Volvo Trucks. Driving Progress

ALTERNATIVE FUELS

The way forward

Contents

In 2007, Volvo Trucks presented seven trucks that could be operated on seven different renewable fuels.

The climate issues are on top of the environmental agenda, with calls for immediately action echoing around the globe. Volvo Trucks recognizes the sense of urgency, and we take action by developing and launching trucks powered by electricity and other alternatives to diesel.

The major challenge for our industry is to reduce the environmental and climate impact of heavy goods transports even though the demand for transports continues to increase.

Volvo Trucks has no hesitation in admitting that we are part of the problem. And we are also determined to be part of the solution.

We have the innovation power it takes to build a sustainable society. We have focused on environmental issues for decades – and we continue to invest a lot in more climate-neutral transport solutions.

This brochure describes the pros and cons of different alternative fuels. It emphasizes the importance of a holistic view and joint efforts by the corporate sector, public agencies and individuals, across national boundaries and between different industries.

Alternative fuels – an overview

CO_2-neutral transports counteract climate change

CO_2-neutral transports are powered by fuels produced from renewable raw materials, such as biomass and fossil-free electricity. Unlike fossil fuels, these fuels add no excess carbon dioxide to the atmosphere. These are the crucial aspects on the implementation of alternative fuels:

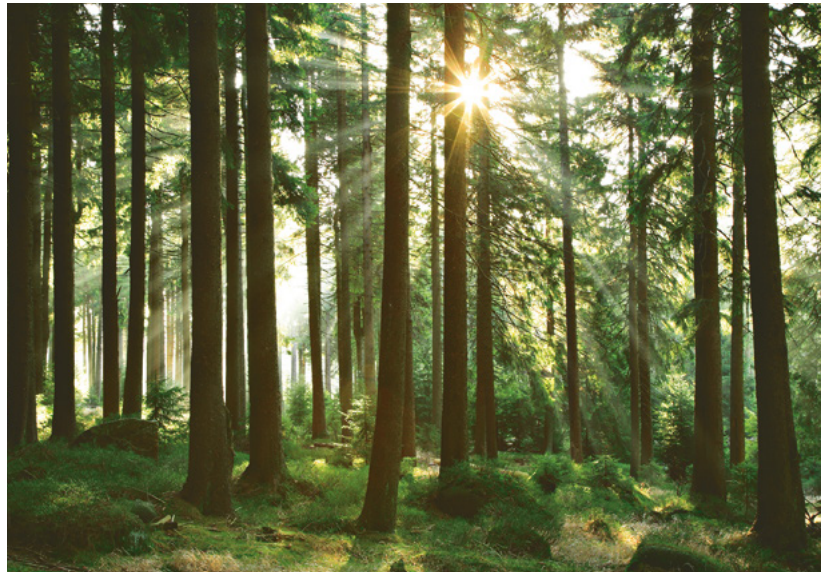
Climate change
Over and over again, reports by the United Nations conclude that use of fossil fuels contributes to global warming, which already has dramatic consequences for our life on Earth.

Increased energy demand
Fossil fuels continues to play a major part in satisfying growing energy needs, as the Earth's population and urbanization grow and the global economy more than doubles in size by 2040. However, the share of electricity and biofuels will increase.

The UN expects a rise in global population from just over 7 billion in 2014 to around 9 billion in 2050. More than 90 per cent of this rise will come from developing countries.

Multi-solution approach
Different types of transports require different solutions. There will not be one single fuel or driveline that can fully address climate change and other environmental issues.

With this in mind, Volvo Trucks is applying a two-path strategy. The first part is to use existing energy sources as efficiently as possible by improving the energy efficiency within our truck range. The second part of the strategy is to evaluate and implement alternative fuels. Our focus includes several possibilities described in this brochure.



Different alternatives – with different prerequisites

Volvo Trucks is studying and evaluating all alternatives with potential for use in our products. In this brochure, we examine the following fuels and energy carriers.

Biodiesel is a renewable, biodegradable fuel made from various vegetable oils, animal fats and recycled restaurant greases. It is produced through a chemical process called transesterification. Glycerine is separated from the fat and vegetable oil. Palm oil-based biodiesel is the most commonly used form. Biodiesel can be mixed with conventional diesel.

HVO, Hydrotreating of vegetable oils or animal fats is an alternative process to esterification for producing bio-based diesel fuels. In the production process, hydrogen is used to remove the oxygen from the vegetable oil.

Synthetic diesel is produced via gasification, which converts a mixture of hydrogen and carbon monoxide – derived from biomass, natural gas or coal – into a liquid fuel. Synthetic diesel is a highly paraffinic product with no sulphur.

Ethanol is a renewable fuel made by fermenting crops that contain starch or sugars. Currently, corn, wheat and sugarcane are the predominant crops for producing ethanol. Waste from paper mills, potato processing plants, breweries and beverage manufacturers can also be used.

Methanol is the simplest alcohol, produced via the gasification process.

DME – Dimethyl ether is a clean-burning non-toxic alternative that can be made from natural gas, coal, or biomass via gasification. DME is a liquid in room temperature at a pressure of 5 bars.

Methane is the main component of natural gas and biogas. Natural gas is a fossil fuel found in the earth; composed of methane, ethane, butane, propane and other gases. Biogas can be produced from all kinds of biomass. The raw biogas is cleaned and the final product consists of methane. LNG and CNG are abbreviations for Liquefied Natural Gas and Compressed Natural Gas.

Hydrogen is used in fuel cells, where it is combined with oxygen. The chemical reaction generates electricity. A clean process with the only other by-products being warm air and water vapor.

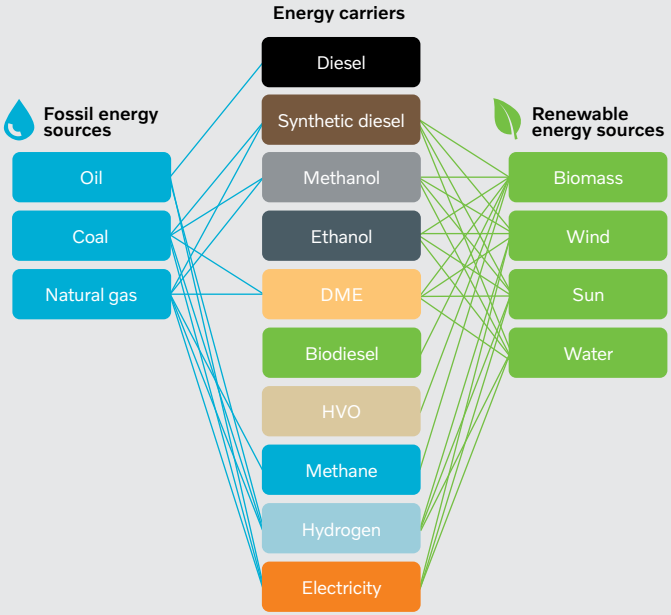
Electricity can be produced from a variety of primary energy sources, including oil, coal, nuclear energy, moving water, natural gas, wind energy, and solar energy.

The fuel evaluation on the following pages is based on what we regard as the seven most important criteria.

1. **Climate impact**
2. **Energy efficiency**
3. **Land use efficiency**
4. **Fuel potential**
5. **Vehicle adaptation**
6. **Fuel cost**
7. **Fuel infrastructure**

It is important to recognise that there are also other criteria to consider. A complete evaluation of each alternative fuel must include all aspects of a sustainability perspective, including social factors.

The graph presents an overview of the relationship between different energy sources and the production of energy carriers.



The four most promising fuels

Based on the evaluation in this brochure, Volvo Trucks has selected four fuels that are the most promising from our point of view.

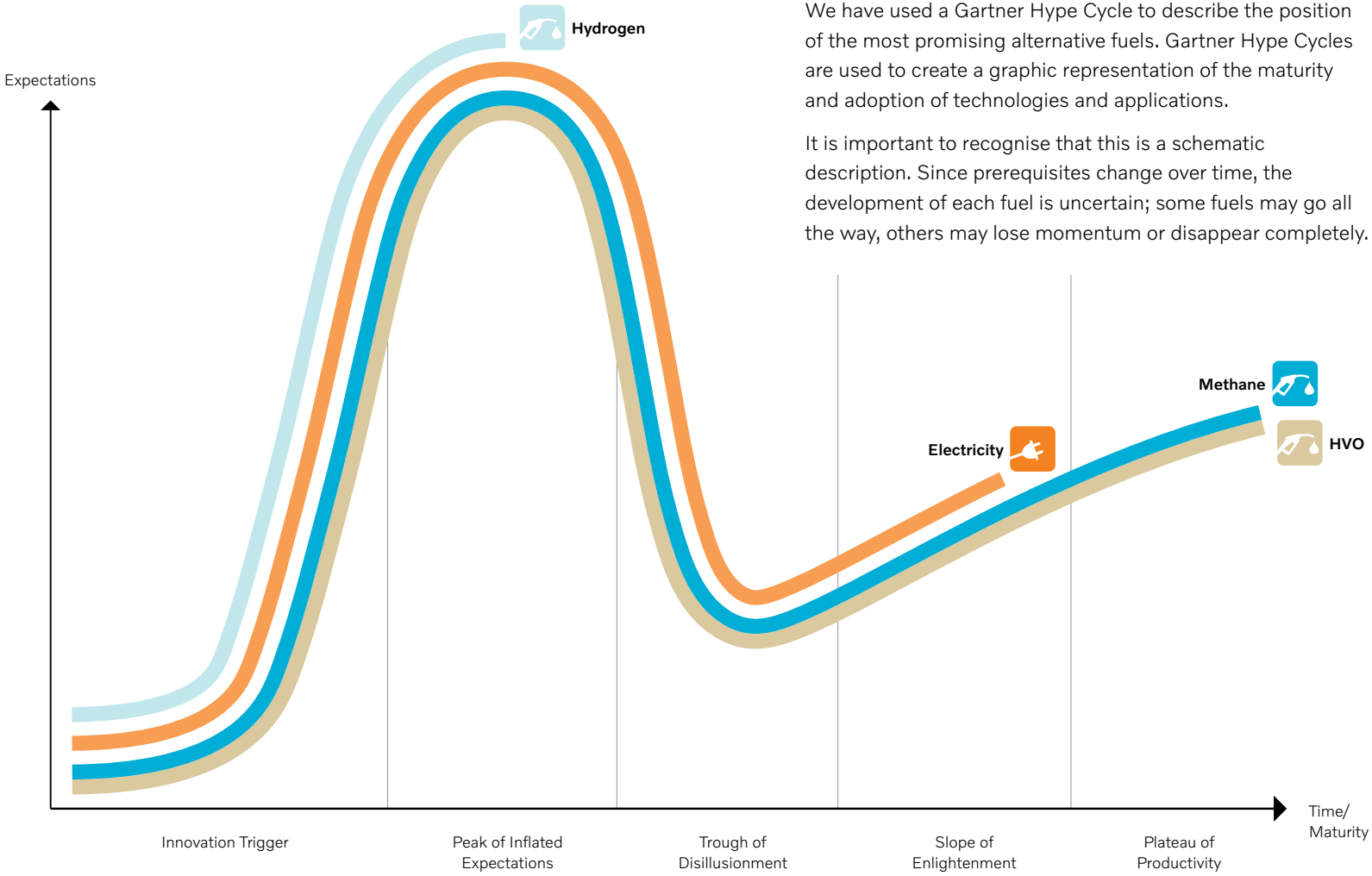
HVO is easy to use in current infrastructure and engines. With animal fat and waste as feedstock, HVO has good climate potential.

Electricity has high efficiency and a low climate impact. It is most suitable for urban and regional applications. Dynamic charging is needed for long distance transport.

Hydrogen is a strong long-term candidate with low climate impact.

Methane, natural gas and preferably biogas, is widely available and already an established alternative for urban applications. Liquefied Natural Gas (LNG) is suitable for long distance transports.

Comments, other analysed fuels
Biodiesel: Low blends are preferred. Availability is limited.
Synthetic diesel: Easy to use but high investment threshold in production.
Methanol: Long-term potential with climate benefits.
Ethanol: At present ethanol has limited climate potential, low blends in petrol are preferred.
DME: Long-term potential with climate benefits.



We have used a Gartner Hype Cycle to describe the position of the most promising alternative fuels. Gartner Hype Cycles are used to create a graphic representation of the maturity and adoption of technologies and applications.

It is important to recognise that this is a schematic description. Since prerequisites change over time, the development of each fuel is uncertain; some fuels may go all the way, others may lose momentum or disappear completely.

Climate impact

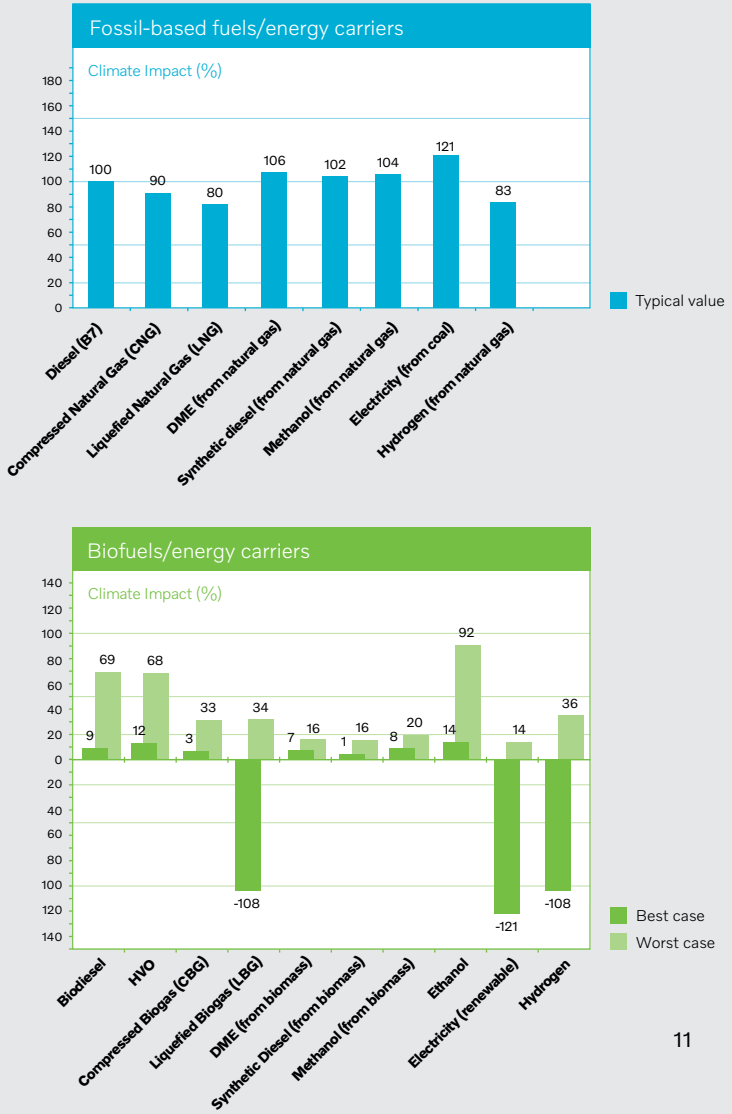
Carbon dioxide (CO_2) emissions
for complete ‘well-to-wheel’ chain.

‘Well-to-wheel’ means that all relevant stages of the fuel chain are considered. This includes the cultivation or extraction of the raw material, its transport to the fuel production plant, production and distribution of the fuel to refuelling stations, and its use in vehicles. Unlike ‘Tank-to-wheel’, which only covers the use in the vehicle, ‘Well-to-wheel’ provides a holistic perspective on the global impact of a fuel.

When relevant, the climate impact calculations shown for each fuel include production from fully renewable raw materials as well as fossil-based energy sources.

The chart shows the reduction/increase of CO_2 emissions compared with conventional diesel fuel. Non-fossil CO_2 emissions are not included since they do not produce a net increase in atmospheric CO_2.

Greenhouse gas emissions have been reported as CO_2 equivalents. In other words, emissions of greenhouse gases other than carbon dioxide are converted to the equivalent quantities of carbon dioxide.



Graph explanations

Value for CNG is EU mix.

The variation between best and worst case for the renewable fuels depends on the feedstock from which they are produced. Examples: Best case for DME, Synthetic Diesel and Methanol is black liquor, which is a waste product in paper production. Worst case is wood.

Best case for electricity is wind, solar and water. Worst is coal.

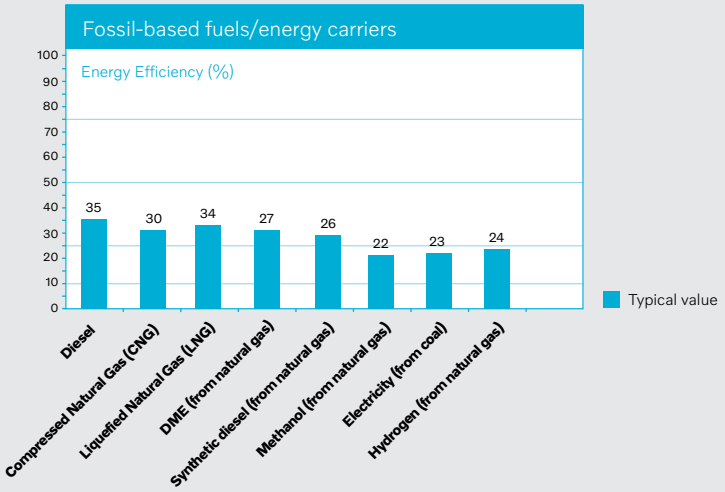
Energy efficiency

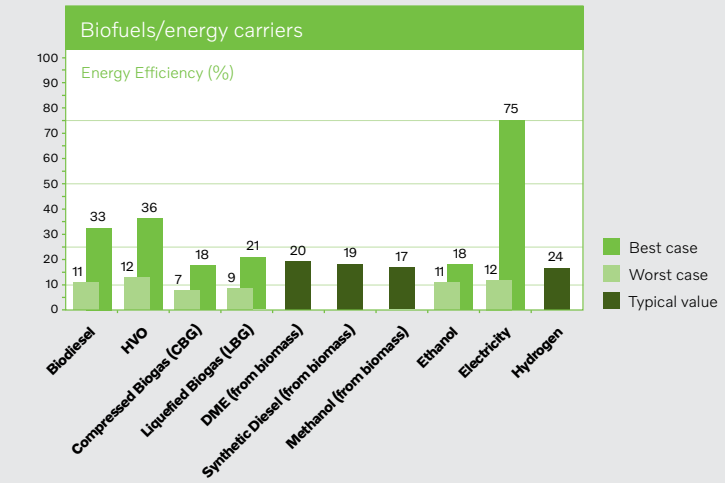
Total ‘well-to-wheel’ energy utilization.

Energy efficiency is expressed as a percentage indicating the proportion of energy reaching the vehicle's driven wheels.

For purposes of comparison, it may be noted that the fossil diesel used today delivers an overall efficiency of approximately 35 per cent. This relatively high value is due to the fact that crude oil may be regarded as a 'semi-finished' product, making the production of diesel very energy-efficient.

The results for the same fuel may vary depending on the production process and/or feedstock used.





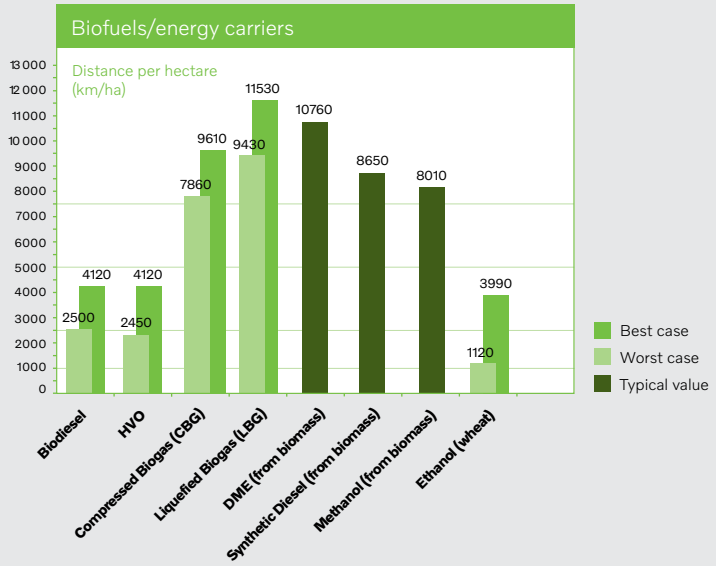
Land use efficiency

Scarcity of land resources makes the efficient use of land a particularly important issue.

Efficient land use will be an increasingly important factor in meeting the world's ever-growing demand for food and fuel.

Driving distance per hectare per year is a measure of the performance of biofuel. Data can be very different based on geographical location and crop type. The selection has been done based on European conditions.

The fossil fuel input for biofuel production (harvesting, production, transport, etc.) is subtracted from the quantity produced. The use of co-products from fuel production has significant impact on the results, e.g. if co-products are used as animal food or for energy purposes.



Graph explanations

The results for the same fuel may vary depending on the production process and/or the use of co-products.

This evaluation criterion is not applicable to fossil fuels or electricity.

Fuel potential

The amount of fuel that can be produced varies considerably depending on the option selected.

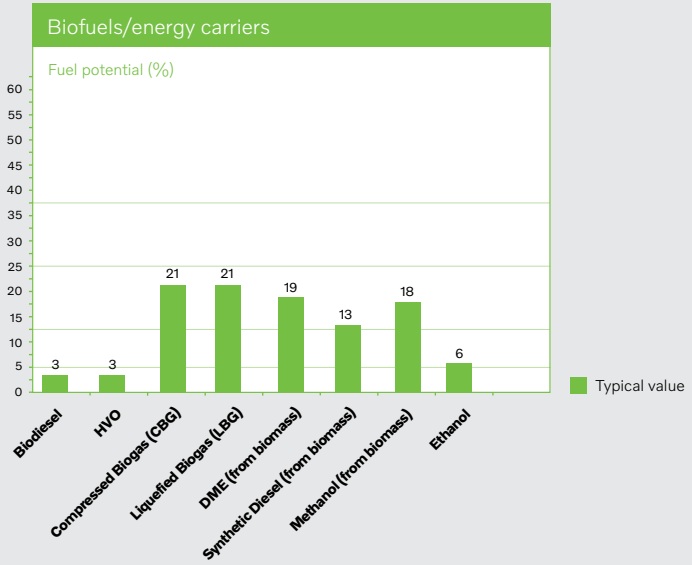
To reduce the climate impact from transports, fossil fuels have to be replaced with biofuels with large volume potential.

The availability of raw material and the choice of production process determine the amount of fuel that can be produced.

While some biofuel processes can use many different feedstocks and complete crops, others are limited to parts of individual crops. Competition from food production is a general problem if feedstocks are derived from agricultural products.

The amount of fossil fuel that can be replaced by biomass also varies depending on the efficiency of the fuel production process and the end use.

The results on the opposite page show that the biomass potential will not be sufficient to replace fossil fuels in the foreseeable future.



Graph explanations

The figure shows the how much of the total energy demand for transport in Europe (4,500 TWh by 2030) that can be covered by each renewable fuel alternative.

Note: Since the same feedstock can be used to produce different fuels, it is not relevant to add up results.

This evaluation criterion is not applicable to fossil fuels or electricity.

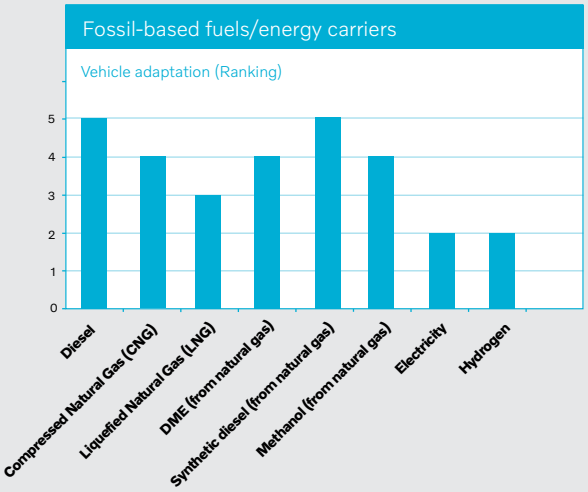
Vehicle adaptation

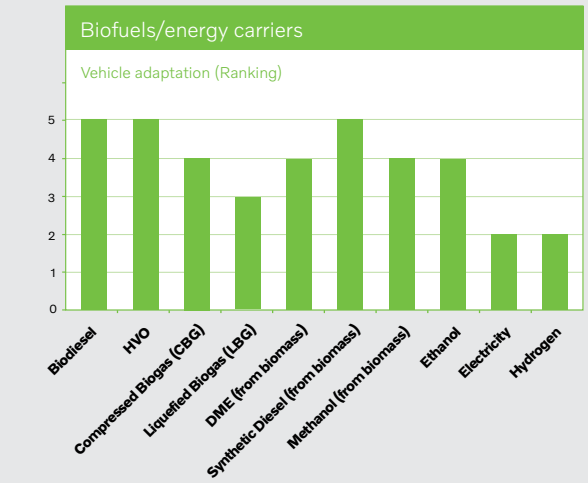
Different fuels require different types of vehicle adaptation.

This is an overall assessment of the technical complexity of adapting vehicles to use the new fuels.

The assessment includes the effects of various parameters on vehicle efficiency, such as maximum engine performance, increased weight and range between refuelling. The last of these, for example, may affect vehicle payload.

The complexity of adaptation includes factors that necessitate additional fuel storage capacity and require new and more expensive components, as well as the technology needed to meet future emission standards. For example, some fuels require more advanced emission control systems than others do.





Graph explanations

Evaluation showing score related to increased complexity and cost of the vehicle:

5 = Suitable for all applications; no special vehicle adaptation required.

4 = Suitable for most applications; no expensive or extensive vehicle adaptation required.

3 = Suitable for most applications; expensive and extensive vehicle adaptation required.

2 = Suitable for up to half of all applications; complex, expensive and extensive vehicle adaptation required.

1 = Suitable for only a limited number of applications; major, expensive and extensive vehicle adaptation required.

Fuel cost

‘Well-to-tank’ production cost.

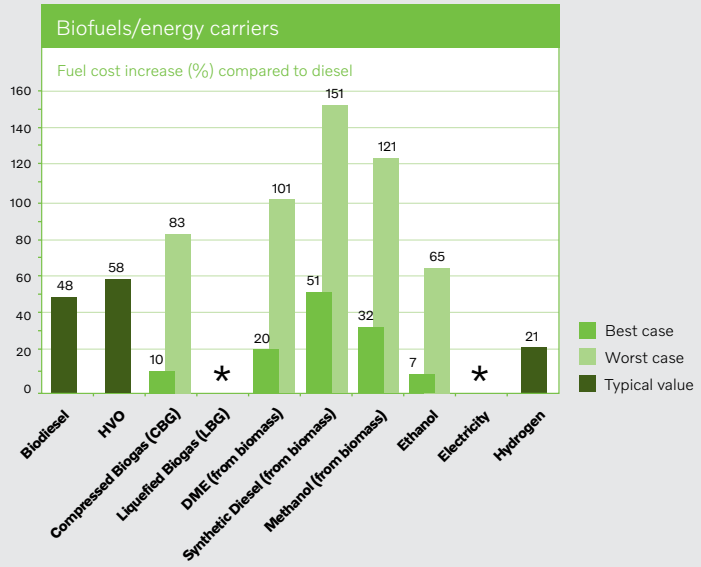
The evaluation includes raw material costs, fixed and variable production costs, transport and infrastructural costs, and the cost of energy utilization in the distribution chain.

In general, future costs are difficult to predict due to fluctuations in raw material prices and the rapid pace of technological development. In many cases, the cost of producing a fuel is only a small share of the price the end user pays, due to taxes and other charges.

In these examples, the cost of the individual fuel is compared with that of conventional diesel oil, assuming a crude oil price of USD 100 per barrel (excluding taxes).

The comparison is made on a per-litre equivalent basis. This means that more than a litre of fuel is required in some cases to obtain the same energy content as provided by a litre of diesel.

The results for the same fuel may vary depending on the feedstock, biomass price, investment cost, etc.



Graph explanations

Fuel cost for fossil fuels are not included since these can vary significantly depending on market conditions.

* Fuel cost of electricity and LBG is not included since the infrastructure cost is unknown, and since the price is set on an individual market basis.

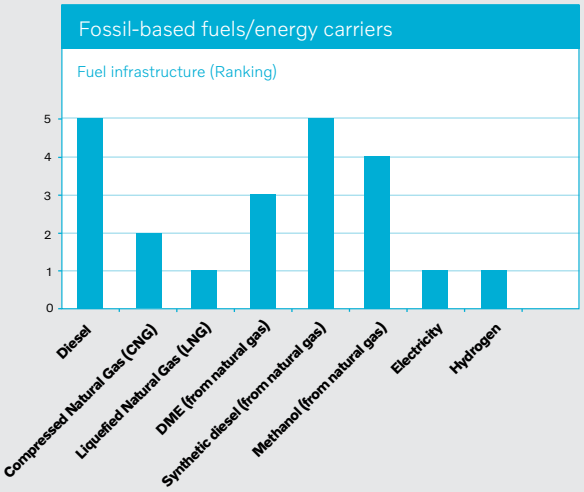
Fuel infrastructure

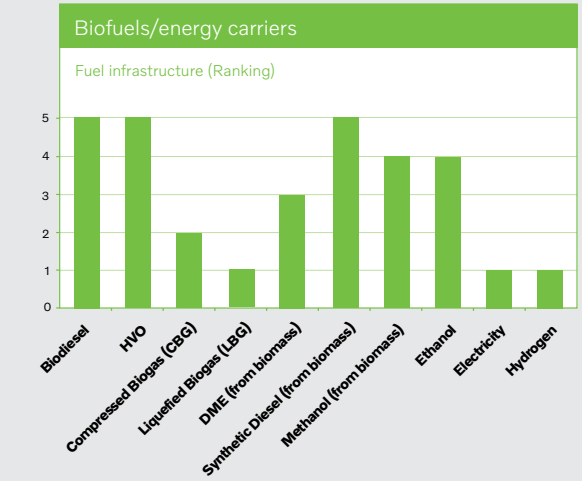
Handling and distribution.

Infrastructure is an important criterion in terms of how quickly and easily a new fuel can be introduced and integrated with existing systems.

This integration is often regarded as a major challenge to the introduction of an alternative fuel. However, it should be noted that in some cases, such as CNG, fuels with a low ranking in the graphs already have a sustainable infrastructure.

Since the infrastructure for conventional fuels is also in continuous need of major investments, infrastructure is a secondary issue in the longer term.





Graph explanations

Evaluation of necessary changes in fuel infrastructure compared to diesel:

5 = No/minor changes (liquid fuel).

4 = Significant changes (liquid fuel).

3 = Gas handled in liquid form at low pressure.

2 = Gas handled at pressure below 200 bar.

1 = Gas handled at pressure above 200 bar or in liquid form at low temperature. Electricity.

A holistic view and co-operation are the keys to success

All fuels described in this brochure have potential for significantly reducing climate emissions from the transport industry.

Volvo Trucks shoulders our share of the responsibility for the climate issues by developing vehicles for all the fuel options discussed here. However, we can't do it alone. Nor is building a sustainable transport society a single-solution effort.

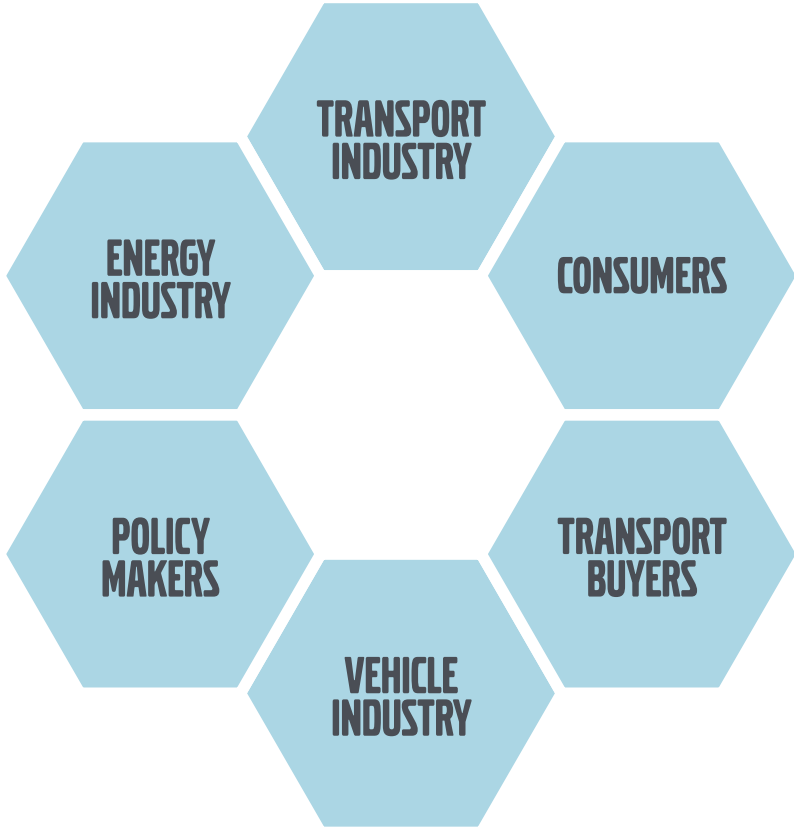
Implementing the fuels of the future requires co-operation between all the players involved. A holistic approach and participation of politicians, government agencies and fuel producers are necessary to making CO_2-neutral solutions more profitable than fossil fuels. Several co-ordinating factors must change to achieve this.

Volvo Trucks is working on establishing close co-operations with public and private partners in the circle on the opposite page.

It is crucial to choose biofuels with large volume potential to speed up the reduction of the climate impact from transports.

Biofuel availability will be limited for a number of years to come, even if current production resources are expanded rapidly.

The best transitional solution is to produce alternative fuels from fossil raw materials, such as natural gas. Renewable fuels can also be blended with established fossil fuels.


TRANSPORT INDUSTRY
CONSUMERS
TRANSPORT BUYERS
VEHICLE INDUSTRY
POLICY MAKERS
ENERGY INDUSTRY

Volvo Truck’s vision is to shape the future with zero emission vehicles. We have the innovation power it takes to be the world leader in sustainable transport solutions. All efforts to minimise the environmental impact of our products and services are totally in line with our purpose to move the world we want to live in; making a positive, lasting impact on our society and our planet.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