CTU Prague and TU Wien

ELECTRIC VS GASOLINE VEHICLES
Economic evaluation and comparison of TCO

Seminar paper

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Abstract

This paper concerns itself about the comparison of the total operating expenses of alternatives to the standard petrol version regarding the situation in Austria and the Czech Republic. Due to the new targets the EU set in the *2030 climate and energy framework,* there must be a reduction of CO_2 emissions from the transport sector. Because of new regulations, there will be various changes in the automotive industry. The dominance of the petrol driven cars in recent years is no coincidence, since they are cheaper in the first place and offer a lot of comfort for their relatively low prices. However, if you compare the total costs of ownership over a longer period, the outcome is different. The data was used from different sources, for example the purchase prices are from a website of a car dealership, to calculate the TCO using the net present value method. This leads to the best solution from an economical point of view. Besides the TCO, a sensitivity analysis has been done, to compare the influence of energy prices and other factors that might change in the future. Due to cheap purchase prices in the first place, petrol cars are mistakenly thought to be the generally cheapest option. The findings and calculations suggest, that over a period of eleven years, the electric version is the cheapest option for Austria and the hybrid version is the cheapest version for the Czech Republic.

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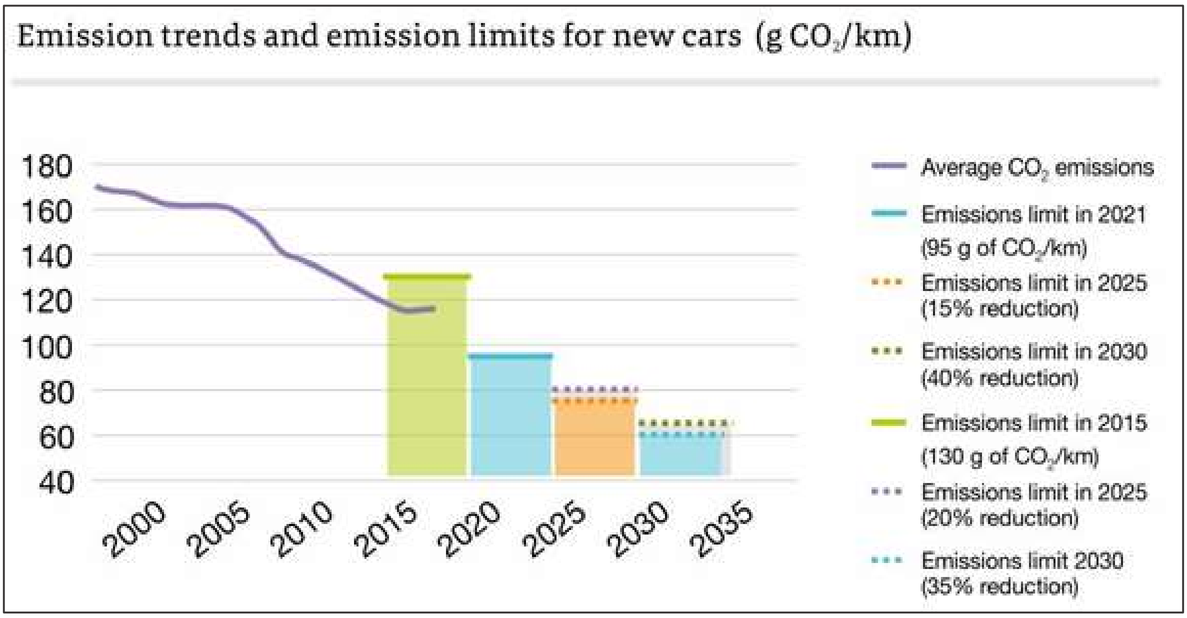
1. Introduction

The aim of this seminar paper is to compare the total operating expenses of conventional cars to electric cars from an investor's point of view, with focus on the specific case of Austria and the Czech Republic. In the first part of the paper, we will describe reasons for the expected expansion of electromobility in the EU. In the second part, we will select a suitable car, that is available with conventional, hybrid and electric engine, and compare their operating expenses. In the third part, the net present value of expenses will be calculated and compared for all three types of cars and later, a sensitivity analysis for key variables will be presented.

2. Expected expansion of electromobility in EU

Within the 2030 climate and energy framework the EU acted and set EU-wide targets and policy objectives to reach the goal for reducing greenhouse gas emissions by at least 55% till 2030. The goal of the EU is to be climate-neutral by 2050. Especially in the electromobility sector, the EU set strict emission limits. The aim is to achieve a 90% reduction in greenhouse gas emissions from the transport sector by 2050 in comparison to 1990. Major polluters are passenger cars with 61% of total CO_2 emissions from EU road transport. To reduce CO_2 emissions from the transport sector, the EU relies on the use of electric vehicles (EV). The expected growth of the number of EV in the EU can be explained due to strict emission limits. Therefore, we want to analyze the situation from an investor's point of view and compare the total operating expenses of both conventional and electric cars [1; 2; 3].

The following graph shows the CO_2 emission limits that car makers will be able to emit for their new cars in the coming years, which means the average for the entire fleet [4].



Graph 1 -Emissions trends and emission limits for new cars [4]

We can see that emissions should decrease by 40 % until 2030, for example. In such a case, the share of electric cars in new car registrations would have to be 38 % in the same year. If, carmakers want to meet these limits and thus avoid significant fines, it is probable that there will most likely be a massive increase in the number of electric cars.

3. Evaluation of the purchase of an electric car

The subject of this chapter will be the evaluation of the purchase of an electric car. In this case, we will try to evaluate the investment from the perspective of the average user. In the following subchapters, we will make a technical and economic comparison of a car with petrol, electric and hybrid drive.

3.1. Description of selected cars

Based on estimated user requirements, we selected a suitable car. Considering other relevant factors, such as brand reputation, spare parts availability and so on, we opted for the new Hyundai Kona model, which we can see in the picture.

Figure 1 - Hyundai Kona [5]

In said comparison we included the petrol-driven version, the one with an electric engine, as well as the HEV one with a hybrid drive. This type of car meets the specified requirements in all the above variants and since it is the same base version, only with a different engine, an economic comparison of the variants is possible.

3.1.1. Comparison of technical parameters

Based on the information available from [5; 6], we made a technical comparison of the individual variants. Some basic parameters are listed in the following table.

Detail	Petrol	Electric car	Hybrid
Purchase price of a new car in CZE [eur]	22 662	33 994	24 685
Purchase price of a new car in AT [eur]	23 500	32 290	25 390
Maximum power [kW]	145.6	100	104
Clear height [mm]	170	158	165
Luggage space volume [l]	374	332	361
Average petrol / electricity consumption [l / 100 km] / [Wh / km]	5.5	143	4.1

Table 1 - Technical parametres of selected variants

This comparison shows that, although the electric version is significantly more expensive than the Petrol and Hybrid versions, almost all its technical parameters are worse. The cheapest one is the petrol version, which has the highest maximum speed, ground clearance, luggage compartment volume and the highest performance. In terms of user comfort, the Petrol and Hybrid versions are also better than the Electric version. The ability to refuel virtually anytime and anywhere is still an indisputable advantage of these types.

Purely based on a comparison of technical parameters, regardless of economic advantages, we would recommend the company versions in this order: 1. Petrol, 2. Hybrid, 3. Electric car.

3.1.2. Calculation of real EV range

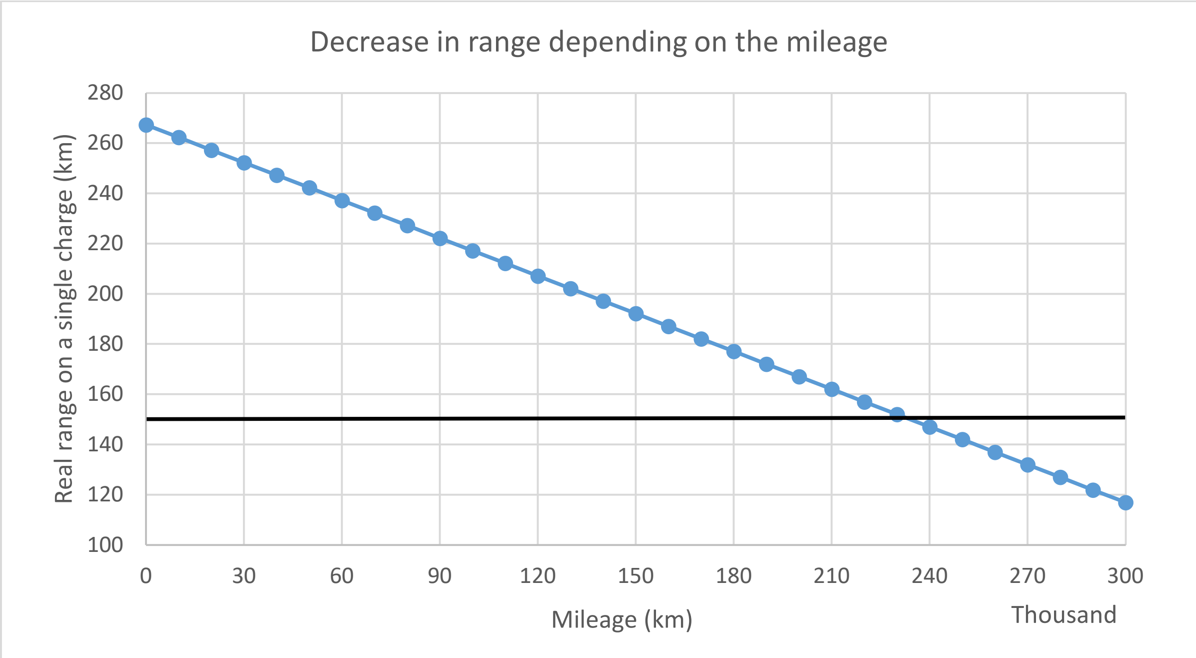
Exclusively for a car with electric drive, we set a requirement for a minimum range per charge for the entire period of its use, which should be higher than 150 km for the entire lifetime considered. We consider this to be the minimum range with regard to maintaining user comfort and practical usability.

According to the information provided by the manufacturer, this parameter is met. However, it is also necessary to consider the degradation of the batteries and the fact that the requirement for a minimum range per charge must be met in all years of operation of the electric vehicle [7]. In this case, it is not possible to follow only the maximum range specified by the manufacturer, and the actual range of the electric car must be calculated. The following table lists all the necessary data needed to calculate the actual range of the electric car depending on the total mileage.

Detail	Value
Battery capacity (kWh)	41.3
DOD (%)	95
Usable capacity (kWh)	39.2
Guaranteed battery capacity after 160,000 km (%)	70
Decrease in usable capacity (% / 10,000 km)	1,875
Average consumption (Wh / km)	143

Table 2 - Battery parameters

The manufacturer lists the total capacity of the battery in the technical data sheets; however, we must assume that these batteries have a certain maximum discharge depth. The manufacturer does not specify this exactly for this car, so we set it at 95%, which is a normal value for lithium batteries used in electric cars. Subsequently, it is possible to calculate the usable capacity of the battery from its range. In addition, the manufacturer guarantees that the battery will retain at least 70% of its original capacity even after 160,000 kilometers. From this value, we calculated the expected average reduction in capacity with an increasing mileage. The maximum expected range can then be calculated, and their dependence on the growing total mileage of the electric vehicle can be seen in the following graph.



Graph 2 - Decrease in the range of the electric car with increasing approach

With the assumed average annual mileage of 20,000 km, the minimal requirement would not be met during the twelfth year of operation. Note that these values are calculated from data on average electricity consumption. In practice, the range of an electric car is of course dependent on many factors, especially on the way of driving and the ambient temperature, when in cold conditions, according to [8], the range on a single charge can be significantly reduced. For this reason, we have set the service life at a maximum of 11 years, which will maintain a reserve respecting these factors, and guarantee a certain fulfillment of the set requirement.

4. Comparison of expenses

In the previous chapter, a suitable type of car was selected, namely the Hyundai Kona. For this type, a technical comparison of available variants with different types of drives was performed. From its results, purely based on technical parameters, we would recommend purchasing the petrol version. However, it is also necessary to evaluate how the individual options are economically advantageous for the investor. The electric car has a significantly higher purchase price. However, it is a well-known fact that electric cars have lower operating costs compared to cars with internal combustion engines. The subject of this chapter will be to evaluate selected variants in terms of their economic viability.

4.1. Investment

The amount of initial investment for individual variants is shown in the following table.

Variant	Investment for CZE (eur)	Investment in AT after subsidies (eur)
Petrol	22 662	23 500
Electric	35 581	28 490
Hybrid	24 685	25 390

Table 3 - Initial investment according to *[5; 6]*, calculated with subsidies and wallbox

For EV, the amount also includes the purchase price of the charging wall box, which ensures the possibility of faster charging at home. We determined the price of the wall box including additional costs with 1587 € for Czech Republic [9]. For Austria, we determined the final price after subsidies with 1200 €. The service life of all variants was determined according to the conclusions of chapter 3.1.2 at 11 years.

4.1.1. Subsidy

Situation for CZE

In the Czech Republic, it is currently not possible to obtain a subsidy for the purchase of EV, if you are only a regular user.

Situation in AT

There are subsidies for buying a new EV from the „Förderungsaktion E-Mobilität für Private 2022“. In order to get the maximum subsidies, which is 5,000 euros (3,000 from the state and 2,000 from the importer), you need to meet certain conditions. These include that the all-electric range must be at least 50 km and gross-list price (basic model without special equipment) of the car must not exceed 60,000 euros. Moreover, the electricity for the vehicle and charging infrastructure must come from renewable energy sources. There are also subsidies for e-charging infrastructure: 600 euros for an intelligent charging cable or for a wall box (home charging station) in a one/two-family house, 900 euros for a communication-capable wall box in an apartment building as a single system or 1,800 euros for a communication-capable charging station with load management when installed in an apartment building as part of a community system [10].

4.2. Operating expenses

In this subchapter, the resulting values of operating costs of all compared variants will be presented. All calculations and exact results in all years of vehicle operation are given in Appendix 1, sheet Operating costs.

4.2.1. Expenses for electricity and gasoline

- **Commodity consumption**

To calculate fuel and electricity costs, it was first necessary to calculate the amount of these commodities consumed. The resulting values for the assumed average annual mileage of 20,000 km are shown in the following table.

Detail	Petrol	Electric car	Hybrid
Petrol consumption (l / year)	1 100	-	820
Electricity consumption (kWh / year)	-	3 011	-

Table 4 - Petrol and electricity consumption

- **Gas price**

According to the information from [11], we set the unit price of petrol for the Czech Republic as an average value of 1,87 eur/l. For Austria, we set the price to 1,97 eur/l according to [12]. It is very difficult to predict the future development of prices for this commodity. According to [13], gasoline consumer prices are affected by several factors, such as the price of crude oil, the safety and stability of its transport due to political instability in the Middle East, unpredictable climate change, etc.

Thus, it is very difficult to say whether prices will fall or rise significantly in the coming years. In the calculations, we will therefore consider the growth in line with inflation for the reference scenario in the long run rather conservatively. When setting it, we based ourselves on the long-term inflation targets, which is 2 % for Austria as well as for the Czech Republic [14; 15]. However, we have recently seen relatively significant growth. For this reason, we set the average inflation value for the calculation model at 2,5 %.

- **Price of electricity**

We also set electricity prices according to tariffs for EV charging. According to [16], we determined the price of 0.32 cents/kWh for the Czech Republic and 0.27 cents/kWh according to [17] for Austria.

As in the case of petrol, an annual change in nominal prices should be considered. From the prices of futures contracts for the following years [18], it can be concluded that prices have probably already reached their maximum at the present time and are expected to fall in the coming years. However, it is difficult to determine at what rate prices will fall. Given the current world events, we assume that prices will not return to their original level. On the other hand, we consider it unlikely that they will continue to grow significantly as in the last year. For this reason, we have rather conservatively resumed the drop in electricity prices to 1.5 % per year.

4.2.2. Third Party Liability

- **Situation in CZE**

When calculating the compulsory liability, we proceeded on the one hand from Act No. 168/1999 Coll. and on the other hand from information on insurance payments of the selected company. We calculated the compulsory liability for the Petrol and Hybrid variants based on the volume of their engine, which is 1.6 liters for both variants. For this engine capacity, the annual payment for the company's liability is 88 eur. In the case of electric cars, insurance companies usually classify these vehicles in the category of cars with the lowest engine capacity, which in this case corresponds to 66 eur.

- **Situation in AT**

In Austria there is no predefined price from the government, the system is integrated in the free market economy. That is why there are a lot of different insurance companies, which differ in prices by a big margin. To make a fair comparison, we used the website [19] and chose the cheapest option for each car. This is very accurate, because you can select the Hyundai Kona and the engine type. We picked standard values for the insurance, which were recommended at the website and made sure to only change the engine type. This resulted in a price of 982 eur for the petrol engine. The insurance for EV is a lot cheaper, almost half of the price of the petrol version, costing 538 eur. This is because EVs are free from the Standard fuel consumption tax (NoVA) and the engine-related insurance tax. The hybrid version has no such benefit, the prices are equal to the petrol version.

4.2.3. Service expenses

The service costs for the compared variants in the first year of operation are listed in the following table, which we determined based on data obtained from invoices from our family members and our own cars.

Detail	Petrol	Electric car	Hybrid
Average service costs CZE (eur / year)	306	218	306
Average service costs AT (eur / year)	444	180	444

Table 5 - Average service costs

For the EV variant, we deducted items from the price that will be dropped due to different technical parameters. This mainly involves changing the engine oil or air filter. However, the rest of the items should also be relevant for an electric car, like tire changes. There are also similar prices named in various user reports on the internet.

4.3 Road taxes and vignettes

The costs associated with paying the road tax and obtaining a motorway stamp for the first year of operation of the vehicles are listed in the following table.

Detail	Petrol	Electric car	Hybrid
Road tax CZE (EUR / year)	119	0	0
Vignette CZE (EUR / year)	60	0	60
Road tax AT (EUR / year)	0	0	0
Vignette AT (EUR / year)	93,8	93,8	93,8

Situation in CZE:

When calculating the road tax for the Petrol variant, we proceeded from Act No. 16/1993 Coll., According to which the tax rate for an engine capacity of 1.6 liters is 119 eur. For the EV and Hybrid variants, vehicles that have an electric or hybrid drive are exempt from road tax by law.

We determined the costs associated with the purchase of the vignette in accordance with Act No. 13/1997 Coll., according to which the exemption from road use charges applies to cars using electricity as fuel. For hybrid vehicles, the exemption only applies if the CO_2 emission value in combined operation does not exceed 50 g/km. This is not met in the case of the Hybrid variant, so we consider the annual cost of 60 eur as for the Petrol version.

Situation in AT:

There is no road tax in Austria. The vignette can be bought for 93,80 eur in 2022 [20].

4.3. Terminal value of pre-owned car

Determining the value of cars as accurately as possible over the years is important. Secondly, the owner needs to know the price at which he will sell the car at the end of its life. For this reason, we set the estimated selling price of the car for all variants. The resulting values are given in Appendix 1, sheet Sales price of cars.

In determining the rate of price decline over the years, we used the information provided in [21], and this information is based on the statistics of the largest Czech advertising server with used vehicles Sauto.cz. These figures show that non-premium brands, including Hyundai, lose 40% to 60% of their original value in the first four to five years. Subsequently, the price of cars stabilizes relatively and falls slightly.

For the EV version, we determined a decrease in the value a bit higher, mainly due to the degradation of the battery. According to the information available from [22; 23] we concluded that at present no one is showing much interest in used electric cars. A possible investment in a new battery often does not pay off, and therefore a significantly lower selling price must be considered. It should be noted that we expect the same price decline for all variants in Austria.

5. NPV of total expenses

In the previous chapter, the key inputs needed to calculate operating costs were clearly defined. Based on these inputs, it is possible to make an economic comparison of possible variants. In our case, we decided to use the NPV method, which provides an unambiguous measure. It estimates wealth creation from the potential investment in today's values, given the applied discount rate.

5.1. Calculation

The principle of calculation will be clearly described in this subchapter. The relations used to calculate the NPV based on the input variables set out in the previous chapter will be presented here. The exact calculation procedure is given in Appendix 1, NPV Model sheet.

The main formulas needed for the calculation can be found in [24]. Key relation for the calculation is given by equation **Fehler! Verweisquelle konnte nicht gefunden werden.**.

$$NPV = -IN_{TOTAL,0} + \sum_{y=1}^{T_{LF}} \frac{CF(y)}{(1+r)^y}$$

Where: $IN_{TOTAL,0}$ is total initial investment [eur]
CF is annual cash flow [eur]
r is discount rate [%]
y is year number [-]
T_{LF} is total service life [years]

1

For the calculation, it was necessary to determine the amount of the initial investment. In our case, it is given by the sum of capital expenditures for the acquisition of a car, wallbox and subsidy, as shown by the equation 2.

$$IN_{TOTAL,0} = IN_{CAR} + IN_{WB} + SUBSIDY$$

Where: IN_{CAR} is total initial investment per car [eur]
IN_{WB} is total investment per wallbox [eur]
$SUBSIDY$ is total subsidy [eur]

2

Since we calculate the net present value of operating expenses, the cash flow in individual years is given by the sum of all expenses according to the equations 3 and 4.

$$CF(y) = EXP_{TOTAL}(y)$$

Where: EXP_{TOTAL} are total annual expenses [eur]

3

$$EXP_{TOTAL}(y) = [EXP_{FUEL}(y) + EXP_{RT}(y) + EXP_{VIG}(y) + EXP_{INS}(y) + EXP_{SER}(y)]$$

Where: EXP_{FUEL} are annual fuel/elektricity expenses [eur]
EXP_{RT} are annual road tax expenses [eur]
EXP_{VIG} are annual vignette expenses [eur]
EXP_{INS} are annual insurace expenses [eur]
EXP_{SER} are annual service expenses [eur]

4

The main operating expense is certainly the expense associated with the purchase of fuel and electricity. To calculate it, we used the equation 5. For simplicity, we considered the average constant annual approach and consumption for all versions.

$$EXP_{FUEL}(y) = \begin{cases} \frac{AAD}{100} * c_E * p_E(1) * [1 + k_E]^{y-1} \\ \frac{AAD}{100} * c_P * p_P(1) * [1 + k_P]^{y-1} \end{cases}$$

Where: AAD is average annual drive [km]
c_E is average electricity consumption [kWh/100 km]
c_P is average petrol consumption [l/100 km]
p_E is price of electricity [eur/kWh]
p_P is price of petrol [eur/l]
k_E is average annual change of electricity price [%]
k_P is average annual change of petrol price [%]

5

We have also introduced equations 6 and 7 for calculating road tax and vignette expenses. We simply consider their same amount for all years of operation.

$$EXP_{RT}(y) = EXP_{RT}(1), \qquad \forall y \in T_{LF}$$

6

$$EXP_{VIG}(y) = EXP_{VIG}(1), \qquad \forall y \in T_{LF}$$

7

Expenditures related to car insurance, on the other hand, increase the set average inflation annually, as shown by the equation 8.

$$EXP_{INS}(y) = EXP_{INS}(1) * \left[1 + k_{i,inflation}\right]^{y-1}$$

Where: $k_{i,inflation}$ is average annual inflation [%]

8

We also considered the annual average growth in inflation in car service expenses, as shown by the equation 9.

$$EXP_{SER}(y) = EXP_{SER}(1) * \left[1 + k_{i,inflation}\right]^{y-1} \quad (9)$$

5.2. Results

After substituting the specific values of the input variables described in chapters 3 and 4 into the given relations 1 to 9, we obtained the resulting values. The following table shows the resulting cost NPV values for all variants compared for discount rate r 4 %, which is common value for households.

Variant	NPV for CZE [EUR]	NPV for AT [EUR]
Petrol	44 698	55 178
Electric car	42 571	39 511
Hybrid	37 586	47 702

Table 6 - Resulting NPV values of individual variants

Situation in CZE:

The resulting values show that, from a purely economic point of view, the purchase of the Hybrid version is the best, because the net present value of all expenditures is the lowest. The second-best alternative is to buy EV and the worst of the economic comparison came out the Petrol version.

Situation in AT:

The situation for purchases is different in Austria. Mainly thanks to the subsidy, the possibility of acquiring EV is the best. The second option is to buy the Hybrid version, and the worst was the Petrol version as in the case of the Czech Republic. It is also clear that the total costs associated with owning a car are significantly higher in Austria than in the Czech Republic, mainly due to more expensive insurance.

The table shows the NPV values for the so-called baseline scenario. However, several input variables influence this result. The subject of the following chapter will therefore be the elaboration of sensitivity analysis, which will show the dependence of the resulting NPV on the most important of these quantities and show whether and under what conditions the electric variant would possibly pay off.

Recommendations for the investor based on the results of technical and economic comparison of individual variants will be made in the conclusion.

6. Sensitivity analysis

The previous chapter presented the results of the economic comparison of variants for the so-called baseline scenario. However, the results of this evaluation depend on several input variables. This chapter will deal with the effect of the change of these variables on the result. For clarity, the dependences of cost NPV on these variables will be shown. The following table summarizes the input values for the baseline scenario, for which sensitivity analysis will be processed in the following subchapters. In the graphs, the relevant values for the baseline scenario will be marked with a green line.

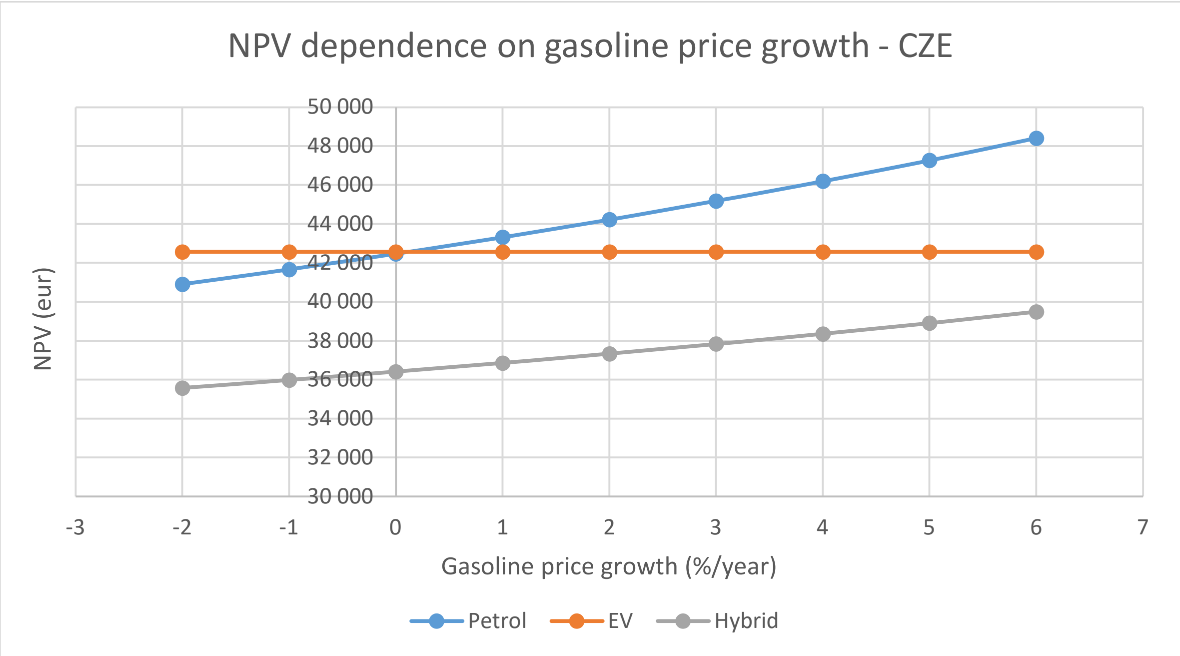
Detail	Value
Average annual growth of petrol prices [% / year]	2,5
Average annual growth of electricity prices [% / year]	-1,5
Amount of subsidy [% / investment]	0 / 15

6.1. Average annual growth of petrol prices

As follows from the information given in sub-chapter 4.2.1, the development of petrol prices is very difficult to estimate. This price usually falls and rises alternately. In our work, we simply consider only the average annual change, while the dependence of the cost NPV on this change is shown in the following graphs.

Situation in CZE:

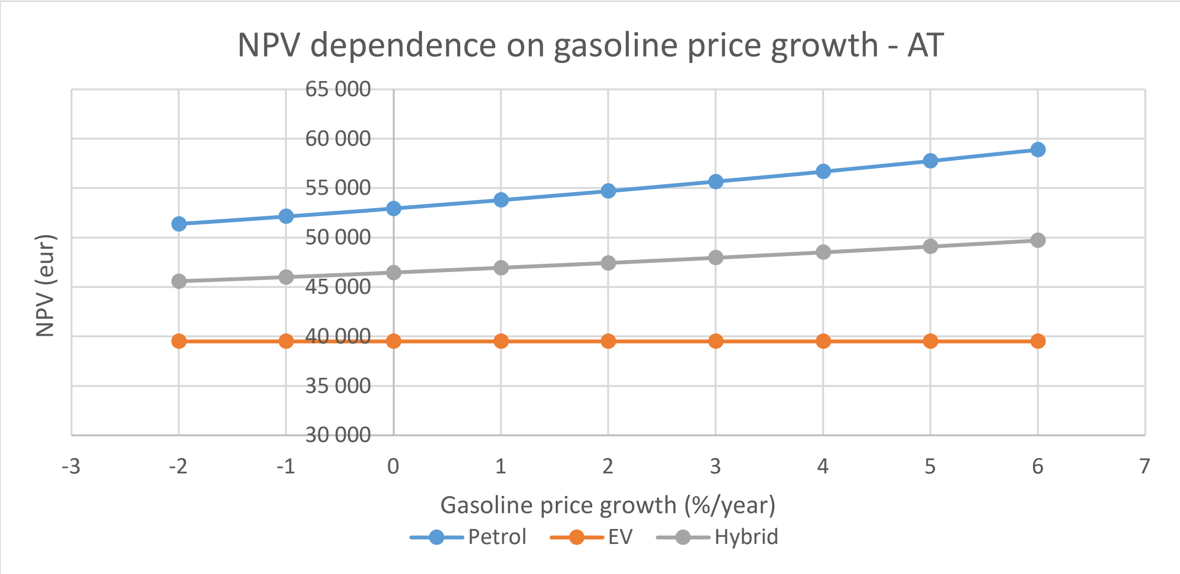
From the graph shown, for all considered scenarios, the Hybrid variant is the best from an economic point of view. Interestingly, however, if the nominal change in gasoline prices were zero or negative, the Petrol version would be more advantageous than an electric car. However, given the current situation, the question is whether such an assumption is realistic.



Graph 3 - NPV dependence on gasoline price growth - CZE

Situation in AT:

In the case of Austria, the situation is completely different. We see that the EV version is the most advantageous for all considered scenarios, mainly due to the subsidy and due to lower insurance for EV. The Petrol version is by far the worst for all scenarios.



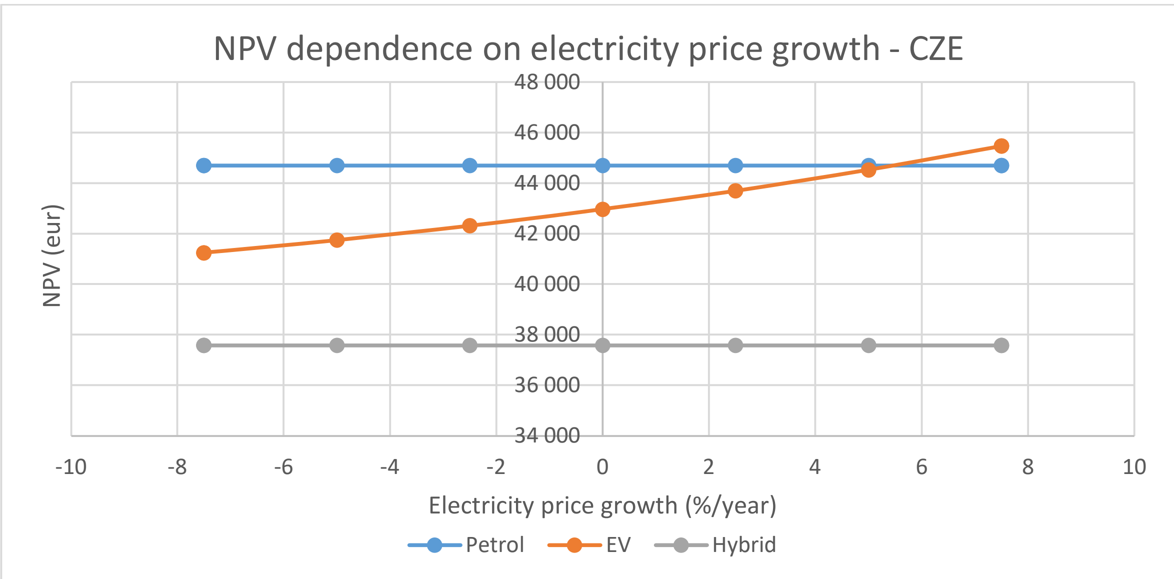
Graph 4 - NPV dependence on gasoline price growth - AT

6.2. Average annual growth in electricity prices

The following graphs shows the dependence of the cost NPV variant of the electric car on the annual growth of electricity prices. The NPV variants Petrol and Hybrid do not change depending on this variable.

Situation in CZE:

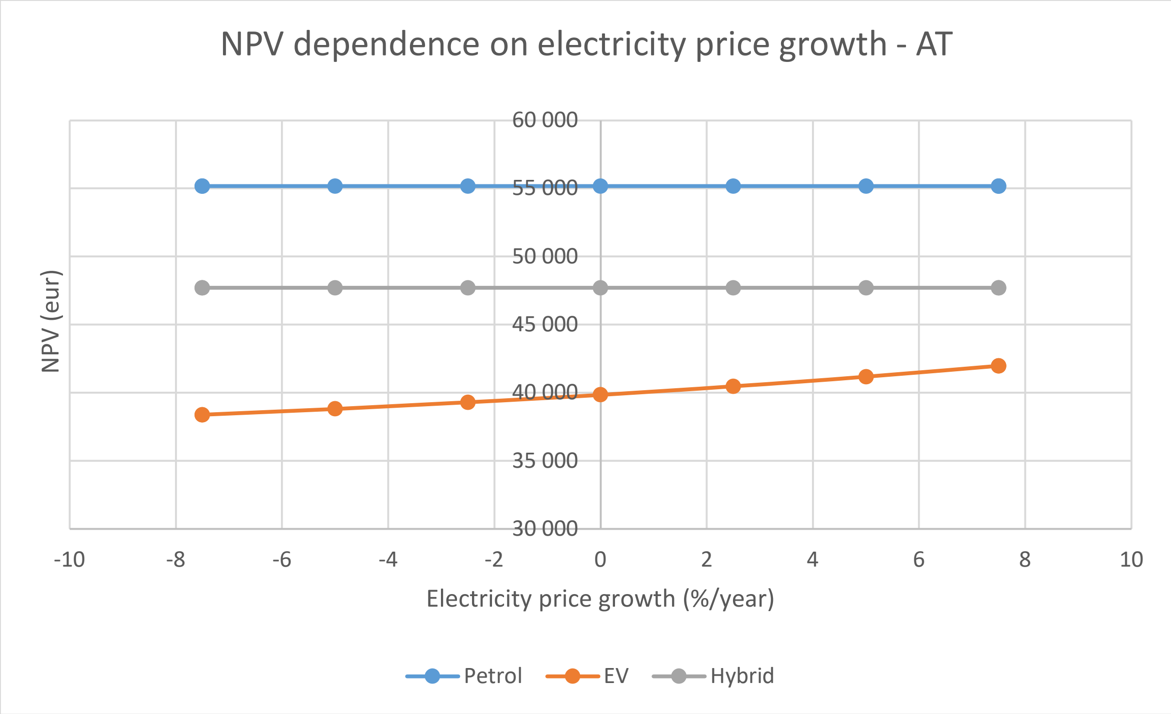
It can be seen from the graph that the Hybrid version is again the most advantageous for all scenarios considered. However, if electricity prices continued to rise significantly, the profitability of the electric car would logically decrease.



Graph 5 - NPV dependence on electricity price growth - CZE

Situation in AT:

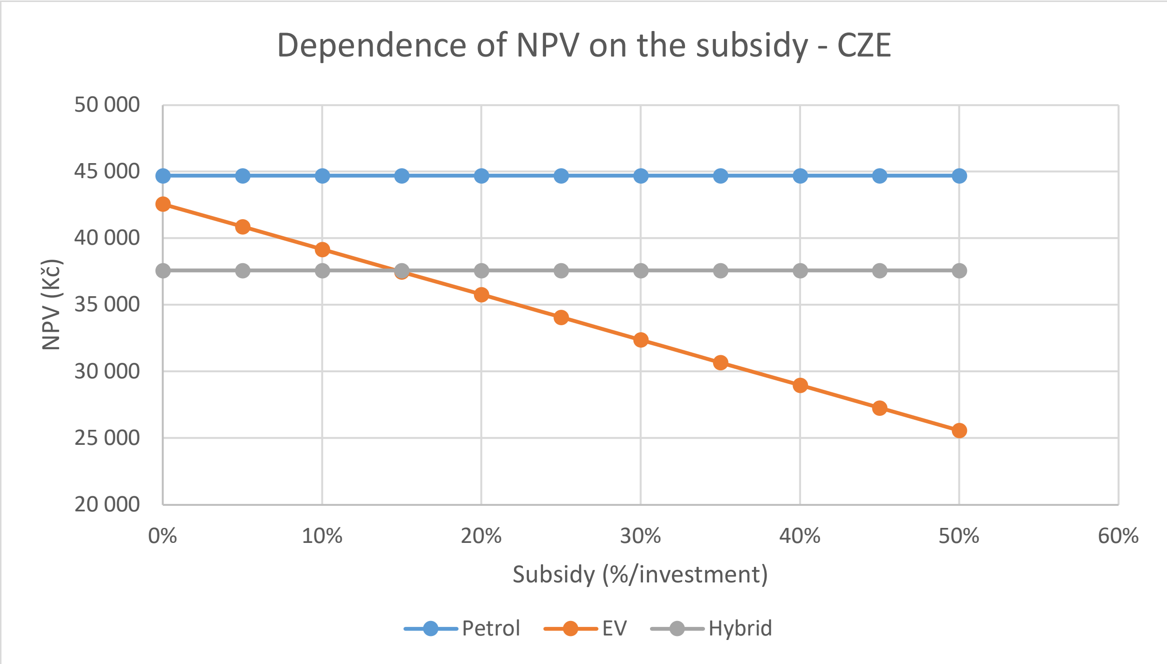
From the graph shown below, for the case of Austria, with increasing electricity prices, the advantage of the EV version also decreases. However, even for relatively high growth, this version is still significantly advantageous. This is due to the same reasons that were already mentioned in the previous subchapter.



Graph 6 - NPV dependence on electricity price growth - AT

6.3. Subsidy

Situation in CZE:

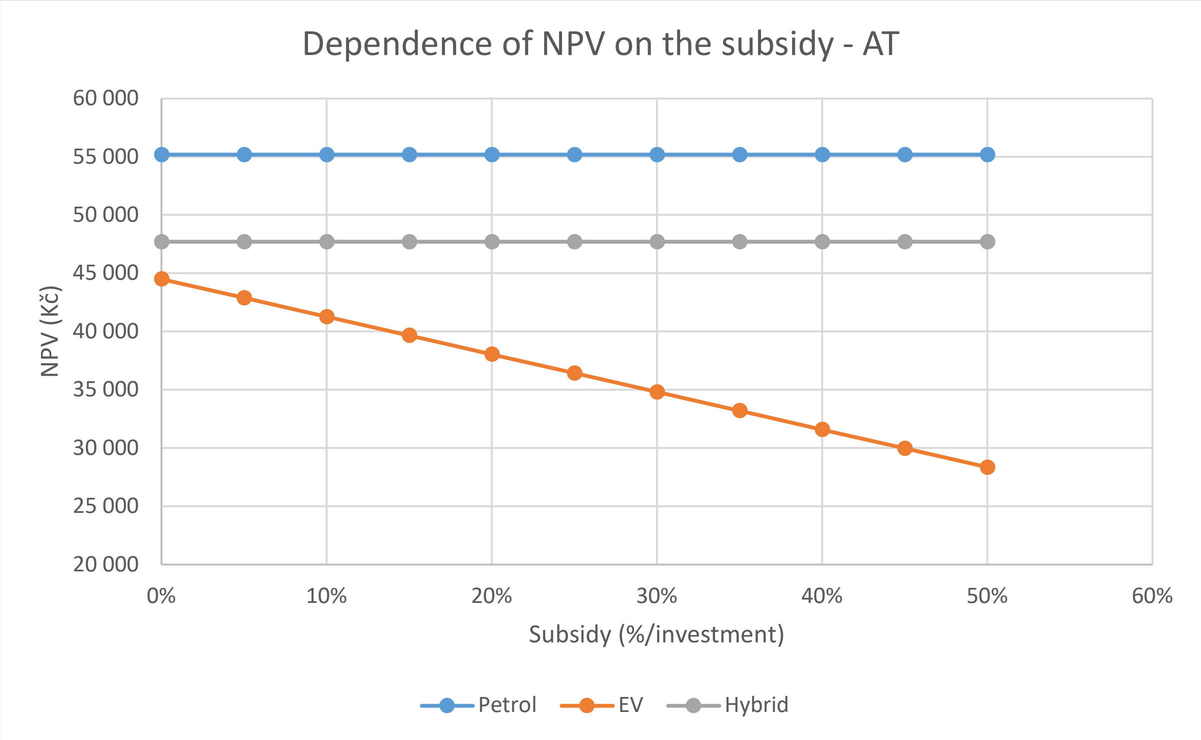


Graph 7 – Dependence of NPV on the subsidy - CZE

As already mentioned, it is currently not possible to obtain a subsidy for the purchase of an electric car. However, it should be noted that this could change in the future. In the graph shown, if the subsidy for the electric car was approximately 15 % of the total investment, the cost NPV of this variant would be almost identical to Hybrid version. If the subsidy were even higher, the electric variant would be even the best choice, based on an economic comparison.

Situation in AT:

As mentioned in subchapter 4.1.1, in Austria it is now possible to receive a subsidy for the acquisition of EV. However, it can be seen from the graph that even without the subsidy, this version would be the most advantageous from an economic point of view. This is very interesting and confirms the fact that there could be a significant expansion of electric cars in the future. Of course, the higher the subsidy support, the more advantageous it would be from the investor's point of view to purchase EV. Therefore, if states want to motivate people to purchase EV, this can be achieved by providing subsidies.



Graph 8 - Dependence of NPV on the subsidy – AT

7. Conclusion

The first part of the paper described the reasons based on which a significant development of electromobility within the entire European Union can be expected in the future. The main subject of the next part of the work was to perform a technical and economic comparison of cars with different types of drive from the user's point of view. First, we selected a suitable car with different engine types available, as well as a comparison of their technical parameters. The petrol variant came out best from the technical comparison, followed by the Hybrid variant, and the electric variant turned out the worst.

In the next part of the work, an economic evaluation was performed. The NPV of total expenses for all compared variants was calculated. Following the case of the Czech Republic, we concluded that the Hybrid variant came out best from an economic point of view. For this reason, we would recommend it to the investor, because it was also the second-best option in the technical comparison. We would also make this recommendation based on the results of the sensitivity analysis, where the Hybrid version worked best for most of the scenarios considered. We would recommend the EV version only, if it will be possible to obtain a subsidy of at least 15 % in the future, which is not possible right now.

However, the situation was different for Austria. The EV version came out significantly better from the economic comparison. This was the case for all considered sensitivity analysis scenarios, even for the case of acquiring a car completely without a subsidy. For this reason, we would recommend to Austrian investors the purchase of an electric car as the most advantageous option, even though it turned out the worst from a technical comparison.

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