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COSTS AND ADOPTION RATES OF FUEL-SAVING TECHNOLOGIES FOR TRAILERS IN THE CANADIAN ON-ROAD FREIGHT SECTOR

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EXECUTIVE SUMMARY

From September 2014 through December 2014, the International Council on Clean Transportation (ICCT) and Pollution Probe collaborated on a study to better understand the costs, performance levels, and current adoption rates of fuel-saving technologies for trailers in the Canadian on-road freight sector. The principal aim of the project was to interview a diverse cross-section of experts from the trucking industry in Canada and build a deeper understanding of the current market for trailer fuel-saving technologies, some of the market barriers to increase adoption, and expectations for trailer technologies in the coming years. These insights can have important implications as policymakers in North America consider policy options for increasing the efficiency of trailers.

Data for this project was collected using telephone interviews of a number of stakeholders throughout the on-road trucking industry. The specific interviewees that were chosen play important roles in their respective companies in regard to the decision-making process surrounding technologies for tractors and trailers. Pollution Probe led the interviews and engaged not only end users (i.e. trucking fleets), but also stakeholders such as manufacturers of trailers, aerodynamic technologies, and tires. The end users included large and medium for-hire and private trucking fleets that operate between roughly 30 and 1,500 tractors and 150 and 3,500 trailers. In all, the study team conducted telephone interviews with 18 companies.

This study is narrowly focused on costs and adoption rates for aerodynamic and tire technologies for trailers and is similar in scope to the work that was carried out by the ICCT and the North American Council for Freight Efficiency to investigate trailer fuel-saving technologies in the United States (US) market (Sharpe and Roeth 2014). A more comprehensive investigation of trailer technologies, market, and policy options can be found in an ICCT report from July 2013 (Sharpe, Clark et al. 2013). In addition, two companion ICCT white papers were released in early 2014 that analyze the costs and benefits of various trailer technology deployment scenarios as well as testing and certification options for trailers in the context of best practices for integrating trailers into the second phase of greenhouse gas (GHG) regulations for heavy-duty vehicles in the US and Canada (Sharpe 2014; Sharpe 2014).

Over the course of the interviews, some common themes emerged across all of the stakeholder groups. The following are the primary findings from the study:

1. ***Trucking fleets are adopting aerodynamic fuel-saving devices based primarily on economics, and the real-world payback is typically 12 to 18 months for most technologies***. Current costs for trailer aerodynamic technologies—particularly side skirts—have decreased significantly in recent years, due to far more market entrants driving cost competition and much higher deployment volumes reducing cost-per-unit. Falling purchase prices coupled with the improved quality and durability of products have motivated a large number of fleets to adopt these technologies. Most end users reported that they are recouping their initial investment in 12 to 18 months.
2. ***Amongst aerodynamic technologies, side skirts have had the largest rate of adoption, while the uptake of underbody, rear-end, and gap reduction devices has been more limited.*** Interview responses and sales data show that side skirts are the dominant trailer aerodynamic technology in Canada, with boat-tails and underbody devices making up a much smaller percentage of the market. Our study team

estimates that approximately 40 to 50% of new box trailers are sold with side skirts. Uptake of both underbody and rear-end devices is estimated to be less than 2% of new box trailer sales, while sales of gap reducers have been fairly negligible, as many fleets are utilizing tractor side extenders or modified king-pin locations to minimize the tractor-trailer gap distance.

3. ***There is widespread utilization of conventional-size low rolling resistance tires, but adoption of wide base tires has been slower.*** From the interview responses of fleets, trailer manufacturers, and a leading tire supplier, we estimate that the majority (roughly 70 to 80%) of new box-type trailers are equipped with conventionally-sized low rolling resistance (LRR) tires. These LRR *duals* have seen much larger adoption than wide base single (WBS) tires, though some fleets commented that they avoid LRR tires due to inferior performance in heavy winter conditions. For WBS tires, a number of fleets contended that the larger risk of being stranded in a remote location was the primary factor for avoiding these tires. Other fleets are of the view that LRR duals can achieve similar fuel savings as WBS tires, and fleets generally only consider WBS tires for the weight savings.

4. ***Trucking fleets are in favor of harmonization of size and weight regulations across the provinces.*** A common thread of feedback from many of the trucking fleets was that the difference in size and weight restrictions from province to province creates challenges in route planning and execution. Furthermore, it seems that the penetration of boat-tails and WBS tires has remained marginal due to some provincial and territorial restrictions. For boat-tails, this situation is changing, as in October 2014, the Council of Ministers Responsible for Transportation and Highway Safety approved amendments to the provincial and territorial Vehicle Weight and Dimensions Memorandum of Understanding, which include an increase in the allowable size of aerodynamic devices on the rear of trailers to 1.52 m (5 ft.). While regulatory or policy changes have not yet been made in all jurisdictions, Ontario and New Brunswick recently allowed longer trailer rear-end devices, and Nova Scotia allowed the use of such devices under permit. Many expect the other provinces to soon follow suit. The case of WBS is more complex, as some of the western provinces have reduced axle weight limits for tractor-trailers with WBS tires, and there was no clear indication from the interviews that there is policy in development to change this situation.

5. ***There are further improvements and efficiency gains that stand to be achieved in trailer aerodynamics and tire technologies.*** In the interviews, all of the component suppliers of aerodynamic and tire technologists spoke of their technology development activities and next generation products that will offer enhanced quality and fuel savings. One of the aerodynamic device manufacturers asserted that their next generation product, which will be released commercially in the next year, will offer roughly an additional 50 to 60% improvement in aerodynamic drag reduction over their current products. This and other anecdotes indicate that important innovations continue to materialize in trailer efficiency technology.

These findings provide evidence that the market for trailer fuel-saving technologies in Canada has matured considerably in recent years. The large majority of fleets surveyed are deploying at least one fuel-saving trailer technology, and for many of the fleets, the investments in various efficiency technologies and strategies are manifold. Though there are important challenges to adoption that persist, as the quality and economics of trailer technologies continue to steadily improve, we expect market forces to drive steady increases in penetration rates across Canadian trucking fleets of all sizes and business models. Moreover, one national regulation for trailers can help to accelerate the uptake of these known cost-effective technologies and also promote additional investment in the development and deployment of new generations of technologies for increasing the fuel efficiency of tractor-trailers.

1. INTRODUCTION

Globally, the on-road freight sector is responsible for a growing share of fuel consumption and greenhouse gas (GHG) emissions from the transportation sector. Various studies suggest that in the next 10 to 20 years, heavy-duty vehicles will overtake passenger cars as the leading contributor to energy use and climate-forcing emissions from transportation worldwide (International Energy Agency 2013; Exxon Mobil Corporation 2014). In North America and many other regions of the world, tractor-trailers are responsible for the majority of fuel consumption and GHG emissions from the commercial vehicle sector (Facanha, Blumberg et al. 2012). In 2011 in Canada, 24% of total Canadian GHG emissions came from transportation sources, and 7% of total emissions came from heavy-duty vehicles alone (Environment Canada 2014). The potential impact of widespread adoption of efficiency technologies in tractor-trailers is thus significant. Many efficiency technologies are commercially available to reduce the aerodynamic and rolling resistance drag of trailers, and the market for many of these technologies has changed dramatically since their introduction in the mid-to-late 2000s.

The rapidly changing landscape of trailer fuel-saving technologies in the United States (US) and Canada can be attributed to a number of factors. These include the improved economics, performance, and quality of efficiency technologies as well as increased awareness and acceptance within the trucking sector of the real-world benefits of these technologies. In the US, governments have also had an important role to play in the accelerated development and deployment of drag-reducing technologies for tractor-trailers.

Since its inception in February 2004, the US Environmental Protection Agency's (EPA) SmartWay program has aimed to create market-based incentives that challenge freight shipping and logistics companies to improve the environmental performance of their operations. One of the earliest and most influential elements of the SmartWay program has been the SmartWay Technologies Program, which focuses on technologies for reducing fuel use and emissions from tractor-trailers. Through the program, equipment and vehicle configurations that are tested and verified to have fuel consumption profiles at or above a given fuel efficiency value are granted *SmartWay* designation. In 2012, Natural Resources Canada began administering the SmartWay Transport Partnership in Canada that is designed to be fully aligned and complementary with the program in the US.

The regulatory program that has had arguably the biggest impact on accelerating the deployment of trailer fuel-saving technologies in the US is the California Air Resources Board's (CARB's) tractor-trailer GHG regulation, which is based heavily on the EPA's SmartWay technology verification program. This regulation, which was first adopted in late 2008 and formally finalized in 2009, is the first in-use GHG regulation for tractor-trailers in the world. There are mandatory tractor and trailer equipment specification provisions for any trucking fleet that operates tractor-trailers in California. The regulation is phasing in over this decade and will be fully implemented by 2020. Together, the SmartWay program and California's tractor-trailer GHG regulation have promoted the sale of thousands of fuel-saving products across the North America, which has driven down the unit costs for these technologies.

In order to better understand the market for trailer fuel-saving technologies in Canada and the experiences of Canadian trucking fleets, this study was commissioned by Environment Canada to investigate the costs and levels of adoption of aerodynamic and tire technologies for trailers. The overarching objective of the project was to gather technical information from a diverse set of stakeholders in the Canadian trucking sector and manufacturing community in order to augment the knowledge base around technologies that improve the aerodynamic and rolling resistance characteristics of commercial trailers.

The paper begins by describing the methodology that was used to gather and analyze data for this project. In this section there is also a description of the different stakeholder groups that participated in the study. Due to the sensitive nature of some of the information shared during the interviews, we do not attribute any of the data to a particular company and have kept all responses anonymous. The subsequent section first summarizes the findings with regard to costs and adoption rates of aerodynamic devices and then turns to technologies that reduce the rolling resistance drag in tires. Following the summary of the results from the interview responses, the concluding section synthesizes the key findings from the project and also presents some opportunities for future work to further investigate the market for trailer efficiency technologies.

2. METHODOLOGY AND PARTICIPANT PROFILES

Telephone interviews were used to collect data on purchase prices, maintenance impacts, performance levels, and adoption rates, as well as any additional noteworthy information about experiences with trailer technologies. The interviews were typically between 30 and 60 minutes and were completed between September 25th and November 7th. Derek May of Pollution Probe conducted all of the interviews and documented the responses. The interviewees for this study were either high-level managers or executives and were chosen based on their comprehensive knowledge of their company's business as well as the trucking industry as a whole.

The breakdown of the various stakeholders that were included in this study is shown in Table 1.[1] The following subsections provide brief descriptions of each of the stakeholder groups.

Table 1: Description of the stakeholder groups for the project interviews

Stakeholder Group	Number of interviews	Description
Trucking fleets	9	Medium and large for-hire and private fleets that operate between roughly 30 and 1,500 tractors and 150 and 3,500 trailers
Trailer manufacturers	3	Market leaders for many trailer types: dry, refrigerated, tanker, flatbed, etc.
Trailer dealership	1	Local dealership network for one of the leading trailer manufacturers in North America that sells, leases, and performs maintenance on a wide range of trailer types
Side skirt manufacturers/ suppliers	4	Three independent side skirt manufacturers as well as one trailer original equipment manufacturer that also makes side skirts
Underbody device manufacturers	2	Industry-leading suppliers of underbody devices
Boat-tail manufacturers	3	Industry suppliers of boat-tails
Tire and wheel manufacturers	1	International tire manufacturer that supplies both dual-size and wide base single tires and wheels for tractors and trailers

2.1. TRUCKING FLEETS

Of the 18 companies interviewed, half were trucking fleets. The nine trucking fleets include both for-hire and private fleets and are fairly diverse in terms of equipment ownership, geographic domain, and operating characteristics. These fleets own and/or operate between roughly 30 and 1,500 tractors and between 150 and 3,500 trailers. The average trailer-to-tractor ratio for these fleets is 2.7. As shown in Figure 1, most of these carriers own a large majority of the tractors and trailers that they operate, and each of the companies owns a slightly higher percentage of their trailers. Trailer ownership is 90% or more for all of the fleets that provided this data, which implies that these companies have almost complete autonomy to make purchase decisions around the technologies equipped on the trailers that they operate and will also reap the fuel savings benefits of any efficiency technology investments.

1 The values in the "Numbers of interviews" column sum to 23, though 18 companies were surveyed. Five of the companies fit into more than one stakeholder categories.

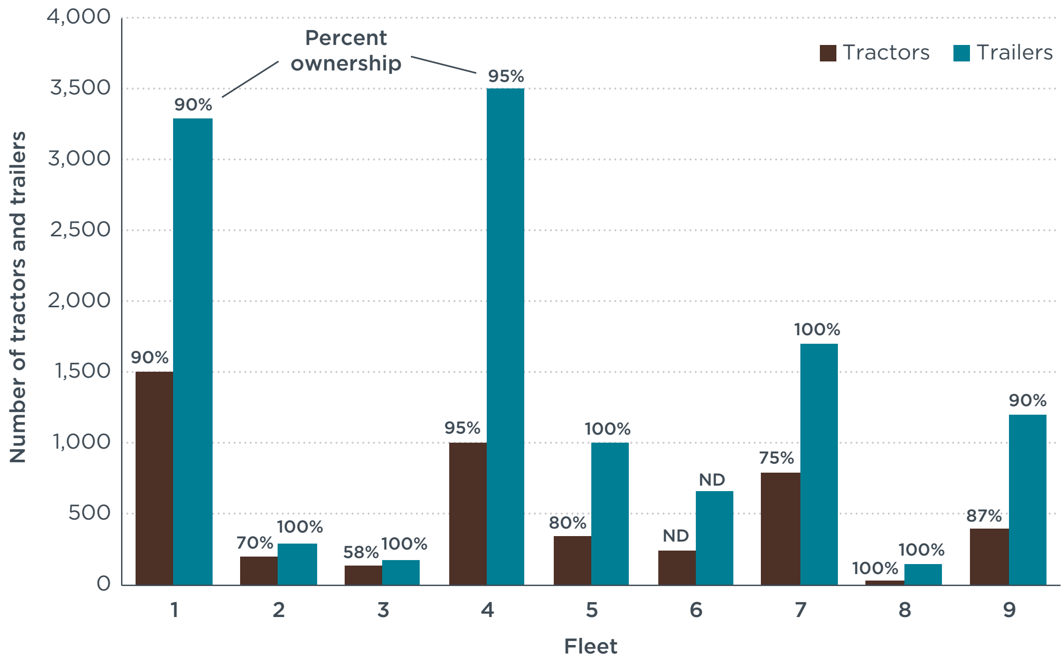

Figure 1: Number of tractors and trailers operated by each of the nine participating fleets. The values above each column represent the percent of equipment that is owned by that company, with the remaining portion of equipment leased. "ND" = no data.

Figure 2 summarizes the types of trailers operated by eight of the nine fleets. For six of the eight trucking companies, dry vans represent the majority of their trailer fleet, though refrigerated and non-box (i.e., any trailer that is not a dry van or refrigerated trailer) categories are reasonably well represented. For this study, the primary focus is on box-type trailers, which make up the majority of sales volumes in North America and likely represent the majority of fuel use within the tractor-trailer sector (R.L Polk & Co. 2012).

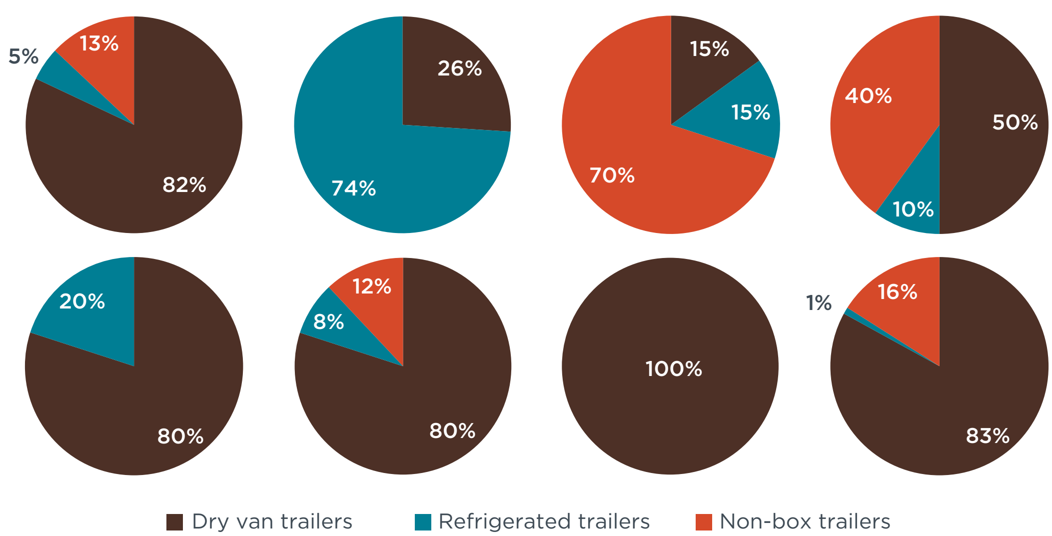

Figure 2: Breakdown of the types of trailer operated by each fleet

For both tractors and trailers, the level of activity in terms of annual kilometers traveled as well as the average ownership cycles was also collected from each of the fleets and are summarized in Figures 3 and 4, respectively. The fleets reported average tractor ownership between 4 and 8 years, and all of the fleets were found to keep their trailers longer, with responses ranging from 7 to 15 years. On average, tractors and trailers are kept for 5 and 12 years, respectively, before being sold to subsequent owners. In terms of activity, all of the fleets reported more average annual kilometers for their tractors compared to their trailers. Tractor activity data points ranged from 110,000 km to 200,000 km with an average of roughly 156,000 km, and trailer activity covered a slightly larger range from 40,000 km to 140,000 km with an average of roughly 79,000 km. This estimate of average annual trailer activity is used in Section 3 for the technology return on investment analysis.

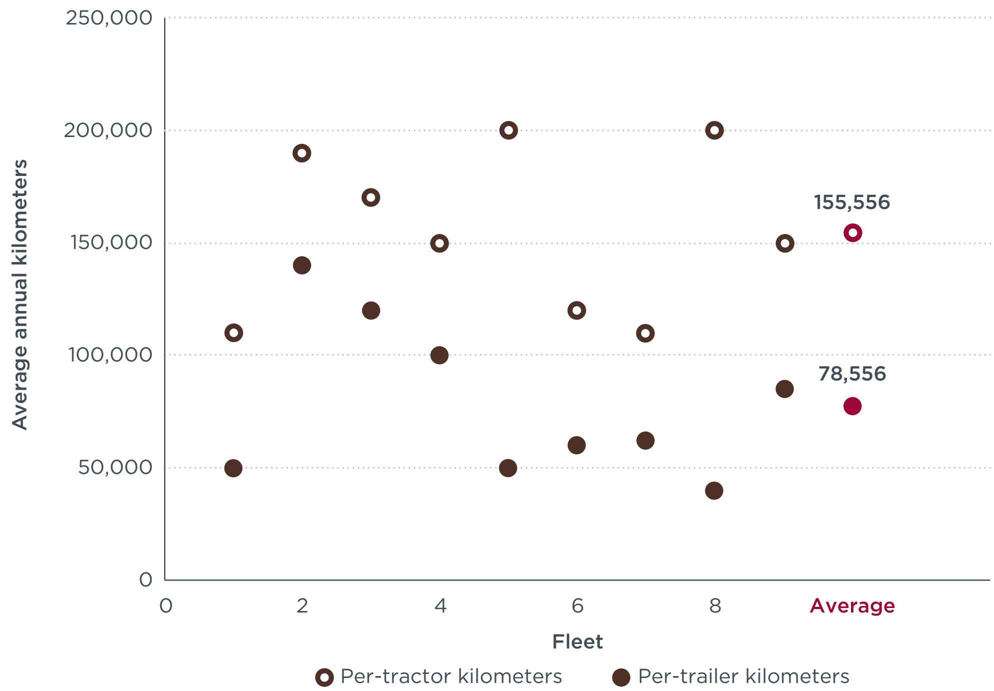

Figure 3: Average annual kilometers traveled for each fleet

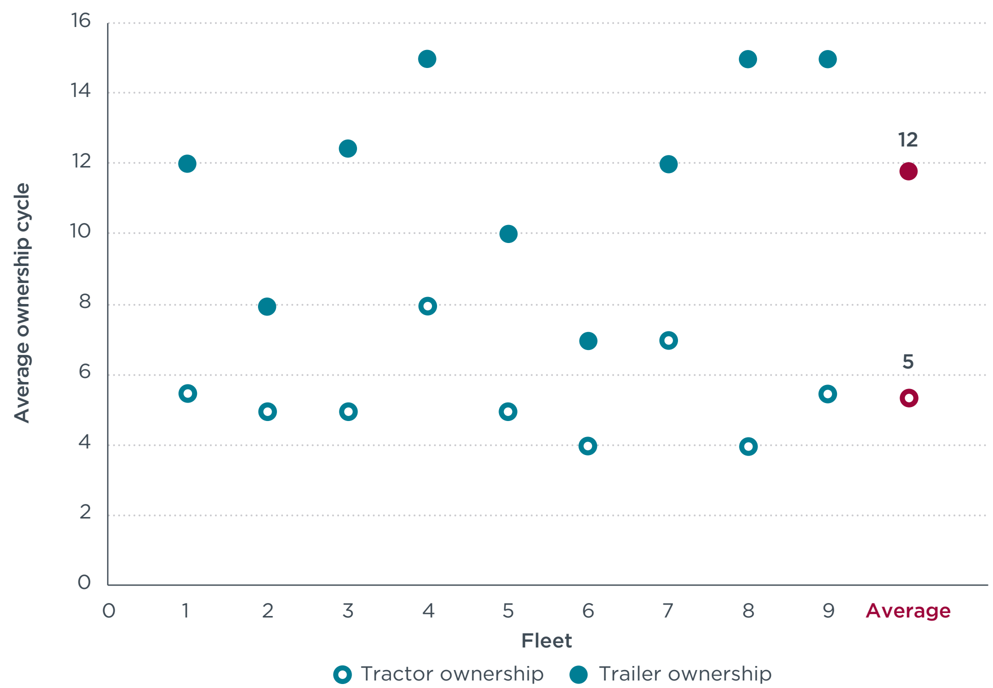

Figure 4: Average ownership cycles for each fleet

2.2. TECHNOLOGY AREAS OF FOCUS

The types of trailer technologies investigated in this study are shown in Figure 5. This includes four aerodynamic technologies: gap reducers, side skirts, underbody devices, and boat-tails. Technologies for improving tire performance include LRR duals, WBS tires, and tire pressure management systems. Though the focus of this study was on aerodynamic and tire technologies, lightweighting is an important technology for increasing the efficiency of trailers, and exploring the costs and current adoption rates of lightweight features is an area for future research. Other trailer technologies, which were not included in this study, but which were mentioned as technologies of interest by some of the fleets, include fuel efficient mud flaps and vortex generators.

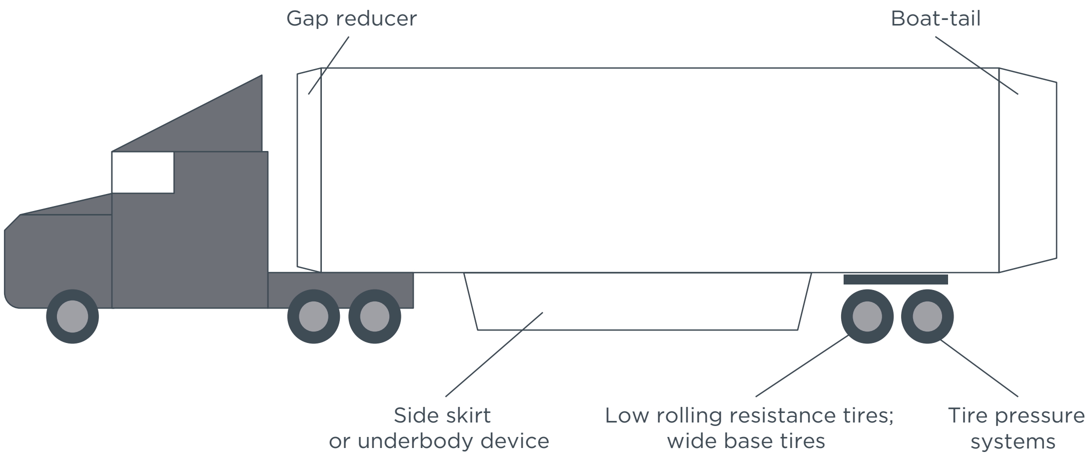

Figure 5: Trailer technologies investigated in this study

A data collection spreadsheet was created for each of the stakeholder groups and was populated over the course of the interviews. For each technology type, Pollution Probe recorded data on purchase prices (including installation costs), any impacts to maintenance costs, and estimated levels of adoption. Other relevant information on each technology such as the typical fuel savings, payback time, and barriers to adoption were also recorded. Given the diversity of the stakeholder groups, questions and areas of discussion were tailored for each particular interview. Moreover, rather than being a regimented set of questions, the interviews consisted more of loosely-structured conversations, and the participants were free to share information about and their unique experiences with fuel-saving technologies. As much of the requested information was sensitive and/or confidential, not all interviewees provided answers to all of the questions.

It should be noted that only factual information was solicited during the interviews and that interviewees were not explicitly asked for their opinions on the technologies. However, survey participants were free to share their views and experiences with trailer fuel-savings technologies and strategies over the course of the conversations.

The study was not designed to yield statistically relevant results or to provide definitive answers to questions about capital costs, fuel saving benefits, or levels of adoption for the Canadian market. However, sufficient information was obtained in order to make some generalized conclusions about the costs and adoption rates of most of the technologies of interest. These results are discussed in Section 3.

2.3. TRAILER MANUFACTURERS AND TRAILER DEALERSHIP

The three trailer original equipment manufacturers (OEMs) that participated in the study are in the top ten of trailer sales in North America, collectively representing approximately 40% of the commercial trailer market in the US and Canada (Trailer-bodybuilders.com 2014). Each of these manufacturers has a fairly diverse portfolio of trailer products, including dry vans, refrigerated trailers, tankers, and flatbed trailers. While all of these trailer manufacturers install aerodynamic devices, the type of tires and any other fuel-saving technologies are based on customer requests. One of the participant trailer OEMs also manufactures their own side skirts (this company is also included in the “side skirt manufacturers/suppliers” row in Table 1). In addition to these three trailer OEMs, the study team was also able to interview a trailer dealership. This dealership not only sells and leases a wide range of trailer types (this dealer is a dedicated affiliate of one particular trailer OEM) but also performs maintenance on all of these trailer products.

2.4. AERODYNAMIC TECHNOLOGY MANUFACTURERS

A total of seven aerodynamic component companies were interviewed: four are side skirt makers, two are underbody (or “undertray”) device suppliers, and three are trailer rear-end device (i.e. “boat-tail”) manufacturers. Two of these rear-end device manufacturers are actually trailer OEMs that are planning to begin manufacturing and selling boat-tails in 2015. All seven of these companies are active across the US and Canada and have their products listed on the EPA’s SmartWay Verified Technologies list (US Environmental Protection Agency 2014). One of the companies manufactures side skirts, underbody devices, as well as gap reducers.

2.5. TIRE TECHNOLOGY MANUFACTURER

For the final stakeholder group, tire and wheel manufacturers, the study team interviewed one company. This multinational corporation supplies tires and wheels to markets worldwide for both light- and heavy-duty vehicles. In the heavy-duty vehicle sector, this company’s products include *conventional* dual-sized tires, low rolling resistance (LRR) duals, and wide base single (WBS) tires. Both their LRR and WBS tire models are SmartWay verified (US Environmental Protection Agency 2014).

3. COSTS AND ADOPTION RATES OF TRAILER TECHNOLOGIES

3.1. AERODYNAMIC TECHNOLOGIES

For tractor-trailers traveling at highway speeds, aerodynamic drag and rolling resistance are generally responsible for the large majority of energy consumption, after accounting for losses in the engine. According to simulation estimates from a recent ICCT report, losses from aerodynamic and rolling resistance drag account for nearly 90% of total non-engine losses at highway speeds (Delgado and Lutsey 2015). As a general rule of thumb, at constant highway speeds and zero grade, a percentage point reduction in aerodynamic drag and rolling resistance yields roughly a half-a-percent and a third-of-a-percent reduction, respectively, in overall fuel consumption.

Looking at the tractor-trailer, there are four primary areas where aerodynamic drag occurs: 1) the front of the tractor, 2) the gap between the tractor and the trailer, 3) the sides and underbody of the trailer, and 4) the rear end of the trailer. Figure 5 illustrates that trailer technologies can be applied to the tractor-trailer gap, the side/underbody, and the rear end of the trailer. The following four sections summarize the interviewees' responses regarding side skirts, underbody devices, boat-tails, and gap reducers.

For all of the cost data, purchase prices are reported in Canadian dollars (c.f. $) unless otherwise specified.

3.1.1. Side skirts

From the interview responses from both the fleets and manufacturers, there was overall consensus that side skirts are the most widely used aerodynamic enhancement for trailers. Another key point from the conversations with fleets was that the reliability and durability of side skirts have much improved since their introduction in the mid-2000s, and none of the fleets cited any additional notable maintenance costs associated with skirts. Compared to boat-tails and underbody devices, side skirts have the longest commercial history and continue as the preferred trailer aerodynamic technology for the majority of trucking fleets.

As a result of the improved quality and economics of the technology, side skirts have seen rapid uptake over the past 5 years and represent the large majority of trailer aerodynamic technologies in use. A summary of survey responses regarding estimated adoption percentage of side skirts in new box trailer sales is shown in Figure 6. Four of the five manufacturers that provided penetration rate information estimate that approximately half of new box trailers are sold with skirts. Of the nine fleets surveyed, six are installing skirts on all of their new box trailer acquisitions. From these responses, the study team estimates that approximately 40 to 50% of new box trailers sold in Canada are equipped with side skirts.

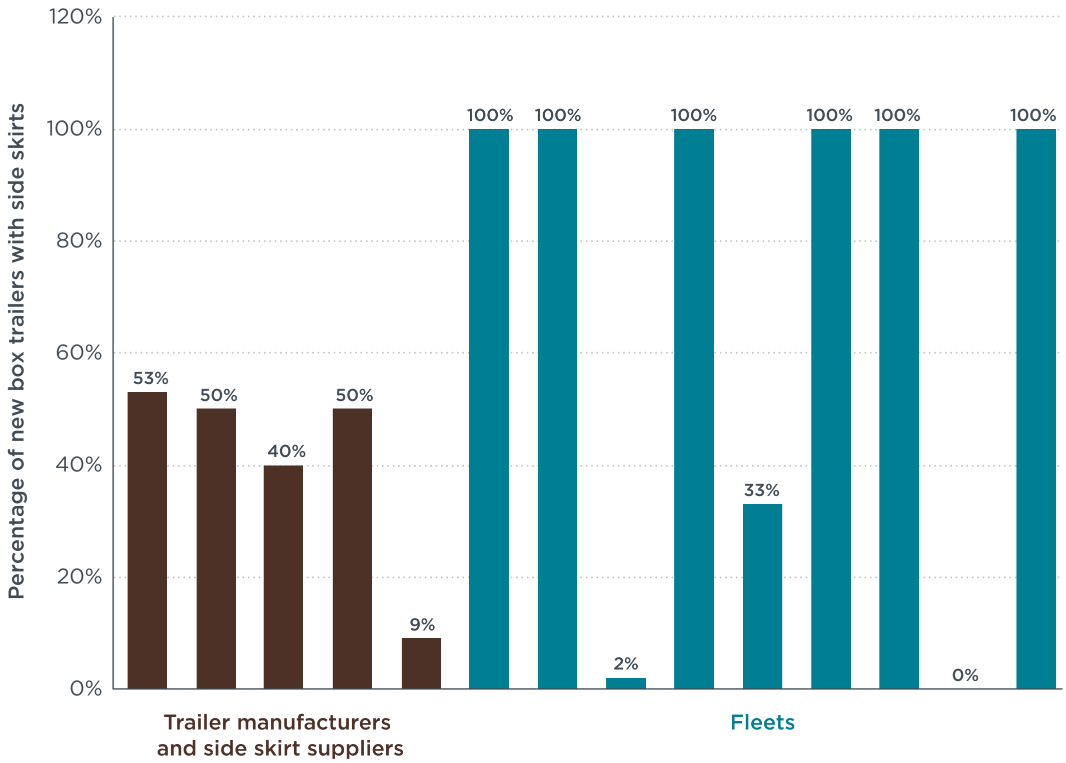

Figure 6: Survey responses on level of uptake of side skirts on new box-type trailers

As a result of the large-scale adoption of side skirts, purchase costs for this technology have dropped fairly substantially in recent years. Looking at estimates from the 2008 to 2010 timeframe compared to the ranges of purchase prices provided in the interview responses for this study, it seems clear that prices of trailer aerodynamic technologies have decreased significantly—especially for side skirts. A TIAX report (November 2009) and a National Academy of Sciences (NAS) report (March 2010) both thoroughly explored technologies for increasing the efficiency of medium- and heavy-duty vehicles in the US and Canada (Kromer, Bockholt et al. 2009; Committee on Assessment of Technologies and Approaches for Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles 2010). Much of the analysis from the TIAX study was used by the NAS Committee to develop their estimates for cost and technology efficacy. In their assessment of trailer technologies, TIAX and the NAS Committee estimated a cost range for full-length (i.e. 7 to 9 m) side skirts at 2,000 to 4,000 USD and 1,600 to 2,400 USD respectively. During the interviews, all of the stakeholder groups were asked to give their best estimate of the price of skirts, including installation, in both a high volume (i.e. lower price) and low volume (i.e. higher price) scenario, and the responses ranged from roughly $600 to $2,000 (~ 540 to 1,810 USD[2]). In Figure 7, the low-volume interview responses are shown with solid blue circles, and the high-volume estimates are shown with the hollow blue circles. The averages for the low- and high-volume points are slightly over $1,300 and $850, respectively.

2 In this study, conversion from Canadian dollars (c.f. $) to US dollars (USD) is done by taking a straight average of the monthly average Canadian-to-US rates for 2013 given here: http://www.x-rates.com/average/?from=CAD

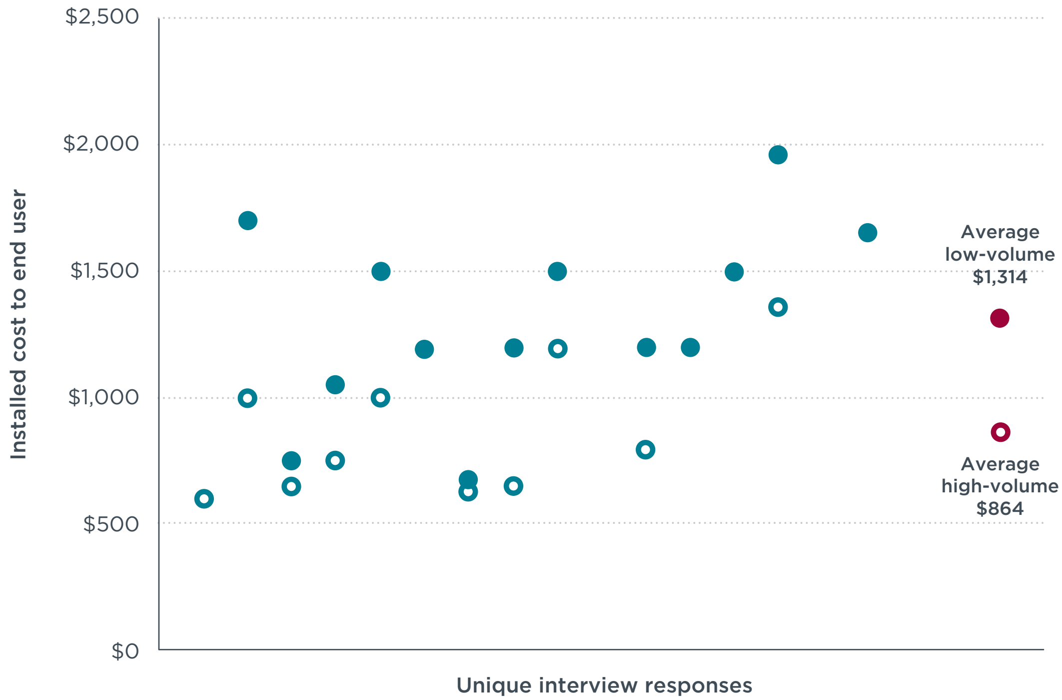

Figure 7: Survey responses on capital costs (including installation) of side skirts

For all 14 of the trucking fleets and manufacturers that provided data for the real-world fuel savings benefits of side skirts, responses ranged from 1% to 7%, with an average of 4%. Most of the fleets have had positive experiences with side skirts, though some said that their actual in-use fuel benefits are only half of the savings claimed by the skirt suppliers. These fleets cited the fact that these technologies are typically tested and verified at constant highway speeds, but over more realistic drive cycles, efficiency improvements are smaller than advertised. Only one of the fleets reported having no experience with side skirts on their trailers. This particular fleet's reasoning was that since they mainly had short-haul and lower-speed routes, skirts would just represent additional weight and only negligible fuel savings. However, the general consensus from the majority of respondents was that side skirts are a proven, mature technology that can offer cost-effective fuel savings for the majority of trucking carriers and that uptake of this technology will continue to expand.

When asked about typical payback times, answers generally ranged from less-than-a-year to two years. The time needed for a technology to save enough money to offset its initial purchase price depends on a number of factors, including kilometers traveled, fuel-saving benefits of the technology, the price of fuel, and any additional maintenance costs that might be incurred as a result of the technology. Another point that was made by many of the fleets was the fact that they generally keep trailers for a period that is, on average, about twice as long as tractors before selling them to secondary users (see Figure 4). Ownership cycles are critical parameters in the decision to adopt a fuel-saving technology, as the longer a fleet owns a truck or trailer, the more time is available to make a return on the initial investment.

Table 2 presents some simple payback calculations using the ranges for side skirt fuel savings and purchase prices from the interviews as well as some reasonable assumptions for the initial fuel consumption rates of tractor-trailers and the average diesel price in Canada (Natural Resources Canada 2014). The value 78,556 kilometers was derived by averaging the data points that each of the nine fleets reported. Using the most optimistic scenario (i.e. low purchase price and 7% fuel savings) yields a payback time of 4 months, while the most conservative estimate results in a payback time of nearly 4 years. No maintenance costs are used in this example, since none of the fleets reported any increased operational expenses associated with using skirts. The "best estimate" capital cost of $1,089 is the straight average of all of the low- and high-volume cost reported by the fleets and manufacturers that provided data. Similarly, the fuel savings value of 4.2% was calculated by averaging all of the interview responses about the real-world benefits of side skirts. With these "best estimate" inputs, the resulting payback time is 9 months.

Table 2: Estimates of fuel savings and payback times for trailer side skirts using the capital cost and technology efficacy ranges given by respondents in this study

	High capital cost, low fuel savings	Best estimate capital cost, average fuel savings	Low capital cost, high fuel savings
Annual trailer activity		78,556 kilometers	
Initial fuel efficiency		36.2 l/100 km (= 6.5 mpg)	
Annual fuel use		28,453 liters	
Average 2014 diesel price		$1.35/liter (= 4.63 USD/gallon)	
Fuel savings	1.0%	4.2%	7.0%
Annual fuel savings	285 liters	1,192 liters	1,990 liters
Annual cost savings	$348	$1,456	$2,434
Technology capital cost	$1,314	$1,089	$864
Payback time	45 months	9 months	4 months

3.1.2. Underbody devices

An underbody (or undertray) fairing is a separate device that consists of a surface angled downward under the body of the trailer, directing the air beneath the axle tubes. Underbody devices are an alternative to side skirts, and one of the primary advantages is that this technology does not impede a driver or technician's access to the side and underbody of the trailer for inspection and maintenance. Moreover, suppliers of this technology posit that while side skirts can limit the breakover angle and can be damaged on humps or railroad tracks, underbody devices are generally more durable.

This technology has had much less time in the market than side skirts, and as a result, uptake is more limited. In addition, there are significantly fewer manufacturers building these types of products. A common theme to emerge from the conversations with fleets is that the adoption of underbody devices in Canada has been limited in large part due to unfavorable testing results from Performance Innovation Transport (PIT), which leads consortium-based technology verification campaigns through its Energotest program at its test facility outside of Montreal. A PIT report from 2013 suggested that underbody devices are less effective than side skirts (Park 2013). From the interviews with fleets, it is clear that some trucking companies are not pursuing underbody devices due to this report and the resulting word-of-mouth within the trucking community thereafter. However, not all of the survey participants were confident in the PIT results and commented that their test methods and conclusion deserve more scrutiny.

All of the fleets that were interviewed were familiar with underbody fairings, though only a few have actually installed these devices on their trailers. Of those fleets with underbody systems in operation, reported fuel savings ranged from 1% to 6%, with an average of 3%, which is slightly less than what was reported for side skirts. Five interviewees provided purchase price estimates for this technology, with responses ranging from roughly $650 to $1,650 (these values include low- and high-volume estimates). Figure 8 shows the data points from the interview responses as well as the average for a low-volume purchase ($1,217) and high-volume purchase ($967). Low-volume data points are shown with the solid blue circles, and high-volume points with the hollow blue circles.

Using an identical payback time estimation methodology as was done for side skirts, the optimistic (i.e., 6% fuel savings, $967 purchase price), “best estimate” (i.e., 3.2% fuel savings, $1,092 purchase price), and conservative (i.e., 1% fuel savings, $1,217 purchase price) inputs yield results of 6, 12, and 42 months respectively.

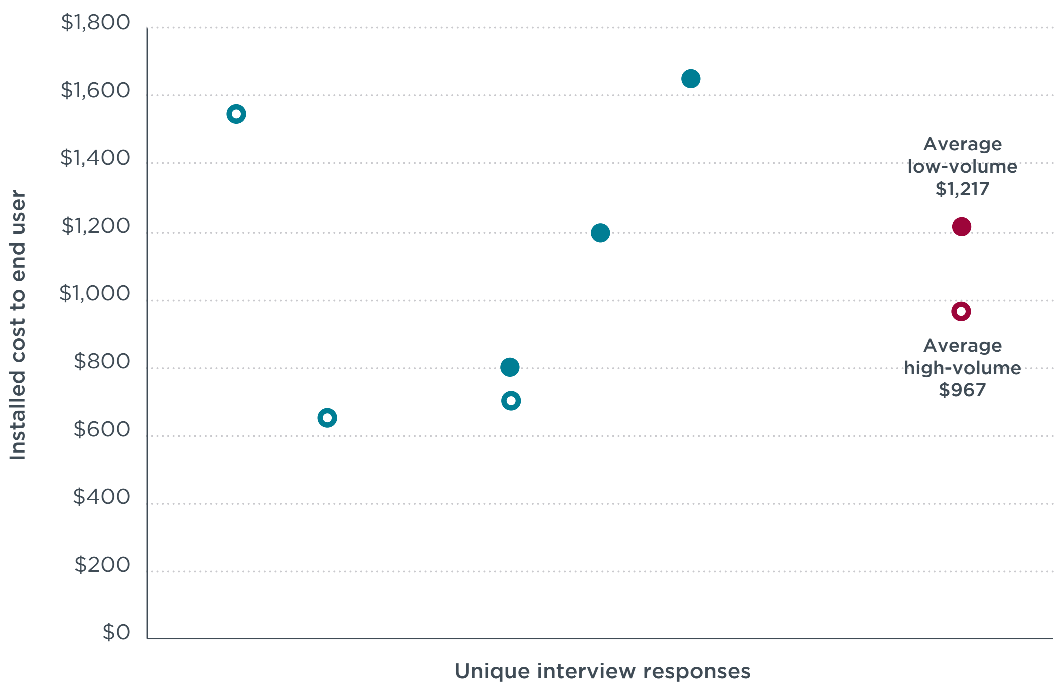

Figure 8: Survey responses on capital costs (including installation) of underbody devices

3.1.3. Boat-tails

While skirts and underbody fairings help control air flow around the side and underneath the trailer, rear-end devices (or “boat-tails”) decelerate the air passing over the roof and/or sides of the trailer and reduce losses in the wake. One of the simplest designs offers two panels, positioned in a similar fashion to trailer doors, which are three-quarters open, extending about three feet behind the trailer. However, the vast majority designs that have been commercialized also include a top panel (i.e., a three-panel design), which contributes to additional aerodynamic drag reduction and fuel savings. Certain boat-tail systems also include a fourth bottom panel. The intent of all rear end devices is to keep the boundary layer attached to these fairings, and to regain pressure by slowing the air to the rear of the trailer sides. Inflatable versions exist, where three panels resemble air mattresses. Several total rear enclosure designs exist, all being "bubbles" or distorted hemispheres. All seek to reduce the trailer tail diameter over three or four feet to the aft of the trailer doors. One drawback is that typically these devices must be deployed manually by the drivers, which many of the fleets reported as being a barrier to increased adoption, since it seems that the majority of fleets prefer *passive* technologies such as skirts, underbody devices, or gap reducers that generally do not require driver intervention. However, newer generations of boat-tails are offering the option to automatically deploy once the tractor-trailer exceeds a certain speed.

As with underbody devices, sales of rear-end fairings have been much less than side skirts. One reason for their limited adoption to date is that boat-tails are a relatively new technology compared to side skirts. However, one message from the interviews is that tractor-trailer provincial and territorial length regulations restricting the use of such rear-end fairings have been the biggest factor in impeding uptake of boat-tails. In August 2014, Ontario became the first province in Canada to allow longer boat-tails (Global Trailer Magazine 2014). In October 2014, the Council of Ministers Responsible for Transportation and Highway Safety approved amendments to the provincial and territorial Vehicle Weight and Dimensions Memorandum of Understanding, which include an increase in the allowable size of aerodynamic devices on the rear of trailers to 1.52 m (5 ft.). Further to Ontario, New Brunswick recently allowed longer rear-end devices, and such rear devices can also be used in Nova Scotia under permit. While more time may be required for regulatory or policy changes to be made in other jurisdictions, one of the aerodynamic technology manufacturers remarked that sales in Canada have surged since this policy revision, and they are expecting further acceleration in adoption once other provinces and territories begin to follow suit.

As result of the regulatory situation, only a subset of the fleets interviewed is currently operating trailers that have rear-end fairings. Of those fleets using three- or four-panel boat-tail systems, fuel savings cited were between 1% and 6%, with an average of 4%. Six of the interviewees provided purchase price estimates for this technology, and responses ranged from $1,000 to $2,300. The scatter of cost data on boat-tails is shown in Figure 9. Low-volume data points are shown with the solid blue circles, and high-volume points with the hollow blue circles. As before, combining the average low-volume cost estimate ($1,700) with the lowest reported fuel savings value (1%) in the return on investment calculation yields a conservative payback time of nearly five years. The optimistic (i.e., 6% fuel savings, $1,267 purchase price) and "best estimate" (i.e., 4.0% fuel savings, $1,483 purchase price) inputs yield results of 7 and 13 months respectively.

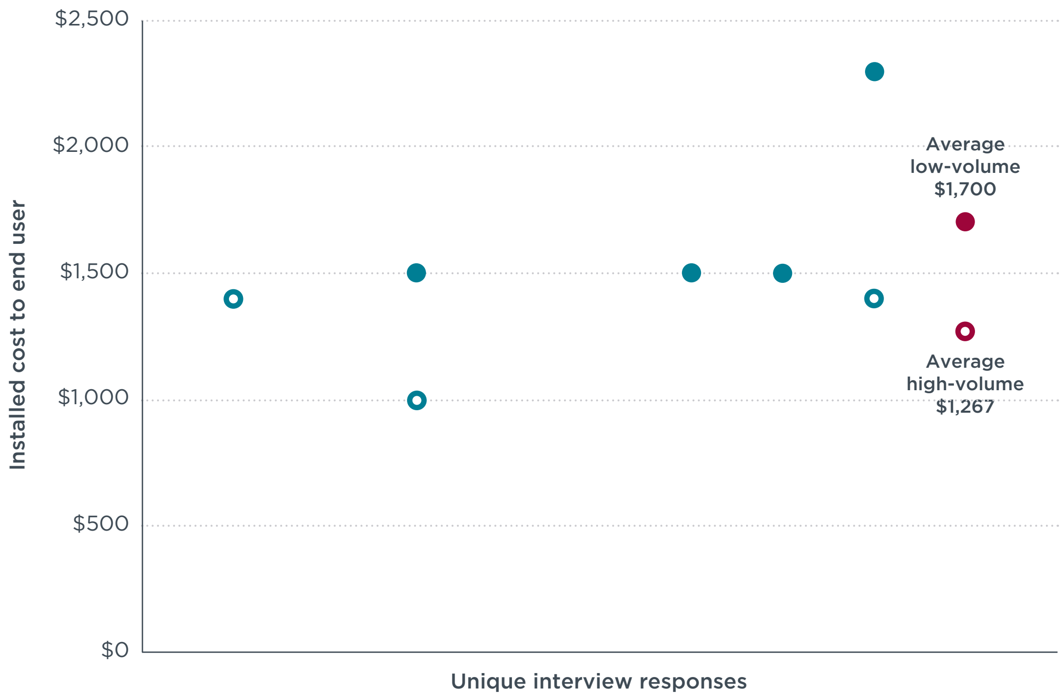

Figure 9: Survey responses on capital costs (including installation) of boat-tails

3.1.4. Gap reducers

A trailer gap fairing is typically a rounded protrusion at the leading edge of the trailer, which may serve to offset losses associated with flow disruptions and pressure differentials in the gap between the tractor and the trailer. Of the trailer aerodynamic technologies currently available, it was clear from the interviews that gap reducers have had the least adoption. Two key themes emerged in the conversations about this technology: 1) the elongation of tractor roof and side extenders has limited the effectiveness of gap reducers mounted to trailers and 2) fleets are much more likely to adjust the kingpin position in order to pull the tractor and trailer closer to one another.

In spite of the lack of uptake to date, one of the aerodynamic technology manufacturers disclosed that they are investing in research and development work to improve the performance of their gap reducers. Given all of the advances in tractor aerodynamics and operational measures to decrease gap distance, it remains to be seen whether or not there will be an uptick in demand for newer generations of gap reduction technologies.

Given the lack of adoption amongst the fleets, only two manufacturers provided data on purchase costs. These two respondents gave high-volume estimates of $600 and $650 for an average of $625. Since none of the survey participants provided a low-volume cost estimate, we used the average value reported from our US study ($1,100 USD) for the payback calculations. The "best estimate" value of $813 was derived by averaging $625 and $1,000 (i.e., 1,100 USD ≈ $1,000). Four interviewees gave answers on typical real-world fuel savings, and they ranged from 1% to 3%, with an average of 2%. Combining these conservative, "best estimate," and optimistic inputs for purchase price and fuel savings rate yields payback times of 35, 15, and 7 months respectively.

3.2. ROLLING RESISTANCE TECHNOLOGIES

The energy losses in tires occur both in the tread and in the sidewalls. Both the tread area and the sidewalls can be designed to absorb less energy, thereby reducing the coefficient of rolling resistance (C_{RR}). This may include a choice of various elastomers, arrangement of belts and reinforcement, and tread design. As a result, there are low rolling resistance (LRR) tires in the marketplace that can be used for tractor steer and drive tires as well as in trailer applications. Further reductions in tire rolling resistance may be gained by using wide base single (WBS) tires. A WBS tire can carry high load and be substituted for a dual tire set. Reduction in drag occurs because there are only two sidewalls to flex rather than four, and the energy associated with deformation is reduced. In addition, the rotational inertia is reduced by use of a WBS tire and wheel, leading to reduced energy loss to friction braking in highly transient operations. Furthermore, there are weight savings of approximately 45 kg (100 lbs.) per wheel end associated with the use of WBS tires (Committee on Assessment of Technologies and Approaches for Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles 2010).

In addition to improved tire designs, automatic tire inflation and air pressure monitoring systems can also lower rolling resistance by helping drivers operate their tires at optimum pressure. Rolling resistance is strongly related to the air pressure in the tire, increasing steadily as tire pressure decreases beyond the manufacturer's recommended inflation pressure. According to Goodyear, the approximate relationship is that every 10-psi under-inflation results in 1% poorer fuel economy (Goodyear Tire & Rubber Company 2014).

The following two sections summarize the interviewees' responses regarding LRR tires and tire pressure systems.

3.2.1. Low rolling resistance tires

From all of the stakeholder interviews—and particularly those with the trucking fleets—it was evident that dual-sized LRR tires and retreads are widely accepted for a number of trailer types and most hauling applications. Data provided by the tire manufacturer and the fleets suggest that the majority of all tires sold to the tractor-trailer industry are SmartWay-verified LRR tires. However, penetration rates of WBS tires have been much lower to date. A summary of the response data for LRR and WBS tires is shown in Figure 10. From the trailer OEMs, all of the respondents reported that 80% or more of new box trailer sales are sold with LRR tires. For the fleets, there was a dichotomy in the responses about adoption of LRR tires. In the five fleets that provided data, three are installing LRR tires on all new trailer purchases, but the other two are not using LRR tires at all. The adopting fleets gave accounts of positive experiences with LRR tires, citing that the tractor-trailer tended to run smoother, and there were decreased maintenance costs as a result. For the non-adopters, weather was the significant barrier, as they said that LRR tires do not offer enough traction in heavy snow and ice conditions. This anecdotal evidence seems to comes at odds with recent experimental evidence that demonstrated that the current generation of LRR tires can offer similar levels of snow traction performance as conventional tires (Chuang 2012).

As shown on the right side of Figure 10, five fleets provide information about their adoption rates of dual-sized LRR tires, and seven reported on uptake of wide base single tires. From the trailer OEM responses on LRR and WBS tire sales in new box trailers, it seems that LRR tires are much more commonplace than WBS tires, though this is not necessarily reflected in the adoption rate data reported by fleets. In the far right of the figure, three of the seven fleets that provided data on WBS tires are installing WBS tires on all of their new box trailer purchases. Only one fleet that was interviewed reported that they are installing both LRR and WBS tires. This particular fleet is currently equipping 90% of its new box trailers with LRR tires and the remaining 10% with WBS tires.

For the non-adopters of WBS tires, there were two reasons that were cited: 1) provincial and territorial regulatory limits for axle weights when operating with WBS tires and 2) the risk of being stranded in a tire blowout situation. Across the majority of conversations with fleets, there was a strong sentiment that the provincial and territorial lower axle weight limits—particularly in the western provinces—are a significant factor in impeding the penetration of WBS tires. One fleet said that using WBS tires would cut their maximum payloads by 5,000 pounds. In addition to regulatory challenges, a few of the fleets held that the risk of being stranded for an extended period of time after suffering a WBS tire blowout was reason enough to stay with conventionally-sized tires. Yet a different fleet interviewee said that this fear of being stranded is overblown for WBS tires. Some of the fleets and trailer OEMs contended that WBS tires are only attractive to fleets that are looking to decrease trailer empty weights and that dual-sized LRR tires can offer comparable fuel savings. Looking at the four trailer OEM responses regarding WBS tire uptake, we estimate that 5 to 10% of box trailers in Canada are being sold with WBS tires.

Compared to aerodynamic technologies, the respondents gave less definitive answers about the incremental costs and payback times associated with LRR and WBS tires. Fleets asserted that one of the problems with tire comparisons is there are many variables that must be isolated or eliminated to allow for an effective comparison. For example, factors like inflation levels and tire alignment need to be comparable between the sets of tests with and without the LRR tires in order to minimize the skewing of the results. Another complication with evaluating tires is that tire life is commonly cited as being shorter for LRR tires (Sharpe and Roeth 2014). Often, there are competing forces at work: the LRR tires can save fuel, but tire replacement will often need to happen more quickly. The fleets also said that the use of LRR and WBS tires can further complicate the evaluation, since maintenance costs can be smaller than when using a standard dual-tire configuration. Due to these and other factors, it was evident from the interviews that determining the extent to which LRR and WBS tires save fleets fuel and money is more challenging than the case for trailer aerodynamic technologies. Despite these measurement challenges, most of the respondents reported that LRR duals and WBS tires for trailers generally provide 1-3% and 2-5% fuel savings respectively. However, due to the somewhat inconclusive data on the incremental costs, the authors have elected to forgo assigning a range of payback times for LRR dual or WBS tires.

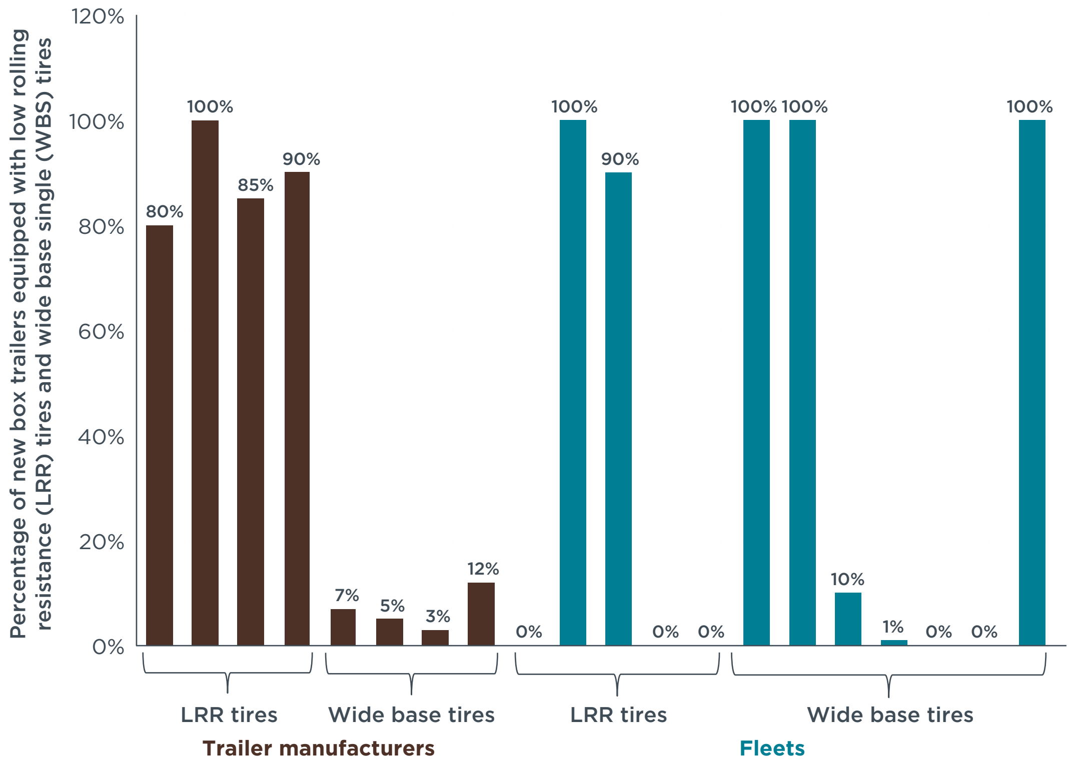

Figure 10: Survey responses on level of uptake of low rolling-resistance tires

3.2.2. Tire pressure systems

Inflation is a pivotal factor in determining the rolling resistance of tires. For trailers, there are two types of tire pressure management systems: tire pressure monitoring systems and automatic tire inflation systems. While tire pressure monitoring systems simply report inflation information to the driver using an alert console in the truck cabin and do not add air to an underinflated tire, these systems provide the most extensive and flexible reporting of actual tire conditions to the driver and are able to warn users about all the types of air losses that may be occurring. On the other hand, an automatic tire inflation system can restore air to tires (with different systems capable of handling different levels of underinflation), but such systems usually do not report the actual inflation pressure in any given tire.

Both the fleets and tire manufacturers emphasized that trucking companies are increasingly interested in installing tire pressure management systems—not only for the improved fuel efficiency but, perhaps more importantly, to improve safety and increase tire life. Some of the fleets contended that the automatic inflation systems are preferred over the monitoring systems because the inflation systems are *passive* and do not require intervention from the driver. However, this view was not shared by all of the fleets, and some respondents said that vigilant maintenance and manual air pressure monitoring schedules by drivers and technicians eliminate the need for tire pressure systems. The responses on adoption percentages in new box trailer sales are shown in Figure 11. Four total fleets provided uptake information about tire pressure systems. Only one fleet reported that they are installing both monitoring-only and automatic inflation systems. This fleet is currently installing each technology on 10% of its new box trailer purchases (i.e., 20% of their total new box trailers have tire pressure management technology installed). Based on the somewhat limited information provided by a subset of the trailer OEMs and fleets, we estimate that monitoring systems are currently being installed on between 5 and 15% of new box trailers, and automatic inflation systems are installed on 20 to 30% of new trailers.

Only one participant provided data as to the additional costs of monitoring-only systems: a low-volume cost of $300 and a high-volume cost of $200. None of the fleets or manufacturers gave fuel savings estimates for monitoring-only systems. Based on the response data from the US study, if we assume conservative and optimistic fuel savings percentages of 0.5% and 1%, respectively, the payback times for monitoring-only tire pressure systems range from less than a year to nearly two years. For automatic inflation systems, responses on additional costs ranged from $800 to $1,360, and fuel savings were cited as being between 1% and 2%. Using these data as inputs results in a conservative payback time of over seven years and an optimistic period of just over one year.

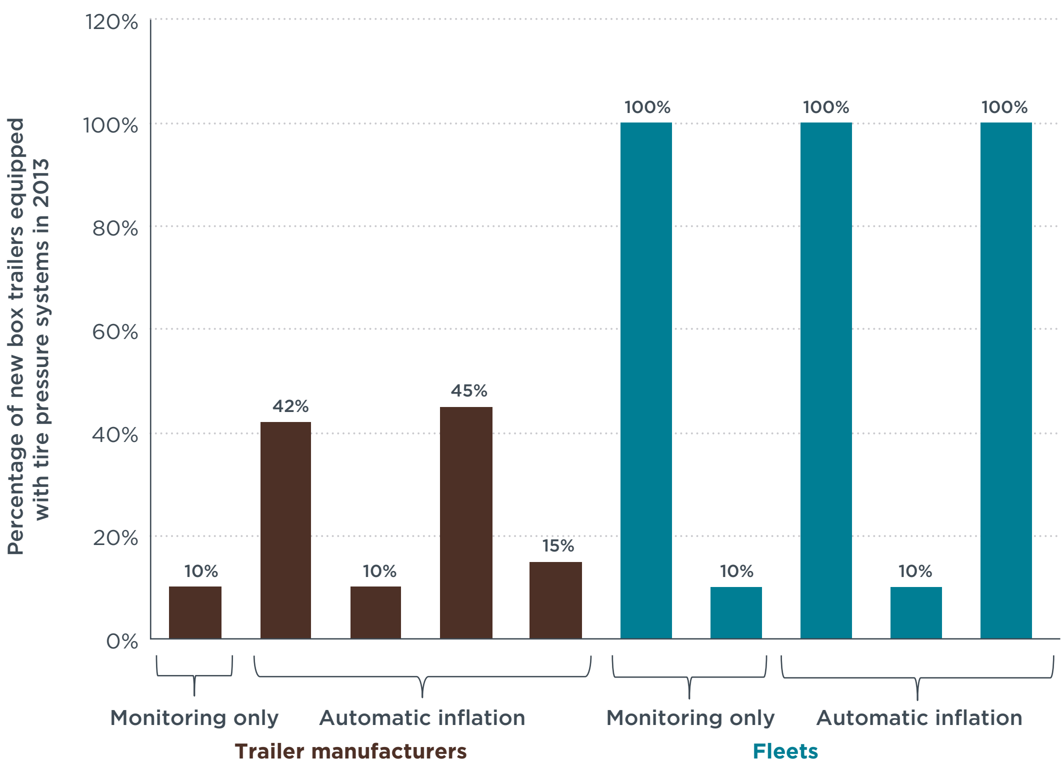

Figure 11: Survey responses on level of uptake of tire pressure systems

4. CONCLUSIONS AND FUTURE WORK

The primary objective of this study was to better understand the current costs and adoption rates of a number of fuel-saving technologies for commercial trailers in Canada. By interviewing a variety of trucking fleets and equipment manufacturers, the study team was able to amass a diverse cross-section of data points on technology costs and level of uptake as well as opinions about technology efficacy and barriers to wider adoption. Though we cannot draw any statistically significant conclusions about trailer technology costs or sales rates from our somewhat limited survey of the industry, the interviews with 18 companies have allowed us to build up the knowledge base in this area and outline areas for future work.

From the interview responses, the most comprehensive data was on incremental costs and fuel savings for aerodynamic devices. Figure 12 summarizes these data in terms of the range of real-world fuel savings estimates provided by the survey participants as well as the study team's calculations for each technology's payback time based on the ranges of responses provided. Across the various aerodynamic improvement technologies, the interviewees cited per-vehicle fuel benefits between 1% and 7%. The average fuel savings values for all of the survey responses for each technology are shown with the white circles with red borders. Using these data points, the study team then estimated payback times. The low-end percentage fuel savings estimates were paired with the high-end capital cost estimates to yield "conservative" results; high-end fuel savings values with low-end cost estimates to give the "optimistic" numbers; finally, "best estimate" payback times were generated by matching the average fuel savings and incremental cost values.

It should be noted that certain fleets in the US and Canada are combining trailer aerodynamic technologies for increased fuel savings. For example, side skirts and boat-tails are highly complementary, as each technology impacts a different air-flow area of the trailer (i.e., the side and underbody versus the rear end of the trailer). While the combined fuel savings are generally more than what each individual device provides, the total benefits are typically not simply additive in terms of percent fuel savings. For example, combining a 5% fuel savings side skirt with a 5% fuel savings boat-tail will likely result in fuel savings on the order of 8% to 9% (rather than 10%) due to complex air flow interactions (National Research Council Canada 2012; Lutsey, Langer et al. 2014).

There were not as many definitive responses about the incremental costs and expected payback times of low rolling resistance (LRR) and wide base single (WBS) tires. Given this lack of cost data combined with some conflicting comments about the lifetimes of LRR and WBS tires compared to conventional tires, the study team is abstaining from making any payback conclusions about these tire technologies.

Tire pressure management systems seem to be gaining in popularity, as fleets are increasingly seeing the safety and fuel savings benefits of these technologies. At present, automatic tire inflation systems, which do not require driver intervention, seem to be more popular than monitoring-only systems. Based on the interview responses, costs for both of these types of systems seem to be lower than for aerodynamic devices, and with fuel savings on the order of 1% to 2%, trucking fleets expect each of these technologies to payback within two years.

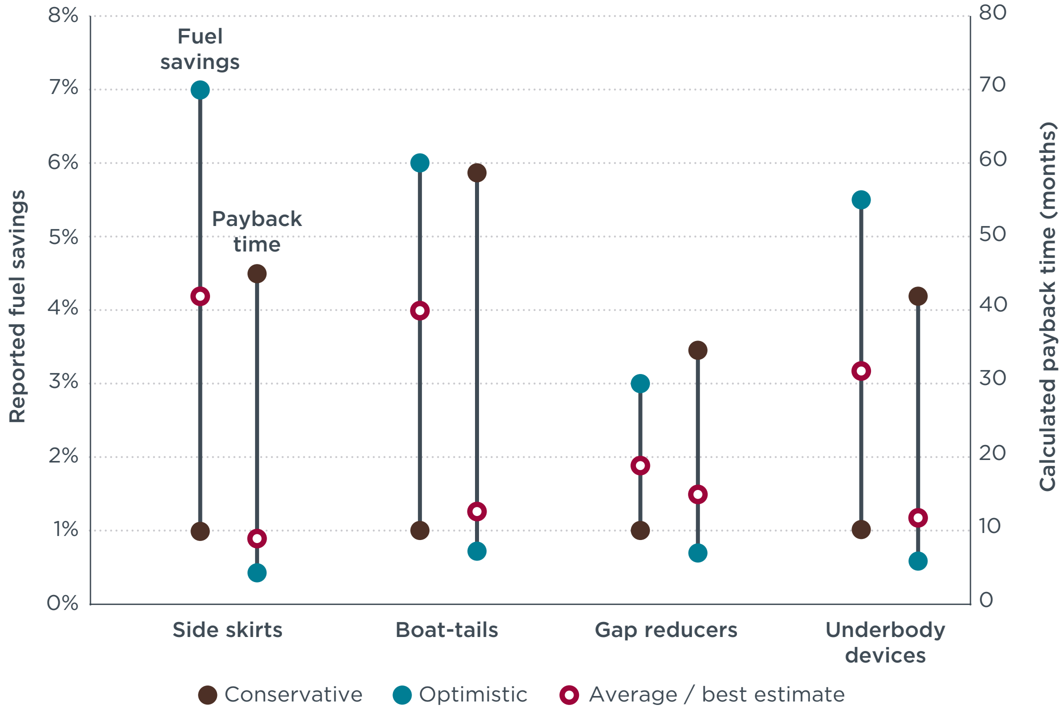

Figure 12: Ranges of reported fuel savings and calculated payback times for aerodynamic technologies

Figure 13 shows our estimates of the current adoption rates of aerodynamic and rolling resistance technologies in new trailers based on our synthesis of all of the interview responses. Our results indicate a large disparity in the penetration levels of these technologies. At the one extreme, the adoption of gap reducers is somewhat negligible, and at the other end, side skirts and LRR dual-sized tires are being sold on half or more of new dry van and refrigerated trailers. Though all of the respondents were confident that sales of side skirts, boat-tails, underbody devices, and tire technologies would continue to expand primarily as a result of favorable economics and improved product quality, there was uncertainty as to what the saturation point would be for these technologies in the absence of policy action designed to increase their deployment.

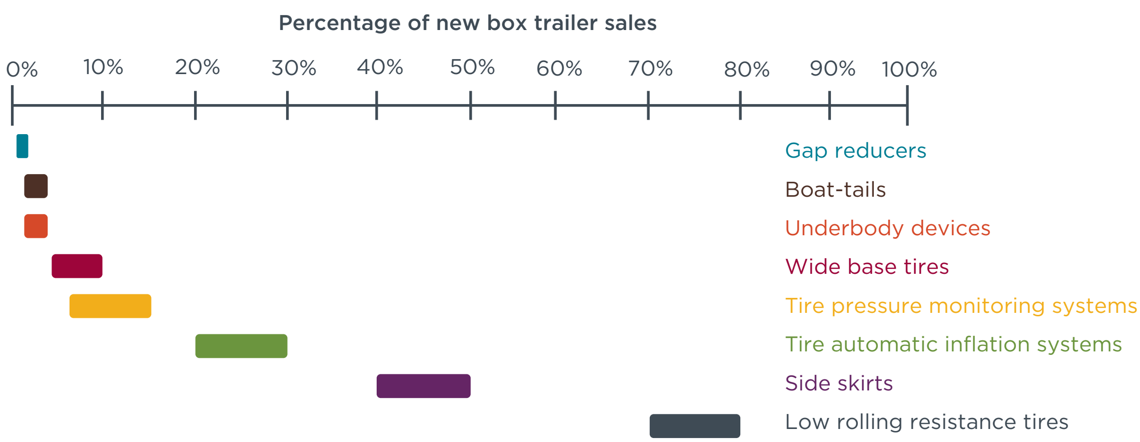

Figure 13: Summary of interview responses on trailer technology adoption

Table 3 summarizes the ranges of responses regarding technology efficacy, capital costs, payback times, and current adoption levels. For each individual technology, fuel savings are generally between 1% and 7%, and capital costs range from $700 to $2,200. The participants' responses regarding average payback times ranged from less than a year to 5 years, which corresponds well with the results from our simple payback calculations using the capital cost and fuel savings ranges reported in the interviews.

Table 3: Summary of interview responses on trailer technology costs and level of adoption

Technology	Average fuel savings	Installed cost			Typical payback time	Estimated adoption in new box trailer sales
		Low	Average	High		
Side skirts	4%	$600	$1,100	$1,960	1–2 years	40-50%
Underbody devices	3%	$650	$1,100	$1,650	1–2 years	< 2%
Boat-tails	4%	$1,000	$1,500	$2,300	1–3 years	< 2%
Gap reducers	2%	$600	$625	$650	1–3 years	< 1%
Low rolling resistance dual-sized tires	2%		Data on costs and payback time inconclusive			70-90%
Wide base single tires	3%		Data on costs and payback time inconclusive			5-10%
Tire pressure monitoring systems	0-1%	$200	$250	$300	1-2 years	5-15%
Automatic tire inflation systems	1-2%	$800	$1,000	$1,360	1-2 years	20-30%

The following are the key findings from the study:

1. ***Trucking fleets are adopting aerodynamic fuel-saving devices based primarily on economics, and the real-world payback is typically 12 to 18 months for most technologies***. Current costs for trailer aerodynamic technologies—particularly side skirts—have decreased significantly in recent years, due to far more market entrants driving cost competition and much higher deployment volumes reducing cost-per-unit. Falling purchase prices coupled with the improved quality and durability of products have motivated a large number of fleets to adopt these technologies. Most end users reported that they are recouping their initial investment in 12 to 18 months.

2. ***Amongst aerodynamic technologies, side skirts have had the largest rate of adoption, while the uptake of underbody, rear-end, and gap reduction devices has been more limited.*** Interview responses and sales data show that side skirts are the dominant trailer aerodynamic technology in Canada, with boat-tails and underbody devices making up a much smaller percentage of the market. Our study team estimates that approximately 40 to 50% of new box trailers are sold with side skirts. Uptake of both underbody and rear-end devices is estimated to be less than 2% of new box trailer sales, while sales of gap reducers have been fairly negligible, as most fleets are utilizing tractor side extenders or modified king-pin locations to minimize the tractor-trailer gap distance.

3. ***There is widespread utilization of conventional-size low rolling resistance tires, but adoption of wide base tires has been slower.*** From the interview responses of fleets, trailer manufacturers, and a leading tire supplier, we estimate that the majority (roughly 70 to 80%) of new box-type trailers are equipped with conventionally-sized low rolling resistance (LRR) tires. These LRR *duals* have seen much larger adoption than wide base single (WBS) tires, though some fleets

commented that they avoid LRR tires due to inferior performance in heavy winter conditions. For WBS tires, a number of fleets contended that the larger risk of being stranded in a remote location was the primary factor for avoiding these tires. Other fleets are of the view that LRR duals can achieve similar fuel savings as WBS tires, and fleets generally only consider WBS tires for the weight savings.

4. ***Trucking fleets are in favor of harmonization of size and weight regulation across the provinces.*** A common thread of feedback from many of the trucking fleets was that the difference in size and weight restrictions from province to province creates challenges in route planning and execution. Furthermore, it seems that the penetration of boat-tails and WBS tires has remained marginal due to some provincial and territorial restrictions. For boat-tails, this situation is changing, as in October 2014, the Council of Ministers Responsible for Transportation and Highway Safety approved amendments to the provincial and territorial Vehicle Weight and Dimensions Memorandum of Understanding, which include an increase in the allowable size of aerodynamic devices on the rear of trailers to 1.52 m (5 ft.). While regulatory or policy changes have not yet been made in all jurisdictions, Ontario and New Brunswick recently allowed longer trailer rear-end devices, and Nova Scotia allowed the use of such devices under permit. Many expect the other provinces to soon follow suit. The case of WBS is more complex, as some of the western provinces have reduced axle weight limits for tractor-trailers with WBS tires, and there was no clear indication from the interviews that there is policy in development to change this situation.

5. ***There are further improvements and efficiency gains that stand to be achieved in trailer aerodynamics and tire technologies.*** In the interviews, all of the component suppliers and aerodynamic and tire technologists spoke of their technology development activities and next generation products that will offer enhanced quality and fuel savings. One of the aerodynamic device manufacturers asserted that their next generation product, which will be released commercially in the next year, will offer roughly an additional 50 to 60% improvement in aerodynamic drag reduction over their current products. This and other anecdotes indicate that important innovations continue to materialize in trailer efficiency technology.

These findings help illustrate that there are a number of cost-effective efficiency technologies for trailers and that the market has changed fairly significantly in recent years. As technology deployment has accelerated, purchase costs have decreased, which continues to spawn additional adoption.

This project was a collaboration between the ICCT and Pollution Probe and will provide data that assists Environment Canada and other policymakers across North America in their evaluation of policy measures for trailers. If and when regulators in the US and Canada develop policy measures for trailers, they can use data and information from this report to help inform estimates of the costs and benefits of any regulatory action for trailers. In addition, this study suggests that there are sizable additional efficiency gains that can be achieved in trailer fuel-saving technologies, and regulation can play a critical role in accelerating the development and deployment of these new innovations and next generation products. Finally, this study has assisted in highlighting knowledge gaps and areas for further research. Some of these areas for future work include a more comprehensive look at weight reduction technologies as well as fuel-saving technology costs and applicability for non-box trailers.

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