Volvo Trucks. Driving Progress

ALTERNATIVE FUELS

– The way forward

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

Climate issues are among the major challenges of our times. Their resolution will require a joint effort by the corporate sector, public agencies and individuals, across national boundaries and between different industries.

The transport industry plays a crucial role in the development of our society and its economy. However, the transport sector also accounts for a significant proportion of the emissions that have adverse effects on our climate.

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 that brings the modern transport society into a sustainable future.

Our aim is to make continuous progress in the areas of energy efficiency and alternative fuels – and we have already demonstrated our ability to develop vehicles for a wide span of fuel options.

Our long-term commitment to improving fuel efficiency will be just as important when the use of alternative fuels grow in the transport sector. Reduced fuel costs will continue to be a top priority for truck owners also in the future.

We are constantly looking for new ways to make our trucks run further with less fuel and less impact on the environment. Our 'Every Drop Counts' philosophy is a down-to-earth approach that made us a leader within fuel efficiency improvements. It is based on the thinking that one per cent here and one per cent there soon add up to noticeable fuel savings.

This brochure describes the pros and cons of different alternative fuels. It emphasises the importance of a holistic view and the co-operation between all the various players involved in the analysis and selection of the fuels that will carry us into a sustainable future.

Broad consensus at the highest levels is needed to ensure the successful development of CO_2-neutral transport. International coordination between producers and legislators is required to develop uniform fuel standards and stable, long-term regulations.

The next major step in the development is to start production and distribution of alternative fuels on a major scale. A transitional solution on the road towards climate neutral transport is to produce some of the fuel alternatives using fossil raw materials, such as natural gas.

Alternative fuels – an overview

CO_2-neutral transports do not add to greenhouse effect.

CO_2 neutral transports are powered by fuels produced from renewable raw materials, such as biomass. Unlike fossil fuels, CO_2-neutral fuels add no excess carbon dioxide to the atmosphere. The combustion process generates exactly the same amount of carbon dioxide as that absorbed by the source material during its growth, and no increase in atmospheric carbon dioxide will result provided that crop regrowth matches the quantities harvested. Three crucial factors make the changeover to renewable fuels urgent:

Climate change
Our use of fossil fuels contributes to global warming which, in the long term, will certainly have dramatic consequences for life on Earth.

Increased energy demand
Fossil fuels will continue 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 biofuels will increase from today's low levels.

United Nations 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 comes from developing countries. By 2028, India will be more populous than China.

Decline in finite resources
The Earth's reserves of oil and other fossil fuels will eventually be exhausted – the only question is when. The price of oil is also continuously unstable due to geopolitical factors.

Different alternatives – with different prerequisites

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

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. Palmoil 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 biobased 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 – to 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 most 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 a gasification process. DME is a liquid in room temperature at a pressure of 5 bars.

Methane, the simplest of hydrocarbons, is the main component of natural gas and biogas. Natural gas is a fossil fuel found in the earth. It is composed of methane, ethane, butane, propane and other gases. Biogas can be produced from all kind of biomass. The biomass is anaerobically fermented into gas. 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.

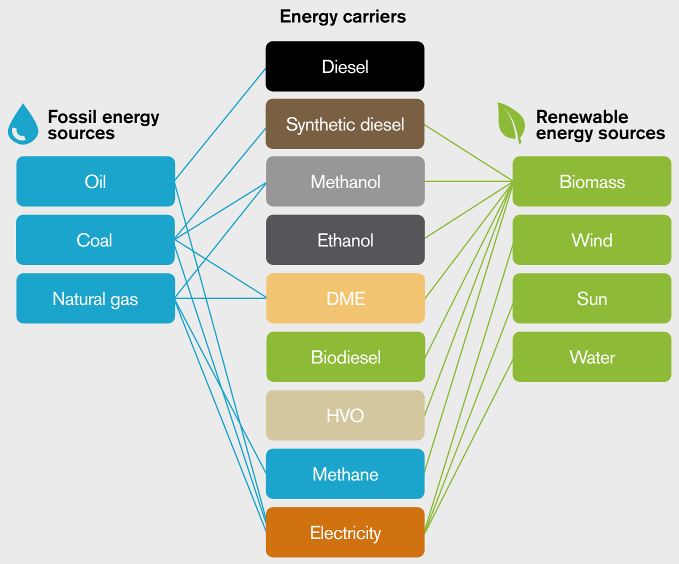
Electricity can be produced from a variety of primary energy sources, including oil, coal, nuclear energy, moving water, natural gas, wind energy, and solar energy.

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 fuels.



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.

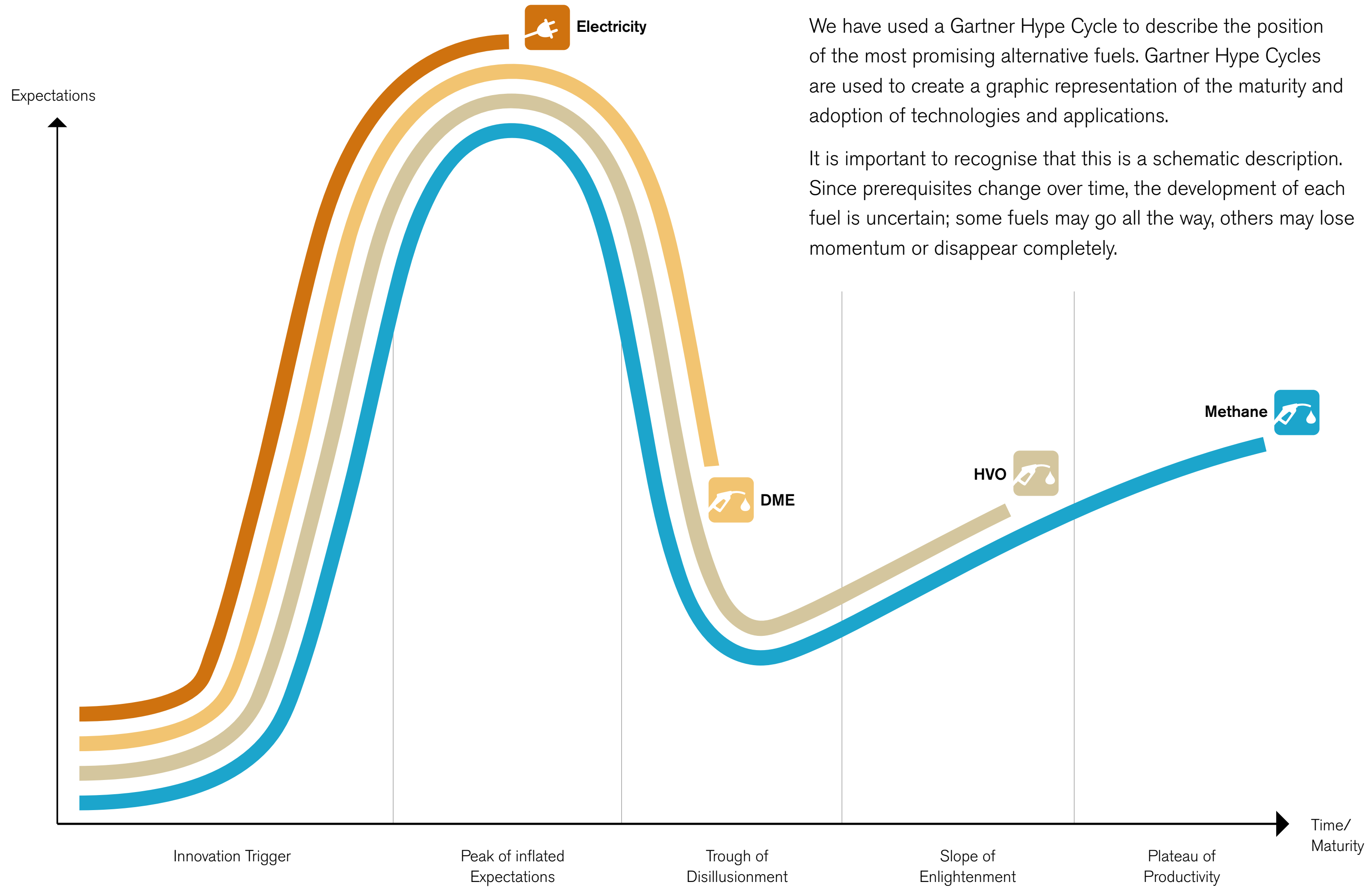
HVO is easy to use in current infrastructure and engines. With animal fat as feedstock, HVO has good climate potential.

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

DME DME is a strong long-term candidate with low climate impact and efficiency benefits.

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: Has technical issues and low blends are preferred. Availability as well as the climate potential is limited.
Synthetic diesel: Easy to use but high investment threshold in production.
Methanol: Long-term potential with climate benefits.
Ethanol: Present ethanol has limited climate potential, low blends in petrol are preferred.



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.

When relevant, the climate impact calculations shown for each fuel include production by 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.

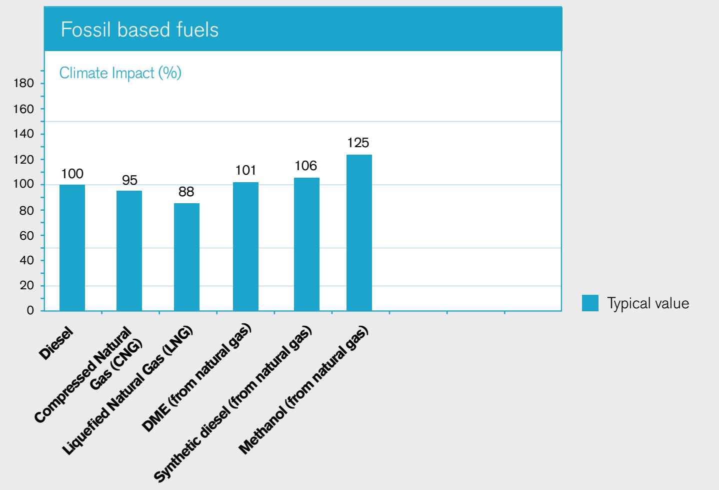
Greenhouse gas emissions have been reported as CO_2 equivalents. In other words, emissions of greenhouse gases other than carbon dioxide are converted to the equivalent quantities of carbon dioxide.

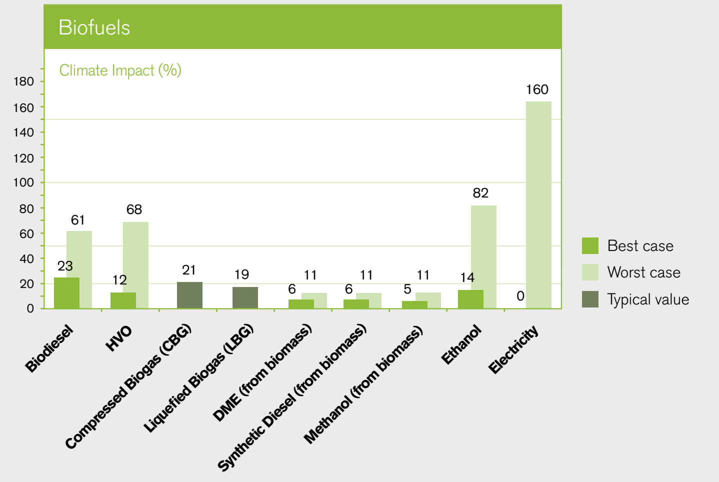
Graph explanations

Value for CNG is EU mix.

The variation between best and worst case for the renewable fuels depends on which feedstock they are produced from. Example: 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.





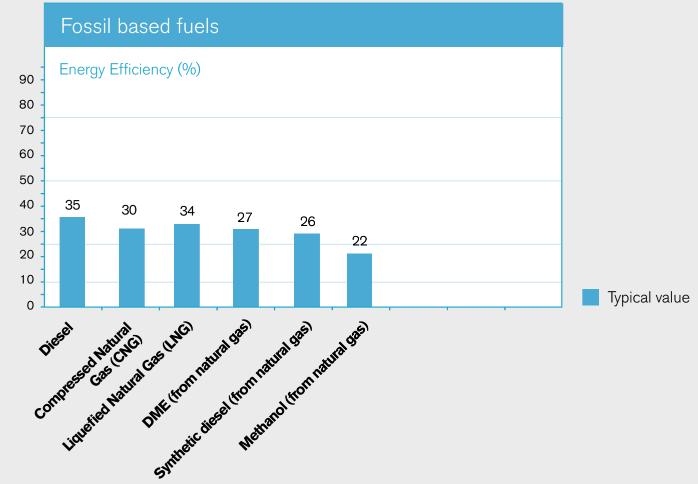
Energy efficiency

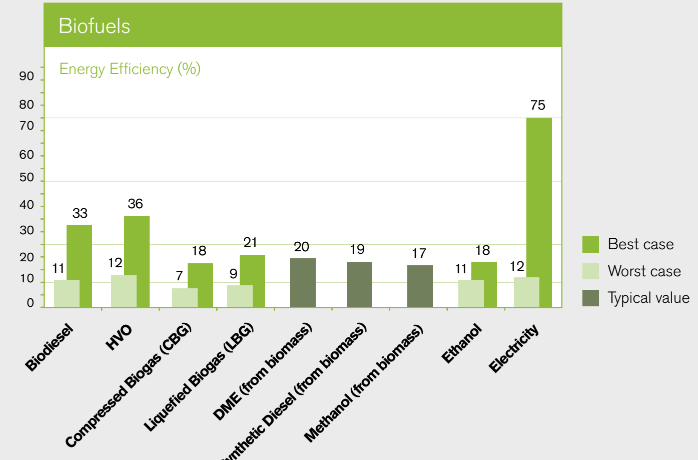
Total ‘well-to-wheel’ energy utilization

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 oil 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 pro¬cess and/or feedstock used.





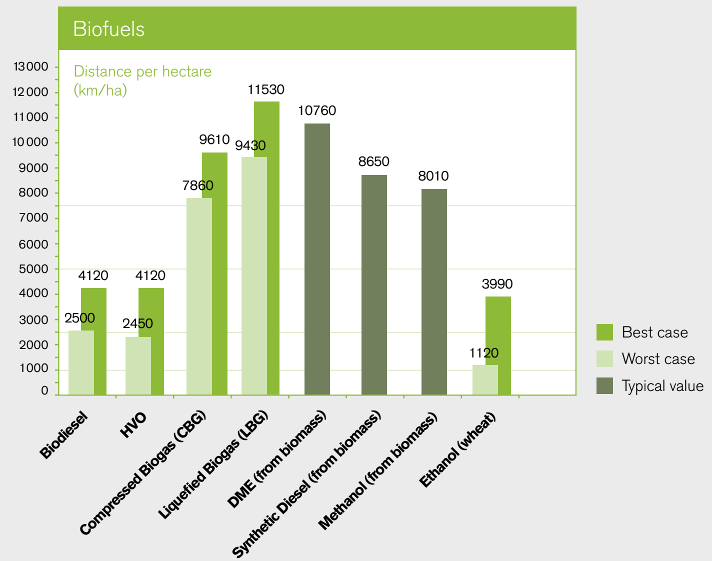
Land use efficiency

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 the biofuel production (harvesting, production, transport, etc.) is subtracted from the quantity produced. The use of co-products from the 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

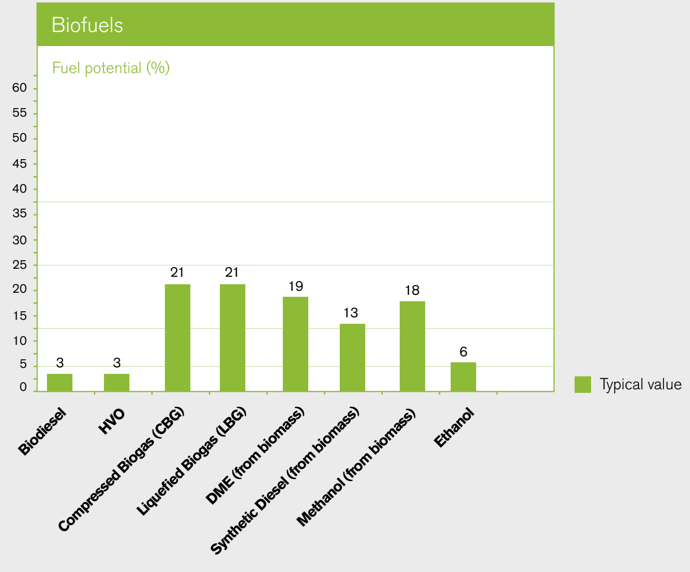
The amount of fuel that can be produced varies considerably depending on the particular option.

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 with feedstocks 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 result shows that the biomass potential will not be sufficient to replace fossil fuels in the foreseeable future.

The potential of fossil-based alternative fuels depends on how long the raw materials are estimated to last. For example, the earth´s oil reserves are estimated to last 50 years. The figure for coal is 135 years, while the natural gas reserves are estimated to last another 60 years.



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 that the maximum potential depends on that one fuel is produced from each feedstock. 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. As an example, some fuels require more advanced emission control systems than others.

Graph explanations

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

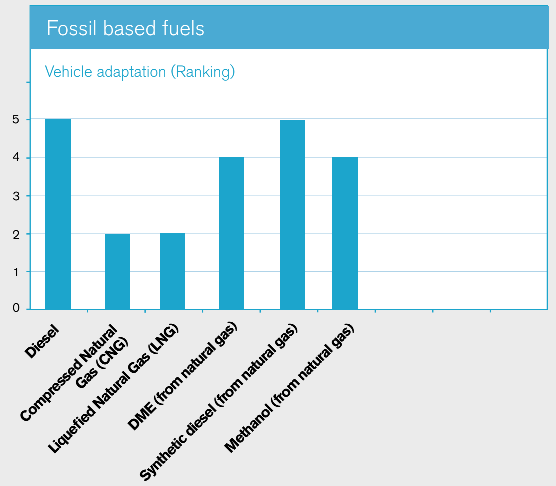
5 = Suitable for all heavy applications; no special vehicle adaptation required.

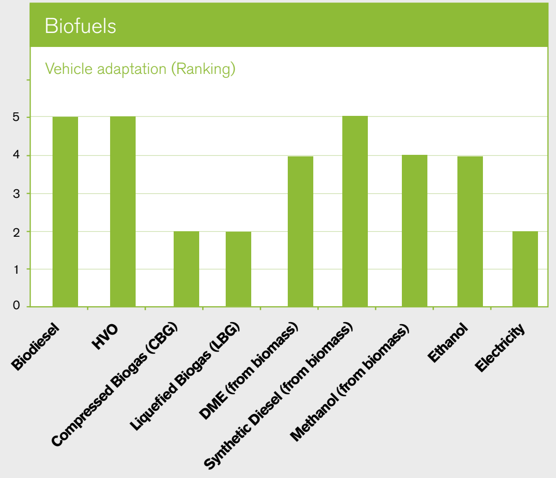
4 = Suitable for most applications; no expensive or extensive vehicle adaptation required.

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

2 = Suitable to 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.

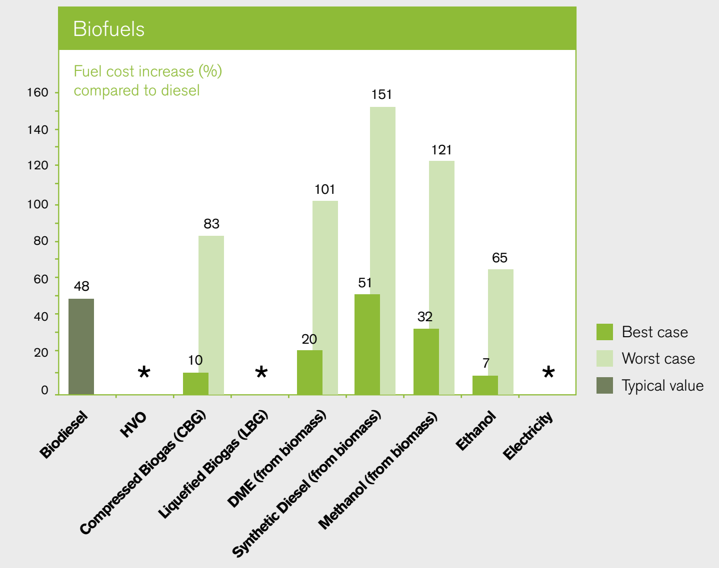
The evaluation includes raw material costs, fixed and variable production costs, transport and infrastructural costs, and the cost of energy utilization in the distribution chain.

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 particular 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 over a litre of fuel is required in some cases to obtain the same energy content as 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 HVO is not available. Fuel cost of electricity and LBG is not included since the infrastructure cost is unknown, and since the price is set on 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 it 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 low marks 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

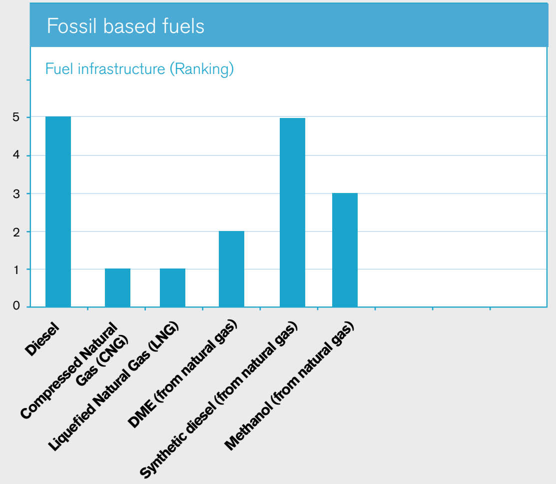
5 = No changes (liquid fuel).

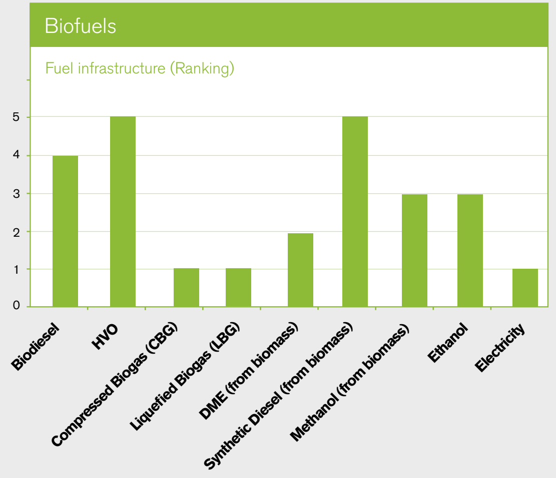
4 = Minor changes (liquid fuel).

3 = Major changes (liquid fuel).

2 = Gas handled in liquid form at low pressure.

1 = Gas handled under high pressure or in liquid form at low temperature.





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

All the fuels described in this brochure have potential to reduce climate emissions from the transport industry by a significant amount.

As one of the world's leading manufacturers, Volvo Trucks is willing and able to shoulder our share of the responsibility for climate issues by developing engines designed to use the new fuels.

All fuels have advantages and disadvantages and choosing the fuels of the future requires a holistic approach and co-operation between all players involved.

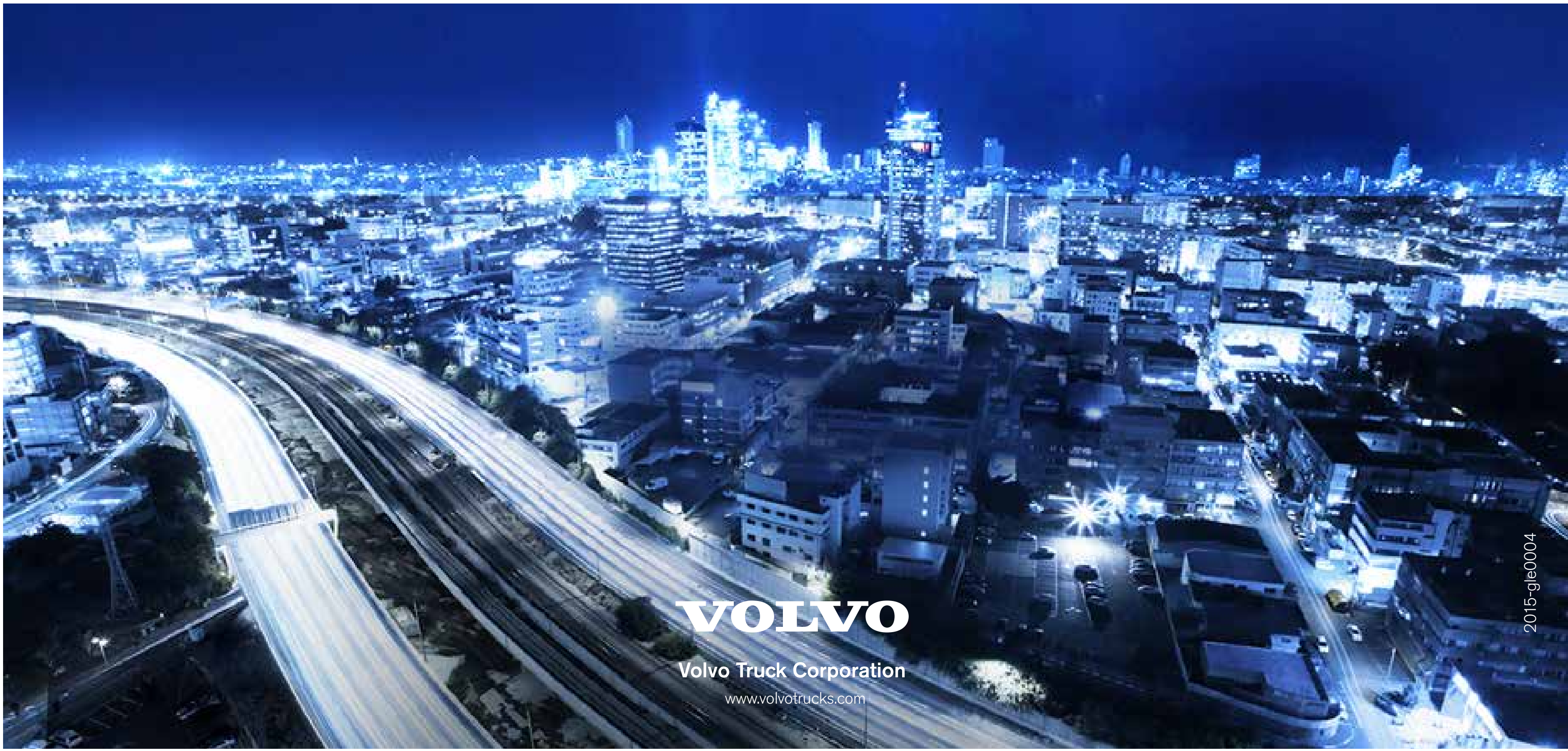
Volvo Trucks has already demonstrated our ability to develop vehicles for all of the fuel options discussed here. However, the development of carbon dioxide-neutral transport will not happen of its accord – nor can we do it alone.

Making CO_2 neutral transport a reality will require active participation of politicians, government agencies and fuel producers. Politicians and government agencies must take international decisions at a regional level or higher to enable stable, long-term regulations to be implemented, while fuel producers must provide the answers as to when production and distribution can begin.

The availability of biofuels is a crucial factor. Even if current production resources are expanded rapidly, availability will be limited for a number of years to come.

For this reason, the best and most logical transitional solution is to accept that alternative fuels can be produced using fossil raw materials, such as natural gas. Renewable fuels can also be blended with today's fossil fuels.

Volvo's vision is to be the world leader in sustainable transport solutions. Our determination to be part of the solution to the complicated environmental challenges has won global recognition. We will continue to improve fuel efficiency and minimise the environmental impact of all our products and services.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