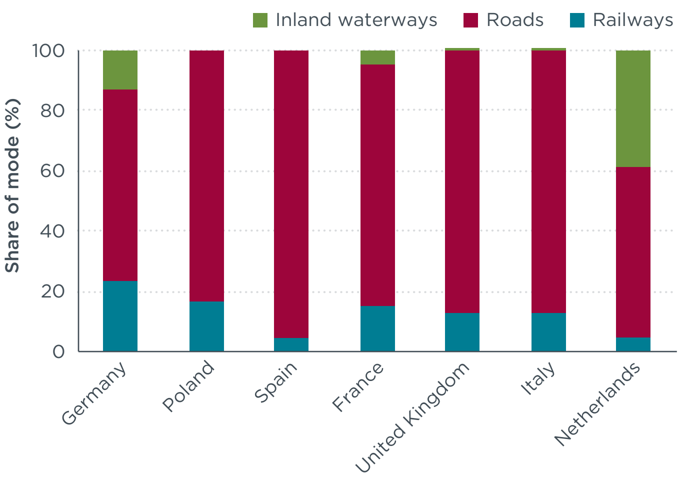

Figure 3. 2013 Modal split of freight transport in the 7 EU member states with the most freight transport activity (tonne-kilometers)

As can be seen in **Figure 4**, approximately 1.7 trillion tonne-kilometers of freight are moved annually by road in the EU, a number that is expected to rise in coming decades (European Commission 2015). This figure also illustrates the divide between domestic and international road freight transport in the EU. Domestic freight transport (meaning the shipment starts and ends in the same country) dominates, representing around two-thirds of road freight transport, while international road freight represents the remaining one-third.

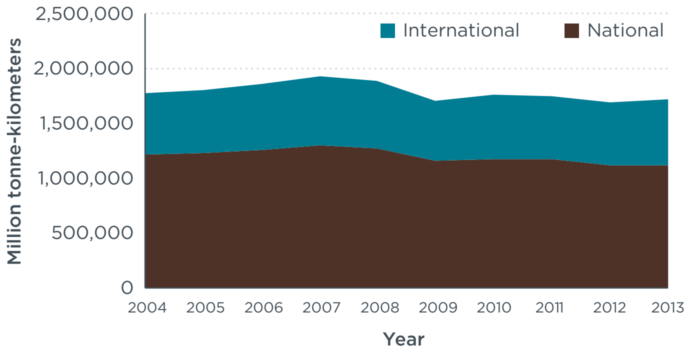

Figure 4. Total road freight transport in the EU, divided by national and international transport (based on origin and destination)

Of the EU's 28 member states, most of the road freight is hauled in relatively few countries. As shown in **Figure 5**, the seven countries of Germany, Poland, Spain, France, United Kingdom, Italy, and the Netherlands together represent nearly three-quarters of the EU's road freight transport in terms of total tonne-kilometers. The remaining 21 member states are responsible for just 27% of the tonne-kilometers from road freight transport (European Commission 2015).

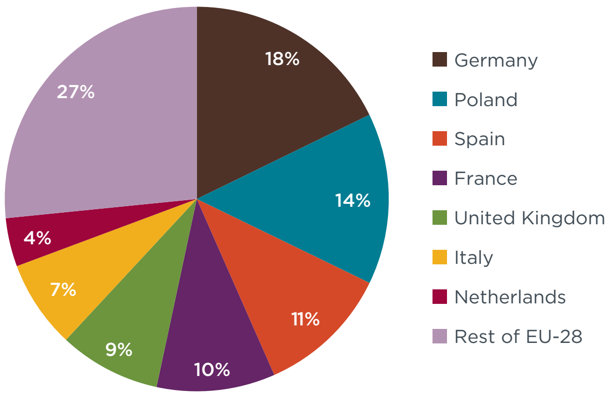

Figure 5. 2013 Share of road freight transport based on tonne-kilometers in EU-28 by member state (originating country).

EU HEAVY-DUTY VEHICLE CO_2 EMISSIONS

To promote climate change mitigation across the Union, the EU's current target is a 40% reduction in greenhouse (GHG) gas emissions by 2030 (European Commission 2015). The European Commission is calling for GHG reductions across all sectors of the economy, and thus HDVs and the road freight sector overall will need improvements in efficiency in order for the EU to achieve its goal.

The need for HDV efficiency improvements is evident when looking at trends from a long-term real-world testing campaign. As shown in **Figure 6**, on-road annual testing data starting in 2002 suggests that the efficiency of new tractor-trailers has been mostly stagnant in the EU for a number of years. Here we focus on tractor-trailers due to the fact that these vehicles are the largest contributor to fuel consumption in the HDV sector in the EU, accounting for nearly 40% of fuel use and GHG emissions from commercial vehicles (Hill, Finnegan et al. 2011).

The data presented in **Figure 6** were obtained from Lastauto Omnibus, a German trucking magazine. The magazine performs extensive real-world fuel consumption testing on a select number of HDVs over a set of different duty cycles each year. For the purposes of our analysis, we looked at the annual average results from tractor-trailer testing on the "overall/average" cycle (the error bars in the figure represent the minimum and maximum fuel consumption values that were obtained each year). The overall/average cycle represents a duty cycle weighting consistent with typical usage of tractor-trailers for long haul operations. Each annual data point represents the average result of between five and ten tractor-trailers. A total of 98 tractor-trailers were tested from 2002 to 2014. As can be seen in the figure, the data indicates that the fuel consumption of tractor-trailers in the EU has not changed significantly over the past 13 years (note that tailpipe emissions were significantly reduced over that same time frame, which has made simultaneous efficiency improvements more challenging[3]).

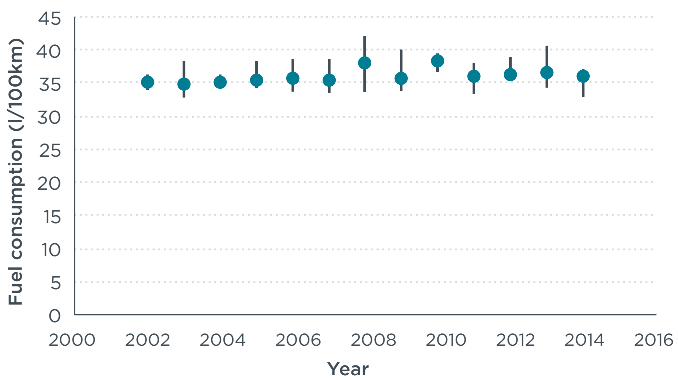

Figure 6. Fuel consumption trends for tractor-trailers in the EU

In light of this evidence that the per-vehicle efficiency of at least one major segment of HDVs in the EU has been stagnant for much of the past 15 years, it is useful to call attention to two comprehensive studies that analyze the technological potential to improve EU HDVs' efficiency and reduce their GHG emissions (Hill, Finnegan et al. 2011, Law, Jackson et al. 2011). Both of these reports find that there are significant opportunities for accelerating the adoption of technologies that will reduce fuel consumption from commercial vehicles, and the per-vehicle technology potential for GHG reductions in the 2015 to 2020 time frame ranges from roughly 30% to 50% (depending on the vehicle category) compared with a 2010 baseline.

3. Market Snapshot and Trends

In order to get a better understanding of the current HDV market in the EU, we analyzed new sales and registration over the past ten years using data purchased from IHS Automotive. It must be noted that while this was a fairly comprehensive data set, there are some items missing. The main deficiencies in the data set are that vehicle type information was not available for France and that the quantity of data marked as "unspecified" varied for various data channels. These caveats are noted in the relevant figures in this section. In this section we begin by looking at the HDV market as a whole, then conduct more in-depth analysis on two key market segments, tractor-trailers and rigid trucks (otherwise known as straight trucks).

HDV MARKET OVERVIEW

Figures 7 and 8 show the total sales by body type over ten years (by sales volume and market share, respectively).[4] Although not shown in the figure, nearly 99% of new and in-use HDVs are powered by diesel engines (Hill, Finnegan et al. 2011). The impact of the 2008 financial crisis can clearly be seen in **Figure 7** with a significant dip in sales starting in 2009. The market has rebounded somewhat, though sales are still only about three-quarters of what they were ten years ago. These figures also indicate the increasing importance of the tractor-trailer segment. In 2005, the rigid truck segment represented the largest percentage of sales, but the tractor truck market has been steadily growing in market share since 2009 and is now the segment with the highest volume of annual sales.

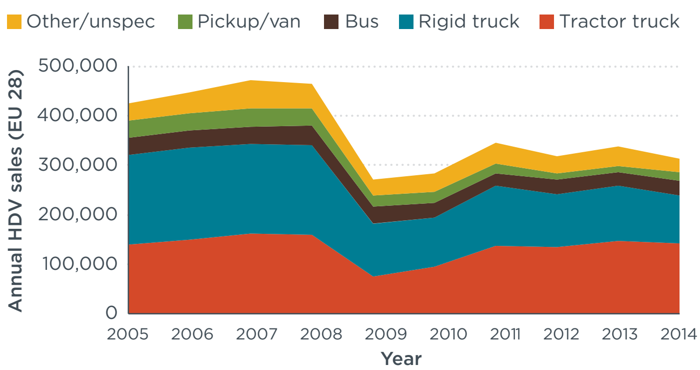

Figure 7. HDV Annual sales by vehicle type in the EU.

3 For a more detailed discussion of how various criteria emission control approaches for HDVs affect fuel efficiency and vice versa, please see Section 3.2 in the following ICCT reference: http://www.theicct.org/sites/default/files/publications/ICCT_ChinaTechPathways_oct11.pdf

4 The vehicle type data for France is assumed have the same breakdown as for the rest of the EU due to the fact that vehicle type data is unavailable for France.

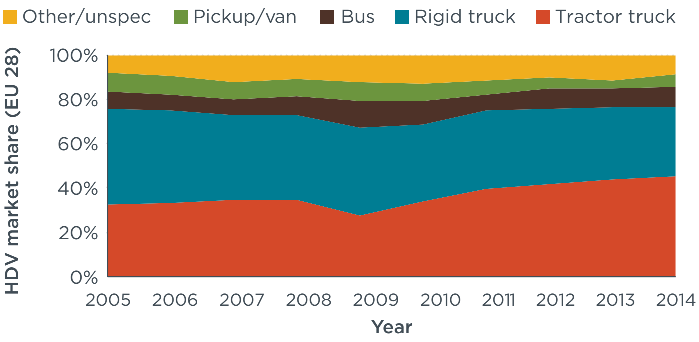

Figure 8. HDV market share by vehicle type in the EU

Looking at the new HDV sales breakdown by country in **Figure 9**, the countries responsible for the most new HDV purchases in 2014 were Germany, the UK, France, Poland, Spain, Italy, and the Netherlands. Comparing this sales information back to the share of road freight haulage in **Figure 5** give some insight as to trends among the biggest players in the road freight sector in the EU.

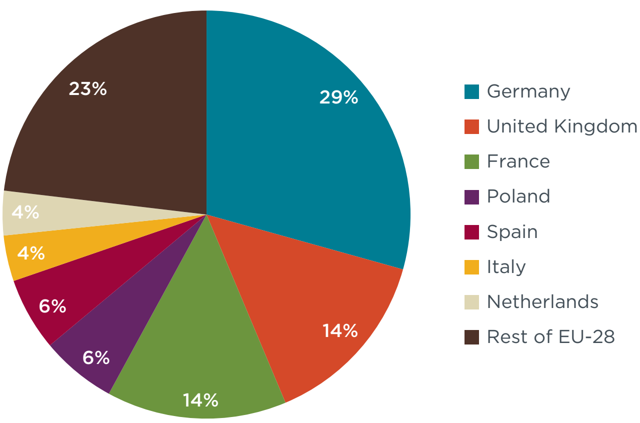

Figure 9. 2014 HDV EU sales market share by member state

The 2014 data in **Figures 5 and 9** are summarized in **Table 1** along with the corresponding data from 2005.[5] The top seven markets tend to represent just over three-quarters of the new vehicle sales and just under-three quarters of road freight transport. In terms of the percent of the total tonne-kilometers transported in the EU, Poland has seen the large boost in freight movement—increasing from 6% in 2005 up to 14% in 2014, which put the country in second place behind Germany (18%). However, in terms of vehicle sales, Poland's market share was 6% in 2014, well behind Germany at 29% and the UK and France with 14% each. In contrast to Poland, the UK shows an opposite situation in freight movement and HDV sales: its share of freight transported (9%) is relatively low compared with its sales market share (14%). Germany, the largest member state in terms of both road transport and vehicle sales, is responsible for nearly one-third of vehicle sales, but less than one-fifth of ton-kilometers transported. Italy and Spain, which together were responsible for more than 20% of the HDV sales in 2005, are now only responsible for 10% of sales. This table suggests that the HDV market is shifting differently in the various EU member states. Presumably, complex macroeconomic forces are driving these disparate changes, and given the somewhat limited data available for this study it is difficult to identify all of the multitude of factors influencing these trends.

Table 1. Road freight transport and vehicle sales for the top seven member states

Rank - 2014	Road freight transport (% of ton-kilometers)		Vehicle sales	
1	Germany	18%	Germany	29%
2	Poland	14%	UK	14%
3	Spain	11%	France	14%
4	France	10%	Poland	6%
5	UK	9%	Spain	6%
6	Italy	7%	Italy	4%
7	Netherlands	4%	Netherlands	4%
Total		**73%**		**77%**

Rank - 2005	Road freight transport (% of ton-kilometers)		Vehicle sales	
1	Germany	17%	Germany	23%
2	Spain	13%	UK	15%
3	Italy	12%	France	14%
4	France	11%	Spain	11%
5	UK	9%	Italy	10%
6	Poland	6%	Netherlands	3%
7	Netherlands	5%	Belgium	3%
Total		**73%**		**79%**

There are only a handful of manufacturers that sell HDVs in both the North American and EU markets. Each global manufacturer typically sells vehicles under a number of different brand names. The brands and corporate parent manufacturers, along with the segment(s) and region of focus, are summarized in **Table 2**. Daimler, Volvo, and PACCAR all have heavy stakes in both the EU and US, whereas Iveco and Volkswagen are focused on the EU market while the cornerstone market for Navistar International is North America.

5 These HDV sales numbers include buses and other vehicles, which are not used for freight transport. These vehicles typically make up no more than 10–15% of the sales in the EU member states.

Table 2. Key vehicle segments and geographic regions for the major US and EU heavy-duty vehicle manufacturers

Corporate parent	Brands	Main segment	Key market
Daimler	Freightliner	Tractor	N. America
	Western Star	Tractor	N. America
	Mercedes-Benz Trucks	Tractor	EU/Int'l
	Mitsubishi-Fuso	Rigid	EU/N.America/ Other
	Thomas Built	Bus	N. America
	Setra	Bus	EU/Other
	Bharat Benz	Rigid	Other
	Mercedes-Benz Omnibusse	Bus	Other
	Mercedes-Benz Vans	Vans	Other
Volvo	Volvo	Tractor/Rigid	EU
	Mack	Tractor	N. America
	UD	Rigid	N.America/ Other
	Renault Trucks	Tractor/Rigid	EU/Other
	Prevost	Bus	N. America
	Nova Bus	Bus	N. America
PACCAR	Kenworth	Tractor	N. America
	Peterbilt	Tractor	N. America
	DAF	Tractor	EU
Volkswagen	MAN	Tractor/Rigid/ Bus	EU
	Scania	Tractor/Rigid/ Bus	EU
	VW	Vans	EU
Navistar International	Navistar International	Tractor/Rigid	N. America
Iveco	Iveco	Tractor/Rigid	EU

Figure 10 shows the 2014 market shares of the major HDV manufacturers in the EU. This includes all HDVs—buses, vans, tractors, rigid trucks, etc. The HDV market is dominated by five manufacturers, with Volkswagen and Daimler responsible for more than half the HDV sales and Volvo, PACCAR, and Iveco responsible for another 40%. All told, the top five manufacturers are responsible for more than 90% of the HDV sales in the EU.

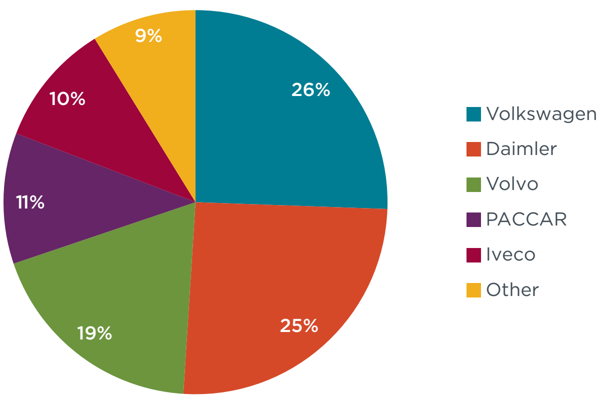

Figure 10. 2014 HDV market share for EU manufacturers

Figure 11 shows the estimated fuel consumption of the new HDV vehicle fleet in 2005 and 2014. These simple estimates are performed using the estimates for in-use fuel consumption rates and annual kilometers traveled of the different vehicle segments from the Lot 1 report (Hill, et al., 2011). With the growth in the fraction of tractor truck sales over the past ten years (see **Figure 8**), we estimate that tractor trucks are now responsible for more than 50% of fuel consumption from new HDVs. After tractors, rigid trucks are estimated to have the second highest total fuel consumption. The "Other" category includes a range of vehicle types such as vans, as well as vehicle types that are unspecified in the original data set. Below we look in more detail into the two vehicle segments that represent the largest contribution to overall sales and fuel consumption: tractor trucks and rigid trucks.

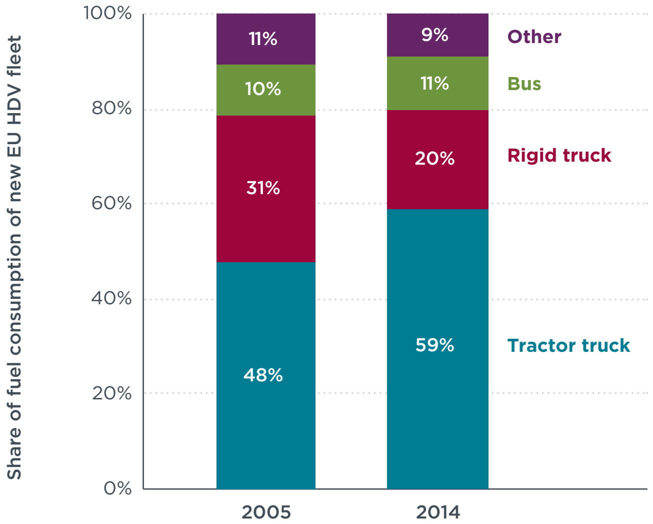

Figure 11. Estimated fuel consumption breakdown of the new EU HDV fleet

TRACTOR TRUCKS

As discussed above, the tractor truck is the HDV segment that represents the largest share of fuel consumption and CO_2 emissions in the EU. Tractor-trailers are crucial for moving freight across Europe. The freight is carried in trailers, which are coupled to the tractor. The configuration of the trailer varies widely based on the freight being hauled. The most common type of trailer in the EU is known as a side curtain trailer (Hill, Finnegan et al. 2011). Refrigerated trailers are utilized for moving items that must remain in a temperature-controlled environment. There are many other types of trailers, including flatbeds, tankers, grain trailers, and auto transporters. While trailers are a critical element of goods movement in the EU, we focus our attention on the tractor market in the remainder of this section. We will investigate the EU trailer market in more detail in future research.

As shown in **Figures 12 and 13**, five manufacturers dominate the tractor market: Volkswagen, Daimler, Volvo, PACCAR, and Iveco.[6] Together, these companies account for more than 99% of total tractor truck sales. **Figure 12** shows the trend of annual tractor sales in the EU. The sales in 2014 were slightly less than sales volumes between 2005 and 2008, prior to the financial downturn. **Figure 13** shows that the top five manufacturers represent virtually the entire market, with only 0.04% of tractor sales coming from other companies.

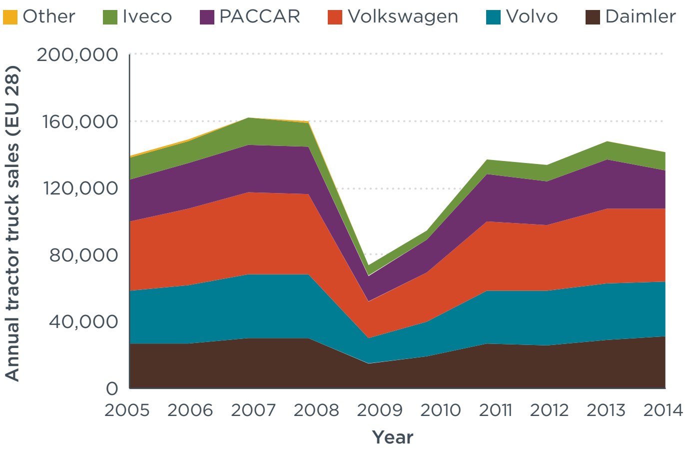

Figure 12. EU annual sales of tractor trucks by manufacturer over ten years

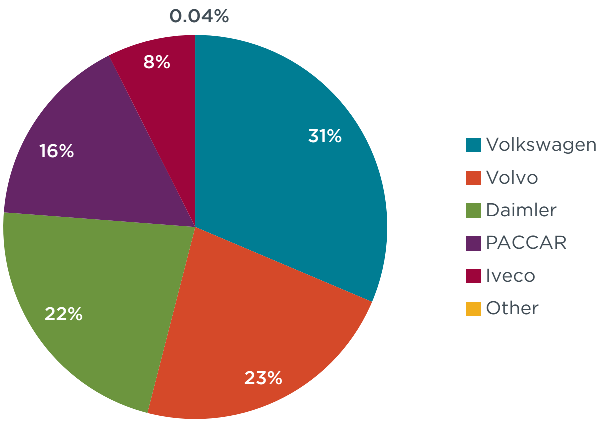

Figure 13. 2014 EU tractor truck market share by manufacturer

Of the five market leaders, most of these manufacturers have one or two models that account for a significant number of their tractor truck sales. For each of these five manufacturers, Table 3 gives the percentage of sales represented by their top-selling tractor model in five of the largest HDV markets in the EU.[7] HDV models are typically customized by the buyer (who can choose the engine, gearbox, axle configuration, etc.), meaning that for the specific models in **Table 3,** there may be hundreds or even thousands of individual variants on the road that have unique specifications.

6 As in Figures 7 and 8, France is assumed to have the same manufacturer market share breakdown as the average of the EU.

7 Poland, which is the fourth largest market for HDVs in the EU, is not included in this table because we do not have Poland-specific data as part of this data set. As mentioned previously, the data set also does not include vehicle type information for France, the third largest HDV market in the EU.

Table 3. Top-selling tractor brands and models in select EU countries

Country	Top-selling brand	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%

The gross vehicle weight (GVW) and gross combined vehicle weight (GCVW) of a tractor truck is an indication of its usage profile. For tractor trucks in the EU, the GVW is typically defined as the curb weight of the tractor plus a portion (approximately half) of the maximum payload, whereas GCVW is typically defined as the maximum operating weight including the curb weight of the combined tractor-trailer plus the maximum payload. Tractor trucks over 16 tonnes GVW are typically used in long-haul applications, whereas lighter tractor trucks are more likely to be used for shorter-haul operations. **Figure 14** shows the breakdown of GVW for tractor sales in 2005 and 2014. More than 99% of tractor truck sales are over 16 tonnes, and over the past ten years there has been a shift to tractor trucks over 20 tonnes.

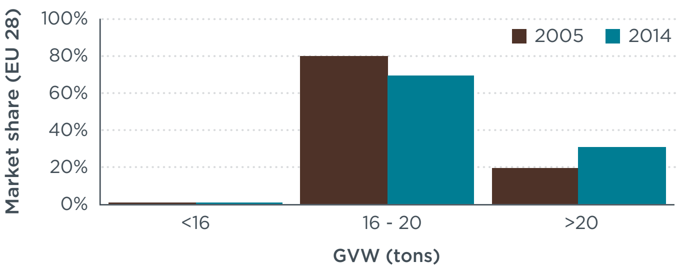

Figure 14. Market share of EU tractor trucks by vehicle weight

Figure 15 shows how engine size (i.e., displacement volume) in tractor trucks has increased between 2005 and 2014. The engine sizes in tractor trucks in the EU have shifted upwards, and the share of engines between 12 and 14 liters is nearly double what it was ten years ago. In addition, over this same time period there has been a shift towards higher engine power, as shown in **Figure 16**.

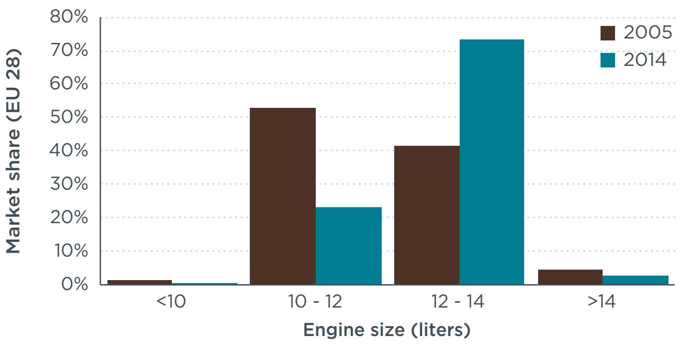

Figure 15. Market share of EU tractor trucks by engine size

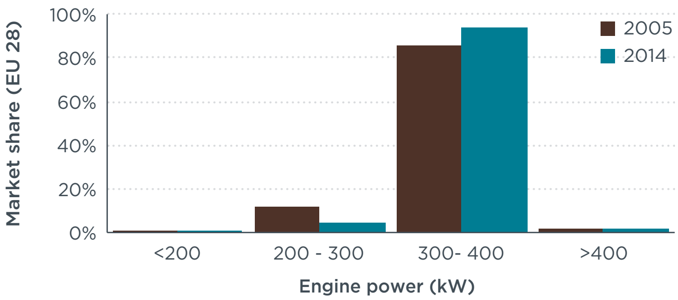

Figure 16. Market share of EU tractor trucks by engine power

The prevailing trend for the tractor market in the EU over the past ten years appears to be towards heavier trucks and larger, more powerful engines. What this means in terms of efficiency and fuel consumption is not necessarily straightforward. Larger engines tend to have higher thermal efficiency due to their cylinders having a smaller area-to-volume ratio, which allows less heat loss than that of smaller engines. The relative proportion of engine auxiliaries' power consumption to total power consumption is also lower for larger engines. Also, an important operational factor is that drivers tend to prefer larger engines due to enhanced drivability (i.e., acceleration and gradability) and torque.

By moving more freight per trip, use of heavier and more powerful trucks can potentially improve freight efficiency (i.e., amount of freight moved per unit of fuel). However, this effect is somewhat counterbalanced by the fact that increased vehicle weight results in a fuel consumption penalty. For tractor-trailers, a rule of thumb is that every 500 kg of additional weight increases fuel consumption by approximately 1% (Hill, Norris et al. 2015). On the other hand, if trucks are over-powered for their particular application, they will not typically be operating their engines in the most efficient point on the speed-load map, and efficiency will decline. In general, there is a trade-off between drivability and efficiency, and ideally fleet operators optimize this tradeoff by "right-sizing" the engine and selecting other vehicle specifications to best match the intended mission profile.

RIGID TRUCKS

The rigid truck market is the second largest sales category of HDV in the EU behind tractor trucks. For rigid trucks (sometimes called straight trucks), the payload-carrying body is fixed and cannot be removed from the chassis as with the tractor-trailer. Rigid trucks have a much wider range of applications than tractor trucks, so this category has much more heterogeneity in terms of sizes, body configurations, and driving profiles. The uses of rigid trucks vary significantly and include regional delivery, local or urban delivery, utility or service applications, dump trucks, construction, and refuse hauling.

Figures 17 and 18 show the manufacturer market shares of rigid trucks in the EU.[8] As with tractor trucks, the market is dominated by the same five manufacturers, although the distribution is a little different. It is interesting to note in **Figure 17** that total sales of rigid trucks have not recovered since the economic downturn to the same extent as tractor trucks. Perhaps it is the case that some fleet operators are shifting to tractor trucks for applications that rigid trucks used to perform.

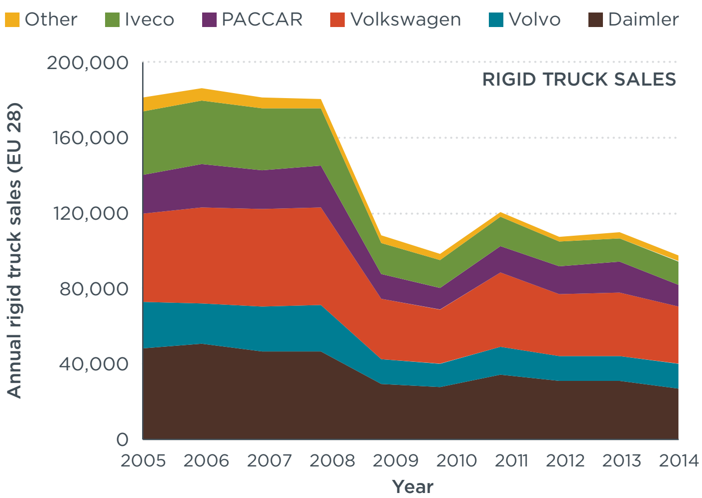

Figure 17. EU annual sales of rigid trucks by manufacturer over ten years

8 The data for France are not included because of the lack of vehicle type data; see earlier notes.

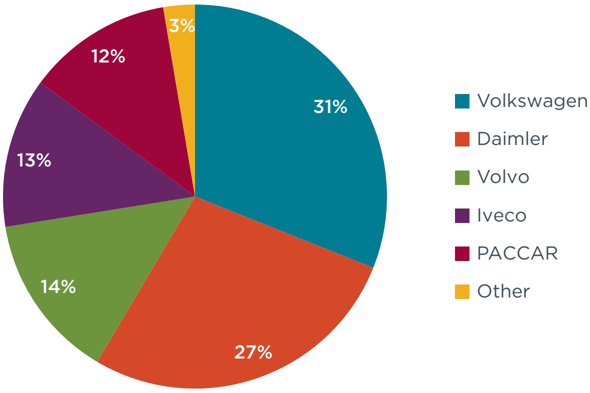

Figure 18. 2014 EU rigid truck market share by manufacturer

As with tractor trucks, manufacturers tend to have one or two models that represent a significant number of their rigid truck sales. For each of the top five manufacturers, Table 4 gives the percentage of sales represented by their top-selling rigid truck model. Comparing the percentages in the far right column of **Tables 3 and 4,** it is evident that the rigid truck market is less consolidated, with the top-selling model accounting for between 48% and 67% of total sales for the leading manufacturer in each country (compared with between 71% and 98% in the case of tractor trucks). Due to the considerable variety of end uses, extensive customization of rigid trucks is even more prevalent than in the tractor truck market. Thus again, for these models shown in the table, there are likely thousands of unique permutations on the road.

Table 4: Top-selling rigid truck brands and models in select EU countries

Country	Top-selling brand	Top-selling model	% of brand's rigid truck sales
Germany	Mercedes Benz (Daimler)	Atego	49%
United Kingdom	DAF (PACCAR)	LF series	67%
Spain	Iveco	Eurocargo	67%
Italy	Iveco	Eurocargo	50%
The Netherlands	DAF (PACCAR)	CF series	48%

Figure 19 shows the weight distribution for rigid truck sales in 2005 and 2014. The definition of GVW for rigid trucks in the EU is different from that of tractor trucks (described in the previous section). For rigid trucks, the GVW is defined as the curb weight of the truck plus the maximum payload. The different definitions make it difficult to directly compare tractor trucks and rigid trucks on a GVW basis. In 2005 and 2014 the GVW distribution of rigid trucks was fairly similar, though there has been a modest shift into the heavier weight bins of trucks over the time period. Another notable aspect of the EU HDV market is that there are significant sales of rigid trucks over 24 tonnes. These represent the heavy work trucks needed for a number of uses, such as construction, refuse and freight hauling.

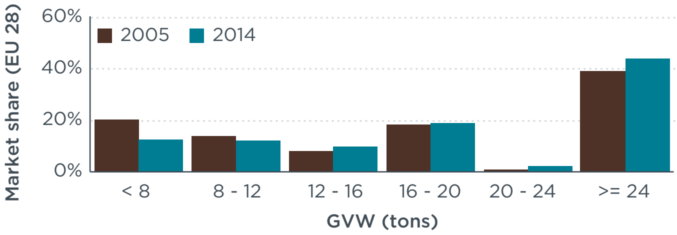

Figure 19. Market share of EU rigid trucks by vehicle weight

Figure 20 gives the breakdown of engine size distributions in 2005 and 2014. In this figure, two distinct ranges of engine sizes—4 to 8 liters and 10 to 14 liters—are together responsible for the majority of total rigid truck sales. For the smaller engine displacement range (4–8 liters), there has been a marked shift from two bins less than 6 liters and into the 6–8 liter category. Similarly, in the larger engine displacement range (10-14 liters), between 2005 and 2014 sales have decreased in the 10–12 liter bin and have more than doubled in the 12–14 liter bin, from 10% to 25% of the rigid truck market. **Figure 21** presents the engine power distribution for the same years. As with tractor trucks, the trend seems to be towards higher-powered engines, with a noticeable decrease in the fraction of engines under 200 kW and a corresponding increase in those greater than 200 kW (most noticeably in the 300 to 400 kW range).

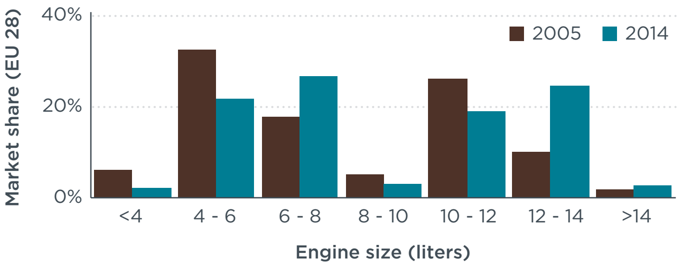

Figure 20. Market share of EU rigid trucks by engine size

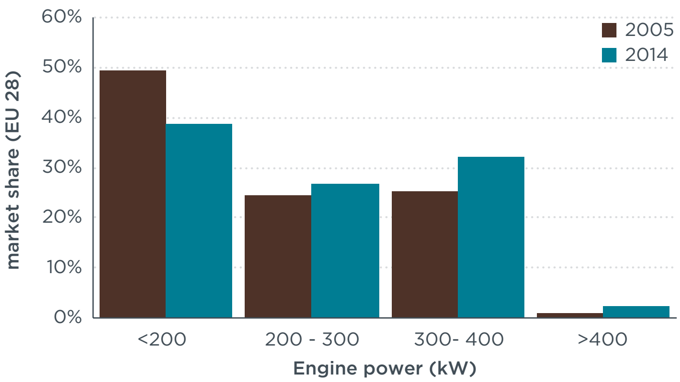

Figure 21. Market share of EU rigid trucks by engine power

4. EU and US HDV Market Comparisons

In the following section, we compare the HDV markets in the EU and US in terms of sales shares of various vehicles types, trends in fuel consumption, manufacturer market shares, and new vehicle characteristics.

Figure 22 compares the 2014 sales breakdown in terms of vehicle types for the US and EU markets. The EU data is for HDVs 3.5 tonnes and heavier, while the US data includes all HDVs over 8,500 pounds (3.9 metric tonnes). One of the key differences between the two markets is the popularity in the US of pickup trucks, which are part of the lightest classes of HDV in the US and are included in the "Other" category in this figure. As shown, pickup trucks and vans—together with other unspecified vehicles in the data set—represent 71% of the HDV market in the US. According to data from the National Highway Traffic Safety Administration (NHTSA), there were approximately 638,000 pickup trucks and vans between 8,500 and 14,000 pounds (3.9–5.2 tonnes) sold in the US in 2014, which represents roughly two-thirds of the nearly 1 million HDVs sold. Commercial vehicles at the lighter end of the spectrum are also quite popular in the EU, though the pickup truck configuration is not at all prevalent, with less than 1,000 pickups sold in 2014. Though not included in the data set that we analyzed for this paper, there were roughly 1.4 million light commercial vehicles[9] (LCVs) sold in the EU in 2014 (International Council on Clean Transportation 2014).

Other differences between the EU and US include the bus market, which is five times larger in the EU in terms of the percentage of HDV sales (10% in the EU versus 2% in the US). However, in absolute terms, bus sales in the EU were only approximately 12,000 units greater than in the US (roughly 32,000 in the EU compared with 20,000 in the US). For tractor trucks, total sales in 2014 were roughly 121,000 in the EU and 16% higher in the US, at just over 141,000 units sold. In both markets, rigid truck sales were less than that of tractors in 2014—approximately 30% lower in the EU (roughly 83,000 units) and 14% lower in the US (nearly 122,000 units).

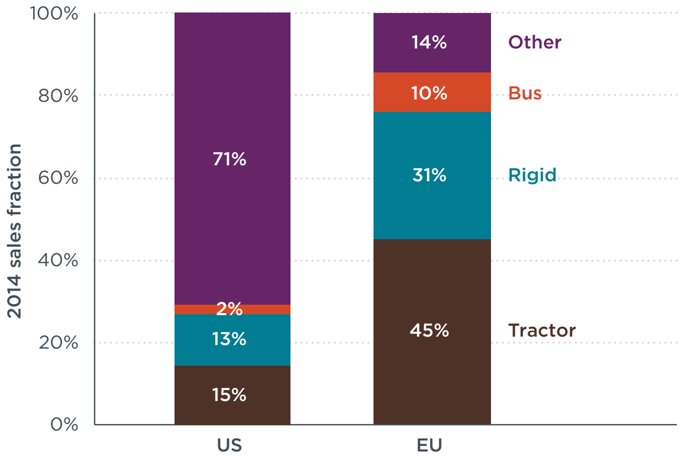

Figure 22. 2014 new HDV sales in the US and EU by vehicle type[10]

Figure 23 shows how these sales breakdowns translate into estimated fuel consumption percentages for the 2014 new HDV fleet. These EU numbers are estimated as previously described in this paper (see **Figure 11**) and the US fuel consumption is estimated using fuel consumption rates and annual mileage data derived from the Motor Vehicle Emissions Simulator (MOVES), the official US vehicle inventory model (U.S. Environmental Protection Agency 2014). Comparing the US columns in **Figures 22 and 23,** the prominence of the "Tractor" and "Other" wedges more or less switch places, as tractors are estimated to account for 60% of fuel use but only 15% of sales. This is primarily driven by the fact that pickup trucks make up the large majority (93%) of the "Other" category, and the fuel consumption rates of pickups are approximately one-third than that of tractor trucks. Examining the two column breakdowns in **Figure 23,** although the tractor truck segment is a smaller fraction of sales in the US, the share of tractor fuel consumption is nearly the same in the two regions, mostly due to much higher average annual mileage in the US (191,000 km) than in the EU (65,000 km). As with the sales market, buses make up a smaller fraction of HDV fuel consumption in the US than in the EU. In terms of the percentage of overall fuel consumption of new HDVs, the rigid truck contribution is relatively similar between the two markets.

9 Light commercial vehicles (N1 category) in the EU are defined as vehicles designed and constructed for the carriage of goods and having a maximum mass not exceeding 3.5 tonnes.

10 As noted previously, the data for France is included in the "other" category due to the fact that no vehicle type data was available.

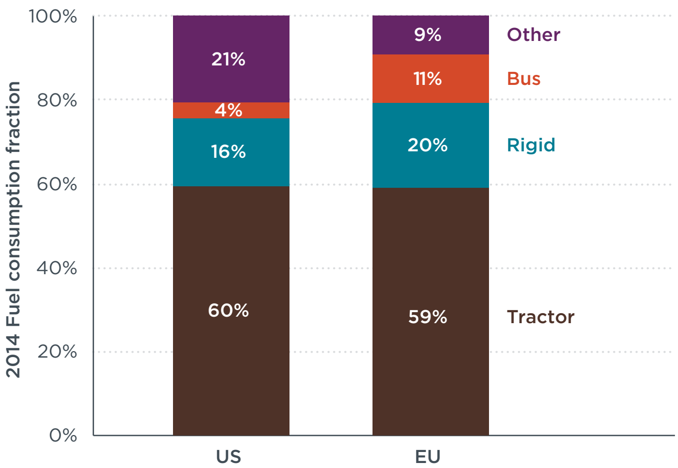

Figure 23. 2014 estimated new vehicle fuel consumption breakdown in the US and EU by vehicle type

There is significant overlap between international manufacturers selling HDVs in the EU and US, as can be seen in **Figure 24**. Together, Daimler, Volvo, and PACCAR represent 80% of the US market and 60% of the EU market for the largest-selling segment, tractor trucks. One positive aspect of the two regions being dominated by only a handful of manufacturers is that there are economies of scale when selling across both markets, as well as cost savings for certain technologies. Therefore, because manufacturers are bringing new efficiency technologies to market as part of complying with the US efficiency regulation, in some cases this may make it much less challenging to bring these technologies to the EU market as well, lowering the potential cost of any HDV efficiency standard.

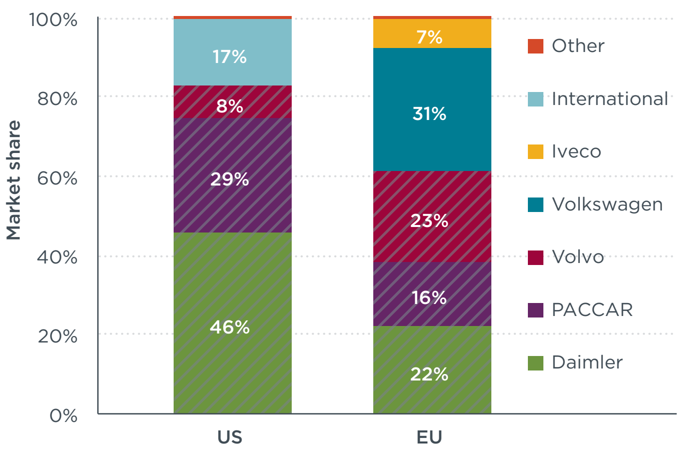

Figure 24. 2014 market share of tractor truck manufacturers in the US and EU. Shaded areas are the common manufacturers between the two.

As discussed in Section 3, the size of engines in the tractor truck segment in the EU has been increasing over the past decade. This is bringing the EU engine size distribution for this segment closer to that of the US. The current comparison between engine size distributions for tractor trucks in the two markets is shown in **Figure 25**. The most common size engine for a tractor truck in the US is between 14 and 16 liters, compared to between 12 and 14 liters for the EU. It is expected that the engine size in the US will start to go down in coming years due to the Phase 1 and 2 HDV standards, as engine downsizing is an important technology pathway for a number of tractor manufacturers (Lutsey, Langer et al. 2014). Both standards promote significant reductions in vehicle road load, meaning there is less need for the higher torque given by these larger engines. In addition, the Phase 2 standards have a particular testing method that credits the fuel savings impacts of downsized engines (International Council on Clean Transportation 2015).

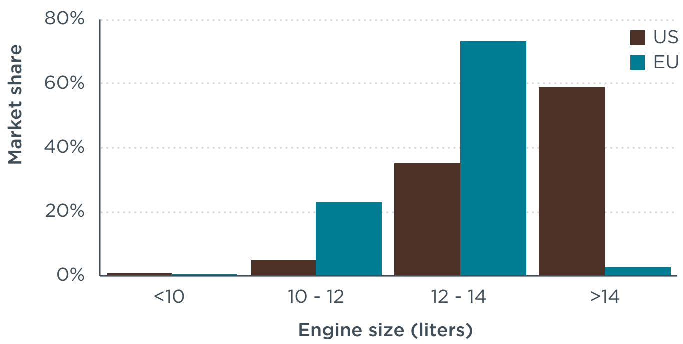

Figure 25. 2014 Market share of tractor trucks by engine size in the US and EU

Direct comparisons between US and EU tractor fuel consumption are difficult due to a number of factors (Sharpe and Muncrief 2015). As can be seen in **Figure 26,** which shows a typical EU and US tractor-trailer combination, the trucks themselves can look very different. Noticeable differences include the configuration of the tractor, which is generally a cab-over-engine and two-axle configuration in the EU and an elongated cab and three-axle configuration in the US. In addition, the most common configuration of EU trailer is a side-curtain type with three rear axles, while the most prevalent trailer in the US is a box van with rigid sides and two rear axles. Other differences include duty cycles, weight, length, and speed restrictions, as well as numerous other factors that contribute to making direct fuel consumption comparisons challenging. For example, highway speed limits for trucks in the EU typically range from 80 to 90 kilometers per hour (kph), while the range in the US is 89 to 121 kph (55 to 75 miles per hour). In the EU the maximum total vehicle weight on most roads is usually 40 metric tonnes, and in the US it is 36 metric tonnes (80,000 pounds), although there are exceptions in certain EU countries, and select US states allow heavier vehicles.

Figure 26. Images of typical tractor-trailers in the EU (left) and US (right)

Figure 27 shows per-vehicle fuel consumption trends for EU tractor-trailers as well as the baseline (2010) and target values from both phases of the US regulation. The EU data is the same as is presented in **Figure 6**. For the US, these data points represent fuel-weighted averages of the regulatory standards for the nine tractor subcategories in the rule.[11]

While we have shown data for the EU and US together in this figure, the two sets of data are not fully comparable for several reasons. For each model year, the EU data points are averages of individual test results of actual tractor-trailers being evaluated in real-world driving conditions (in each year, between five and ten tractor-trailers were tested). In contrast, the US data points are based on vehicle simulation using the agencies' Greenhouse gas Emission Model (GEM), which is the mandatory compliance tool used in the US regulation for tractors and vocational vehicles. For the US, the 2010 data point in the figure represents the regulatory agencies' best estimate of the fuel consumption rates for new tractor-trailers in that year, which was set as the baseline year in the Phase 1 regulation. The Phase 1 and Phase 2 data points in the figure represent the reductions that will be required in each model year step in the two regulations. While not shown here, it should also be noted that prior to the introduction of the Phase 1 HDV standard, available data indicates that real-world fuel consumption had been flat for two decades (Oak Ridge National Laboratory 2014).

While there is limited value in comparing the absolute values of the data points from the two regions, we have shown them together in this figure to emphasize the magnitude of the expected efficiency improvements motivated by the US regulations compared with the relative efficiency stagnation in the EU evidenced by the Lastauto Omnibus testing campaigns. On average, the combined Phase 1 regulation and proposed Phase 2 regulation will result in a 33% reduction in per-vehicle fuel consumption rates in tractor-trailers from a 2010 baseline. Studies also indicate the potential for significant fuel consumption reduction for US tractor-trailers in the 2020–2030 time frame. Though not shown in **Figure 21,** a previous study by ICCT shows that there is potential for tractor-trailers to achieve 19 l/100km in the 2020–2030 time frame (Delgado and Lutsey 2015). Relatedly, industry led teams from the Department of Energy's SuperTruck program—the purpose of which is to accelerate the commercialization of efficiency technologies for tractor-trailers (Delgado and Lutsey 2014)—demonstrated tractor-trailers achieving between 19-22 l/100km with a suite of advanced technologies (Freightliner 2015, Peterbilt Motors Company 2015). Given that testing data provides evidence that EU tractor-trailer fuel efficiency has been relatively constant for more than a decade, the level of efficiency improvements expected from the US regulations suggest that there is an opportunity for performance-based standards in the EU to bend this trend line downwards and promote more efficiency technologies in the new HDV fleet. As the US regulatory program progresses over the next 15 years, regulators will need to implement a robust real-world testing program in order to validate that the levels of fuel consumption reductions expected from the rule are indeed manifesting in real-world operations.

11 In both the Phase 1 and 2 US heavy-duty vehicle GHG regulations, tractor trucks are divided into nine regulatory subcategory based on gross vehicle weight rating (Class 7 or 8), roof height (low, medium, or high), and cab configuration (sleeper or day cab). For fuel use weighting factors for the nine tractor subcategories, please see Section 5.3.2.2.1 in the Phase 2 Draft Regulatory Impact Analysis.

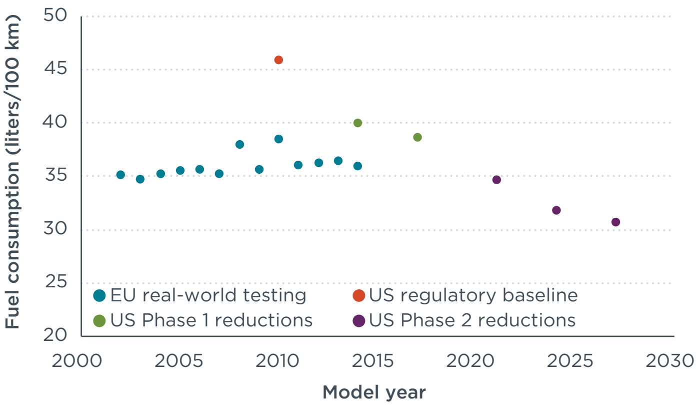

Figure 27. Comparison of tractor-trailer fuel consumption trends for US and EU

5. Conclusions and Policy Recommendations

This paper summarizes the current state of HDV CO_2 emissions and sales in the EU. HDVs are responsible for one-third of CO_2 emissions in the EU and this number is project to grow. Of note, seven member states (Germany, Poland, Spain, France, United Kingdom, Italy, and The Netherlands) are responsible for approximately three-quarters of the HDV CO_2 emissions.

This study presents evidence that the efficiency of tractor-trailers, the highest CO_2 emitting segment in the EU, has remained constant for more than a decade. Assessing sales trends over the past ten years illustrates that the trend in the EU is towards heavier vehicles and larger engines, more similar to those currently being sold in the US. Five truck manufacturers, namely Volkswagen, Volvo, Daimler, PACCAR, and Iveco, dominate the EU market. Three of these manufacturers (Volvo, Daimler, and PACCAR) are also dominant in the US market. Projections, based on existing and proposed regulations in the US demonstrate that HDV efficiency trends in the EU are relatively flat compared with a trend towards annual efficiency improvements in the US.

Noting the many similarities between the EU and US HDV markets, it is likely that many of the same technologies could be applied to the HDV fleet in the EU as are expected in the US under the Phase 1 and 2 efficiency regulations (such as improved aerodynamics for trailers, automatic tire inflation, and improved engine efficiency). Next steps resulting from this work are to study, at a more detailed level, the potential baseline CO_2 reduction and cost savings from available and emerging HDV efficiency technologies.

The policy recommendations resulting from this study are as follows:

1. Consider policy options to ensure HDV efficiency improvements. While addressing market forces with a CO_2 labeling scheme for HDVs could result in CO_2 reductions from some new trucks and buses, there is no evidence to guarantee this approach will result in any fleet-wide CO_2 reduction. Mandatory fuel efficiency or CO_2 standards give a much higher level of certainty that efficiency technologies will be invested in and deployed at larger scale by manufacturers and suppliers. Standards also ensure that leading cost-effective technologies are more widely taken up by the fleet, resulting in reduced CO_2 emissions.
2. Focus on the member states with the largest HDV CO_2 footprints. These seven member states have perhaps the greatest interest in reducing the CO_2 emissions (and the resulting fuel costs) from their freight movements. Working with specific member states to develop country-wide strategies and complementary policies (such as green freight programs or CO_2-based road taxing) to incentivize the uptake of efficiency technologies could help familiarize the fleets with new technologies and help gain acceptance in the marketplace.
3. Take advantage of synergies between US and EU markets. As discussed above the US and EU fleets are not identical. However, there are opportunities to take advantage of the ability to achieve greater economies of scale, including the development of technologies by common manufacturers and suppliers, and learning lessons from the US approach to increasing HDV efficiency (such as strategies for policy design as well as flexibility provisions to ensure minimal disruption to the market). There is a significant amount of new publicly available research on HDV efficiency technologies in the US that could be utilized to inform the EU market.

References

Delgado, O. and N. Lutsey (2014). *The U.S. SuperTruck program: Expediting the development of advanced heavy-duty vehicle efficiency technologies.* Washington, DC; The International Council on Clean Transportation.

Delgado, O. and N. Lutsey (2015). *Advanced Tractor-Trailer Efficiency Technology Potential in the 2020-2030 Timeframe*. Washington, DC: The International Council on Clean Transportation.

European Commission. (2015, October 27). *2030 Energy Strategy.* Retrieved October 27, 2015, from http://ec.europa.eu/energy/en/topics/energy-strategy/2030-energy-strategy.

European Commission. (2015). *Eurostat: Transport Data Tables.* Retrieved October 27, 2015, from http://ec.europa.eu/eurostat/web/transport/data/main-tables.

Facanha, C., J. Miller and Z. Shao (2014). *Global Transportation Roadmap Model v1.0.* Washington, DC The International Council on Clean Transportation.

Freightliner. (2015). *Advanced Engineering.* Retrieved November 9, 2015, from https://www.freightliner-trucks.com/TruckInnovation/Advanced-Engineering/.

Hill, N., S. Finnegan, J. Norris, C. Brannigan, D. Wynn, H. Baker and I. Skinner (2011). *Reduction and Testing of Greenhouse Gas (GHG) Emissions from Heavy Duty Vehicles – Lot 1: Strategy.* London: Ricardo-AEA.

Hill, N., J. Norris, F. Kirsch, C. Dun, N. McGregor, E. Pastori and I. Skinner (2015). *Light weighting as a means of improving Heavy Duty Vehicles' energy efficiency and overall CO2 emissions.* Oxfordshire, UK: Ricardo-AEA Ltd.

International Council on Clean Transportation. (2014). *European Vehicle Market Statistics: Pocketbook 2014.* Washington, DC: ICCT. Retrieved October 27, 2015, from http://eupocketbook.theicct.org/.

International Council on Clean Transportation (2015). *Policy update: United States efficiency and greenhouse gas emission regulations for model year 2018-2027 heavy-duty vehicles, engines, and trailers.* Washington, DC: ICCT.

Law, K., M. Jackson and M. Chan (2011). *European Union Greenhouse Gas Reduction Potential for Heavy-Duty Vehicles.* Cupertino, Calif.: TIAX LLC.

Lutsey, N., T. Langer and S. Khan (2014). Stakeholder workshop report on tractor-trailer efficiency technology in the 2015-2030 timeframe. *Emerging Technologies for Heavy-Duty Vehicle Fuel Efficiency.* Washington, DC: International Council on Clean Transportation.

Meszler, D., N. Lutsey and O. Delgado (2015). *Cost effectiveness of advanced efficiency technologies for long-haul tractor-trailers in the 2020–2030 timeframe.* Washington, DC: The International Council on Clean Transportation.

Oak Ridge National Laboratory (2014). *Transportation Energy Data Book: Edition 33.* Oak Ridge, Tenn.: Oak Ridge National Laboratory Office of Scientific and Technical Information.

Peterbilt Motors Company. (2015). Cummins-Peterbilt SuperTruck Achieves 10.7 mpg in Latest Test. Retrieved November 9, 2015, from http://www.peterbilt.com/about/media/2014/396/.

Sharpe, B. and M. Muncrief (2015). *Literature review: Real-world fuel consumption of heavy-duty vehicles in the United States, China, and the European Union.* Washington, DC: International Council on Clean Transportation.

U.S. Environmental Protection Agency (2014). Motor Vehicle Emission Simulator (MOVES2014). Washington, DC.