



ELECTRICITY

APPLICATION FOR FREIGHT TRANSPORT

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**Høje-Taastrup
Kommune**



ENERGI
STYRELSEN

Preface

Today's transport sector is heavily dependent on fossil fuels, which causes significant increases in air pollution. This is in particular crucial in urban areas with high density of transportation. The transition towards alternative fuels is a key factor to fight pollution and to achieve decarbonisation, sustainability and competitiveness of the transport sector.

In Denmark, Høje-Taastrup Municipality is especially concerned and proactive in this area. The project Høje-Taastrup Going Green was launched on 1st of January 2014, where one of the main goals is promoting a fossil free transport sector. Particularly the freight sector is targeted due to the high level of pollution it creates.

A main objective of the project is to create a platform for further use and development of alternative fuels in the freight transportation sector. A special focus is therefore on illustrating the possibilities and perspectives of the alternative fuels: electricity, hydrogen, gas (CNG, LNG and biogas) and biodiesel. At the moment, the application of alternative fuels is not competitive with traditional fossil based propellants. Thus, it is important to prospectively set up the framework and establish the infrastructure to integrate and foster alternative fuels in Høje-Taastrup Municipality.

In line with the project, a set of catalogues of different propellants were developed, focusing on the utilisation of electricity, hydrogen, gas and biodiesel for freight vehicles. Each catalogue analyses the propellant in terms of technology, environmental impact, economics and related policy instruments, in order to point out its applicability and hurdles.

The following catalogue will elaborate on electrical driven vehicles.

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1 OVERVIEW

1.1 EU and Danish Goals and Targets

The EU's goal is to reduce emissions by 80 to 95% by 2050 compared to 1990 levels. The transport sector is a significant and still growing source of greenhouse gas (GHG) emissions. Therefore, a reduction of at least 60% of GHGs by 2050 with respect to 1990 is required from the transport sector, which is then followed by a comparable reduction in oil dependency. In order to achieve the target, the EU white paper on transport includes these relevant goals:

- “Halve the use of ‘conventionally fuelled’¹ cars in urban transport by 2030;
- Phase them out in cities by 2050;
- Achieve essentially CO₂-free city logistics in major urban centres by 2030”. [1]

To strengthen this, Denmark has a challenging goal to reach 100% fossil fuel independence within the transport sector by 2050. Regarding this, almost the entire vehicle fleet needs to become zero-emission.

As a fact, EU transport is 95% dependant on oil and its products. Figure 1 illustrates the final energy consumption in the transport sector in 2011 by type of fuel and emphasise the need of taking actions towards greener transport.

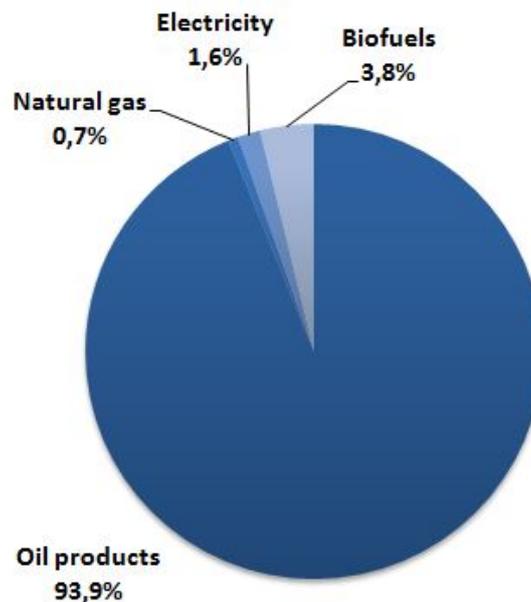


Figure 1: Final energy consumption in EU transport sector by type of fuel

¹ The term refers to vehicles using non-hybrid, internal combustion engines.

1.2 Application of Alternative Fuels

The transport sector cannot rely only on one single type of alternative fuel. In the long run, it should be based on a mix of several different fuels, with respect to the needs of each transport mode. The coverage of travel range by different alternative fuels is summarised in Table 1 for urban, light-duty and heavy-duty vehicles. Biofuels stand for biodiesel and methane stands for CNG/CBG (compressed natural gas/biogas) and LNG/LBG (liquefied natural gas/biogas). [2]

Vehicle								
	Urban	Short	Medium	Long	Short	Medium	Long	
Electricity								
Hydrogen								
Biofuels								
Methane							LNG/LBG	

Table 1: Application of alternative fuels for different transport modes [2]

To conclude, electricity can be applied only for short travel distances, hydrogen and CNG/CBG up to medium distances, and biofuels and LNG/LBG up to long distances. [2]

Electricity, both battery vehicles and fuel cell vehicles, is expected to be applied mainly for the car fleet. Regarding heavy-duty transport, biofuels and methane are prioritised due to the technical reasons. As a result, for the freight transport sector, in particular for long-distance transportation, limited alternative fuels are available. [2]

However, the set of catalogues examines all the different alternative fuels (electricity, hydrogen, biodiesel, CNG/CBG and LNG/LBG) and their possibility to be applied to heavy-duty vehicles.

Electricity application for the heavy-duty vehicles is limited yet. Therefore, information given in this report is more relevant to the light-duty vehicles, which then provides a general understanding of prospects and hurdles of the technology.

2 INTRODUCTION

Electric vehicles are one of the most advanced transport means using alternative fuel. Deployment of this technology can help increase energy security by reducing reliance on imported fuel, improve fuel economy and reduce emissions. It is a sound pathway to support green transportation and achieve a targeted 60-80% reduction in GHG by 2050, which is a focus of EU attention.

Electric vehicles are strongly supported at the EU level and seen as a key player in the future transport. According to the different national and regional targets set out during recent years, about 5 million electric vehicles are foreseen in the EU by 2020. [2] Denmark aims for 200.000 electric vehicles by then. [3] Currently, there are over 2.000 electric vehicles driven in Denmark.

2.1 Fuel Production Method and Availability

Electricity is a widely-available power source all over the world. Electricity can be domestically produced from a variety of primary energy sources, both fossil fuels based and renewable, including oil, coal, natural gas, biomass, nuclear energy, wind, solar or hydro energy. Electricity is fed into the electricity grid. Electric vehicles are able to draw the electricity from this off-board electrical power source by plugging-in and store it in their batteries. [4]

Most of the primary sources of energy are used directly or indirectly to move the blades of a turbine connected to an electric generator, where mechanical energy is converted into electrical energy. In the case of coal, oil, natural gas, biomass, nuclear fission or solar thermal power, the heat is produced by the primary resources and used to create steam, which moves the blades of the turbine. Regarding hydro and wind power, turbine blades are directly affected by flowing water and wind respectively. Finally, as an exception, photovoltaic (PV) panels convert sunlight directly to electricity. Therefore, PV panels on the rooftops might be taken as an advantage of distributed renewable energy source and applied for fleets. [4]

Electricity travels long distances from generating facilities to the end users through a transmission grid. When electricity leaves a generating facility, the voltage is increased by a transformer in order to minimise the power losses over long distances (high-voltage transmission lines). Once electricity arrives in the load areas, voltage is decreased by transformers at distribution substations. Finally, it is lowered further for end users. In Europe, residential customers use single phase 230 V, while commercial and industrial customers might use both single phase 230 V and three phase 400 V. [4]

Electricity demand is fluctuating and depends on both time of the day and time of the year. Electricity production, transmission and distribution capacity is built to be able to meet peak demand. However, most of the time electricity infrastructure is not operating at its full capacity. Therefore, electric vehicles might be charged predominantly during these off-peak hours, such as late at night when the electricity demand is at a minimum and, regarding freight sector, most transport is not operating. This way, costly electricity generation during peak periods is avoided. Furthermore, in case of considerable share of fluctuating renewable energy integrated to the grid, excess electricity can be exploited during the periods, when production is higher than demand. On the other hand, increasing number of electric vehicles might require additional capacity. [4] According to the prospects of EU, the energy need for electric vehicles can be covered by the existing electricity generation system with no additional capacity needed for the next 15-20 years, taking into consideration the expansion of electric vehicles fleet. [2]

Nowadays, vehicles and supply equipment, i.e. charging stations, can be programmed to restrict charging to off-peak times. Some of them are able to communicate with the grid and charge automatically when electricity demand and prices are lowest. [4] It is called a smart grid.

2.1.1 Electricity from Renewable Energy

If electric vehicles had a direct access to clean electricity from renewable sources, they could be considered as zero-emission vehicles. Denmark is well known worldwide for being skilled at capturing the power of wind and exploiting its resources for electricity generation. Figure 2 shows electricity production by different generation plants and electricity consumption. In general, Danish electricity consumers experience the highest level of security of supply among other EU countries, meaning that power is on 99,99% of the time. [5]

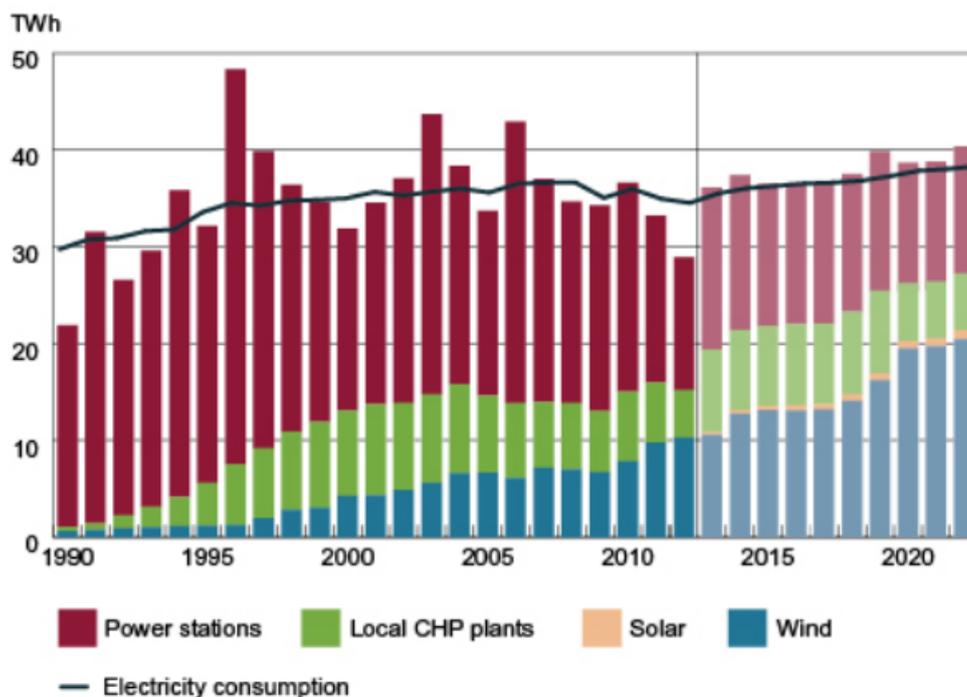


Figure 2: Power consumption and generation in Denmark in the period 1990-2022 [6]

In Denmark fossil fuels are being replaced by renewable energy sources for electricity generation. Electricity generated from wind energy is constantly increasing. In 2012, it covered around 30% of annual electricity consumption, against only 2% in 1990. Significant expansion in wind turbines is also expected during further years. Furthermore, it is expected to have a growing share of solar energy within the next years. According to energinet.dk, power consumption is also expected to increase by 10% in period 2012-2022 due to an expected increase in number of electric boilers, heat pumps and electric vehicles. [6]

In the future, due to the expansion of the wind power capacity, a huge amount of excess electricity will be generated during windy periods. Thanks to the smart grid, it is expected to be utilised beneficially through intelligent demand side. Prices that reflect the cost of electricity at a certain time should be offered to

consumers as an economic incentive to adjust the existing usage of electricity (grey area) to the periods of excess production. Moreover, if the actual pricing is not delivered to the consumers or appliances directly, the expected load diagram of the day might result in a “boiling point” due to increased electricity demand within the years. This might call for the expansion of electricity system’s capacity. Time differentiated prices would give incentives to the consumers to charge their electric vehicles during the periods with high renewable energy share or available electricity capacity in the grid. Shifting time of consumption is illustrated in Figure 3. [7]

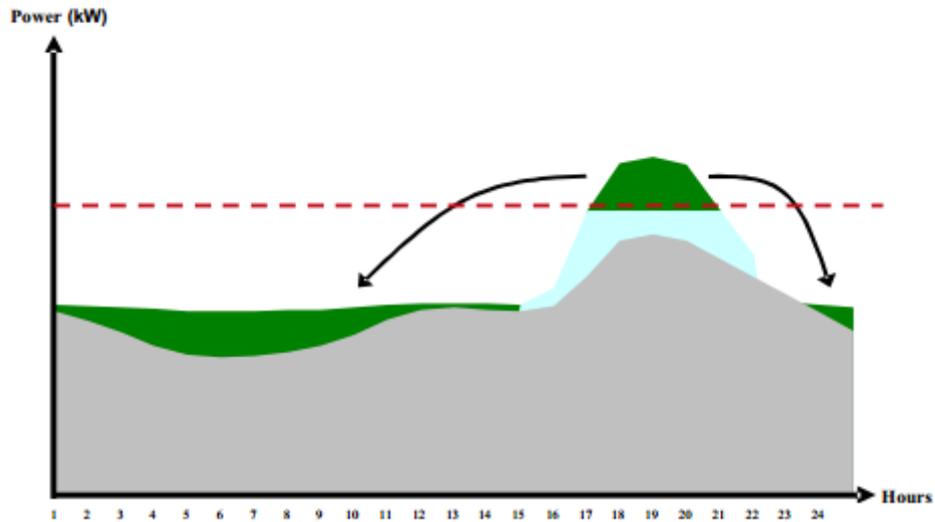


Figure 3: Optimisation of the grid capacity [7]

As a result, wind energy should be considered as a great potential source for charging electric vehicles and, at the same time, a key factor in addressing environmental issues. However, as it is mentioned before, integration of electric vehicles requires well developed optimisation, which enables to use electricity advantageously, i.e. integration of a smart grid.

3 TECHNOLOGY

Main reasons for using electricity as an alternative fuel are:

- Electricity system is well-developed and widely available;
- Zero-emission vehicles;
- Already advanced technology and high efficiency of electric vehicles.

There are three different types of vehicles powered by electricity: hybrid electric vehicle, plug-in hybrid electric vehicle and battery electric vehicle (running only on electricity and called EV further in the report). The latter is in the focus due to the emission-free operation powered by electricity only, in contrast to the first two, which run on conventional or alternative fuel and are supported by electricity. [4]

3.1 Technology Description

Electric vehicles are one of the simplest forms of self propelled mechanical transport. It simply consists of the three main components: rechargeable battery pack, controller and electric motor (see Figure 4).

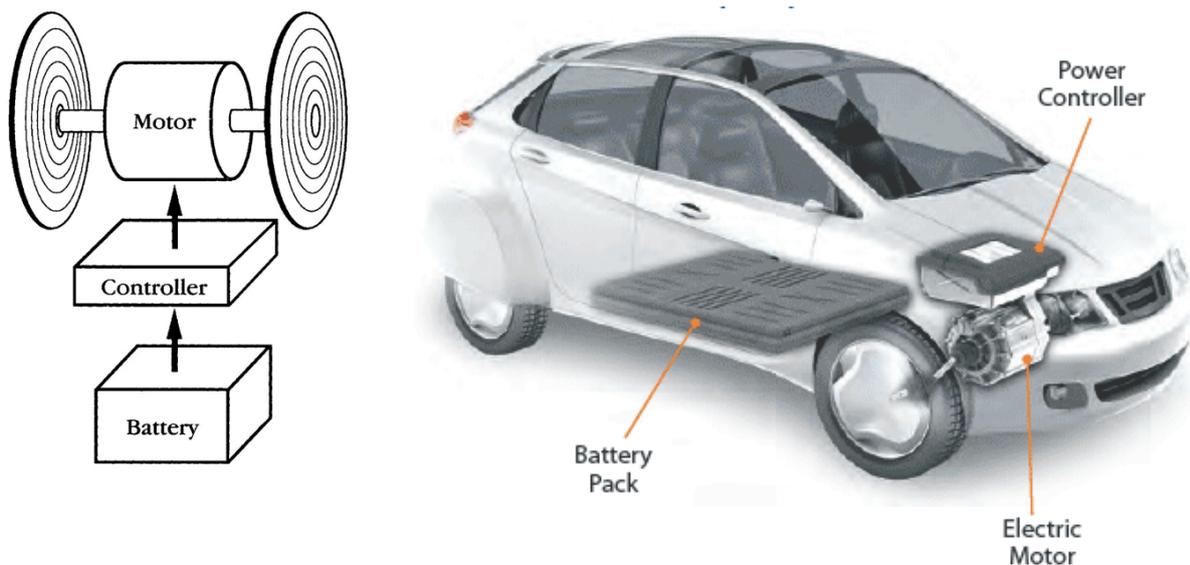


Figure 4: Schematic of an electric vehicle [8]

EV batteries are charged by plugging the vehicle into an off-board electric power source. In this way, battery stores the electrical energy which is later used to power the motor. A controller is a device that controls the electricity flow from the battery to the motor, in accordance with the input from the accelerator pedal. The motor consists of a tightly wrapped coil of wires, which starts rotating very quickly when electricity is fed to the coil and magnetic field is created. The coil is fastened to the axle, which rotates along with the coil and thereby drives the wheels. [4]

Thanks to the battery, EVs are also capable to recover braking energy, i.e. to convert kinetic energy into electricity during braking and store it in the battery. Later, the power recovered can be used for propulsion again. [9]

The main technological differences between conventional internal combustion engine vehicle and electric vehicle can be seen in Figure 5.

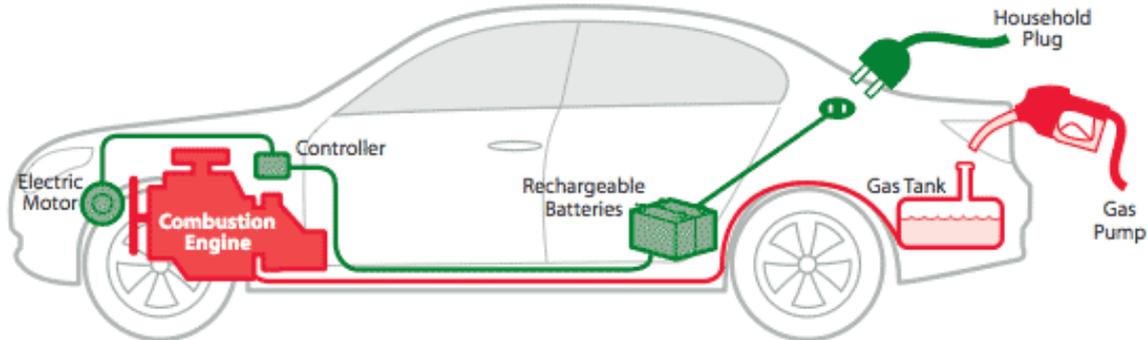


Figure 5: Difference between technologies of conventional (red) and electric (green) vehicles [10]

3.1.1 Conversion

Even though the technologies of EV and conventional vehicle are entirely different (see the figure above), there is a possibility to convert a vehicle with an internal combustion engine into an EV by removing the engine and adding a battery pack, an electric motor, high-voltage cables and other necessary instrumentation. [4] Regarding heavy-duty vehicles, their conversion is though expensive and often not successful.

3.2 Main Characteristics

3.2.1 Fuel

In Denmark, the same as in the whole Europe, the standard supply voltage is single phase 230 V, either it is domestic supply (slow charging at home) or commercial supply (fast charging at public stations). Sometimes three phase 400 V can be used in fast charging stations. Both alternative (AC) and direct (DC) current are used. The latter is applied only for fast charging. [11]

Mostly, the fuel efficiency of an EV is measured in kilowatt-hours per kilometre (kWh/km) and therefore it is difficult to compare it with conventional fuel efficiency, which is measured in l/km (or km/l). The average electric usage of EVs is only 0,15-0,25 kWh/km including charging losses. Therefore, EVs are very energy efficient compared to conventional vehicles, which use at least 0,5 kWh/km. [12] Converted into km/l gasoline equivalent, it would be 60 km/l and 18 km/l respectively. [13]

The main characteristics of electricity as an alternative fuel for vehicles are presented in Annex 1.

3.2.2 Battery

The battery is an energy storage system and the heart of EV. Further described batteries are commonly used.

- Lithium-ion batteries are mostly used in plug-in hybrid electric vehicles and battery electric vehicles. They have high energy per unit mass, high power-to-weight ratio and energy efficiency, good high-temperature performance and low self-discharge. However, the development of how to reduce the cost and extend useful life cycle of batteries is still ongoing. At the moment, lithium-ion batteries are leading and the most promising among the others.
- Nickel-metal hydride batteries are widely used in hybrid electric vehicles, but are also successfully applied to battery electric vehicles. The main challenges with this type of batteries are their high cost, high self-discharge and heat generation at high temperatures.
- Lead-acid batteries are inexpensive, safe and reliable, yet they have low specific energy, poor cold temperature performance and short life cycle.
- In ultracapacitors the energy is stored in a polarized liquid between an electrode and an electrolyte. Energy storage capacity increases when the liquid's surface area is enlarged. This type of battery can be used as additional power element, e.g. during acceleration, or facilitator to recover braking energy. Due to the ability to help electrochemical batteries level load power, ultracapacitors can also be useful as secondary energy storage devices. [4]

In general, the battery has a low energy density by weight. For instance, EVs with advanced lithium-ion batteries have 50 times lower energy density compared to conventional liquid fuels based vehicles. Even though energy efficiency is 3 times higher, 15 times larger battery weight is needed for onboard storage to meet the same driving range as it can be done with an internal combustion engine vehicle. This punitive payload constrains the energy storage and thus limits driving range, which remains one of the main drawbacks of EVs. [2] According to manufacturers, a typical driving range of EVs is around 160 km on a fully charged battery. It means, EVs driving range is considerably shorter per charge than most conventional vehicles have per tank of fuel. [4]

In addition to this, the efficiency and driving range of EVs substantially depends on driving conditions and habits:

- Firstly, rapid acceleration and high driving speed reduces the driving range due to the additional energy required to overcome increased drag.
- Secondly, hauling heavy loads, which is in particular relevant to freight sector, or driving up significant inclines also negatively affects the range.
- Finally, the range is reduced during winter period due to the decreased speed of chemical processes and other hurdles related to the rigorous climate conditions. Also, during extreme outside temperatures more energy must be used to heat or cool the cabin. [4] According to the measurements, driving range at -7°C (with indoor heating) is 47% of the range at 23°C . In general, the expected driving range in winter time is 50-60% of the theoretical range. [9] In order to deal with this problem, diesel boilers can be used to heat the cabin in cold temperatures and thus to save energy in the battery, which is though not desirable due to the use of fossil fuels. [32]

As a result, EVs are suitable for relatively short distances and thus can be reasonably applied for urban transportation. Urban transport can be characterised by low speed (50 km/h) and number of starts and stops because of crossroads and traffic. In connection with the bullets above, accelerating process (start) requires the most energy. For instance, the amount of energy to propel EV up to 50 km/h is equal to the amount of energy necessary to maintain the speed over 400-500 meters. On the other hand, in general

lower driving speed means less energy used. For example, driving speed of 80 km/h requires more than twice energy than driving speed of 50 km/h. [9]

Battery Recycling

Some of raw materials, used for EV technology, are discussed to be limited. This refers to lithium used for batteries as well as some other materials used in motors and magnets. Even though it is not a serious issue, as reserves look sufficient enough, the industrialised stock in circulation can be preserved by recycling. [2]

There are some possibilities of recycling batteries in order to minimize their life cycle impacts: smelting, direct recovery and intermediate process. As electric vehicles become increasingly common, widespread battery recycling would avoid hazardous materials entering the waste stream, both at the end of a battery's lifetime and during its production. Furthermore, valuable materials can be efficiently used again. In order to facilitate recycling processes and improve cost-effectiveness, standardisation of batteries, materials and cell design is needed. [4]

Battery Swapping

The main charging method of EVs is with plugging-in battery, which is mainly discussed in this report. However, there is a possibility of swapping battery instead of charging it. This could be applied for long distance travel, where fast charging is not available. For instance, Tesla Motors has developed battery swap infrastructure which enables drivers to change a depleted battery to a fully charged one in a station within several minutes, which is less than to fuel a conventional vehicle. This can be applied only to electric vehicles with a compatible swappable battery pack. [4]

In Denmark, battery swapping infrastructure does not exist after the bankruptcy of Better Place in 2013. Better Place, founded in 2007 in USA, had a business model of cheap vehicles and wide network of battery swap stations in Denmark, Israel and to some extent Netherlands. Even though battery swap system seems to solve the main issue of long charging, certain weaknesses hampered Better Place idea to succeed. A strong pathway of integration to the market is needed to bring EVs with swappable batteries on the roads. [14]

3.2.3 Fuelling

Charging can be done at different power levels, which determines slow or fast charging. Home charging only offers charging with either 3,7 kW, 11 kW or 22 kW. Therefore, home charging is categorised as slow charging, while public charging stations offers up to 50 kW (in Denmark) and is categorised as fast charging. [15] At the moment, a variety of charging plugs are used.

CHAdEMO (JEVS G105-1993) is currently the most common Japanese DC fast charger. CHAdEMO charges with up to 500 V and provides 50 kW, which is the fastest charging at the moment. Battery is charged only up to 80% due to the slow charging rate when the battery is almost full (above 80%). However, if activated again, it charges the last 20%. [15]

Type 2 is an AC charger (German), usually called Mennekes, which delivers up to 43,6 kW. However, in Denmark it delivers only up to 22 kW. Type 2 is expected to transfer 70 kW DC in the future. [15] The driver has to bring Mennekes cable in order to connect the car to the charging spot. It is expected to adopt Type 2 as a European standard for charging below 22 kW (AC). [9]

Similarly, **Type 2 Combo** (AC/DC) is becoming the standard for quick charging in Europe. However, firstly it has to overtake the leading CHAdeMO. Type 2 Combo is an ordinary Type 2 connector with two additional poles that can deliver up to 100 kW DC. [15]

Type 1 (J1772) is a widespread charger of up to 19,2 kW. It is applied to American and Japanese manufactured vehicles. Currently Type 1 Combo is being developed, which provides up to 90 kW. However, this type will only be used by American and Japanese car manufactures and will only appear with imported vehicles. [15]

The overview of the different connectors and vehicle inlets can be seen in Table 2.

	CHAdeMO	Type 2	Type 2 Combo	Type 1
Power Output in Denmark	50 kW (DC)	22 kW (AC)	50 kW (DC)	3,7 (AC)
Connector				
Vehicle Inlet				

Table 2: Types of charging plugs

EVs that use J1772 connector can also be charged in Type 2/Mennekes charging point by using a cable with Mennekes connector on one side and J1772 connector on the other side. [9]



Figure 6: Connector Type2 – Type1

Charging time depends on the type of electric vehicle supply equipment, mentioned above, as well as the type of battery, how depleted it is and how much energy it holds. Therefore, charging time can range from 15 minutes to 20 hours or more. [4] For instance, if the battery is nearly empty, it charges slowly. Between 20 and 80% it can charge quickly, unless the battery gets hot. The last 10-20% charges slowly and, therefore, it is more rational to drive the obtained range until the next charging station instead of spending a lot of time charging the battery fully. As an example, Table 3 shows the driving range obtained, depending on power source and charging time. This is applied to a vehicle with the efficiency of 18,5 kWh/100 km. [15]

Time/Power	3,7 kW	6,6 kW	11 kW	22 kW	50 kW
10 minutes	3 km	6 km	10 km	20 km	45 km
30 minutes	10 km	18 km	30 km	59 km	135 km
1 hour	20 km	36 km	59 km	119 km	270 km

Table 3: Driving range in connection with power source and charging time [15]

In general, batteries do not benefit from being discharged completely or overcharged. Therefore, it is very important to charge it regularly, i.e. whenever it is available. [9]

3.2.4 Motor

The overall energy efficiency of electric motors is significantly higher compared to internal combustion engines, by a factor of 3 for light-duty road vehicles and by a factor closer to 2 for heavy-duty vehicles. [2] Theoretical efficiency of light-duty EV energy storage-to-torque can reach 85-90%. [9] This is far better than vehicles with internal combustion engine, which has efficiency of around 20%.

In general, electric vehicles have an exclusive advantage of excellent acceleration and high torque. Electric motors generate maximum torque at zero speed, which is convenient due to the need for maximum torque to pull away from a start. Therefore, strong and smooth acceleration is guaranteed. Electric motor creates the speed from 0 to 100 km/h in over 5-15 seconds for passenger vehicles. It takes longer for the vehicles with higher weight.

Some models are designed for urban transportation and have limited speed of around 60-80 km/h, while most of the newer models can easily reach over 110 km/h.

3.3 Fuelling Infrastructure

A strong advantage of EVs is that one significant part of infrastructure, i.e. electricity grid, already exists. [2] This is more discussed in previous chapter. Yet well developed network of EVs charging stations is still needed in order to provide EV drivers with complete affordability, range and thus convenience and confidence. At the moment, the number of public EVs charging stations is not comparable to conventional fuel stations and needs to be increased. [4]

3.3.1 *Infrastructure & Requirements*

There are several different options of charging EVs. Regarding freight transport, majority of charging is expected to be done at fleet facilities. Also, access to charging might be offered at workplaces and other public places, such as libraries, shopping centres, parking lots, hospitals, airports, hotels or other businesses, where vehicle owners are highly concentrated. [4]

Regarding freight or service transport, fleets that incorporate EVs into their operations, planning of charging infrastructure should be based on vehicle models, duty cycles, routes, distances, garaging locations and availability of off-site charging stations. Depending on these factors, charging facility might be necessary in the fleet centre only, or it might be necessary to charge EVs one or several times within the route. City planners, fleet managers and utility companies should collaborate to determine the best strategic locations and types of charging units. However, relatively long charging time should be taken into consideration as charging station in the middle of the route might be considered as downtime. Charging overnight is the most likely and favourable option. [4]

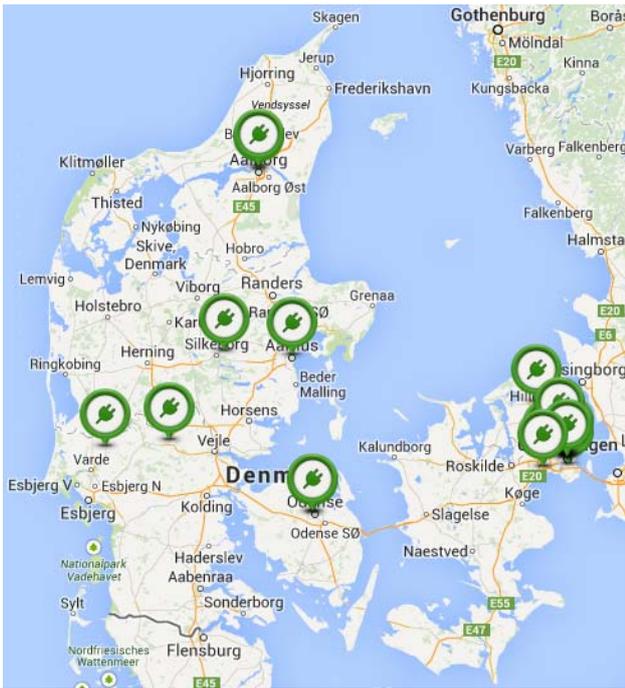
A roll-out of EVs market and infrastructure requires an intelligent optimisation between the vehicles and the electricity source. Therefore, development of a smart electricity grid and a smart electricity metering systems are crucial. As discussed previously, the main difference between today's conventional grid and "smart" grid is that the latter enables communication flows within the network. Due to this feature, generation and demand sides are intelligently controlled, excessive power demand is avoided as well as fluctuations of the grid are stabilised. Furthermore, the configuration of the network and recovery after faults are ensured. [2] To support this, development of smart grid and metering systems is a target towards not only EVs penetration but also overall improvement of electricity system.

Regarding grid-to-vehicle connections technology, EU-wide standardisation is necessary. Common hardware solution between socket, connector and charging point would ensure possibility to charge EVs at any place in Europe. As it is mentioned before, standardisation of charging plugs at EU level is already proceeding. Standardisation is also necessary for the software of communication between the EV and the electricity grid. This should be eventually established worldwide in order to support manufacturers with a future oriented hardware, thus avoiding market fragmentation and reducing costs. [2]

3.3.2 *Current Situation in Denmark & Suppliers*

According to Clean Power for Transport, 5.000 public charging points have to be established in Denmark by 2020. At the moment, a nationwide network of below 2.000 public charging stations is established in Denmark. [3]

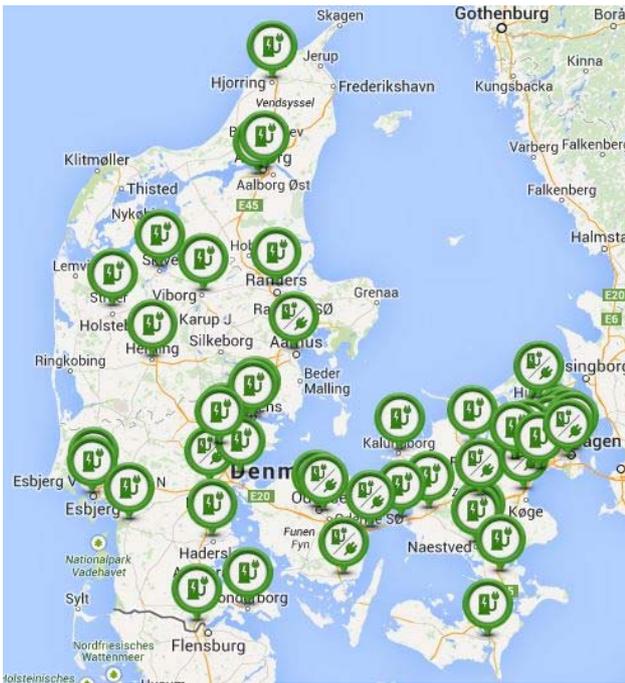
CLEVER is the leading electric mobility operator in Denmark, owning the biggest share of charging stations. The network of CLEVER's charging stations enables to charge any EV on the Danish market since it has both slow and fast charge stations. They include Type 1, Type 2, Type 2 Combo and CHAdeMO plugs. According to CLEVER, it takes 20-30 minutes to charge EV in the fast charge stations, which can be found along the highway and in supermarket areas. [9] The distribution of different charging plugs offered by CLEVER can be seen in Figure 7. Type 2 and CHAdeMO are the most common. Much more stations are available over Denmark, established by E.ON and Clean Charge (CC), which are discussed later.



Type 1



Type 2



CHAdEMO



Type 2 Combo

Figure 7: CLEVER charging stations in Denmark [9]

German energy supplier E.ON is the second largest provider of EV services in Denmark, which has a network of more than 700 public charging spots all over the country. Its charge network includes only Type 2/Mennekes connectors, AC 11 kW, and can be applied for all EVs, except from Renault Zoe ZE. It is worth

to mention that E.ON promotes green and sustainable energy solutions and supplies only environmentally certified electricity from hydropower – one of renewable energy sources. [16]

Finally, Clean Charge plays a significant role towards the development of infrastructure for EVs in Denmark. Type 1, Type 2/Mennekes and CHAdeMO connectors can be found in different CC charging stations. [17]

Currently, main charging stations are concentrated in urban areas. However, in 2015 12 new charging stations are expected to be established and ready to operate along the newly fixed Danish Core Road Network. It is a crucial step made by E.ON towards easier connection and moving across the country as well as competition with conventional vehicles. [18]

3.4 Operation and Maintenance Facilities

Due to internal combustion engines, hybrid electric vehicles and plug-in hybrid electric vehicles have similar maintenance requirements to those of conventional vehicles. The rest electrical system, which includes battery, motor and necessary electronics, requires minimal regular maintenance. Therefore, battery electric vehicles have significantly fewer maintenance needs. The main reasons are the following:

- There are less moving parts, compared to an internal combustion engine;
- There are fewer fluids to change;
- Brake system lasts longer, due to regenerative braking. [4]

Batteries used in EVs have a limited number of times they can be charged and discharged. Battery life and warranties should be ensured when purchasing. Also, battery recycling policy of manufacturer should be taken into consideration. [4]

3.5 Safety

Safety requirements for EVs are similar to those of conventional vehicles. EVs have high-voltage (100-600 V) electrical systems. Their battery packs are encased in sealed shells and has to meet standards regarding overcharge, vibration, extreme temperatures, short circuit, humidity, fire, collision and water immersion. EVs are designed with insulated high-voltage lines and safety measures, such as cut-off switches, that deactivate the electrical system in case of detected collision or short circuit. [4]

Regarding driving safety and reliability, EVs tend to have a lower centre of gravity and therefore are less likely to roll over, compared to conventional vehicles. [4]

Regarding charging stations, outdoor installation and its use are as safe as indoor, even if EVs are charged in the rain. These installations require outdoor-rated charging equipment. [4]

From the pedestrians' point of view, silence of driving EV can be seen as a disadvantage. People are used to notice cars by sound if they are coming up behind them or beside them. In case of EV, this is hardly noticeable and thus might cause accidents. [19]

4 ENVIRONMENTAL IMPACT

4.1 Emissions

Vehicles that run only on electricity are categorised as zero-emission vehicles because they produce no tailpipe emissions. However, there are emissions associated with the production of most of the country's electricity. If electricity production is based on relatively low-polluting energy sources, EVs have a strong life cycle emissions advantage over similar conventional vehicles. If electricity is generated only from renewable energy sources, an EV has near-zero life cycle GHG emissions. [4] In any case, EVs with no tailpipe emissions are ideally suitable for populated urban areas, where air quality is an issue.

More precisely, reduction of 30% in CO₂ emissions can be achieved when replacing an internal combustion engine vehicle by an electric vehicle, assuming that it is powered by the EU electricity mix. It is calculated, that projected 5 million EVs in the EU by 2020 could reduce emissions by 5 Mt CO₂/year, while the total CO₂ emissions from road transport is recently around 920 Mt CO₂/year. [2]

Figure 8 compares life cycle emissions of electric and conventional gasoline vehicle. The latter has a range of fuel economy from 20 to 50 MPG (miles per gallon), which corresponds to 8,5 to 21 km/l. [20]

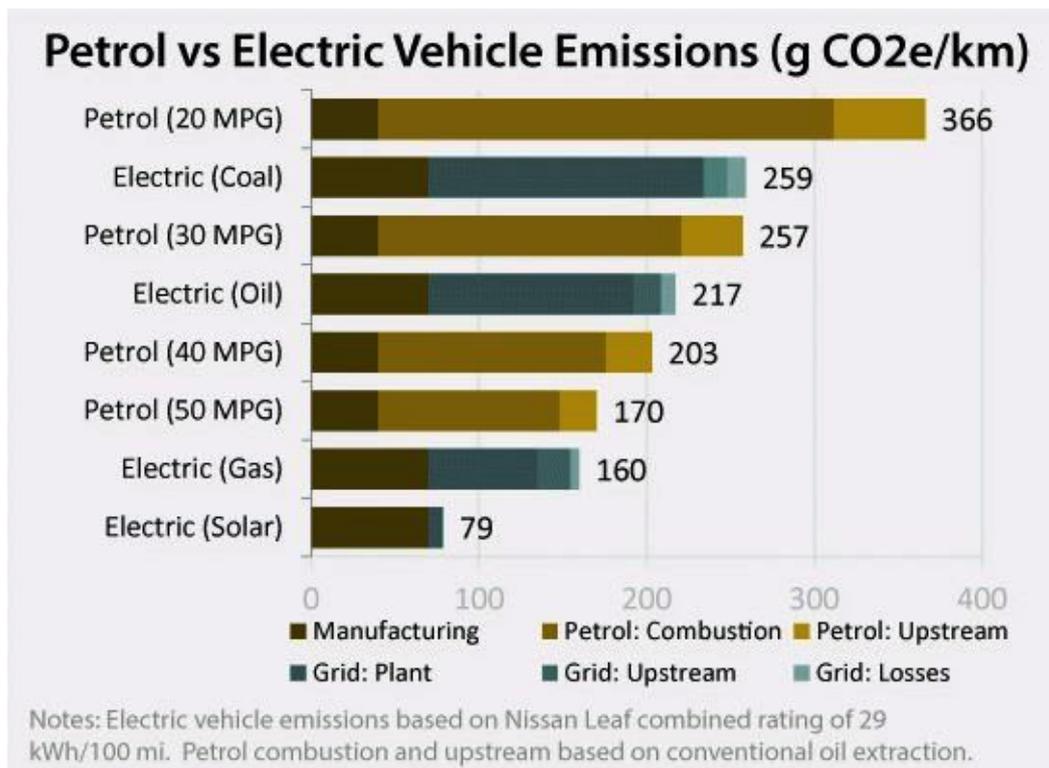


Figure 8: Emissions of conventional gasoline and electric vehicles [20]

It can be seen, that EVs powered with electricity produced from solar energy have the lowest impact to the environment. The biggest share goes to manufacturing due to the technology used. It is assumed that electricity from wind energy might result in lower life cycle emissions.

However, at the moment the whole electricity production is mainly based on fossil fuels. According to Figure 8, EVs powered with electricity produced from coal or oil sources have higher emissions than more efficient gasoline vehicles, which might weaken the status of electricity powered vehicles.

Figure 9 gives a broader overview of gasoline, diesel, electric and fuel cell vehicles in terms of driving range and CO₂ emissions in the period of 2010-2050. BEV stands for battery EV, PHEV for plug-in hybrid EV, ICE for internal combustion engine vehicles and FCEV for fuel cell electric vehicles. Due to developed technology, EVs together with fuel cell vehicles can achieve significantly low CO₂ emissions in the future. A short driving range still remains the main disadvantage of EVs.

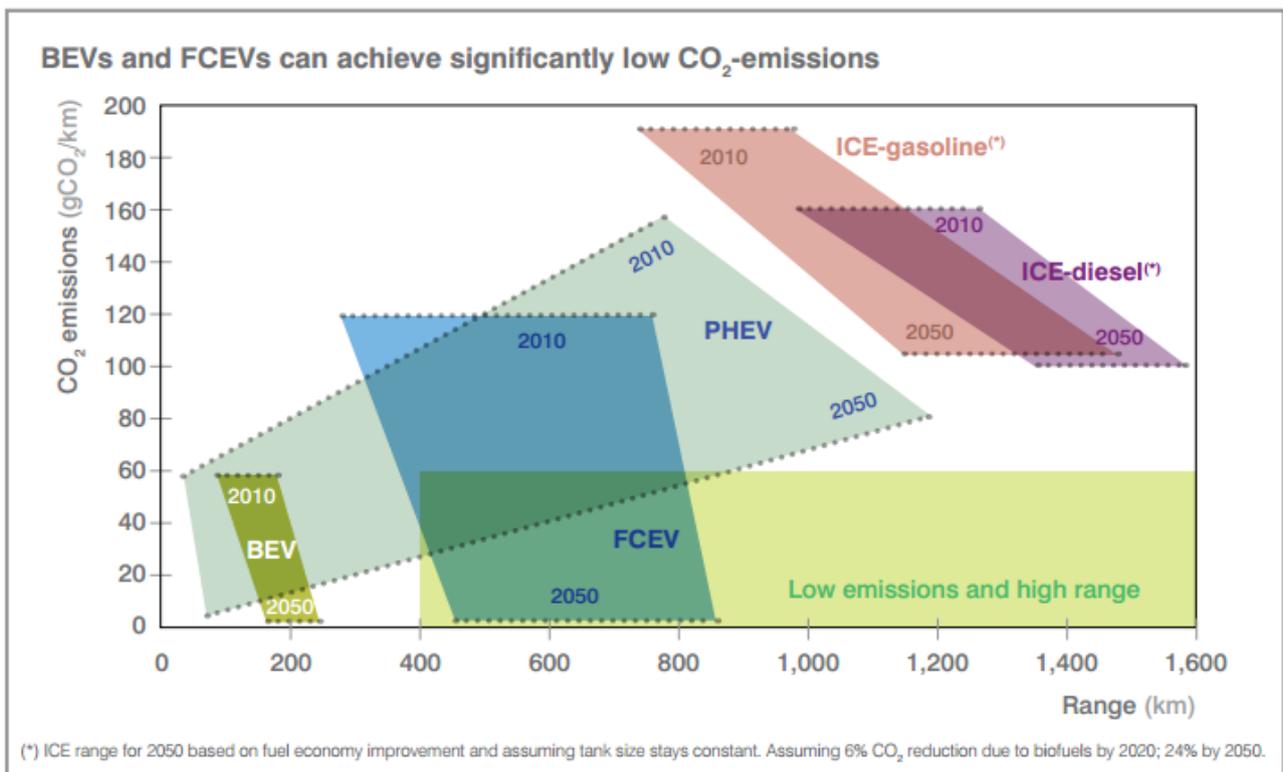


Figure 9: Comparison of CO₂ emissions [21]

4.2 Smell

Pure electricity powered vehicles have no tailpipe emissions and thus no smell pollution.

4.3 Noise

An electric motor is almost silent and smooth as there is no internal combustion and moving parts. Only during acceleration a small amount of motor noise can be heard, which becomes more noticeable when the speed increases. During depressing accelerator pedal, EVs move almost in silence. This makes EVs extremely attractive for urban areas where noise pollution is a big issue. [19] On the other hand, as it is mentioned before, it might cause some accidents from the pedestrians' point of view.

5 ECONOMICS

At the moment, electric vehicles seem to be more expensive solution due to their high initial purchase price, hindering EVs competitiveness with conventionally fuelled vehicles. However, operation and maintenance costs can be noticeably lower.

5.1 Investment Cost

5.1.1 Vehicles

Purchase price of EVs is an important hurdle towards market penetration as it is still significantly higher than those of conventional vehicles due to the high cost of battery. The prices are expected to decrease once technology improves and production volumes boost. [2, 4]

As an example, the initial purchase price of electric passenger vehicle Nissan e-NV200 Premium is around 220.00 DKK while its conventional counterpart costs around 160.000 DKK, i.e. 30% less, both including registration taxes and excluding VAT. However, some models, such as Citroen Berlingo Electric or Peugeot Partner Van Electric, cost twice as their conventionally fuelled counterparts.

5.1.2 Fuelling Infrastructure

According to E.ON, the installation of a standard charging station with two outlets costs around 10.400 DKK (excl. VAT) for hanging, and 12.000 DKK (excl. VAT) for standing configuration. The price per charging station is lower, if more than one is installed on site. [16]

5.2 Operation & Maintenance Cost

Despite the high purchase price of EV, the operation and maintenance cost is lower compared to conventional vehicles. This is explained by the tax exemptions, cheaper insurance, fuel (electricity) cost and reduced need for maintenance. [9] For instance, manufacturers of Nissan e-NV200 expect maintenance costs to be up to 40% lower than those for conventional vehicles. [22]

EVs have a strong advantage over conventional vehicles in terms of total cost of ownership. As an example, calculations of TCO were done for passenger vehicles and the conclusion showed that, for instance, to run a conventional vehicle with a purchase price of 275.000 DKK costs 4,90 DKK/km. Whereas to run an electric vehicle with the similar purchase price, for instance, Nissan LEAF of 273.285 DKK, including charging installation, costs 3,81 DKK/km. That is potential savings of around 21.800 DKK/year. [9]

5.3 Fuel Cost

In general, EVs can reduce operation costs significantly due to the lower cost of electricity compared to conventional fuel. Electricity cost varies from country to country and depends on the type of generation. Time of use is also important as lower rates during off-peak periods can be offered. [4]

In Denmark, retail electricity price is one of the highest among OECD countries. This is mainly due to high taxation rates, which accounts for more than half of the total bill (around 55%). Figure 10 shows the breakdown of the end-user electricity price in Denmark in 1998-2013. [23]

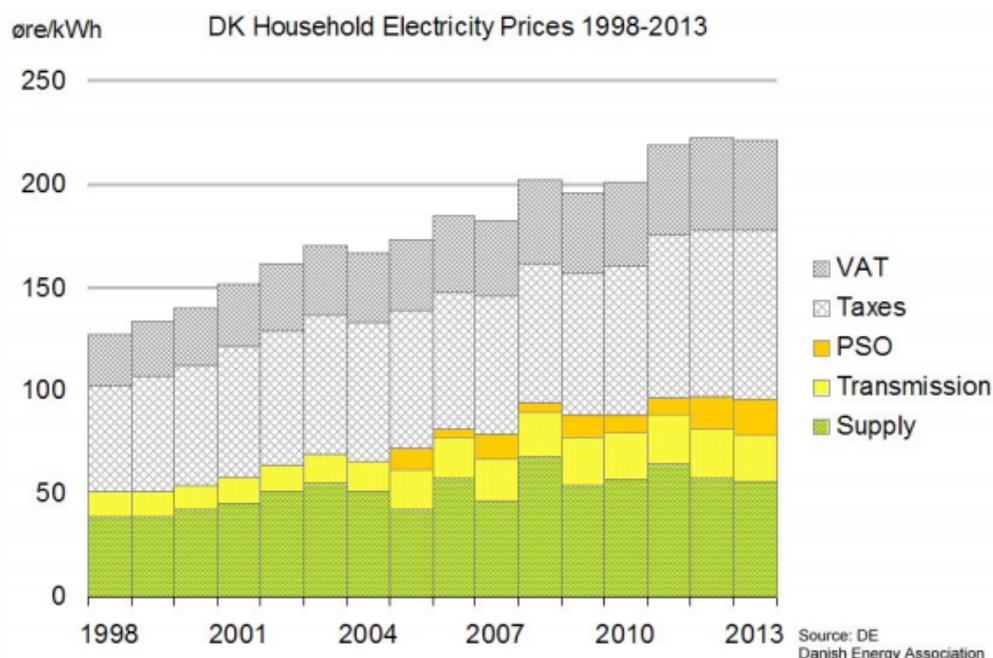


Figure 10: Breakdown of electricity price in Denmark in the period 1998-2013 [23]

In more details, supply and transmission components cover purchase of electricity in the market, cost of connections, operation and maintenance of the grid and overall quality of supply. PSO is paid as a contribution to the green transition in Denmark. These three components make the basic electricity price, which is close to EU average. However, on top of that, high electricity taxes are paid, including number of different elements, such as CO₂, SO₂, energy taxes. Finally, VAT adds 25% to all other cost elements. [23]

In 2013 the electricity price for the household was 2,24 DKK/kWh (0,3 €/kWh). [24]

The cost of charging publicly depends on the provider. Table 4 shows the prices offered in CLEVER and E.ON charging stations in Denmark. E.ON has an offer of onetime charging for a fixed price per charge. For those who charge their EVs more often, there are two options offered by both E.ON and CLEVER: paying onetime initial price and charging for higher electricity price, or paying monthly subscription and charging for lower electricity price. The customer is provided with a card for convenient charging.

Prices [DKK]	E.ON			CLEVER	
	Rarely	Sometimes	Often	GO	GO More
Creation	-	99	-	350	-
Monthly subscription	-	-	99	-	99
Electricity	99 /charge	5,25 /kWh	3,25 /kWh	5,50 /kWh	3,50 /kWh

Table 4: EV charging prices in public charging stations [9, 16]

Another option is to install own charging stations in workplace or at home and charge EVs with a regular electricity price (2,24 DKK/kWh in 2013). In this way, electricity refund is offered by both E.ON (when more than 750 km per month is driven) and CLEVER (when charging box is leased). Finally, in case of E.ON, installation of own charging station gives an access to public charging stations as well. All the prices are summarised in Table 5. Charging equipment H1 means that not all EVs can be charged.

Prices [DKK]	E.ON		CLEVER	
	H1	Keba	Bought	Leased
Charging box	5.995	12.995	7.195	-
Installation	-	-	1.895 – 4.995	
Monthly subscription	249		-	299
Refund	1,04 /kWh		-	1 /kWh
Access to public charging	3,25 /kWh		-	-

Table 5: EV charging prices in own charging stations [9, 16]

Regarding medium- and heavy-duty EVs, the fuel economy is highly dependent on the cargo and the duty cycle. Most of the time, right applications can provide visible fuel-cost advantage over their conventional counterparts. [4]

5.4 Lifetime

The most important element of EV is a battery, which tends to wear out eventually. The average warranty is around 5 years/100.000 km. [9] Several manufacturers can offer up to 8 year/160.000 km warranties for their EV. However, the lifetime can reach up to 15 years, depending on climate conditions and driving or charging habits. [4]

5.5 TCO Analysis

The purpose of the TCO (total cost of ownership) is to improve decision-making by including all expenses unique to each vehicle. To make the investment on EVs comparable, both EVs and conventional vehicles, available on the market, are taken into account in the TCO. These are given in Table 6.

Electric Vehicles	Conventional Vehicles
Nissan E-NV200 Comfort	Nissan NV200 Comfort
Nissan E-NV200 Comfort Plus	
Nissan E-NV200 Premium	Nissan NV200 Premium
Citroën Berlingo Electricque	Citroën Berlingo City van
Peugeot Partner Van Electric	Peugeot Partner Van
Renault Kangoo ZE	Renault Kangoo Express

Table 6: Electric and conventional vehicles included in TCO analysis

First, data about each vehicle are explored. This includes initial purchase price, delivery costs, fuel economy (km/l), range, insurance, maintenance, taxes and descriptive information (such as motor type and power, loading capacity, etc.). Second, estimates of data input are researched. Data input consists of workdays (km/day), taxes, scrap value, cost of diesel and cost of electricity. Third, the TCO within the desired timeframe, i.e. 7 years of ownership, is calculated. The TCO contains calculations of total purchase price, operational costs, deductions and scrap value. All the inputs and calculations can be seen in Annex 2.

The calculated total cost of 7 years of ownership is seen in Figure 11. Despite the fact that EVs have higher initial purchase prices, Nissan e-NV200 Comfort has the lowest TCO in a 7 year period. Part of the explanation is EV's exemption from the high Danish taxes, lower insurance cost and better fuel economy. The result is of course sensitive to changes in e.g. electricity and diesel prices, thus making either conventional vehicle or EV cheapest depending on the scenario. This means that the decision making is very sensitive to changes in the environment of fuel prices.

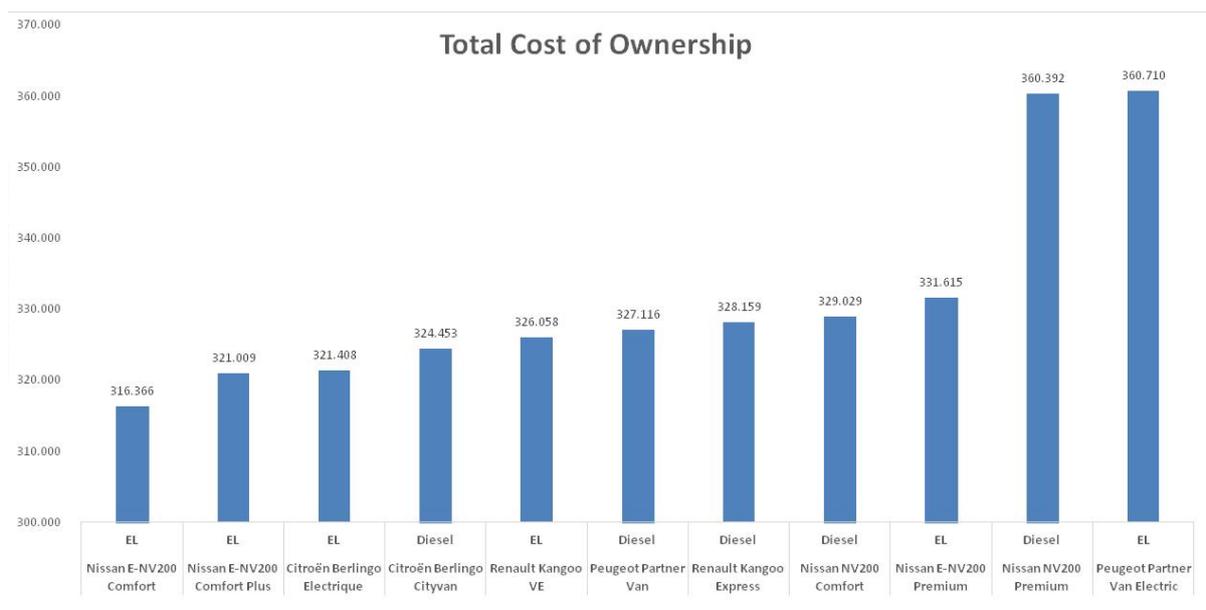


Figure 11: Results of TCO analysis

Another sensitive input is the number of total kilometres driven. Diesel vehicles are more sensitive to number of kilometres driven than EVs, thus resulting in an advantage EVs gain if more kilometres are driven. However, the range of EVs must be taken into account as it cannot utilise this advantage unlimited. This means that the better the battery and range is, the more kilometres it obtains and hence the more favourable the EV is.

6 POLICY INSTRUMENTS

EVs are well recognised and supported at EU level. The European Commission contributes to a Europe-wide electro mobility initiative, Green eMotion, with a budget of 24,2 million €. The Green eMotion involves over forty partners from industry, utilities, electric vehicle manufacturers, municipalities as well as universities and technology and research institutions. The main goal of the initiative is to exchange and develop experience as well as explore basic conditions needed for the market roll-out of EVs in Europe. [25]

Denmark has adopted number of instruments to foster the roll-out of electric vehicles. These measures are the following:

- Battery electric vehicles are exempted from registration taxes. For the vans under 2,5 tons, first 13.700 DKK of the base purchase price is untaxed and 50% tax is applied on the rest. Furthermore, FCEVs are inherently exempted from annual green taxes, which are based on the fuel consumption per km. Exemptions are in force until and including 2015.
- For companies involved in commercial electric vehicle charging, electricity tax is reimbursed until 2015.
- Electric vehicles can be used as an instrument to meet energy saving obligation schemes. Energy companies can buy energy savings that EVs obtain when replacing conventional vehicles.
- 40 million DKK are allocated to electric vehicle partnerships. The scheme runs in the period of 2013-2015. Municipalities and businesses can receive support to acquire EVs and necessary infrastructure in this way promoting the deployment and visibility of EVs.
- 500 million DKK are allocated for researches and conducting trials that show advantages and prospects of electric and hybrid electric vehicles. The scheme runs in the period of 2008-2015. [26]
- The environmental zones are established in Denmark with strict regulations. The best example is the majority of Copenhagen and all of Frederiksberg, which has been an environmental zone since 2008. All diesel powered vehicles above 3,5 tons must either meet at least Euro IV emission standard or be improved with an effective filter. All heavy-duty diesel powered vehicles, both domestic and foreign, are required to have an environmental zone label in case they want to enter an environmental zone. It is also implemented in Aarhus, Aalborg and Odense. [27]

There are still some viable solutions to promote EVs, which could be applied in Denmark. These are the following:

- Incentives related to spatial planning, such as allowing EVs to drive in bus lanes, park for free or charge for free at certain urban charging points operated by the municipalities, could be considered. Free parking used to be applied to EVs in the city of Copenhagen. However it was cancelled at the end of 2011 due to national regulations.
- In order to encourage vehicle charging when electricity demand is the lowest, lower rates at off-peak periods could be offered as it is already applied for hydrogen production in Denmark.

7 EXAMPLES OF EVs FOR DISTRIBUTION

Both heavy- and light-duty EVs are commercially available. Even though electric light-duty vehicles are more developed and deployed, vans and trucks powered by electricity are getting more and more visible on today's market.

7.1 EMOSS e-Trucks

EMOSS is one of the leading hybrid and electric drive systems manufacturers. With their knowledge, any base vehicle can be equipped with an electric propulsion system. A range of application for electric trucks, offered by EMOSS, is a great solution for zero-emission inner city distribution. [28]

First of all, different gross weight e-trucks are available: 10, 12, 16, 19 tons and some other configurations. Beside this, with configurable battery packs, including 40, 80, 120, 160, 200 and 300 kWh, the vehicles can meet a driving range up to 300 km. It is shown in Figure 12. Moreover, EMOSS offers the possibility of electrically powered auxiliaries, such as freight refrigeration system. [28]



Figure 12: Flexible configurations of EMOSS e-trucks [28]

As an example, the description of CM 19 e-Truck (19 tons of gross vehicle weight) is given. It is one of the largest trucks in Europe. Different configurations are available. The main characteristics of CM 19 e-Truck performance and dimensions can be seen in Table 7. [28]

			
Manufacturer:	EMOSS		
Model:	CM 1916	CM 1920	CM 1924
Performance			
Motor:	Type	Electric	
	Motor Power	230 kW	
	Torque	3.390 Nm	
Acceleration:	85 km/h		
Top speed	85 km/h		
Battery:	Lithium Iron Phosphate		
	Battery Pack	160 kWh	200 kWh
	Charge time (63 A)	3,6 or 7,3 hours	4,5 or 9 hours
	Range (NEDC ² , 80% payload)	150 km	190 km
			240 kWh
			5,5 or 11 hours
			230 km
Charge system:	44 kW or 22 kW		
Operating Limits:	18.600 kg		
	Gross Vehicle Weight	18.600 kg	18.600 kg
	Payload	10.966 kg	10.430 kg
			18.600 kg
			9.894 kg
Exterior dimensions			
	Length	9,07 m	
	Width	2,46 m	
	Height	2,77 m	

Table 7: Main characteristics of EMOSS CM 19 e-truck

This battery electric truck was applied by the HEINEKEN Company to distribute beers within the city of Rotterdam, Netherlands. Other models, including CM 16 e-Truck and CM 12 e-Truck (16 and 12 tons GVW respectively), were also adopted by the Dutch companies, responsible for relocations and distribution of goods. It contributes to the long-term ambition to have all main cities in the wholesale distribution area running on EVs. [28]

² New European Driving Cycle

7.2 NISSAN e-NV200

Japanese Nissan Motor Co launched a commercial van Nissan e-NV200 in 2014. The main characteristics of performance can be seen in Table 8. [22]

	
Manufacturer:	Nissan Motor Co
Performance	
Motor:	
Type	Electric
Power	80 kW
Torque	280 Nm
Acceleration:	
Top speed (full loading)	120 km/h Achieving 100 km/h in 13 seconds
Battery:	
Battery Pack	Lithium Ion 24 kWh
Normal charge time (220 V)	~8 hours (full charge)
Quick charge time (400 V)	30 minutes (80% charge)
Range (NEDC)	170 km
Operating Limits:	
Cargo Space	4,2 m ³ (2,04 m length)
Payload	Up to 770 kg

Table 8: Main characteristics of Nissan e-NV200

Nissan e-NV200 is very manoeuvrable and suitable for city driving, as the energy output is minimised due to the regenerative braking system and ECO mode possibility, which is favourable in start and stop traffic. Also, it easily fits into tight parking spots or garages, has a turning circle of 11,2 m, low centre gravity and

compact body size. Easier cargo stacking is guaranteed due to the flattened wheel wells, tall rear doors and sliding doors on both sides. Moreover, 2,04 m cargo length allows carrying up to two Euro pallets³. This is in case of 2-seater, but 5-seat model (with three foldable back seats) is also optional. The model offers excellent comfort and functionality: bright and modern cabin and large touch screen monitor. [22]

Regarding warranty, Nissan e-NV200 is covered for 5 years or 100.000 km if the battery range drops below 9 bars (out of 12 bars), which is displayed on the dashboard. [22]

In case of 2-seater model and purchased (non-leased) battery, the price is around 200.000-220.00 DKK depending on the configuration (before VAT).

7.3 Renault Kangoo ZE

Another example of commercial vans is Renault Kangoo ZE launched by French Renault S.A. The main characteristics of performance can be seen in

Exterior dimensions [32]	
Length	4.282 mm
Width	1.829 mm
Height	1.818 mm

Table 9. [29]

A Kangoo Maxi ZE model is 400 mm longer and has an additional 1,1 m³ of payload. It has an exclusive torque of 226 Nm compared to its conventional counterpart with the torque of 160 Nm. [32]

Regarding warranty, Renault Kangoo ZE battery system is also covered for 5 years or up to 100.000 km. The initial purchase price is around 160.000 DKK (before VAT).

³ Standard European pallet: 1200x800x144 mm

		
Manufacturer:	Renault S.A.	
Performance		
Motor:	Type	Electric
	Power	44 kW
	Torque	226 Nm
Acceleration:	Top speed (full loading) 130 km/h	
	Achieving 50 km/h in 5,1 seconds	
Battery:	Battery Pack	Lithium Ion 22 kWh
	Normal charge time (220 V)	8 hours (full charge) or 4,5 hours (from 20 to 80%)
	Range (NEDC)	170 km
	Standard consumption	0,155 kWh/km
Operating Limits:	Cargo Space	3 m ³ (1,48 m length)
	Payload	715 kg
	Curb weight	1501 kg
	Total weight	2126 kg
Exterior dimensions [32]		
	Length	4.282 mm
	Width	1.829 mm
	Height	1.818 mm

Table 9: Main characteristics of Renault Kangoo ZE

7.4 BYD T5 Light Truck

Recently, Chinese company BYD is on its way to present a new T5 battery electric light truck, which can revolutionise the transport in China. Despite the top speed of 50 km/h, the model has an exclusive feature of a driving range reaching up to 400 km. This is significantly higher compared to the most common EVs driving range of 200 km, making it a perfect solution for transportation within urban areas. [30]

It is an ordinary flat nose single-cab van. The battery pack is installed between the front and rear axles under the cargo area. Therefore, both the cabin and the truck bed are elevated. BYD T5 light truck can be seen in Figure 13. [30]



Figure 13: BYD T5 Light Truck [30]

8 SUMMARY

Table 10 summarises the main findings about electricity as an alternative fuel for the transport sector and technology of battery electric vehicles, with a focus on freight transport. Strengths and weaknesses are found in terms of technology, environment, economics and policy instruments.

	Strengths	Weaknesses & Improvements needed
Technology	<ul style="list-style-type: none"> Advanced technology of electric vehicles High overall efficiency up to 90% Accessibility of electricity Existing wide network of charging stations 	<ul style="list-style-type: none"> Long charging Short driving range Standardisation of charging equipment Development of smart grid
Environment	<ul style="list-style-type: none"> No tailpipe emissions No smell and extremely low noise Renewable energy used to generate electricity results in zero life cycle emissions 	
Economics	<ul style="list-style-type: none"> Increasing number of EVs on the market reduces costs Lower operation and maintenance costs Total cost of ownership (TCO) proves EVs being competitive with conventional vehicles 	<ul style="list-style-type: none"> Prices of EVs are still higher than those of conventional vehicles
Policy	<ul style="list-style-type: none"> Registration tax exemption Annual green tax exemption Electricity tax reimbursement 	

Table 10: Strengths and weaknesses of hydrogen and fuel cell electric vehicles

In conclusion, technology of battery electric vehicles is developed and is ready to be deployed. Technological issues, such as long charging and short range, are solved by expanding network of charging stations, including fast charging. Furthermore, due to rather short range required by urban freight transport, EVs application could be a solution to face environmental problems. Economic part should not be seen as an obstacle as TCO proves EVs being competitive with conventional vehicles, even though the purchase prices are still higher. This is partly due to policy instruments applied, which include high tax exemptions for alternative zero-emission vehicles.

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ANNEX 1: FUEL PROPERTIES COMPARISON

Table 11 gives an overview of the main properties of different alternative fuels, which can then be compared to conventional fuels. These are the following:

- **Physical state.**
- **Feedstock.**
- **Composition.**
- **Gasoline gallon equivalent** is the amount of alternative fuel, which has the same energy content as one gallon of gasoline. This factor is used to compare the energy content of different competing alternative fuels to the conventional fuels. As a note, 1 US gallon is equal to 3,8 litres.
- **Density** is mass of certain substance per unit volume.
- **Calorific value** of the fuel shows the amount of energy released as heat by the complete combustion of fuel (unit of mass or volume).
- **The flash point** of a volatile liquid is the lowest temperature where the fluid evaporates to form a combustible concentration of gas. It indicates how easy a chemical may burn. Chemicals with higher flash points are less flammable or hazardous, making the fuel safer to handle and transport. [31]
- **The autoignition temperature** is the minimum temperature at which gas or vapour spontaneously self-ignites in air without external source of ignition (spark or flame). Higher autoignition temperature typically indicates a safer substance. [31]

The values of the properties are approximate and can differ depending on the fuel composition.

Characteristics	Units	Conventional fuels		Alternative fuels				
		Petrol (gasoline)	Diesel	Electricity	Hydrogen	Biodiesel	CNG/CBG	LNG/LBG
Physical state	-	Liquid	Liquid	Electricity	Compressed gas or liquid	Liquid	Compressed gas	Cryogenic liquid
Fuel material (feedstock)	-	Crude oil	Crude oil	Coal, nuclear, natural gas, hydro, wind and solar	Natural gas, methanol, electrolysis of water	Fats and oils from sources such as soy beans, waste cooking oil, animal fats, and rapeseed	NG: Underground reserves BG: Biomass, sewage, agricultural waste, certain industrial wastes, municipal waste, energy crops	
Composition	-	C ₄ to C ₁₂	C ₈ to C ₂₅	N/A	H ₂	Methyl esters of C ₁₂ to C ₂₂ fatty acids	CH ₄ (83-99%), C ₂ H ₆ (1-13%) ⁴	CH ₄
Gasoline gallon equivalent	-	100%	1 gallon of diesel has 113% of the energy of 1 gallon of gasoline	33,7 kWh has 100% of the energy of 1 gallon of gasoline	1 kg of H ₂ has 100% of the energy of 1 gallon of gasoline	0,96 gallon of B100 or 0,90 gallon of B20 has 100% of the energy of 1 gallon of gasoline	3,9 gallons (2,6 kg) of CNG has 100% of the energy of 1 gallon of gasoline	1,56 gallons of LNG has 100% of the energy of 1 gallon of gasoline
Density (average)	kg/m ³	749	851	N/A	40	860-890	175	455
Lower calorific value	MJ/l	32,4	35,8	3,6 (MJ/kWh)	4,8	33,4 (B100)	8,2	20,8
	MJ/kg	43,3	42,1		121	38,2	47,1	45,7
Flash point	°C	-45	126	N/A	N/A	min. 120	-184	-188
Autoignition temperature	°C	257	210	N/A	500	373-448 (B100)	580	580

Table 11: Comparison of different alternative and conventional fuels

⁴ Composition of row biogas: CH₄ (50-80%), CO₂ (20-50%)

ANNEX 2: TCO ANALYSIS

	EL varebiler						Diesel varebiler				
	Nissan E-NV200 Comfort	Nissan E-NV200 Comfort Plus	Nissan E-NV200 Premium	Citroën Berlingo Electrique	Peugeot Partner Van Electric	Renault Kangoo ZE	Nissan NV200 Comfort	Nissan NV200 Premium	Citroën Berlingo Cityvan	Peugeot Partner Van	Renault Kangoo Express
Tekniske specifikationer											
Type	Comfort	Comfort Plus	Premium	Electrique	CITYVAN L1N2	Kangoo Ze	Comfort	Premium	L1N1	L1	L1
Motor	80 KW	80 KW	80 KW	49 KW	42 KW	44 KW	1.5 dCi	1.5 dCi	1.6 HDi	1.6 Hdi	1.5 dCi
Hestekræfter	109	109	109	67	57	60	89	89	75	75	90
Lastevne (kg)	667	667	667	685	625	715	667	667	685	625	734
Varerum (m3)	4.2	4.2	4.2	3.3	3.0	3.0	4.2	4.2	3.3	3.3	3.0
Batteri (kWh)	24	24	24	23	23	22	-	-	-	-	-
Rækkevidde (km/dag)	170	170	170	170	120	170	-	-	-	-	-
Levetid	7	7	7	7	7	7	7	7	7	7	7
km/l	-	-	-	-	-	-	20.4	20.4	19.6	19.6	19.2
	7.1	7.1	7.1	7.6	5.2	7.7					
Omkostninger											
Pris (inkl. registreringsafgift excl. moms)	199,900	205,810	219,310	205,000	240,000	158,900	118,790	158,708	109,990	113,990	124,900
Varevogn moms	49,975	51,453	54,828	51,250	60,000	39,725	22,484	28,265	20,915	21,253	23,230
Leveringsomkostninger (excl. moms)	3,740	3,740	3,740	3,740	3,260	3,740	3,740	3,740	3,740	3,260	3,740
Batteri leasing (pr år)	-	-	-	-	-	9,648	-	-	-	-	-
Forsikring	5,112	5,112	5,112	5,700	5,700	4,572	9,601	9,601	9,601	9,601	7,701
Vedligehold	15,180	15,180	15,180	15,180	15,180	15,180	22,000	22,000	22,000	22,000	22,000
Årlige grønne afgifter	-	-	-	-	-	-	4,280	4,280	4,280	4,280	4,280

Data Input

Generel	
Alternative Cost of capital	10% p.a.
Arbejdsdage	300 dage
km pr dag	100 km
Virksomhedsskat	24.5%
Skrapværdi	10%
Moms fradragsberettiget?	Ja

Ladning	
Kilde	E.ON
Abonnement	249 kr
Kr pr kWh	2.25 kr
Godtgørelse pr kWh	1.04 kr
Ladninger hjemme	80% af alle opladninger
Ladestation installation	12,995 pr station
Benzin	
kr/l diesel	8 kr
Afskrivning	
Saldometode	25% pr år

Total Cost of Ownership											
	EL varebiler						Diesel varebiler				
	Nissan E-NV200 Comfort	Nissan E-NV200 Comfort Plus	Nissan E-NV200 Premium	Citroën Berlingo Electricque	Peugeot Partner Van Electric	Renault Kangoo VE	Nissan NV200 Comfort	Nissan NV200 Premium	Citroën Berlingo Cityvan	Peugeot Partner Van	Renault Kangoo Express
Købspris											
Pris (excl. moms)	199,900	205,810	219,310	205,000	240,000	158,900	118,790	158,708	109,990	113,990	124,900
Leveringsomkostninger (excl. moms)	3,740	3,740	3,740	3,740	3,260	3,740	3,740	3,740	3,740	3,260	3,740
Ladestation installation	12,995	12,995	12,995	12,995	12,995	12,995	-	-	-	-	-
Total	216,635	222,545	236,045	221,735	256,255	175,635	122,530	162,448	113,730	117,250	128,640
Driftsomkostninger [pr år]											
Batteri leasing	-	-	-	-	-	9,648	-	-	-	-	-
EL forbrug	9,529	9,529	9,529	8,934	12,938	8,735	-	-	-	-	-
EL abonnement	2,988	2,988	2,988	2,988	2,988	2,988	-	-	-	-	-
EL godtgørelse	-3,524	-3,524	-3,524	-3,304	-4,784	-3,230	-	-	-	-	-
Brændstofforbrug	-	-	-	-	-	-	11,765	11,765	12,245	12,245	12,500
Forsikring	5,112	5,112	5,112	5,700	5,700	4,572	9,601	9,601	9,601	9,601	7,701
Vedligehold	15,180	15,180	15,180	15,180	15,180	15,180	22,000	22,000	22,000	22,000	22,000
Grøn ejeravgift	-	-	-	-	-	-	4,280	4,280	4,280	4,280	4,280
Total (pr år)	29,286	29,286	29,286	29,498	32,022	37,893	47,646	47,646	48,126	48,126	46,481
Nutidsværdi (7 år)	142,575	142,575	142,575	143,610	155,894	184,480	231,959	231,959	234,297	234,297	226,289

Total Cost of Ownership												
	EL varebiler						Diesel varebiler					
	Nissan E- NV200 Comfort	Nissan E- NV200 Comfort Plus	Nissan E- NV200 Premium	Citroën Berlingo Electric	Peugeot Partner Van Electric	Renault Kangoo VE	Nissan NV200 Comfort	Nissan NV200 Premium	Citroën Berlingo Cityvan	Peugeot Partner Van	Renault Kangoo Express	
Fradrag [pr år]												
1. års afskrivning	49,975	51,453	54,828	51,250	60,000	39,725	29,698	39,677	27,498	28,498	31,225	
2. års afskrivning	37,481	38,589	41,121	38,438	45,000	29,794	22,273	29,758	20,623	21,373	23,419	
3. års afskrivning	28,111	28,942	30,840	28,828	33,750	22,345	16,705	22,318	15,467	16,030	17,564	
4. års afskrivning	21,083	21,707	23,130	21,621	25,313	16,759	12,529	16,739	11,601	12,022	13,173	
5. års afskrivning	15,812	16,280	17,348	16,216	18,984	12,569	9,396	12,554	8,700	9,017	9,880	
6. års afskrivning	11,859	12,210	13,011	12,162	14,238	9,427	7,047	9,416	6,525	6,763	7,410	
7. års afskrivning	8,894	9,157	9,758	9,121	10,679	7,070	5,286	7,062	4,894	5,072	5,557	
1. års fradrag	12,244	12,606	13,433	12,556	14,700	9,733	7,276	9,721	6,737	6,982	7,650	
2. års fradrag	9,183	9,454	10,075	9,417	11,025	7,299	5,457	7,291	5,053	5,236	5,738	
3. års fradrag	6,887	7,091	7,556	7,063	8,269	5,475	4,093	5,468	3,789	3,927	4,303	
4. års fradrag	5,165	5,318	5,667	5,297	6,202	4,106	3,070	4,101	2,842	2,945	3,227	
5. års fradrag	3,874	3,989	4,250	3,973	4,651	3,079	2,302	3,076	2,132	2,209	2,421	
6. års fradrag	2,906	2,991	3,188	2,980	3,488	2,310	1,727	2,307	1,599	1,657	1,815	
7. års fradrag	2,179	2,244	2,391	2,235	2,616	1,732	1,295	1,730	1,199	1,243	1,362	
Nutidsværdi af fradrag	32,586	33,550	35,750	33,418	39,123	25,903	19,364	25,871	17,930	18,582	20,360	
Skrapværdi [i år7]												
Gensalg af varebil	19,990	20,581	21,931	20,500	24,000	15,890	11,879	15,871	10,999	11,399	12,490	
Nutidsværdi af gensalg	10,258	10,561	11,254	10,520	12,316	8,154	6,096	8,144	5,644	5,849	6,409	
Total Cost of Ownership												
Nutidsværdi af 7 års drift	316,366	321,009	331,615	321,408	360,710	326,058	329,029	360,392	324,453	327,116	328,159	
Difference til billigste varebil	-	4,643	15,250	5,042	44,345	9,692	12,664	44,026	8,088	10,750	11,794	