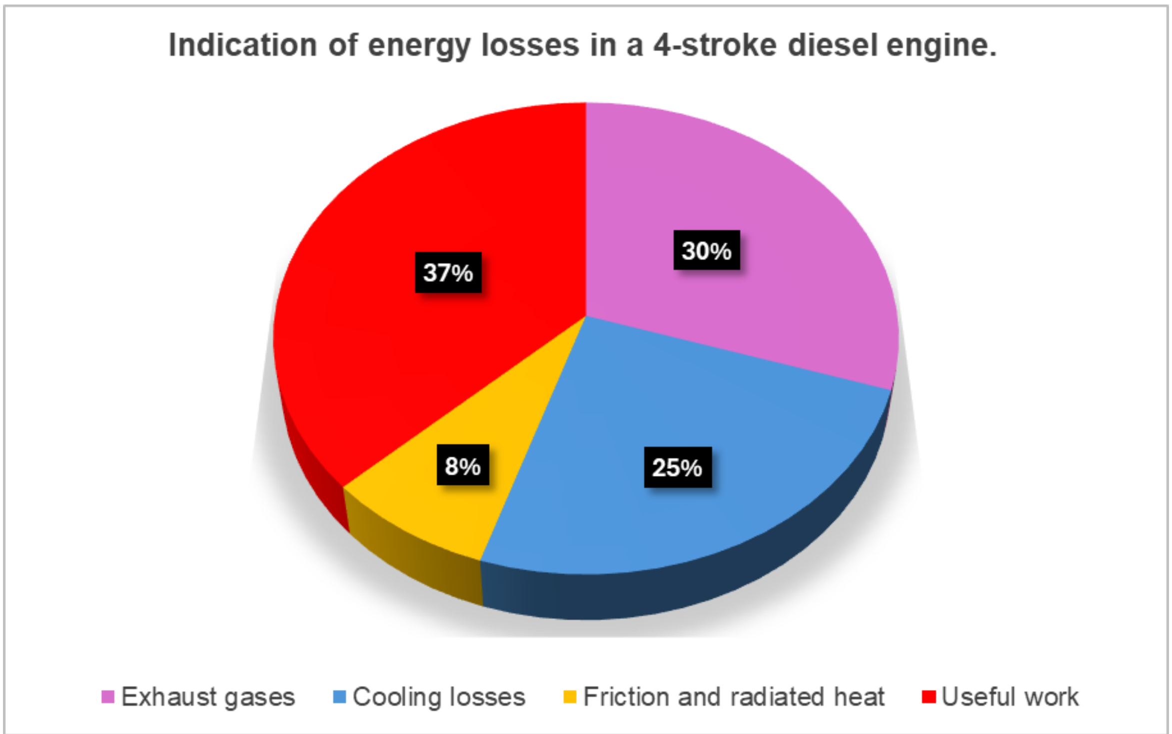
Understanding Fuel Efficiency – Russell Walsh

When Nicolaus Otto succeeded in producing a workable 4-stroke engine in the 1870s he would never have thought that over 150 years later the principals of his engine, the Otto cycle was named after him, would still be the mainstay of road transport in the 21st century. Although engine manufacturers have spent billions of dollars on development in the intervening period it is unlikely that a viable alternative will be in widespread use in the foreseeable future. Chrysler had a go when they produced a gas turbine car in 1963 one of which toured New Zealand. The programme was cancelled in 1979 due to the engines failure to reach emission standards and its high fuel consumption. Other manufacturers also developed gas turbine powered vehicles but none of these entered serious production.

A 4-stroke engine has two main characteristics that impact on its ability to be efficient, these are that it produces heat, and it generates friction. As shown in the following chart the amount of energy lost in the engine, that is the energy not available to provide work is quite substantial.



Heat can be managed by an efficient cooling system. Friction can be reduced by use of high-grade engine oil and low friction materials. The days of frictionless engines however are a long way off.

An engine fitted with a turbocharger does however recover some of the energy that would otherwise be wasted out of the exhaust system to drive the turbocharger. A supercharger on the other hand is driven by mechanical energy derived from the engine.

Energy content

The principle of any engine is to convert the energy contained in the fuel it burns into useable energy: we burn diesel in an engine to provide energy to power a vehicle.
Energy contained in fuel is measured in Megajoules, (MJ). A litre of diesel fuel will produce 38 MJ of energy however as shown in the table below much of this energy is absorbed in the operation of the

engine resulting in only about 15 MJ of the energy content of the fuel been realised to move the vehicle.

Example: A vehicle that is calculated as having a fuel consumption of 1.25 litres per one kilometre travelled will have a fuel energy input of 47.5 MJ but 63% (30MJ), will be lost in the operation of the engine.

Friction within an engine

A research paper produced in October 2003[i] shows the potential friction causes within a diesel engine.

Engine area	Range of potential friction
Engine auxiliaries	20% to 25%
Valve train	7% to 15%
Piston ring assembly	45% to 50%
Engine bearings	20% to 30%

These sources are related to the operation of the engine only. In moving a vehicle along the road other sources of friction come into play that must also be overcome including, friction created within the transmission and driveline, tyre interaction with the road surface, friction generated by the vehicle moving through the air and aerodynamic drag, (air friction and aerodynamic drag are two different influences but have a similar effect). A related discussion, Filling the Cylinder can be found on the IRTENZ website https://irtenz.org.nz/assets/Uploads/Technical-torque/Technical-Torque-8.pdf
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Determining fuel consumption

How to determine fuel economy is a complex subject, one that has resulted in numerous research projects many of which are published on-line. The issue with many of these are that they are based on theoretical propositions and do not necessarily reflect real world operating conditions.

Many international standards for measuring fuel consumption of a diesel engine also exist, these include:

- International Standards Organisation ISO 15550:2016 Internal combustion engines — Determination and method for the measurement of engine power — General requirements ISO 15550:2016 - Internal combustion engines — Determination and method for the measurement of engine power — General requirements

- The heavy-duty Federal Test Procedure Transient cycle in the United States
  Emission Test Cycles: HD FTP Transient (dieselnet.com)

As with many research projects the standards are often very technical in nature and application sometimes requiring laboratory conditions, the result is that many of these standards are impractical for everyday use.

Common practice therefore is to use the volume of fuel consumed over a given distance, example, litres of fuel used over one hundred kilometres. This is very crude and basic measure as it does not take into consideration the value, in energy terms of fuel used nor the income derived from the payload carried. If you move goods on tonnage basis then the calculation should be based upon the tonnes moved over the total distance travelled. If goods are dropped off and/or picked up along the way, then the weight should reflect the maximum weight carried. If liquid cargo is carried the calculation should use the volumetric weight of the load (litres). Stock transport could use a head count of the stock that was transported. Bulk transport such as shingle can use the cubic capacity of the load.

The important thing to remember when working out fuel consumption is that it must be linked to the income derived from the payload otherwise it is not providing usable information therefore a measure such as litres/tonne kilometre (l/tkm) is valid.

European standard engines (Euro)

Euro standard engine requirements became compulsory in 1992 (Euro1) and have been revised regularly since then, we now see Euro 7. These standards were initially introduced to control emissions emitted from fossil fuel burning engines, they were not designed to improve fuel consumption, in some cases research has suggested that Euro compliant engines may have the opposite effect and increase fuel use.

Engine manufacturers specifications

Engine manufacturers regularly publish performance statistics for their engines. Often these will include the Euro standard the engine has been tested as meeting; it is however uncommon to find fuel consumption data, but this is often available if requested.

Conclusion

Despite all the initiatives employed over the years to improve fuel efficiency the Otto cycle 4-stroke engine is, due to its inherent characteristics, still relatively inefficient. We can expect to see gradual improvement in coming years, but radical rethinking will be necessary to replace this type of engine in the many applications it is used in now.

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[i] An Introduction to Heavy-Duty Diesel Engine Frictional Losses and Lubricant Properties Affecting Fuel Economy, https://www.semanticscholar.org/paper/An-Introduction-to-Heavy-Duty-Diesel-Engine-Losses Comfort/6d39e3400efcfc87d56031ceb35f29fb9c4c937a