WHY EMBRACE FREIGHT TON EFFICIENCY?

EXPLAINING FREIGHT TON EFFICIENCY AND WHY IT IS A BETTER MEASURE OF TRUCK FUEL ECONOMY

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SHELL LUBRICANT SOLUTIONS

WHY EMBRACE FREIGHT TON EFFICIENCY?

In 2021, Shell Starship 2.0 made a 2,315-mile coast-to-coast run across the USA, and achieved nearly three and a half times greater freight ton efficiency (FTE) than the North American average.[1]
This represents a huge carbon dioxide (CO_2) emission reduction and fuel savings. But what is FTE, and why use it rather than the more familiar fuel economy measured in miles per gallon (mpg)? This paper explains why FTE is a metric the on-highway commercial trucking industry should embrace.

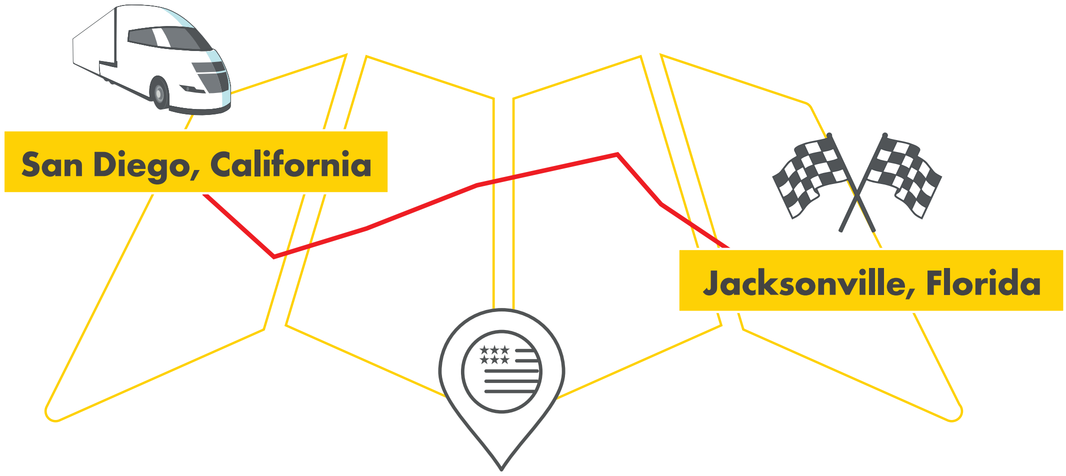


Figure 1. Shell Starship 2.0 coast-to-coast run

ABOUT THE STARSHIP INITIATIVE

Shell Starship Initiative is a joint project between Shell Lubricant Solutions and Shell Technology, demonstrating how Class 8 truck sector energy usage can be reduced when the benefits of many currently available energy efficient technologies are utilised.

The focus of the Starship initiative is to demonstrate how the commercial road transport sector could increase fuel economy, improve freight ton efficiency and reduce emissions using commercially available fuel-efficient technology. These include low-viscosity lubricants, aerodynamic enhancements and an optimised drivetrain configuration. All of these concepts were drawn into one operational vehicle, the Shell Starship 2.0. The result is a world-class example of Shell's technology leadership in the On-Highway sector, and clearly illustrates how Shell Lubricants is helping the fleet sector to improve efficiencies, lower operational costs and meet sustainability goals.

"SHELL STARSHIP 2.0... ACHIEVED NEARLY THREE AND A HALF TIMES GREATER FREIGHT TON EFFICIENCY THAN THE NORTH AMERICAN AVERAGE.[1]"

"**FILLING A TRUCK** LOWERS ITS FUEL ECONOMY AS MEASURED IN MPG, BUT GREATLY REDUCES THE AMOUNT OF CO_2 EMISSIONS PRODUCED IN MOVING THE GOODS COMPARED TO…TRANSPORTING THE SAME LOAD IN MULTIPLE TRUCKS."

WHAT IS THE PROBLEM WITH MILES PER GALLON (MPG)?

Imagine that you want to attend a convention in a nearby town, but you are concerned about the financial and environmental costs of the trip.

Your car gets 30 mpg and the return journey is going to cost you $50 in fuel. Two friends announce that they want to go too. Your fuel economy will fall to 28 mpg as a result of the extra weight of your passengers, but your fuel cost, assuming the bill is split equally, will be cut by nearly two-thirds.

It is clearly more efficient for three people to travel in one car than for each to drive independently. So rather than mpg, person-miles per US gallon would be a better unit of measurement for comparison purposes (Figure 2).

Everyone is familiar with mpg (or litres per kilometre) figures. Indeed, it is difficult to engage in discussions about engine efficiency without talking in terms of mpg. However, the example above shows why this measurement can be misleading when considering the efficiency per person or unit of freight.

Trucks exist to transport goods. Consider two trucks with fuel economies of 10 and 7 mpg. One appears to be more fuel efficient than the other. But if the 10-mpg truck was carrying 1 ton and the 7-mpg truck had a cargo of 20 tons, the picture changes completely. With this additional knowledge, it is easy to see that the almost empty truck offers poor energy efficiency per ton: 10 ton-miles/US gal compared with 140-ton-miles/US gal – that is 14 times worse (Figure 3)!

Filling a truck lowers its fuel economy as measured in mpg, but greatly reduces the amount of CO_2 emissions produced in moving the goods compared to the emissions that would have been produced by transporting the same load in multiple trucks. As trucks are all about moving goods, an energy efficiency metric such as FTE that considers the freight is necessary.

One car with one person, 30 mpg

Equivalent to
30 person-miles per gallon

One car with three people, 28 mpg

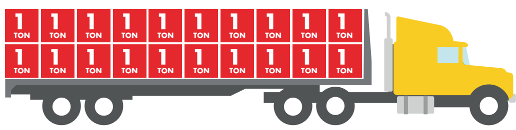
Equivalent to
84 person-miles per gallon

Figure 2. Comparing the efficiency of transporting one and three people in a car.

One truck carrying 1 ton of cargo gets 10 MPG

Equivalent to
10 ton-miles per gallon

One truck carrying 20 tons of cargo gets 7 MPG



Equivalent to
140 ton-miles per gallon

Figure 3. Why freight weight matters.

EXPLORING FTE

As a truck carries more goods, its fuel economy, expressed in mpg, will deteriorate, while its FTE improves. If FTE is to be widely adopted as the most appropriate energy efficiency metric for goods transport, it needs to be better understood. So, what influences FTE?

How is FTE expressed?

FTE is the vehicle's fuel economy multiplied by the mass of cargo being carried. In North America, the most common expression of FTE is ton-miles of goods shifted per US gallon of fuel (ton-miles/gallon).

How can FTE be influenced?

The primary objective of freight transport is to move goods from A to B. Secondary aims are to do so using the smallest amount of energy possible, to minimise CO_2 emissions and to keep operational costs low.

In simple terms, FTE is miles per US gallon multiplied by the tons of goods carried. Miles per US gallons is the energy used. The energy used is the force opposing the motion times the distance travelled.

So, **to improve FTE**, it is necessary to focus on either **reducing the forces opposing the motion** or **increasing the mass of goods being carried** (Figure 4).

Figure 4. Increasing FTE.

Reducing the forces opposing the motion

FTE can be improved by reducing the forces opposing motion in four areas.

Aero resistance.
FTE can be improved by cutting:

- the drag coefficient;
- the cross-sectional area;
- the speed; and
- increasing the mass of goods carried.

Some of these changes are intuitive. Most people know that high-speed driving burns more fuel and that streamlined shapes offer efficiencies. More surprising is that the importance of aero resistance is cut by increasing the mass of goods carried – aero resistance remains the same, but becomes a diminishing part of the total amount of energy being consumed as mass of goods increases.

Acceleration.
FTE can be improved by:

- avoiding acceleration and unnecessary braking;
- reducing the mass of the truck; and
- increasing the mass of goods carried.

Uphill movement.
FTE can be improved by:

- avoiding hills;
- reducing the mass of the truck; and
- increasing the mass of goods carried.

Rolling resistance.
FTE can be improved by:

- reducing the mass of the truck; and
- increasing the mass of goods carried.
- choosing tyres with a low-rolling-resistance coefficient;

In all four areas, increasing the mass of the goods carried helps to improve the FTE. This is because the energy required to overcome aero or rolling resistance or to accelerate the truck is a fixed cost that becomes less significant per ton of goods as the mass of goods carried increases. Likewise, the mass of the truck is also a fixed cost that becomes less significant per ton as the weight of freight carried increases.


Shell ROTELLA
STARSHIP

"IF EVERY TRUCK IN THE USA WERE TO CARRY ITS MAXIMUM LOAD AND BE AS EFFICIENT AS SHELL STARSHIP 2.0, WE COULD LOWER EMISSIONS FROM TRUCKING BY OVER 71%."

What about low-density goods?

Increasing the mass of goods helps to reduce the FTE but what about bulky, low-density products? Imagine you had boxes of table tennis balls to ship. You would not be able to reach your truck's maximum load capacity. Perhaps the answer would be to combine loads using freight scheduling systems? For example, a truck carrying a large industrial pump may be close to its maximum allowed weight but have plenty of space for boxes of table tennis balls.

Combining high- and low-density loads will not always be practical, but freight scheduling systems are already commonly used to help reduce the number of empty return journeys – keeping trucks loaded. This could also potentially be accomplished by shippers collaborating to seek mutually beneficial efficiencies.

Either way, it is always more energy and cost efficient to load the truck as fully as possible, whether by mass or volume.

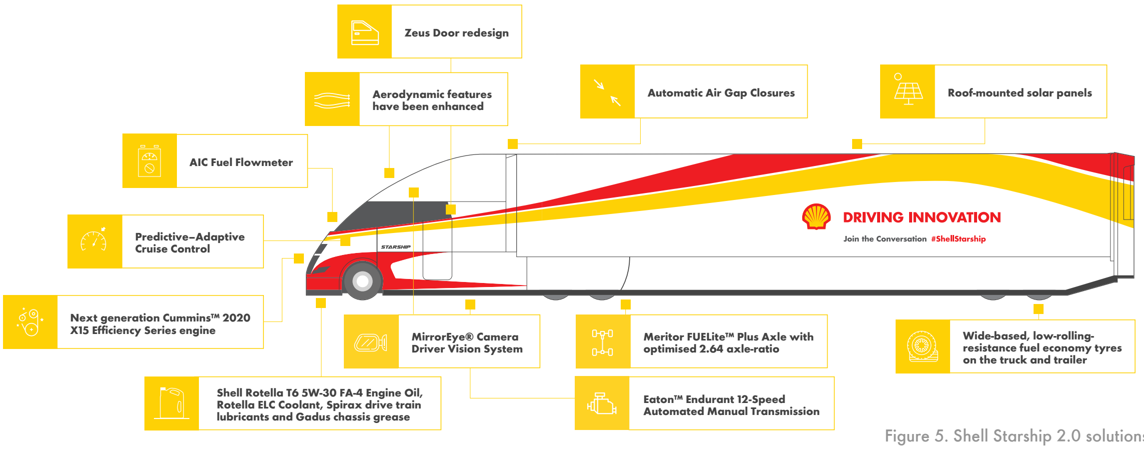


Figure 5. Shell Starship 2.0 solutions.

IMPLICATIONS FOR TRUCK DESIGN

Breaking FTE into components helped to drive the Starship truck's design. The exercise highlighted the need to increase the mass of goods and decrease the truck's drag coefficient, cross-sectional area, velocity, acceleration, mass and rolling resistance coefficients. Naturally, the efficiency of the engine and the driveline delivering the energy were also considered.

The solutions (Figure 5), all of which were existing technologies, included:

- devices for improving driver behaviour, for example, for less acceleration and braking;
- a bespoke hyper-aerodynamic carbon fiber cab for a lighter truck and a lower drag coefficient;
- an aerodynamic boat tail that streamlines air flow around the trailer and reduces drag;
- a wide-based tyre setup that offers lower rolling resistance and reduces weight;
- a 12-speed automated transmission and a 6x2 axle configuration delivers drivetrain efficiency;
- a 5,000-watt solar array charges the main battery bank and reduces the engine load from the alternator;
- a low-viscosity (5W-30) Shell Rotella T6 heavy-duty engine oil that meets American Petroleum Institute FA-4 performance standards, a low-viscosity, fully synthetic Shell Spirax transmission fluid and Shell wheel hub oil for drivetrain efficiency.

The average North American truck has a fuel economy of 6.6 MPG and carries 11.25 tons for a FTE of 74 ton-miles/US gal. Shell Starship 2.0 carried 23.55 tons, yet still managed 10.8 MPG on it's 2,325-mile journey across the USA. This delivered a FTE of 254 ton-miles/US gal.[2]

Carrying a full load contributed significantly to the impressive results. If every truck in the USA were to carry its maximum load, 1,045,000 fewer trucks would be necessary to move the same amount of cargo. If the remaining trucks achieved the Starship's 10.8 MPG and ran fully loaded, then the fleet's CO_2 emissions would be reduced by up to 71.5%.[3]

It is clearly not always practical to carry a maximum load, and new technologies can take a long time to propagate into the fleet. Nevertheless, the Shell Starship 2.0 initiative demonstrates the size of the prize and provides inspiration, highlighting current technologies fleet operators can adopt to reduce emissions and costs. It also highlights the importance of shifting focus from mpg to FTE to properly consider a truck's reason to exist (the transport of goods) in our efforts to reduce emissions and costs.

[1]North American Council for Freight Efficiency: "Run on less report," (2018): nacfe.org/run-on-less-report

[2]North America Council for Freight Efficiency data verification report for Starship truck coast-to-coast test drive

[3]Reductions in annual CO_2 emissions calculated as if all trucks in the USA operated at the same FTE (ton-miles/US gal) as the Starship and the scale of the fleet was reduced to balance the increased loading. CO_2 emissions refer to those from the combustion of diesel fuel alone with a standard emission rate of 22.4 lb of CO_2 per US gallon of diesel fuel.