



TRUCKING EFFICIENCY CONFIDENCE REPORT: Trailer Aerodynamics Executive Summary

The fuel costs faced by the tractor-trailer industry have been swiftly and steadily rising over the past decade. In 2014 diesel fuel costs were \$0.58 per mile, costing the industry as much per annum as the costs of drivers' wages and benefits combined. Despite recent fuel cost decreases, all indications are that fuel price volatility will continue, forcing the industry to find solutions that increase its fuel efficiency in order to stay profitable.

Fortunately, myriad technologies that can cost-effectively improve the fuel efficiency of Class 8 trucks are readily available on the market today. Unfortunately, multiple barriers have stymied industry adoption of such technologies, including a lack of data about the true performance gains these technologies offer, and a lack of confidence in the performance testing data that does publicly exist today. To

overcome those barriers and facilitate the industry's trust in and adoption of the most promising fuel efficiency technologies, the North American Council for Freight Efficiency (NACFE) partnered with Carbon War Room (CWR) to form Trucking Efficiency. The work of Trucking Efficiency has begun by producing a series of Confidence Reports, of which this report on technologies to improve the aerodynamics of trailers is the eleventh.

The goals of this Confidence Report are: (a) to give the industry a foundational understanding of trailer aerodynamic devices, (b) to provide an unbiased review of available trailer aerodynamic technologies on the market today, and (c) to increase investment into cost-saving trailer aerodynamic technologies.

Methodology

This report's conclusions were generated through desk research, conversations at a variety of trucking industry events around the country, and a series of structured interviews with fleets, truck and trailer OEMs, and many of the trailer aerodynamic manufacturers active in the North American market today.

FUEL SAVINGS AND OTHER BENEFITS OF TRAILER AERODYNAMICS

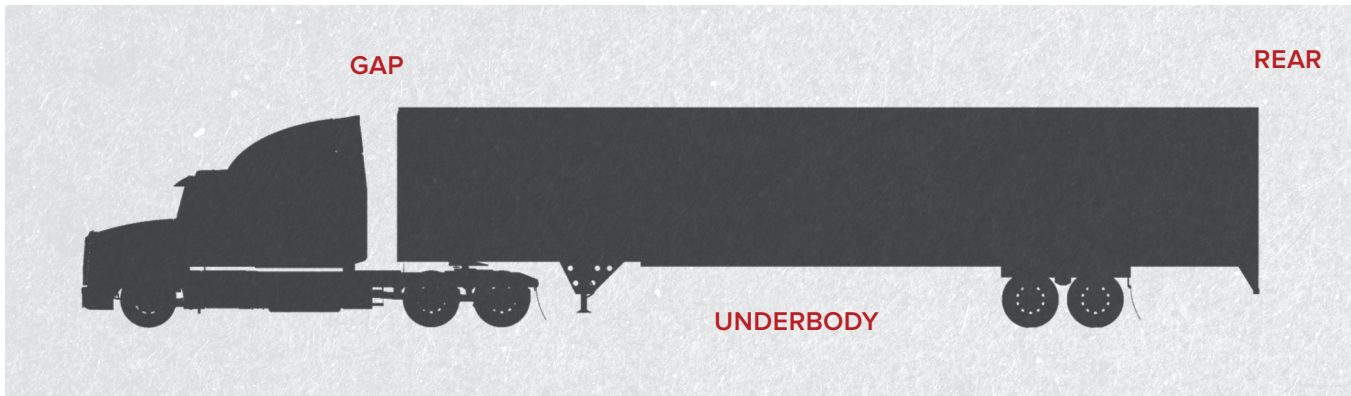
Trailer aerodynamic devices help to increase fuel efficiency by lowering air resistance so that it takes less fuel to move down the road as speed increases. The per-vehicle fuel economy benefit of trailer aerodynamic devices can be high, ranging from 1% to over 10%, depending on the devices chosen. Given these potential savings, trailer aerodynamic devices are excellent technologies for significantly increasing fuel efficiency. However, it is quite a large technology set, and they can be complicated to adopt.

Trailer aerodynamic devices can also improve stability and rollover, splash and spray, and driver fatigue.

"FLEETS HAVE
MOVED FROM ASKING
WHY THEY NEED
AERODYNAMIC DEVICES
ON THEIR TRAILERS TO
DETERMINING WHEN
AND HOW THEY WILL
ADD THEM."

Mike Roeth, Operation Lead,
Trucking Efficiency

AREAS OF OPPORTUNITY



CHALLENGES OF TRAILER AERODYNAMICS

The challenges of integrating trailer aerodynamic technologies into fleet operations include:

- Added weight
- Complicated and difficult-to-compare methods for testing device performance
- Confusion between precision and accuracy, and the difficulty of obtaining accuracy in aerodynamics testing
- Variance among aerodynamic device manufacturer information
- The need to optimize tractor/trailer ratios
- Questions of device reliability and/or durability

While the devices currently available on the market do add some weight to the vehicle, weight's impact on fuel economy is just 0.5–0.6% per 1,000 lbs. of added weight. Even the most aggressive aerodynamic fairings for trailers add less than 2,000 lbs. today, so the maximum mile-per-gallon reduction due to the weight of aerodynamic fairings would be less than 1.2%—much less so than the 9%+ mpg gain offered by advanced trailer aerodynamic systems in on-highway hauls for typical van trailers.

The main challenge preventing widespread adoption is the perceived complication of improving trailer aerodynamics. The physics involved in testing trailer aerodynamic device performance can be complex, and there are multiple ways of measuring and evaluating performance (described in the Determining Efficiency Confidence Report available at www.TruckingEfficiency.org). Additionally, fleets will see the greatest benefit from adopting multiple aerodynamic devices, but as the net benefits from the package of devices do not simply equal the sum of each individual device, it's difficult for fleets to prioritize investment decisions and feel confident in their paybacks.

TRAILER AERODYNAMIC TECHNOLOGIES

Obviously all vehicles are concerned with fuel economy and freight efficiency, but to date the focus of aerodynamic trailer technology development (and of rulemaking) has almost exclusively been on van trailers. Van trailers are the most common trailer type, travel the most miles, are “large boxes” with wheels, and are most easily adapted to aerodynamic improvement. Reducing the aerodynamic drag of a basic van trailer comes down to adding one or

more devices onto three key areas of the trailer: the underbody, the rear, and the gap.

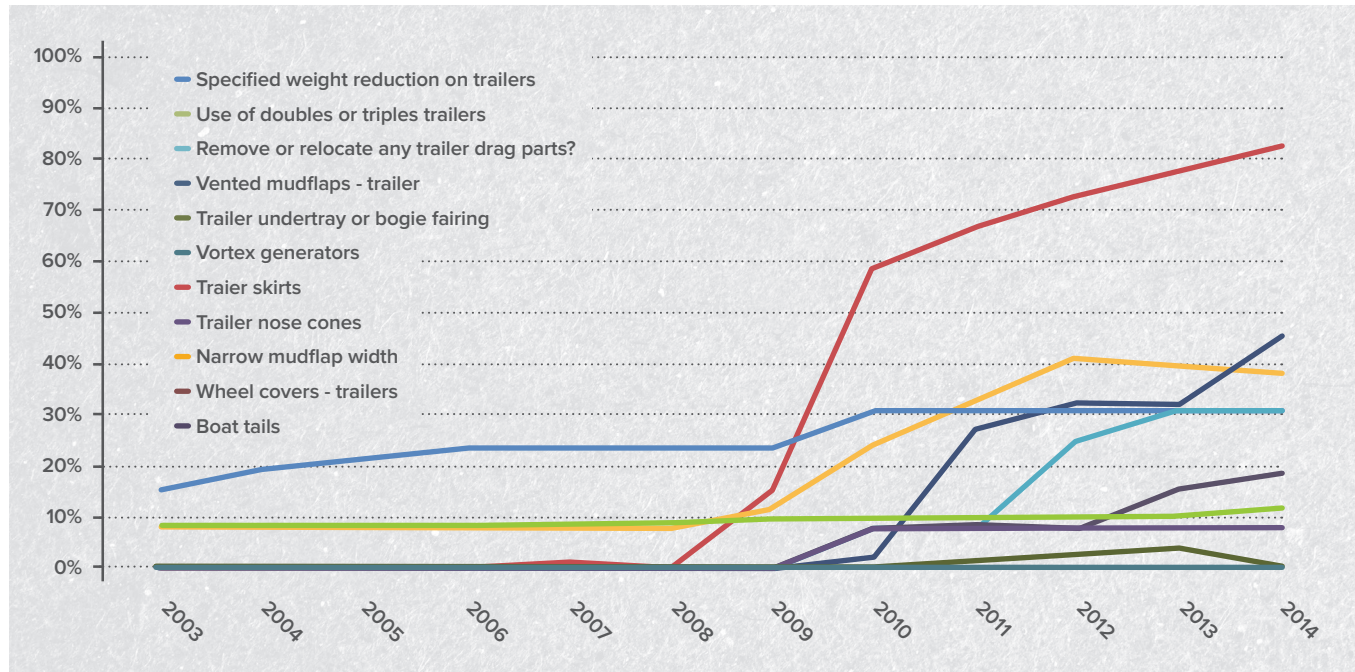
This Confidence Report details devices for improving the aerodynamics of these three key areas, as well as more novel options, such as vortex generators, wheel covers, and mud flaps.

Underbody: For the underbody, trailer skirts are the most popular devices for addressing drag. All trailer underbody skirts serve to extend the trailer side walls much closer to the ground, preventing wind from ducking in under the trailer and running into the non-aerodynamic trailer bogie. Trailer skirts offer 1% to more than 5% fuel savings versus non-skirted trailers.

Rear: Devices to mount at the rear of trailers are generally called boat tails or trailer wake devices. They modify the air flow as it leaves the trailing edge of the side and top surfaces of the trailer. The goal in all rear trailer devices is to reduce the wake field following the trailer, which can affect air some distance from the back of the trailer. Trailer tails are the most common device in use to improve aerodynamics at the rear of the vehicle, but have deploy and retract challenges.



FIGURE ES1: TECH ADOPTION - TRAILER AERODYNAMICS



Gap: Tractor-to-trailer gap management devices are relevant for a subset of the industry, in large part due to the evolution of the current aerodynamics of many tractors. Highly aerodynamic tractors have largely reduced the importance of trailer aerodynamic gap devices. However, many older tractors and daycabs, which require a higher tractor-to-trailer gap for maneuverability, would still benefit from trailer devices that address drag in the gap.

There is a clear prioritization in the industry of which areas to address with aerodynamic devices: the underbody, with nearly 30% of trailers equipped with skirts today, followed by the rear, with about 5% of trailers equipped with tail devices, followed by the gap and the other smaller novel ideas.

Overall, roughly one-quarter of all trailers on the road in the U.S. have at least one aerodynamic technology installed, and by 2015, in excess of 30%

of new trailers were being equipped with trailer aerodynamic devices. Feedback from trailer and component manufacturers gives evidence of a robust market for aerodynamic technologies for both new and used trailers. In addition, the cost of trailer aerodynamic technologies—particularly side skirts—has decreased significantly in recent years, due to far more market entrants driving cost competition and much higher deployment volumes, reducing cost per unit and availability of devices directly from the trailer manufacturers.

CURRENT INDUSTRY TRENDS

Tractor and trailer aerodynamic design concepts have been around for a very long time. A series of trends over the last 20 years have moved the industry from asking, “Why should my fleet use trailer aero devices?” to “When and how will my fleet implement trailer aero devices?”

The most recent NACFE Annual-Fleet-Fuel-Study found that since 2008 or 2009, fleets began ramping up their investment into trailer aerodynamics, most notably trailer skirts, as shown in Figure ES1.

Extensive insights into fleet decision making on trailer technologies were recently assembled through a fleet survey by Ben Sharpe of ICCT and Mike Roeth of NACFE in the February 2014 ICCT/NACFE white paper *Costs and Adoption Rates of Fuel-Saving Technologies for Trailers in the North American On-Road Freight Sector*. That report provided a summary of cost and adoption rates shown in Table ES1.

While the desire to save fuel in an era of volatile and often high fuel prices does motivate the adoption of trailer aerodynamic devices by fleets, regulations also play a major role in this technology space.

TABLE ES1: SUMMARY OF INTERVIEW RESPONSES ON TRAILER TECHNOLOGY COST AND LEVEL OF ADOPTION

TECHNOLOGY	FUEL SAVINGS	COST TO END USER		TYPICAL PAYBACK TIME	ADOPTION IN NEW TRAILER SALES
		HIGH	LOW		
Side skirts - average	3%	\$1,100	\$700	1–2 years	40%
Side skirts - best	7%			< 1 year	
Boat tails - average	3%	\$1,600	\$1,000	2–3 years	3%
Boat tails - best	5%			1–2 years	
Gap reducers	1–2%	\$1,000	\$700	2–5 years	Minimal
Underbody devices	2–5%	\$2,200	\$1,500	2–5 years	3%
Low rolling resistance dual-sized tires	1–3%	Data on costs and payback time inconclusive			50%
Wide base single tires	2–4%	Data on costs and payback time inconclusive			10%
Tire pressure monitoring systems	1%	\$1,000	\$750	1–2 years	10%
Automatic tire inflation systems	1%	\$1,000	\$700	1–2 years	30%

In the last half of the 1990s, regulatory focus dramatically increased on truck engine emission standards, including the Environmental Protection Agency's (EPA) Clean Air Act emissions regulations and EPA's Phase 1 Greenhouse Gas (GHG) rules. These rules initially focused on engines and components, but evolved into vehicle-level standards. In parallel with ever-more-demanding emissions rules came federally-legislated reductions in the sulfur content of fuels, as well as the introduction of "no idle" rules in many locations. Nearly all of these requirements have resulted in increased tare weight or other changes that worsened fuel economy.

With respect to tractor aerodynamics, OEMs have continually introduced

new and improved models over the last 20 years, such that the tractor side of the industry has achieved, in general, net improvements in fuel economy over that period. Yet both government and industry have recently realized that tractor efficiency improvements alone could only go so far toward saving fuel. The EPA very recently proposed requiring trailer aerodynamics as part of its Phase 2 GHG rulemaking, to come into effect in 2018. Other regulations, such as the rules enacted in 2008 by the California EPA Air Resources Board, which mandated the use of SmartWay-certified tractors and trailers in California, are likewise driving investment in trailer aerodynamics. The industry should expect the next few years to see a continuation of this regulatory trend. Improving the

aerodynamic performance of trailers is an excellent option for the industry looking to meet regulations and offset other fuel economy losses.

PERSPECTIVES FOR FUTURE SYSTEMS

Trailer aerodynamic technologies and strategies are constantly and rapidly evolving. The options detailed in the report are all currently available on the market today, and most are mature with a good track record of functionality, though they may be more or less economical depending on the specifics of a fleet's operations. In the near-term, new technologies and/or regulatory changes that open the door for platooning, long combination vehicles, and longer trailers, could significantly improve



aerodynamics and increase fuel economy. Other technologies that are under development but have not yet reached market-readiness include:

- Active Flow Control Systems
- On-Board Aerodynamic Sensing
- Aero Adaptive Cruise Control and Routing Systems
- Automation Systems
- Trailer Geometry Morphing
- Trailer/Tractor Ratio Reduction
- Dedicated Truck Highways and Lanes
- Hybrid Electric Vehicles
- Combining Technologies

CONCLUSIONS

This report focuses primarily on sleeper tractors pulling van trailers on-highway in North America. It describes both individual and combinations of technologies and practices available to fleets in pursuit of fuel economy improvement, operating

“EVERY TRAILER WILL BENEFIT FROM IMPROVEMENTS IN AERODYNAMICS BUT THERE ARE NO ONE-SIZE-FITS-ALL SOLUTIONS. THIS REPORT REDUCES THE CONFUSION AND EXPLAINS THE COMBINATIONS THAT MAKE SENSE FOR FLEETS.”

**Rick Mihelic, Program Manager
NACFE**

TABLE ES2: SUGGESTED ACTIONS ON TRAILER AERODYNAMICS

IF YOU ARE CURRENTLY RUNNING THIS TRAILER CONFIGURATION:	THIS MIGHT BE YOUR NEXT BEST STEP FOR BETTER TRAILER AERODYNAMICS:
Aero tractor with typical dry van trailer	Add trailer skirts
Trailer with side skirts	Add trailer rear boat tail device
Trailer with side skirts and manually deploying rear boat tail	Convert to automatically deploying trailer rear boat tail device to increase time in use
Trailer with side skirts and rear boat tail	Add trailer front nose fairing
Trailer with side skirts, rear boat tail, and nose fairing	Start investigating other minor areas such as wheel covers, license plate position, and vented mud flaps.
Day cab tractor without air fairings or cab extenders	Add trailer nose dome to the upper front portion of the trailer

cost reduction, and greenhouse gas emissions decrease through the use of trailer aerodynamic devices. The study team found the following conclusions with respect to fleets, truck and trailer OEMs, manufacturers, and others concerning the adoption of trailer aerodynamic devices:

- Trailer aerodynamic devices save fuel.
 - Devices have matured and will continue to improve.
 - There are unique challenges such as trailer-to-tractor ratios, a split incentive in that trailer owners do not always buy the fuel for tractors, and deployment of devices.
- Performance for each fleet is difficult to determine.

RECOMMENDATIONS

The study team has the following recommendations for those engaged in adopting or providing aerodynamic devices:

- Both aerodynamic device suppliers and fleet end users need to have better communication on performance.
- Manufacturers and trailer integrators should increase development efforts to improve the total cost of ownership/payback of the devices.
- Research into advanced aerodynamic technologies should continue.
- Organizations such as SAE, TMC, EPA, and CARB need to push for improved aerodynamic assessment and correlation to real world conditions.

Table ES2 suggests actions that should be considered by fleets to prioritize their adoption of aerodynamic devices.



CONFIDENCE RATING

For each of the Confidence Reports completed by Trucking Efficiency, the various assessed technologies are plotted on a matrix in terms of the expected payback in years compared to the confidence that the study team has in the available data on that technology—that is, not only how quickly fleets should enjoy payback on their investment but also how certain Trucking Efficiency is in the assessment of that payback time. Technologies in the top right of the matrix have a short payback, usually thanks to their low upfront cost,

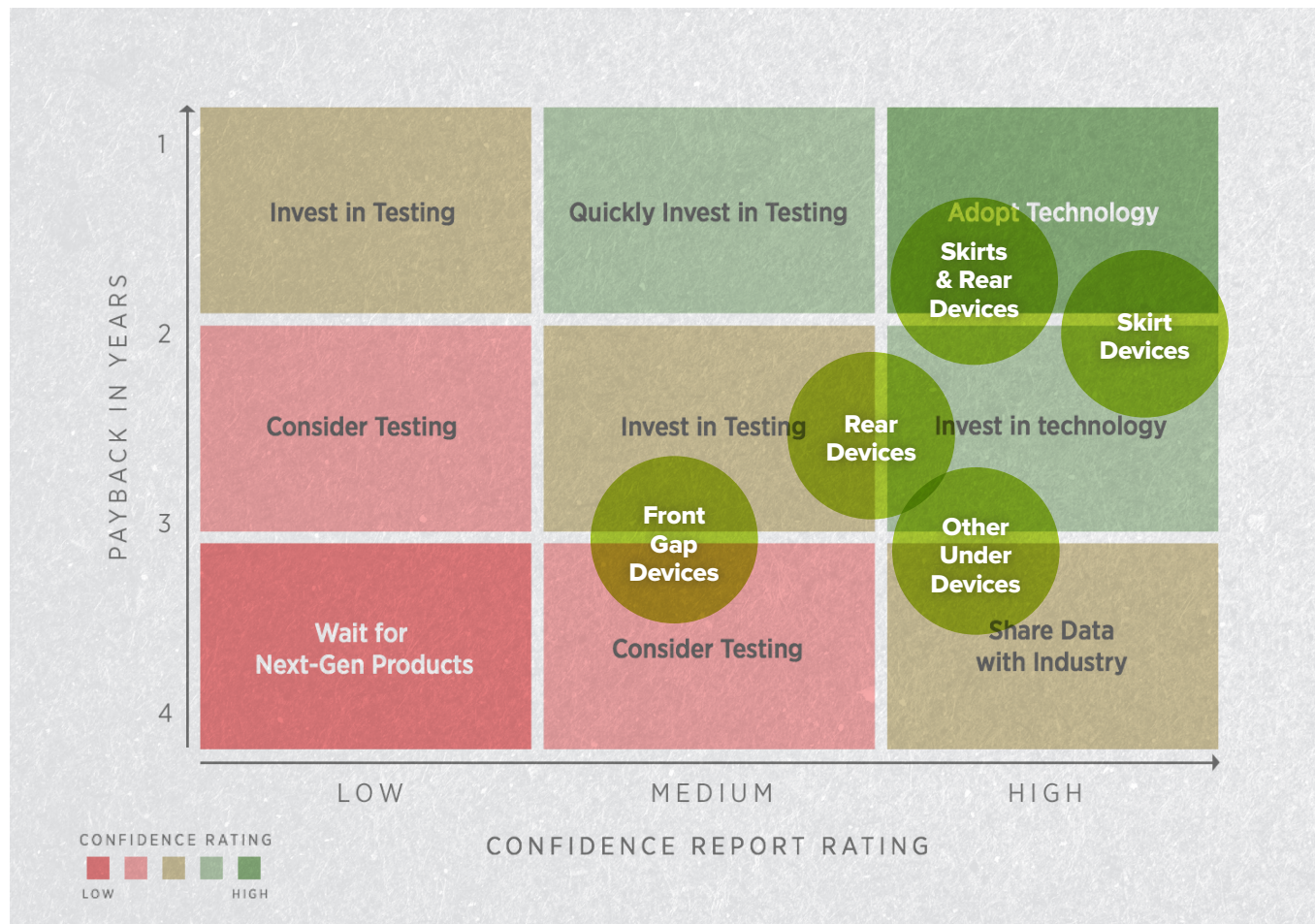
and moreover Trucking Efficiency has high confidence in those short payback times, usually because the technology is more mature and/or has a more substantial track record of results.

Trucking Efficiency is highly confident that all fleets should be considering the aerodynamics of their trailers and the adoption of devices that will improve those aerodynamics as a major opportunity to save fuel. The best device or package of devices to adopt will depend on a fleet’s unique duty cycle. But overall, available

savings are likely quite high, up to 10%, for the majority of fleets running 53’ dry box trailers. Moreover, many regulations are likely to mandate the adoption of trailer aerodynamic devices in coming years, so fleets which have not even begun to consider this opportunity will be wise to do so in anticipation of mandates.

Trucking Efficiency is always seeking to expand the data or case studies that we can provide to the industry. We invite you to share your own experiences with trailer aerodynamic technologies.

FIGURE ES2: CONFIDENCE MATRIX FOR TRAILER AERODYNAMICS



TRUCKING EFFICIENCY



Trucking Efficiency is a joint effort between NACFE and Carbon War Room to double the freight efficiency of North American goods movement by eliminating barriers associated with information, demand, and supply.

Worldwide, heavy-duty freight trucks emit 1.6 gigatons of CO₂ emissions annually—5.5% of society's total greenhouse gas emissions—due to the trucking sector's dependence on petroleum-based fuels. With fuel prices still commanding nearly 40% of the cost of trucking, the adoption of efficiency technologies by all classes of trucks and fleets offers significant cost savings to the sector while reducing emissions. These technologies are relatively cheap to implement and widely available on the market today.

Trucking Efficiency provides detailed information on cost-effective efficiency technologies, including data from across a variety of fleets and best practices for adoption. This Confidence Report series from Trucking Efficiency aims to serve as a credible and independent source of information on fuel efficiency technologies and their applications.

In order to generate confidence on the performance claims of efficiency technologies, Trucking Efficiency, via these reports, gathers and centralizes the multitude of existing sources of data about the performance results of different technology options when employed in a variety of vehicle models and duty cycles, and makes all of that data openly accessible and more easily comparable. Furthermore, we assess the credibility of the available data, and provide an industry-standardized ranking of confidence in performance results, including ROI and efficiency gains.

www.truckingefficiency.org

Trucking Efficiency welcomes outside views and new partners in our efforts to help accelerate the uptake of profitable, emission-reducing trucking technologies.



CARBON WAR ROOM



Carbon War Room (CWR) was founded in 2009 as a global nonprofit by Sir Richard Branson and a group of likeminded entrepreneurs. It intervenes in markets to accelerate the adoption of business solutions that reduce carbon emissions at gigaton scale and advance the low-carbon economy. CWR merged with Rocky Mountain Institute (RMI) in 2014 and now operates as an RMI business unit. The combined organization engages businesses, communities, institutions, and entrepreneurs to transform global energy use to create a clean, prosperous, and secure low-carbon future. The combined organization has offices in Basalt and Boulder, Colorado; New York City; Washington, D.C.; and Beijing.

www.carbonwarroom.com



The North American Council for Freight Efficiency works to drive the development and adoption of efficiency-enhancing, environmentally-beneficial, and cost-effective technologies, services, and methodologies in the North American freight industry by establishing and communicating credible and performance-based benefits. The Council is an effort of fleets, manufacturers, vehicle builders, and other government and non-governmental organizations coming together to improve North American goods movement.

www.nacfe.org

