EMISSIONS AND COSTS CALCULATOR FOR VANS AND LORRIES – USER MANUAL AND BASIS OF CALCULATION

Heikki Liimatainen[1], Riku Viri[1], Joonas Munther[2], Jyri Seppälä[2,3]

[1] Tampere University
[2] Finnish Environment Institute
[3] Finnish Climate Change Panel

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1. PURPOSE AND BASIC PRINCIPLES

The emissions and costs calculator for vans and lorries is an online calculator intended to support companies in their van and lorry purchase decisions. The calculator allows users to see the cumulative life-cycle greenhouse gas emissions and costs of different cars that use different power sources. The purpose of the calculator is to highlight the climate impacts of different options. Therefore, the calculator does not take into account any other impacts on the environment. The user can select 1–6 different car options to be compared. The results are shown graphically as annually cumulative emissions and costs. The smaller the greenhouse gas emissions, the better the car is for the climate. At the point where the cumulative emissions of different car options intercept, one option becomes superior to the other. The same also applies to costs.

The comparison is based on primary data provided for different car options that the user can modify freely. In terms of both emissions and costs, the calculator includes certain default data to help the user enter information and produce an end result. All primary data used in the calculation can be replaced with the specific details of different car models if they are known. Some primary data is shared by all cars that use the same power source. They are selected on the basis of the best current knowledge, but even this data can be modified in the user's personal analysis.

The calculator consists of the following sections:

- Service time in years
- Vehicle-specific details
- Default calculation data independent of the selected car
- Additional information and settings
- The end result presented graphically and in table form

Cumulative emissions (kg CO2eq) *Cumulative costs (€)*

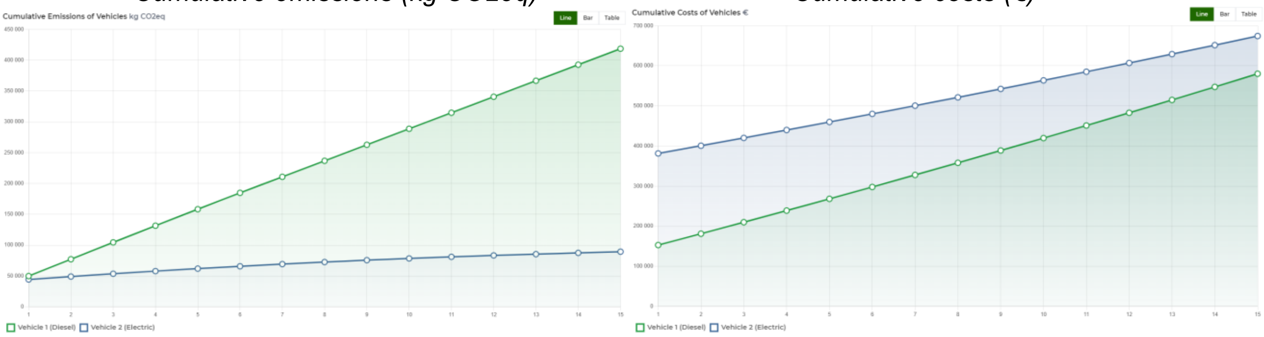


Figure 1. *The calculator produces graphs that show the cumulative emissions and cumulative costs of different car options.*

2. PRIMARY DATA AND USER INTERFACE

2.1. General

Some fields and headings on the website feature an additional information icon that offers further help with using the calculator.

The graph or table representation of the emissions and cost analysis results for the compared car options changes as the primary data is changed.

Clicking on “Show details”-shows what additional data the user can enter into the section in question.

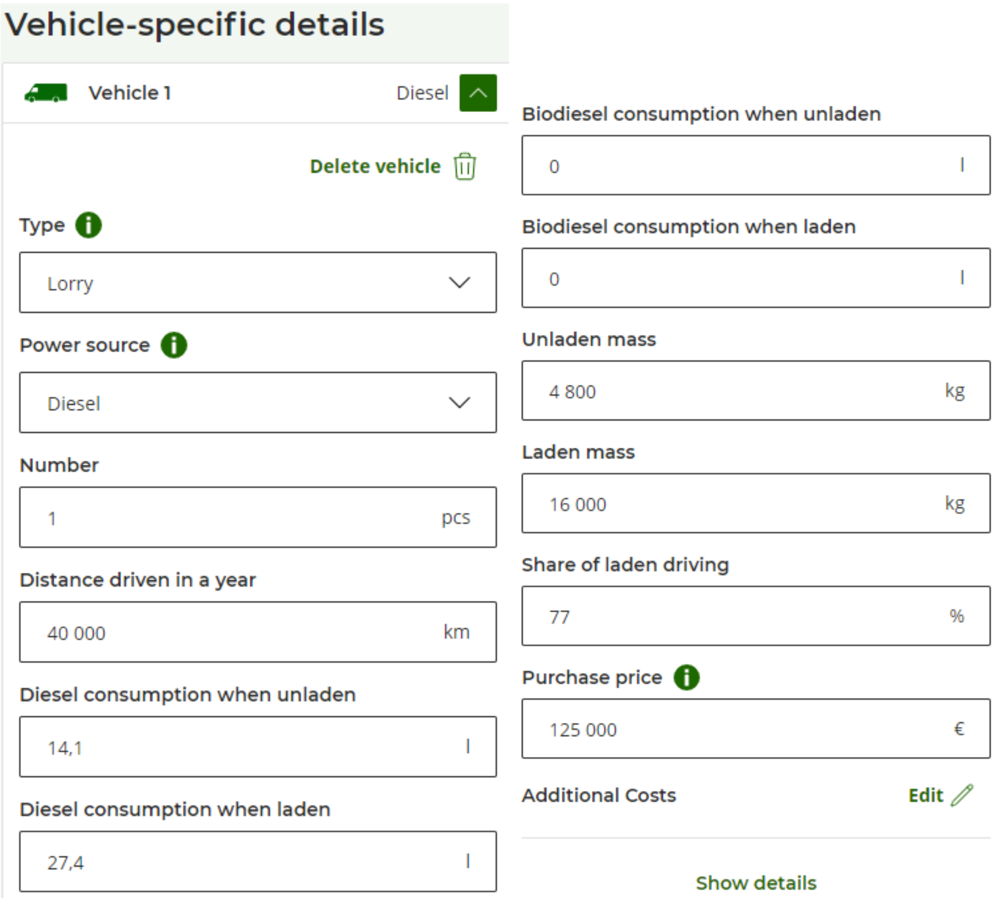
The “Add vehicle” button adds a new vehicle to the calculator. A vehicle can be deleted by opening its data and clicking on “Delete vehicle”.

The calculator works on the most common web browsers.

2.2. Vehicle-specific details

The user can select 1–6 different van or lorry options to be compared. The number of vehicles can be changed by clicking on ”Add vehicle” and ”Delete vehicle”.

The key details to enter include vehicle type (van, lorry, articulated vehicle or articulated vehicle with trailer), power source, distance driven in a year, fuel consumption when unladen, fuel consumption when laden, share of laden driving, purchase price and battery capacity. Additional information under ”Show details” make the calculation more specific and allow the user to enter other calculation parameters, such as the purchase cost of a home charger, maintenance costs, residual value of the vehicle and other additional costs. The user can also enter a nickname, e.g. the actual make and model, on the heading row of an individual vehicle.



The user must first enter the vehicle type that provides the primary assumptions for evaluating the purchase price and maintenance costs and the emissions generated during the manufacturing and use of the vehicle. The calculator features four size categories that correspond with the typical vehicles used in general cargo transport: van (total mass 3.5 t), delivery lorry (16 t), articulated vehicle (44 t) and articulated vehicle with trailer (76 t).

The primary power source is selected for each vehicle. The available options are diesel, natural gas, electric and plug-in hybrid (electric/diesel).

Gas vehicles can run on both natural gas or biogas, which is why there is no separate biogas option in the selection.

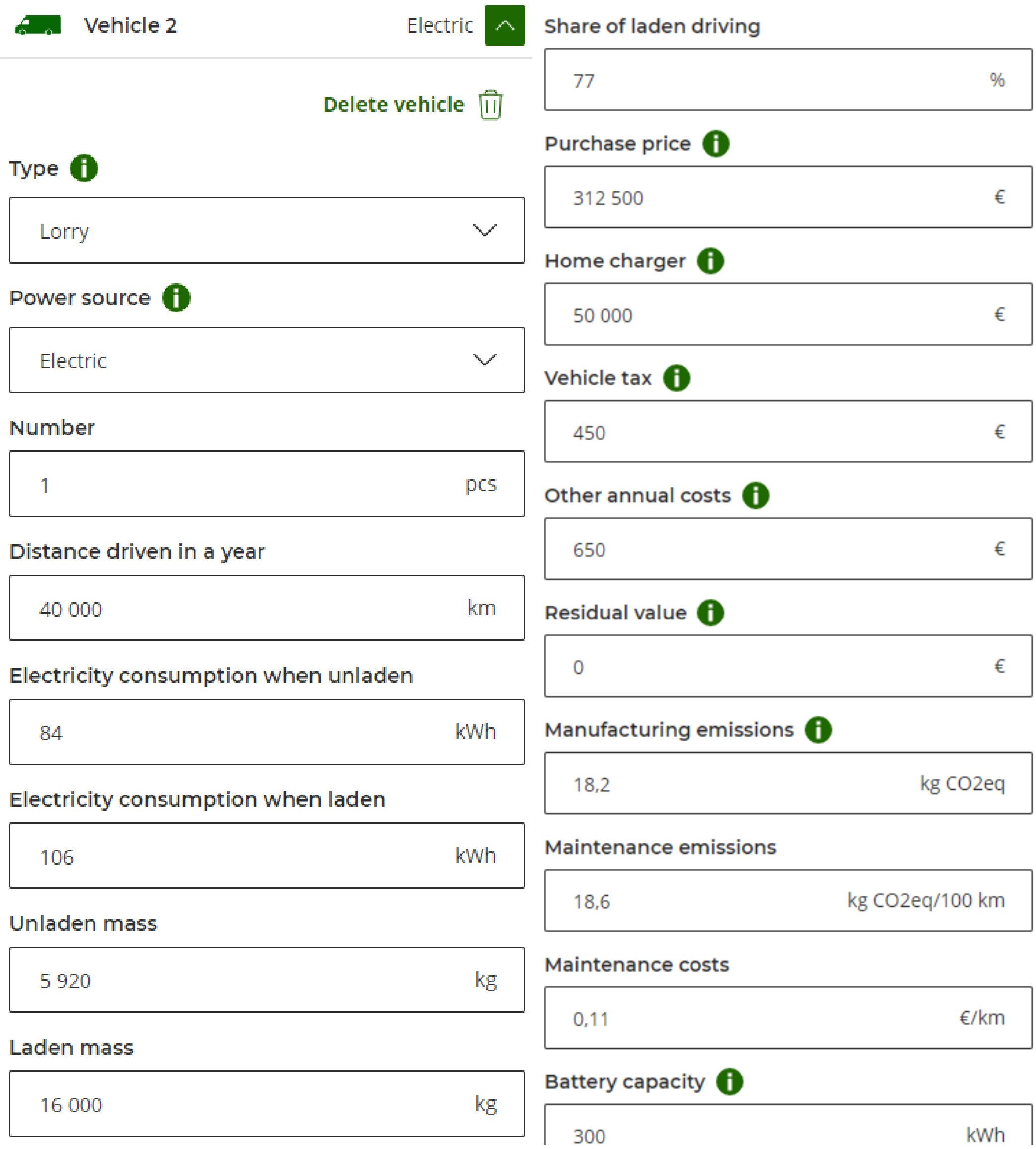
Plug-in hybrid vehicles differ from traditional full hybrids in that their energy comes partly from fuel and partly from externally charged electricity. A plug-in hybrid has a diesel engine in addition to an electric motor and a traction battery that can be charged from the mains through an external electrical connection.

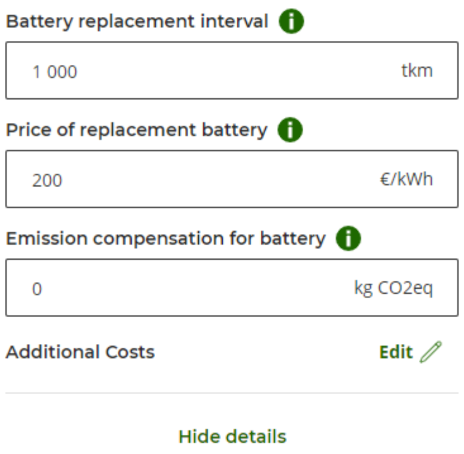
The unladen mass accounts for the mass of the batteries, in which case the payload of electric cars is smaller than that of combustion engine cars.

The manufacturing emissions of lorries with different power sources are assessed on the basis of TU Delft (Huismans, 2018) and TU Munich (Wolff et al., 2020) that are both based on the EcoInvent database (EcoInvent 2022). The manufacturing emissions of electric cars are calculated separately for the vehicle and the battery, as the battery manufacturing emissions account for the majority of the manufacturing emissions of an electric car and depend fully on the capacity of the battery. Without the battery manufacturing emissions, the electric car manufacturing emissions are around 15–20% lower than those of a combustion engine car.

On the basis of the selected vehicle type and power source, the calculator provides default data on the vehicle purchase price (€), home charging station (€) and battery capacity (kWh). The user can change this default data to correspond with the vehicles they have chosen for comparison. The default distances driven are estimated on the basis of statistics on goods transport by road and the cost index of road transport of goods (Statistics Finland 2012).

Clicking on “Show details” allows the user to see the vehicle-specific details.





These details automatically include default data on size category and power source that the user can replace with type-specific data.

The type-specific *vehicle tax* can be retrieved from the Traficom vehicle tax calculator https://www.traficom.fi/en/transport/road/vehicle-tax-calculator. The calculator provides a rough estimate on the basis of prior empirical results from the Traficom calculator for each power source and vehicle size category.

Other annual costs. Here you can enter all other undefined annual costs, such as insurance policies, car washing and fuel additives (such as AdBlue). Maintenance and tyre change costs are included in the estimate given below under "Maintenance costs (€/km)", and they are based on the VTT (2021) estimate on maintenance costs and Palomäki's (2013) estimate on tyre costs.

The battery capacity of plug-in hybrids and electric cars often varies even within the same model (e.g. long range models), so it is best to find out the battery capacity reported by the manufacturer and use it instead of the default data for a particular size category.

Battery replacement interval is ultimately a piece of user-specific primary data, although the default value is 1,000,000 km. It should also be noted that the battery replacement interval is not solely dependent on kilometres driven, but also on the number of recharges. The estimated service life of a lithium iron phosphate battery in a lorry is 3,000–7,000 charge cycles (Nyqvist and Olsson, 2021; Mauler et al., 2022; Teichert et al., 2023), in which case the average mileage is 143–333 km per charge cycle. In practice, the duration of batteries varies, e.g. due to battery capacity, their cooling systems and the personal charging habits of the end user. A significant share of the battery capacity may well remain even after 1,000,000 kilometres driven. The matter can also be discussed with car dealerships.

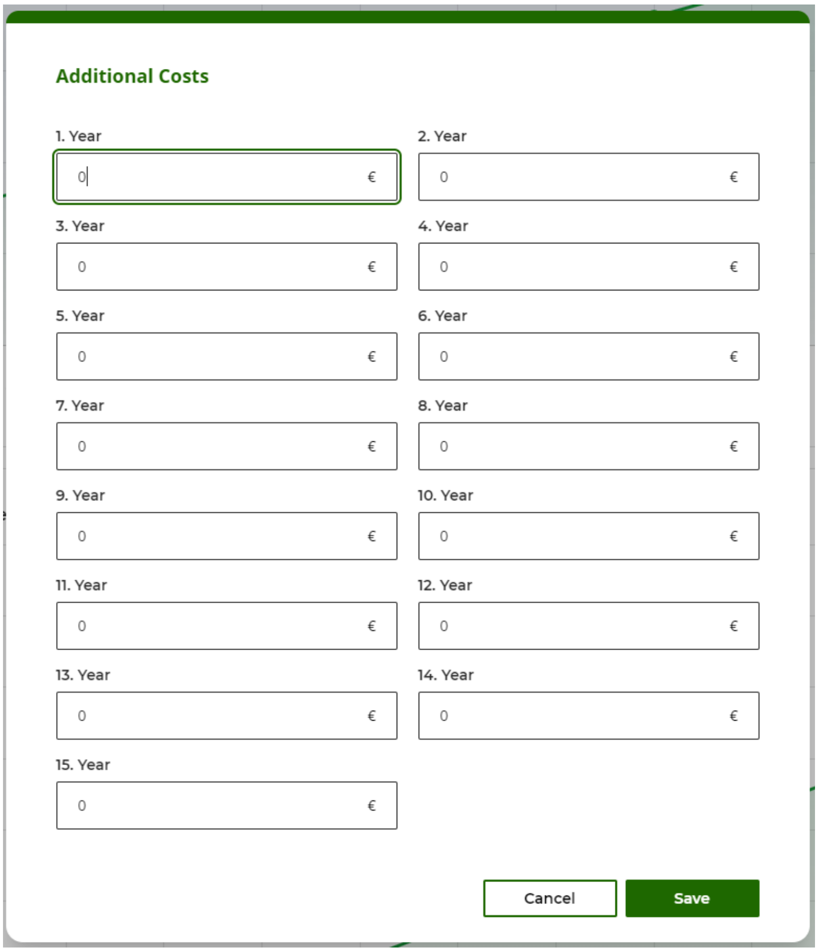
Emission compensation for battery refers to a situation where old batteries are made available for further use and this activity generates emission benefits. It is clear that when an electric car purchased today reaches the end of its life-cycle, there will be ample opportunity to recycle the battery. The secondary use of batteries will also become more common (e.g. use as electricity storages for solar panels), which can help replace the use of fossil fuels. After being used for storage in a decentralised energy system, the raw materials of the battery can likely be recovered. EU legislation includes strict framework conditions for recycling. There are notable uncertainty factors associated with the assessment of the emission compensation, but based on the information in the appendix, the moderate default emission compensation in this context is 20% of the emissions of the original battery (Bieker, 2021). The emission compensation reduces the life-cycle emissions of the vehicle with the amount in question.

Vehicle scrapping generates its own emissions, and these emissions are also roughly assessed based on the EEA report (2018). The amount of emissions is minimal, and the same default value is used for all vehicle size categories.

In terms of materials other than the battery, the recycling compensations of a vehicle at the end of its life-cycle are taken into account in the vehicle manufacturing emissions (EEA 2018).

The starting point is that the accurate purchase prices of the cars being compared are entered by the users themselves. The calculator provides indicative default values by size category and power source. The estimated price increase factor of gas lorries compared to diesel is 1.3 for vans and delivery lorries (CNG) and 1.4 for vehicle combinations (LNG). The estimated price increase factor of plug-in hybrids is 2 and of electric lorries 2.5. The assessment of the purchase prices is based on several sources. The purchase prices for vans are taken from car dealership price lists. The sources for lorry prices include the VTT (2021a) assessments and several research articles (Nyqvist and Olsson, 2021; Guerrero et al., 2020; Gunawan and Monaghan, 2022; Mauler et al. 2022; ITF 2022). The research articles typically focus on articulated vehicles, meaning that the information on delivery lorries and articulated vehicles with trailers is estimated on that basis. In terms of purchase prices of electric lorries, it must be noted that the price difference to a diesel alternative offered in research literature is generally less than double, whereas the actual purchase price may be notably more than double, as the electric lorry production numbers continue to be low, and the demand is likely to be notably greater than the supply (IEA 2022).

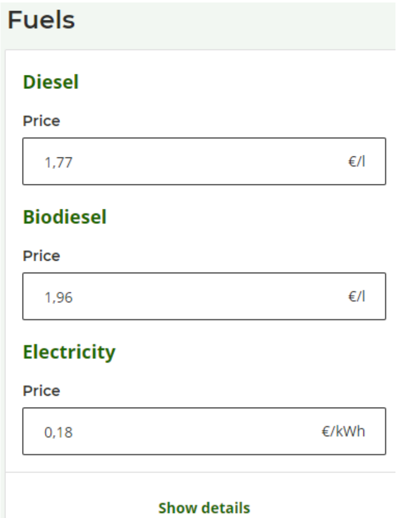
The user can enter accurate additional costs for each year under “Additional costs” and “Edit”.



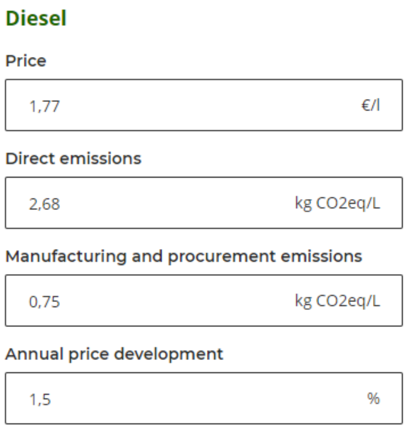
At the end of vehicle-specific data, the user has the opportunity to change the default calculation data that is not vehicle-specific. This data is discussed in section 2.2.

2.3. Fuel data

The calculator uses the fuel price information from autumn 2022 as default. The user can freely change these prices in accordance with the daily price situation.



Clicking on ”Show details” opens more fields that allow the user to enter emission factors and the annual price development:



The direct emissions of fuels refer to the emissions from the use of different fuels per unit. The LCA addition refers to the greenhouse gas emissions from the fuel raw material procurement and manufacturing (kg CO2eq/unit). In this context, the petrol and diesel emission factors do not include the emission impact of the biocomponent of fuels sold at distribution stations. It is calculated separately in accordance with the fuel blending ratio that changes over time (see section 4.1).

The direct and indirect emissions of petrol and diesel come from Lutsey (2017). The life-cycle emissions of natural gas are taken from the Ricardo report (2016). Leakage occurring during the procurement of natural gas is included, and it corresponds to the estimated situation in the Central European distribution network that includes gas coming from the Russian pipeline. In reality, the emissions from the production stage of natural gas vary by source. No accurate estimate is available on the emissions of Russian natural gas.

The default emission factors of biodiesel are the same as for regular diesel that include the biocomponent ratio derived from the biodiesel distribution obligation. This means that a user of biodiesel receives the same calculation result as a user of regular diesel. This solution is based on the calculation rules of Finland’s biofuel blending obligation and the fact that the global volumes of biodiesel with sustainable product chains are limited. The current rules of the Finnish petrol and diesel biofuel blending obligation lead to a situation where separately fuelled biodiesel does not create additional emissions reductions at the system level. If a driver does not separately refuel on biodiesel, the corresponding amount of biofuel will nonetheless be added into distribution. If a driver fills their tank with biodiesel, then the same amount of biofuel will not be blended into regular diesel (see also section 2.6. and appendix). Due to the limited availability of bio-based fuels, system-level thinking on the volume restricted by the blending obligation is well-founded. No volume greater than the blending obligation remains for distribution, as international demand directs it away from domestic use.

The calculator allows for a calculation based solely on biodiesel by changing the emission factor of the life-cycle greenhouse gas emissions of the biocomponent used in the diesel blending obligation under ”Settings” (see sections 2.6 and 5.2).

The life-cycle emissions of biogas vary greatly depending on the raw material source and process technology. According to information received from Gasum, the life-cycle emissions of the biogas they sell are currently 19 g CO2eq/MJ (Nevalainen, 2019). In terms of kilograms, this means 0.95 kg CO2eq/kg, which is used as the default biogas emission factor in the calculator. The emission factor may change from the default value in the future, e.g. based on how much animal manure can be directed into biogas production. The biogas emission factor used in the calculator is 0.93 kg CO2eq/kg.

Biogas is currently included in the distribution obligation. This is why the emissions benefits of separately fuelled biogas are not fully allocated to the user of a gas vehicle. The emissions of separately fuelled biogas are evaluated as follows: the amount of refuelled biogas times its emission factor plus the emissions created when the biogas amount exceeding the biogas share of the distribution obligation for the year in question reduces the same energy content of diesel from the distributed gas (see calculation formula in section 4.1). The emissions reduction in relation to natural gas increases over time as the amount of biocomponent in the distributed fuel increases along with the increase in the biofuel share of the distribution obligation.

The life-cycle emission factors of electricity represent the average emission factor of electricity production in Finland. In other words, they do not include the impact of imported electricity on the emission factors. The life-cycle emissions of imported electricity are likely to be lower than the life-cycle emission factors of electricity produced in Finland, as in recent years, more than 70% of electricity has been imported from the Nordic countries (Finnish Energy 2019) and electricity is expected to be imported from elsewhere than Russia in the future. For example, the life-cycle emission factor of Swedish electricity production in 2013 was around 2.5 times smaller than that of electricity produced in Finland (Moro and Lonza, 2018).

The default primary data for calculating the emissions of electricity use is the emission factor for the direct specific emissions of production that corresponds to the average emission factor for domestic electricity production in 2021 provided by Fingrid. It is defined in cooperation with Statistics Finland and Finnish Energy. At that time, the average of emission factors for electricity produced in Finland was 81 g CO2eq/kWh (Fingrid 2022). Based on Moro and Lonza (2018), the emission factor of raw material procurement and manufacturing of Finnish electricity is estimated to be 16 g CO2eq/kWh. This data represents the situation in 2014, which is why it can be assumed to have been somewhat smaller in 2021.

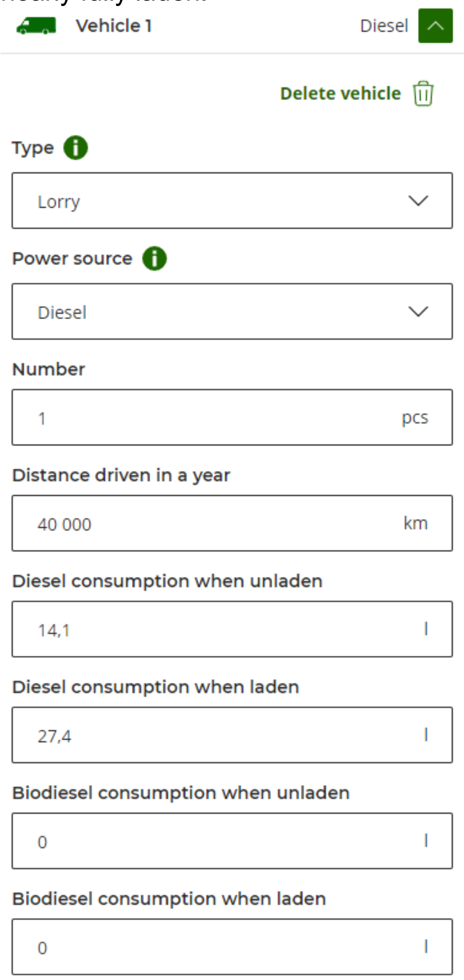
According to the WAM policy scenario of Lehtilä et al. (2021), the specific emissions of electricity are developing rapidly. According to the scenario, the specific emissions of direct emissions will fall below 10 g CO2eq/kWh already by 2030. In the calculator’s default scenario this change is somewhat slower, and the direct specific emissions of electricity production experience a linear reduction from the 2023 value of 80 g CO2eq/kWh to 10 g CO2eq/kWh by 2035. The emissions will then fall to 5 g CO2eq/kWh by 2040 and remain on that level moving forward. The specific life-cycle emissions of other stages of electricity production develop from the 2023 value of 15 g CO2eq/kWh to 10 g CO2eq/kWh by 2035 and remain on that level.

The user can provide a suitable future price development for different fuels. The default for all fuels is that their price will increase by 1.5% each year.

2.4. Vehicle consumption data

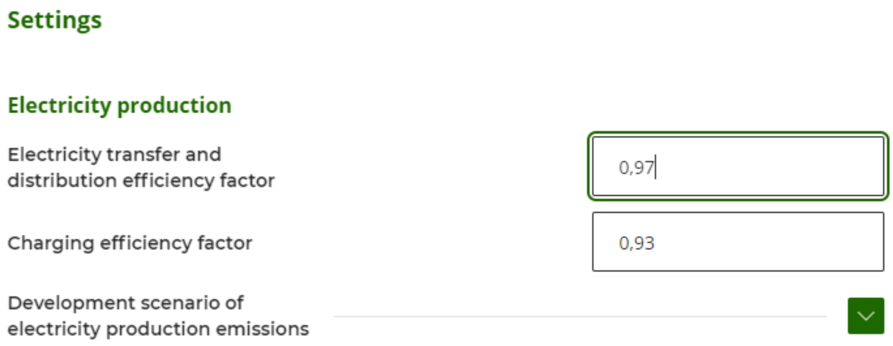
The user has the opportunity to provide different energy consumption data per hundred kilometres driven. The assumption is that the data entered by the user corresponds with the actual consumption. If the user already has a car that offers consumption values through its trip computer, these values should be used in the calculation. The consumption values are estimated based on the same sources as the purchase prices in addition to the consumption functions developed in Tampere University (Liimatainen and Pöllänen, 2011; Jahangir Samet et al., 2021).

The total mass of a lorry has a great impact on its energy consumption, which is why consumption is given both as unladen and laden. Based on the statistics on goods transport by road, the share of unladen driving is estimated to be 23% of the distance driven. The consumption when laden is estimated for a vehicle that is nearly fully laden.



2.5. Default calculation data that is not vehicle-specific

Clicking on "Settings" (see section 2.2) shows the primary calculation data that is not vehicle-specific and that the user is expected to change only under exceptional circumstances.



By default, the calculator shows data for a period of 15 years. The time scale can be increased and decreased with the buttons provided. The default setting of a bar graph can be changed into a line graph that is better suited for examining the differences between car options on a longer time scale in particular. The results can also be examined in table form by selecting "Table" in the buttons above the graphs.

There are three variables linked to the calculation of electricity production emissions. The default electricity transfer and distribution efficiency factor corresponds to the average situation of the Finnish electricity system (Honkapuro et al., 2015), i.e. it is 0.97, whereas the European average is 0.935 (Lutsey, 2017). Loss also occurs in the charging of electric cars. The calculator's charging efficiency factor is 0.93, which corresponds with the European average (Lutsey, 2017).

The calculator assumes that the greenhouse gas emission factor of electricity production (kg CO2eq/kWh) develops as described in section 2.4 in the default basic scenario. The user can also provide their own emission factor scenario by storing annual values for each year under settings.

Table 1. Future development of the biofuel share of fuels used in the car calculator for vans and lorries.

Year	Petrol Ethanol %	Diesel Biodiesel %	Natural gas Biogas %	Fuel sold Biofuel share %
2023	10.0	17	50	13.5
2024	10.0	36	76	28
2025	10.0	37	78	29
2026	10.0	37	78	29
2027	10.0	38.5	80	30
2028	10.0	39.5	80.5	31
2029	10.0	40.5	81	32
2030	10.0	42.8	83	34
……	……	……	……	……
2050	10.0	42.8	83	34

The biofuel shares of fossil petrol and diesel are expected to develop in line with Finland's distribution obligation policies (Finnish Parliament 2022). The law states that the combined distribution amount of petrol and diesel must meet the distribution percentage describing the energy content of biofuels. However, the starting point for petrol vehicles is that current vehicles cannot run on petrol blends where the amount of ethanol exceeds 10%. Therefore, the assumption here is that E10 petrol is used from now on in the cars available for selection (default 10% ethanol). This is based on the assumption that no new petrol standard E20 will enter the market. The biofuel shares of diesel and biogas are extrapolated from the figures given in the low carbon roadmap for road transport WAM scenario up until 2030 (VTT 2021b), after which the biofuel shares of the distribution obligation will remain unchanged (Table 1).

Settings allow the user to separately enter the life-cycle emission factor of the biodiesel biocomponent (kg CO2eq), since it cannot be entered in connection with the fuel data (section 2.4). The life-cycle emissions of the diesel biocomponent per litre are assumed to be 80% lower than those of the combustion and manufacturing of fossil diesel. The starting point in Finland is that diesel is blended with 7% of traditional biodiesel (so-called FAME) that meets the emissions reduction requirements for new plants set in the RED directive (new plants must have 70% smaller emissions than fossil diesel). The rest of the biodiesel in the blending obligation is paraffinic diesel fuel that reaches an 80–90% emissions reduction in relation to traditional biodiesel (emission reductions reported by Neste and UPM Kymmene).

The calculator does not assume that the consumption of the vehicle changes along with the increase of biodiesel, as the energy contents of paraffinic biodiesels are equal to the energy content of fossil diesel (36 MJ/litre).

The settings also allow the user to change the life-cycle emission factor of the petrol biocomponent (ethanol) (kg CO2eq). Its value changes annually depending on the raw material base. In this context, the emission factor is expected to be 60% smaller on average than the life-cycle emissions of fossil petrol per litre.

The user can also change the energy content of different fuels.

Fossil fuels

Life-cycle emission factor of diesel biocomponent	0,69 kg CO2eq/L

Furthermore, the following default data can be changed at the end of the settings:

Other details

Electric vehicle battery manufacturing emission factor	70 kg CO2eq/kWh
Annual cost decrease of new battery	4 %
Annual development of battery manufacturing emission factor (%)	3,35 %
Interest rate for tied-up capital	2 %

The default electric battery emission factor describes the greenhouse gas emissions generated in the battery raw material procurement and manufacturing. The emission factor varies greatly between different research results (ICCT 2018). The cleanness of the energy used for manufacturing is a major contributing factor. In their studies, Romare and Dahllöf (2017) have estimated that energy emissions account for a minimum of 50% of the life-cycle emission factor of batteries. In this context, the calculator uses the average result of recent studies (Bieker, 2021; Green NCAP 2022), which is only 760 kg CO2eq/kWh (see the emissions and costs calculator for passenger cars user manual, Seppälä et al., 2023).

The estimated default price of a new battery corresponds to the current situation (€300/kWh) (see section 2.3). It is expected to decrease by around 4% annually. Similarly, the emission factor of battery manufacturing is expected to decrease by 3.35% annually.

The calculation of costs (see section 4.2) allows the user to modify the interest rate for tied-up capital. The default is 2%.

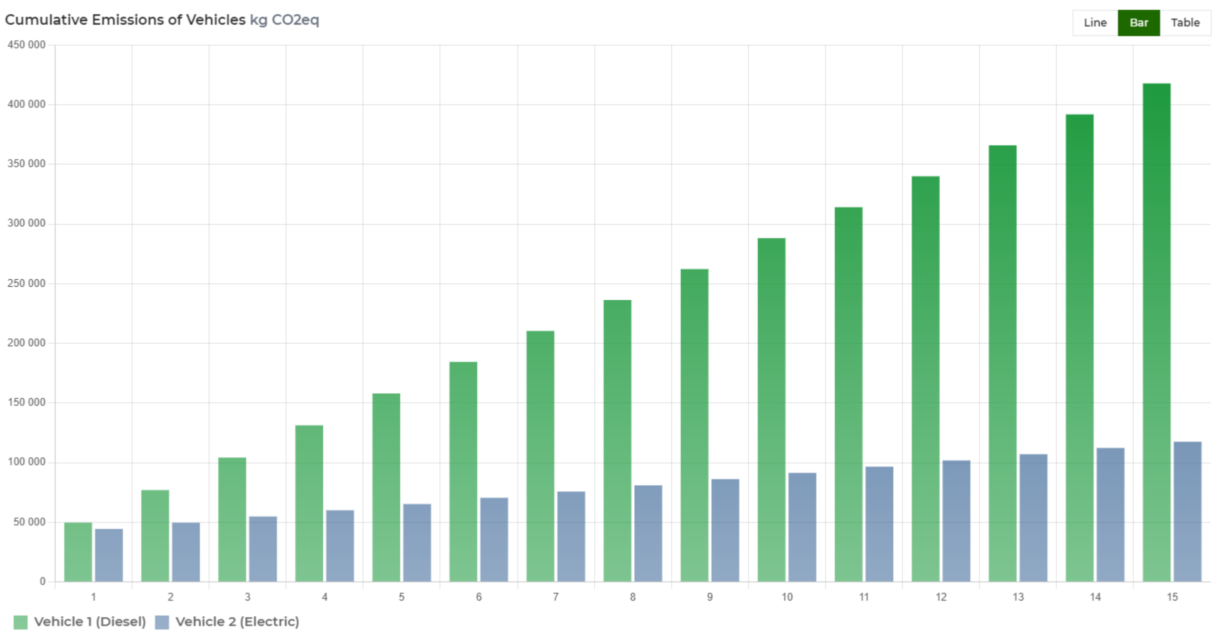
2.6. Additional information and settings

Settings can be found in the top right corner of the calculator. Clicking on ”Settings” shows the primary calculation data that is not vehicle-specific and that the user is expected to change only under exceptional circumstances. These are explained in more detail in section 2.6.

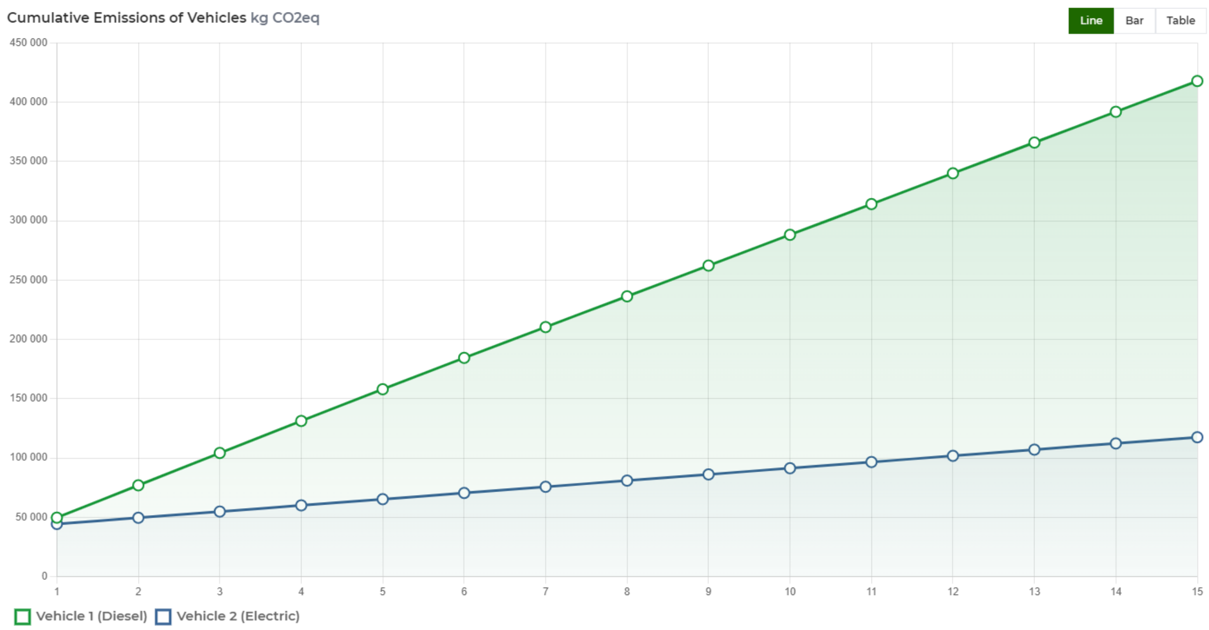
3. ANALYSIS RESULT AND ITS INTERPRETATION

The analysis of emissions is shown as default on the right side of the application. The life-cycle emissions of the different car options are added together for each year, showing the so-called cumulative emissions either as bars (default), lines or a table (the user can select between the graph, line or table representation) in relation to time. The smaller the greenhouse gas emissions, the better the car is for the climate. At the point where the cumulative emissions of different car options intercept, one option becomes superior to the other. The similar representation and interpretation of results applies to costs.

In the figure below, the emissions of an electric car become lower than those of a compared petrol car after only two years of use. The numeric values for each year can be viewed by placing the cursor on top of the bars or lines.



The line graph provides the same information as the previous bar graph, but in a more familiar manner. When using the line graph, you must note that selections providing similar results are shown on top of each other, which can make it difficult to separate the results between different vehicles.



The third option, the table, provides the cumulative emissions of vehicles for each year. The bottom row of the table describes the average annual emissions of the vehicle. Costs can also be examined as a table using the same logic.

Cumulative Emissions of Vehicles kg CO2eq

Line Bar **Table**

Year	Vehicle 1 (Diesel)	Vehicle 2 (Electric)
2023 (1)	49726	44419
2024 (2)	76985	49639
2025 (3)	104244	54859
2026 (4)	131237	60079
2027 (5)	157962	65298
2028 (6)	184421	70518
2029 (7)	210347	75738
2030 (8)	236272	80958
2031 (9)	262197	86178
2032 (10)	288123	91397
2033 (11)	314048	96617
2034 (12)	339974	101837
2035 (13)	365899	107057
2036 (14)	391824	112276
2037 (15)	417750	117496
Average Costs / Year	27850	7833

4. CALCULATION FORMULAS

The emission calculation formulas in section 4 are based on the Finnish Climate Change Panel's emissions and costs calculator for passenger cars (Seppälä et al., 2023).

4.1. Basis of emission calculation

The manufacturing emissions of lorries with different power sources are assessed on the basis of TU Delft (Huismans, 2018) and TU Munich (Wolff et al., 2020) that are both based on the EcoInvent database (EcoInvent 2022). The manufacturing emissions also contain the emissions of material procurement and manufacturing and the impact of car assembly and material recycling. However, the values do not include the emissions of battery material procurement and manufacturing, nor the emission compensation for batteries. They are accounted for elsewhere in the calculation.

Assessment of life-cycle emissions

The emissions of each vehicle option after n service years are calculated as follows:

$GE_n(v)$ = VehicleME(v) + BatteryME(v) + $FE_1(v)$ + … + $FE_n(v)$ + VehicleS(v) + BatteryR(v) + BatteryS(v) + $MM_n(v)$ (1)

where

- $GE_n(v)$ = greenhouse gas emissions of vehicle v as carbon dioxide equivalent tonnes after n service years (kg CO2eq)
- VehicleME(v)= raw material procurement and manufacturing emissions and vehicle manufacturing emissions of vehicle v (kg CO2eq)
- BatteryME(v)= raw material procurement and manufacturing emissions and battery manufacturing emissions of the electric battery of vehicle v (kg CO2eq)
- $FE_i(v)$ = fuel use emissions of vehicle v in year i
- VehicleS(v) = vehicle v scrapping emissions
- BatteryR(v) = vehicle v electric battery replacement emissions (kg CO2eq)
- BatteryS(v) = emission compensation due to the further use of the electric battery of vehicle v after scrapping (negative emissions, kg CO2eq)
- $MM_n(v)$ = emissions from the maintenance measures of vehicle v after n service years (kg CO2eq).

Values for variables Vehicle ME(v), VehicleS(v) and BatteryS(v) in equation (1) are received directly as input data for each vehicle option. The emissions of replaceable batteries decrease linearly, being 60% of the original after 15 years. Here, the assumption is that battery technology keeps on developing and the energy emissions from battery manufacturing are reduced by 80%. In their studies, Romare and Dahllöf (2017) have estimated that energy emissions account for a minimum of 50% of the life-cycle emission factor of batteries.

Battery emissions are calculated as follows:

BatteryME(v) = life-cycle emission factor of vehicle v electric battery manufacturing (kg CO2eq/kWh) * battery capacity (kWh) (2)

Emissions from the use of diesel and biodiesel

The annual emissions from the use of a diesel vehicle are calculated with the following equation 3 (FED_i(v)), but with the petrol and ethanol emission factors replaced with the diesel and biodiesel emission factors (SDC, VDC, SBDC, VBDC).

$FE95E10_i(v)$ = [(SPC+VPC) * (1-SB_i) + (SEC_i+VEC_i)* SB_i]*DY*C$95E10(v)$/100 (3)

where

$FE95E10_i(v)$ = 95E10 petrol fuel use emissions of vehicle v in year i
SPC = emission factor of petrol combustion (consumption) (kg CO2eq/litre)
VPC = life-cycle emission factor of petrol from oil procurement to distribution (kg CO2eq/litre)
SB_i = biofuel (ethanol) share (%) of the distribution obligation in year i
SEC_i = emission factor of ethanol combustion (consumption) (kg CO2eq/litre) in year i
VEC_i = life-cycle emission factor of ethanol from raw material procurement to distribution (kg CO2eq/litre) in year i
DY = distance driven in a year (km)
C95E10(v) = vehicle v 95E10 petrol consumption per 100 km (contains the distribution obligation share of ethanol).

By default, the emissions of the separate fuelling of biodiesel are calculated in a similar manner as those of diesel (see section 2.5). The emissions impact of the separate fuelling of biodiesel without the impact of the distribution obligation can be calculated as shown in section 5.2.2.

Emissions from the fuel use of diesel hybrids

The emissions from the fuel use of diesel hybrid vehicles are calculated similarly as the fuel use emissions of diesel vehicles.

Emissions from the fuel use of gas vehicles

The total fuel use emissions of gas vehicle *gv* are calculated based on the amounts of natural gas, biogas and petrol used per 100 km:

$$TFEi(gv) = [(SNGC+VNGC) * CNG(gv) + TFEBG_i(gv) + (S95EC*V95EC)*C95E(gv)]*DY/100 \quad (4)$$

where

SNGC = emission factor of natural gas combustion (consumption) (kg CO2eq/kg)
VNGC = life-cycle emission factor of natural gas from gas procurement to distribution (kg CO2eq/kg)
CNG(*gv*) = gas vehicle *gv* natural gas consumption (kg) per 100 km
TFEBGi(*gv*) = total emission impact of gas vehicle *gv* biogas consumption in year *i*
S95EC = emission factor of 95E petrol combustion (consumption) (kg CO2eq/litre)
V95EC = life-cycle emission factor of 95E petrol from oil procurement to distribution (kg CO2eq/litre)
C95E(*gv*) = gas vehicle *gv* 95 petrol consumption (l) per 100 km
DY = distance driven in a year (km).

Biogas is currently covered by the distribution obligation. Therefore, the overall impact of biogas use is formed by the use emissions and the indirect emission surcharge created as the amount of biogas exceeding the distribution obligation reduces the biodiesel share of distributed diesel. The use of natural gas in road transport is so minimal that the change is expected to take place in the amount of distributed biodiesel. The calculation of the total biogas emissions impact (TFEBGi(*gv*)) of gas vehicle *gv* in each year *i* is carried out in the following manner:

$$TFEBG_i(gv) = FEBG_i(gv)+ ESBD_i(gv) = FEBG_i(gv) + SMFD_i(v)*[(SFDC+VFDC) - (SDC_i+VDC_i)] \quad (5)$$

where

$FEBG_i(gv)$ = biogas use (DY*KPK(*gv*)) emissions of vehicle *gv* in year *i*
ESBD*i*(*gv*) = emission surcharge due to the replaced biodiesel from the biogas used by vehicle *gv* in year *i*
$SMFD_i(v)$ = fossil diesel addition in the diesel distribution obligation amount caused by the use of biogas by vehicle *v* in year *i*
SFDC = emission factor of fossil diesel combustion (consumption) (kg CO2eq/litre)
VFDC = life-cycle emission factor of fossil diesel from biodiesel procurement to distribution (kg CO2eq/litre)
SDC_i = emission factor of diesel combustion (consumption) (kg CO2eq/litre) within the distribution obligation in year *i*
VDCi = life-cycle emission factor of diesel within the distribution obligation from biodiesel procurement to distribution (kg CO2eq/litre) in year *i*
DY = distance driven in a year (km)
CBG(v) = vehicle *v* biogas consumption (kg) per 100 km.

SMFDi(*v*) is otherwise calculated with the following equation (6), but the energy ratio (21/36) is replaced with the biogas/diesel ratio (50/36), in which case the biogas consumption in kilograms is converted into diesel litres.

$$SMFD_i(v) = ((EE-(PE+EE)*X_i)/X_i)*DY*CE85(v)*23.2/36 \quad (6)$$

where 36 is the diesel energy content (MJ/l) and 23.2 is the E85 energy content (MJ/l).

4.2. Cost calculation

The cumulative costs of a vehicle include the procurement cost, i.e. investment cost, car tax, vehicle tax, annual costs and, in case of electric cars, battery replacement. Annual costs include refuelling or charging costs, vehicle tax, interest on the investment and maintenance. The interest charge of the investment is calculated with a 2% interest on the purchase price of a vehicle.

In addition to the above, a residual value can also be estimated for the vehicle. It is not included in the calculator as default, but the user can choose to enter a residual value for the vehicle to the dedicated field. As a result, the calculator will deduct the entered amount from the last year of the selected examination period.

Calculation formula for the cumulative costs of the use of an electric car:

$$\mathrm{CC_n(ev)} = \mathrm{INV} - \mathrm{RV} + \mathrm{CT} + \mathrm{RC} + \sum_{i=1}^{n}\left(\mathrm{W_{c,i}C_i} + \mathrm{M_i} + \mathrm{VT_i} + \mathrm{r}^{i} * (\mathrm{INV} - \mathrm{RV})\right) \qquad (7)$$

where
- $CC_n(ev)$ = cumulative costs of using an electric car for *n* years, €
- INV = purchase price, i.e. investment cost, €
- CT = car tax, €
- RV = residual value, €
- RC = battery replacement cost, €
- $W_{c,i}C_i$= electricity price €/kwh times energy consumption kwh/year, i.e. charging costs, € per year
- M = maintenance costs, € per year
- VT = vehicle tax, € per year
- r = interest on the investment, %
- n = examination period in years.

For plug-in hybrids:

$$\mathrm{CC_n(h)} = \mathrm{INV} - \mathrm{RV} + \mathrm{CT} + \sum_{i=1}^{n}\left(\mathrm{W_{f,i}C_i} + W_{c,i}\mathrm{C_i} + \mathrm{M_i} + \mathrm{VT_i} + \mathrm{r}^{i} * (\mathrm{INV} - \mathrm{RV})\right) \qquad (8)$$

where
- $CC_n(v)$ = cumulative costs from use other than electric for *n* years €
- INV = purchase price, i.e. investment cost, €
- CT = car tax, €
- RV = residual value, €
- $W_{f,i}K_i$= fuel price €/l times fuel consumption l/year, i.e. fuelling costs, € per year
- $W_{c,i}C_i$= electricity price €/kwh times energy consumption kwh/year, i.e. charging costs, € per year
- M = maintenance costs, € per year
- VT = vehicle tax, € per year
- r = interest on the investment, %
- n = examination period in years.

For other vehicles:

$$\mathrm{CC_n(v)} = \mathrm{INV} - \mathrm{RV} + \mathrm{CT} + \sum_{i=1}^{n}\left(\mathrm{W_{f,i}C_i} + \mathrm{M_i} + \mathrm{VT_i} + \mathrm{r}^{i} * (\mathrm{INV} - \mathrm{RV})\right) \qquad (9)$$

where
- $CC_n(v)$ = cumulative costs from use other than electric for *n* years €
- INV = purchase price, i.e. investment cost, €
- CT = car tax, €
- RV = residual value, €
- $W_{f,i}K_i$= fuel price €/l times fuel consumption l/year, i.e. fuelling costs, € per year
- M = maintenance costs, € per year

- VT = vehicle tax, € per year
- r = interest on the investment, %
- n = examination period in years.

5. EXTENDED USES OF THE CALCULATOR

Section 5 is based on the emissions and costs calculator for passenger cars user manual (Seppälä et al., 2023).

5.1. Sensitivity analyses

The default data in the calculator can be modified, and the results for both emissions and costs are shown to the user immediately in the graphs.

The origin of the charging electricity has a great impact on the emissions of an electric car. A sensitivity analysis can be carried out e.g. by selecting between extremes where electricity is produced by wind power (10=0+10 g CO2eq/kWh), coal (1,390=1,029+361) g CO2eq/kWh) or with the average European electricity emission factor (351 = 296 + 45 g CO2eq/kWh). The life-cycle emission factors of wind and coal come from Koffi et al. (2017). The average emission factor for European electricity production is taken from the EEA publication (2018) (EU20 direct emission factor in 2016) and for life-cycle upstream emissions from Moro and Lonza (2018).

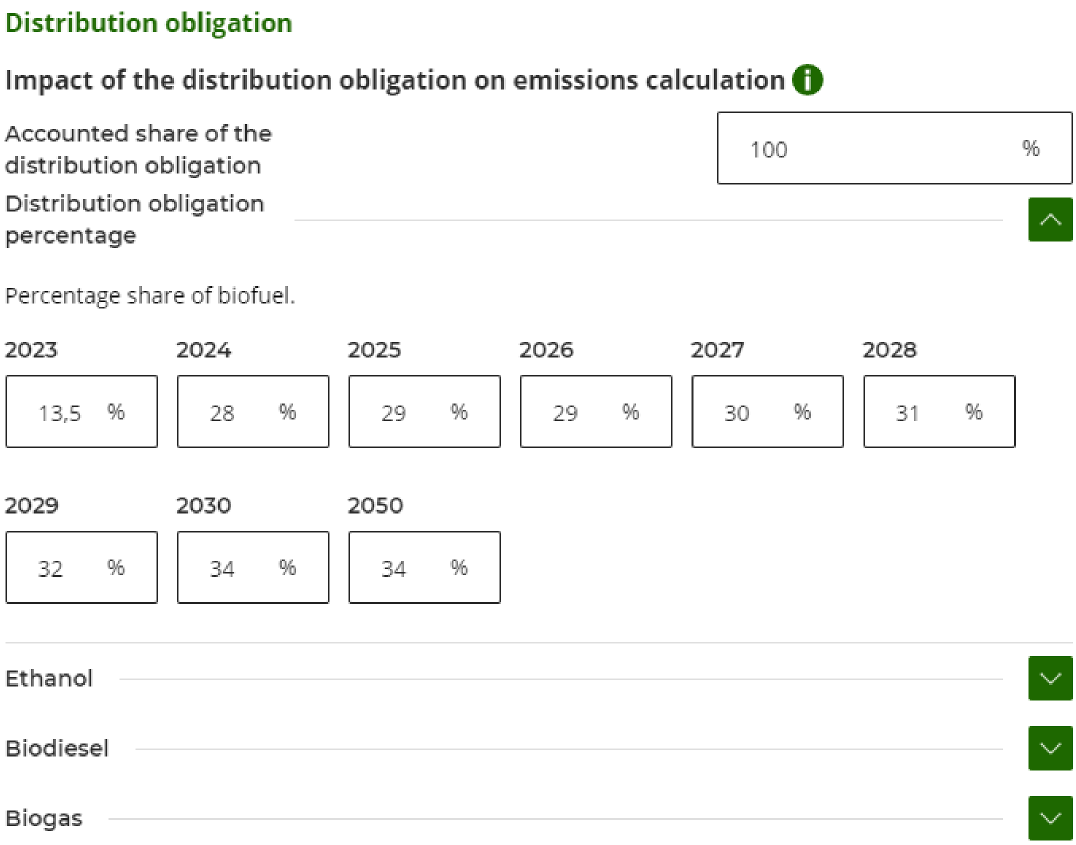
There are great uncertainties related to electric car batteries, mainly depending on their origin. Batteries manufactured in Asia have the highest emissions due to the high emissions of the electricity used for battery manufacturing there. For the purposes of a sensitivity analysis, a suitable range of variation for the emission factor of battery manufacturing is 60–100 kg CO2eq/kWh (cf. section 2.6).

There can be great variation in the manufacturing emissions of cars within the same size category, even within the same power source. This is why the comparison of car options should also evaluate the sensitivity of the end result by modifying the manufacturing emission factors.

The emission factors of biofuels vary due to manufacturing technology and raw materials, the impact of which can be examined by modifying the emission reduction e.g. with a 60–80% range of variation in relation to fossil fuels.

5.2. Impact assessment of the separate use of biodiesel and biogas

The calculator accounts for the system-level emission impact of the separate use of biodiesel, biogas and ethanol (E85), where the emission surcharge returned by the distribution obligation is added to the life-cycle emissions of biofuels (distribution obligation numbers provided in section 2.5). The matter is discussed in more detail in the Finnish Climate Change Panel’s emissions and costs calculator for passenger cars user manual (Seppälä et al., 2023). Should the user wish to see the calculated emissions of said fuels without the impact of the distribution obligation, the user can disable this system-level default calculation (accounted share of the distribution obligation changed to 0%), in which case the calculation only uses the life-cycle emission factors of the biofuel production.


Distribution obligation
Impact of the distribution obligation on emissions calculation
Accounted share of the distribution obligation
100 %
Distribution obligation percentage
Percentage share of biofuel.
2023
13,5 %
2024
28 %
2025
29 %
2026
29 %
2027
30 %
2028
31 %
2029
32 %
2030
34 %
2050
34 %
Ethanol
Biodiesel
Biogas

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